Composition, diversity and short-term temporal fluctuations of zooplankton communities in fish culture ponds (Pindamonhangaba), SP

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(With 7 figures)

Abstract

The present study aimed at evaluating the composition, diversity and short-term temporal fluctuations of zooplankton communities in fish ponds. The study was carried out in two fish ponds, with 180 m^2 of water surface (6 × 30 m) each, located in the Aquiculture Centre of the Pindamonhangaba Fisheries Institute – São Paulo. The study was developed over eight weeks, from February 16 to April 6, 1998. The physical and chemical conditions of the water in the fish ponds were adequate for zooplankton development. The zooplanktonic community was characterised by high richness of species and a greater diversity was observed in the first fish pond, with a superior density of Rotifera. Temporal changes in zooplankton composition occurred in both ponds with Cladocera appearing in abundance later, in the fourth week, whereas copepods and rotifers were well represented since the beginning. Many species found are typical of fish ponds and are considered to constitute an excellent food source, showing high nutritional value for fish larvae, a good example being individuals from the Rotifera group and the micro-crustacean species *Moina minuta* and *Thermocyclops decipiens*.

Keywords: fish pond, zooplankton, diversity, temporal fluctuations.

Composição, diversidade e flutuações temporais de curto prazo da comunidade zooplanctônica de viveiros de piscicultura (Pindamonhangaba), SP

Resumo

O presente estudo visou avaliar a composição, a diversidade e a flutuação do zooplâncton em dois viveiros escavados na terra com 180 m^2 de espelho d'água (6 × 30 m) cada um, no Núcleo de Aquicultura do Instituto de Pesca de Pindamonhangaba-SP. O estudo foi realizado durante oito semanas, no período de 16 de fevereiro a 6 de abril de 1998. As condições observadas, em relação às características físicas e químicas da água dos viveiros, foram adequadas ao desenvolvimento dos organismos zooplanctônicos. A comunidade zooplanctônica foi caracterizada por elevada riqueza de espécies, com maiores densidades de organismos pertencentes ao grupo Rotifera. Mudanças temporais na composição do zooplâncton ocorreram em ambos os tanques, com Cladocera aparecendo em maior abundância mais tarde, na quarta semana, enquanto que copepodos e rotíferos foram bem representados desde o início. Muitas espécies encontradas são típicas de viveiros de piscicultura e constituem excelente fonte alimentar, apresentando alto valor nutritivo para larvas de peixes, como por exemplo os indivíduos do grupo Rotifera e as espécies *Moina minuta* e *Thermocyclops decipiens.*

Palavras-chave: viveiros, zooplâncton, diversidade, flutuações temporais.

1. Introduction

In recent years, freshwater aquaculture has undergone many advances due to efforts made to increase fish production (Sipaúba-Tavares et al., 1994). Shallow artificial reservoirs, such as fish-ponds, are extremely dynamic, due to wind action, precipitation and continuous water flow, presenting planktonic communities with peculiar characteristics due to the short residence time and the wide fluctuations of environmental characteristics (Rietzler and Rocha, 2000).

In fish cultures, water quality and the success in its management depend on a strong knowledge of the structure and functioning of the ponds, particularly with regard to the water's physical and chemical variables and to the biological communities (Sipaúba-Tavares et al., 1994).

The fresh water zooplankton is constituted mainly by microcrustaceans belonging to the Cladocera and Copepoda groups as well as by the Rotifera, in addition to some individuals from minor groups. In a eutrophic environment, the zooplankton community is usually dominated by the micro-zooplankton (Rotifera, Protozoa and copepod nauplii) (Sampaio et al., 2002). In fish culture activities, plankton production is a factor of great importance since it constitutes the most adequate food for the fish in their youngest phase, especially the rotifers and the cladocerans; the presence of these organisms in the environment may lead to better larval development (Feiden and Hayashi, 2005).

The diversity of zooplankton species in fish ponds is usually high, especially regarding rotifers, and many species can be used as water quality indicators (Macedo and Sipaúba-Tavares, 2005).

As in natural ecosystems, the zooplankton community of such ponds is also influenced by environmental variables, being dependent especially on the pH, alkalinity and temperature, as well as dissolved oxygen, nitrogen, phosphorus and ammonia concentrations (Sipaúba-Tavares and Moreno, 1994).

The present study attempted to evaluate the relations between zooplankton composition, diversity and short-term fluctuations of abundance, and environmental factors in two fish ponds at the Aquaculture Centre of the Pindamonhangaba Fisheries Institute - São Paulo.

