Acta Limnologica Brasiliensia

Publication of the
Brazilian Association of
Limnology

Original Article
Acta Limnologica Brasiliensia, 2024, vol. 36, e15
https://doi.org/10.1590/S2179-975X8322
ISSN 2179-975X on-line version

Shallow reservoirs in urban perimeter: evaluation of trophic status and relations with the zooplanktonic community

Reservatórios rasos em perímetro urbano: avaliação do estado trófico e relações com a comunidade zooplanctônica

Heytor Lemos Martins[1*], Eliana Aparecida Panarelli[2], Jaqueline Souza Borges[2], Vanesca Korasaki[2] and Rodrigo Ney Millan[2]

[1]Universidade Estadual Paulista "Júlio de Mesquita Filho" – UNESP, Via de Acesso Professor Paulo Donato Castellane, s/n, Vila Industrial, CEP 14884-900, Jaboticabal, SP, Brasil

[2]Universidade do Estado de Minas Gerais – UEMG, Av. Escócia, 1001, Cidade das Águas, CEP 38202-436, Frutal, MG, Brasil

*e-mail: heytor.lemos18@gmail.com

Cite as: Martins, H.L. et al. Shallow reservoirs in urban perimeter: evaluation of trophic status and relations with the zooplanktonic community. *Acta Limnologica Brasiliensia*, 2024, vol. 36, e15. https://doi.org/10.1590/S2179-975X8322

Abstract: Aim: The zooplankton community is used as a bioindicator of environmental changes and can be an indicator of trophic status in aquatic environments through changes in the composition of the community. The objective of this work was to study the variation of shallow reservoir systems in an urban park, evaluating the relationships between physical, chemical, and biological variables. **Methods:** The collections were conducted monthly for a year in the surface of reservoirs. The physical and chemical variables of the water were measured using a multiparametric probe on the surface. Nutrient analysis was performed using spectrophotometry in the laboratory. Zooplankton was collected using a plankton net (60 μm mesh size). Principal Coordinate Analysis (PCoA) was used to verify whether the three reservoirs present differences in zooplankton community composition. **Results:** Altogether, 43 taxa belonging to 16 families were collected. Rotifera was the most representative group, with 27 taxa, Cladocera had 13 taxa, and Copepoda had only three taxa. The environmental variables indicated different trophic status between the reservoirs, demonstrating greater eutrophication in reservoirs 1 and 3. An association between the composition of the zooplankton community and the trophic state of the reservoirs was verified. **Conclusions:** The composition of the zooplankton community shows differences among three of the shallow urban reservoirs studied. Reservoir 1 exhibited *Filinia terminalis* and *Asplanchna herrick* as indicator species. As for reservoir 2, with a lower trophic status, the indicative species were *Bosmina freyi* and *Diaphanosoma polyspina*, correlated with lower concentrations of nitrate, nitrite, total phosphorus, pH, and lower values of electrical conductivity. Reservoir 3 exhibited *Brachionus angularis* and *Brachionus calyciflorus* as indicator species, demonstrating a similar nutrient profile to R1, but with higher nitrate concentrations.

Keywords: bioindicator; Cladocera; Copepoda; Rotifera.

Resumo: Objetivo: A comunidade zooplâncton é utilizada como bioindicador de mudanças ambientais e pode ser um indicador do estado trófico em ambientes aquáticos através de mudanças na composição da comunidade. O objetivo deste trabalho foi estudar a variação de sistemas de reservatórios rasos em um parque urbano, avaliando as relações entre variáveis físicas, químicas e biológicas. **Métodos:** As coletas foram realizadas mensalmente durante um ano na superfície dos reservatórios. As variáveis físicas e químicas da água foram medidas por meio de sonda multiparamétrica na superfície. A análise dos nutrientes foi realizada por espectrofotometria em laboratório. O zooplâncton foi coletado com rede de plâncton (malha de 60 µm). A Análise de Coordenadas Principais (PCoA) foi utilizada para verificar se os três reservatórios apresentam diferenças na composição da comunidade zooplanctônica. **Resultados:** Ao todo foram coletados 43 táxons pertencentes a 16 famílias. Rotifera foi o grupo mais representativo, com 27 táxons, Cladocera teve 13 táxons e Copepoda teve apenas três táxons. As variáveis ambientais indicaram diferentes estados tróficos entre os reservatórios, demonstrando maior eutrofização nos reservatórios 1 e 3. Foi verificada associação entre a composição da comunidade zooplanctônica e o estado trófico dos reservatórios. **Conclusões:** A composição da comunidade zooplanctônica apresenta diferenças entre três dos reservatórios urbanos rasos estudados. O reservatório 1 exibiu *Filinia terminalis* e *Asplanchna herrick* como espécies indicadoras. Já no reservatório 2, com menor status trófico, as espécies indicativas foram *Bosmina freyi* e *Diaphanosoma polyspina*, correlacionadas com menores concentrações de nitrato, nitrito, fósforo total, pH e menores valores de condutividade elétrica. O reservatório 3 exibiu *Brachionus angularis* e *Brachionus calyciflorus* como espécies indicadoras, demonstrando perfil nutricional semelhante ao R1, mas com maiores concentrações de nitrato.

Palavras-chave: bioindicador; Cladocera; Copepoda; Rotifera.

1. Introduction

Urban reservoirs are essential for the sustainable development of cities and for the stability of ecosystems. They are created for thermal comfort, aesthetics, recreation (Ding et al., 2015; Luthy et al., 2020), and in some cases, for use as a water resource and rainwater retention basin (Gu et al., 2017). However, the lack of urban planning, disorderly constructions, untreated discharge of pollutants into water resources, and lack of maintenance make aquatic environments susceptible to degradation (Spahr et al., 2020, Chen et al., 2021). When built for rainwater storage, the reservoirs receive the insertion of allochthonous material, responsible for the incorporation of nutrients and pollutants (for example, nitrogen and phosphorus, coming from punctual or diffuse contamination media, such as sewage), causing a eutrophication process, which can bring as consequences the change in physical and chemical parameters, with modification of the composition of the aquatic community (Shen et al., 2021, Shen et al., 2022). In addition to other anthropic factors involved in the construction of these systems (such as land use, change in the watercourse, and use of water resources, which will impact the quality and quantity of water), natural factors are also associated, such as soil type, presence of riparian forest, geology, and terrain slope. The depth of aquatic environments also influences hydrodynamics, with shallow systems having the potential for particle resuspension through animal and climatic action (such as wind action), increasing the rate of nutrients and the trophic status (Scheffer, 2004; Ji, 2008; Antenucci et al., 2013). To detect the influence of these factors on water quality, ecological knowledge of these systems is necessary, both in their natural condition and in their responses to anthropic interference (Bucci et al., 2015).

The environmental quality of lentic systems, such as urban reservoirs, can be analyzed based on biological communities, such as the zooplankton community, which plays a vital role in nutrient and energy cycling (Ngochera & Bootsma, 2018; Zhang et al., 2018), in addition to locomotion capacity and longitudinal and latitudinal variation in the water column (Santos et al., 2018). Zooplanktonic organisms can be used as an indicator of environmental quality, reflecting changes in physical, chemical, and biological processes (Midya et al., 2018; Raut & Shembekar, 2015), because they have characteristics such as a short life cycle and rapid response to the various impacts that occur in the environment through changes in quantity, composition, and diversity (Das & Kar, 2016). However, studies are still needed to adjust their use as biological indicators in low-order rivers that have been transformed into reservoirs.

