African Journal of Biotechnology Vol. 12(17), pp. 2234-2248, 24 April, 2013
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.684
ISSN 1684–5315 ©2013 Academic Journals

Full Length Research Paper

Environmental impact analysis of aquaculture in net cages in a Brazilian water reservoir, based in zooplankton communities

Maria Cristina Crispim[1]*, Karla Patrícia Ponte Araújo[1], Hênio do Nascimento Melo Júnior[2]

[1]Universidade Federal da Paraíba, CCEN, DSE, LABEA - Laboratório de Ecologia Aquática, Cidade Universitária, Campus I, João Pessoa, Paraíba, CEP 58091-700.
[2]Laboratório de Limnologia e Aqüicultura/Depto. de Ciências Biológicas/Universidade Regional do Cariri.

Accepted 24 January, 2012

The aim of this study was to characterize zooplankton community composition at Padre Azevedo reservoir and to determine their relationship to water quality, following a gradient of distance from an aquaculture site. Monthly samples were collected by filtering 15 L of water with a plankton net (45 μm mesh size), and fixing it with a 4% formaldehyde solution saturated with sugar. Zooplankton community composition was dominated by rotifers, mostly *Keratella tropica*, *Brachionus havanaensis* and *Brachionus calyciflorus*, and Cyclopoida copepods (mostly nauplii). These species are typically associated to eutrophic environments. During the dry season, a higher diversity of rotifers was observed, whereas density of cladocerans increased during the rainy season. Sampling station P_4, the most distant station from the culture site, showed lower zooplankton densities. The most distant sampling station showed higher water quality, as particularly during the dry season, suggesting that aquaculture negatively affects water quality at nearby areas, as evidenced by zooplankton composition.

Key words: Environmental impact, fish culture, net cages, zooplankton.

INTRODUCTION

In northeastern Brazil, where water shortage is common, reservoirs are particularly valuable, serving multiple purposes. According to Esteves (1998), reservoirs provide food for local human populations via aquaculture or fish farming. The increased demand for animal protein, due to the ongoing human population growth, has made fish farming an attractive activity worldwide. Despite the negative outcomes arising from the introduction of fishes in novel environments (Gophen et al., 1999), it remains as a widespread practice in the northeastern Brazilian region, these activities being frequently encouraged by the government. However, studies investigating how water quality is affected by these activities are rare in this area, thus compromising water consumption. Net-cage aquaculture is a widespread activity of intensive food production at both local and industrial scales (Schmittou, 1997; Outtara et al., 2003; Liao et al., 2004). As suggested by Colt and Montgomery (1991), despite its advantages, underlying environmental impacts and lack of sustainability from these activities are strong negative factors, frequently making this an unpractical activity.

Fluctuations in aquatic environments promote temporary corresponding changes in habitat availability, therefore affecting communities which are dependent upon these habitats (Schwart and Jenkins, 2000). Key species from natural communities function as indicators of environmental quality by reacting to habitat disturbances via increase or decrease in population size or by being rapidly substituted by other species (for example, short life cycle species) (Margalef, 1974).

*Corresponding author. E-mail: ccrispim@hotmail.com.

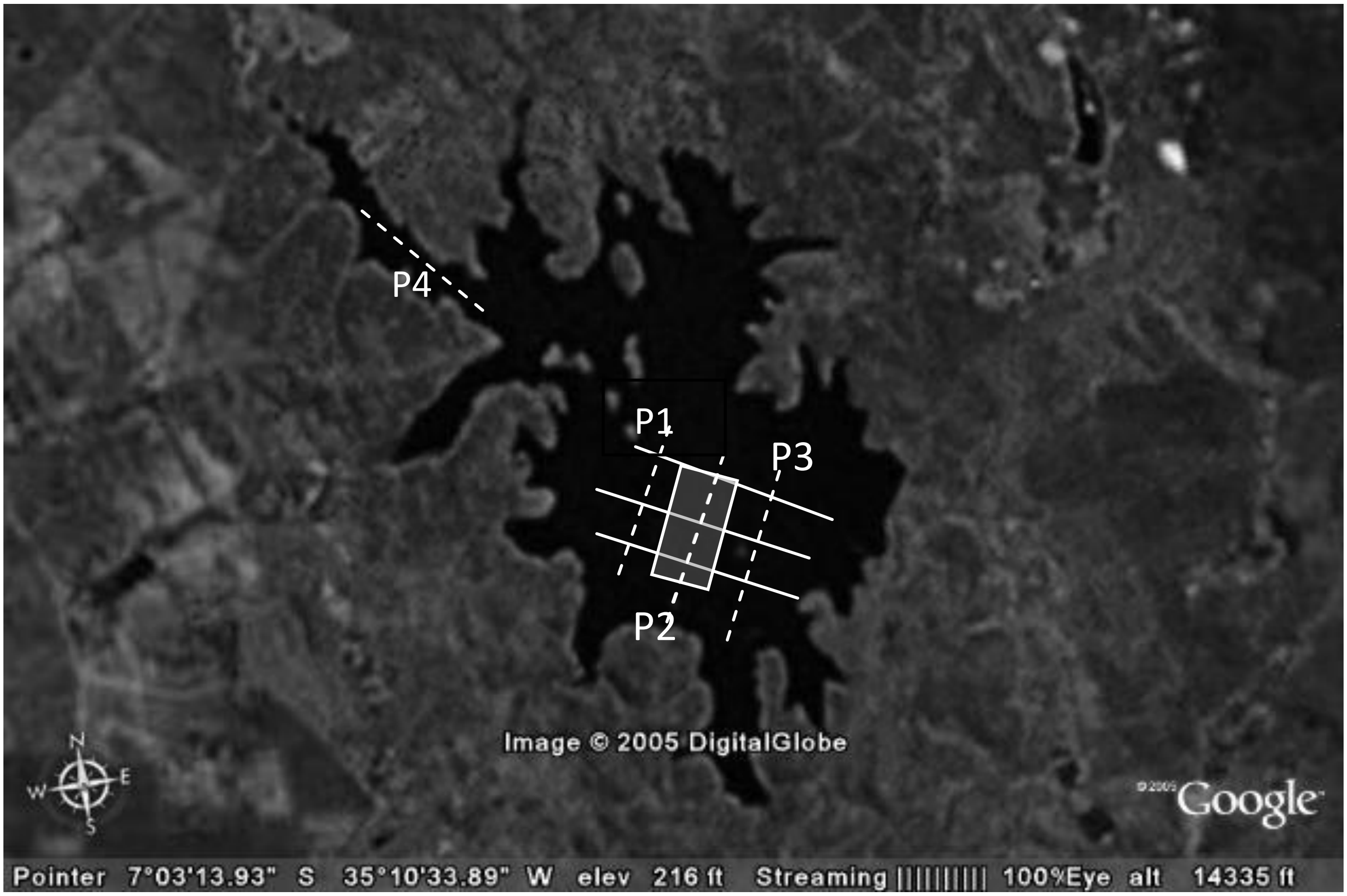

Figure 1. Location of Padre Reservoir Azevedo, showing sampling stations. The rectangle area indicates the culture site. The dashed white lines indicates the transects at the sampling stations. Lines indicate the transects of the replicates. The line intersection points show the sampling stations.

Furthermore, aside from their somewhat fast responses to habitat disturbance, these species also play central roles linking trophic levels (transferring energy) on aquatic ecosystems, being influenced by both downward (top-down) and upward (bottom-up) processes (Lampert, 1997; Pinto-Coelho, 2004; Pinto-Coelho et al., 2005).

To determine the negative outcomes from net-cage aquaculture activities, zooplankton communities were evaluated throughout a period of approximately one year, encompassing dry and rainy seasons. Key zooplankton species are important bioindicators, and since they are primary consumers, their densities reflect the productivity of aquatic ecosystems. Zooplankton evaluations have been successful at providing information on the mechanisms of community development and organization (Landa and Mourguês-Schurter, 2000). In the present study, the zooplankton community was tested as a tool to determine the impact of net-cage aquaculture at the Padre Azevedo Reservoir of Fazenda Pacatuba on its community dynamics and on the overall water quality of the reservoir.

MATERIALS AND METHODS

Study area

Padre Azevedo reservoir of Fazenda Pacatuba is located in the Sapé district, distant 7 km away from town. Geographically, the reservoir is located between 07°02'20.41"S, 035°11'15,03"W and 07°04'07,12"S, 035°09'59,43"W (Figure 1).

The reservoir has a perimeter of 15,380 m (AESA, 2005), encompassing a surface area of 2,317,000 m², and a volume capacity of 11,500,000 m³ (DNOCS, 1940). It is incorporated to the Paraíba river basin (State Government of Paraíba, 1985; 2003; DNOCS, 1940) and the Una streamlet runs to the Padre Azevedo reservoir (DNOCS, 1940).

