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Rapid assessment of river water quality using an adapted BMWP index: a practical tool to evaluate ecosystem health

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Introduction

Biological communities reflect overall ecological features (e.g. chemical, physical, and biological), integrating effects from different stressors, and therefore providing a broad measure of the combined impacts. The use of biological indices is an important tool in the assessment of freshwater ecosystem health, providing accessible results to political decision-makers. More than 50 different methods for biological evaluation of water quality have been developed in temperate countries (DE PAUW & VANHOOREN 1983). Biotic indices usually use score systems, based on established water-quality tolerance values for the studied taxa (RESH & JACKSON 1993).

Score systems based on benthic macroinvertebrate communities have been used to facilitate the interpretation of large amounts of data using the watershed as an ecological unit (BARBOSA et al. 1999). These programs are carried out to detect changes in freshwater communities. The results take the form of taxa lists, with or without the abundances, which are analyzed to produce a score, class or index (ARMITAGE et al. 1983). The score systems, such as BMWP, require limited taxonomic precision, saving time and economic resources.

The main objective of the present study was to use an adaptation of the BMWP index (modified from JUNQUEIRA et al. (2000)) in the nearly pristine water conditions in the upper (Serra do Cipó National Park – SCNP) and in the anthropogenically influenced area of the middle Doce River basin in southeastern Brazil as a tool to evaluate ecosystem health.

Study area and methods

This study was developed in the upper and middle parts of the Doce River basin, Minas Gerais State, Brazil. The upper part from the 1st- to the 9th-order stretches, located inside the SCNP (19° 12'–19° 34' S, 43° 27'–43° 38' W), was studied. The middle part of the Doce River basin (19° 10'–20° 00' S, 41° 50'–43° 40' W) was also studied, and included seven sub-basins (Caraça Stream, Santa Bárbara River, Piracicaba River, Peixe River, Severo Stream, Ipanema River and Doce River). Benthic samples were collected in Serra do Cipó from 19 sampling stations at Indaiá Stream (1st–5th orders) and Peixe River (7th and 9th orders). The organisms were collected in triplicate from mosses, angiosperms, biofilm, filamentous algae and riparian vegetation using a Surber dredge (30 × 30 cm, 250-µm mesh). In the middle part, benthic samples were collected using a Petersen dredge (15 × 30 cm). Following sorting and identification using a stereomicroscope, the organisms were deposited in the Reference Collection of Benthic Macroinvertebrates of the Instituto de Ciências Biológicas/UFMG, Belo Horizonte. One hundred and eighty-seven samples on nine lotic systems were collected for the study. Details of river and site selection were given by BARBOSA et al. (1999) and CALLISTO et al. (2001). The sites in Serra do Cipó were sampled in the rainy and dry seasons of 2000, while the sites in the middle Doce River basin were sampled only in the rainy season of 2000. The scores used were those given by ALBA-TERCEDOR & SÁNCHEZ-ORTEGA (1988) and JUNQUEIRA et al. (2000) (Table 1). The physical features of the sites were recorded on standard forms at the time of biological sampling using the rapid characterization protocol of the hydrographic basin stretch ecological conditions (CALLISTO et al. 2000).

The BMWP system uses binary data and relies on taxonomic resolution only. Pollution-intolerant families receive high scores (e.g. Odontoceridae), whereas pollution-tolerant families are given low scores (e.g. Oligochaeta and Chironomidae) (JOHNSON et al. 1993). Some groups were not identified to family level, such as Hydracarina and Oligochaeta. The sum of the scores of individual families present in a sample yields the site score. The site score was divided by the number of scoring taxa in the sample, in order to reduce the sampling effort errors (see JOHNSON et al. 1993). The average score per taxon (ASPT) in each site was compared to the sum of the scoring families to confirm the utilization of the BMWP.

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Table 1. The BMWP score system used in the upper and middle Doce River basin.

Families	Score
Helicopsychidae, Odontoceridae, Hydroscaphidae, Grypopterygidae, Leptophlebiidae	10
Calopterygidae, Psephenidae, Libellulidae, Leptohyphidae, Perlidae	8
Veliidae, Leptoceridae, Polycentropodidae, Hydrobiosidae, Coenagrionidae, Glossomatidae, Hydroptilidae	7
Nepidae, Hydropsychidae	6
Naucoridae, Simuliidae, Gomphidae, Gerridae, Elmidae, Hydrophilidae, Baetidae, Corixidae, Tipulidae	5
Caenidae, Hydracarina, Dytiscidae, Corydalidae, Empididae, Ceratopogonidae	4
Thiaridae, Tabanidae	3
Chironomidae, Psychodidae	2
Oligochaeta (whole class), Culicidae	1

The data were analyzed using Statistica for Windows 5.1. Parametric tests were employed whenever their requirements were met. Quadratic transformations were used for some of the variables. BMWP, ASPT, and number of taxa were assessed using two-way nested ANOVA while density was analyzed using the Kruskall–Wallis test. The analysis of variance was applied to verify the significance of differences between the upper and middle Doce River basin.

Results and discussion

The results obtained from the rapid characterization protocol showed natural conditions in the sampling stations located inside the SCNP and in the stream inside the Caraça Park (Table 2). On the other hand, the sampling stations outside the SCNP and in the middle Doce River basin presented characteristics typical of altered and heavily impacted sub-basins (e.g. Piracicaba and Ipanema River).

