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ZOOPLANKTON-BASED ASSESSMENT OF THE TROPHIC STATE OF A TROPICAL FOREST RIVER IN NIGERIA

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Abstract — In this study, we explore the usefulness of zooplankton as a tool for assessing the trophic status of a Nigerian forest river. The river was sampled monthly and investigated for water physico-chemistry and zooplankton community structure using basic statistical measurement of diversity indices to characterize the zooplankton fauna. The trophic status of the river evaluated from its physico-chemical parameters indicates that the river is oligotrophic. The zooplankton composition was typical of a tropical freshwater river, with a total of 40 species, made up of 16 rotifers, 12 cladocerans, and 12 copepods and their developing stages in the following order of dominance: Rotifera > Cladocera > Cyclopoida > Calanoida. There were strong correlations between the lake's trophic status and its zooplankton communities. The zooplankton community was dominated by numerous species of rotifers and crustaceans, which are typical of oligotrophic to mesotrophic systems, such species including *Conochilus dossuarius* and *Synchaeta longipes*. However, the most dominant zooplankton species in West African freshwater ecosystems, viz., *Keratella tropica, Keratella quadrata, Brachionus angularis, Trichocerca pusilla, Filinia longiseta, Pompholyx sulcata*, and *Proales* sp., and others that are indicator species of high trophic levels, were not recorded in the river. The river is very clear and can be used for all manner of recreational activities.

Key words: Trophic status, zooplankton, bioindicators, forest river, tropics, Nigeria

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INTRODUCTION

The zooplankton community is a dynamic system that responds promptly to environmental changes, and to understand such changes or to draw comparisons between natural systems and those that suffer disturbances, some knowledge of the structure of the community and the main processes involved in nutrient cycling and production is therefore required (Rocha et al., 1997). The succession and spatial distribution of zooplankton species result from differences in ecological tolerance to abiotic and biotic environmental factors (Marneffe et al., 1998), yet bioindicator approaches using the responses of organisms to evaluate the trophic state of water have often been neglected in favor of chemical and physical techniques. In particular, despite the considerable potential of zooplankton as effective indicators of environmental change and their fundamental importance in energy transfer and nutrient cycling in aquatic ecosystems, zooplanktonic communities have not been widely used as indicators of the condition ecosystems (Stemberger and Lazorchak, 1994).

The use of zooplankton community structure as an indicator of the wellbeing of lakes dates back to as early as the Birge-Juday era, 1879-1910 (Frey, 1963). In Nigeria, investigation of the response of zooplankton to pollution is not common; for the Ovia River in particular, there are very limited water quality data, including data on physical, chemical, and biological conditions (Ogbeibu et al., 2001; Ogbeibu and Omoigberale, 2005; Omoigberale and Ogbeibu, 2005), even though the river is an important source of water for drinking and domestic use, washing, bathing, and fishing and therefore vulnerable to anthropogenic impacts. Elsewhere around the world, several investigations have been carried out in this direction (Gannon and Stemberger, 1978; Bays and Crisman, 1983; Pace, 1986; Beaver and

Crisman, 1990; Canfield and Jones, 1996; Pedrozo and Rocha, 2005; Dulić et al., 2006). The reasons for this are that zooplankton have wide geographical distributions, they are relatively easy to identify, particularly when community sensitivity can be ascertained on the basis of zooplankton body sizes or gross taxonomic classifications, and the time of zooplankton generation may be short enough to respond quickly to acute stress but long enough to integrate the effects of chronic problems (Cairns et al., 1993).

Typically, the inference of water quality characteristics relies on monthly sampling of a variety of indicators. In this report, we investigate the environmental variables that appear to be most influential in shaping the zooplankton community and explore the usefulness of zooplankton as a tool for monitoring this forest river. The community composition of zooplankton is documented and the resulting species datasets used to infer quality of the river's water. The hypothesis behind the present study was that zooplankton species would show, through analysis of qualitative and quantitative sample data, that the state of the environment is oligotrophic. The species with constant frequency of occurrence in the system and showing low numerical abundance in response to the water's nutrient level would be classified as bioindicators.

