Zooplankton Composition and Vertical Distribution in a Tropical, Monomictic Lake (Dom Helvécio Lake, Southeastern Brazil).

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ABSTRACT: Zooplankton composition and vertical distribution in a tropical, monomitic lake (Dom Helvécio lake, southeastern Brazil). In order to determine the influence of the stratification and food availability on the composition and vertical distribution of the zooplankton populations of Dom Helvécio Lake, studies were undertaken during one stratification period (February, 2000) along a 24 h diurnal cycle. Samplings were done in a fixed point of the limnetic region, at five different depths (surface, 3, 6, 9 and 18 meters). The lake showed a well defined stratification, with the thermocline between 3 and 10 m and a general tendency for the increase of the nutrients and chlorophyll-a concentrations starting at the metalimnion. Zooplanktonic community was characterized by the quantitative dominance of rotifers (mainly Ptygura sp and Keratella cochlearis) and Cyclopoida copepods (specially Thermocyclops minutus). The current composition of the community suggests that Dom Helvécio Lake has mesotrophic characteristics. The quality of the available food and bottom-up effects are the possible determinants of the observed pattern of the zooplankton composition. Zooplankton densities were higher at metalimnion and lower at epilimnion. It was observed that different factors influenced the vertical distribution of the zooplanktonic populations in the Lake Dom Helvécio: temperature and oxygen had more effect on rotifers, which were preferentially distributed at the epilimnion while food resources (quality) probably determined the vertical distribution of copepods at the metalimnion.
Key-words: zooplankton, composition, vertical distribution, tropical lake, Brazil.

RESUMO: Composição e distribuição vertical do zooplâncton de um lago tropical monomítico (Lago Dom Helvécio, sudeste do Brasil). Com o objetivo de verificar a influência da estratificação e da disponibilidade de alimento sobre a composição e distribuição vertical da comunidade zooplanctônica no lago Dom Helvécio, foi realizado um estudo durante um período de estratificação (fevereiro/2000), ao longo de um ciclo nictemeral de 24 h. As amostragens foram efetuadas em um ponto fixo da região limnética, em cinco profundidades (superfície, 3, 6, 9 e 18 metros). O lago apresentou uma estratificação bem definida, com a termoclina situada entre 3 e 10 m e uma tendência geral de aumento de nutrientes e clorofila-a a partir do metalímnio. A comunidade zooplanctônica caracterizou-se pela dominância quantitativa de rotíferos (principalmente Ptygura sp e Keratella cochlearis) e copépodes Cyclopoida (destacando-se Thermocyclops minutus). A composição atual da comunidade sugere características mesotróficas para o lago Dom Helvécio, sendo a qualidade do alimento disponível e efeitos "bottom-up" os possíveis determinantes do padrão registrado. O zooplâncton apresentou maiores densidades no metalímnio e menores no epilímnio. Foi observado que fatores distintos influenciaram a distribuição vertical das populações zooplanctônicas no lago Dom Helvécio: temperatura e oxigênio exerceram maior efeito sobre rotíferos, que distribuíram-se preferencialmente no epilímnio, enquanto a qualidade do alimento provavelmente determinou a distribuição vertical dos copépodes no metalímnio.
Palavras-chave: zooplâncton, composição, distribuição vertical, lago tropical, Brasil

Introduction

The identification of the controlling factors for the modifications in the structure and distribution of zooplanktonic communities in aquatic ecosystems is still one of the greatest challenges of limnology. Disturbances that alter physical and chemical characteristics of the environment or that modify the competitive balance between species have been pointed out as a determinant factor in population rearrangements (Locke & Sprules, 1993; Gregory, 1996).

Studies conducted at the lakes of the State Park of Rio Doce in the 80's revealed that trophic conditions, oxygen and thermal gradients were the primary factors determining the composition of the zooplankton community, and that both types of gradients also influenced the vertical distribution of these organisms (Okano, 1980; Matsumura-Tundisi, 1997).

Nevertheless, few attempts were made in order to evaluate the influence of these gradients associated with the vertical distribution of food and the zooplankton composition and vertical distribution in the Lake Dom Helvécio. In this study, the effects of thermal-chemical gradients and vertical food availability (measured as chlorophyll-a concentration) on the vertical distribution of zooplankton were considered during a stratification period, in a diurnal cycle of 24 h. The species composition of zooplankton was also described, in order to examine the present status of the community structure in the lake.

