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# Diversity measures in macroinvertebrate and zooplankton communities related to the trophic status of subtropical reservoirs: Contradictory or complementary responses?

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ABSTRACT

Macroinvertebrate communities have been widely used as a tool for assessing the environmental quality of freshwater ecosystems, whereas zooplankton communities have been to some extent neglected. However, the importance of using different indicators to achieve a more comprehensive framework of assessment regarding water quality has been recognized. This study compared estimates of species richness (number of species) and the Shannon–Wiener index for data on macroinvertebrate and zooplankton communities in tropical reservoirs and related them to their trophic state. The trop+hic classification was obtained by applying the Carlson index (1977) modified by Toledo et al. (1983), and the index of the Brazilian Society of the Environmental Technology Agency. The comparative response of the different indicators was analyzed using a series of bivariate correlations (Draftsman's plot). The results illustrate that diversity measures, namely species richness, responded differently when related to the trophic classification of reservoirs, depending on the community considered. The species richness of zooplankton was positively related to hypereutrophic conditions, due to the higher number of rotifer species, including tolerant generalist species and at the same time, as a result of the exclusion of species from other groups, whereas for macroinvertebrates, species richness was negatively related to hypereutrophic conditions. *Melanoides tuberculatus*, which exhibits a high tolerance and competitive ability under such conditions, was the dominant species in macroinvertebrate communities, which excluded endemic species and reduced local richness and diversity. The same indicators applied to the zooplankton and macroinvertebrate communities might therefore provide contradictory responses regarding ecological quality assessment in tropical reservoirs, which suggest that zooplankton should be taken into account among the biological quality elements considered in the ecological quality assessment, management, and restoration of water bodies.



## 1. Introduction

Rivers and watershed natural ecosystems are subjected to strong human pressure (Duffy et al., 2007), and despite differences in anthropogenic stressors among regions, the most common changes in aquatic ecosystems result from intensive exploitation, nutrient enrichment, acidification and changes in the hydrology and morphology of the basin (Lücke and Johnson, 2009). A deterioration in the quality of water bodies is also observed in artificial aquatic ecosystems (Chellappa et al., 2009), such as reservoirs, which are frequently affected by eutrophication, which causes potentially negative changes to local biodiversity and ecosystem processes (Smith et al., 1999; Revenga et al., 2005).

The magnitude of anthropogenic changes on either natural or artificial aquatic ecosystems has encouraged ecologists globally to develop tools for the classification and bio-monitoring of ecological status (Moreno et al., 2009; Tixier et al., 2011). The ecological status is defined as the structural and functional quality of water bodies and is assessed in various aquatic ecosystems (e.g., lakes, rivers, transitional waters or artificial ecosystems) by assessing

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biological communities, combined with physical, chemical, morphological, and hydrological characteristics, (Heiskanen et al., 2004; Molozzi et al., 2012).

The assessment of the ecological status in aquatic ecosystems is often based on different biological quality elements: diatoms (Pan et al., 1996; Kelly et al., 2008; Bere and Tundisi, 2010), aquatic macrophytes (Dodkins et al., 2005; Stelzer et al., 2005), benthic macroinvertebrates (Klemm et al., 2002; Teixeira et al., 2009; Molozzi et al., 2013) and fish (Schiemer, 2000; Pont et al., 2006). Nevertheless, although the reasons are unclear, the zooplankton community is disregarded in approaches for assessing the ecological status and in the drawing up of guidelines worldwide (Caroni and Irvine, 2010).

Although the zooplankton community has to some extent been neglected, its structure is a good indicator of the trophic status of water bodies, since it is related to water chemistry and anthropogenic pressures on these ecosystems (An et al., 2012). Additionally, studies such that of Gulati and Van Donk (2002); Zhao et al. (2008); Peretyatko et al. (2009) have also demonstrated the bio-indicator potential of the community in monitoring recovery processes in various ecosystems. The value of zooplankton as bio-indicators is also associated with their position in the food chain, directly related to bottom-up and top-down control mechanisms (Jeppesen et al., 1997; Rejas et al., 2005; Scheffer and van Nes, 2007), as well as to the alternative pathway of the microbial loop (Christoffersen et al., 1990; Moustaka-Gouni et al., 2006).

