Environmental assessment of two small reservoirs in southeastern Brazil, using macroinvertebrate community metrics.

FUSARI[1], L.M. & FONSECA-GESSNER[1], A.A.

[1] Laboratório de Entomologia Aquática, Depto. de Hidrobiologia, Universidade Federal de São Carlos, C.P.676, 13.565-905, São Carlos, SP.
e-mail:[1]liviafusari@yahoo.com.br; [2]gessner@power.ufscar.br

ABSTRACT: Environmental assessment of two small reservoirs in southeastern Brazil, using macroinvertebrate community metrics. In the work reported here, the aim was to investigate the applicability of benthic macroinvertebrate community metrics in the assessment of the environmental condition of two small reservoirs in southeast Brazil with differing inputs of nutrients and states of conservation. Eleven metrics were applied, organized in five categories: richness, enumeration, diversity, similarity and functional feeding groups. Most metrics responded as predicted in the literature, in accordance with the amount of human interference and state of conservation of the two reservoirs, except the Shannon Diversity, Pielou Uniformity and McNaughton Dominance indices, which should be avoided, at least for discriminating the environmental condition of these two tropical reservoirs.
Key-words: diversity, richness, Chironomidae, Oligochaeta, lentic systems.

RESUMO: Avaliação ambiental de duas represas no Sudeste do Brasil, por meio de métricas da comunidade de macroinvertebrados bentônicos. O objetivo deste estudo foi analisar a aplicabilidade de métricas da comunidade de macroinvertebrados bentônicos avaliando as condições ambientais de duas represas com diferentes aportes de nutrientes, graus de trofia e conservação. Onze métricas ordenadas em cinco categorias foram aplicadas: riqueza, enumeração, diversidade, similaridade e grupos funcionais de alimentação. A maioria das métricas respondeu conforme predito por informações da literatura considerando a influência humana e estado de conservação das represas, exceto os índices de diversidade de Shannon, de uniformidade de Pielou e de dominância de McNaughton que não foram adequados para discriminar as condições ambientais das represas em estudo.
Palavras-chave: diversidade de espécies, riqueza, Chironomidae, Oligochaeta, sistemas lênticos.

Introduction

Bioassessment is widely used in the monitoring and management of environmental quality and integrity of aquatic ecosystems, complementing traditional physical and chemical methods (Karr, 1999; Linke et al., 2005).

Methods that have been adopted in both water quality assessment and ecological monitoring make use of multimetric systems, which involve several measures of environmental conditions aimed at evaluating and comparing them in various impact scenarios. The advantage of these multimetric systems lies in their capacity to integrate measurements from variables of different types, to produce a general classification of environmental conditions without losing data furnished by each of the metrics involved. For this purpose, a variety of biotic metrics are used, organized in 5 categories: richness, enumeration, similarity, diversity and functional feeding group (Resh & Jackson, 1993; Barbour et al., 1996).

Benthic macroinvertebrates are widely employed in impact assessment and are recommended for environmental monitoring (Fonseca–Gessner & Guereschi, 2000), as they possess several features that make them outstanding biological indicators (Hellawell, 1986; Rosenberg & Resh, 1993). Multimetric assessments are often applied to the study of lotic systems (Thorne & Williams, 1997; Karr, 1999; Linke et al., 2005; Nijboer et al., 2005; Silveira et al., 2005, among others).

The aim in the present case was to analyze the viability of applying a variety of metrics to the study of lentic systems, as well as to evaluate whether the results thus obtained reflect the conditions in those systems. To this end, the benthic macroinvertebrate communities were compared in two reservoirs of modest dimensions, in the tropical region of upstate São Paulo, which differ markedly in nutrient input, degree of trophy and state of conservation.

Materials and methods

Study area

The research was conducted in two small reservoirs, both located in the campus of the Federal University of São Carlos (UFSCar), São Carlos city, SP, Brazil: Monjolinho Reservoir and Fazzari Reservoir were chosen for their very different nutrient inputs. The former has eutrophic features, as reported in the work of Regali-Seleghim (2001) and Cunha-Santino et al. (2002), and algal blooms have been seen there in certain periods of the year, whereas Fazzari is noted for its oligotrophic character (Irene Lucinda, work in progress).

The Monjolinho Reservoir (21°59´S and 47°52´W), situated in a built-up area of the University (Fig.1), was formed by damming the Monjolinho stream. Its surface area is 4.69 ha, water volume 73,251 cubic meters and average and maximum depths 1.5m and 3.0m, respectively (Regali-Seleghim, 2001; Correia, 2004). The patterns of flow and water quality of this reservoir arise from its geomorphology and the use of the land upstream of the reservoir (rural and urban districts on the outskirts of São Carlos, in addition to some industrial plants, particularly a chicken abattoir); it is also worth mentioning that the head of the reservoir, where the stream enters, is inhabited by a population of capybaras.