2. Material and Methods

The study was carried out in two fish ponds, dug in the ground, of 180 m^2 of water surface (6 × 30 m) each, which were stocked with tilapia larvae (*Oreochromis niloticus*) with initial densities of about 128 to 131 larvae per m^2. During 50 days data regarding water temperature, water transparency (Secchi disk), pH and electrical conductivity were recorded weekly. The depth of the euphotic zone was calculated multiplying the value of the Secchi disk reading by the empirical coefficient of extinction, equal to 2.7 (Margalef, 1983). Each week, the concentrations of ammonia, nitrate, nitrite and dissolved and total phosphorus in the pond waters were determined. Diurnal variations of dissolved oxygen concentrations (D.O.) were analysed (measurements every 6 hours) at weekly intervals. Suspended solids concentrations were also measured once a week. These analyses followed the APHA (1998) methodology. Chlorophyll *a* concentration was determined weekly, using the methodology described in Golterman and Clymo (1969), with the modifications proposed by Wetzel and Likens (1991).

Zooplankton was collected weekly by horizontal net hauls in all the ponds' extension (30 m), using a plankton net with a mesh size of 60 µm. The volume filtered was calculated using the equation for calculating the volume of a cylinder ($\omega r^2 h$) being r the value of half of the diameter of the net mouth. The organisms were preserved in 4% formaldehyde. The qualitative and quantitative analyses were done under a stereoscopic microscope (50×) and an optical microscope (2,000×). For taxonomic identifications, a specialised bibliography was utilized (Edmondson, 1959; Koste, 1978; Reid, 1985; Segers, 1995; Elmoor-Loureiro, 1997; Silva and Matsumura-Tundisi, 2005). Counting of the organisms belonging to the Cladocera and Copepoda groups was performed in squared acrylic plaques, using sub-samples, or the whole sample for rare organisms. For the Rotifera, sub-samples of 1mL in a Sedgewick-Rafter chamber were utilised.

Diversity Shannon-Wiener index (in base 10) was calculated (Magurran, 1998). The constancy index was calculated considering: constant the species that occurred in more than 50% of the samples, accessory species that occurred in more than 25% and rare or accidental the species that occurred in less than 25% the samples (Dajoz, 1983).

3. Results

In Tables 1 and 2, the values relative to the parameters of the physical and chemical variables are shown. Figures 1 and 2 show the diurnal variations in dissolved

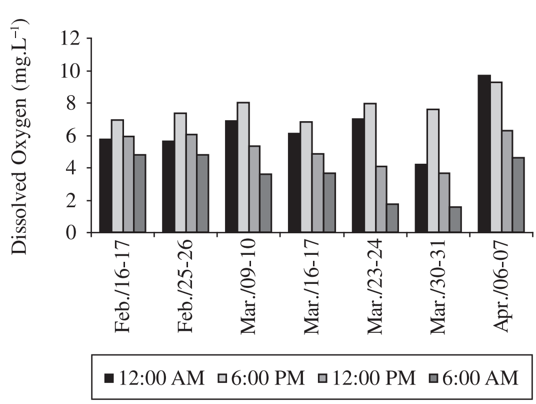

Figure 1. Diurnal variation of dissolved oxygen in pond 1, in Pindamonhangaba Aquaculture Station, from February to April, 1998.

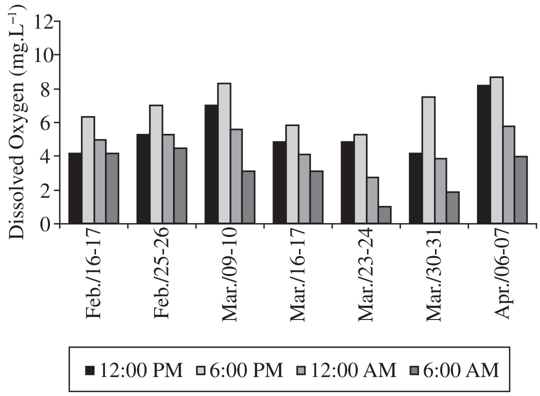

Figure 2. Diurnal variation of dissolved oxygen in pond 2, in Pindamonhangaba Aquaculture Station, from February to April 1998.

oxygen. The water temperature in both ponds varied from 24.5 to 30.8 °C. Water transparency was low during the whole study with values between 0.2 and 0.7 m. The pH in the ponds varied from slightly acid (6.7) to alkaline (7.7). Water conductivity varied from 42 to 74 µS.cm^{-1} in pond number 1 and from 41 to 70 µS.cm^{-1} in pond number 2. Oxygen concentrations in the water varied between 1.56 and 9.66 in pond number 1 and between 0.97 and 8.65 in pond number 2, during the diurnal cycle, reaching the minimum at 06:00 AM. The mean value of suspended solids was 16.3 ± 3.7, indicating high amounts of particles in the water.

The weekly average dissolved oxygen concentrations varied from 3.4 to 7.0 mg.L^{-1} over the study period. The ammonia concentrations varied from 0.14 to 1.36 mg.L^{-1}, nitrite from 2.1 to 82.9 µg.L^{-1}, nitrate from

Table 1. Mean values of physical, chemical and biological variables measured in Fish Pond 1, in Pindamonhangaba Aquaculture Station, during the period between February 16th and April 6th, 1998.