Study area

Dom Helvécio Lake has an area of 6.7 km² and is the largest and deepest lake of the Rio Doce lake district (maximum depth 33m). The lake has been classified as oligotrophic (Tundisi et al., 1981), it is dendritic shaped and is surrounded by dense Atlantic forest vegetation type (Fig. 1).

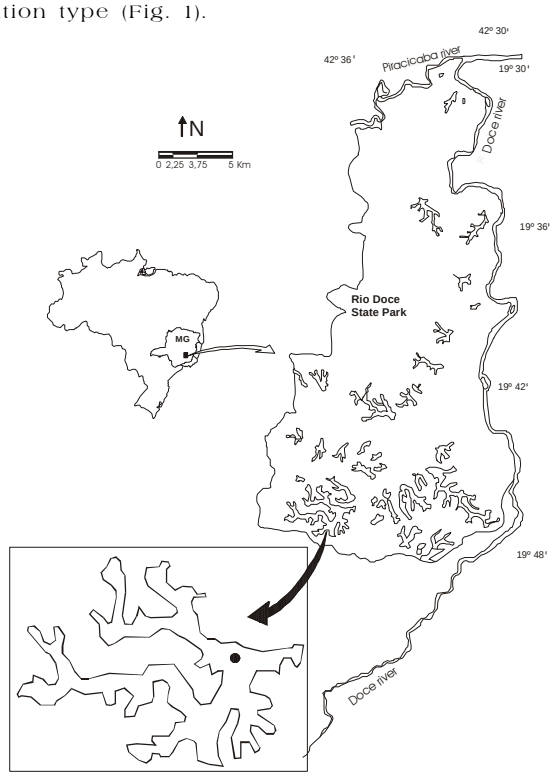

Figure 1: Map of the study area showing Lake Dom Helvécio and the sampling station.

The lake remains thermal and chemically stratified during the period of September until May, showing, in the winter, a brief period of circulation. During the thermal stratification period the hypolimnion becomes anoxic with elevated concentrations of sulphidric acid in the sediments (Barbosa & Tundisi, 1989).

Material and Methods

Samples were collected at a station of the limnetic region on February 15th (at 9 and 12h a.m. and 3, 6, 9 and 12h p.m.) and 16th (at 3, 6 and 9h a.m.), 2000 (rainy period). In a 24h diurnal cycle, five depths were sampled: surface, 3, 6, 9 and 18 meters. Water temperature, dissolved oxygen concentration and conductivity were measured with a Horiba U-22 multi-analyzer at the same specified depths (except 6m, due to technical problems) and times. Water samples were also collected for nutrient determination (ammonium, nitrite, nitrate, nitrogen and soluble reactive phosphorus), according to Mackereth et al. (1978) and chlorophyll-a concentration was obtained according to Lorenzen (1967).

Zooplankton samples were obtained with a Van Dorn bottle from each depth. Twelve liters of water were filtered in a 68 mm mesh plankton net and preserved with neutral formaldehyde (4%). For quantitative analyses, sub-samples were counted in a Sedgwick-Rafter chamber. Species diversity was measured according to Shannon (1948). Ordination analysis of zooplankton and environmental data were performed through Principal Component Analysis using a statistic software (STATISTICA).

Results

Vertical structure of the lake

The thermal profiles showed a well defined stratification with thermocline located at the metalimnion (3-10 m). Temperature varied 7.0ºC from the surface (30.8ºC) to the bottom (23.4ºC). The oxygen profile was characteristically clinograde with concentrations ranging from 8.2 mg/L at the sub-surface and decreasing towards the bottom, resulting in an anoxic hypolimnion. Values for chlorophyll-a concentrations were reduced at the epilimnion (maximum of 2.7 mg/L) but increased at the metalimnion and hypolimnion up to 21.4 mg/L. This same vertical stratification pattern was observed for nutrients (NO_2-N - from 0.1 mg/L at the epilimnion to 1.0 mg/L at the hypolimnion; NO_3-N - from 4.7 mg/L to 10.7 mg/L; NH_4-N - from 5.5 mg/L to 635.8 mg/L) and conductivity (from 36 to 62 mS/cm). A small vertical decrease was observed only for PO_4-P (from 2.1 mg/L to 1.9 mg/L) (Fig. 2).