The statistical treatments showed that all variables analyzed were significantly different between the upper and middle parts of the Doce River, reflecting the ecological conditions in the watershed (BMWP: $F = 49.87$, $P < 0.001$; ASPT: $F = 82.99$, $P < 0.001$; N taxa: $F = 28.10$, $P < 0.001$; density: $X^2 = 26.19$, $P < 0.001$). The comparison of the BMWP, ASPT, number of taxa, and density values between each sampling station in the upper and middle parts of the Doce River basin showed that they were not were not significantly different ($P > 0.05$). In the upper part, the highest BMWP scores were found for the whole basin, suggesting good water quality and ecological characteristics that were near 'pristine' conditions, reflecting well-preserved ecosystem health (GALDEAN et al. 2000). Some ecological characteristics are very peculiar in each sampling station and are closely related to the ecosystem health. In the 1st-order stretch, there are many pools with FPOM and filamentous algae that are used by aquatic insects as refuge zones against large predators (e.g. dobsonflies and odonates) and also as hatching grounds (e.g. mayflies). On the other hand, the low score of the 2nd order can be explained by the oligotrophic conditions, lack of shading, minimum input of allochthonous detritus, the near absence of autochthonous primary producers, homogenous stony substrata and low diversity of habitats to be colonized. There is an increase in the scores at the 3rd and 4th orders due to the streambank surfaces being covered by native vegetation, which contributed to an input of allochthonous organic matter (e.g. litter, small fallen logs and sticks). Patches of boulders, gravel, bedrock, cobble and pebbles covered by biofilm and mosses are also important factors in determining the local benthic communities. Despite having been classified as altered stretches by the rapid characterization protocol, the 7th and 9th stretches received high BMWP scores. The presence of organic loads, mainly from surrounding farm lands and cattle farms, is responsible for this characterization. The

Table 2. Results of the rapid characterization protocol of the ecological conditions, BMWP score, number of taxa, and density (mean and variance) in the upper and middle Doce River basin.

Sites	Protocol	BMWP	ASPT	N taxa	Density
Indaiá Stream – 1st order	Natural	209	11.6	20	7500 ± 4009.5
				21	8860 ± 6677.4
Indaiá Stream – 2nd order	Natural	64	5.8	13	22,100 ± 24,683.6
				04	9850 ± 10,315.8
Indaiá Stream – 3rd order	Natural	97	6.1	12	14,833 ± 2800.6
				18	8633 ± 1747.4
Indaiá Stream – 4th order	Natural	127	6.3	21	6783 ± 5818.4
				14	4150 ± 4363.8
Indaiá Stream – 5th order	Natural	116	5.5	19	14,989 ± 16,975.7
				21	20,044 ± 17,152.9
Peixe River – 7th order	Altered	143	5.7	11	13,766 ± 9,511.7
				24	30,844 ± 22,127.8
Peixe River – 9th order	Altered	125	5.7	15	1642 ± 782.8
				21	7053 ± 7950.1
Caraça Stream	Natural	35	3.9	09	2329 ± 3039.2
Santa Bárbara River	Altered	63	5.2	12	221 ± 257.8
Piracicaba River	Altered	32	4	09	6943
Peixe River	Impacted	19	3.8	05	425.8 ± 387.1
Severo Stream	Impacted	53	4.4	12	5061.6 ± 2477.3
Ipanema River	Impacted	10	2.5	04	3241.7
Doce River	Impacted	28	4	05	1098.2 ± 454.4

Peixe River at the 7th order stretch was wider, had fast current and had a greater amount of aquatic macrophytes, mosses and biofilm, and therefore contributed to the maintenance of the benthic macroinvertebrate communities (directly related to the high BMWP score).

The main anthropogenic influences in the middle Doce River are the presence of cattle farms, mining, iron/steel plants, *Eucalyptus* plantations and the cellulose industry (Barbosa et al. 1999). Furthermore, the low water quality and sandy substrata with high organic matter of anthropogenic origin (domestic sewage, hospital waste) led to the lowest scores. In these sampling stations the highly tolerant oligochaetes and chironomids dominated and influenced the lowering of the scores, hence indicating that the ecosystem health had deteriorated (see Barbosa et al. 2000).

Ecological relationships may exist between the number of species and the BMWP scores. The use of biotic indices reflects altered features in the river bottom and margins (habitat diversity), as well as physical and chemical characteristics, which can be related to the benthic species composition and community structure. In other words, high BMWP evaluations suggest great freshwater biodiversity.

Balancing ecological destruction and restoration, or even increasing the rate of ecological restoration relative to the rate of ecological destruction, will require substantial behavioral changes on the part of political organizations and individuals (Cairns 1999). The use of the adapted BMWP index in the upper and middle Doce River basin showed that biotic indices can be an important and valuable tool in determining ecosystem health in long-term biomonitoring programs. This approach provides a means for the local environmental agencies for the conservation of the natural freshwater resources and the management and restoration of impacted areas. The present study also assures and encourages others on the importance of monitoring efforts and the restoration of anthropogenically induced damages in freshwater ecosystems.

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