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Aquatic macroinvertebrates survey and assessment of two artificial reservoirs into conservation units from the Southeast Region of Brazil

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Abstract. This study aims to inventory and assess the aquatic macroinvertebrates fauna in two artificial reservoirs into conservation units with differences regarding conservation level and to anthropogenic impacts. The samplings were carried out in Caetetus Ecological Station and Bauru City Zoological Park, where some physical and chemical variables also were measured. The results obtained indicated that the Caetetus Ecological Station is more effective in the conservation of the diversity of aquatic macroinvertebrates compared to Bauru City Zoological Park. These results can be attributed to the strong anthropogenic impact suffered by the reservoir in Bauru and demonstrate the importance of these areas in maintaining the diversity of aquatic macroinvertebrates community.

Keywords: Conservation Units, Chironomidae, diversity, reservoir, ecology

Resumo. Levantamento e avaliação dos macroinvertebrados aquáticos em dois reservatórios artificiais em unidades de conservação da região sudeste do Brasil. Este estudo objetivou inventariar e avaliar a fauna de macroinvertebrados aquáticos em dois reservatórios artificiais localizados em unidades de conservação com diferentes níveis de conservação e impactos antrópicos. As amostragens foram realizadas na Estação Ecológica de Caetetus e no Zoológico Municipal de Bauru, onde algumas variáveis físicas e químicas também foram aferidas. Os resultados obtidos indicam que a Estação Ecológica de Caetetus é mais efetiva na conservação da diversidade de macroinvertebrados aquáticos comparada ao Zoológico Municipal de Bauru. Estes resultados podem ser atribuídos ao forte impacto antropogênico sofrido pelo reservatório em Bauru e demonstra a importância destas áreas na manutenção da diversidade da comunidade de macroinvertebrados aquáticos.

Palavras chave: Unidades de Conservação, Chironomidae, diversidade, reservatório, ecologia

Introduction

The creation of protected areas is one of the most important methods for the preservation of biodiversity. It does not necessarily mean that the creation of these areas will guarantee the proper conservation of all biodiversity. It is necessary to evaluate the site, the protection capacity and the ecological status of this environment and if the management is effective (Paz *et al*. 2008).

The establishment of protected areas through the creation of conservation units is a method that is accepted worldwide as one of the most important actions of governments for the protection of biodiversity (Rylands & Brandon 2005).

Conservation units are environmental spaces with defined limits and are under special administrative regimes. These locations have important natural characteristics and are legally established by government agencies with conservation objectives.

Most protected areas are created to protect species of terrestrial fauna and flora, but occasionally they protect a considerable number of aquatic ecosystems, making them of great importance for aquatic species (Agostinho *et al*. 2005, Nel *et al.* 2007). Within these species, aquatic macroinvertebrates have been widely used as biological indicators of water quality and anthropogenic impacts.

The construction of a dam seems to have a great impact upon whole aquatic life (Ward & Stanford 1980, Armitage 1987, Penczak *et al*. 1998, 2006). The most obvious effects from placing dams on rivers result from formation of new lentic or semi-lentic environments upstream from the dam, and tailwater environments downstream from the dam (Jackson & Marmulla 2001).

Impoundment studies can be conducted using aquatic communities, since as biological indicators they have the advantage of monitoring water quality over a period of time, providing a measure of anthropogenic effects on aquatic ecosystems, whereas physical and chemical data provide only instantaneous evidence (Camargo *et al*. 2004, Callisto *et al.* 2001). Freshwater macroinvertebrates have frequently been used in water quality studies as bioindicators. These animals, when used in such investigations, offer several benefits including easy identification at high taxonomic levels by non-specialists, high sensitivity of a great number of species to environmental stress, a wide distribution in various freshwater habitats and a relatively sedentary behavior and short life cycle, in comparison to fish, which facilitate the detection of changes over time (Johnson *et al.* 1993).

