MACROINVERTEBRATE COMMUNITY IN RECREATIONAL AREAS IN A KARST RIVER (BONITO, BRAZIL): IMPLICATIONS FOR BIOMONITORING OF TOURIST ACTIVITIES

COMUNIDADE DE MACROINVERTEBRADOS EM ÁREAS RECREACIONAIS EM UM RIO CÁRSTICO (BONITO, BRASIL): IMPLICAÇÕES PARA BIOMONITORAMENTO DE ATIVIDADES TURISTICA

Suzana Cunha Escarpinati (1), Fabio de Oliveira Roque (2), Paulino Barroso Medina-Jr (3) & Josué Raizer (3)

(1) Programa de Pós-Graduação em Entomologia e Conservação da Biodiversidade, Universidade Federal da Grande Dourados (UFGD)
(2) Departamento de Biologia, Universidade Federal de Mato Grosso do Sul (UFMS)
(3) Faculdade de Ciências Biológicas e Ambientais, Universidade Federal da Grande Dourados (UFGD)

Dourados - MS - scescarpinati@yahoo.com.br

Abstract

Tourism has increased in several natural areas of the world, and the scenic beauty, uniqueness and biodiversity are the main attractions. Little is known about the consequences of tourism impacts in the biodiversity of freshwater systems. In this study, we investigate how the macroinvertebrate community is spatially distributed, especially between reference and recreational areas in a karst river in the second largest tourist destination in Brazil - Bonito, Mato Grosso do Sul. No clear macroinvertebrate distributional patterns between areas were revealed by NMDS analysis; however it shows that recreational areas have more inter-sample macroinvertebrate diversity variability than the reference areas. Some non-exclusive reasons could explain these results, such as management strategies, public behavior, invasive and attractive species, and historic aspects.

Key-Words: Bonito; Environmental Impact; Tourism; Bioindicator; Aquatic Insects.

Resumo

O turismo tem aumentado em várias áreas naturais do mundo, sendo a beleza cênica, a singularidade e a biodiversidade os principais atrativos. Pouco se sabe sobre as conseqüências dos impactos do turismo na biodiversidade dos sistemas de água doce. Neste estudo, investigamos como a comunidade de macroinvertebrados é espacialmente distribuida entre áreas de referência e áreas recreacionais em um rio no segundo maior destino turístico do Brasil - Bonito, Mato Grosso do Sul. A análise de NMDS não detectou claro padrão de distribuição dos macroinvertebrados entre as áreas, no entanto a análise mostra maior variação na composicão de macroinvertebrados entre as áreas de recreação, quando comparado com áreas de referência. Algumas razões não-exclusivas podem explicar estes resultados, tais como estratégias de gestão, comportamento do público, espécies invasoras, espécies atraentes aos visitantes e aspectos históricos .

Palavras-Chave: *Bonito; Impacto Ambiental; Turismo; Bioindicador; Insetos Aquáticos.*

1. INTRODUCTION

Tourism has increased in several natural areas of the world (FENNELL; WEAVER, 2005), with scenic beauty and biodiversity being the main attractions (TURTON, 2005). Despite this growth in some environments, little is known about of the environmental impacts that are associated with the visiting public in terrestrial and aquatic ecosystems.

Despite the possible contribution of tourism to nature conservation, researches conducted in terrestrial systems such as forests (COLE; LANDRES, 1996; TALBOT et al., 2003), mountains (HEIL et al., 2005; GENELETTI; DAWA, 2009), and polar areas (AYRES et al., 2008) have shown that these activities cause a loss of local biodiversity. In aquatic systems, studies have also shown deleterious impacts on algae (FLETCHER; FRID, 1996; DAVENPORT;

DAVENPORT, 2006), invertebrates (LIDDLE, 1975; CHANDRASEKARA; FRID, 1996; CASU et al., 2006; BONTE; MAES, 2008), and fish communities (SABINO et al., 2005).

Because of their high biodiversity, the propensity for anthropogenic impacts and the demand for multiple uses, freshwaters are among the most fragile environments and are a priority for worldwide conservation (RAMSAR CONVENTION, 1975; CONVENTION OF BIOLOGICAL DIVERSITY, 1992; MILLENIUM ECOSYSTEM ASSESSMENT, 2005). Although there are an increasing number of conservation strategies and monitoring systems of freshwaters in the world, they all depend upon access to basic information regarding the distribution of organisms that are facing anthropogenic impacts (BALMFORD et al., 2005).

Since the early 1800's, with studies initially performed in Europe, there has been an increasing number of studies that evaluate the effects of environmental changes, such as the increased amounts of heavy metals (FÖRSTNER; WITTMANN, 1983), different land uses (ALLAN, 2004), organic pollution (DAHL et al., 2004), climate change (WALTHER et al., 2002), and sedimentation (RUNDE; HELLENTHAL, 2000), on aquatic communities - particularly on macroinvertebrates (BONADA et al., 2006). However, little is know about the responses of macroinvertebrates that are exposed to activities related to public recreational areas, such as the use of vessels, diving, rafting and tubing (LIDDLE; SCORGIE, 1980).