The region is climatically characterized by hot and wet air temperatures with higher precipitation episodes throughout the fall and winter (W. Koeppen). A stable sub-coastal depression characterizes the topographic relief of the region, with low, flat zones interspersed with low-profile hills with convex mounts. The soil is sandy, and/or sandy/silt of low fertility (Spodosols and Latosol) deposited over Tertiary sediments with an altitude between 100 and 200 m.

The reservoir's main service is to supply irrigation water to sugarcane agriculture at Fazenda Pacatuba. Also, water used in net-cage aquaculture is a developing activity which aggregates value to the reservoir.

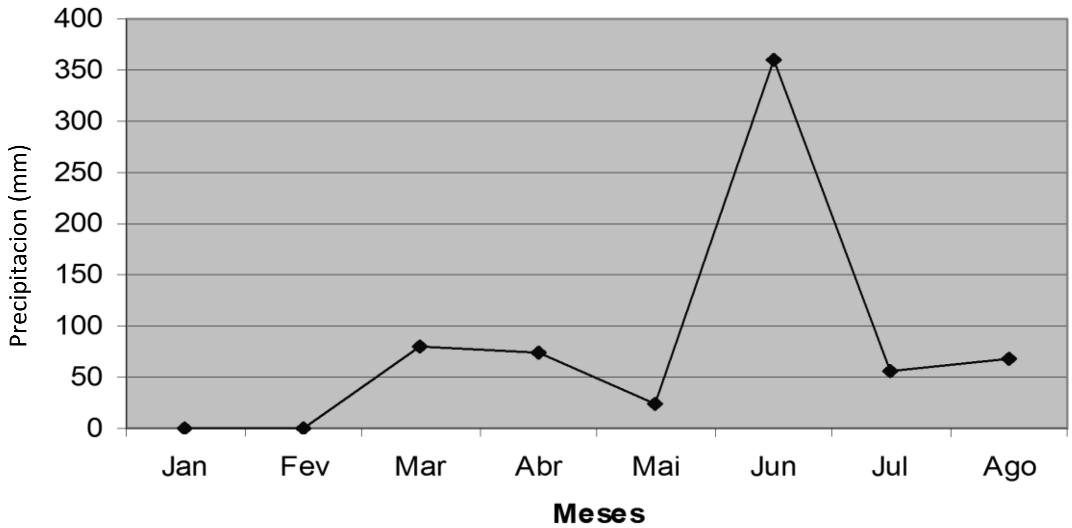

Figure 2. Monthly rainfall in the Padre Azevedo Reservoir "Pacatuba Farm" from Jan/07 to Aug/07. Source: http://www.cptec.inpe.br/proclima2/balancohidrico.shtml

The Pacatuba net-cage aquaculture production unit, at the Padre Azevedo reservoir, initially sustained a total of 300 net-cages, each with 4 m^3 water capacity. Nowadays, the number of these cages has been largely reduced due to decreased water quality (Figure 3).

Furthermore, each net-cage produced approximately 800 fishes with an initial average weight of 70 g (density of 200 fishes per m^3), which was subsequently reduced to 700 fishes (175 fishes per m^3) and 600 fishes (150 fishes per m^3).

Three replicate samplings (RP_1, RP_2 and RP_3) were collected along a transect line at each of four sampling stations (P_1, P_2, P_3 and P_4). Prevailing wind direction is southeast/northwest. Sampling station P_1 is located upstream from the culture site, P_2 is among the net-cages and P_3 is located downstream from the culture site. P_4 is the furthermost sampling station, located upstream, nearby the Una streamlet (Figure 2). Also, islets are formed between stations P_1 and P_4, therefore narrowing the reservoir and further isolating station P_4.

Samples were collected monthly and the study was conducted between February and September 2007.

Zooplankton evaluation

Zooplankton individuals were collected by filtering 15 L of surface water through a plankton net (mesh size: 45 m) and stored at properly labeled glass bottles. Individuals were fixed in field with a 4% formaldehyde solution saturated with sugar, to prevent morpho-logical deformities (Haney and Hall, 1973).

A qualitative evaluation was carried out by taxonomically identi-fying the organisms based on taxonomic keys and specialized lite-rature (Koste, 1972; Ruttner-Kolisko, 1974; El Moor-Loureiro, 1997). Where possible, taxa were identified to species-level. Cope-pods were identified only to Order level. Quantitative assessment of sub-samples was carried out with at least 100 individuals. Random sub-samples were taken from each sample with a Hensen-Stempel pipette (1 ml volume) for both qualitative and quantitative analyses, which were assessed on a Sedgwick-Rafter counting chamber. Val-ues used hereafter are average values obtained from the replicates at each sampling station.

RESULTS

Precipitation data were evaluated between January and August 2007. Higher precipitation rates were recorded between March and July 2007 (Figure 2). Further, the rainy season started in March, with somewhat low rainfall, and June showed the highest precipitation rates (that is, 360 mm). Lowest precipitation rates (that is, 0.25 mm) were recorded between January and February.

Zooplankton community was represented by 18 spe-cies (Rotifera: 15; Cladocera: 3). Copepoda indivi-duals were identified to the Order level, but categorized as nau-plii, copepodites and adults (Calanoida and Cyclo-poida). A summary of the identified species is shown in Table 1.

Zooplankton community showed two peaks of density, namely, in March (late dry season) and in August (late rainy season) (Figure 3). Furthermore, maximum density observed in August reached 4,579.25 ind.L^{-1}.

Rotifers showed the highest number of species and individuals throughout the study. Stations P_1 and P_2 sho-wed similar overall densities on both spatial and temporal scales. Rotifers and copepods alternated as the most abundant groups from February to April, but the former persisted as the most abundant group thereafter. Density of rotifers reached maximum values of 1,300 and 1,150 ind.L^{-1} at stations P_1 and P_2, respectively. At station P_3 rotifers were most abundant in February and March (ma-ximum density: 1,050 ind.L^{-1}), showing lower values at the subsequent months. A different pattern was observed at station P_4 where, throughout the study, copepods (Cy-clopoida) were the most abundant group, particularly, during the first months (maximum density: 800 ind.L^{-1}) (Figure 3).

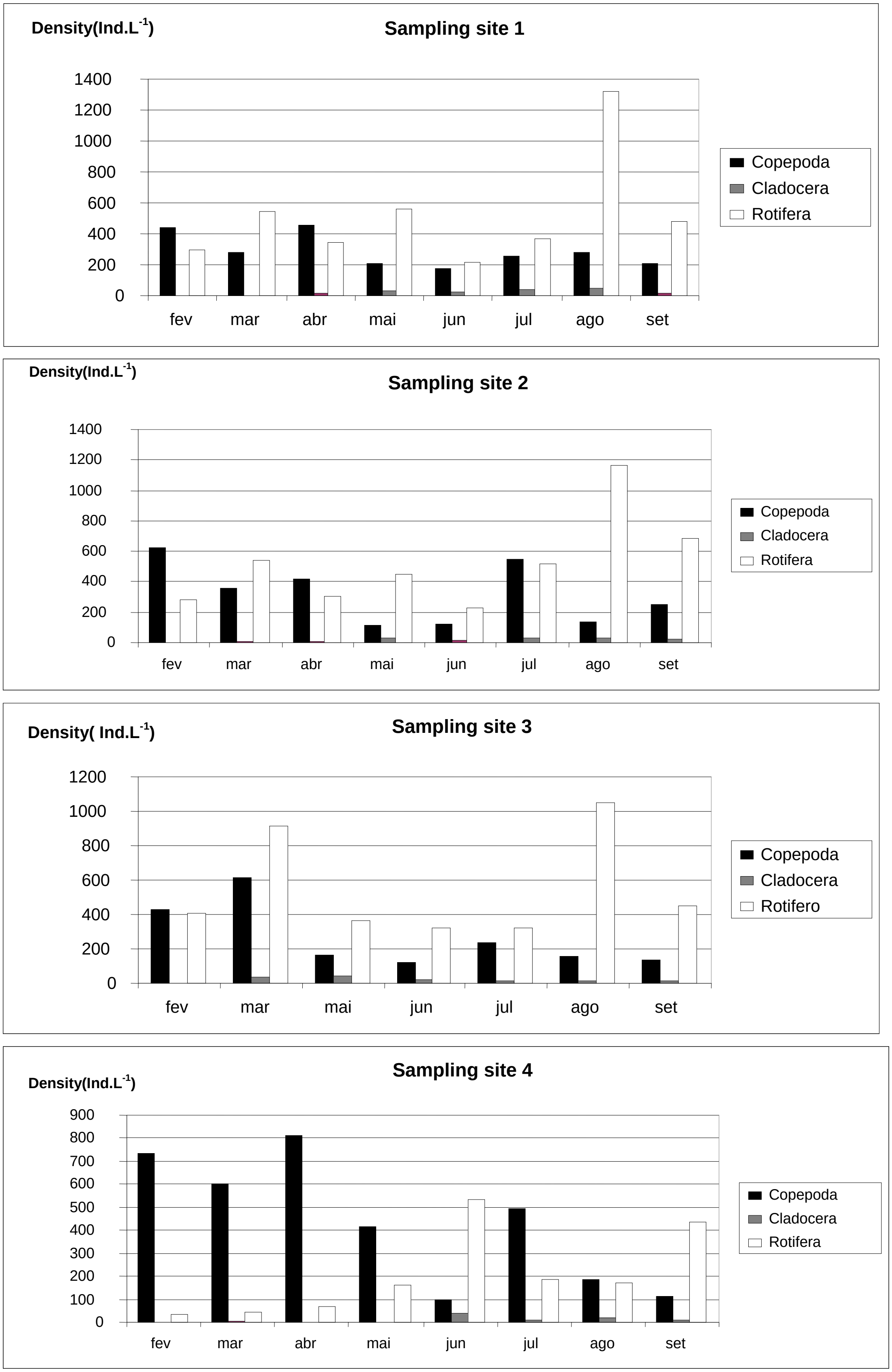

Figure 3. Temporal variation of zooplankton density at Padre Azevedo Reservoir from Feb/07 to Sep/07.