	Water temperature (°C)	Air temperature (°C)	Transparency (m)	Euphotic zone (m)	pH	Conductivity(µS.cm^{-1})	Dissolved oxygen (mg.L^{-1})	Ammonia (mg.L^{-1})	Nitrite (mg.L^{-1})	Nitrate (mg.L^{-1})	Dissolved total P (µg.L^{-1})	Total P (µg.L^{-1})	Suspended solids (mg.L^{-1})	Chlorophyll-*a* (mg.L^{-1})
02/16/1998	25.5	24.5	0.5	1.4	6.7	44.8	6.8	0.15	2.5	0.11	38.1	116.5	10.8	8.0
02/25/1998	28.5	27.5	0.6	1.6	7.4	68.0	5.8	0.31	5.0	0.12	50.4	123.9	10.4	8.2
03/03/1998	29.5	29.0	0.7	1.9	7.5	73.5	5.9	0.47	4.7	0.13	53.0	81.4	-	-
03/09/1998	30.8	29.0	0.6	1.6	7.1	42.8	5.5	0.30	3.2	0.09	32.0	113.4	21.6	22.0
03/16/1998	27.5	27.1	0.5	1.4	7.0	42.0	5.0	0.48	6.5	0.11	32.9	117.1	16.2	14.0
03/23/1998	27.5	27.5	0.5	1.4	7.2	54.0	5.1	0.54	2.8	0.11	34.3	152.9	18.8	10.6
03/30/1998	27.0	27.0	0.5	1.4	6.9	41.8	5.7	1.36	82.9	0.12	52.7	219.0	29.6	17.2
04/06/1998	24.5	21.0	0.2	0.5	7.7	42.5	5.6	0.80	7.4	0.11	44.6	111.1	34.4	20.0

Table 2. Mean values of physical, chemical and biological variables measured in Fish Pond 2, in Pindamonhangaba Aquaculture Station, during the period between February 16th and April 6th, 1998.

	Water temperature (°C)	Air temperature (°C)	Transparency (m)	Euphotic zone (m)	pH	Conductivity(µS.cm^{-1})	Dissolved oxygen (mg.L^{-1})	Ammonia (mg.L^{-1})	Nitrite (mg.L^{-1})	Nitrate (mg.L^{-1})	Dissolved total P (µg.L^{-1})	Total P (µg.L^{-1})	Suspended solids (mg.L^{-1})	Chlorophyll-*a* (mg.L^{-1})
02/16/1998	25.5	24.5	0.5	1.4	6.8	46.5	7.0	0.14	2.8	0.14	34.2	103.9	8.0	20.9
02/25/1998	28.5	27.5	0.5	1.4	7.3	67.3	4.9	1.10	6.5	0.11	59.9	118.5	8.2	18.0
03/03/1998	29.5	29.0	0.7	1.9	7.3	69.9	5.5	0.43	3.9	0.13	53.0	91.8	-	-
03/09/1998	30.8	29.0	0.7	1.9	7.1	45.3	6.0	0.22	2.3	0.08	25.0	127.9	22.0	15.1
03/16/1998	27.5	27.05	0.5	1.4	6.9	42.3	4.5	0.44	4.3	0.11	26.2	105.9	14.0	26.7
03/23/1998	27.5	27.5	0.6	1.6	7.0	59.7	3.4	1.12	4.9	0.11	68.3	184.4	10.6	22.7
03/30/1998	27.0	27.0	0.4	1.0	6.7	40.8	4.3	1.18	57.4	0.09	40.1	194.2	17.2	23.4
04/06/1998	24.5	21.0	0.6	1.6	7.3	43.3	6.6	0.76	2.1	0.08	27.6	96.4	20.0	48.7

0.08 to 0.14 mg.L^{-1}, total dissolved phosphate from 25.0 to 68.3 µg.L^{-1} and total phosphorus from 81.4 to 219.0 µg.L^{-1}.

The zooplankton community was represented by 65 taxa: 14 cladocerans, three copepods and 48 rotifers (Tables 3 and 4, and Figures 3 and 4). A greater richness of species was observed for rotifers, followed by the cladocerans. The richness varied between ponds, the first one having greater richness at the beginning of the study while, in the second pond, richness was greater during the middle of the period of observations. There was a similar tendency in both ponds of a greater richness during the first week, decreasing for the next two weeks, with the lowest value on the 3rd of March, and rising again on the 9th. Constant species (with more than 50% frequency of occurrence in the samples) amongst the cladocerans were *Bosmina tubicen, Diaphanosoma spinulosum* and *Moina minuta*; *Thermocylops decipiens* amongst the Copepods and *Asplanchna sieboldi, Asplanchnopus* sp., *Brachionus calyciflorus, Brachionus caudatus, Conochilus* sp., *Keratella* sp., *Hexarthra intermedia* and *Sinantherina* sp.

