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Lotic ecosystems of Serra do Cipó, southeast Brazil: water quality and a tentative classification based on the benthic macroinvertebrate community

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Abstract

A general characterization of the water quality of representative rivers of Serra do Cipó, State of Minas Gerais, Brazil is provided as well as the composition and distribution of benthic macroinvertebrates, mainly Plecoptera, Ephemeroptera, Trichoptera and Diptera (Chironomidae). These data are used as a basis to propose a river classification for the area, comprising three major categories: undisturbed waters (Class 1), with no evidence of human influences and showing high taxa richness; waters with intermediate disturbances (Class 2), showing some degree of change in the quality of their trophic resources, due mainly to the influence of human activities (e.g., deforestation, sewage discharges); and disturbed waters (Class 3), showing evidence of eutrophication, although still preserving some diversity of benthic organisms. This proposed classification system, although broad and simple, is believed to provide the necessary basic scientific information to allow for definition of conservation policies in the area, thus contributing to the preservation of rivers and their associated biota.

Keywords: Biodiversity; River classification

1. Introduction

The adoption of the watershed as a unit, including the relationships between the aquatic and surrounding terrestrial ecosystems, together with socio-economic and cultural aspects, is essential for the definition of policies and strategies for conservation and management of the environment (Tundisi and Barbosa, 1995). Keeping this in mind, the distribution and utilization of trophic resources by benthic macroinvertebrates from some rivers in Serra do Cipó were assessed in order to understand the status of the aquatic resources of the area.

The lotic ecosystems of Serra do Cipó belong to two of the most important watersheds in Brazil: the Doce and São Francisco rivers. Within these two watersheds, some regions are in 'nearly' pristine conditions (e.g., Indaiá and Congonhas streams, located within the Serra do Cipó National Park) while other regions (rivers Cipó, Peixe, and Preto do Itambé) have been affected by human activities to varying degrees. The most important impacts are related to past deforestation, disposal of untreated organic sewage from riverine human populations,

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cattle ranching, and use of the land for agricultural practices. No region, however, has suffered heavy impacts.

Communities of benthic macroinvertebrates can reflect some of the main processes of river ecosystems when existing knowledge (taxonomy, ecology, and zoogeography) of the main groups (Plecoptera, Ephemeroptera, Trichoptera and Diptera-Chironomidae) comprising these communities we can also use the distribution data of different groups in an aquatic basin to predict the status of the community and of the ecosystem based upon the assessment of community structure. Anthropogenic influences upon lotic ecosystems have been increasing worldwide. These influences change the energy flux of the system by modifying the riparian vegetation and, consequently, affect the input of allocthonous matter, thus affecting nutrient cycling (Hildrew and Giller, 1995; Raffaelli et al., 1995).

The present study is aimed primarily to: (i) assess the present health of representative aquatic ecosystems of Serra do Cipó; (ii) propose a classification of the rivers based on the distribution of benthic macroinvertebrates; and (iii) predict the potential changes caused by the economic development of the State of Minas Gerais.

2. The study area

Serra do Cipó is located in the central part of the State of Minas Gerais (19–20°S; 43–44°W), dividing two important watersheds: the São Francisco and Doce rivers. The characteristic vegetation in the area is predominantly high rupestrian fields (regionally called 'campos rupestres' and, in the lower areas (<1000 m), savanna (locally called 'cerrado') predominates. The area contains several rivers, streams, creeks, and during the rainy season, some ponds. The dark color of the waters suggests considerable amounts of humic substances, which are probably a consequence of the contribution of the riparian vegetation. Despite existing seasonal differences, the waters in the area can generally be classified as clean, not showing any particularly important contamination (Maia-Barbosa et al., 2000). Furthermore, they are probably of low autochthonous productivity, depending greatly on allocthonous material to enhance the normally limited phosphorus levels (maximum recorded values of 80.3 $\mu g\, l^{-1}$ total P (TP)).

In a preliminary survey of these waters Maia-Barbosa et al. (2000) pointed out their high quality due to the minimum human impacts and the existence of Serra do Cipó National Park. Such waters are unfortunately under threat due to the growing need for good quality potable waters and the relative proximity of Belo Horizonte, the State capital. This city, located ca 130 km southward, is growing rapidly and is relatively short of alternative water sources, features likely to bring some extra pressure on the waters of Serra do Cipó and their future quality (Fig. 1).