Table 1. Species and Orders (Copepoda) recorded at the Padre Azevedo Reservoir, throughout the study period.

TAXA	
ROTIFERO	**COPEPODA**
Asplanchna sp.	Nauplio
Anueropsis fissa	Copepodite
Brachionus calyciflorus	Calanoide
Brachionus caudatus	Cyclopoide
Brachionus havanensis	
Brachionus urceolaris	
Cephalodella sp.	
Filinia terminalis	
Keratella tropica	
Lecane bulla	**CLADOCERA**
Lecane luna	*Diaphanosoma spinulosum*
Lepadela patella	*Ceriodaphnia cornuta*
Poyarthra vulgaris	*Moina minuta*
Polyarthra dolichoptera	
Rotaria sp.	

Temporal variation of Rotifera

A total of 15 Rotifera species were recorded, *Brachionus* being the most common genus. An increase in rotifer abundance was observed, with a maximum density recorded in August at stations P_1, P_2 and P_3. Station P_4 was somewhat unusual, with higher rotifer abundance recorded in June. Also, compared to the other stations abundance was always lower at station P_4. *Keratella tropica*, the most abundant species reached a maximum density of 1,156.8 ind.L^{-1} in August, thereby elucidating its observed negative correlation to precipitation rates (R=N-PC).

Temporal variation of Cladocera

Three Cladocera species (*Diaphanosoma spinulosum*, *Moina minuta* and *Ceriodaphnia cornuta*) were recorded, but their densities were somewhat low throughout the study period. Higher densities of these species were recorded in May and August 2007, being *D. spinulosum* the most abundant species, particularly in May (42.35 ind.L^{-1}). It is worth mentioning that this group was not recorded in February. Cladocerans were highly influenced by environmental fluctuations, being positively affected by precipitation during the rainy season. Frequently, cladocerans are negatively affected by eutrophization, the opposite being observed for rotifers. Evidence to support this observation comes about from the effects of rainfall, reducing trophic levels, and its positive influence on densities of cladocerans.

Spatial analysis revealed that stations near the culture site were similar, with higher abundance of *D. spinulosum*. *C. cornuta* was observed in June and *M. minuta* in September, but with somewhat low densities. Also, lower densities were recorded at station P4 when compared to the others.

Temporal variation of Copepoda

Highest and lower densities of copepods were recorded in February and in June, respectively. Culmination of the dry season occurred in February (Figure 5), thereby increasing the trophic state and the density of rotifers and, in turn, benefiting copepods which feed on these smaller organisms. The lowest peak of density recorded in June may be related to increasing precipitation rates which diluted nutrients and negatively influenced rotifers and copepods.

Spatial variation of zooplankton community

Cladocerans were not recorded in February 2007. Copepods and rotifers showed similar densities from stations P_1 to P_3, but Calanoida copepods were more abundant than rotifers at station P_4, suggesting a reduced trophic state (Figure 4), given that individuals of the former group positively correlated to oligotrophic waters.

Cladocerans (*D. spinulosum*) were recorded in March at all but one station (that is, P_1). Copepods (mostly Cyclopoida) were most abundant at stations P_3 and P_4. A decrease in the density of Calonoida copepods was recorded at station P_4 in March, albeit low rotifer densities persisted. This suggests that limnetic conditions were somewhat constant amongst all stations and that the

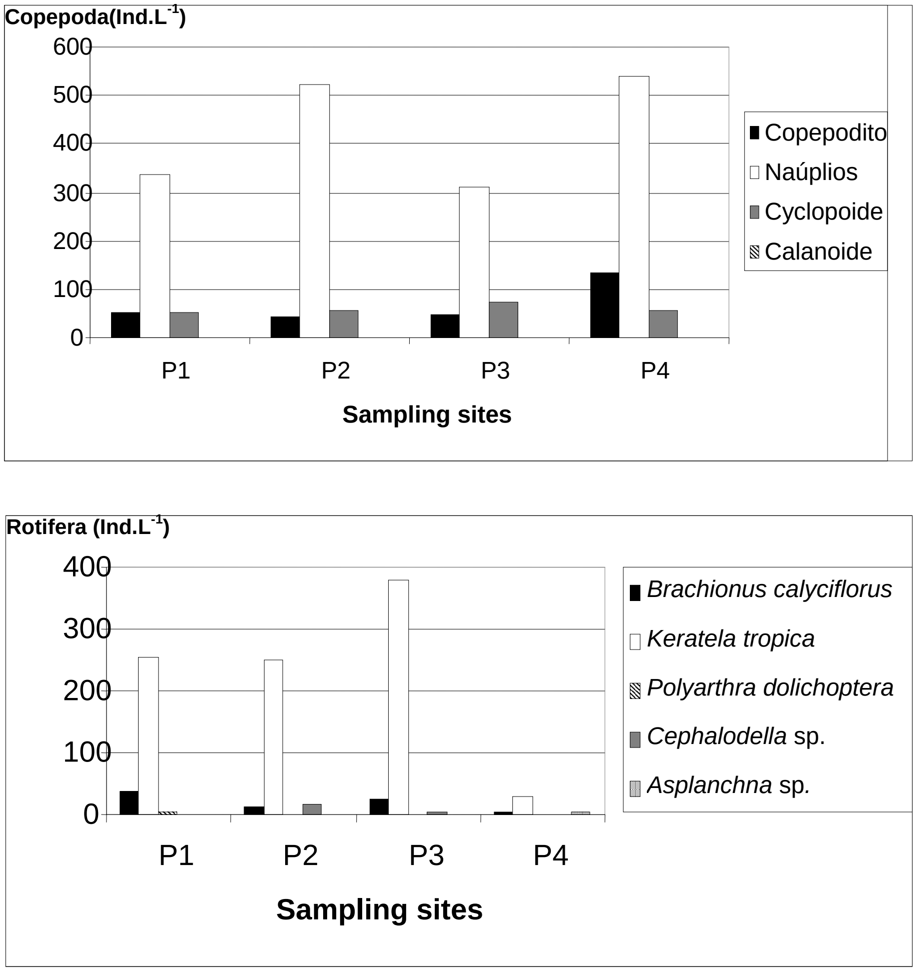

Figure 4. Spatial variation of zooplankton density at Padre Azevedo Reservoir in February.

decrease in rotifer numbers were the result of higher predation rates by Cyclopoida copepods.

Due to technical issues, sampling was precluded at station P_3 in Abril. Station P_4 persisted showing low rotifer densities (Figure 6) and densities of copepods were similar across all stations. Although *K. tropica* persisted as the most abundant species during this month, nauplii were more abundant at station P_4, followed by *Anuraeopsis fissa*.

In May, higher densities of copepods (mostly nauplii and Cyclopoida) were recorded at station P_4. Calanoida copepods were only recorded at station P_3. The cladoceran *D. spinulosom* was recorded, albeit in low numbers, at station P_4. As in the other months, rotifers were also less abundant at station P_4.

In June, copepods were more abundant at station P_1 and gradually decreased throughout the other stations. Calanoida copepods showed higher abundances at stations P_1 and P_4. Cladocerans showed a higher richness at station P_2, with the presence of *C. cornuta* and *D. spinulosum*. The latter species was recorded at all stations, being more abundant at P_1. Density of rotifers increased from stations P_1 to P_4, *Brachionus havanaensis* being the most abundant species, this month.

In July, overall zooplankton density increased, particularly, that of copepods. Station P_2 showed higher nauplii density than P4 (Figure 9). Increased densities of copepods, particularly nauplii, are common during the beginning of rainy seasons (Crispim et al., 2006). Cladocerans showed a similar pattern to the preceding month, with two species recorded at station P3 and a decrease in *D. spinulosum* density from P_1 to P_4. Within rotifers, *K. tropica* was the most abundant species, followed by *B. calyciflorus*. *Brachionus urceolaris*, recognized as an indicator of eutrophic conditions (Pejler, 1983) was only recorded at station P^1. Station P^4 showed low densities of rotifers.