Table 3. Composition and density (org.m^{-3}) of Cladocera and Copepoda in the two Fish Ponds, in Pindamonhangaba Aquaculture Station, from February to April 1998.

	P1							
	2/16/98	**2/25/98**	**3/3/98**	**3/9/98**	**3/16/98**	**3/25/98**	**3/30/98**	**4/6/98**
Cladocera								
Bosmina hagmanni (Stingelin, 1904)	2	-	-	-	-	-	-	-
Bosmina freyi (De Melo and Hebert, 1994)	11	-	-	23	-	-	-	-
Bosmina tubicen (Brehm, 1953)	91	12	-	23	34	126	48	-
Ceriodaphnia cornuta cornuta (Sars, 1886)	68	-	-	3	2	25	48	-
Ceriodaphnia cornutaintermedia (Sars, 1886)	6	12	-	-	2	25	5	3
Ceriodaphnia cornuta righaudi (Sars, 1886)	-	-	-	-	-	-	-	23
Ceriodapnia silvestrii (Daday, 1902)	46	25	-	-	-	-	-	5
Daphnia gessneri (Herbst, 1967)	11	-	-	-	-	-	-	-
Diaphanosoma brevireme (Sars, 1901)	23	-	-	-	23	25	-	23
Diaphanosoma spinulosum (Herbst, 1967)	23	25	47	117	-	-	24	-
Diaphanosoma sp.	-	25	-	-	-	-	-	-
Ilyocryptus spinifer (Herrick, 1882)	-	-	-	-	-	76	-	-
Macrothrix sp.	-	-	-	6	-	-	-	-
Moina minuta (Hansen, 1899)	148	147	71	329	928	7231	5365	1664
Simocephalus latirostris (Stingelin, 1906)	-	-	-	3	928	-	-	-
Simocephalus serrulatus (Koch, 1841)	-	-	-	-	-	-	-	1
Copepoda								
Adult Calanoida	-	-	-	-	68	-	120	-
Copepodids Calanoida	297	25	118	-	11	-	0	-
Nauplii Calanoida	365	98	283	-	-	-	120	116
Mesocyclops sp.	-	-	-	-	68	-	120	-
Thermocylops decipiens (Kiefer, 1929)	23	74	-	23	-	101	241	1040
Copepodids Cyclopoida	1849	2453	1321	305	408	2351	962	3120
Nauplii Cyclopoida	1918	2208	3396	2678	158	379	5894	11903
	P2							
	2/16/98	**2/25/98**	**3/3/98**	**3/9/98**	**3/16/98**	**3/25/98**	**3/30/98**	**4/6/98**
Cladocera								
Bosmina hagmanni (Stingelin, 1904)	-	-	-	12	-	-	-	-
Bosmina freyi (De Melo and Hebert, 1994)	12	-	-	-	11	-	-	-
Bosmina tubicen (Brehm, 1953)	25	22	-	3	102	146	46	24

Table 3. Continued...

	P2							
	2/16/98	**2/25/98**	**3/3/98**	**3/9/98**	**3/16/98**	**3/25/98**	**3/30/98**	**4/6/98**
Ceriodaphnia cornuta cornuta (Sars, 1886)	25	22	-	-	34	-	-	16
Ceriodapnia silvestrii (Daday, 1902)	25	22	-	24	-	-	-	-
Daphnia gessneri (Herbst, 1967)	12	-	-	-	-	-	-	-
Diaphanosoma brevireme (Sars, 1901)	-	-	-	24	136	364	-	-
Diaphanosoma spinulosum (Herbst, 1967)	12	-	25	120	-	-	69	24
Diaphanosoma sp.	-	86	-	12	-	-	-	-
Ilyocryptus spinifer (Herrick, 1882)	-	-	-	24	23	36	46	120
Moina minuta (Hansen, 1899)	12	259	50	168	996	4333	4923	625
Simocephalus latirostris (Stingelin, 1906)	-	-	-	-	11	36	-	-
Copepoda								
Adult Calanoida	-	-	-	-	-	-	92	241
Copepodids Calanoida	270	130	100	-	-	-	462	-
Nauplii Calanoida	589	151	400	24	-	73	347	120
Mesocyclops sp.	-	-	-	-	-	-	92	241
Thermocylops decipiens (Kiefer, 1929)	12	151	-	-	11	109	462	722
Copepodids Cyclopoida	883	2463	925	479	1630	2003	2196	5894
Nauplii Cyclopoida	2723	2895	4250	2875	475	983	6703	8540

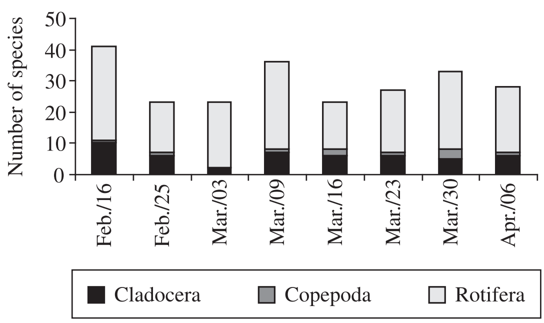

Figure 3. Total species number of the zooplankton communities in pond 1, in Pindamonhangaba Aquaculture Station, from February to April 1998.