Considering the applicability of the macroinvertebrates as a tool in bioassessments, this study aims to inventory and assess the aquatic macroinvertebrates fauna in two artificial reservoirs into conservation units with differences regarding conservation level and to anthropogenic impacts.

Study Area

The sediment samplings were carried out in two small reservoirs, both located in the southeast region Brazil (Figure 1). These places present differences regarding conservation level and to anthropogenic actions.

The first environment, located within the Caetetus Ecological Station, is the result of the damming of the Barreiro stream. The reservoir has a maximum depth 0.80 m, and it is shaded by dense riparian vegetation (semideciduous forest). The Caetetus Ecological Station is located in the cities Gália and Alvinlândia (22º20’ and 22º30”S, 49º40’ and 49º45”W) and has an area of 2,176.1 ha. The station was created by State Decree 26,718 of 6 February 1987 (São Paulo 1987) and is the object of an institutional program aimed at establishing new management categories for the conservation of nature through the protection of important territories that are owned by the state government and harbor complex and fragile ecosystems.

The second location studied is in the Bauru City Zoological Park and is the result of damming. The reservoir, which has a maximum depth of 2.50 m, receives organic matter from the cleaning of animal cages nearby. There is no riparian vegetation. The Bauru City Zoological Park (22°20' and 31°48’S, 49°1' and 4.53"W) is located within Vargem Limpa – Campo Novo Municipal Environmental Protection Area. The park has an area of 121.0 ha and was created by Law n° 4,126 (Bauru 1997), which established the Master Plan of the city of Bauru, with the objective to protect and preserve environmental quality and biodiversity of native vegetation of Bauru in order to improve the quality of life of the population.

Material and Methods

The samplings were carried out in two periods in order to obtain data that characterize the faunas of the stations: rainy (March/April – 2001) and dry (July/August – 2001). A total of 84 samples (3 replicates in each site) were collected using an Ekman-Birge grab (0,0225m^2 area), during seven days in the rainy and dry seasons (2 seasons X 2 environments X 3 replicates X 7 days = 84 samples). The samples were immediately fixed in a 10% formalin solution and transported to the laboratory, where they were washed using 0.250 mm sieves, sorted and preserved in 70% ethanol. The organisms were subsequently identified, under stereomicroscope, using appropriate literature (Brinkhurst & Marchese 1989, Merrit & Cummins 1996, Fernandez & Dominguez 2001), and counted. Special emphasis was put on chironomid assemblages (Diptera) because as numerical dominants in the studied reservoirs, they seem to play a key role in energy transformation and elements cycling (Trivinho-Strixino 2011).

The temperature, pH and electrical conductivity values were determined *in situ* by mercury thermometer, a Corning – pH 30 meter and a Corning – CD-55 meter, respectively. The oxygen concentration was determined in laboratory by the Winkler method (Golterman *et al.* 1978). The canopy percentage was determined in the field visually.