The objective of this work was to study the variation of shallow reservoir systems in an urban park, evaluating the relationships between physical, chemical, and biological variables, with the following hypotheses: i) the structure of the zooplankton community changes between the three connected urban reservoirs and between the sampling points within each reservoir due to the habitat condition; ii) the physical and chemical parameters influence the composition of the zooplankton community in the analyzed reservoirs system.

2. Materials and Methods

2.1. Study area

Three urban reservoirs were studied, built by damming a first-order river and connected in series:

reservoir 1 (R1) is fed by water from a spring, reservoir 2 (R2) receives water from the first reservoir and surface runoff and its flow rushes directly into reservoir 3 (R3), which still receives water from the rainwater system, functioning as a retention basin. Reservoir 1 has birds (ducks and geese), R2 has the rooted macrophyte *Typha domingensis* (approximately 37% of it is occupied). The reservoirs are located in Parque dos Lagos, at a headwater of the Córrego Vertente Grande watershed, a tributary of the Frutal river (20º01'27" and 20º01'23"S; 48º55'20" and 48º55'33"W), with altitude varying between 527 and 540 m and about 53.000 m^2 in area, in the city of Frutal, Minas Gerais, Brazil (Figure 1).

The climate of the region is seasonal tropical Aw, according to the Köppen-Geiger classification (Alvares et al., 2013), with dry winters and rainy summers, and an average annual temperature and precipitation of 23.8ºC and 1626.9 mm, respectively (Accuweather, 2020). The total monthly precipitation for the sampled period was obtained from Accuweather (2020).

2.2. Physical and chemical variables and trophic state of reservoirs

Water samples were monthly collected from May/2019 to April/2020. Physical and chemical parameters of the water were measured at three sampling points in each reservoir (one at the water inlet, one at the intermediate (central) region, and another at the water outlet), totaling nine collection points (108 samples), with samples taken from the subsurface layer of water (Figure 1).

At each sampling point we measured the water temperature (Temp; °C), electrical conductivity (Cond; µS cm^{-1}), pH, turbidity (Turb; NTU), dissolved oxygen (DO; mg L^{-1}), oxidation -reduction potential (ORP; mV), and total dissolved solids (TDS; mg L^{-1}), using a multiparameter probe (HORIBA, U-50). The water samples for chemical determination were placed in previously cleaned polyethylene bottles with a storage capacity of 500 mL. Total phosphorus (TP; µg L^{-1}), orthophosphate (OP; µg L^{-1}), nitrate (NO_3; µg L^{-1}), nitrite (NO_2; µg L^{-1}), and total ammonia nitrogen (TAN; µg L^{-1}) were determined spectrophotometrically, according to Golterman et al. (1978) and Koroleff (1976).

The trophic state index of the reservoirs was calculated according to the phosphorus concentration (Lamparelli, 2004).

2.3. Definition of the sample volume, collection, and identification of the zooplankton community

A pilot sampling was performed to determine the sample volume. Therefore, 20, 50, 100, and 200 L were collected in the three reservoirs using a graduated bucket. Each volume was filtered through a plankton net (60 µm mesh size), placed in 500 mL dark flasks, and preserved in 4% formalin.

A qualitative analysis of the organisms was conducted using a stereomicroscope, binocular microscope, and taxonomic bibliography (Koste, 1978; Reid, 1985; Segers, 1995; Perbiche-Neves, 2011; Elmoor-Loureiro & Sousa, 2021). Quantitative analysis of cladocerans and copepods was performed on cross-linked acrylic plates. Stereomicroscope, nauplius, and rotifers were quantified in 1 mL subsamples in Sedgewick-Rafter chambers, with a binocular microscope. Quantification was conducted until reaching 100 individuals of the most abundant species, or

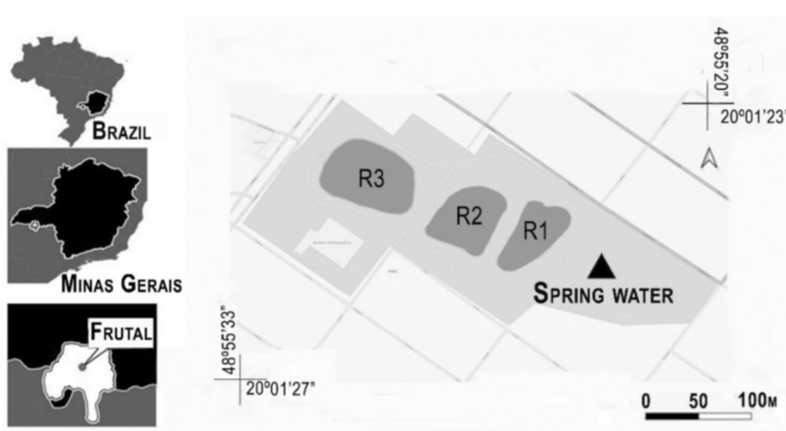

Figure 1. Location of the study area, with identification of each reservoir (Frutal, Minas Gerais, Brazil). Where: R1 = reservoir 1; R2 = reservoir 2; R3 = reservoir 3.

the entire sample when the density did not reach this value (Bicudo & Bicudo, 2004).

Friedman's nonparametric test was used to verify differences in species richness and abundance between different volumes, with Dunn's post hoc test. The volume of 20 liters presented a higher abundance of species and richness, so this quantity was used for the quantitative sampling of the zooplankton community (Figure 2). The 20 L sampling was conducted first, and it might have interfered with the subsequent samplings, given the small size of the reservoirs. As the other volumes were withdrawn sequentially, the initial extraction could have influenced the reduction in species richness due to disturbances in the same area.

With the volume of 20 defined, the zooplankton community was sampled at three points in each reservoir (Figure 1), totaling nine collection points, with sampling between May/2019 and April/2020 (n=108). The sampling, sorting, and identification procedures were the same as those presented for choosing the sample volume.

2.4. Data analysis

The ecological attributes richness, density (ind m^{-3}), abundance, relative abundance, Shannon index, and Simpson's dominance were calculated using the Past software (Hammer et al., 2001).

To verify the difference in the physical and chemical variables between the reservoirs, the average of the sampling points of each reservoir was used, where the months were considered replicas (Gotelli & Ellison, 2016). The normality of the data and homoscedasticity of the variances were verified by the Lillierfors and Bartlett's test at the significance level $\alpha = 0.05$, verifying that the data do not fit the premises for the analysis of variance with the R Development Core Team (2021). Abiotic data were evaluated by Principal Components Analysis (PCA) and undertaken according to software Statistica 10 (StatSoft, Inc., 2011).

Principal Coordinate Analysis (PCoA) was performed based on the similarity matrix using the Bray-Curtis index to verify whether the three reservoirs have differences in community composition. The data were standardized and transformed into square roots. Differences in community composition between reservoirs and collection points, as well as interaction, were analyzed using Permutational Multivariate Analysis of Variance (PERMANOVA) with a two-way crossed design (Anderson, 2001), with reservoir and collection site being fixed factors.

The relationship between zooplanktonic composition and abiotic variables was examined using Distance-Based Linear Model Analysis (DistLM) (Legendre & Anderson, 1999). After performing the correlation analysis between the variables, it was decided to remove the TDS variable from the model due to the autocorrelation (70%) with Cond. The "step-wise" selection procedure and the adjusted R^2 selection criterion were used. Distance-based redundancy analysis (dbRDA) was used to visualize the DistLM results (Anderson et al., 2008; Clarke & Gorley, 2006; Clarke & Warwick, 2001).