The Fazzari Reservoir (21°59´S and 47°52´W), situated in a built-up area of the University (Fig. 1), was formed by damming a stream of the same name, whose spring is located approximately 500m upstream, whence it runs through and is protected by gallery forest. The reservoir is 1.30 ha in area and 1.5m deep and its banks are protected by typical Cerrado (neotropical savannah) vegetation (Albuquerque, 1990; Paese, 1994).

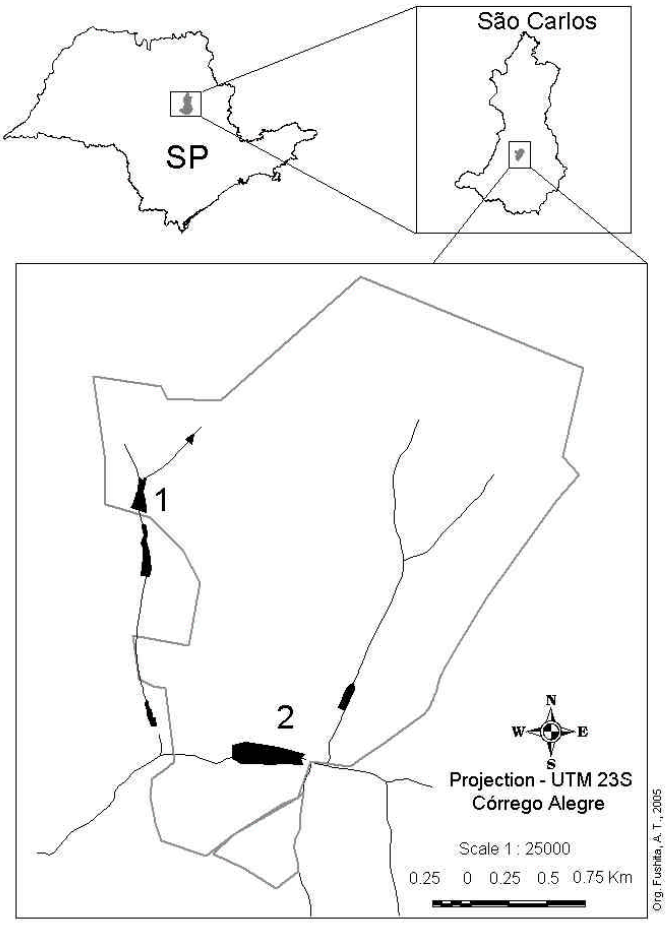

Figure 1: Location of study area: 1. Fazzari Reservoir; 2. Monjolinho Reservoir. Both reservoirs are within the campus of UFSCar (São Carlos, SP, Brazil), indicated by grey line.

Collection

Samples were collected on two occasions: June and December, 2004. In each reservoir, 12 sampling sites were chosen at random and 3 samples were taken from each site, giving a total of 72 samples. Abiotic variables (pH, electric conductivity, dissolved oxygen concentration and temperature in the water) were measured at the same time, in situ, with a Horiba U-10 multi-probe. The proportion of organic matter in the sediment was calculated from the change in weight after the samples were incinerated in a muffle furnace at 550°C for 4h, as described by Trindade (1980).

The samples, collected with an Ekman-Birge grab (225 cm²), were packed in screw-top plastic jars and taken to the laboratory, where the sediment was washed gently in a jet of water on a 200mm-mesh sieve. The invertebrates were separated from the material retained on the sieve, fixed and preserved in 70% ethanol.

Specimens were assigned to families with the aid of identification keys (McCafferty, 1981; Merritt & Cummins, 1986). Chironomid larvae (Diptera) were identified to genus level (Wiederholm, 1983; Trivinho-Strixino & Strixino, 1995) or separated into morphotypes. Oligochaeta were identified to species (Brinkhurst & Marchese, 1989). Functional feeding groups were established in conformity with the Merritt & Cummins classification (1986).

Data Analysis

To assess environmental quality, the benthic macroinvertebrate communities in the reservoirs were analyzed in terms of 11 metrics, organized in 5 categories: richness, enumeration, diversity, similarity and functional feeding group. The expected qualitative responses were predicted, for the known relative degrees of trophy and states of conservation of the two reservoirs, on the basis of data from the literature (Tab. 1).

Table I: Predicted responses of the biotic metrics for the two reservoirs, based on their known degrees of trophy.