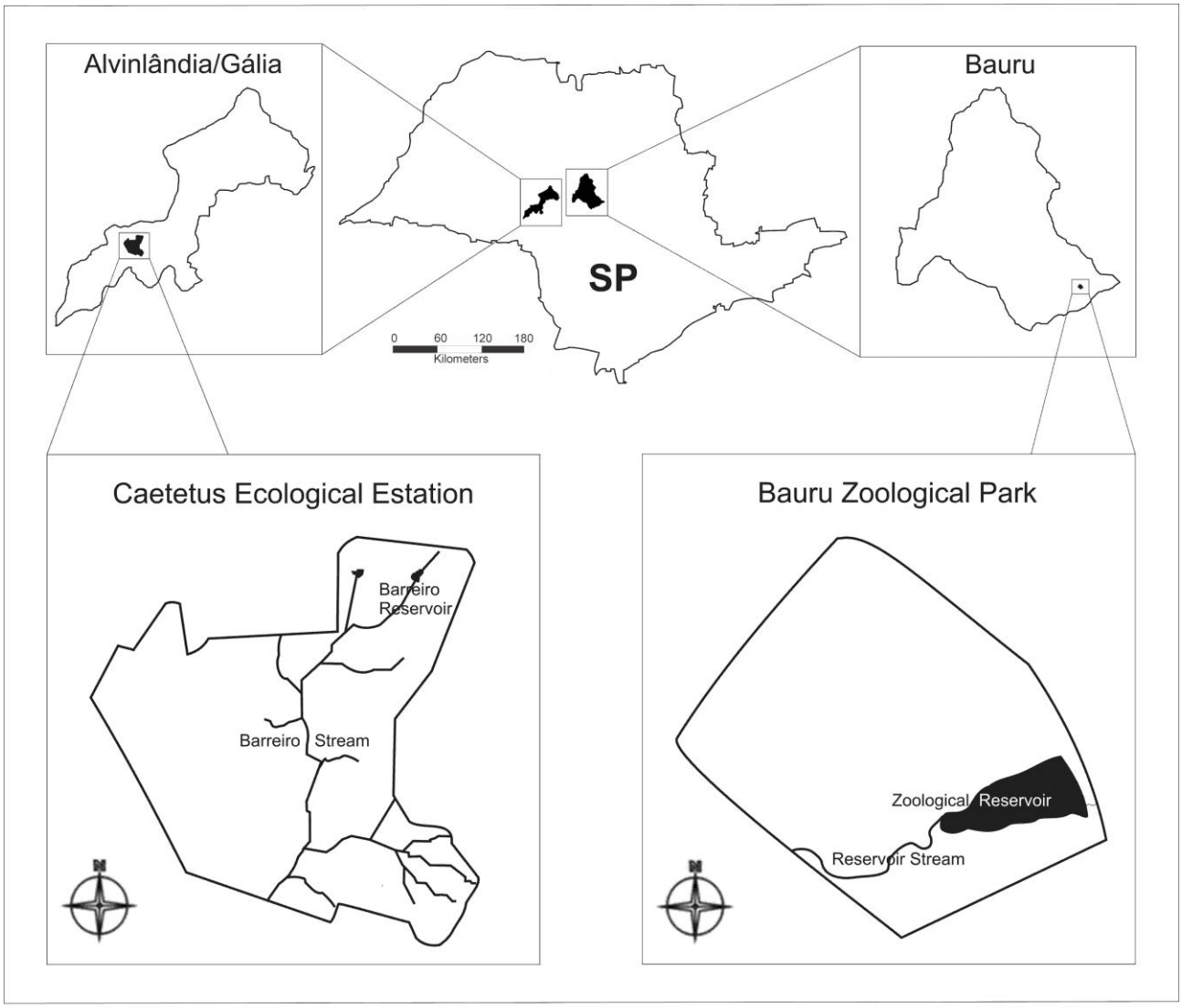

Figure 1 - Location of study area: Barreiro reservoir, Caetetus Ecological Station, Alvilândia/Gália, SP and Zoological reservoir, Bauru City Zoological Park, SP.

After identification, the specimens of each system were counted and the ecosystem diversity was evaluated through species richness, Shannon-Wiener diversity index, Pielou evenness index (equitability) and Simpson dominance index, according to Pinto-Coelho (2002). The percentages of EPT (Ephemeroptera, Plecoptera and Trichoptera), of Chironomidae and the ratio of EPT by Chironomidae were calculated according to Trivinho-Strixino *et al.* (2008). The UPGMA analysis (cluster analysis) was performed to verify the similarity between the reservoirs of Bauru City Zoological Park and Caetetus Ecological Station, using the BioDiversity Pro 2.0 software (McAleece *et al.* 1997).

Results and Discussion

In this study, 3,226 specimens belonging to 37 macroinvertebrate taxa and 14 families were collected (Table I and II). The results indicate a predominance of organisms within the Chironomidae and Tubificidae families in all of the

samples. The high densities of these organisms may indicate an input of organic matter in the system, given that these families are known for their high tolerance to organic enrichment, as compared to other organisms (Fusari & Fonseca-Gessner 2006, Silva *et al*. 2009).