Several freshwater areas in the world may be facing loss of biodiversity due to tourism impacts. Among the tropical areas with a high scenic beauty and tourist potential, which are mainly based on natural freshwater systems, the Bonito karst region in Brazil stands out in South America. In the year 2010 the Bonito region receives 276,164 visitors (BOGGIANI, 2011). The scenic beauty of the Bonito region is due to the presence of pure and soluble limestone that, as it dilutes, absorbs and decants the few impurities present, turning the waters highly crystalline and promoting the formation of unique and sensitive habitats, which are appropriate for the implementation of recreational areas (BOGGIANI, 2011). These areas are under potential impact, related to activities such as diving and swimming, which involve movement and trampling (CASU et al., 2006). Considering that multiple recreational activities can change the structure of the aquatic macroinvertebrate community by crushing, redistributing, increasing drift, changing habitats, and favoring the species most pleasing to visitors, we expect that the taxonomic composition of macroinvertebrates will discriminate between reference areas and public recreational areas in the most visited river in Bonito. Additionally, given the growing demand for efficient methods of rapid bioassessment in tropical rivers (MELO, 2005), based on criteria representing optimal cost-benefit trade-offs (JONES, 2008; MARSHALL et al., 2006), we evaluated the response of the aquatic macroinvertebrate community using high taxonomic resolution (genus and tribe) and low taxonomic resolution (family).

Our focus on aquatic macroinvertebrates is justified by their widespread recognition in biomonitoring programs worldwide (ROSENBERG; RESH, 1993; CALLISTO, 2001; BONADA et al., 2006), including programs in tropical countries like Brazil (BAPTISTA, 2008). Among the many advantages for this use, we highlight those that are related to rationality (e.g., a greater potential for impact discrimination and a more predictive power that is grounded in ecological theory, as compared to the use of other aquatic organisms), implementation (low cost and simple protocols) and performance (easy interpretation of the results and wide applicability).

2. METHODS

2.1. Study area

We conducted fieldwork in the karst region of the Bodoquena Plateau in southwestern Mato Grosso do Sul, Brazil, a water division between the hydrographic basin of the Paraguay River (west) and the sub-basins of the Apa (south) and Miranda (east) rivers. The main waterways of the Bodoquena Plateau are Formoso, Prata, Perdido and Salobra rivers. The draining land is known as a limestone karst, and it is the predominant formation on the region (BOGGIANI, 2011).

The basin area is 1,334 km^2 Rio Formoso is 1,334 km^2 and it is located in the central region of the Bonito municipality in Mato Grosso do Sul, Brazil. The Formoso River is approximately 100 km long, from spring to mouth, and flows through rural areas of the Bonito municipality.

2.2. Sampling areas

To characterize the sampling sites and evaluate the distribution of the aquatic macroinvertebrate community, we sampled five public recreational areas (RcAs) and five reference areas (RfAs) in the Formoso River (Figure 1). The sampling stations are at least 1.5 km away from each other, with the RcA and their respective RfA being separated by at least 50 m. All sampled areas correspond to a 10 m long stretch of the river across its width.

2.3. Macroinvertebrate sampling and identification

The macroinvertebrates were collected using a D-frame aquatic net (250 µm) during 3 minutes. We identified the specimens with the aid of identification keys and we confirmed the identifications by consulting experts (see acknowledgments). The specimens were deposited at the Museu da Biodiversidade of the Universidade Federal da Grande Dourados in Dourados/MS, Brazil.

2.4. Environmental characterization

To measure the conductivity, pH, temperature, dissolved oxygen, water velocity, number of submersed woods, and organic matter we selected three sections of each sampling area with the highest uniformity and the lowest possible irregularity of the river floor were selected.

We measured the conductivity, pH, temperature and dissolved oxygen using the Hanna HI9828 multiparameter sensor. We measured the water velocity using the float method (MARQUES; ARGENTO, 1988). We measured the number of submersed woods and organic matter, as these are considered to be good indicators of the heterogeneity, habitat complexity and food availability for aquatic macroinvertebrates (WALLACE et al., 1997). To measure the number of woods, we consider, only submersed woods with a diameter greater than 8 cm, regardless of length. We count the number of submerged wood in each sampling area. Organic matter was collected using the same method applied to macroinvertebrates. Dry weight values of fine (<5 mm) and course (>5 mm) organic matter were measured. We also considered the proportion of the coarse organic matter in relation to the fine organic matter as a variable.