Zooplankton composition and vertical distribution

Thirty taxa were identified in the zooplankton community of Lake Dom Helvécio, of which 16 belong to Rotifera (Anuaeropsis sp, Bdelloidea sp, Brachionus angularis, Brachionus falcatus, Brachionus forficula, Brachionus sp, Collotheca sp, Euchlanis sp, Filinia longiseta, Hexarthra intermedia, Keratella cochlearis, Keratella tropica, Keratella sp, Polyarthra sp, Ptygura sp and Trichocerca sp), 6 to Cladocera (Bosmina tubicen, Bosminopsis deitersi, Diaphanosoma birgei, Diaphanosoma sp, Moina sp and Ephemeropus barroisi) and 3 to Copepoda (Thermocyclops minutus, Tropocyclops prasinus and Notodiaptomus iheringi), besides Protozoa (Arcella vulgaris) (Tab. I).

Species diversity was low (average 2.36 bits/ind) mainly due to the numeric dominance of few species. For instance, in some samplings rotifers (mainly Ptygura sp and Keratella cochlearis) contributed with more than 70% of the total zooplankton (3h p.m. - 0 m).

Copepod nauplius, particularly of Thermocyclops minutus, were also abundant representing more than 60% of the zooplanktonic community in some samplings (9h a.m. - 9 m and 12h p.m. - 9 m). Densities of copepodids and adult copepods of

Table I. Zooplankton composition in Lake Dom Helvécio (February/2000)

PROTOZOA	**CLADOCERA**
Arcella vulgaris Ehrenberg, 1843	Bosmina tubicen Brehm, 1949
ROTIFERA	Bosminopsis deitersi Richard, 1894
Anuaeropsis sp	Bosminopsis sp
Bdelloidea sp	Diaphanosoma birgei Korinek, 1981
Brachionus angularis Gosse, 1851	Diaphanosoma sp
Brachionus falcatus Zacharias, 1898	Moina sp
Brachionus forficula Wierzejki, 1851	Ephemeropus barroisi
Brachionus sp	**COPEPODA**
Collotheca sp	Náuplio Calanoida
Euchlanis sp	Náuplio Cyclopoida
Filinia longiseta Ehrenberg, 1843	Thermocyclops minutus (Lowndes, 1834)
Hexarthra intermedia (Hauer, 1953)	Tropocyclops prasinus Kiefer, 1927
Keratella cochlearis Gosse, 1851	Notodiaptomus iheringi Wright, 1927
K. tropica (Apstein, 1907)	**DIPTERA LARVAE**
Keratella sp	
Polyarthra sp	
Ptygura sp	
Trichocerca sp	