In the Caetetus Ecological Station, the predominance of the Chironomidae and Tubificidae families associated with organic enrichment can be attributed to the constant input of allochthonous material vegetation (leaves, branches and trunks) from dense riparian vegetation (90% of cover) that surrounds the system (Table III). The presence of these taxa in the Bauru City Zoological Park can be attributed to the fact that this environment receives elevated amounts of organic matter from the cleaning of the animal cages.

The largest numerical density in both systems was recorded in the dry season. The higher density is possibly related to the greater stability found in the substrate during this period. During the rainy season, these environments are more susceptible to physical changes, such as higher discharge and energy, imposed by pluvial influences because of their small size. Fusari (2006) also observed this tendency in her study of the macroinvertebrates communities in the Monjolinho and Fazzari reservoirs (São Carlos, SP). In those locations, the total density of sampled organisms was also higher in the driest months than in the rainy months. The lower density during the rainy season can be attributed to disruption of stability in the macroinvertebrates community habitats due to environmental changes (Callisto *et al*. 2001), as well as the modification of the substrate and high input of allochthonous organic matter.

The Shannon-Wiener diversity index values indicated little variation between sampling points (Table II), displaying an increase only in the Caetetus Ecological Station. This result can be explained by the relation between the richness and the relative abundance of macroinvertebrates in this site. In the Bauru City Zoological Park, however, the predominance of Tubificidae and *Chironomus* (Chironomidae) resulted in less diversity and richness. Pielou evenness values produced a similar pattern, with the highest values in the Caetetus Ecological Station and the smallest in Bauru City Zoological Park (Table II). The high value in the Caetetus Ecological Station can be attributed to the homogenous distribution of individuals among the taxa collected. Simpson's dominance (D) index was highest in the Caetetus Ecological Station, during dry season (D = 0.324), and lowest during the rainy season (0.092). The large number of individuals belonging to Tubificidae and the better distribution of individuals within the taxa can explain, respectively, the results obtained in the Caetetus Ecological Station.

In environmental assessment, an elevated amount of individuals belonging to Chironomidae family might indicate organic enrichment and poor water quality (Silva *et al*. 2009). In this study, however, the high Chironomidae percentage in the Caetetus Ecological Station does not imply poor water quality given that there was not a predominance of genera tolerant to organic pollution, as *Chironomus*, *Polypedilum* and *Tanypus* (Strixino & Trivinho-Strixino 1982, Lindegaard 1995, Fusari & Fonseca-Gessner 2006), which were dominant in Bauru City Zoological Park. These results reveal the need of reviewing the use of Chironomidae on a family level in organic pollution assessments. In regards to the percentage and ration of EPT in both seasons, the reservoir of Caetetus Ecological Station presented elevated numbers in comparison to the Bauru City Zoological Park. These results suggest the higher organic enrichment in the latter reservoir.

Most aquatic ecosystems exhibit pH values varying from 6 to 8 (Esteves 1998). The pH measured in both systems and stations were around 6.00 (Table III), characterizing the water system as neutral. The pH value is influenced, in part, by concentrations of carbon dioxide and organic acids dissolved in the water.

During this study, the electrical conductivity values were much lower in both systems and stations (Table III). Electrical conductivity is more strongly influenced by physical (climate, hydrology) and chemical than biological factors (Pedrosa & Rezende 1999). However, high concentrations of decomposing organic matter increase the quantity of ions dissociated in the water, which results in an elevated electrical conductivity. Both reservoirs have intense currents, which enhance the transport of materials from this site to others, consequently resulting in a smaller local conductivity.

The dissolved oxygen concentration depends on two main factors: equilibrium between the inputs from the atmosphere and photosynthesis and the losses due to chemical and biological oxidation (Wetzel 1993). The reservoir of the Bauru City Zoological Park presented elevated values of dissolved oxygen, which might be attributed to high photosynthetic rates, common in systems without

Table I. Taxa recorded in the reservoirs of the Caetetus Ecological Station and the Bauru City Zoological Park during the rainy and dry seasons.