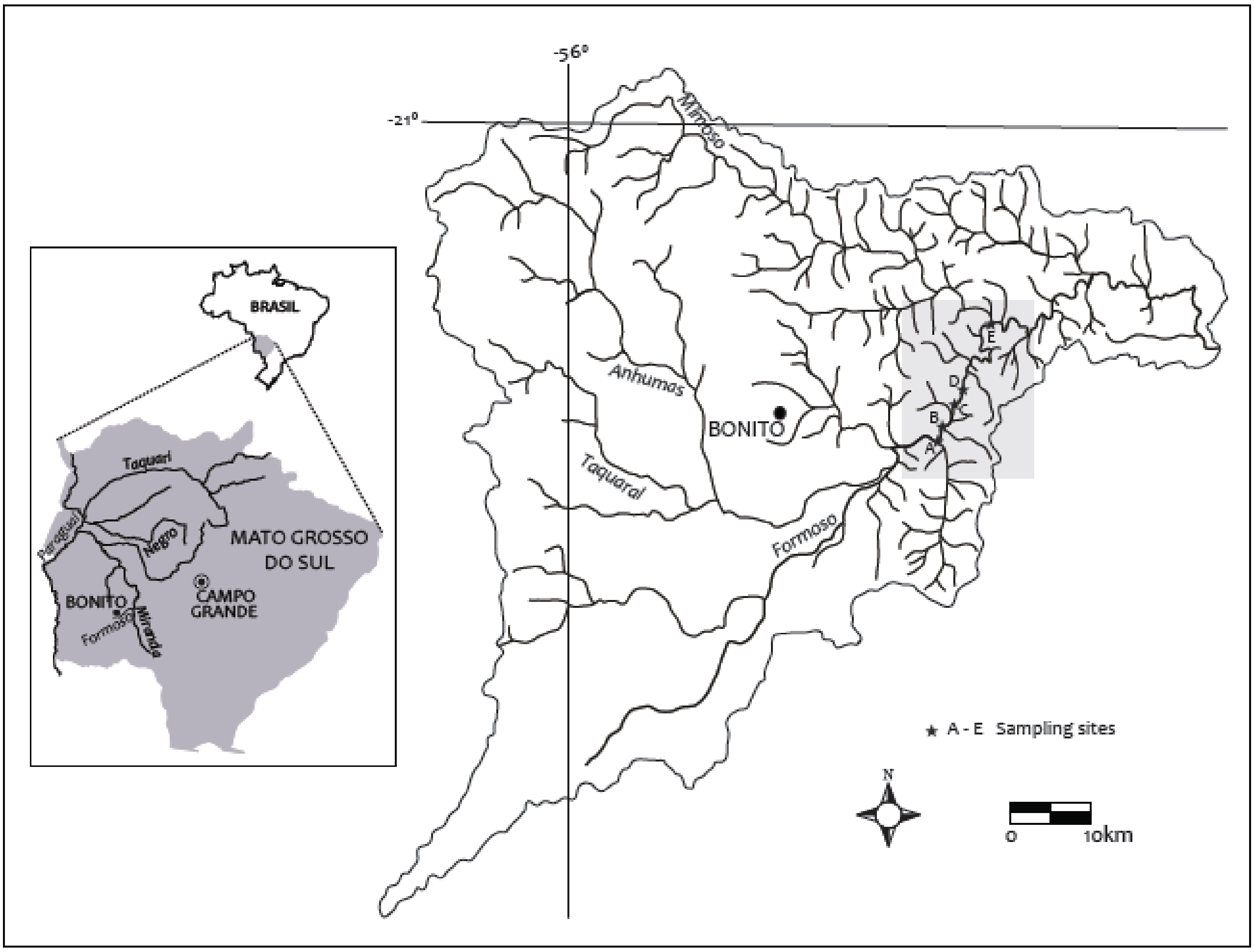

Figure 1 - Location of the Hydrographic Basin of the Rio Formoso, Region of Bonito, Mato Grosso do Sul, Brazil, highlighting the location of each of the sampling sites. Adapted project: GEF Rio Formoso (Final Report). Graphic design by Raquel Taminato.

Considering that the macroinvertebrate abundance may respond to the amount of the fish *Brycon hilarii* Valenciennes, in the Formoso river, we measured the number of fish for a period of 3 min at each sampling site using visual survey of belt transect (10 m length 3 m width, one observer). A number of biases may influence the accuracy and precision of density estimates when using the visual transect technique (CHEAL; TOMPSON, 1997), however it is important to note that we are interested only in a general estimation for comparative analysis.

2.5. Data analysis

We used a PCA to reduce environmental data dimensionality. Subsequently, we used the PCA scores in a multivariate analysis of variance (MANOVA) to determine if they discriminate RcAs vs. RefAs.

To ordinate samples according to taxa composition and abundance, at high and low taxonomic level, using only a few dimensions, we used non-metric multidimensional scaling (NMDS). The number of dimensions was chosen by considering the proportion of the variance (r^2) that was explained by the final distances between the samples in the ordination and the distances between the samples in the Bray-Curtis distance matrix. We considered the relative abundance of each taxa for the calculation of Bray-Curtis distances.

3. RESULTS

We recorded 2379 individuals in 109 taxa (for the complete community dataset, contact the first author). Diptera and Gastropoda represented 91% of the fauna.

The samples in reference sites resulted in 1712 individuals in 92 taxa, and the most abundant taxa were: *Goeldichironomus* (Diptera: Chironomidae); *Polypedilum* (Diptera: Chironomidae); *Ablabesmyia* (Diptera: Chironomidae), and *Heleobia* (Gastropoda: Cochliopidae). The samples in public recreational areas summed 667 individuals for 70 taxa. The most abundant taxa were: *Cricotopus* (Diptera: Chironomidae); *Ablabesmyia* (Diptera: Chironomidae); *Goeldichironomus* (Diptera: Chironomidae); and *Melanoides tuberculatus* (Gastropoda: Cochliopidae).

The first three axes of the principal component analysis (PCA) recovered 74.01% of the variance in the sample set of environmental variables (First axis = 38.03%, second 20.65%, and third 15.33%). We can distinguish the samples from the RcAs vs. RfAs by ordination from the PCA (Figure 2, MANOVA: Pillai Trace =0.83; F=9.61; gl=3 and 6; p=0.01).