Water quality improved in August (winter), densities of copepods declined and Calanoida copepods were recorded at all station in August (winter) (Figure 10). Cyclopoida

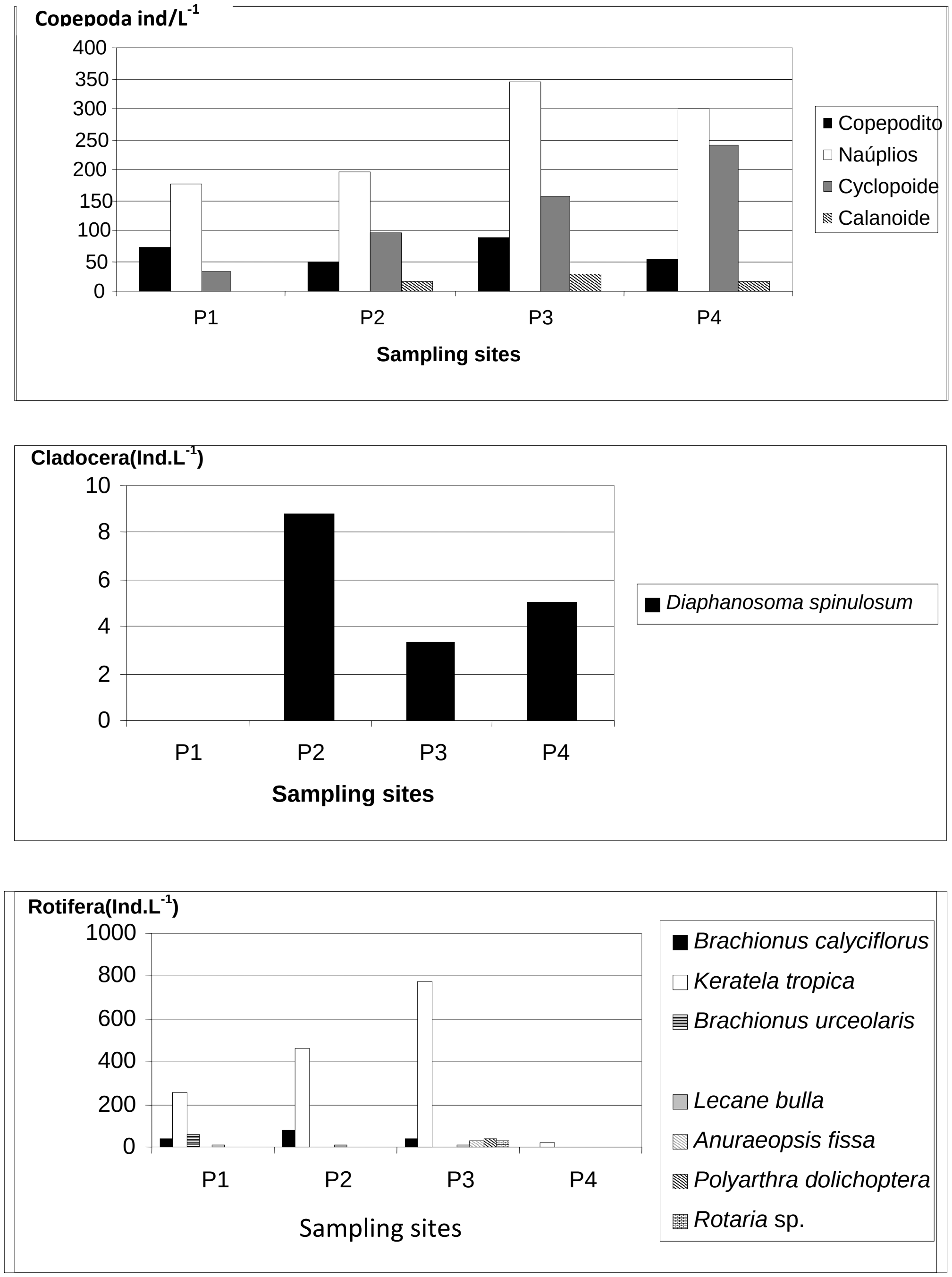

Figure 5. Spatial variation of zooplankton density at Padre Azevedo Reservoir in March.

copepods were less abundant, whereas Calanoida copepods were most abundant, at station P_4, suggesting a somewhat good water quality at this station. *D. spinulosum* and *C. cornuta* were recorded at all stations, the former being most abundant at P_1 and the latter at P_4. Rotifer density (mostly *K. tropica*) highly increased, but densities were relatively low at station P_4, even for *K. tropica*. Station P_3 and P_4 showed higher species richness.

In September, copepods showed similar densities and overall composition to the preceding months. Cladocerans also showed a similar pattern, but *D. spinulosum* density decreased, particularly at stations P_1 and P_2 (Figure 11). *B. havanaensis* was, once more, the dominant species at all stations and a non-identified Bdeloidea species was recorded at stations P_1 to P_3, with higher density at P_2.

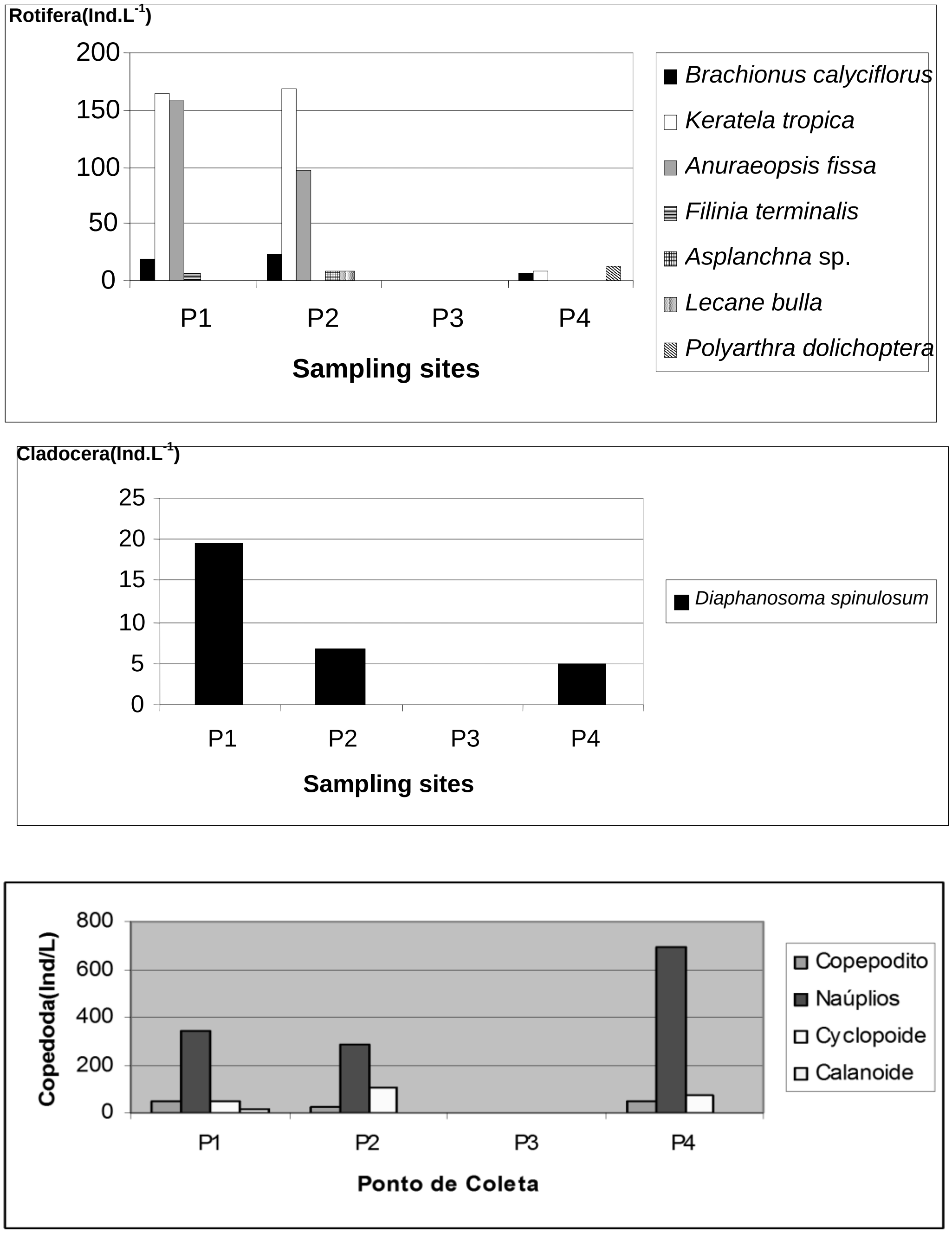

Figure 6. Spatial variation of zooplankton density at Padre Azevedo Reservoir in April.

Spatial analysis of zooplankton community

To evaluate and compare the spatial and temporal distribution, similarity analysis was employed. This analysis showed that during the dry season (or with lower rainfall between February and May) sampling station P_4 distinguished isolated groups. Further, station P_4 separated from the others in July, but in June, August and September, showed a higher similarity, nearby the culture site (Figure 12). Station P_2, in the center of the culture site, showed higher similarities with both stations P_1 (upstream) and P_3 (downstream), suggesting that this activity is starting to influence on the water quality at areas nearby the culture site.