Analysis of indicator species (IndVal) was performed to identify potential zooplanktonic species indicating the trophic status of the reservoirs, considering the number of individuals and environmental parameters (Dufrene & Legendre, 1997). Species with significant IndVal results ($p<0.05$) above 70% were considered indicator species for environmental conditions, being more sensitive to environmental changes. Species with intermediate IndVal, between 45% and 70%, were considered species that detect environmental conditions, being more resistant to environmental changes, with higher adaptability to environmental

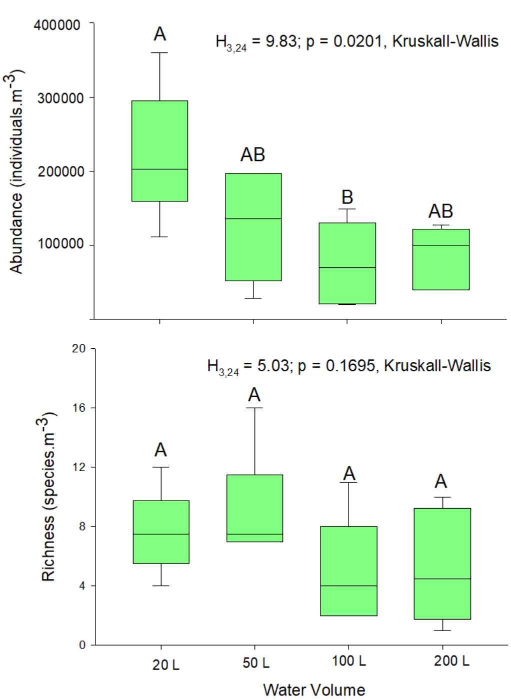

Figure 2. Friedman's non-parametric test, used to verify differences in species richness and abundance between different volumes, with Dunn's post hoc test.

changes. In this study, the value ≤45% was used as a limit to demarcate the IndVal index, following the criterion adopted by Verdú et al. (2011).

Abundance distribution was performed to verify whether the dominance of species varied between reservoirs. These curves ordered the species from the most abundant to the least abundant. Ranks were constructed for each reservoir. The abundance data were transformed into log + 1.

3. Results

3.1. Physical and chemical variables of reservoir water

The principal component analysis (PCA) with 12 abiotic variables retained 48.36% of the variability from the original data on the first two axes (axis 1 = 27.84%; axis 2 = 20.52%). The variables TDS (-1.79), OP (-1.70), Cond (-1.68), Turb (1.52), and NO_2 (-1.22), positioned on the negative side of PC1, associated with most of the points representing R1 and R3. The variables Temp (0.80) and ORP (0.36) positioned on the positive side of PC1, associated with R2. The variable NO_3 (-2.33) is positioned on the negative side of PC2 (Figure 3). Observing the distribution of points, it is possible to identify that in PC1 we have the representation of the trophic degree, where there is an increase in it from the positive side to the negative side.

All reservoirs had mesotrophic conditions (Table 1).

3.2. Zooplankton community structure

A total of 43 taxa were identified and distributed in 16 zooplankton families. Rotifera was the most representative group with 27 taxa (61.90%), followed by Cladocera with 13 taxa (30.95%) and Copepoda with only three taxa (7.17%). Rotifera was represented by seven families (Brachionidae, Asplanchnidae, Gastropodidae, Trochosphaeridae, Lepadellidae, Lecanidae, and Synchaetidae). The two families that contributed significantly to the species richness in the reservoirs were Lecanidae, with ten species, and Brachionidae, with eight species.

Cladocera was represented by five families (Chydoridae, Bosminidae, Macrothricidae, Sididae, and Ilyocriptidae), with the following species most found in the samples: *Bosmina freyi*, *Diaphanosoma polyspina*, *Diaphanosoma spinulosum*, *Chydorus* cf. *sphaericus*, and *Chydorus pubescens*. Copepoda was represented by three families: Diaptomidae and Cyclopidae, with species *Notodiaptomus deitersi*, *Thermocyclops decipiens*, and *Thermocyclops minutus*, and an unidentified family belonging to the order Harpacticoida.

In the Rotifera group, 14 species were recorded in R1 and 13 species in the other two reservoirs. *Brachionus* and *Lecane* were the most represented genus in this study. For Cladocera, 12 species were recorded in reservoir 1 (R1), 11 in reservoir 2 (R2), and only one in reservoir 3 (R3). The most represented genus were *Bosmina* and *Chydorus* (three species each). For Copepoda, three species were recorded, belonging to the genera *Notodiaptomus* and *Thermocyclops*, and all of them appeared in the three reservoirs.

The largest number of individuals among the three reservoirs was found in R3, with a value seven times higher than in the other reservoirs

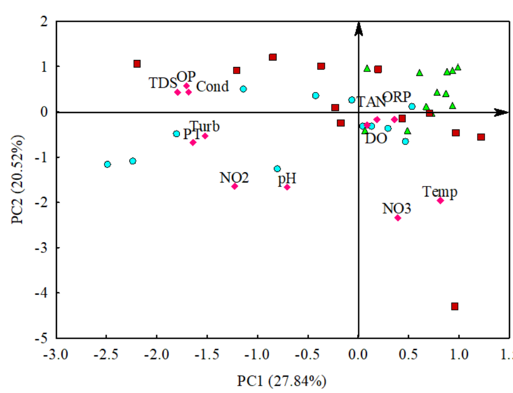

Figure 3. Principal component analysis (PCA) of the physical and chemical parameters from the water of the three reservoirs studied. Where: circles = R1; triangle = R2; square = R3; DO = Dissolved oxygen; Temp = Temperature; Cond = Electrical conductivity; TDS = Total Dissolved Solids; ORP = Oxidation-reduction potential; Turb = Turbidity; NO_3 = Nitrate; NO_2 = Nitrite; TAN = Total Ammonia Nitrogen; PT = Total Phosphorus; OP = Orthophosphate.

Table 1. Values found for the trophic state index of water in the studied reservoirs, according to Lamparelli (2004).

Sites	TSI (PT)			Classification
	Minimum	Maximum	Mean	
R1	35	59	49.9	mesotrophic
R2	37	53	41.8	mesotrophic
R3	40	53	46.9	mesotrophic

R1 = Reservoir 1; R2 = Reservoir 2; R3 = Reservoir 3; TSI = Trophic State Index.

(Figure 4). Rotifera was the group with the highest relative abundance in all reservoirs (92.7% in R1; 62.3% in R2 and 99.7% in R3). The highest relative abundance of Cladocera was observed in R2 (21.6%), followed by R1 (1.4%). Among the orders of Copepoda, Calanoida showed higher relative abundance than Cyclopoida. Cyclopoida had higher relative abundance in R1 (1.1%), followed by R2 (0.9%), and R3 (0.3%) (Figure 4).

The reservoir R1 showed the highest richness (9), followed by R2 (8) and R3 (7). Species dominance ranged from 0.36 (R1) to 0.38 (R2). When analyzing the result of the Shannon index, which assigns the same value to rare and abundant species, it is possible to state that the three reservoirs have species uniformity (Table 2).

3.3. Classification of species (Ranks)

Based on the species classification (ranking), *Brachionus calyciflorus* showed abundance values higher than 0.05 in both R1 and R3, demonstrating high abundance (Figure 5). Another species that stood out as abundant in R3 is *Brachionus angularis*. In R2, the most abundant species was *Notodiaptomus deitersi,* followed by *Brachionus dolabratus*. Note that the genus *Brachionus* was the one that stood out the most in terms of abundance.