Considering the correlations of the variables with the PCA axes (Table 1), we expected to find more *B. hilarii* in the faster waters in RcA and more submersed woods, larger amounts of organic matter, a higher pH and higher conductivity in RfA. The environmental structure is more variable between the RfAs than it is among the RcAs (Figure 2).

Table 1 - Correlation of environmental variables with the first three axes of principal component analysis for 10 samples. Featuring bold values greater than 0.5.

	PC1	PC2	PC3
Number of *Brycon hilarii*	**0.80**	0.24	-0.09
Water velocity (m/min)	**0.70**	0.14	-0.13
Coarse particulate organic matter (%)	0.48	**-0.52**	**0.53**
Average depth (m)	0.21	**-0.79**	0.32
Oxygen (DO) (mg l^{-1})	-0.02	**-0.79**	**-0.52**
Temperature (°C)	-0.28	-0.06	**0.86**
Conductivity (µS cm^{-1})	**-0.57**	0.28	0.12
pH	**-0.67**	**-0.61**	-0.27
Organic matter (g)	**-0.85**	0.11	0.13
Number of submersed woods	**-0.91**	0.07	-0.09

No clear patterns between areas were revealed by NMDS analysis applied to the dataset at low taxonomic resolution (Figure 3), however it shows that the RcAs, positioned around the RfAs, have more inter-sample macroinvertebrate diversity variability (high taxonomic resolution) than the RfAs (Figure 4).

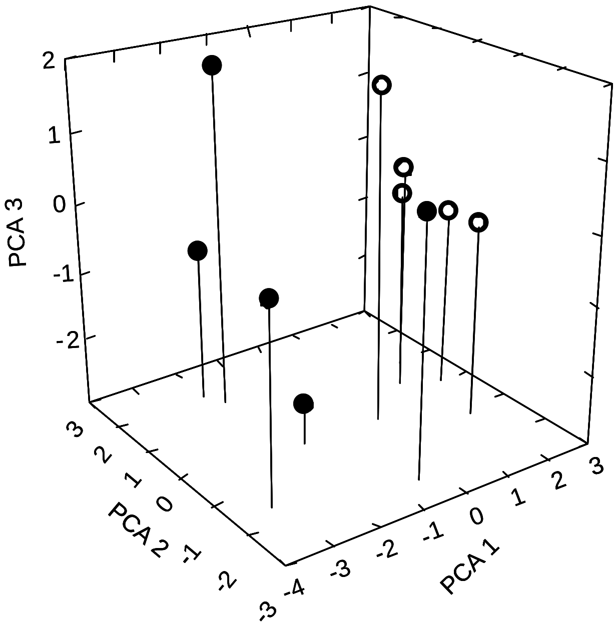

Figure 2 - Ordination of samples of environmental variables by principal components analysis (PCA). Filled points correspond to samples taken in reference sites (without visitation) and empty spots on samples in public recreational sites.

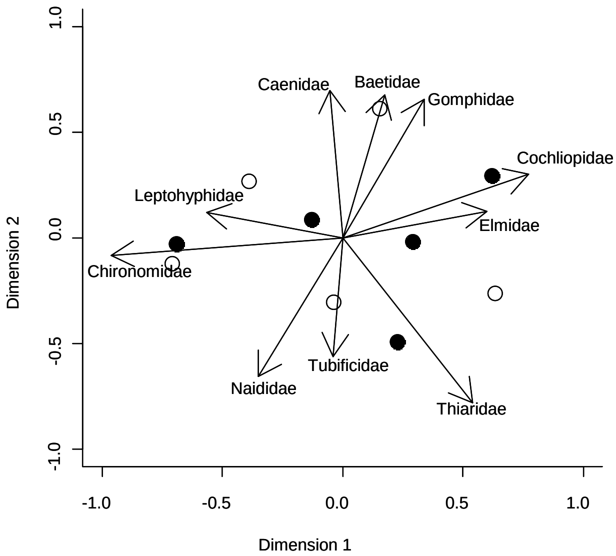

Figure 3 - Ordination of macroinvertebrate samples at low taxonomic resolution by non-metric multidimensional scaling (NMDS). Filled points correspond to samples taken in reference sites (without visitation) and empty spots on samples in public recreational sites. The vectors indicate the loadings of each family ($r^2 > 0.5$) for the configuration of the plan ordination.

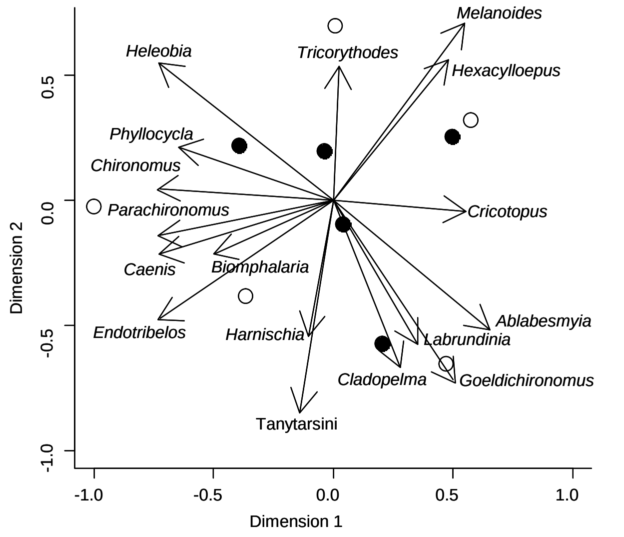

Figure 4 - Ordination of macroinvertebrate samples high taxonomic resolution by non-metric multidimensional scaling (NMDS). Filled points correspond to samples taken in reference sites (without visitation) and empty spots on samples in public recreational sites. The vectors indicate the loadings of each taxa ($r^2 > 0.5$) for the configuration of the plan ordination.