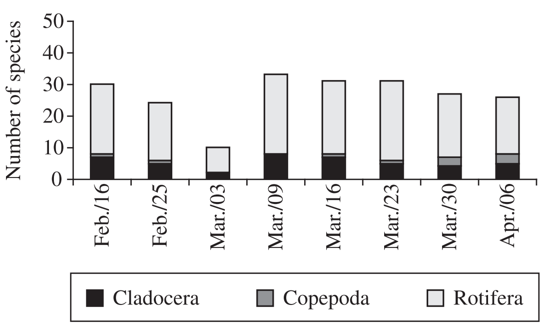

Figure 4. Total species number of the zooplankton communities in pond 2, in Pindamonhangaba Aquaculture Station, from February to April 1998.

In the first weeks of the study, when nutrient quantities were lower, the favoring of smaller organisms like nauplii and copepodids occurred. At the start of the fifth week, along with the increase of nutrients and chlorophyll a, these organisms were substituted by larger forms, like the species *Moina minuta*, but once again, during the last week of the experiment, another substitution occurred, large forms to smaller forms.

The density of the different species varied between ponds during the entire study period (Tables 3 and 4; Figures 5 and 6). Greatest density occurred in pond 1 on the 6th of April, and in pond 2 on the 23rd of March. Rotifera species reached the highest densities during almost the entire study, especially in pond 1. In the latter pond, *Moina minuta* was the most abundant cladocerans, with an increase in density starting in the fourth week. In the second pond, this species was also abundant, but increasing in the fifth week.

In pond 1, dominance of the species *Brachionus calyciflorus*, *B. caudatus* and *Hexartha intermedia* was observed, with high densities during the whole period. In the second pond, *Brachionus calyciflorus* was found in greatest density, followed by *Sinantherina* sp. There was a bigger variability in density in pond 2, with frequent alterations in species dominance throughout the study.

Values of the Shannon Wiener diversity index varied from 0.7 to 1.3, following the same tendency in both ponds (Figure 7). There was a decrease in the index from the beginning until the third week, rising again afterwards. The smallest index values seen in both ponds coincided with the smallest richness values and with the greatest abundance of *Brachionus calyciflorus* in pond 1

Table 4. Composition and density (org.m^{-3}) of Rotifera in the two Fish Ponds, in Pindamonhangaba Aquaculture Station, from February to April 1998.

	P1							
	2/16/98	**2/25/98**	**3/3/98**	**3/9/98**	**3/16/98**	**3/25/98**	**3/30/98**	**4/6/98**
Rotifera								
Anuraeopsis sp.	-	-	-	117	340	-	-	-
Ascomorpha sp.	228	-	-	235		-	-	347
Asplanchna sieboldi (Leydig, 1854)	114	-	1533	117	1245	379	241	-
Asplanchnopus sp.	114	491	2712	1879	1925	1517	-	-
Brachionus angularis (Gosse, 1851)	-	-	-	470	-	-	1083	1040
Brachionus calyciflorus (Pallas, 1766)	685	123	25708	9749	3396	10745	1203	693
Brachionus caudatus (Barrois and Daday, 1894)	1598	3434	708	4346	3396	12009	4932	21611
Brachionus falcatus (Zacharias, 1898)	114	-	-	117	-	-	-	-
Brachionus mirus (Daday, 1905)	342	-	-	-	-	-	-	-
Brachionus sp.	228	-	472	470	-	-	-	-
Conochilus coenobasis (Skorikov, 1914)	-	123		117	-	126	-	116
Conochilus natans (Seligo, 1990)	114	-	-	-	-	253	-	-
Conochilus unicornis (Rousselet, 1892)	1027	-	-	352	-	379	361	347
Conochilus sp.	114	-	236	1057	340	1896	361	116
Dicranophorus sp.	-	-	-	1292	-	-	241	-
Euchlanis dilatata (Ehrenber, 1832)	-	-	-	-	-	-	-	116
Euchlanis sp.	114	-	-	-	-	126	120	116
Filinia opoliensis (Zacharias, 1898)	-	-	-		-	-	120	
Gastropus sp.	-	736	-	705	-	-	361	116
Hexartra intermedia (Wiszniewski, 1929)	1370	368	1887	5050	453	758	120	231
Horaëlla thomassoni (Koste, 1973)	-	-	-	117	113	-	-	116
Keratella americana (Carlin, 1943)	1826	3925	1887	-	-	126	120	-
Keratella cochlearis (Gosse, 1851)	-	613	354	117	-	126	120	-
Keratella tropica (Apstein, 1907)	-	-	-	-	1019	-	-	347
Keratella sp.	2968	736	590	940	-	379	-	347
Lecane bulla (Gosse, 1886)	114	-	-	-	-	-	-	-
Lecane luna (Müller, 1776)	114	-	-	117	-	-	120	-
Lecane lunaris (Ehrenberg, 1832)	-	123	118	-	-	-	120	-
Lecane papuana (Murray, 1913)	342	-	118	-	-	506	1564	116
Lecane sp. 1	457	123	118	-	113		120	
Lecane sp. 2	114	-	472	-	-	-	-	-
Lepadella sp.	1712	-	118	-	-	-	-	-
Macrochaetus sp.	-	-	-	470	-	-	-	-
Plationus macracanthus (Daday, 1905)	114	123	-	1644	340	-	5	-
Plationus patulus (Müller, 1786)	46	-	354	23	-	-	-	-
Platyias quadricornis (Ehrenberg, 1832)	114	-	118	-	-	253	120	-
Polyarthra sp.	114	368	118	470	113	758	361	1156
Sinantherina sp.	114	123	118	587	-	2655	-	809
Synchaeta sp.	114	-	118	235	113	-	120	116
Testudinella patina (Hermann, 1783)	114	123	-	470	453	126	962	693
Trichocerca sp.	-	1840	118	352	113	-	120	-
Bdelloidea	114	-	-	-	-	632	962	578