MATERIALS AND METHODS

Study site

The study was carried out on a stretch of the Ovia River, about 20.5 km from Benin City, along the Lagos-Benin highway (6.54ºN, 5.52ºE), within the tropical rainforest belt of Southern Nigeria. The river takes its source from the Akpata Hills in Ekiti State and flows in a southwesterly direction. Downstream it becomes the Osse River. The latter flows through the Gwato creeks into the Benin River, which empties into the Atlantic Ocean.

The study area is composed mostly of secondary rainforest vegetation that has suffered extensive deforestation. Among other forms of plant life, palm trees (*Elaeis guinensis*), shrubs, and floating *Salvinia* sp., *Lemna* sp., and water hyacinth (*Eichorrnia crassipes*) are common in the area. The climate in the study area is typically tropical with a pronounced seasonality of rainy and dry periods. The rainy season is from April to October, with peak rainfall occurring during the months of June to August, while the dry season extends from November to March. Although the onset of the season fluctuates from year to year, it is still relatively stable. The mean annual rainfall usually exceeds 60 cm, while mean annual temperature fluctuates, between 31.8 and 34.2°C.

Three sections were selected for sampling: an upstream, a mid-course, and a downstream section. The downstream section (Station 1) was located about 150 m downstream from the Lagos-Benin highway bridge. This sampling station has a de-vegetated bank exposed to flowing water and the direct effects of sunlight. There were several aquatic macrophytes like *Salvinia* sp., *Lemna* sp., and water hyacinth (*Eichorrnia crassipes*). The most conspicuous human activities noticed at the station were fishing and excavation of laterite by payloaders.

The mid-course section (Station 2) was located about 150 m upstream from the Lagos-Benin highway bridge. The river bank here has luxuriant vegetation, with tree canopies that shade the station from the direct effects of sunlight. The station was almost covered with water hyacinth at the peak of the rainy season. Water lettuce was also found, but it was very scanty. Bamboo (*Bambusa bambusa*), palm trees (*Elaies guinensis*), and some other trees characteristic of tropical rainforests are present at this station. There is a local palm oil processing mill near the station, and water for drinking and domestic use it taken by the villagers at this point; other human activities here include laundering, bathing, and fishing.

The upstream (Station 3) was located about 300 m away from the bridge. The station is open to direct rays of the sun. There are several aquatic macrophytes like *Salvinia* sp., *Lemna* sp., and *E. crassipes.*

Sampling and analysis

Monthly sampling on sections of the Ovia River was carried out between April, 2005 and June, 2006. Sampling was conducted between 0800 and 1100 h from stations 1, 2, and 3 in that order each sampling day.

Subsurface water samples were collected at the three stations using a 3.5-liter Van Dorn water sampler in triplicate and homogenized before being sub-sampled for physico-chemical analyses. Air and water temperatures were taken *in situ* during the survey. Conductivity, dissolved oxygen, and pH were also recorded *in situ* using a WTW water sampler probe. Other physico-chemical variables were measured based on the procedures suggested in APHA (1998).

Qualitative plankton samples were collected by towing a 55-μm mesh Hydrobios plankton net tied to a 25 HP engine-powered boat driven at low speed just below the water surface for 5 minutes at each sampling station. Quantitative samples, on the other hand, were collected by filtering 100 liters of water fetched with a bucket through a 55-μm mesh Hydrobios net. Samples of both kinds were preserved separately in 4% buffered formalin solution.

In the laboratory, specimens were sorted and dissected where necessary under a binocular dissecting microscope (American Optical Corporation, Model 570), while counting and identifications were done with an Olympus Vanox Research Microscope (mag 60), Model 230485. Identification of specimens was carried out at the University of Benin's Zooplankton Laboratory using relevant literatures (Smirnov, 1974; Van de Velde, 1984; Gabriel, 1986; Jeje and Fernando, 1986; Jeje, 1988; Boxshall and Braide, 1991; Imoobe, 1997; Korinek, 1999).

The percentage relative abundance of specimens was estimated by direct count. Each quantitative sample was concentrated to 10 ml, and from this 1 ml of sample was taken and all individual taxa present were counted. Relative abundance was calculated as the number of individuals per liter of water filtered through the net.