Table 2. Mean and standard deviation of the results of the ecological indices of the three reservoirs studied.

	Richness	Dominance	Shannon
R1	9±2.4	0.36±0.1	1.34±0.3
R2	8±2.5	0.38±0.2	1.34±0.2
R3	7±2	0.37±0.2	1.30±0.4

R1 = Reservoir 1; R2 = Reservoir 2, R3 = Reservoir 3.

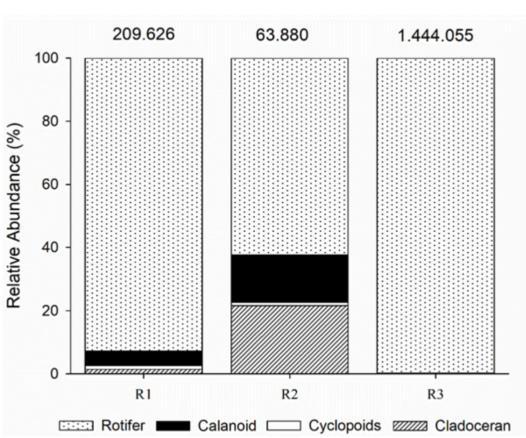

Figure 4. Relative abundance graph of the groups studied in the three reservoirs. R1: Reservoir 1, R2: Reservoir 2, R3: Reservoir 3. Values above the bars represent the number of individuals m^{-3} in each reservoir.

3.4. Influence of environmental variables on the zooplankton community

The composition of the zooplankton community showed a difference between the three reservoirs (Pseudo-F = 28.983; p = 0.001), where R1 was different from R2 (t = 4.14; p = 0.001), R1 different from R3 (t = 6.65; p = 0.001), and R2 different from R3 (t = 5.38; p = 0.001). Neither the sampling location within the reservoirs (Pseudo-F = 0.56004; p = 0.897) nor the interaction of factors (Pseudo-F = 0.66145; p = 0.922) proved to be significant (Figure 6).

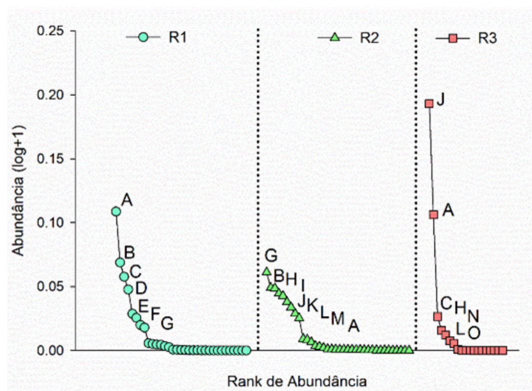

Figure 5. Rank of zooplankton species found in the studied reservoirs. Where: circles = R1; triangle = R2, and square = R3. (A) *Brachionus calyciflorus*; (B) *Brachionus dolabratus*; (C) *Gastropus* cf *hyptopus*; (D) *Asplanchna cf herrick*; (E) *Filinia terminales*; (F) *Lecane* cf *inermes*; (G) *Notodiaptomus deitersi*; (H) *Polyartrha vulgaris*; (I) *Bosmina freyi*; (J) *Brachionus angularis*; (K) *Diaphanosoma polyspina*; (L) *Brachionus falcatus*; (M) *Lecane bulla*; (N) *Trichocerca pusila*; (O) *Brachionus dimidiatus*.

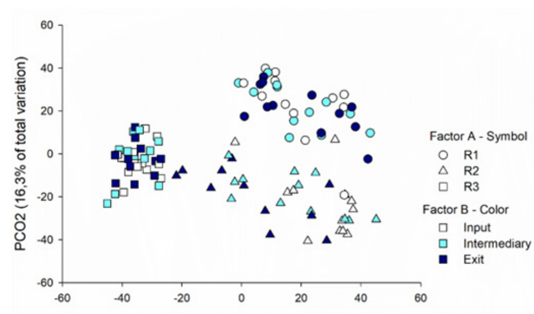

Figure 6. Principal Coordinate Analysis (PCoA) constructed from the Bray-Curtis dissimilarity matrix of the three reservoirs and three sampling points within each reservoir.

The dbRDA plot for the composition of the zooplankton community and environmental variables demonstrates that the variables pH, electrical conductivity (Cond), dissolved oxygen (DO), oxidation-reduction potential (ORP), nitrite (NO_2), and total phosphorus (TP) influence the community composition, explaining 32.5% of the total variation in the data (Figure 7). In the marginal test, pH, DO, Cond, ORP, NO_2, and TP showed a significant relationship with the multivariate cloud of the data derived from the species when considered alone, without considering the other variables (Table 3). Variables NO_2, pH, Cond, TP, ORP, and DO explain around 11%, 10%, 7%, 7%, 6%, and 5% of the variation, respectively.

Nitrite was taken first in the sequential test. In addition, the variable that most increased the R^2 criterion was electrical conductivity (Cond). These two explain around 39% of the variation

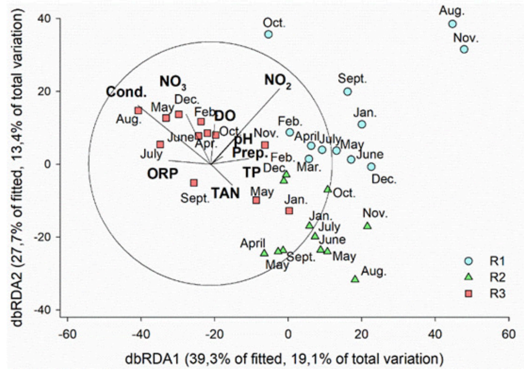

Figure 7. Distance-based redundancy analysis (dbRDA). Relationship between the ordering of sampling points based on the composition of the zooplankton community and environmental variables, as follows: DO (dissolved oxygen), Cond. (electrical conductivity), NO_3 (nitrate), NO_2 (nitrite), Prep. (precipitation), TP (total phosphorus), ORP (oxidation-reduction potential), and TAN (total ammonia nitrogen).

Table 3. Results of Distance-Based Linear Modeling (DistLM) between the relationship of environmental variables and the composition of the zooplankton community in marginal tests (variation explained by a single variable) and in sequential tests (variation explained by adding new variables at a time to obtain the criterion of optimal fit) using the adjusted R^2 selection procedure.

DistLM marginal test result				
Variables	**SS (trace)**	**Pseudo-F**	**P**	**Proportion**
Dissolved oxygen	4576.8	20.959	0.047*	0.0581
pH	8507.1	41.135	0.003*	0.1079
Temperature	2223.4	0.9868	0.476	0.0282
Conductivity	5533.0	25.668	0.019*	0.0702
ORP	5212.9	24.078	0.030*	0.0661
Turbidity	3808.4	17.261	0.097	0.0483
Nitrate	3408.8	15.369	0.161	0.0436
Nitrite	8837.7	42.935	0.001*	0.1121
TAN	1910.5	0.8446	0.597	0.0242
Total Phosphorus	5817.8	27.095	0.010*	0.0738
Orthophosphate	2704.6	12.081	0.286	0.0343
Precipitation	1928.0	0.8525	0.552	0.0244

DistLM sequential test result						
Variables	**R2**	**SS (trace)**	**Pseudo-F**	**P**	**Proportion**	**Cumul. P**
Nitrite	0.0860	8837.7	42.935	0.001*	0.1121	0.1121
Conductivity	0.1365	5815.5	29.907	0.022*	0.0737	0.1859
Nitrate	0.2097	7220.7	40.574	0.002*	0.0916	0.2775
DO	0.2561	5018.2	29.956	0.006*	0.0636	0.3411
pH	0.2865	3725.6	23.186	0.028*	0.0472	0.3884
Precipitation	0.2997	2470.1	15.663	0.134	0.0313	0.4197
TAN	0.3037	1828.5	11.661	0.314	0.0231	0.4429
Total Phosphorus	0.3046	1625.6	10.381	0.396	0.0206	0.4636
ORP	0.3067	1690.0	10.825	0.368	0.0214	0.4850

ORP = Oxidation Reduction Potential; DO = Dissolved oxygen; TAN = Total Ammonia Nitrogen; SS = Sum of Squares; Cumul. P = Cumulative value of P. *P<0.05.

in the data cloud. The best solution suggested was the model with nine variables (pH, electrical conductivity, dissolved oxygen, nitrate, nitrite, ammonia nitrogen, total phosphorus, ORP, and precipitation), which combined explain around 48% of the total variation (Table 3).