Taxa	Caetetus Ecological Station		Bauru City Zoological Park	
	Rainy	Dry	Rainy	Dry
Rhynchobdellida				
Glossiphoniidae	–	72	–	–
Tubificida				
Naididae	–	–	174	205
Tubificidae	25	378	367	556
Coleoptera				
Gyrinidae	–	1	–	–
Diptera				
Ceratopogonidae	–	7	–	–
Chaoboridae	–	–	156	9
Chironomidae				
Ablabesmyia	13	8	–	–
Aedokritus	–	4	8	20
Alotanypus	3	–	–	–
Beardius	1			
Caladomyia	25	14	–	244
Chironomus	34	39	6	132
Cladopelma	–	–	14	27
Clinotanypus	1	–	–	–
Denopelopia	–	18	–	–
Dicrotendipes	1		1	
Fittkauimyia	1	1	–	–
Goeldichironomus	10	21	–	49
Harnischia complex	–	–	1	68
Macropelopia	10	1	–	–
Labrundinia	1	–	–	–
Larsia	–	23	–	–
Parachironomus	4	–	–	–
Phaenopsectra	1	1	–	
Polypedilum	7	13	2	155
Procladius	5	3	–	–
Stenochironomus	1	5	–	1
Tanypus	–	–	103	13
Tanytarsus	–	–	–	9
Zavreliella	–	5	–	–
Tabanidae	4	–	–	–
Ephemeroptera				
Polymitarcyidae	9	56	–	1
Odonata				
Aeshnidae	2	–	–	–
Corduliidae	10	24	–	–
Gomphidae	–	–	1	–
Trichoptera				
Polycentropodidae	13	19	1	–
Veneroida				
Sphaeriidae	9	–	–	–

riparian vegetation and high solar exposure (Chalar 2009), whereas in the reservoir of Caetetus Ecological Station, the large input of allochthonous leaf material associated with elevated temperature during rainy period, might have contributed to increase of decomposition rates and consequently to

the oxygen depletion (Table III). An increased quantity of organic matter in a water system intensifies biological processes, producing an accelerated consumption of oxygen (Fusari & Fonseca-Gessner 2006).

Table II. Values of biotic metrics calculated in the reservoirs of Caetetus Ecological Station and Bauru City Zoological Park during the rainy and dry seasons.

Metrics	Caetetus Ecological Station		Bauru City Zoological Park	
	Rainy	Dry	Rainy	Dry
N° of Individuals	190	713	834	1489
Richness	23	21	12	14
Dominance	0.09	0.32	0.29	0.21
Shannon	2.65	1.77	1.46	1.88
Pielou	0.85	0.59	0.59	0.71
% Chironomidae	62.1	21.9	16.2	48.2
% EPT	11.6	10.5	0.12	0.07
EPT/Chironomidae	0.19	0.48	0.01	0.00

Cluster analysis, based on the abundance of genera collected, revealed the formation of two groups (Figure 2): (1) represented by samples collected in the Caetetus Ecological Station, showed a similarity of 60.0%; (2) formed by samples collected in the Bauru City Zoological Park, presented a similarity of 61.5%. From the cluster analysis, it was possible to infer that, in this study, the seasonal alterations were not determinants of the distribution of the macroinvertebrate communities.