3. Material and methods

Benthic samples were collected from 18 sampling stations at rivers Cipó, Peixe, and Preto do Itambé, and streams Indaiá and Congonhas, during the rainy (February) and dry (May) periods of 1997. Organisms were collected from stones, mud, leaves, moss, aquatic macrophytes and sand by hand and with a dredge. Following collection, samples fixed in 10% formalin. At the laboratory, samples were washed through a 0.125 mm sieve, using tap water. After sorting and identification the organisms were fixed with 70% alcohol and deposited in the limnological collection of the Federal University of Minas Gerais.

In the same areas, physical and chemical parameters were measured (using a Hydrolab multiprobe apparatus) in order to assess water quality. The following variables were measured: water temperature, pH, conductivity, dissolved oxygen, and redox potential. Water samples were taken to the laboratory to determine the concentrations of total nitrogen (TN), total phosphorus (TP), soluble reactive phosphorus (SRP), ammonium-, nitrite-, nitrate-nitrogen and soluble reactive silica according to Golterman et al. (1978) and Mackereth et al. (1978).

Each of the taxonomic groups (Plecoptera, Ephemeroptera, Trichoptera, and Diptera-Chironomidae) was characterized according to trophic necessities based on laboratory analyses, field observations, and the available literature (Wiederholm, 1983; Merritt and Cummins, 1988; Epler, 1995; Pescador, 1997).

Fig. 1. Map of Serra do Cipó, southeast Brazil, showing the distribution of the studied rivers within the two watersheds.

Additionally, taxonomic composition and genera richness were assessed.

4. Results and discussion

4.1. The present quality of the waters

The waters in Serra do Cipó are, in general, somewhat dark colored, reasonably well oxygenated (53–136% saturation), of low conductivity (<20 $\mu S\ cm^{-1}$, except for the Cipó river, where conductivity can reach up to 82.1 $\mu S\ cm^{-1}$ during the rainy period), and pHs between 3.83 and 8.81 during the dry and rainy periods, respectively. Ammonium-nitrogen was usually the dominant ion during the rainy period, with values ranging between 31.4 and 588.4 $\mu g\ l^{-1}$ (a value of 972.1 $\mu g\ l^{-1}$ was recorded at stream Indaiá, while during the dry period nitrate-N reached up to 236.7 $\mu g\ l^{-1}$ (river Preto do Itambé). The SRP levels are characteristically low (<20 $\mu g\ l^{-1}$) although values as high as 139.4 $\mu g\ l^{-1}$ were recorded during the rainy season at Peixe river. Total N levels ranged between 6.1 $\mu g\ l^{-1}$ (Indaiá stream) up to 1077.8 $\mu g\ l^{-1}$ (Peixe river) and TP concentrations were usually below 50 $\mu g\ l^{-1}$ although

the concentration reached 80.3 $\mu g\, l^{-1}$ in the Peixe river during the dry period of 1997. The prevailing low concentrations suggest the existence of P limitation in several of the environments (Maia-Barbosa et al., 2000). Soluble 'reactive' silica varied considerably, reaching up to 57.8 $mg\, l^{-1}$ at Tanque river and 53.8 $mg\, l^{-1}$ at Cipó river during the rainy season of 1997.

4.2. Composition and distribution of benthic macroinvertebrates

Each river showed biological patchiness, with different types of communities distributed in different substrates and microhabitats.

Plecoptera are very primitive aquatic insects, found only in waters of very good quality. Specimens belonging to the suborder Antarctoperlaria (family Gripopterygidae) and Arctoperlaria (family Perlidae) were collected. The former are restricted to gondwanian areas (= South American), and species of the subfamily Gripopteryginae are exclusively South American (Fittkau et al., 1969; Banarescu, 1990). Species of the family Perlidae were present in the majority of the sampling points with low densities (50 ind m^{-2}), while those of the family Gripopterygidae were restricted to the Indaiá stream (50 ind m^{-2}) (Table 1). The presence of the latter family suggests pristine conditions.

The main families of Ephemeroptera (in terms of frequency and abundance) in the study area were primarily Leptophlebiidae (*Farrodes, Thraulodes, Hermanella, Hyllister, Dactylophlebia, Masartella*), followed by Baetidae, especially the genera *Baetis, Baetodes* and *Camelobaetidius*. All are generally associated with aquatic macrophytes. The family Tricorythidae (*Leptohyphes* and *Trichorythodes*) was not abundant despite habitats rich in fine particulate organic matter.

The presence of the family Oligoneuriidae (*Spaniophlebia*) is restricted, depending upon a very special biotope (rounded boulders with a layer of periphyton). Only a small population in the Cipó river was found, associated with other mayflies, Trichoptera, Plecoptera and Coleoptera. According to Galdean (1997) a restricted distribution such as seen here may be used as an indicator of stable conditions of the habitat.