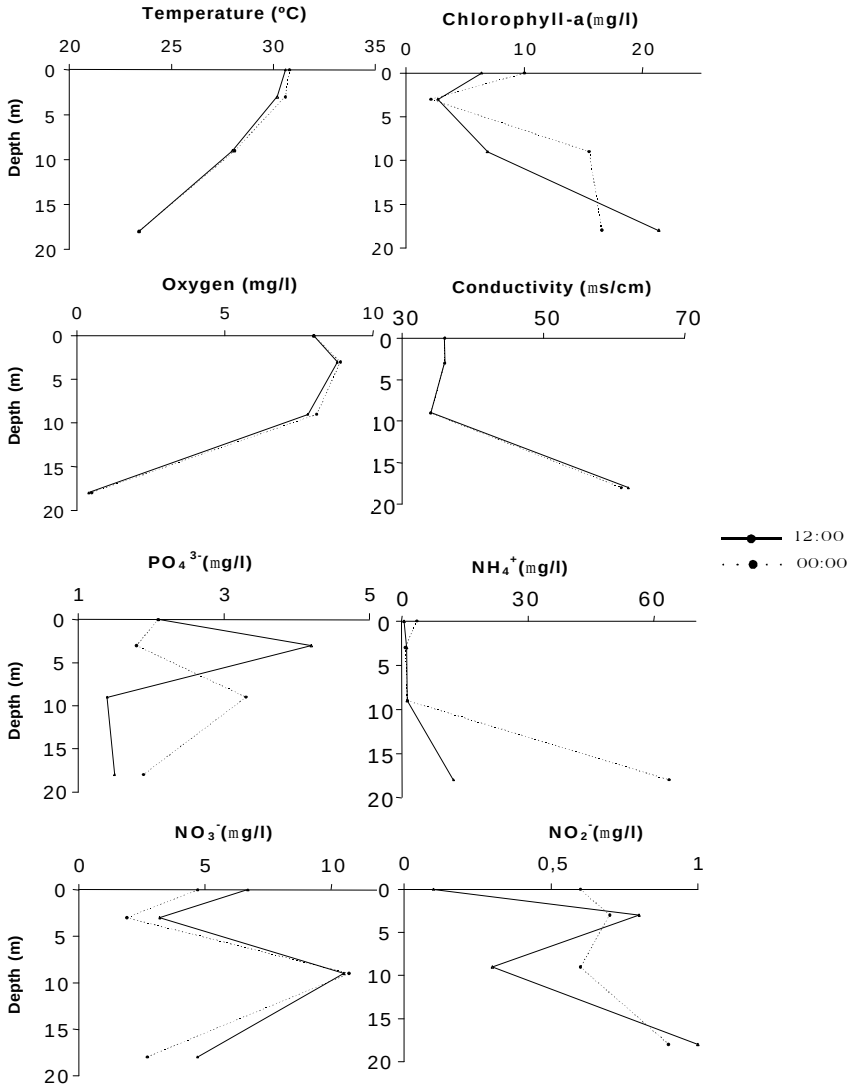

Figure 2 : Vertical profiles of physical-chemical parameters and chlorophyll-a (mg/l) at noon and midnight during period of stratification (February/2000) in Lake Dom Helvécio.

Thermocyclops minutus were similar to those observed for naupliar forms. The maximum density recorded for T. minutus was 84,000 org./m³ (9h a.m. - 9.0 m) and for N. iheringi, 9,000 org./m³ (12h p.m. - 6 m), the former comprising, in some periods, more than 40% of the total zooplankton. Only cladocerans showed very low densities, comprising not more than 5% of the zooplankton community.

The maximum density of total zooplankton was recorded at 9 m (1.240,000 org/m³ - 9h a.m. - 9 m), and high values were also observed at 6 m. The lowest density values were recorded at the surface (minimum of 42,000 org/m³ at 3h a.m.) (Fig. 3). In general, a higher zooplankton concentration was observed in the metalimnion (between 3 and 9 m) except for Rotifera which were preferentially distributed in the epilimnion (between 0 and 3 m). It was not possible to identify any vertical distribution pattern for cladocerans due to its low density (‹ 5% of total zooplankton). In general the species were grouped in the meta/hypolimnion with eventual displacement to the epilimnion during the day (12h a.m.) and night (6 and 9h p.m.) (Fig. 4).

Copepods (nauplius, copepodits and adults) were distribuited mainly in the metalimnion/hipolimnion. Eventually, peaks of densities were recorded at surface during both day (12h a.m.) and night (9h p.m. and 12h p.m.) (Fig. 4).