Basic statistical measurement of diversity indices was used to describe the zooplankton community structure. Three indices of species diversity were used: Margalef's index, the Shannon-Wiever index, and an evenness index expressing the degree of uniformity in the distribution of individuals among taxa in the collections (Magurran, 1988). The SPDIVERS BASIC program for diversity indices was used to determine diversity, while inter-station comparison was carried out to test for significant differences in the abundance of zooplankton using one-way analysis of variance (ANOVA) (Zar, 1984).

RESULTS AND DISCUSSION

Environmental conditions

A summary of the physical and chemical conditions at the study stations is presented in Table 1. The water temperature ranged between 25.0 and 29°C throughout the study, with the highest mean temperature value (27.22 ± 1.11°C) recorded at the downstream Station 1. Turbidity, which is a function of dissolved and suspended particulates in the water, had values which ranged from a minimum of 0 NTU (Station 3) to a maximum of 1.2 NTU recorded at Station 1. Generally, the lake's water was relatively clear at all the stations sampled, and there was no significant difference ($P > 0.05$).

The water was generally fresh, with conductivity values ranging from 0.008 to 0.03 μS cm^{-1}. The buffering capacity measured as alkalinity was low, and a weakly acidic to weakly alkaline pH range of 5.98-7.18 was observed across the stations. The concentration of calcium and magnesium salts combined with various anions (usually carbonates), which constitutes the total hardness of water, was also generally low, indicating the river to be a soft water river.

Mean dissolved oxygen concentration was high (5.82 to 6.93 mg l^{-1}), while the mean BOD_5 was low (1.97 to 3.46 mg l^{-1}). Levels of the essential primary productivity nutrients – nitrate (0.0 to 2.0 mg l^{-1}), sulfate (0.0 to 2.4 mg l^{-1}), and phosphate (0.004 to 0.12 mg l^{-1}) – were low. Forest ecosystems readily immobilize phosphorus (Downing and McCauley, 1992), thus limiting its input to the river. The river's watershed, combined with the lack of residential housing or farms surrounding the river, probably

Table 1. Mean (± SD) values of some physical and chemical conditions at the study stations on the Ovia River from April, 2005 to June, 2006 (minimum and maximum in parenthesis). N = Number of samples/sampling station.

Sampling stations	N	1	2	3
Temperature °C (Air)	15	27.27 ± 1.37 (24.8 – 28.7)	26.77 ± 1.28 (24.8 – 28.0)	26.97 ± 1.33 (24.8 – 28.5)
Temperature °C (Water)	15	27.22 ± 1.11 (26.1 – 29.0)	26.47 ± 0.89 (25.3 – 27.5)	26.72 ± 1.70 (25.0 – 29.0)
Turbidity (NTU)	15	0.47 ± 0.64 (0.02 – 1.2)	0.54 ± 0.45 (0.02 – 0.8)	0.57± 0.55 (0.0 – 1.1)
Conductivity (μS cm^{-1})	15	0.022 ± 0.009 (0.01 – 0.03)	0.022± 0.009 (0.008 – 0.03)	0.022± 0.008 (0.01 – 0.03)
TDS (mg l^{-1})	15	20.01 ± 6.09 (14.2 – 29)	18.27± 6.99 (11 – 28.8)	19.81± 5.68 (14.5- 28.6)
TS (mgl^{-1})	15	26.63 ± 4.77 (23.25 – 30)	26.45± 5.02 (22.9 – 30)	27± 5.66 (23.- 31)
pH	15	6.59 ± 0.4 (6.59 – 7.04)	6.58 ± 05 (5.98 – 7.18)	6.60± 0.41 (6.1 – 7.12)
Alkalinity (mg l^{-1} $CaCo_3$)	15	56.12 ± 27.1 (24.4 – 91.5)	51.24 ± 21.39 (24.4 – 73.2)	51.24± 14.04 (36.6 – 67.1)
Calcium (mg l^{-1})	15	4.89 ± 3.95 (0.8 – 9.22)	4.81± 5.42 (0.4 – 12.83)	5.61± 4.42 (0.8 – 10.82)
Magnesium (mg l^{-1})	15	2.33 ± 2.18 (024 – 5.35)	1.60± 1.5 (0.24 – 3.89)	1.65± 1.5 (0.24 – 3.65)
Dissolved oxygen (mg l^{-1})	15	5.82 ± 0.83 (4.4 – 6.55)	6.93 ±1.67 (5.15 – 9.0)	6.59 ± 1.41 (5.1 – 8.25)
BOD (mg l^{-1})	15	1.97 ± 0.81 (1.3 – 3.35)	3.46 ±1.91 (1.5 – 5.8)	3.27 ± 2.1293 (0.3 – 6.05)
Sulfate (mg l^{-1})	15	0.77 ± 0.67 (0.0 – 1.2)	1.4 ± 1.22 (0.0 – 2.2)	1.4 ± 1.25 (0.0 – 2.4)
Phosphate (mg l^{-1})	15	0.032 ± 0.05 (0.004 – 0.12)	0.023 ± 0.032 (0.006 – 0.08)	0.023 ± 0.032 (0.004 – 0.08)
Nitrate (mg l^{-1})	15	0.66 ± 0.65 (0.0 – 1.5)	0.76± 0.79 (0.0 – 2.0)	0.69 ± 0.75 (0.0 – 1.8)
Chloride (mg l^{-1})	15	23.71 ± 5.3 (16.33 –31.24)	19.6 ± 3.61 (13.49 – 22.01)	24.28± 4.85 (19.17 – 31.95)