3.5. Indicator species (IndVal)

The IndVal test identified four indicator species and 12 detectors of the environmental conditions of the reservoirs (Table 4). For reservoir 1 (R1), *Asplanchna herrick* and *Filinia terminalis* can be considered as indicator species, while *Brachionus dolabratus*, *Notodiaptomus deitersi*, and *Thermocyclops minutus* were classified as detector species. The reservoir 2 (R2) does not have indicator species but has two detector species belonging to the Cladoceran order (*Bosmina freyi* and *Diaphanosoma polyspina*). The reservoir 3 (R3) had two indicator species (*Brachionus angularis* and *Brachionus calyciflorus)* and five detectors (*Brachionus falcatus*, *Brachionus dimidiatus*, *Polyarthra vulgaris*, *Trichocerca pusila*, and *Thermocyclops decipiens*).

4. Discussion

The study showed that the zooplankton community is sensitive to changes in the physical and chemical characteristics of the aquatic environment, altering the structure of the community when there are changes in trophic conditions, being efficacious and good indicators of environmental quality in shallow urban water systems, with indicator and detectors species of trophic conditions. The zooplankton community structure is influenced by abiotic factors, climatic and hydrological regime (Serafim-Júnior et al., 2011; Medeiros et al., 2020).

The pH of reservoirs R2 and R3 was lower, comparing to R1. This result may be associated with the frequent input of allochthonous material from surface runoff, and, consequently, higher decomposition rates, increasing the electrical conductivity values, especially in R3. Under artificial conditions, such as those found in this study, the high electrical conductivity values are due to wastewater discharges from urban activities — which occurs directly in the studied environments — and it is a crucial variable in the identification of pollutant load in aquatic environments, collaborating to evaluate the availability of ions in aquatic systems (Leira et al., 2017). The total phosphorus concentration (TP) is also incorporated into natural environments, mainly due to human activities, such as the discharge of urban wastewater containing superphosphate detergents (Yuan et al., 2018). Thus, the highest amounts observed in R1 and R3 may originate from the action of surface runoff, introducing allochthonous material. In addition, the presence of aquatic avifauna in R1, composed of members of the Anatidae family (e.g., ducks, geese), helps in the increase of nutrients promoted by their activities, acting in the process of increasing the trophic status of the system (Adhurya et al., 2021). The time factor also has an influence on this nutrient — the longer the life and use of the systems, the higher the presence of phosphorus due to its retention in the

Table 4. Values obtained for indicator species of the studied environments.

Species	Reservoirs	Note IV	Mean	SD	p (*)	Classification
Filinia terminalis	R1	77.4	15.9	4.3	0.0002	Indicator
Asplanchna herrick	R1	74.5	15.3	3.6	0.0002	Indicator
Thermocyclops minutus	R1	53.6	19.7	4.9	0.0002	Detector
Brachionus dolabratus	R1	50.4	19.2	4.3	0.0002	Detector
Notodiaptomus deitersi	R1	50.3	28.9	3.9	0.0006	Detector
Bosmina freyi	R2	61.1	16.5	4.0	0.0002	Detector
Diaphanosoma polyspina	R2	58.7	25.3	5.2	0.0004	Detector
Brachionus angularis	R3	85.4	41.8	6.6	0.0002	Indicator
Brachionus calyciflorus	R3	81.6	73.4	4.7	0.0344	Indicator
Polyarthra vulgaris	R3	68.0	25.2	5.8	0.0002	Detector
Trichocerca pusila	R3	65.0	29.0	6.7	0.0002	Detector
Brachionus falcatus	R3	64.3	21.7	4.7	0.0002	Detector
Thermocyclops decipiens	R3	60.1	20.2	4.4	0.0002	Detector
Brachionus dimidiatus	R3	46.7	18.3	4.5	0.0004	Detector

Where: R1 = reservoir 1; R2 = reservoir 2; R3 = reservoir 3; Note IV = index result for each species; SD = standard deviation. Significant values are in bold and with *. The highlighted species are those that have an index above 70%, being considered as an indicator.

sediment. In R1, the existence of birds promotes upturn, resuspending nutrients to the water column (Reddy et al., 1996).

The zooplankton community has several species that are perceptible to changes in the environment. Most are sensitive and end up being replaced, while others can thrive and occupy the various available niches (De-Carli et al., 2017). Rotifera were the most abundant organisms in the zooplankton community in all reservoirs. It is due to their opportunistic habits and high environmental adaptability, which give them the ability to colonize environments, especially in environments with high levels of nutrients (Arruda et al., 2017; Brito et al., 2020). *Brachionus* was the most abundant genus among the Rotifera, also observed by other authors who studied reservoirs (García-Chicote et al., 2019; De-Carli et al., 2017), proving to be a good indicator of environments with greater trophy (García- Chicote et al., 2019) due to the high abundance in R1 and R3 (Figures 4 and 7; Table 4).

The results of the dbRDA analysis indicated the importance of the variables nitrate and electrical conductivity in the structure of zooplankton communities (Figures 6 and 7). The high values for these parameters in the third reservoir (R3) occur because the system receives surface rainwater runoff from upstream neighborhoods and clandestine sewage disposal, which increases the nutrient load and the trophic status. Similar results were found in the research carried out by Rosińska et al. (2019), that verified that the concentration of physical and chemical parameters in urban lakes models the structure of the zooplankton community, causing the selection of species according to their plasticity (Zaganini et al., 2011).

The Cladoceran fauna showed higher abundance in R2 (Figure 4). It can be inferred that the representative presence of this group only in R2 is related to the presence of aquatic macrophytes (Elmoor-Loureiro & Mendonça-Galvão, 2008), which have a sheltered role and help in the process of removing nutrients from the system, which consequently reduces the trophic status (Sahidin et al., 2018; Jurczak et al., 2019). The presence of Cladocera is related to less eutrophic conditions, such as low levels of nitrate, nitrite, total phosphorus, orthophosphate, and electrical conductivity (Mashkova et al., 2021), a fact that was observed in this study through the association of the detector species *Bosmina freyi* and *Diaphanosoma polyspina* and the low concentrations of the variables mentioned above, corroborating the studies by Jurczak et al. (2019) and Otake et al. (2020), in which the community responds directly to the nutrient concentrations in the system and its productivity.