Metric	Predicted response		References
	Monjolinho	Fazzari	
Taxon richness	¯	-	Barbour et. al. (1992); Resh & Jackson (1993)
Enumeration			
% Bloodworms/Total macroinvertebrates	-	¯	Strixino & Trivinho-Strixino (1982, 1998); De Léo (1999)
% Bloodworms/Total chironomids	-	¯	Strixino & Trivinho-Strixino (1982, 1998); De Léo (1999)
Oligochaetes.m^2	-	¯	Wright & Tidd (1933); Wiederholm (1980)
O/(O+C)	-	¯	Wiederholm (1980)
Diversity			
H´	¯	-	Odum (1988); Margalef (1983)
J	¯	-	Odum (1988); Margalef (1983)
D_2	-	¯	Odum (1988);Cairns & Pratt (1993); Margalef (1983)
Similarity			
Jaccard	Low		Plaflin et. al. (1989); Resh & Jackson (1993)
Bray-Curtis	Low		Magurran (2004)
Functional feeding groups			
% Collectors	-	¯	Resh & Jackson (1993)

Key: ¯ = lower value; - = higher value

Richness: The measure of richness was the total number of taxa present (Resh & Jackson, 1993).

Enumeration: Four metrics in this category were applied:

1) The number of chironomid bloodworms as a percentage of the total number of macroinvertebrates collected (% red Chironomidae / total organisms).

2) The percentage of chironomid bloodworms among all chironomid larvae (% red Chironomidae/Chironomidae). In this analysis, chironomid bloodworms included the following taxa: Chironomus spp, Polypedilum (Polypedilum) sp, Polypedilum (Tripodura) sp (Lindegaard, 1995), Cladopelma spp, Harnischia spp, and finally Tanypus stellatus, which is considered a

tolerant species, indicative of eutrophicated water (Strixino & Trivinho-Strixino, 1998).

3) The total density of Oligochaeta per m², used to indicate the amount of organic enrichment by a method adapted from that proposed by Wright & Tidd (1933, apud Myslinski & Ginsburg, 1977), which considers the environment to be in natural equilibrium when there are fewer than 1,000 oligochaetes per m², moderately enriched with organic matter between 1,000 and 5,000 and strongly enriched when there are more than 5,000 oligochaetes per m².

4) The degree of trophy of the reservoirs was estimated from the trophic index O/(O+C) (Wiederholm, 1980), where O is the number of oligochaetes and C the number of sedentary chironomids (those that live in tubes or on the surface of the sediment). The higher this ratio becomes (approaches its maximum value 1), the higher is the degree of organic pollution. In this analysis, all Tubifidae (Oligochaeta) and the larvae of Chironominae and Orthocladiinae (Chironomidae) were counted.

Diversity: This category included the Shannon Diversity Index (H'), Pielou's Uniformity Index (J) (Odum, 1988) and McNaughton´s Dominance Index (D_2) determined as described by Kaniewska-Prus & Kidawa (1983), which takes account of the numerical proportion of the two most abundant taxa, relative to the total number of animals in the sample. According to Margalef (1983), eutrophic water-bodies exhibit lower diversity and higher population densities, with a few species dominating.

Similarity: Two indices were applied in this category: Jaccard´s Similarity (qualitative) and Bray-Curtis Similarity (quantitative) (Magurran, 2004).

Functional Feeding Groups: Benthic macroinvertebrates can be divided into 5 functional groups with respect to their feeding methods (shredders, scrapers, collector-gatherers, filter-collectors and predators), according to the type of food they eat and how they acquire it (Merritt & Cummins, 1986). In this analysis, the filter-collectors and gatherers were combined as collectors.

Results and discussion

Environmental variables:

The mean pH values indicate a nearly neutral condition in the Monjolinho Reservoir, while the water in the Fazzari Reservoir was rather acidic (Tab. II).

Table II: Values of abiotic variables in the water and percent organic matter in the sediment, in the two reservoirs.

Variables		Monjolinho Reservoir		Fazzari Reservoir	
		Mean	SD	Mean	SD
pH	-	7.16	0.191	5.47	0.366
Electrical conductivity	(mS.cm^{-1})	35	0.004	6	0.002
Dissolved oxygen	(mg.L^{-1})	8.42	1.525	6.45	0.944
Temperature	(°C)	21.75	3.845	20.40	3.592
Organic matter	(%)	15.8	5.639	35.2	12.818

SD : Standard deviation

According to Calijuri et al. (1999), photosynthetic activity results in a raised pH, as the concentration of free carbon dioxide diminishes. Hence, the algal blooms that occur at certain times in the year may contribute to the higher pH value in Monjolinho Reservoir.