4. DISCUSSION AND CONCLUDING REMARKS

Recreational activities may have multiple effects on aquatic biological communities. These impacts can act in isolation or synergistically; examples include the collection of organisms by visitors (WYNBERG; BRANCH, 1997), the death of individuals by crushing (CASU et al., 2006), the redistribution of the organisms (GARCÍA-CHARTON et al., 2008), a propensity to invasion by exotic species (FOIN et al., 1998), an increase in the abundance of the species preferred by the visitors (SABINO et al., 2005), a change in the habitat structure (KAY; LIDDLE, 1989) and a change in the organism behavior (BROSNAN; CRUMRINE, 1994). Our results, showing a greater variability of macroinvertebrates, at high resolution identification, in the areas under different levels of recreational impacts when compared to RfAs is consistent with recent studies in marine environments, especially in coastal regions (NEWTSON, 2003; AIROLDI et al., 2005; CASU et al., 2006; ROSSI et al., 2007). Some non-exclusive reasons could explain this higher variability of macroinvertebrates in RcAs, such as management strategies, public behavior, invasive and attractive species, and historic aspects.

Changes in the light intensity, wind, anthropic disturbances (ex. visitor moviments), rain and predators are often factors that influence the process of macroinvertebrate drift in lotic systems

(ANDERSON; SEDELL, 1979; MATHOOKO; MAVUTI, 1994). Visitors who use the stretches of the river where the depth does not exceed 2 m, as sampled in this study, generally have contact with the river floor, may cause the death of organisms by trampling, as has been documented in experimental studies with marine macroinvertebrates (BROSNAN; CRUMRINE, 1994; BONTE; MAES, 2008). In our case, the activities associated with visitor movement recorded at RcAs may favor the process of invertebrate drift and trampling, resulting in changes in macroinvertebrate communities in the RcAs.

The local problem of increased food supply to *B. hilarii* by visitors has led to a greater concentration of fish in RcAs**,** as well as about a 19% increase in fish weight (SABINO et al., 2005) and consequent enrichment in organic fecal substrate. This organic enrichment, associated with substrate compaction from the pressure exerted by tourists and visitors, may favor taxa that occur in substrates that are consolidated with high amounts of organic matter, such as the chironomid *Cricotopus*, commonly find in this type of environment (WOLFRAM, 1996). The accumulation of feces may have also favored the greatest abundance of the invasive species *Melanoides tuberculatus* (Gastropoda: Thiaridae) in RCAs, as these mollusks feed on organic matter particles embedded in the substrate and are usually more abundant in altered areas (RADER et al., 2003).

Organic matter values, submersed woods and fish numbers contributed greatly to the discrimination of RcAs vs. RfAs; however, we cannot consider these variables to be good surrogates of macroinvertebrate diversity, because our results did not show congruence between the two datasets (environmental characterization and fauna). The clear separation of RcAs vs. RfAs, based on environmental characterization data, is due to entrepreneur management strategies aiming to increase visitor comfort at RcAs (e.g. they clean the riverbed, remove tree trunks and organic matter, and feed the *B. hilarii*).

The history of the sampling sites, especially when evaluating natural systems in the absence of sampling units standardized by intensity, type and frequency of public visitation, makes it difficult to interpret the current patterns of biodiversity because it is not possible to separate the influence of each component on the historical context (here, it was not possible to rescue quantifiable information about the history of the enterprises). In other words, our data are subject to the ghost effects of the past on contemporary ecological patterns (HARDING et al., 1998). Furthermore, studies that categorically evaluate multiple anthropogenic stressors (e.g., the division of reference area versus recreational ones) may express environmental simplifications resulting in a low response of biological metrics (HEINO, 2009). In our case, this may also partially explain the low discriminatory capacity of macroinvertebrate community.

<u>Implications for the development of biomonitoring systems</u>

Monitoring strategies for natural systems depend on classifications that are based on the environment and the biological community. Classification is, therefore, a critical component in many bioassessment programs designed to assess the condition of aquatic systems (BAILEY et al., 1998). Our results show that the macroinvertebrate community, regardless of taxonomic refinement, is not in concordance with *a priori* dicotomic classification of the RcAs vs. RfAs. However, more variability in the distribution of macroinvertebrates at high taxonomic resolution is evident between the RcAs. Within the context of elaborating the biomonitoring programs in the region, it becomes imperative to understand the underlying mechanisms and their relationships to the multiple impact factors of visitor activities (GRANTHAM et al., 2010), based on the more detailed knowledge of the type, magnitude and variability of these disturbances.