DISCUSSION

The three most important zooplankton groups (Rotifera,

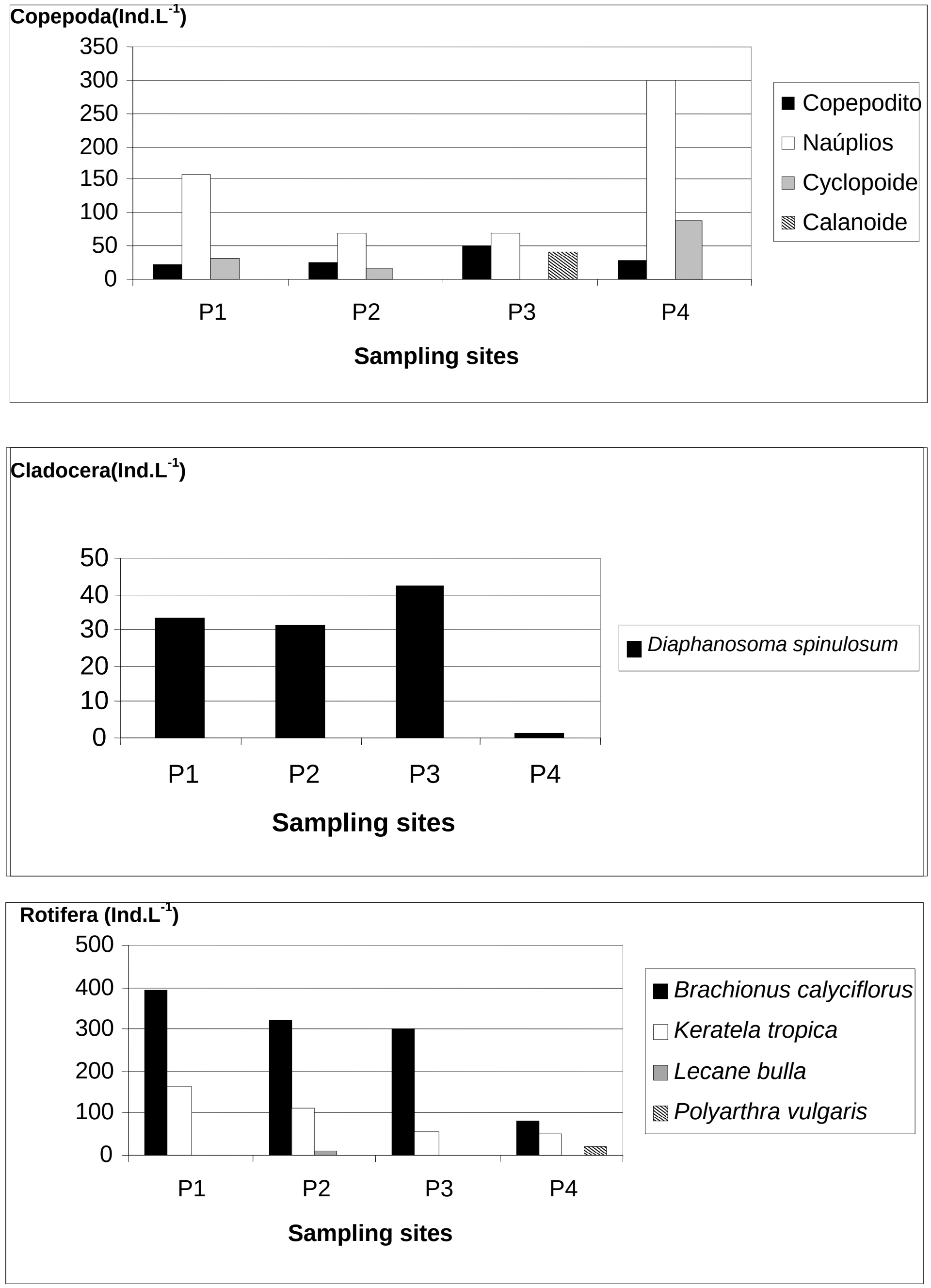

Figure 7. Spatial variation of zooplankton density at Padre Azevedo Reservoir in May.

Cladocera and Copepoda) were recorded at all sampling stations throughout most of the evaluated months. Most of the species recorded at the present study have also been recorded in other aquatic environments of Paraíba state (Crispim and Watanabe, 2000b; Vieira et al., 2000; Vieira, 2001; Crispim et al., 2006; Ribeiro, 2006) and several other tropic environments (Vasquez and Rey, 1992; Pinto-Coelho et al., 2005; Landa and Mourgues-Schurter, 2000).

The somewhat low zooplankton diversity recorded at the present study may be linked to the short study period (that is, eight months), but also, to the high trophic conditions of the reservoir.

Rotifers were the most frequent and abundant organisms, as similarly acknowledged by Gomes (2007). Higher rotifer richness is common in lentic environments (Landa and Mourgues-Schurter, 2000b). Sendacz et al. (2006) also suggested that rotifers make up a dominant zooplankton

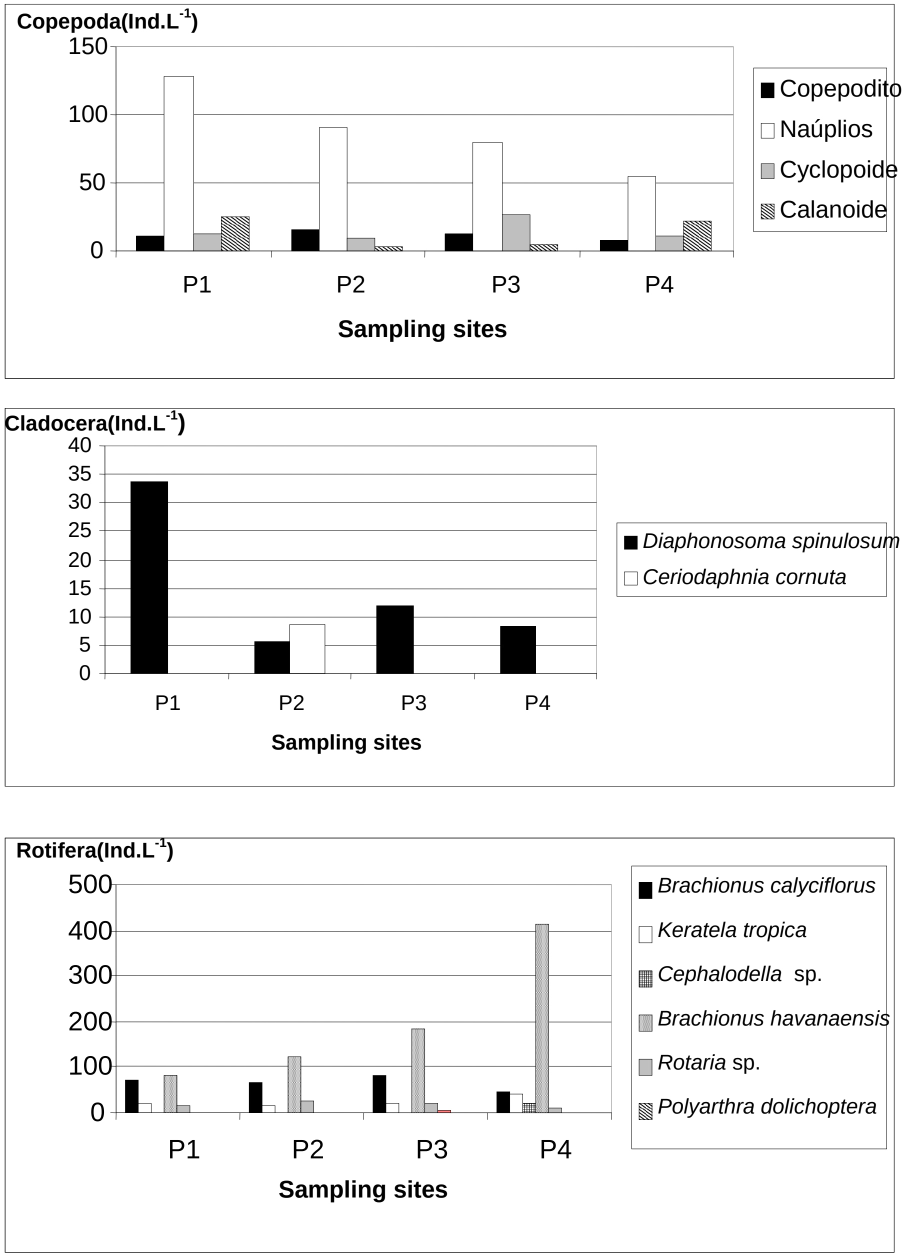

Figure 8. Spatial variation of zooplankton density at Padre Azevedo Reservoir in June.

group at aquatic environments of Brazil. Their high abundances are the consequences of several factors: Opportunistic habits which enable them to explore various environmental conditions, more than do cladocerans and copepods (Allan, 1976), high dispersal ability, resistant eggs, among others (Esteves, 1998).