Electrical conductivity is a measure of the number of ions free to conduct electricity in the aqueous medium (Wetzel & Likens, 1991) and thus indicates the total amount of ionized matter (Maier, 1978). In addition, it provides information on the metabolism of the aquatic ecosystem and on phenomena occurring in the catchment area that contributes water to the sample (Esteves, 1988). In these continental water-bodies, the principal ions are usually those containing nitrogen and phosphorus. The mean value of electrical conductivity (35mS.cm^{-1}) recorded in the Monjolinho Reservoir, may thus reflect a higher concentration of nutrients in the water than in the Fazzari Reservoir, where the mean reading was 6mS.cm^{-1}. This low figure reveals an environment rather poor in ions, indicating that the Fazzari system had suffered little human interference.

The concentration of dissolved oxygen (DO) in water depends on the equilibrium between the inputs, from the atmosphere and photosynthesis, and the losses due to chemical and biological oxidation (Wetzel, 1993). In the Monjolinho Reservoir, the mean value of DO at the surface was 8.42 $mg.L^{-1}$, which is considered high, while in the Fazzari a lower mean value, 6.45 $mg.L^{-1}$, was recorded. A factor that may help to explain this low DO is the large quantity of allochthonous leaf material that enters the reservoir, carried from the gallery forest by the stream. An increased quantity of organic matter in a water system intensifies biological processes, producing an accelerated consumption of oxygen.

In both reservoirs, the water temperature reflected the air temperature, the mean recorded values being 21.75°C in the Monjolinho and 20.40°C in the Fazzari (Tab. II).

The organic matter content of Monjolinho Reservoir attained a mean value of 15.8%, while in the Fazzari a much higher value of 35.2% was found (Tab. II), reflecting the greater rate of input of allochthonous particulate organic matter, which had accumulated in the sediment. Similar observations were made by Pamplin (2004) in two reservoirs with differing degrees of trophy. In the eutrophic Bariri Reservoir, 11.8% and 15.3% of organic matter were found in the sediment, while in the oligotrophic Ponte Nova Reservoir, higher contents were recorded, viz. 22.7% and 28.9%.

Benthic Macroinvertebrate Community and Biotic Metrics:

In the Monjolinho Reservoir, 939 organisms were collected, among which the most abundant taxa were Limnodrilus hoffmeisteri (Tubificidae) (31.2%), Polypedilum (Polypedilum) sp (Chironominae) (20.9%) and Tanypus stellatus (Tanypodinae) (15.2%). Out of 1804 organisms sampled from the Fazzari Reservoir, the highest numbers recorded were in the taxa Chaoboridae (Diptera) (47.1%) and Campsurus sp (Ephemeroptera) (22.3%) (Tab. III).

Analysis of the results demonstrated a greater taxon richness in the Fazzari

Table III: Relative abundance (%), taxon richness and number of macroinvertebrates collected in the Monjolinho and Fazzari Reservoirs.

		Monjolinho Reservoir	Fazzari Reservoir
	Helobdella sp	0.2	0.1
	Branchiura sowerbyi	0.9	
	Limnodrilus hoffmeisteri	31.2	
Annelida	Dero (D.) evelinae		0.2
	Pristina breviseta		0.1
	Pristina synclites	0.6	
	Pristinella jenkinae	0.2	
Hydracarina		0.3	
	Caenidae		0.4
	Leptophlebiidae		0.1
	Campsurus sp		22.3
	Libellulidae		0.1
Insecta	Hydropsychidae		0.1
	Elmidae		0.1
	Ceratopogonidae	0.1	1.3
	Chaoboridae	0.7	47.1
	Chironomidae		

Table III: Cont.

Insecta	Aedokritus sp		0.8
	Beardius sp2		0.1
	Caladomyia ortoni	0.4	1.0
	Chironomus sp	8.5	0.7
	Cladopelma forcipis		2.5
	Cladopelma sp1	11.2	
	Cladopelma sp2		0.3
	Cryptochironomus sp		0.2
	Endotribelos sp2		0.9
	Harnischia (complexo) sp	0.5	1.5
	Fissimentum desiccatum		3.7
	Fissimentum sp1		0.8
	Gênero X sp		2.2
	Paratendipes sp		0.1
	Polypedilum (Polypedilum) sp	20.9	5.0
	Polypedilum (Tripodura) sp	6.6	0.4
	Tanytarsus sp1		0.1
	Tanytarsus sp2	0.3	
	Corynoneura sp2		0.1
	Ablabesmyia sp		0.1
	Ablabesmyia gr.annulata sp		7.3
	Ablabesmyia (Karelia) sp		0.5
	Alotanypus sp	0.1	
	Clinotanypus sp	0.1	
	Labrundinia sp	0.3	
	Larsia sp		0.1
	Pentaneura sp		0.1
	Procladius sp	1.5	
	Tanypus stellatus	15.2	0.1
	Total organisms	939	1804
	Richness	20	34

Reservoir, with 34 taxa, than in the Monjolinho, where 20 taxa were seen (Tab. III). Taxonomic richness is known to decline in polluted or stressed environments (Barton & Metcalfe-Smith, 1992; Resh & Jackson, 1993), so that this result accords with expectation, since the Fazzari Reservoir is in an environmentally protected area, as is the stream that feeds it.