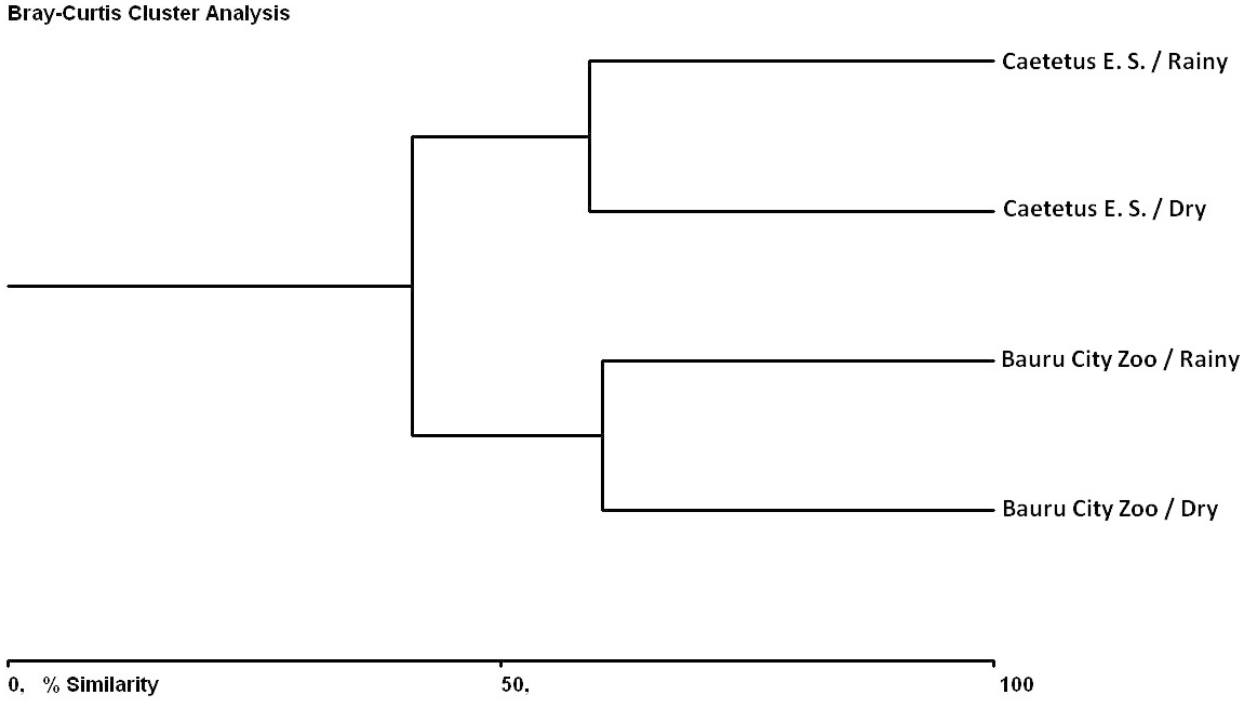

Figure 2. Classification of samples obtained in the reservoirs of Caetetus Ecological Station (Caetetus E. S.) and Bauru City Zoological Park (Bauru City Zoo) during the rainy and dry seasons using UPGMA linkage and Bray–Curtis distance.

The analysis of the results shows that both reservoirs presented similar physical and chemical characteristics. However the faunistic results demonstrate differences that indicate better environmental conditions at reservoir of the Caetetus Ecological Station, which suggest a more effective

conservation of aquatic macroinvertebrate diversity as compared to reservoir located in the Bauru City Zoological Park. This result possibly can be attributed to fact that the former location has more restricted access than the latter, which suffers from the elevated input of organic matter caused by the cleaning of the animal cages. The data obtained in this study demonstrate the significance of these areas in maintaining the diversity of aquatic macroinvertebrate communities and reaffirm the importance of using these fauna as bioindicators in environmental diagnoses.

Table III. Values of water abiotic metrics and canopy percentage in the Caetetus Ecological Station and Bauru City Zoological Park during the rainy and dry seasons.

Metrics	Caetetus Ecological Station		Bauru City Zoological Park	
	Rainy	Dry	Rainy	Dry
Temperature (°C)	21.90	17.0	26.7	18.4
Electrical Conductivity ($\mu S.cm^{-1}$)	22.00	19.0	29.7	30.1
Dissolved Oxygen ($mg.L^{-1}$)	2.70	6.80	7.10	8.50
pH	6.15	6.31	6.70	6.70
Canopy Percentage (%)	90		0	

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