Rotifer species indicators of environmental quality (that is, eutrophic environments) such as *B. calyciflorus* (Pejler, 1983), *K. tropica* and *Polyarthra dolichoptera* (Crispim and Boavida, 1995) were recorded in the present study. However, since some *Brachionus* and *Keratella* species are also common at mesotrophic conditions, we are not certain if their presence indicated an exclusive eutrophic condition in the reservoir, further investigations being necessary. Nevertheless, the presence of *B. angularis* and *B. urceolaris*, strong indicators of eutrophization, suggests that the reservoir is, indeed, under high trophic levels. Furthermore, the high densities of these species are also indicative of high productivity levels.

Higher species richness of Rotifera during dry seasons was also recorded elsewhere (Landa and Mourgues-

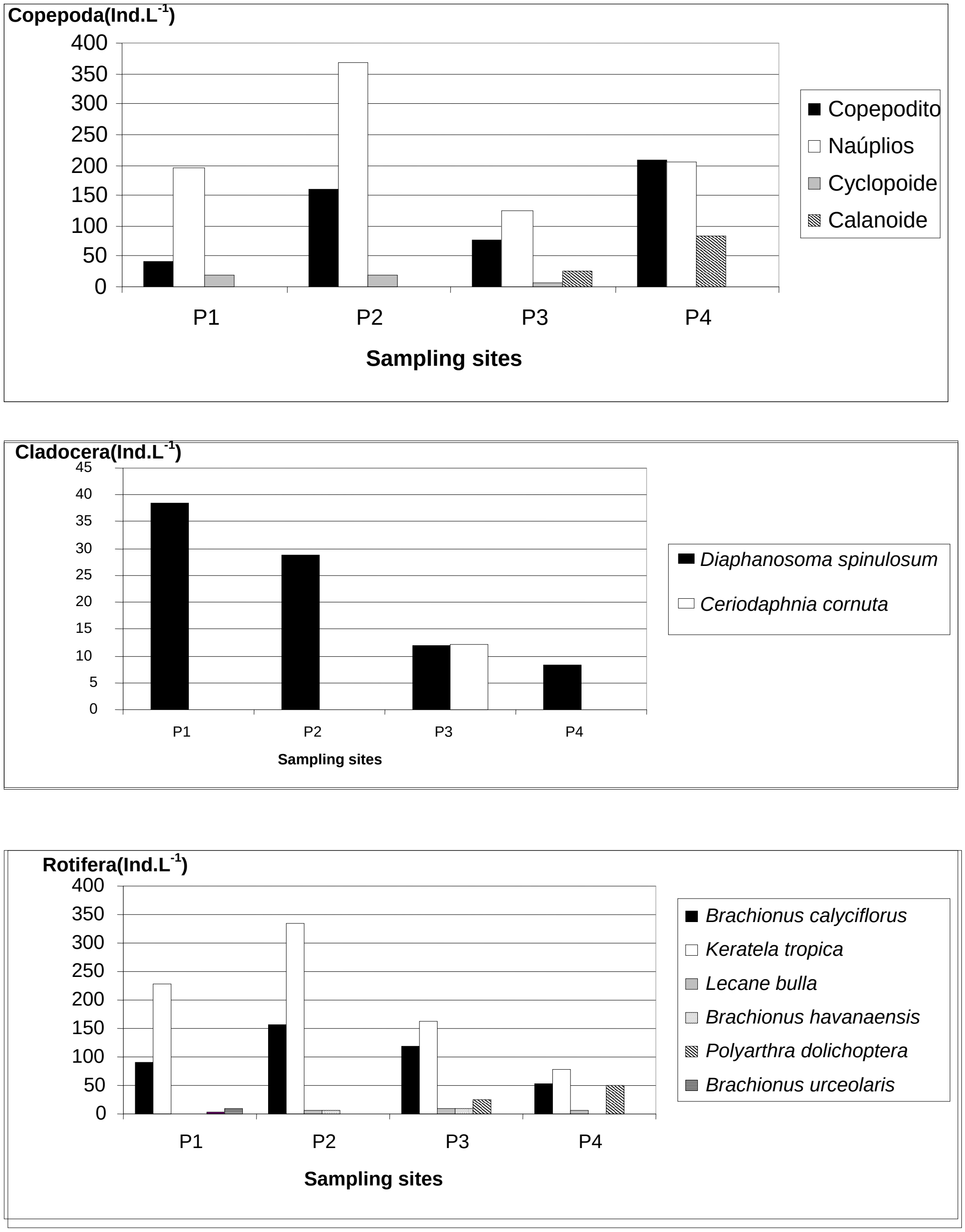

Figure 9. Spatial variation of zooplankton density at Padre Azevedo Reservoir in July.

Schurter, 2000). Moreover, rotifers and some copepods benefit from eutrophization processes (Esteves and Sendacz, 1988; Moredjo, 1996). Rotifer species indicators of high trophic conditions and high densities of Cyclopoida copepods, as recorded in the present study, support this observation. Copepods (mostly nauplii) were the second most abundant group in the reservoir. Juvenile stages of copepods (nauplii and copepodites) are commonly observed at higher densities than adults (Crispim and Watanabe, 2000a; Crispim et al., 2006). It is noteworthy, however, that juvenile stages occupy different ecological niches from adults (Perticarrari et al., 2004), often prevailing at different depths and, therefore, reducing competition and minimizing predation from potential adult copepods (Crispim, 1998). The intense interspecific competition within this group may also lead to lower limnetic diversity (Vieira et al., 2000).

The observed variety of copepod life stages in the reser-

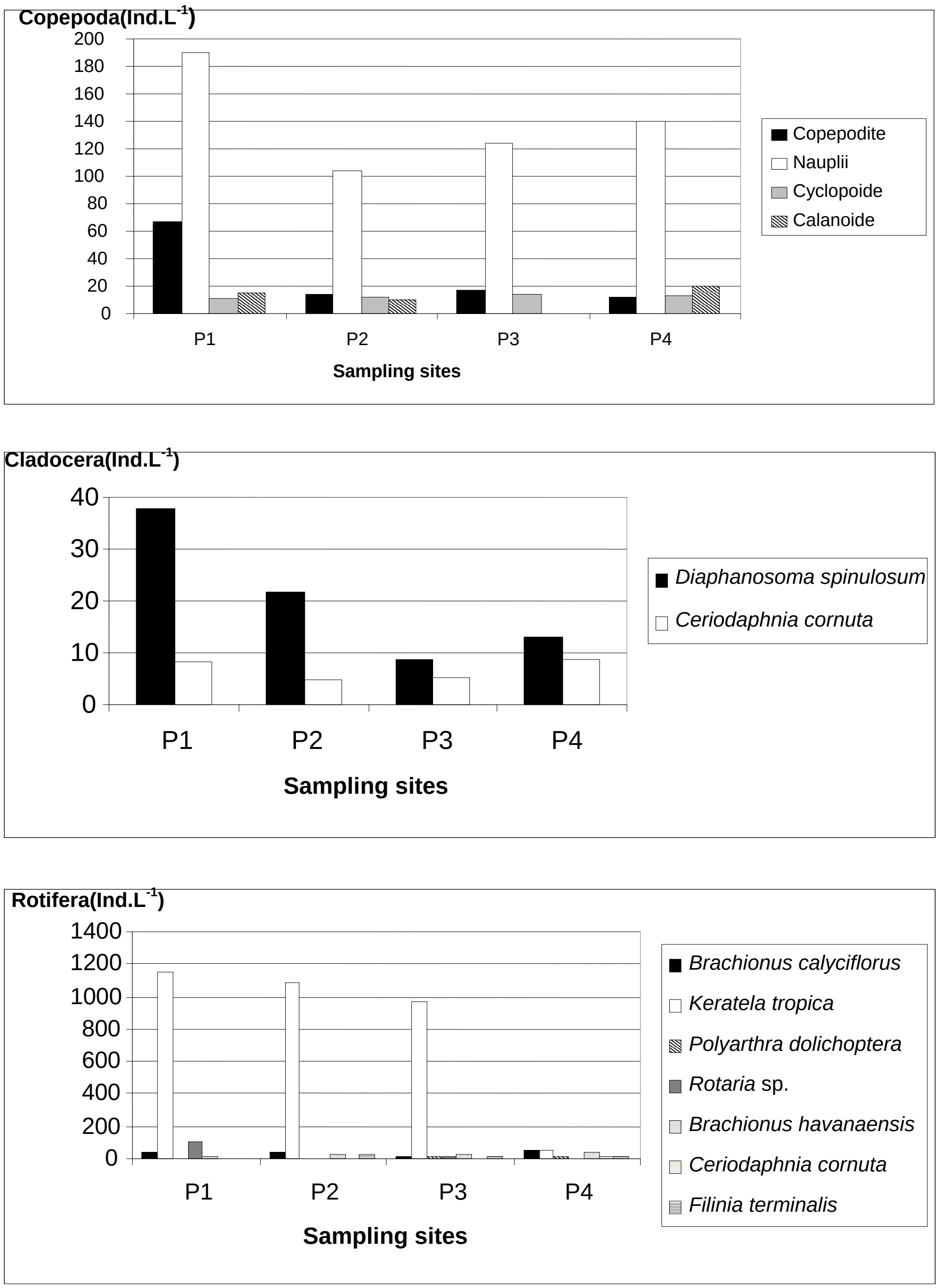

Figure 10. Spatial variation of zooplankton density at Padre Azevedo Reservoir in August.

voir may also be indicative of their continuous reproductive behavior, a strategy triggered by their underlying unstable environment. Different life stages of Calanoida copepods were also recorded here. Species of this group are mostly detritivores and herbivores.