limits nutrient input. Generally, evaluation of the river's trophic status using Carlson's trophic state index (Carlson, 1977) and the trophic state designations assigned by Kratzer and Brezonik (1981) indicates that its water is oligotrophic. The low levels of nutrients are fundamental to the river's oligotrophic status. Evidence for low production is also seen in its oxygen profile, which does not fall below 4.4 mg l^{-1} (Table 1), a condition which also contributes to the lake's phosphorus limitation through the binding of phosphorus to oxidized iron (Fe^{3+}) in the sediments.

Zooplankton species composition

Forty species of zooplankton were recorded during the 15-month sampling period of the study (Table 2). The greatest diversity was observed among Rotifera, with 16 species in 10 families, a pattern that is common in tropical freshwaters, whether in lakes, ponds, reservoirs, rivers, or streams (Neves et al., 2003). Cladocera and Copepoda were represented by 12 taxa each. Nauplii and copepodids, the developmental stages of Copepoda, were quite common. Although most of the species identified indicated a typical tropical assemblage, predominantly temperate forms like *Synchaeta* and *Collotheca* sp. were also recorded. As in most tropical freshwaters, the cladoceran fauna included *Bosmina longirostris*, *Diaphanosoma excisum*, *Ceriodaphnia cornuta*, and *Moina micrura*. The genus *Daphnia* was absent, which is typical of most tropical waters.

Small organisms like nauplii and rotifers predominated, even among the cladocerans, and small forms like *Bosmina longirostris* and *Ceriodaphnia cornuta* occurred frequently in high densities. An

Table 2. Composition, relative abundance, and frequency of occurrence (%) of zooplankton species in the area of study. Number of samples (n) = 45.

SPECIES COMPOSITION	Freq. of occurrence %	Relative abundance %
CLADOCERA		
Alona rectangula	62	2.6
Bosmina longirostris	53	2.2
Bosminopsis deitersi	49	2.0
Ceriodaphnia cornuta	58	2.3
Chydorus sphaericus	53	2.1
Diaphanosoma excisum	47	2.1
Echinisca triseralis	44	2.0
Ilyocryptus spinifer	58	2.4
Kurzia longirostris	49	1.9
Macrothrix spinosa	42	1.9
Moina micrura	58	2.6
Simocephalus vetulus	49	2.3
COPEPODA		
Afrocyclops curticornis	49	2.1
Diacyclops thomasi	47	2.2
Ectocyclops phaleratus	56	2.3
Eucyclops agiloides	53	1.9
Halicyclops korodiensis	58	2.5
Mesocyclops leukarti	51	2.3
Metacyclops minutus	49	2.0
Microcyclops varicans	60	2.5
Thermocyclops negletus	62	2.7
copepodids	42	2.1
nauplii	64	2.7
CALANOIDA		
Diaptomus minutus	58	2.7
Thermodiaptomus galebi	60	2.9
Tropodiaptomus incognitus	49	2.1
copepodids	60	2.7
ROTIFERA		
Ascomorpha ovalis	49	2.3
Asplanchna priodonta	44	2.0
Brachionus diversicornis	49	2.3
Collotheca sp.	58	2.45
Conochilus dossuarius	56	2.45
Conochilus unicornis	64	2.8
Euchlanis dilatata	40	1.9
Kellicottia longispina	51	2.2
Keratella cochlearis cochlearis	62	2.7
Keratella longispina	49	2.45
Lecane bulla	53	2.45
Polyarthra remata	49	2.1
Proales decipiens	53	2.2
Synchaeta longipes	62	3.0
Trichocerca cylindrica chattoni	58	2.8
Trichocerca similis Wierzejski, 1893	42	1.8