The analysis of indicator species (IndVal) showed that each environment has a set of species. Among the 14 species presented, 10 are detector species and the other four are indicators. However, some studies (McGeoch et al., 2002; García-Chicote et al., 2019; Schmidt et al., 2020) claim that indicator species with high IV values may not be efficient in monitoring ecological changes, as they are highly specific and restricted to particular environmental conditioning. Therefore, detector species that present moderate levels of specificity are more useful in verifying environmental conditions, as they have higher adaptability to different variations of the environment, resisting and remaining in it (McGeoch et al., 2002; Hunt & Hosie, 2006). Detector or generalist species have a greater possibility of locomotion to nearby habitats with elevated speed when there are changes in habitat conditions, unlike indicator or specialist species, which undergo abrupt change and may be replaced or disappear from that environment (McGeoch et al., 2002).

Concerning the environmental conditions of indicator and detector species, for R1, the community composition is associated with the nitrite variable. The species *B. dolabratus*, *T. minutus*, and *N. deitersi* are usually found in environments with eutrophic conditions (De-Carli et al., 2017; Landa & Colchete, 2020). In R3, among the seven species found as indicators and detectors, four are of the genus *Brachionus*, one of *Trichocerca*, one of *Polyarthra*, and one representative of Copepoda (*Thermocyclops decipiens*), which, according to the dbRDA analysis, are indicators of the conditions of this reservoir, that is, an environment with conditions of high conductivity and nitrogenous compounds concentrations, as observed by Oliveira et al. (2015).

The community structure in the studied systems did not show differences in ecological indices, richness, abundance, and diversity. However, the community composition was different among the three studied environments, and the abiotic variables are responsible for modeling the community composition. The sensitivity of the analyses can explain this since the indices show an overview of the community, which is widely used for quick sampling (Chawla et al., 2012) and have more or less strong correlations with other parameters.

An example is the Shannon index, which is influenced by species richness and composition uniformity (Magurran, 2013).

As much as the three environments have connections, the PCoA analysis showed that the community composition is different among the three systems. This information agrees with the data collected by Cottenie & De-Meester (2003), that, when studying connectivity parameters between reservoirs, did not find evidence that this is a determining parameter for the composition of the dam community. However, this is not a single pattern. Local and specific characteristics of each area involve biotic and abiotic interactions that interfere in the dynamics of each community, shaping its structure (Thompson & Townsend, 2006).

The Shannon index showed that the reservoirs have low species diversity compared to other urban reservoirs studied by Rosińska et al. (2019) and Gayosso-Morales et al. (2017). This low species diversity may be linked to environmental conditions, such as depth and physical and chemical changes in the water. In the abundance rank in which it is used as an ecological pattern of dominance, the species *B. calyciflorus* and *B. dolabratus* showed the highest dominance for R1, the species *Notodiapttomus deitersi* and *B. dolabratus* were dominant in R2, and *B. angularis* and *B. calyciflorus* were in R3. Despite its dominance (as demonstrated by the ranking of species), IndVal indicated that *B. calyciflorus* is not an indicator or detector species due to the analytical criteria and parameters. IndVal is a more sensitive analysis; it evaluates the composition of parameters attributing habitat specificity (presence in samples and abundance). Therefore, when evaluating the dbRDA analysis with IndVal, it can be inferred that the species that detect the conditions found in R1 (*T. minutus, B. dolabratus*, and *N. deitersi*) are associated with the variable nitrite. The species *B. freyi* and *D. polyspina* were the detector species for R2, which according to the dbRDA analysis, is associated with total ammonia nitrogen (TAN). And for R3, the detector species were *P. vulgaris*, *T. pusila*, *B. falcatus*, *T. decipiens*, and *B. dimidiatus*, which according to the dbRDA, are associated with the variables electrical conductivity, nitrate, dissolved oxygen and ORP.

5. Conclusion

The composition of the zooplankton community shows differences among three of the shallow urban reservoirs studied. The community composition in R1 and R3 was associated with total dissolved solids, orthophosphate, electrical conductivity, turbidity, total phosphorus, and nitrite concentration. R1 exhibited *Filinia terminalis* and *Asplanchna herrick* as indicator species. As for R2, with a lower trophic status, the indicative species were *Bosmina freyi* and *Diaphanosoma polyspina*, correlated with lower concentrations of nitrate, nitrite, total phosphorus, pH, and lower values of electrical conductivity. R3 exhibited *Brachionus angularis* and *Brachionus calyciflorus* as indicator species, demonstrating a similar nutrient profile to R1, but with higher nitrate concentrations.

Acknowledgements

Thanks to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship granted to the first author to conduct the project. VK thanks the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and the Universidade do Estado de Minas Gerais (UEMG) for funding.

References

Accuweather, 2020. Condições meteorológicas de São Paulo. Retrieved in 2020, May 21, from https://www.accuweather.com/pt/br/autode/39298/weather-forecast/39298

Adhurya, S., Das, S., & Ray, S., 2021. Simulating the effects of aquatic avifauna on the Phosphorus dynamics of aquatic sysms. Ecol. Modell. 445, 109495. http://doi.org/10.1016/j.ecolmodel.2021.109495.

Alvares, C.A., Stape, J.L., Sentelhas, P.C., Gonçalves, J.D.M., & Sparovek, G., 2013. Köppen's climate classification map for Brazil. Meteorol. Z. 22(6), 711-728. http://doi.org/10.1127/0941-2948/2013/0507.

Anderson, M.J., 2001. A new method for non-parametric multivariate analysis of variance. Austral Ecol. 26(1), 32-46. http://doi.org/10.1111/j.1442-9993.2001.01070.pp.x.

Anderson, M.J., Gorley, R.N., & Clarke, K.R., 2008. PERMANOVA+ for PRIMER: guide to software and statistical methods. Plymouth, UK: PRIMER-E Ltd.

Antenucci, J.P., Tan, K.M., Eikaas, H.S., & Imberger, J., 2013. The importance of transport processes and spatial gradients on in situ estimates of lake metabolism. Hydrobiologia 700(1), 9-21. http://doi.org/10.1007/s10750-012-1212-z.

Arruda, G.D.A., Diniz, L.P., Almeida, V.L.D.S., Neumann-Leitão, S., & Melo Junior, M., 2017. Rotifer community structure in fish-farming systems associated with a Neotropical semiarid reservoir in north-eastern Brazil. Aquacult. Res. 48(9), 4910-4922. http://doi.org/10.1111/are.13310.

Bicudo, C.E.M., & Bicudo, D.C., 2004. Amostragem em limnologia. São Carlos: Rima.

Brito, M.T.D.S., Heino, J., Pozzobom, U.M., & Landeiro, V.L., 2020. Ecological uniqueness and species richness of zooplankton in subtropical floodplain lakes. Aquat. Sci. 82(2), 43. http://doi.org/10.1007/s00027-020-0715-3.

Bucci, M.M.H.S., Delgado, F.E.D.F., & Oliveira, L.F.C., 2015. Water quality and trophic state of a tropical urban reservoir for drinking water supply (Juiz de Fora, Brazil). Lake Reserv. Manage. 31(2), 134-144. http://doi.org/10.1080/10402381.2015.1029151.

Chawla, A., Yadav, P.K., Uniyal, S.K., Kumar, A., Vats, S.K., Kumar, S., & Ahuja, P.S., 2012. Long-term ecological and biodiversity monitoring in the western Himalaya using satellite remote sensing. Curr. Sci. (Online), 102(8), 1143-1156. Retrieved in 2020, May 21, from https://www.jstor.org/stable/24107757

Chen, S.S., Tsang, D.C.W., He, M., Sun, Y., Lau, L.S.Y., Leung, R.W.M., Lau, E.S.C., Hou, D., Liu, A., & Mohanty, S., 2021. Designing sustainable drainage systems in subtropical cities: challenges and opportunities. J. Clean. Prod. 280, 124418. http://doi.org/10.1016/j.jclepro.2020.124418.