Therefore, high densities of these individuals may be indicative of waters with somewhat low trophic conditions (Pinto-Coelho et al., 2005). Calanoida copepods were substantially less abundant than Cyclopoida copepods throughout the study, once more suggesting that high trophic conditions prevail in the reservoir.

The higher densities of Cyclopoida copepods are likely to be an effect of the intrinsic omnivorous and herbivorous habits of their nauplii and copepodites (Perticarri et al., 2004). Moreover, the constant high densities of their prey (that is rotifers) also favored species of this group. Several authors also recognized that Cyclopoida copepods are often associated to sites with high trophic levels

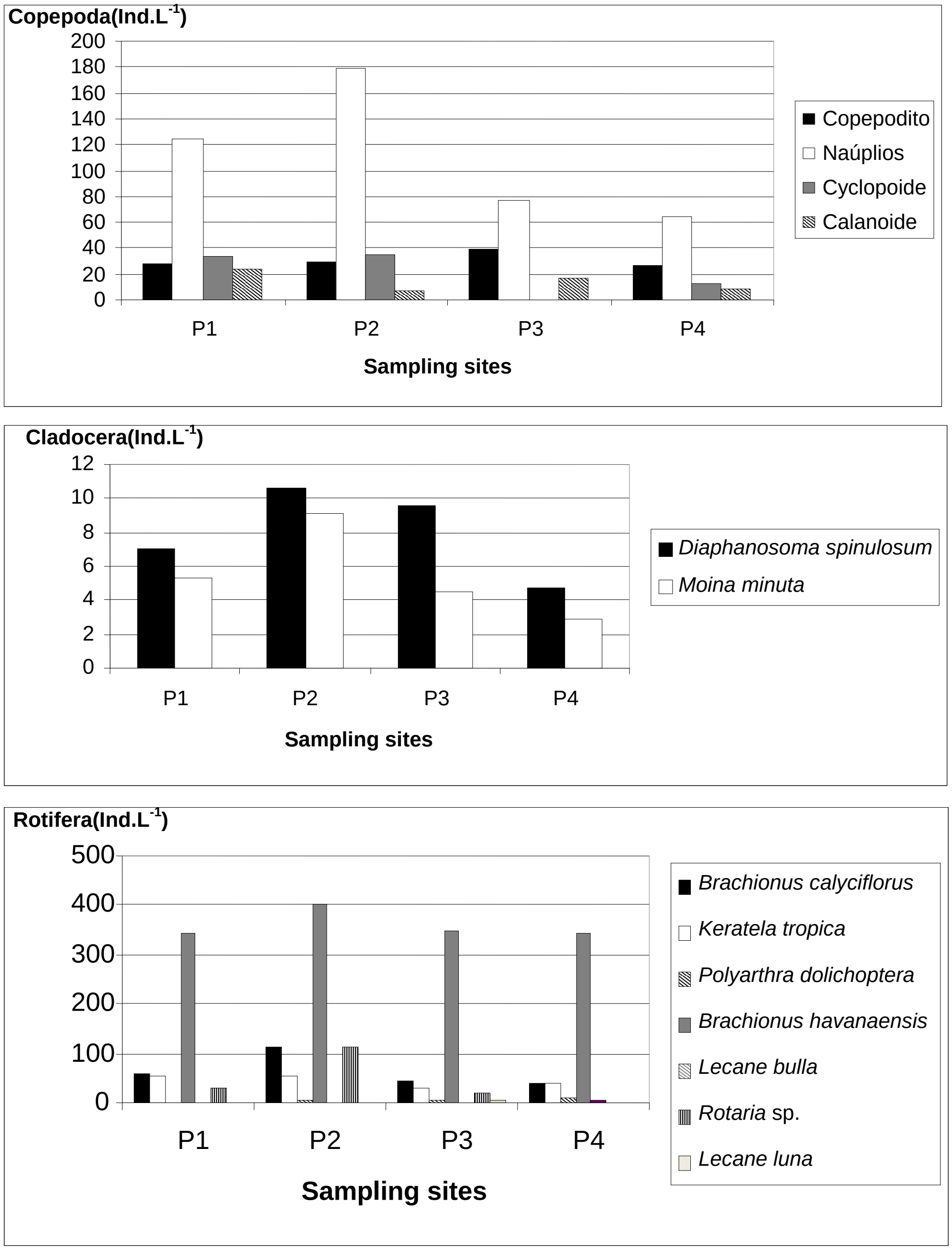

Figure 11. Spatial variation of zooplankton density at Padre Azevedo Reservoir in September.

(Gannon and Stemberger, 1978; Landa and Mourgues-Schurter, 2000b). Precipitation rates, which started in February, had a major influence on the overall zooplankton community. Basu and Pick (1996) stated that sites which are subject to periodic overflows may suffer a decrease in plankton biomass, as a direct consequence of mechanical stress, or due to a shift in environmental conditions. The peak of zooplankton density observed in March was related to increased trophic levels and cascade effects via phytoplankton production (summer). However, overgrazing by zooplankton soon reduced phytoplankton availability, therefore, also reducing their populations. With the late rainy season, a nutrient input further supplied phytoplankton with food and, once more, benefited zooplankton populations, as observed in the second peak of zooplankton density.

High densities of Cyclopoida copepods at station P_4 were probably related to a reduced predation pressure at this station, given that fishes were most abundant nearby the culture site (that is, stations P_1, P_2 and P_3), where

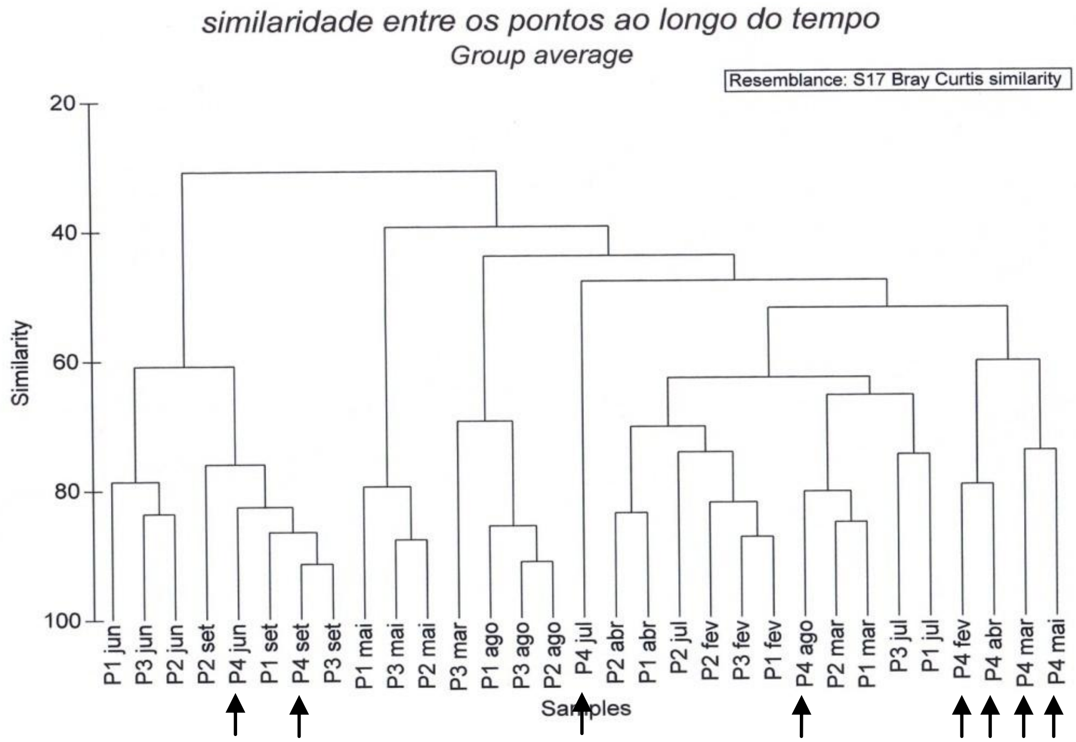

Figure 12. Dendrogram of similarity regarding zooplankton communities (density/species).

excessive artificial food attracts these fishes (fishermen's personal communication). Densities of copepods varied on both spatial and temporal scales. Also, factors not considered in the present study may have also been important. For example, selective predation of fishes towards larger, visible zooplankton individuals (Timm and Moss, 1984; Sarma et al., 2004; Rejas et al., 2005) may have played a role in determining the observed zooplankton composition.