The taxonomic resolution used in our analysis has consequences for the implementation of biomonitoring programs. Only the fauna identified at high taxonomic resolution were distributed differently between the areas under activities of the recreation. These results do not agree with previous studies that show clear ecological patterns based on family information (MARCHANT et al., 1995; MELO; FROEHLICH, 2001; FEIO et al., 2006), suggesting that this level of identification is not enough for the detection of ecological patterns with regard to the types of impacts studied here. In other words, the recreacional activities may exert less conspicuous impacts that result in a more subtle response of the aquatic macroinvertebrate community than those that are usually measured in environmental impact studies (e.g., the effect of heavy metals, intense sedimentation, and organic pollution).

In summary , the approach considered here (distributional patterns), although is a pre-requisite to understand the influences of anthropogenic impacts on natural systems, it is too exploratory for untangling the mechanisms behind recreational influences on macroinvertebrate community in aquatic systems and more research is needed to provide solid evidences to meet rationale criteria for biomonitoring systems.

ACKNOWLEDGEMENTS

We are grateful to Fundação O Boticário de Proteção à Natureza for their financial support (Project n. 0791_20081). We are grateful also to the entrepreneurs and the Municipal Secretary of Tourism of Bonito/MS- Brasil. This work was partly supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico (Project n. 476484/2008-1) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior. We express our thanks for the helpful identification specimens from Melissa O. Segura, MsC, Coleoptera; Dr. Frederico Falcão Salles, Ephemeroptera; Rafael Moretto, MsC, Trichoptera; Dr. Silvana Thiengo, Molusca; Lucas Lecci, MsC, Plecoptera; and Juliana Freires, MsC, Hemiptera. F.O. Roque receives a productivity grant from CNPq (process no. 303293/2009-8).

REFERENCES

ANDERSON, N.H.; SEDELL, J.R. Detritus processing by macroinvertebrates in stream ecosystems. **Annual Review of Entomology,** v. 24, p. 351-377, 1979.

AIROLDI, L.; BACCHIOCCHI, F.; CAGLIOLA, C.; BULLERI, F.; ABBIATI, M. Impact of recreational harvesting on assemblages in artificial rocky habitats. **Marine Ecology Progress Series**, v. 299, p. 55-66, 2005.

ALLAN, J.D. Landscape and riverscapes: the influence of land use on stream ecosystems. **Annual Review of Ecology, Evolution and Systematics**, v. 35, p. 257-284, 2004.

AYRES, E.; NKEM, J.N.; WALL, D.H.; ADAMS, B.J.; BARRETT, J.E.; BROOS, E.J.; PARSONS, A.N.; POWERS, L.E.; SIMMONS, B.L.; VIRGINIA. R.A. Effects of human trampling on populations of soil fauna in the McMurdo Dry Valleys, Antarctica. **Conservation Biology**, v. 22, p. 1544-1551, 2008.

BAILEY, R.C.; KENNEDY, M.G.; DERVISH, M.Z.; TAYLOR, A.R.M. Biological assessment of freshwater ecosystems using a reference condition approach: comparing predicted and actual benthic invertebrate communities in Yukon streams. **Freshwater Biology**, v. 39, p. 765-774, 1998.

BALMFORD, A.; BENNUN, L.; BRINK, B.T.; COOPER, D.; CÔTE, I.M.; CRANE, P.; DOBSON, A.; DUDLEY, N.; DUTTON, I.; GREEN, R.E.; MARTIN, J.; PAUL, J.; VALMA, J.; JOAH, M.; KAT, M.; NORMAN, M.; SHAHID, N.; JOUNI, P.; MATTHEW, R.; SERGIO, R.; JOAN, R.; KATE, T.; R. KERRY, T. The convention on biological diversity's 2010 target. **Science**, v. 307, p. 212-213, 2005.

BAPTISTA, D.F. Uso de macroinvertebrados em procedimentos de biomonitoramento em ecossistemas aquáticos. **Oecologia Brasiliensis,** v. 12, p. 425-441, 2008.

BOGGIANI, P.C.; TREVELIN, A.C.; SALLUN FILHO, W.; OLIVEIRA, E.C.; ALMEIDA, L.H.S. Turismo e Conservação de Tufas Ativas da Serra da Bodoquena, Mato Grosso do Sul. **Pesquisas em Turismo e Paisagens Cársticas**, v.4, p. 55-63, 2011.

BONADA, N.; PRAT, N.; RESH, V.H.; STATZNER, B. Developments in aquatic insect biomonitoring: a comparative analysis of recent approaches. **Annual Review of Entomology**, v. 5, p. 495-523, 2006.

BONTE, D.; MAES, D. Trampling affects the distribution of specialized coastal dune arthropods. **Basic and Applied Ecology**, v. 9, p. 726-734, 2008.

BROSNAN, D.M.; CRUMRINE, L.L. Effects of human trampling on marine rocky shore communities. **Journal of Experimental Marine Biology and Ecology**, v. 177, p. 79-97, 1994.

CALLISTO, M.; MORETTI, M.; GOULART, M.D.C. Macroinvertebrados bentônicos como ferramenta para avaliar a saúde de riachos. **Revista Brasileira de Recursos Hídricos**, v. 6, p. 71–82, 2001.