Table 4. Continued...

	P2							
	2/16/98	**2/25/98**	**3/3/98**	**3/9/98**	**3/16/98**	**3/25/98**	**3/30/98**	**4/6/98**
Rotifera								
Ascomorpha sp.	-	-	-	599	113	91	231	-
Asplanchna sieboldi (Leydig, 1854)	368	756	-	1078	679	91		-
Asplanchnopus sp.	858	2484	-	2516	566	182	116	-
Brachionus angularis (Gosse, 1851)	123	-	-	120	-	-	116	361
Brachionus calyciflorus (Pallas, 1766)	245	108	125	2276	5094	16478	1156	601
Brachionus caudatus (Barrois and Daday, 1894)	5274	1944	1250	958	679	5917	1040	1804
Brachionus dolabratus (Harring, 1914)	123	-	-	-	-	-	-	-
Brachionus mirus (Daday, 1905)	-	-	-	-	-	91	-	-
Brachionus quadridentatus (Hermann, 1783)	-	-	-	-	-	91	347	241
Brachionus sp.	123	108	-	-	-	-	-	-
Cephalodella sp.	-	108	-	-	-	-	-	-
Conochilus coenobasis (Skorikov, 1914)	-	-	-	120	453	91	-	-
Conochilus natans (Seligo, 1990)	-	-	-	479	340	91	231	-
Conochilus unicornis (Rousselet, 1892)	123	-	-	120	453	637	116	241
Conochilus sp.	858	-	-	2276	2038	3642	693	241
Dicranophorus sp.	-	-	-	839	-	91	116	-
Filinia opoliensis (Zacharias, 1898)	245	-	-	-	-	-	231	-
Gastropus sp.	-	2160		359	-	-	-	120
Hexartra intermedia (Wiszniewski, 1929)	123	540	625	3115	1245	1183	231	120
Horaëlla thomassoni (Koste, 1973)	-	-	-	-	113	-	-	
Keratella americana (Carlin, 1943)	1962	5617	250	240	-	273	-	120
Keratella cochlearis (Gosse, 1851)	1717	108	1750	-	-	637	-	
Keratella tropica (Apstein, 1907)	-	756	-	-	113	91	-	361
Keratella sp.	123	2160	750	1078	113	819	-	
Lecane bulla (Gosse, 1886)	-	-	-	-	-	273	-	120
Lecane luna (Müller, 1776)	-	-	-	-	340	-	-	-
Lecane monostyla (Daday, 1897)	-	-	-	-	-	-	116	-
Lecane papuana (Murray, 1913)	123	-	-	120	-	182	809	120
Lecane sp. 1	-	216	-	-	-	-	231	-
Lecane sp. 2	123	-	-	-	-	-	-	-
Macrochaetus sp.	-	-	-	479	226	-	-	-
Plationus macracanthus (Daday, 1905)	123	108	-	3834	453	-	116	-
Plationus patulus (Müller, 1786)	-	-	-	-	340	-	-	-
Platyias quadricornis (Ehrenberg, 1832)	123	-	-	479	340	546	925	8
Polyarthra sp.	491	108	-	120	340	364	231	361
Sinantherina sp.	123	108	250	1797	906	11380	578	120
Synchaeta sp.	-	-	-	599	-	-	-	-

Table 4. Continued...