Given that the most abundant rotifers were indicators of eutrophization, their reduced densities at station P4 may be indicative of higher water quality there. For example, *B. calyciflorus*, a species frequently associated to eutrophic sites, was less abundant at this station.

The presence of Bdeloidea at stations P_1 to P_3 suggests that these areas were subject to high concentrations of organic debris in the water column, given the tendency of individuals from this group to associate to particulated organic matter. The presence of this group at stations nearby the culture site, and their absence at station P_4, suggests that areas nearby the culture site are subject to greater disturbances, due to constant accumulation of organic matter nearby this area.

In 2008, new evaluations conducted at the same site found no differences among sampling stations, supporting the above mentioned statements on the cumulitive negative effects of fish aquaculture to the overall water quality (Crispim et al., unpublished data).

Conclusion

Based on the results of the present study, the following conclusive statements were made:

(i) Zooplankton community at the study area consisted of three groups, namely, Rotifera (15 species), Cladocera (3) and Copepoda (identified to the order level).

(ii) Rotifers were the most abundant group at stations P_1, P_2, P_3 and P_4. Copepods were most abundant at station P_4.

(iii) Dominant species varied throughout the study, *B. calyciflorus* being dominant in June, *B. havanaensis* being dominant in June and September and *K. tropica* being dominant in July and August.

(iv) Indicator species of eutrophization were recorded at the reservoir, with higher observed densities during the dry season, coinciding with higher trophic levels.

(v) Similarity analysis revealed that station P4 formed isolated groups among the evaluated months, suggesting an impact of aquaculture on the areas surrounding the culture site.

(vi) An ongoing monitoring of the reservoir is necessary to further understand of the processes and annual variations of zooplankton communities.

ACKNOWLEDGEMENT

We are highly indebted to CNPq, for providing financial support via Edital Universal process number 486337/2006-5.

REFERENCES

Allan JD (1976). Life History Patterns in Zooplankton. Am. Nat. 110 (971):165-180.

Basu BK, Pick FR (1996). Factors regulating phytoplankton and zooplankton biomass in temperate Rivers. Limnol. Oceanogr. 41 (7): 1572-1577.

Colt J and Montgomery JM (1991). Aquaculture production systems. J. Anim.Sci. 69: 4183-4192.

Crispim MC, Boavida MJ (1995). Comparison of rotifer communities in Maranhão Reservoir (Portugal) before its complete emptying and refilling. Hydrobiologia 313/314: 325-332.

Crispim MC (1998). Estudo do impacte do esvaziamento da Albufeira do Maranhão sobre a comunidade zooplanctônica – Principais relações bióticas que afectam os cladóceros. Tese de doutorado. Faculdade de Ciências da Universidade de Lisboa. Lisboa.

Crispim MC and Watanabe T (2000a). Caracterização limnológica das bacias doadoras e receptoras de águas do Rio São Francisco: 1 – Zooplâncton. Acta Limnol. Bras. 12: 93-103.

Crispim MC and Watanabe T (2000b). Ovos de resistência de rotíferos presentes em sedimentos secos de um açude no semi-árido paraibano. Acta Limnol. Bras. 12(1): 89-64

Crispim MC, Ribeiro LL, Gomes SEM, Freitas GTP, Serpe FR (2006). Comparison of different kind of semi-arid aquatic environments based on zooplankton communities. Revista de Biologia e Ciências da Terra. 6:98-111.

El Moor-Loureiro LMA (1997). Manual de identificação dos cladóceros límnicos do Brasil. Brasília. UCB, p. 100.

Esteves FA (1998). Fundamentos de Limnologia. 2a. ed. Rio de Janeiro: Interciência, p. 602.

Esteves FA and Sendacz S (1988). Relações entre a biomassa do zooplâncton e o estado trófico de reservatórios do Estado de São Paulo. Acta Limnol. Bras. 2: 587-604

Gannon JE, Stemberger, RS (1978). Zooplankton (Especially Crustacean and Rotifers) as Indicator of Water Quality. Transactions of the American Microscopical Society. 97(1): 16-35.

Gomes SEM (2007). Caracterização da Comunidade Zooplanctônica do Açude Soledade, Semi-Árido Paraibano. Universidade Federal da Paraíba. Monografia.

Gophen M, Walline P, Ostrovsky I, Azoulay B, Easton J (1999). Water quality and fishery management in Lake Kinneret, Israel. In: Tundisi, JG, Straškraba, M. (ed.). Theoretical reservoir ecology and its applications. São Carlos: Brazilian Academy of Sciences, International Institute of Ecology and Backhuys Publishers: 493-503.

Haney JS, Hall DJ (1973). Sugar-coated *Daphnia*: a preservation technique for Cladocera. Limnol. Oceanogr.18: 331-333.

Koste W (1972). Rotatorien aus Gewässern Amazoniens. Amazoniana, 3(3/4):258-505.

Lampert W (1997). Zooplankton research: the contribution of limnology to general ecology paradigms. Aquatic Ecology, 31:19-27.

Landa GG, Muorguês-Schurter, LR (2000a). Caracterização da comunidade zooplanctônica de um sistema artificial (represa zootecnia), no campus da Universidade Federal de Lavras – MG. Acta Limnol. Bras. 12: 69-83.

Landa GG, Mourgues-Schurter LR (2000b). Composição e abundância do zooplâncton de duas represas do Campus da Universidade Federal de Lavras, Minas Gerais, Brasil. Acta Limnol. Brasil. 12(2): 29-43.

Margalef R (1974). Ecologia**.** Barcelona. Omega. p. 951.

Moredjo A (1996). Avaliação dos efeitos das atividades humanas sobre o estado trófico dos açudes paraibanos, com ênfase na utilização da comunidade zooplanctônica como bioindicadora. PRODEMA-Programa de Pós-Graduação em Desenvolvimento e Ambiente. Universidade Federal da Paraíba. Dissertação de mestrado

Pejler B (1983). Zooplankton indicators of trophy and their food. Hydrobiology.101: 111-114.

Perticarrari A, Arcifa MS , Rodrigues RA (2004). Diel vertical migration of copepods in a Brazilian lake: a mechanism for decreasing risk of *Chaoborus* predation? Braz. J. Biol*.* 64(2): 289-298.

Pinto-Coelho RM (2004). Métodos de coleta, preservação, contagem e determinação de biomassa em zooplâncton de águas epicon-tinentais. In: Bicudo, CEM, Bicudo, DC (ed.). Amostragem em Limnologia. São Carlos: RiMa: 149-166.

Pinto-Coelho RM, Bezerra-Neto JR , Morais-Jr. CA (2005). Effects of eutrophication on size and biomass of crustacean zooplankton in a tropical reservoir. Brazil. J. Biol. 65(2): 325-338.

Rejas D, Villarpando P, Carvajal F (2005). Variaciones estacionales en la dieta de *Moenkhausia dichroura* Kner (Pisces, Characidae) en una laguna de la várzea Del rio Ichilo (Cochabamba-Bolivia). Revista Boliviana de Ecologia y Conservación Ambiental. 17: 49-54.

Ribeiro LL (2006). Zooplâncton em um açude no Cariri paraibano: relações entre a diversidade e a qualidade da água. Monografia de Graduação. João Pessoa. Universidade Federal da Paraíba.

Ruttner-Kolisko A (1974). Plankton Rotifers: Biology and Taxonomy. Die Binnengewässer v. Supplement, 26: 1-146.

Schwartz SS, Jenkins DG (2000). Temporary aquatic habitats: constraints and opportunities. Aquatic Ecology, 34: 3-8.

Sendacz S, Caleffi S, Santos-Soares J (2006). Zooplankton biomass of reservoirs in different trophic conditions in the State of São Paulo, Brazil. Braz.J.Biol. 66(1B): 337-350.

Timms RM , Moss B (1984). Prevention of growth of potentially dense phytoplankton populations by zooplankton grazing, in the presence of zooplanktivorous fish, in a shallow wetland ecosystem. Limnol. Oceanogr. 29(3): 482-486.

Vásquez E , Rey J (1992). Composition, abundance and biomass of zooplankton in Orinoco floodpain lakes, Venezuela. Annals Limnol. 28(1): 3-18.

Vieira DM, Crispim MC, Watanabe T (2000). Impacto da cheia e da seca sobre a comunidade zooplanctônica do Açude São José dos Cordeiros, no semi-árido paraibano. Anais do V Simpósio de Ecossistemas Brasileiros: Conservação. 10 a 15 de Outubro de 2000. Vitória, ES: 401-407.

Vieira DM (2001). Estudo da composição dos rotíferos (zooplâncton) de três açudes da Bacia do Rio Taperoá, semi - árido paraibano, nos períodos de seca e chuva. Universidade Federal da Paraíba, Monografia de graduação. João Pessoa. p. 25.