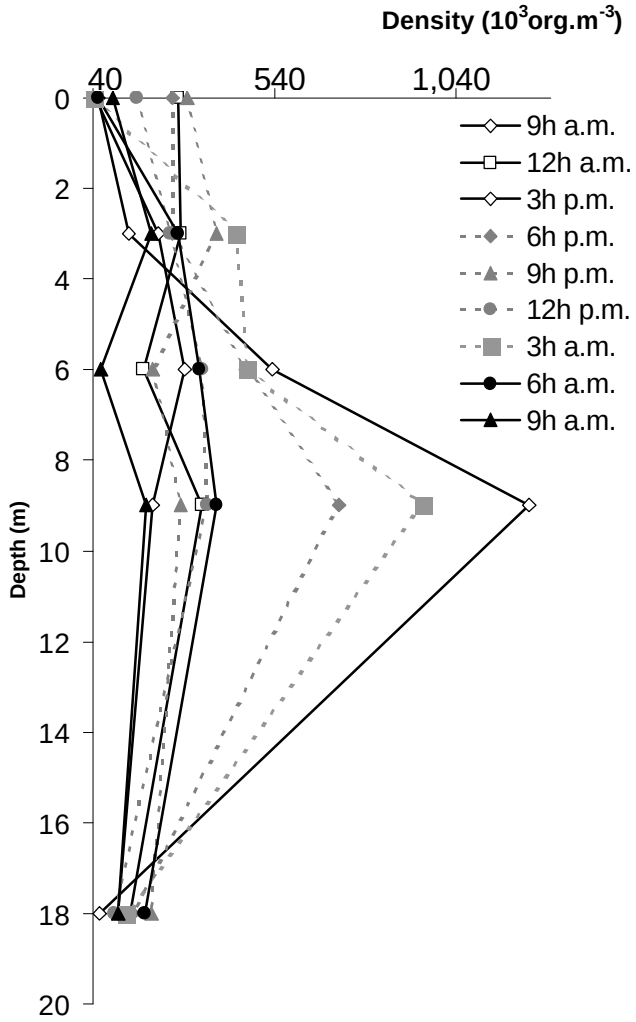

Figure 3: Vertical distribution of the zooplankton density (10³ org.m⁻³). (—) Diurnal samples; (- - -) nocturnal samples.

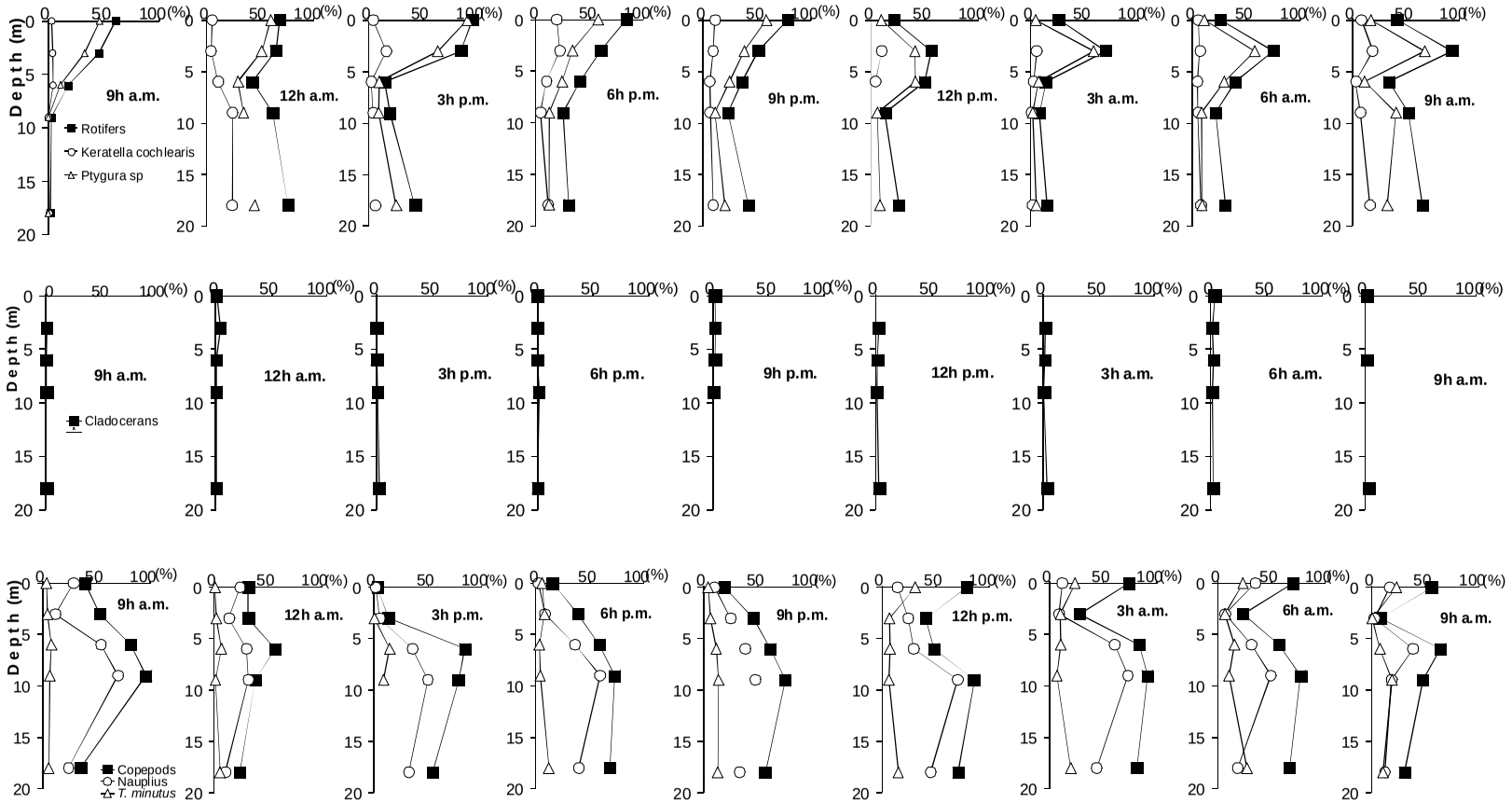

Figure 4: Vertical distribution of rotifers, cladocerans and copepods density (% of total zooplankton) in Lake Dom Helvécio (February/2000).