Clarke, K.R., & Gorley, R.N., 2006. PRIMER v6: user manual/tutorial. Plymouth, UK: PRIMER-E.

Clarke, K.R., & Warwick, R.M., 2001. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth, UK: PRIMER-E, 2 ed.

Cottenie, K., & De-Meester, L., 2003. Connectivity and cladoceran species richness in a metacommunity of shallow lakes. Freshw. Biol. 48(5), 823-832. http://doi.org/10.1046/j.1365-2427.2003.01050.x.

Das, B.K., & Kar, D., 2016. Diversity of zooplankton in river Siang of Arunachal Pradesh, India. Fish, &. Ocean. Opj. 1(2), 555558. http://doi.org/10.19080/OFOAJ.2016.01.555558.

De-Carli, B.P., Doval, J.C.L., Rodrigues, E.H.C., & Pompêo, M.L.M., 2017. Variação espacial e sazonal do zooplâncton nos reservatórios do Sistema Cantareira, Brasil. Rev. Ambient. Água 12(4), 666-679. http://doi.org/10.4136/ambi-agua.1935.

Ding, L., Chen, K.L., Cheng, S.G., & Wang, X., 2015. Water ecological carrying capacity of urban lakes in the context of rapid urbanization: a case study of East Lake in Wuhan. Phys. Chem. Earth Parts ABC 89-90, 104-113. http://doi.org/10.1016/j.pce.2015.08.004.

Dufrene, M., & Legendre, P., 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr. 67(3), 345-366. http://doi.org/10.2307/2963459.

Elmoor-Loureiro, L.M.A., & Mendonça-Galvão, L., 2008. Fauna associada a macrófitas. In: Fonseca, F.O., ed. Águas emendadas. Brasília: Seduma, 280-281.

Elmoor-Loureiro, L.M.A., & Sousa, F.D.R., 2021. Cladocera do Brasil. Retrieved in 2021, October 18, from http://www.cladoceradobrasil.com

García-Chicote, J., Armengol, X., & Rojo, C., 2019. Zooplankton species as indicators of trophic state in reservoirs from Mediterranean river basins. Inland Waters 9(1), 113-123. http://doi.org/10.1080/20442041.2018.1519352.

Gayosso-Morales, M.A., Nandini, S., Martínez-Jeronimo, F.F., & Sarma, S.S.S., 2017. Effect of organic and inorganic turbidity on the zooplankton community structure of a shallow waterbody in Central Mexico (Lake Xochimilco, Mexico). J. Environ. Biol. 38(6(SI)), 1183-1196. http://doi.org/10.22438/jeb/38/6(SI)/03.

Golterman, H.L., Clymo, R.S., & Ohstad, M.A.M., 1978. Methods for physical and chemical analisys of freshwater. Oxford: Blackwell Scientific Publications.

Gotelli, N.J., & Ellison, A.M., 2016. Princípios de estatística em ecologia. Porto Alegre: Artmed.

Gu, L., Wu, J., Hua, Z., Zhao, X., Liu, X., Dai, B., 2017, Mar 7. Bio-retention Pond capable of continuously processing initial rainwater in drought period. CN 106930397.

Hammer, O., Harper, D.A.T., & Ryan, P.D., 2001. Past: paleontological statistics software Packaged for education and data analysis. Version 1.94b. Palaeontol. Electronica 4, 1-9.

Hunt, B.P.V., & Hosie, G.W., 2006. The seasonal succession of zooplankton in the Southern Ocean south of Australia, part I: the seasonal ice zone. Deep Sea Res. Part I Oceanogr. Res. Pap. 53(7), 1182-1202. http://doi.org/10.1016/j.dsr.2006.05.001.

Ji, Z.G., 2008. Hydrodynamics and water quality: modeling rivers, lakes, and estuaries. Hoboken: John Wiley e Sons. http://doi.org/10.1002/9780470241066.

Jurczak, T., Wojtal-Frankiewicz, A., Frankiewicz, P., Kaczkowski, Z., Oleksińska, Z., Bednarek, A., & Zalewski, M., 2019. Comprehensive approach to restoring urban recreational reservoirs. Part 2 -Use of zooplankton as indicators for the ecological quality assessment. Sci. Total Environ. 653, 1623-1640. PMid:30107888. http://doi.org/10.1016/j.scitotenv.2018.08.006.

Koroleff, F., 1976. Determination of nutrients. In: Grashof, E., & Kremling, E., eds. Methods of seawater analysis. New York: Verlag Chemie Wenhein.

Koste, W., 1978. Rotatoria: Die Rädertiere Mitteleuropas. Berlin: Gebrüder Borntraeger.

Lamparelli, M.C., 2004. Grau de trofia em corpos d'água do estado de São Paulo: avaliação dos métodos de monitoramento [Tese de doutorado em Ecologia Aplicada]. São Paulo: Departamento de Ecologia, Universidade de São Paulo. Retrieved in 2021, October 18, from https://www. teses.usp.br/teses/

disponiveis/41/41134/tde-20032006-075813/ pt-br.php

Landa, G.G., & Colchete, I.V.H., 2020. Limnologia da comunidade zooplanctônica em um sistema lêntico em Belo Horizonte/MG. Acta Biol. Bras. 3(1), 68-78.

Legendre, P., & Anderson, M.J., 1999. Distance-based redundancy analysis: testing multispecies responses in multifactorial ecological experiments. Ecol. Monogr. 69(1), 1-24. http://doi.org/10.1890/0012-9615(1999)069[0001:DBRATM]2.0.CO;2.

Leira, M.H., Cunha, L.T., Braz, M.S., Botelho, H.A., & Reguim, L.S., 2017. Qualidade da água e seu uso em pisciculturas. Pubvet 11(1), 11-17. http://doi.org/10.22256/pubvet.v11n1.11-17.

Luthy, R.G., Wolfand, J., & Bradshaw, J.L., 2020. Urban water revolution: sustainable water futures for California cities. J. Environ. Eng. 146(7), 04020065. http://doi.org/10.1061/(ASCE)EE.1943-7870.0001715.

Magurran, A., 2013. Medindo a diversidade biológica. Curitiba: UFPR.

Mashkova, I.V., Kostryukova, A., Shchelkanova, E., & Trofimenko, V., 2021. Zooplankton as indicator of trophic status of lakes in ilmen state reserve, Russia. Biodiversitas 22(3), 1448-1455. http://doi.org/10.13057/biodiv/d220348.

McGeoch, M.A., Van Rensburg, B.J., & Botes, A., 2002. The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. J. Appl. Ecol. 39(4), 661-672. http://doi.org/10.1046/j.1365-2664.2002.00743.x.

Medeiros, R., Berezuk, A., Pinto, A., & Alves, L., 2020. Qualidade dos recursos hídricos da bacia hidrográfica do córrego Formosinho, Bonito/MS. Geogr. Ordenam. Territ. 19(19), 3-28. http://doi.org/10.17127/got/2020.19.001.

Midya, S., Bhattacgarya, S., Islam, S.S., Ganguly, R.K., & Chakraborty, S.K., 2018. Observation on freshwater zooplankton and hydrophytes composition in different wetlands of Paschim Medinipur, West Bengal (India). Int. J. Zool. Stud. 3(2), 5-9.