In general, Trichoptera are more diverse and tolerant to a wider range of conditions than Plecoptera and Ephemeroptera, having different feeding strategies, and using different trophic resources. Among the identified taxa in Serra do Cipó the most important family is Hydrobiosidae, which has a Gondwanian distribution. This family was present in small numbers, especially in the Indaiá stream.

Another important group is the family Hydropsychidae, especially the genus *Leptonema,* which has an Inabrezian distribution (Banarescu, 1990). This genus contains species which are filtering collectors and are indicative of the quantity and quality of the suspended organic particles.

From a zoogeographical and ecological point of view, the understanding of the competition between the gondwanian groups and those which are North American or widespread is very important. The presence of the first group may reveal the preservation of natural conditions, while a prevalence of the second suggests changes in the aboriginal fauna. Typical representatives of pristine conditions are Plecoptera (Gripopterygidae), Ephemeroptera (Leptophlebiidae) and Trichoptera (Hydrobiosidae and Hydropsychidae (genus *Leptonema*).

Chironomids were present at all sampling stations. The distribution of the genera depends on the availability of trophic resources (e.g., moss, filamentous algae, fine particulate organic matter and leaves), and they are involved in the main processes of benthic communities. In the streams Congonhas and Indaiá high genus richness was recorded (respectively, 35 and 44 genera belonging to Tanypodinae, Orthocladiinae and Chironominae sub-families), especially those indicating oligotrophic conditions, of which various Tanytarsini and *Thienemanniella* are examples. The Orthocladiinae genera (*Cricotopus, Corynoneura* and *Nanocladius)* were also numerically important, probably due to the high altitude of the area (Cranston, 1995), a situation not common in other regions of Brazil as it is in Amazonian lotic ecosystems (Callisto, 1997; Callisto et al., 1998a,b). In the stream Congonhas, where prevailing water temperatures were low, the presence of the genus *Cricotopus* in high numbers represented the normal reaction of the ecosystem to the development of an important trophic resource, in this case blue-green filamentous algae colonizing the surfaces of the

Table 1
Density (ind m^{-2}) in rainy and dry seasons of 1997 in Tanque river, Peixe river, Preto do Itambé river, Congonhas stream, Indaiá stream and Cipó river (Ra: rainy season; Dr: dry season; A: Sumidouro locality; B: Pirapama locality; C: Santana do Riacho locality; D: Duas Barras locality)

	Tanque		Peixe		Preto do Itambé		Congonhas		Indaiá		Cipó			
Taxa	Ra	Dr	Ra	Dr	Ra	Dr	Ra	Dr	Ra	Dr	A	B	C	D
Turbelaria	50									50			50	
Oligochaeta	500	50	50		200	50		50			50	50	50	50
Bivalvia														
Sphaeriidae	800			50		50						50		
Unionidae												50		
Crustacea														
Decapoda											50		50	
Plecoptera														
Perlidae		50		50	50		50	50	50		50	50	200	
Gripopterygidae									50	50				
Ephemeroptera														
Oligoneuriidae														
Spaniophlebia													50	
Baetidae														
Baetis	800	500	50	500	50	200	200	200	200	200	50	200	50	50
Baetodes							50	200	50	50	50		50	
Camelobaetidius		500	50					50	50	50		50	50	
Cloeodes		50	500		200		200		50					
Leptophlebiidae														
gr. *Farrodes*	50	200	200	50	200	50	50	50	50	50	200	500	500	
gr. *Hermanella*									200	200	50		50	
Leptohyphidae	50	200	50	50	50	50	50	50	50	50	50	50	200	
Polymitarcyidae					50	50								
Heteroptera														
Naucoridae	50	50	200	50	200	50	200	50	50	50	50	50	50	
Megaloptera		50				50	50		200	200	50			
Trichoptera														
Calamoceratidae														
Phylloicus							50	50						
Hydropsychidae														
Smicridea	50	200	50		50				500	500	500	50	500	
Leptonema			50											
Helicopsychidae														
Helicopsyche		50						50	200	200	200			
Hydrobiosidae														
Atopsyche		50						200	50					
Leptoceridae														
Triaenodes	500		50		50				500		50			
Nectopsyche	200		50	50	200			200			50	50		
Grumichella									500	500				
Oecetis												50		
Odontoceridae														
Marilia								200	50	50		50		
Barypenthus							50	50						
Philopotamidae														
Chimarra		200						50		50	50		200	
Polycentropodidae														
Cyrnellus														
Polycentropus												50		
Hydroptilidae														
Oxyethira		50		50			200	50						50
Ochrotrichia		50		50				50	500	200				
Hydroptila								50						
Lepidoptera					50		50	200	500	50	50			50
Diptera														
Simulidae		800	50	50	50	50	50	200	200	500	50	200	50	50
Chironomidae	500	500	500	500	500	500	500	500	500	500	500	500	500	500

stones. In the stream Indaiá, the carnivorous *Ablabesmyia* and *Larsia* were the major organisms regulating abundances of Tanytarsini (together with Megaloptera, mainly Corydalidae) since Tanytarsini larvae were present in their gut contents as seen via microscopic examination.