The relationship between zooplankton groups and environmental variables is revealed in the PCA results. (Fig. 5). Factor 1 represents the influence of the environmental characteristics of the water column (temperature and oxygen) on the zooplankton vertical distribution. The negative quadrant shows copepod nauplius, which were distributed mainly together with chlorophyll-a peaks, and did not show vertical distribution associated with physical-chemical profiles. The positive side of factor 1 includes rotifers, which occur associated with warmer and more oxygenated conditions found in the epilimnion. The positive association of cladocerans and nutrients is probably due to the distribution of this group in deeper layers of the water column, where concentrations of nitrite, nitrate and ammonia-nitrogen were usually higher. Factor 2 represents biotic factors such as chlorophyll-a and rotifers, which were negatively correlated. Copepods (adults and nauplius) also showed a negative correlation with chlorophyll-a, suggesting that food resources other than phytoplankton particles (e.g. detritus) could be contributing to the vertical distribution pattern of these organisms in the water column.

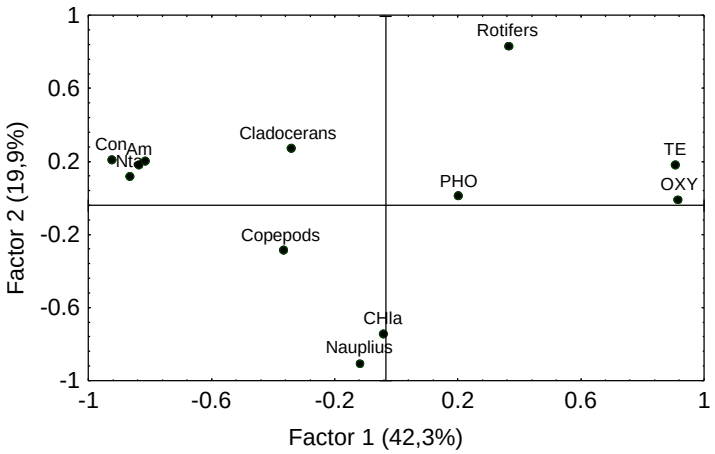

Figure 5: Results of principal component analysis performed for stratification period in Lake Dom Helvécio. TE = Temperature; OXY = Oxygen; PHO = Phosphate; Con = Conductivity; Am = Ammonia; Nta = Nitrate; CHLa = chlorophyll-a.

Discussion

The data recorded in the present study showed that significant modifications occurred in the structure of the zooplankton community of Dom Helvécio Lake in relation to that observed by Matsumura-Tundisi & Okano (1983) and Matsumura-Tundisi (1997). In those studies, Copepoda (mainly Calanoida species) was pointed as the predominant group in addition of being the richest. From the five species recorded previously - Argyrodiaptomus furcatus, Scolodiaptomus corderoi, Thermocyclops minutus, Mesocyclops longisetus and Tropocyclops prasinus - only Thermocyclops minutus and Tropocyclops prasinus were identified in the present study. The current quantitative pattern of the zooplanktonic community in the lake showed dominance of microzooplankton, specially rotifers and T. minutus nauplius.

The previous structure of the zooplankton community in Dom Helvécio Lake was considered by Matsumura-Tundisi (1997) as an indicator of oligotrophy, considering the dominance of Calanoida copepods over Cyclopoida and the low densities of rotifers and cladocerans. The current zooplankton composition suggests mesotrophic conditions for Dom Helvécio Lake, considering the quantitative dominance of rotifers and Cyclopoida copepods. However, the observed nutrient (P and N) and chlorophyll concentrations do not confirm this trend, since they show

values close to those described by Aleixo (1981) and Tundisi et al. (1981) for this lake. The question still open is what could have caused such a significant change in the structure of the zooplanktonic community?