Ngochera, M.J., & Bootsma, H.A., 2018. Carbon, nitrogen, and phosphorus content of seston and zooplankton in tropical Lake Malawi: implications for zooplankton nutrient cycling. Aquat. Ecosyst. Health Manage. 21(2), 185-192. http://doi.org/10.1080/14634988.2017.1280294.

Oliveira, T.B., Silva, T.A., & Terra Nova, L.S., 2015. Rotíferos como indicadores da qualidade de água em cultivo de tilápias (*Oreochromis niloticus*) com utilização de águas salobras. Acta Fish. Aquat. Res. 3(1), 65-76. http://doi.org/10.2312/Actafish.2015.3.1.65-76.

Otake, Y., Ohtsuki, H., Urabe, J., Kimura, S., Yamada, K., & Yoshida, T., 2020. Long-term dynamics of a cladoceran community from an early stage of lake formation in Lake Fukami-ike, Japan. Ecol. Evol. 11(3), 1240-1253. PMid:33598127. http://doi.org/10.1002/ece3.7112.

Perbiche-Neves, G., 2011. Copépodes planctônicos (Crustacea, Calanoida e Cyclopoida) em reservatórios e trechos lóticos da bacia do Rio da Prata (Brasil, Paraguai, Argentina e Uruguai): taxonomia, distribuição geográfica e alguns atributos ecológicos [Tese de doutorado em Zoologia]. São Paulo: Intituto de Biociências de Botucatu, Universidade Estadual Paulista "Júlio de Mesquita Filho".

R Development Core Team, 2021. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. Retrieved in 2021, October 18, from http://www.R-project.org

Raut, K.S., & Shembekar, V.S., 2015. Manipulation of Zooplankton as bio-Indicators of water quality at Borna [Chandapur] dam near Parli V Dist Beed Maharashtra, India. Indian J. Appl. Res. 5(8), 587-592.

Reddy, K.R., Fisher, M.M., & Ivanoff, D., 1996. Resuspension and diffusive flux of nitrogen and phosphorus in a hypereutrophic lake. J. Environ. Qual. 25(2), 363-371. http://doi.org/10.2134/jeq1996.00472425002500020022x.

Reid, J.L.W., 1985. Chave de identificação e lista de referências bibliográficas para as espécies continentais sulamericanas de vida livre da ordem Cyclopoida (Crustacea, Copepoda). Boll. Zool. 9(9), 17-143. http://doi.org/10.11606/issn.2526-3358.bolzoo.1985.122293.

Rosińska, J., Romanowicz-Brzozowska, W., Kozak, A., & Gołdyn, R., 2019. Zooplankton changes during bottom-up and top-down control due to sustainable restoration in a shallow urban lake. Environ. Sci. Pollut. Res. Int. 26(19), 19575-19587. PMid:31079295. http://doi.org/10.1007/s11356-019-05107-z.

Sahidin, A., Zahidah, Z., Herawati, H., Wardiatno, Y., Setyobudiandi, I., & Partasasmita, R., 2018. Macrozoobenthos as bioindicator of ecological status in Tanjung Pasir Coastal, Tangerang District, Banten Province. Indonesia. Biodiversitas 19(3), 1123-1129. http://doi.org/10.13057/biodiv/d190347.

Santos, J.S., Simões, N.R., & Sonoda, S.L., 2018. Distribuição espacial e variação temporal da assembleia de microcrustáceos (Cladocera e Copepoda) em diferentes compartimentos de um reservatório no semiárido brasileiro. Acta Limnol. Bras. 30, e108. http://doi.org/10.1590/s2179-975x9616.

Scheffer, M., 2004. Ecology of shalow lakes. Dordrecht: Kluwer Academic Publishers. http://doi.org/10.1007/978-1-4020-3154-0.

Schmidt, J., Andrade, P.D.B., & Padial, A.A., 2020. Zooplankton trajectory before, during and after a hydropower dam construction. Acta Limnol. Bras. 32, e18. http://doi.org/10.1590/s2179-975x9519.

Segers, H., 1995. The Lecanidae (Monogononta. Rotifera 2). In: Dumont, H.J., ed. Guides to the identification of microinvertebrates of continental waters of the world. Netherlands: SBP Academic.

Serafim-Júnior, M., Perbiche-Neves, G., Fieto, C., & Naliato, D.A.O., 2011. Zooplâncton. In: Cunha, C.L.N., Carneiro, C., Gobbi, E.F., Andreoli, C.V., eds. Eutrofização em reservatórios: gestão preventiva-estudo interdisciplinar na Bacia do rio Verde. Curitiba: UFPR.

Shen, J., Qin, G., Gu, X., Liu, Y., An, S., Liu, R., Leng, X., & Wan, Y., 2022. Effects of seasonal hydrological regulation of cascade dams on the functional diversity of zooplankton: implications for the management of massive reservoirs and dams. J. Hydrol. (Amst.) 610, 127825. http://doi.org/10.1016/j.jhydrol.2022.127825.

Shen, J., Qin, G., Yu, R., Zhao, Y., Yang, J.G., An, S., Liu, R., Leng, X., & Wan, Y., 2021. Urbanization has changed the distribution pattern of zooplankton species diversity and the structure of functional groups. Ecol. Indic. 120, 106944. http://doi.org/10.1016/j.ecolind.2020.106944.

Spahr, S., Teixidó, M., Sedlak, D.L., & Luthy, R.G., 2020. Hydrophilic trace organic contaminants in urban stormwater: occurrence, toxicological relevance, and the need to enhance green stormwater infrastructure. Environ. Sci. Water Res. Technol. 6(1), 15-44. http://doi.org/10.1039/C9EW00674E.

StatSoft, Inc., 2011. STATISTICA, ver. 10. Tulsa.

Thompson, R., & Townsend, C., 2006. A truce with neutral theory: local deterministic factors, species traits and dispersal limitation together determine patterns of diversity in stream invertebrates. J. Anim. Ecol. 75(2), 476-484. PMid:16638000. http://doi.org/10.1111/j.1365-2656.2006.01068.x.

Verdú, J.R., Numa, C., & Hernández-Cuba, O., 2011. The influence of landscape structure on ants and dung beetles diversity in a Mediterranean savanna-forest ecosystem. Ecol. Indic. 11(3), 831-839. http://doi.org/10.1016/j.ecolind.2010.10.011.

Yuan, Z,, Jiang, S.Y., Sheng, H., Liu, X., Hua, H., Liu, X.W., & Zhang, Y., 2018. Human perturbation of the global phosphorus cycle: changes and consequences. Environ. Sci. Technol. 52(5), 2438-2450. PMid:29402084. http://doi.org/10.1021/acs.est.7b03910.

Zaganini, R.L., Perbiche-Neves, G., Naliato, G.D.A.O., & Carvalho, E.D., 2011. Baixa diversidade de zooplâncton na desembocadura de uma represa eutrófica (SP, Brasil): reflexo da poluição? Estud. Biol. 32-33(76-81), 17-24. http://doi.org/10.7213/reb.v32i76/81.22860.

Zhang, K., Xu, M., Wu, Q., Lin, Z., Jiang, F., Chen, H., & Zhou, Z., 2018. The response of zooplankton communities to the 2016 extreme hydrological cycle in floodplain lakes connected to the Yangtze River in China. Environ. Sci. Pollut. Res. Int. 25(23), 23286-23293. PMid:29869213. http://doi.org/10.1007/s11356-018-2144-6.

Received: 17 December 2022
Accepted: 28 March 2024

Associate Editor: Priscilla de Carvalho.