CASU, D.; CECCHERELLI, G.; CASTELLI, A. Immediate effects of experimental human trampling on mid-upper intertidal benthic invertebrates at the Asinara Island MPA (NW Mediterranean). **Hydrobiologia**, v. 555, p. 271–279, 2006.

CHANDRASEKARA, W.U.; FRID, C.L.J. Effects of human trampling on tidalflat infauna. **Aquatic Conservation: Marine and Freshwater Ecosystems**, v. 6, p. 299-311, 1996.

CHEAL, A.J.; THOMPSON, A.A. Comparing visual counts of coral reef fish: implications of transect width and species selection. **Marine Ecology Progress Series**, v. 158, p. 241-248, 1997.

COLE, D.; LANDRES, P.B. Threats to wilderness ecosystems: impacts and research needs. **Ecological Applications**, v. 6, p. 168–84, 1996.

CBD. Convention on Biological Diversity, International Legal Materials, vol. 31 (Washington, D.C.: American Society of International Law, 1992), p. 818, 1992.

DAHL, J.; JOHNSON, R.K.; SANDIN, L. Detection of organic pollution of streams in southern Sweden using benthic macroinvertebrates. **Hydrobiologia**, v. 516, p. 161–172, 2004.

DAVENPORT, J.; DAVENPORT, J.L. The impact of tourism and personal leisure transport on coastal environments: A review. **Estuarine, Coastal and Shelf Science**, v. 67, p. 280–292, 2006.

FEIO, M.J.; REYNOLDSON, T.B.; GRAÇA, M.A.S. The influence of taxonomic level on the performance of a predictive model for water quality assessment. **Canadian Journal of Fisheries and Aquatic Sciences**, v. 63, p. 367–376, 2006.

FENNELL, D.; WEAVER, D. The ecotourium concept and tourism-conservation symbiosis. **Journal of Sustainable Tourism**, v. 13, p. 373-390, 2005.

FLETCHER, H.; FRID, C.L.J. Impact and management of visitor pressure on rocky intertidal algal communities. **Aquatic Conservation: Marine and Freshwater Ecosystems**, v. 6, p. 287–297, 1996.

FOIN, T.C.; RILEY, S.D.; PAWLEY, A.L.; AYRES, D.R.; CARLSEN, T.M.; HODUM, P.J.; SWITZER, P.V. Improving recovery planning for threatened and endangered species. **BioScience,** v. 48, p. 177-184, 1998.

FÖRSTNER, U.; WITTMANN, G.T.W. **Metal pollution in the aquatic environment**. Berlin: Springer-Verlag, 1983. 486 p.

GARCÍA-CHARTONA, J.A.; PÉREZ-RUZAFAA, A.; MARCOS, C.; CLAUDET, J.; BADALAMENTIC, F.; BENEDETTI-CECCHID, L.; FALCÓNE, J.M.; MILAZZOF, M.; SCHEMBRIG, P.J.; STOBARTH, B.; VANDEPERREI, F.; BRITOE, A.; CHEMELLOF, R.; DIMECHG, M.; DOMENICIJ, P.; GUALAK, I.; LEDIRE´ACHL, L.; MAGGID, E.; PLANESM. S. Effectiveness of European Atlanto-Mediterranean MPAs: Do they accomplish the expected effects on populations, communities and ecosystems? **Journal for Nature Conservation**, v. 16, p. 193-221, 2008.

GENELETTI, D.; DAWA, D. Environmental impact assessment of mountain tourism in developing regions: A study in Ladakh, Indian Himalaya. **Environmental Impact Assessment Review**, v. 29, p. 229–242, 2009.

GRANTHAM, T.E.; MERENLENDER, A.M.; RESH, V.H. Climatic influences and anthropogenic stressors: an integrated framework for streamflow management in Mediterranean-climate California. U.S.A. **Freshwater Biology**, v. 55, p. 188–204, 2010.

HARDING, J. S.; BENFIELD, E. F.; BOLSTAD, P. V.; HELFMAN, G. S.; JONES, E. B. D. Stream biodiversity: The ghost of land use past. **Proceedings of the National Academy of Sciences**, v. 95, v. 14843-14847, 1998.

HEIL, L.; FERNANDEZ-JURICIC, E.; RENISON, D.; CINGOLANI, A.M.; BLUMSTEIN, D.T. Avian responses to tourism in the biogeographically isolated high Córdoba Mountains, Argentina. **Biodiversity and Conservation**, v. 16, p. 1009-1026, 2005.

HEINO, J. Biodiversity of aquatic insects: spatial gradients and environment correlates of assemblage-level measures at large scales. **Freshwater reviews**, v. 2, p. 1-29, 2009.

JONES, F.C. Taxonomic sufficiency: The influence of taxonomic resolution on freshwater bioassessments using benthic macroinvertebrates. **Environmental Reviews**, v. 16, p. 45–69, 2008.

KAY, A.; LIDDLE, M. Impact of human trampling in different zones of a coral reef-flat. **Environmental Management**, v. 13, p. 509–520, 1989.

LIDDLE, M.J. A selective review of the ecological effects of human trampling on natural ecosystems. **Conservation Biology**, v. 7, p. 17–37, 1975.