The two reservoirs differed appreciably in their percentage of bloodworms, relative either to total macroinvertebrates or to total chironomids. These relative abundances were higher in Monjolinho Reservoir (Tab. IV), reflecting the organic enrichment in this system. The input of organic substances into such a system can reduce the level of DO, hindering the respiration of the animals present, so that more sensitive species may not survive (Wiederholm, 1984). Chironomid bloodworms, known to tolerate situations of extreme hypoxia (Wiley & Kohler, 1984), predominated in Monjolinho Reservoir, even though such conditions were not found there.

The numerical density of Oligochaeta affords information on the degree of trophy of the medium (Wiederholm, 1980) and, in this study, the metric Oligochaeta.m^{-2} responded appropriately to the trophic state of the two water-bodies, since in the Monjolinho Reservoir the density of this group was 4,577 per m^2, whilst in the Fazzari it was only 74 per m^2 (Tab. IV).

The trophic index in the Monjolinho Reservoir was 0.4, while in the Fazzari it could not be calculated, since no tubificid worms were found. In the Monjolinho, Limnodrilus hoffmeisteri (Tubificidae) was seen in large numbers (Tab. III); this species is known to tolerate organic pollution (Hawkes, 1979) and is associated with eutrophic water (Lauritzen et al., 1985; Lang, 1990), again indicating the poor environmental condition of this reservoir. A study of benthic fauna carried out by Corbi (2001) in an oligotrophic reservoir indicated that Oligochaeta represented fewer than 20% of all benthic macroinvertebrates, whereas in the reservoir at Americana (SP, Brazil), which shows hypereutrophic characteristics, 73% of the invertebrates collected by Pamplin (1999) were oligochaetes.

Table IV: Biotic metrics data for the two reservoirs and matches with predicted responses.

Metric	**Results**		**Response agrees with prediction**
	Monjolinho	**Fazzari**	
Taxon richness	20	34	yes
Enumeration			
% Bloodworms/Total macroinvertebrates	51	6	yes
% Bloodworms/Total chironomids	96	35	yes
Oligochaetes.m^2	4577	74	yes
O/(O+C)	0.4	-	yes
Diversity			
H´	0.84	0.79	no
J	65	52	no
D_2	52	69	no
Similarity			
Jaccard	20		yes
Bray-Curtis	9		yes
Functional feeding groups			
% Collectors	81	42	yes

Diversity indices are also used to evaluate the environment. These indices are generally found to be lower in a community exposed to organic pollution or some other kind of environmental stress (Odum, 1988; Margalef, 1983). As a rule, in such conditions, the more sensitive species are eliminated, decreasing the amount of competition and predation of the few tolerant species (Benke, 1984; Cairns & Pratt, 1993). Both of the reservoirs in the present study had low diversity indices and there was no perceptible difference between them (Tab. IV). These low values reflect the dominance of few species in each of the systems. Even in the Fazzari Reservoir, where a higher index would be expected, the predominance of just two taxa (Chaoboridae and Campsurus sp) strongly influenced the final value of this metric. An analogous result was obtained by Pamplin (2004) in Bariri and Ponte Nova Reservoir's (SP, Brazil), who made a comparative study of two reservoirs with differing degrees of trophy and found that their diversity indices were similar.

Another component metric of the category of diversity is the uniformity index (J), which, according to Odum (1988), should be 80% or higher in ecosystems with high values of species diversity and correspondingly low dominance indices (D_2). In the Monjolinho Reservoir, the value of J was 65% and that of D_2 52% (Tab. IV), owing to the high relative abundances of two taxa, Limnodrilus hoffmeisteri (Tubificidae) (31.2%) and Polypedilum (Polypedilum) sp (Chironominae) (20.9%). In the Fazzari Reservoir, J was 52% and D_2 69%, again because of the great abundance of two taxa, Chaoboridae (Diptera) and Campsurus sp (Ephemeroptera/ Polymitarcyidae) (Tab. III). The genus Campsurus, like most species of Ephemeroptera, shows a preference for apparently clean water with high concentrations of oxygen (Wetzel, 1993). Chaoborus (Chaoboridae) and Campsurus sp have similarly been recorded in high abundance by Cleto-Filho (2005) in Lake Monte Alegre, also in the state of São Paulo. Decomposing allochthonous material collects around the head of Fazzari Reservoir, carried in from the riverside gallery forest by the Fazzari stream, and this may be responsible for a raised content of humic compounds, supporting the development of large populations of Chaoboridae and Campsurus sp.