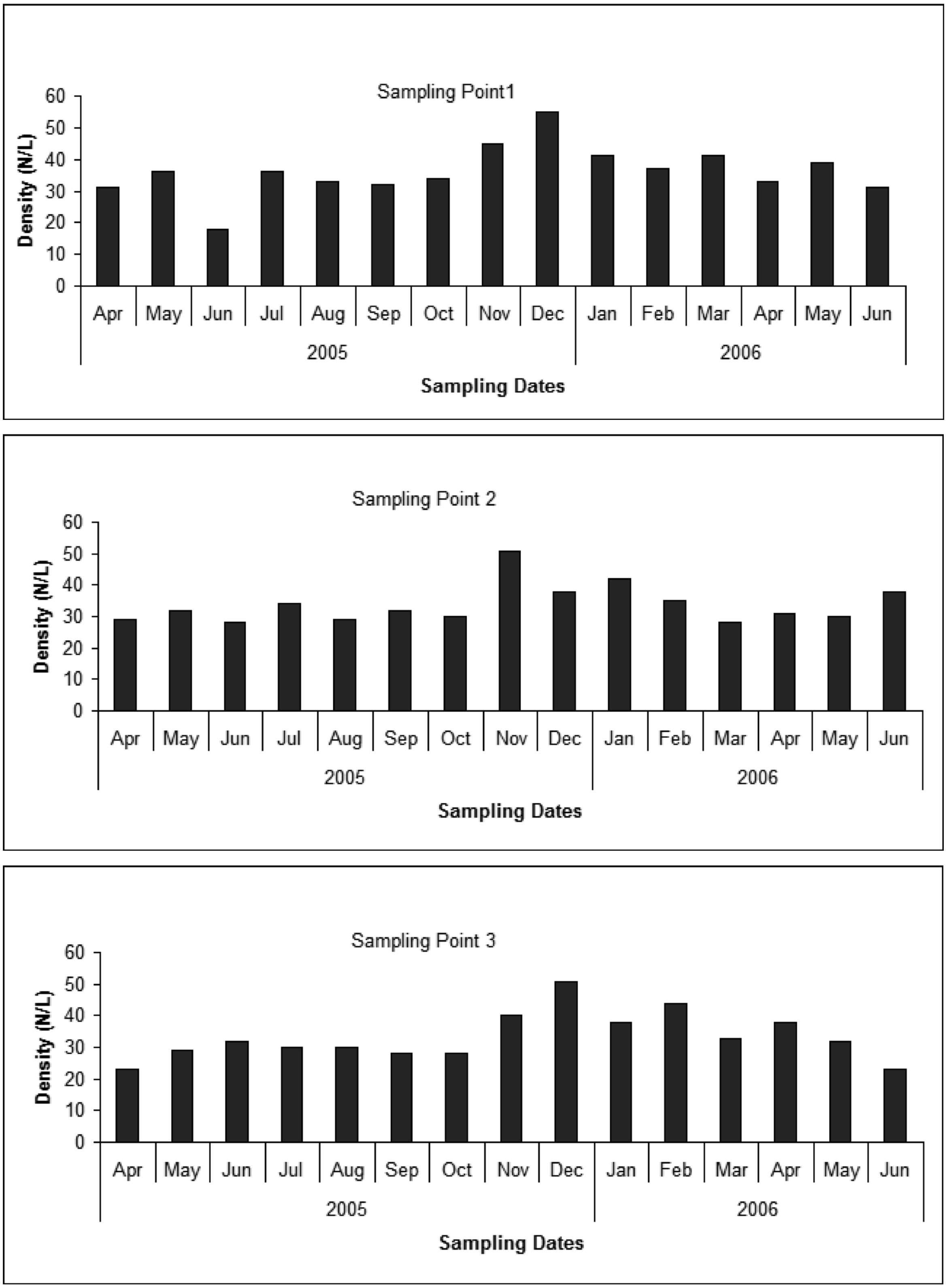

Fig. 1. Temporal variation in density of zooplankton in the Ovia River.

Table 3. Total individuals (N), total taxa (S), Margalef richness (d), Pielou evenness (E), and Shannon diversity (H') for the study area averaged over all sampling dates.

N	1548
S	40
D	5.718
H	3.75
E	0.998

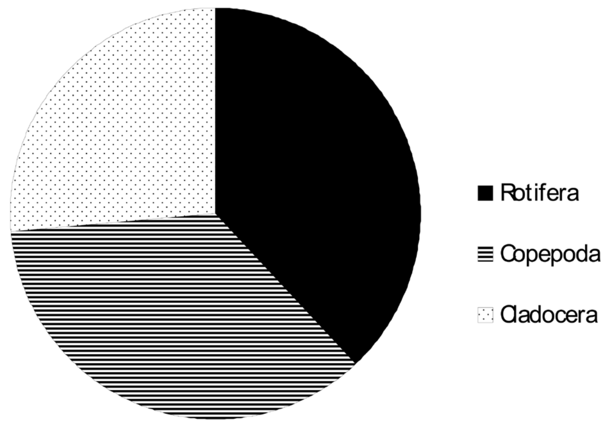

Fig. 2. Relative abundance of the major groups of zooplankton in the Ovia River.

important consideration when there is a predominance of smaller species in rivers is the possible relation to suspended material in the water column due to the constant influence of wind or due to predation pressure from planktivorous fishes (Carpenter et al., 1985; Stemberger and Lazorchak, 1994).

Numerous species of rotifers and crustaceans considered good indicators of the trophic state of rivers and lakes were found in the zooplankton community. Rotifer species recorded that are typical of oligotrophic to mesotrophic systems included *Conochilus dossuarius* and *Synchaeta longipes*. However, the regularly most dominant species in West Africa freshwater ecosystems, viz., *Keratella tropica*, *Keratella quadrata*, *Brachionus angularis*, *Trichocerca pusilla*, *Filinia longiseta*, *Pompholyx sulcata*, and *Proales* sp., which are indicator species of high trophic levels, were not recorded in the river.