Unlike zooplankton, macroinvertebrates have commonly been used to analyze the ecological status of water bodies since the 1990s (Hering et al., 2006). Organisms that comprise the community are considered to be water-quality bio-indicators, mainly because they are ubiquitous organisms represented by diverse taxonomic groups; many taxa are sedentary, with long life cycles and can record cumulative effects and habitat changes. These organisms are also sensitive to physical and chemical changes in different ecosystems and their responses to these changes are detectable and measurable (Barbour et al., 1996; Moreno and Callisto, 2006). Currently, the macroinvertebrate community has also been used to design predictive ecological tools, as has often occurred in European and U.S countries (Bonada et al., 2006; Feio and Poquet, 2011; Berthon et al., 2011; Smith et al., 1999; Demars et al., 2012). In Brazil, some studies have been performed on rivers (Baptista et al., 2007; Oliveira et al., 2011) and reservoirs (Molozzi et al., 2012, 2013).

Numerous biological attributes of these communities can be used as indicators of the ecological quality of water bodies, such as: (i) abundance – used as a tool in the context of trophic status, relating the number of individuals observed to the fluctuation in environmental variables (Watson and Carpenter, 1974; Guijun et al., 2012; Tasevska et al., 2012); (ii) richness – an important attribute whose variation is associated with several factors intrinsic to the dynamics of the system. Researchers admit that richness can be used to prioritize areas for conservation, although it is an attribute that is influenced by the geographic region and sampling effort (Graça et al., 2004; Fleishman et al., 2006); (iii) taxonomic diversity – considers the presence and absence of species as a system evaluation criterion, and is often related to the observed pattern of abiotic variables (Arcifa, 1984; Patalas, 1971); and (iv) biomass – used in the development of metrics for environmental assessment, particularly in terms of system maintenance power (Salas et al., 2005; Peretyatko et al., 2009; Silow and In-Hye, 2004; Molozzi et al., 2013).

The inclusion of the zooplankton community into the framework of ecological indicators for the assessment of environmental conditions of water bodies appears to be relevant, in view of the recognition of its bio-indicator potential in distinct ecological assessment contexts (Jeppesen et al., 2009) and the considerably lower costs compared to the costs of monitoring fish communities (Jeppesen et al., 2011). Additionally, the need to use different ecological indicators in an integrated way has been considered to be a significant factor to achieve a more complete result from ecological quality assessments at the ecosystem level or as a holistic approach (Jørgensen et al., 1995; Borja et al., 2008).

Thus, the main objective of this study was to compare estimates of species richness (number of species) and the Shannon–Wiener index for data on macroinvertebrate and zooplankton communities in tropical reservoirs, and to relate it to their trophic state. We tested the hypothesis that the same indicators applied to zooplankton and benthic macroinvertebrates provide different possibly complementary information with regard to assessing the ecological status of these ecosystems.

## 2. Material and methods

### 2.1. Study area

Two reservoirs, Poções and Camalaú, were selected for study, which are located in the Paraíba River basin, northeastern Brazil (6°51′31″; 8°26′2″S and 34°48′35″; 37°2′15″W). The Paraíba River will receive part the divert waters the San Francisco River, and the Poções and Camalaú reservoirs are receptor ecosystems of waters in the eastern axis of the transposition. The climate is BSh, semi-arid hot Köppen–Geiger (Köppen, 1936) with a mean rainfall of 400 mm/year and a minimum air temperature between 18 and 22 °C (July and August) and a maximum temperature between 28 and 31 °C (November and December) (AESA, 2010). The reservoirs are located in the upper reach of the Paraíba River. Data characterizing the two reservoirs are shown in Table 1.

### 2.2. Sampling sites, periods and water volume

In each reservoir, samples were taken at eight sampling sites, four in the littoral zone and four in the limnetic zone (Fig. 1). The intermittent condition of the tributary, characterized by non-continuous flow, makes the reservoirs more homogeneous

**Table 1**
Characterization of Poções and Camalaú reservoirs, Paraíba River basin, State of Paraíba, northeastern Brazil.
Source: Executive Agency of Water Management of the State of Paraíba (AESA, 2010).

| Characteristics | Poções reservoir | Camalaú reservoir |
|---|---|---|
| Geographic location | 7°53′38″S and 37°0′30″W | 7°53′33.94″s and 36°50′39.16″W |
| Year of construction | 1982 | [a] |
| Altitude (m) | 596 | 565 |
| Maximum accumulation capacity (m$^3$) | 29,861,562 | 48, 107, 240 |
| Water surface (m$^2$) | 19,005,95 | 19, 457, 18 |
| Hydraulic retention time | 3–5 years | 3–5 years |
| Presence of macrophytes | – | *Egeria densa* and *Chara* sp. |

[a] Non-reported data.