According to Jaccard´s similarity index, which compares both the presence and the absence of taxonomic groups, the two reservoirs had a similarity of only 20%, showing the considerable differences between their benthic communities, which reflect their contrasting environmental quality. The Bray-Curtis index (9%) confirmed this low similarity (Tab. IV).

Organic enrichment influences the distribution and relative abundance of the various functional feeding groups, by altering the availability and quality of each type of food. A rise in the availability of fine particulate organic matter (FPOM) produces an increase in the abundance of many organisms, especially the collectors, which live on this kind of food (Resh & Jackson, 1993; Thorne & Williams, 1997). The presence of a small range of food types may arise from the simplicity of the sediment or, rather, the selectivity of the environment towards specific groups of animals. In the Monjolinho Reservoir, the percentage of collectors was high (81%), consistent with the eutrophic conditions (Tab. IV). In contrast, only 42% of the macroinvertebrates in the Fazzari Reservoir were collectors.

Eutrophication of bodies of fresh water has been investigated very thoroughly in most parts of the world, as it is recognized as one of the main factors affecting water quality and leading to an impoverishment of species diversity (Pamplin, 2004). Therefore, the assessment and monitoring of the degree of eutrophication of freshwater systems are valuable tools for decision-making in the maintenance and recovery of the quality of water resources, apart from providing the data required for an understanding of environmental dynamics and the structure of local communities (Lind et al., 1993).

Analysis of the results from most of the metrics employed pointed to the contrasting environmental conditions existing in the Monjolinho and Fazzari Reservoirs. The eutrophic character of the Monjolinho, where the community is dominated by a small number of species that tolerate organic enrichment, was confirmed by these results. In this case, the organic input could arise from the spillage of waste material into the stream that feeds the reservoir, at points upstream. In addition, the reservoir is habitat to a population of capybaras at its head, which contribute significantly to the fertilization of the water. On the other hand, the Fazzari Reservoir, being located in a permanent conservation area, its banks protected by a gallery forest that also extends along the entire stream that feeds it, is characterized by populations of more sensitive species.

To be effective, a multimetric system should incorporate measurements that reflect relevant changes in the environment under study and these metrics should not contain duplicated information (Barbour et al., 1992). In the present study, the results obtained by applying the multimetric system did correspond to the quality of the two water bodies. Out of the 11 metrics used, 3 did not respond as expected: the Shannon Diversity, Uniformity and Dominance Indices are thus unsuitable for this kind of study in this region. Nevertheless, the remaining metrics confirmed the trophic condition of each reservoir and can therefore be applied to lentic environments.

In conclusion, the assessment of water quality by several biotic metrics proved effective, generating data that confirmed the actual quality of two contrasting water-bodies, showing that this can be a useful tool in environmental management.

Acknowledgements

We thank Dr Fabio Oliveira Roque for suggestions in the manuscript, and Dr Roberto Gama Alves for oligochaetes confirmation.

References

Albuquerque, L.B. 1990. Entomofauna aquática do litoral de dois reservatórios da região de São Carlos -SP. São Carlos, UFSCar, 94p (Master Thesis).

Barbour, M.T., Gerritsen, J., Griffith, G.E., Frydenborg, R., McCarron, E., White, J.S. & Bastian, M.L. 1996. A framework for biological criteria for Florida stream using macroinvertebrates. J. North Am. Benthol. Soc., 15:185-211.

Barbour, M.T., Plafkin, J.L., Bradley, B.P., Graves, C.G. & Wisseman, R.W. 1992. Evalution of EPA´s rapid bioassessment benthic metrics: metric redundancy and variability among reference stream sites. Environ. Toxicol. Chem., 11:437-449.

Barton, D.R. & Metcalfe-Smith, J.L. 1992. A comparison of sampling techniques and summary indices for assessment of water quality in the Yamaska River, Quebec, based on benthic macroinvertebrates. Environ. Monit. Assess., 21:225-244.

Benke, A.C. 1984. Secondary production of aquatic insects. In: Resh, V.H. & Rosenberg, D.M. (eds.) The ecology of aquatic insects. Praeger Publishers, New York. p.289-322.