Average zooplankton abundance in the river was very low throughout the period of study, the densities of zooplankton ranging from 18 to 55 individuals/l (Fig. 1). However, Margalef richness, evenness, and Shannon diversity were high (Table 3). Also, the river had a zooplankton community dominated by a crustacean zooplankton made up of copepods and cladocerans (Fig. 2). Copepod abundance was driven mostly by increased numbers of nauplii and cyclopoid copepodids, although they were surpassed by rotifers. The dominant cladoceran was generally *Bosmina longirostris*, *Bosminopsis deitersi*, *Moina micrura*, *Alona rectangula*, *Ceriodaphnia cornuta*, and *Simocephalus vetulus* were also represented in most samples.

CONCLUSION

The zooplankton community of the Ovia River – an oligotrophic system with very little primary production and low densities of zooplankton – appears to be controlled by bottom-up mechanisms, where nutrient inputs are probably low, thus limiting phytoplankton abundance and primary production, which limits zooplankton densities. Zooplankton size, however, appears to be limited by the nature of the zooplanktivory. The Ovia River was not strongly affected by cultural eutrophication at the time of sampling; extensive forests in the watershed may have helped to alleviate anthropogenic nutrient input. Most of the land surrounding the lake is forested, with no residential homes or farming, which are typical sources of nutrient loading.

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