	P2							
	2/16/98	**2/25/98**	**3/3/98**	**3/9/98**	**3/16/98**	**3/25/98**	**3/30/98**	**4/6/98**
Testudinella patina (Hermann, 1783)	-	-	-	839	792	91	809	241
Trichocerca chattoni (de Beauchamp, 1907)	368	-	-	-	-	-	-	-
Trichocerca similis (Wierzejski, 1893)	-	-	-	240	-	-	-	120
Trichocerca sp.	-	216	125	-	113	91	-	-
Bdelloidea	123	324	-	120	340	91	-	241

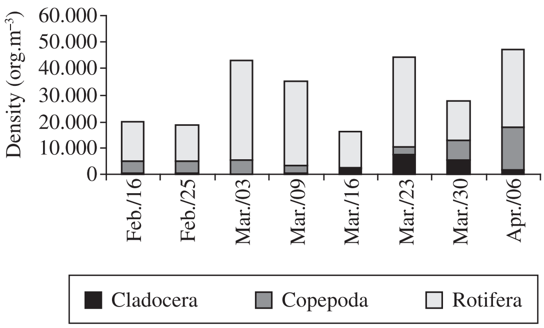

Figure 5. Densities of main zooplankton groups in pond 1, in Pindamonhangaba Aquaculture Station, from February to April 1998.

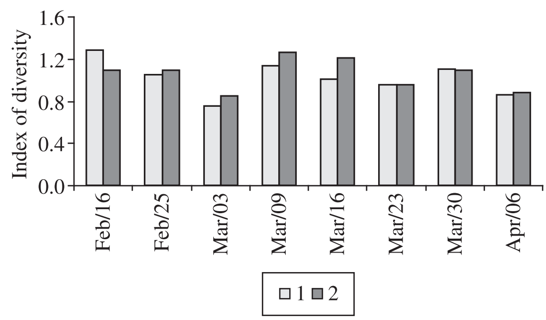

Figure 7. Values of the Shannon-Wiener diversity index for zooplankton communities of fish pond 1 and 2, in Pindamonhangaba Aquaculture Station, from February to April 1998.

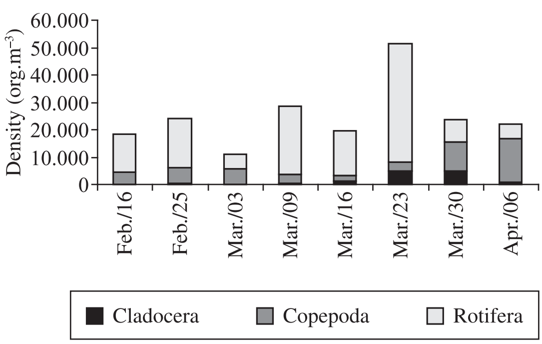

Figure 6. Densities of main zooplankton groups in pond 2, in Pindamonhangaba Aquaculture Station, from February to April 1998.

(25,708 ind/m^3) and the third greatest abundance of cyclopoid nauplii in pond 2 (4,250 ind/m^3).

4. Discussion

The study was carried out at the end of summer, thus explaining the relatively high water temperatures. Regarding the physical and chemical conditions of the water, it could be observed that the ponds' conditions were adequate for the development of zooplankton, considering that they were relatively well oxygenated, with a slight pH variation from acid to alkaline, and with a moderate water conductivity. As evidenced by the inverse relation between water transparency and the concentration of suspended material, the low water transparency was probably partly due to the shallow environment, a fact that favors re-suspension of the sediment, and partly due to the elevated phytoplankton biomass.

According to Sipaúba-Tavares et al. (1994) the conductivity values in eutrophic reservoirs in the Brazilian southeast have been found to reach 240 µS.cm^{-1}, but due to the short residence time of the water and the lower accumulation of ions in fish ponds, registered values for the latter environments are generally much lower. Dissolved oxygen concentrations varied greatly during the day, being usually low during the night because of the total community respiration, but high during the day, especially in the afternoon, with oversaturation, caused by photosynthesis (Melo et al., 1988).

Values of ammonia concentrations in the ponds were smaller during the early weeks of the study. Later, the excretion of nitrogen compounds, especially by the Tilapia, could have contributed significantly to the increase of this ion until the end of the study.

The zooplankton community of the fish ponds was characterised by elevated richness of species, as usually observed for this kind of system. Sixty five species were registered in this study, being superior to the value of 59 reported by Eler et al. (2006) for a fishpond in the hydrographic basin of the Mogi-Guaçu river and also superior to that found by Sipaúba-Tavares and Colus (1997) in fishponds in the campus of the São Paulo State University, in the municipality of Jaboticabal.