Food availability is an important factor in the regulation of zooplankton communities. As was noted by Hino et al. (1986) and Reynolds (1997), the best representative of Cyanobacteria in Dom Helvécio Lake were the small cells (especially Microcystis wesenbergii and M. aeruginosa) and solitary filamentous forms such as Lyngbia and Spirulina. A recent study on the phytoplanktonic community of this lake shows a predominance of Desmidiales in the epilimnion and Cyanobacteria represented mostly by Cylindrospermopsis raciborskii, in the meta/hypolimnion (Barbosa & Pádisak, 2001).

The rigid filaments of C. raciborskii could be a limiting factor for ingestion by specialized filter-feeding copepods such as Calanoida. The occurrence of Desmidiales also do not appear to favor Calanoida filter feedings, since at Dom Helvécio Lake, the most abundant desmids species exhibit a great size variation, according to Barbosa & Pádisak (2001), with volumes from 236 μm^3 to 29,100 μm^3, and filter feeding in Calanoida generally occurs when food particles are smaller than 50 μm (Paffenhofer, 1984). Thus, food resource can not be completely excluded as one of the possible factors regulating zooplankton composition of Dom Helvécio Lake.

Predation is also frequently implicated as a potential key factor shaping zooplankton community structure (Lampert, 1989; Leibold, 1990; Masson et al., 2001). Several lakes at Rio Doce State Park exhibit, among the fish fauna, introduced predator species such as Cichla ocellaris and Pygocentrus nattereri. Extinction and marked reduction of populations of native fish species due to introduction of these species have been reported by Godinho et al. (1994). Although predation estimates have not been contemplated in this study the confirmed alterations in the fish community suggest that these modifications could have affected the whole trophic structure of the lake. Thus, the observed alterations in the zooplanktonic community could also be related to occurrence of bottom-up effects in Dom Helvécio Lake.

Considering the stratification period, the vertical food distribution (chlorophyll-a concentration) seems to constitute the main factor determing the vertical structure of zooplankton in Dom Helvécio Lake, with an apparently higher influence than oxygen and thermal gradients.

The epilimnion was characterized by the presence of rotifers, while copepods (nauplius, copepodids and adults) were preferentially grouped in the metalimnion. Biological interactions such as interspecific competition for food resources, endogenous mechanisms of the species and influence of environmental parameters can be responsible for the vertical distribution patterns of the zooplankton (Tang et al., 1994). As demonstrated by PCA analysis, vertical distribution of rotifers in Dom Helvécio Lake is intimately related to higher temperatures in the epilimnion. Rotifers feeding habits can also be used to explain this vertical distribution. As generalist filters, rotifers are able to ingest various type of food such as bacteria, small algae, flagellates and detritus, but have limitations for ingestion of filamentous Cyanobacteria (Sládecek, 1983). The quantitative dominance of filamentous Cyanobacteria in the metalimnion of Dom Helvécio Lake could restrict the occurrence of rotifers at this layer.

According to Matsumura-Tundisi et al. (1997a), the vertical distribution of copepods in Lake Dom Helvécio is characterized by the occupation of different layers of the water column, as a consequence of adaptive strategies of the species. According to these authors, T. minutus, for example, explores the epilimnion/metalimnion interface, as observed in the present study. Since this species is omnivorous it can use different food resources such as bacterioplankton, large phytoplankton cells, small zooplankters and also Cyanophyceae, as observed by Rietzler & Espíndola (1998). The ingestion of Cyanobacteria, according to Matsumura-Tundisi et al. (1997b), would explain the higher densities of T. minutus in the metalimnion, where these

microalgae are abundant. However, according to Hino et al. (1986), Microcystis wesenbergii and M. aeruginosa were the dominant Cyanobacteria species in the lake until mid 80's, replaced later by Cylindrospermopsis raciborskii the present dominant species (Barbosa et al. 2002). Colonial Cyanobacteria (Microcystis wesenbergii and M. aeruginosa) could be more easily ingested by T. minutus than the large filaments (› 50mm) of C. raciborskii. This would explain the absence of correlation between chlorophyll-a and the density of copepods shown in the PCA analysis, indicating that, although C. raciborskii could represent an abundant source of food it is not an edible species and T. minutus could be exploring an additional food resource.

The data obtained in the present study suggest that different factors influence on the vertical distribution of zooplankton in Dom Helvécio Lake. Thus, environmental parameters such as temperature, oxygen and nutrients would regulate the distribution range of rotifers and cladocerans, while the quality of the available food probably constitutes the key factor in the vertical distribution of copepod populations.

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