LIDDLE, M.J.; SCORGIE, H.R.A. The effects of recreation on freshwater plants and animals: a review. **Biological Conservation**, v. 17, p. 183-206, 1980.

MARCHANT, R.; BARMUTA, L.A.; CHESSMAN, B.C. Influence of sample quantification and taxonomic resolution on the ordination of macroinvertebrate communities from running waters in Victoria, Australia. **Marine & Freshwater Research**, v. 46, p. 501–506, 1995.

MARQUES, J.S.; ARGENTO, M.S.F. Geociências. **São Paulo**, v. 7, p. 173-186, 1988.

MARSHALL, J.C.; STEWARD, A.L.; HARCH, B.D. Taxonomic resolution and quantification of freshwater macroinvertebrate samples from an Australian dryland river: the benefits and costs of using species abundance data. **Hydrobiologia**, v. 572, p. 171–194, 2006.

MATHOOKO, J.M.; MAVUTI, K.M. Factors influencing drift transport and concentration in a second-order high altitude tropical river in central Kenya. **African Journal of Ecology**, v. 32, p. 39–49, 1994.

MELO, A.S.; FROEHLICH, C.G. Macroinvertebrates in neotropical streams: richness patterns along a catchments and assemblage structure between 2 seasons. **Journal of the North American Benthological Society**, v. 20, p. 1–16, 2001.

MELO, A.S. Effects of taxonomic and numeric resolution on the ability to detect ecological patterns at a local scale using stream macroinvertebrates. **Archiv für Hydrobiologie**, v. 164, p. 309-323, 2005.

Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC. 2005. Disponível em: < www.maweb.org/>. Acesso em: 16 jun. 2011.

NEWTSON, C. Effects of mechanical fracturing and experimental trampling on Hawaiian corals. **Environmental Management**, v. 31, p. 377–384, 2003.

RAMSAR CONVENTION. Wetlands and Biological Diversity: Cooperation between The Convention of Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, Iran,1971) and The Convention on Biological Diversity, Document

UNEP/CBD/COP/3/Inf.21. 1996. Disponível em: www.ramsar.org. Acesso em: 16 jun. 2011.

RADER, R.; BELK, M.; KELEHER, M. The introduction of an invasive snail (*Melanoides tuberculata*) to spring ecosystems of the Bonneville Basin, Utah. **Journal of Freshwater Ecology**, v. 18, p. 647–657, 2003.

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

ROSSI, F.; FORSTER, R.M.; MONTSERRAT, F.; PONTI, M.; TERLIZZI, A.; YSEBAERT, T.; MIDDELBURG, J.J. Human trampling as short-term disturbance on intertidal mudflats: effects on macrofauna biodiversity and population dynamics of bivalves. **Marine Biology**, v. 151, p. 2077-2090, 2007.

RUNDE, J.M.; HELLENTHAL, R.A. Behavioral responses of *Hydropsyche sparna* (Trichoptera: Hydropsychidae) and related species to deposited bedload sediment. **Environmental Entomology**, v. 29, p. 704-709, 2000.

SABINO, J.; MEDINA-JR, P.B.; ANDRADE, L.P. Visitantes mal-comportados e piraputangas obesas: a pressão da visitação pública sobre *B. hilarii* no Balneário municipal de Bonito. Mato Grosso do Sul. **Anais do encontro nacional de inovação científica para o homem do século XXI**, v. 1, p. 321–332, 2005.

TALBOT, L.M.; TURTON, S.M.; GRAHAM, A.W. Trampling resistance of tropical rainforest soils and vegetation in the wet tropics of north east Australia. **Journal of Environmental Management**, v. 69, p. 63-69, 2003.

TURTON, S.M. Managing environmental impacts of recreation and tourism in rainforests of the Wet Tropics of Queensland World Heritage area. **Geographical Research**, v. 43, p. 140-151, 2005.

WALLACE, J.B.; EGGERT, S.L.; MEYER, J.L.; WEBSTER, J.R. Multiple trophic levels of a forest stream linked to terrestrial litter inputs. **Science**, v. 277, p. 102-104, 1997.

WALTHER, G.R.; POST, E.; CONVEY, P.; MENZEL, A.; PARMESANK, C.; BEEBEE, T. J. C.; FROMENTIN, J. M.; HOEGH-GULDBERG, O.; BAIRLEIN, F. Ecological responses to recent climate change. **Nature**, v. 416, p. 389–395, 2002.

WOLFRAM, G. Distribution and production of chironomids (Diptera: Chironomidae) in a shallow, alkaline lake (Neusiedler See, Austria). **Hydrobiologia**, v. 318, p. 103–115, 1996.

WYNBERG, R.P.; BRANCH, G.M. Trampling associated with bait-collection for sandprawns *Callianassa kraussi* Stebbing: effects on the biota of an intertidal sandflat. **Environmental Conservation**, v. 24, p. 139–148, 1997.

***Editorial flow*/Fluxo editorial**:
Received/Recebido em: 13.09.2011
Accepted/Aprovado em: 02.12.2011

TOURISM AND KARST AREAS
(*formely*/formalmente: Pesquisas em Turismo e Paisagens Cársticas)
Brazilian Speleological Society / Sociedade Brasileira de Espeleologia (SBE)
www.cavernas.org.br/turismo.asp