The authors cited above registered a smaller richness of Rotifera species than the present study. Some of the observed species in the present study were also registered by these authors: the cladocerans *Bosmina hagmanni, Bosmina freyi, Ceriodaphnia cornuta, Diaphanosoma brevireme, Macrothrix* sp. and *Moina minuta,* the copepod *Thermocyclops decipiens,* and the rotifers *Asplanchna sieboldi, Brachionus angularis, Brachionus calyciflorus, Brachionus caudatus, Brachionus falcatus, Brachionus quadridentatus, Keratella americana, Keratella cochlearis, Keratella tropica, Conochilus unicornis* and *Trichocerca similis.*

Most zooplankton species that occurred in great abundance in this study are commonly found in fish ponds, as found by Eler et al. (2006).

Abundance was greatest for the Rotifera group, during almost all of the study period, followed by Copepoda and Cladocera, in that order. The zooplankton communities were characterised by ample density fluctuations in short periods of time. Such a pattern is characteristic of species with short generation times and quick turnover such as the rotifers and small cladocerans (Sommer et al., 1986)

According to Roche and Rocha (2005), the presence of fish usually reduces the abundance of the biggest zooplankton, especially cladocerans, favouring the increase of small sized zooplankton like rotifers. However, filter-feeding fish may lead to an increase of copepods, whose escape mechanism is well developed, a fact that could suppress the rotifers. Larger species (like Daphnia) may be strongly selected as food items by fish.

Oreochromis niloticus was the fish species present in the ponds during the study. This fish is tolerant to environmental variations, resistant to stress and reproduces readily, being widely cultivated in tropical countries (Baccarin, 1999). In its natural habitat, this species usually feeds on plant material (algae, aquatic plants, seeds, etc.) and small animals (crustaceans, insect larvae, worms, mollusks, amphibians, smaller fish, etc.). It has been reported that this species can efficiently feed on plankton (Kubitza and Kubitza, 2000).

Various zooplankton organisms are utilised by fish as a primary source of food, mainly rotifers, nauplii, copepodite and adult copepods such as the copepod *Argyrodiaptomus furcatus* (Maia-Barbosa and Matsumura-Tundisi, 1984), and cladocerans such as *Moina minuta* (Lazzaro, 1987). The latter two may be positively selected due to, respectively, slower movement and eye pigmentation. *Moina minuta*, considered constant in the present study, is turbidity tolerant (Hart, 1987) and for this reason is common in fish ponds. According to Sipaúba-Tavares and Rocha (2003), this cladoceran has high nutritional value and through parthenogenic reproduction reaches high population densities in short periods of time.

Thermocyclops decipiens is a predator and was also abundant during the study, as found by Santos-Wisniewski and Rocha (2007) in the eutrophic reservoir of Barra Bonita. The presence of this species may be attributed to its high fecundity and longevity, as well as its short generation time, factors that are important for competition, favouring its predominance (Melão et al., 2005). Rocha et al. (2002) also verified constant occurrence and abundant of this species in eutrophic ecosystems. Leitão et al. (2006), in a study on the zooplankton communities in three reservoirs in the metropolitan area of Fortaleza (Ceará, Brazil), noted the abundance of *Thermocyclops decipiens* to be related to high ammonia concentrations, as observed in the present study.

As found in the present study, zooplankton communities in eutrophic environments are normally composed of micro-zooplankton (rotifers, protozoans, nauplii and copepodites). (Pinto-Coelho et al., 2005). According to Sipaúba-Tavares et al. (1994), rotifers are more abundant but contribute less to the biomass in zooplankton communities.

Smallest values of the Shannon-Wiener diversity index in both ponds were related to lower species richness and to the dominance of *Brachionus calyciflorus*. The species *Brachionus calyciflorus* and *B. angularis* are cosmopolitans, usually occurring in alkaline waters, and are frequent in fish ponds (Eler et al., 2006). According to the latter authors, these species tolerate organic pollution, being found even in oxidation lagoons and activated sludge. Matsumura-Tundisi (1999) stated that *Brachionus calyciflorus* and *Asphanchna sieboldi* are indicators of elevated trophic state; both were constant in the present study.

With regard to the fluctuations in composition and density of the zooplankton observed over short periods of time, there was no regular pattern for zooplankton succession, with species apparently being substituted randomly, during the study period. Environmental characteristics are determinant factors for the occurrence of zooplankton species due to the latter's fast response to any changes in the former. According to Ruttner (1975), many rotifer species are present during the entire year in different densities; however, others apparently disappear in certain periods, reappearing later on. This happens principally because phytoplankton succession can occur over very short time periods, promoting changes in availability and adequacy of food, to which the zooplankton can respond rapidly (Sommer et al., 1986).

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