Brinkhurst, R.O. & Marchese, M.R. 1989. Guia para la identification de Oligoquetos aquaticos continentales de Sud y Centroamerica. Clímax, Santa Fe. 207p.

Cairns Jr., J. & Pratt, J.R. 1993. A history of biological monitoring using benthic macroinvertebrates. In: Rosenberg, D.M. & Resh, V.H. (eds.) Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall, New York. p.11-27.

Calijuri, M.C., Deberdt, G.L.B. & Minoti, R.T. 1999. A produtividade primária pelo fitoplâncton na Represa de Salto Grande. In: Henry, R (ed.) Ecologia de reservatórios: estrutura, função e aspectos sociais. FUNDIBIO/FAPESP, Botucatu. p.109-148.

Cleto Filho, S.E. 2005. Estrutura, composição, distribuição espacial e variação temporal da comunidade zoobentônica do Lago Monte Alegre/SP. São Paulo, USP, 108p (PhD Thesis).

Corbi, J.J. 2001. Distribuição espacial e batimetrica dos macroinvertebrados bentônicos da Represa do Ribeirão das Anhumas (Américo Brasiliense – SP). São Carlos, UFSCar, 75p (Master Thesis).

Correia, L.C.S. 2004. Contribuição para o conhecimento do gênero Chironomus Meigen, 1803 na Região Neotropical. São Carlos, UFSCar, 148p (PhD Thesis).

Cunha-Santino, M.B., Bianchini Jr., I. & Serrano, L.E.F. 2002. Aerobic and anaerobic degradation of tannic acid on water samples from Monjolinho Reservoir (São Carlos, SP, Brazil). Braz. J. Biol., 62:585-590.

De Léo, F.C. 1999. Avaliação ambiental da represa do Monjolinho (campus UFSCar) através dos macroinvertebrados bentônicos. São Carlos, UFSCar, 44p (Monograph).

Esteves, F.A. 1988. Fundamentos de limnologia. Interciência/FINEP, Rio de Janeiro. 575p.

Fonseca-Gessner, A.A. & Guereschi, R.M. 2000. Macroinvertebrados bentônicos na avaliação da qualidade da água de três córregos na Estação Ecológica de Jataí, Luiz Antonio, SP, Brasil. In: Santos, J.E. & Pires, J.S.R. (eds.) Estudos Integrados em ecossistemas: Estação Ecológica de Jataí, Rima, São Carlos. v.2, p.707-731.

Hawkes, H.A. 1979. Invertebrates as indicators of river water quality. In: James, A. & Evison, L. (eds.) Biological indicators of water quality. John Wiley & Sons, New York. cap.2, p.1-45.

Hellawell, J.M. 1986. Biological indicators of freshwater pollution and environmental management. Elsevier Applied Science, London. 546p.

Kaniewska-Prus, M. & Kidawa, A. 1983. Application of some benthic indices for quality evaluation of water highly polluted with municipal sewage. Polish. Arch. Hydrobiol., 30:263-269.

Karr, J.R. 1999. Defining and measuring river health. Freshwater Biol., 41:221-234.

Lang, C. 1990. Quantitative relationship between oligochaete communities and phosphorus concentrations in lakes. Freshwater Biol., 24:327-334.

Lauritsen, D.D., Mozley, S.C. & White, D.S. 1985. Distribuition of oligochaetes in lake Michigan and comments on their use as indices of pollution. J. Greats Lakes Res., 11:67-76.

Lind, O.T, Terrell, T.T. & Kimmel, B.L. 1993. Problems in reservoir trophic-state classification and implications for reservoir manegement. In: Straskraba, M., Tundisi, J.G. & Duncan, A. (eds.) Comparative reservoir limnology and water quality manegement. Kluwer Academic Publishers, Dordrecht. p.57-67.

Lindegaard, C. 1995. Classification of water-bodies and pollution. In: Armitage, P., Cranston, P.S. & Pinder, L.C.V. (eds.) The chironomidae. The biology and ecology of non-biting midges. London: Chapman & Hall, London. p.385-404.

Linke, S., Norris, R.H., Faith, D. P. & Stockwell, D. 2005. ANNA: a new presiction method for bioassessment programs. Freshwater Biol., 50:147-158.

Maier, M.H. 1978. Considerações sobre características limnológicas de ambientes lóticos. Bol. Inst. Pesca, 5:75-90.

Magurran, A.E. 2004. Measuring biological diversity. Blackwell Publishing, Malden. 256p.

Margalef, R.1983. Limnologia. Omega, Barcelona. 1010p.

McCaffert, W.P. 1981. Aquatic entomology: the fishermen's and ecologists illustrated guide to insects and their relatives. Jones and Barlett, Boston. 448p.

Merritt, R, Cummins, K. 1986. An introduction to the aquatic insects of North America. 2nd ed. Kendall/Hunt Publishing, Duduque. 862p.

Myslinski, E. & Ginsburg, W. 1977. Macroinvertebrates as indicators of pollution. J. Am. Wat. Wks. Assoc., 69: 538-544.

Nijboer, R.C., Verdonschot, P.F.M. & Van Der Werf, D.C. 2005. The use of indicator taxa as representatives of communities in bioassessment. Freshwater Biol., 50:1427-1440.

Odum, E.P. 1988. Ecologia. Guanabara, Rio de Janeiro. 434p.

Paese, A. 1994. Caracterização limnológica da Represa do Fazzari – campus da UFSCar. São Carlos, UFSCar, 59p (Monograph).

Pamplin, P.A.Z. 1999. Avaliação da qualidade ambiental da Represa de Americana (SP-Brasil) com ênfase no estudo da comunidade de macroinvertebrados bentônicos e parâmetros ecotoxicológicos. São Carlos, USP, 111p (Master Thesis).

Pamplin, P.A.Z. 2004. Estudo comparativo da estrutura da comunidade bentônica de duas represas com diferenças no grau de eutrofização. São Carlos, UFSCar, 113p (PhD Thesis).

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K. & Hughes, R.M. 1989. Rapid bioassessment protocols for use in streams and rivers. benthic macroinvertebrates and fish. EPA/444/4-89/001. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington.

Regali-Seleghim, M.H.R. 2001. Rede trófica microbiana em um sistema eutrófico raso (Reservatório do Monjolinho – São Carlos – SP) - estrutura e função. São Carlos, UFSCar, 92p (PhD Thesis).

Resh, V.H. & Jackson, J.K. 1993. Rapid assessment approaches to biomonitoring using benthic macroinvertebrates. In: Rosenberg, D.M. & Resh, V.H. (eds.) Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall, New York. p.195-233.

Rosenberg, D.M. & Resh, V.H. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates In: Rosenberg, D.M. & Resh, V.H. (eds.) Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall, New York. p.1-9.

Silveira, M.P., Baptista, D.F., Buss, D.F., Nessimian, J.L. & Egler, M. 2005. Application of biological measures for stream integrity assessment in south-east Brazil. Environ. Monit. Assess., 101:117-128.

Strixino, G. & Trivinho-Strixino, S. 1982. Macrobentos da Represa do Monjolinho (São Carlos- SP). Rev. Bras. Biol., 42:165-170.

Strixino, G. & Trivinho-Strixino, S. 1998. Povoamentos de Chironomidae (Diptera) em lagos artificiais. In: Nessimian, J.L. & Carvalho A.L. (eds.) Ecologia de insetos aquáticos. PPGE/UFRJ, Rio de Janeiro. p.141-154. (Séries oecologia brasiliensis, 5)

Thorne, R.S.J & Williams, W.P. 1997. The response of benthic macroinvertebrates to pollution in developing countries: a multimetric system of bioassessment. Freshwater Biol., 37:671-686.

Trindade, M. 1980. Nutrientes em sedimentos da Represa do Lobo (Brotas-Itirapina, SP) São Carlos. São Carlos, UFSCar, 219p (Master Thesis).

Trivinho–Strixino, S. & Strixino, G. 1995. Larvas de Chironomidae (Diptera) do Estado de São Paulo: guia de identificação e diagnose dos gêneros.PPG/ ERN/UFSCar, São Carlos. 229p.

Wetzel, R.G. 1993. Limnologia. Fundação Calouste Gulbenkian, Lisboa. 1010p.

Wetzel, R.G. & Likens, G.E. 1991. Limnological analyses. 2nd ed. Springer-Verlag, New York. 391p.

Wiederholm, T. 1980. Use of benthos in the lake monitoring. J. Water Pollut. Control. Fed., 52:537-547.

Wiederholm, T. 1983. Chironomidae of the Holartic region. Keys and diagnoses: part 1. Entomol. Scand. Suppl., 19:1-457.

Wiederholm, T. 1984. Responses of aquatic insects to environmental pollution. In: Resh, V.H. & Rosenberg, D.M. (eds.) The ecology of aquatic insects. Praeger Publishers, New York. p.508-557.

Wiley, M.J. & Kohler, S.L. 1984. Behavioral adaptations of aquatic insects. Resh, V.H. & Rosenberg, D.M. (eds.) The ecology of aquatic insects. Praeger Publishers, New York. p.101-133.

Received: 13 April 2006
Accepted: 12 June 2006