In the river Cipó, Chironominae genera were numerically dominant, their abundance being especially related to the amount of detritus (*Chironomus* and *Polypedilum*), or associated with the riparian vegetation, which is washed out by the flowing water (*Stenochironomus*, *Goeldichironomus, Rheotanytarsus* and *Fissimentum*). Likewise, in the rivers Peixe and Preto do Itambé, Chironominae genera were prevalent (*Goeldichironomus, Stenochironomus, Polypedilum, Chironomus, Fissimentum, Glyptotendipes* and various Tanytarsini). These organisms depend on the fine and ultra-fine particles of organic matter available on top of the sandy substratum.

The phytophilous fauna (sensu Staicu, 1997) in the rivers Peixe and Preto do Itambé reflects the reaction of the ecosystems to the presence of excessive amounts of nutrients (Allan, 1995). According to our observations, these rivers have different compositions of trophic groups depending on which aquatic macrophytes are present. The Peixe river contains many carnivorous groups: Turbelaria, Plecoptera (Perlidae), Odonata, Megaloptera, Coleoptera, Trichoptera (Odontoceridae, Polycentropodidae, Hydrobiosidae), chironomids *Larsia, Ablabesmyia* and *Tanypus*. Furthermore, there are groups capable of using periphyton and detritus, such as Ephemeroptera (Leptophlebiidae and Baetidae), chironomids (*Stenochironomus, Endochironomus, Goeldichironomus*), and filtering collectors Trichoptera Hydropsychidae and Diptera Simuliidae.

This high diversity underscores the ability of the communities, especially the macroinvertebrates, to use available trophic resources. On the other hand, in the Preto do Itambé river, there is a relatively low diversity, dominated by Ephemeroptera (Baetidae, genus *Baetis* (very competitive), and Chironomidae (Tanytarsini, *Rheotanytarsus*) and *Thienemaniella*). Finally it must be mentioned that the presence in both rivers of the mayfly genus *Dactylophlebia*, usually characteristic of cold waters (Pescador and Peters, 1980), is a very important indicator of good environmental quality.

4.3. A proposed river classification

Based on the recorded data a classification of the rivers or sectors of the studied rivers into three major categories or classes may be proposed. (a) Class 1, represented by those environments in which practically no human influence can be detected, possessing unchanged natural conditions, probably close to 'quasi- pristine' conditions. These areas show high taxa richness (Table 2), with taxa of special zoogeographical significance present. The streams Indaiá and Congonhas are examples. (b) Class 2, represented by rivers or sectors of rivers where some degree of human impacts can be detected, resulting in some degree of change in the quality of the waters and their trophic resources. Environments in this category are mainly impacted by deforestation and untreated sewage discharges from surrounding small farms, and demonstrate the onset of eutrophication. However, these environments preserve a reasonable richness of benthic macroinvertebrate taxa, of which *Chironomus, Endochironomus* and *Polypedilum* are examples. The rivers Peixe and Preto do Itambé are the examples found in the study area. (c) Class 3, represented by rivers or sectors of rivers under

Table 2
Richness (R) and Shannon diversity index (H') calculated for the three classes of rivers in the Cipó river: A, Sumidouro locality; B, Pirapama locality; C. Santana do Riacho locality; D, Duas Barras locality

	Class 1				Class 2				Class 3			
	Indaiá		Congonhas		Peixe		Preto		Cipó			
	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	A	B	C	D
R	65	63	49	56	23	21	21	17	18	16	15	6
H'	3.66	3.54	3.26	3.72	2.07	1.78	2.30	1.79	1.38	1.26	1.25	1.17

permanent impact from farm lands and sewage discharges from small villages. The result is higher levels of eutrophication, though some diversity of benthic organisms is still preserved. In this type of environment the water quality is lower and the available trophic resources are mainly dominated by production of the existing phytobenthos (filamentous algae and mosses), which is guaranteed by the relatively high nutrient content of the waters, low depth and sufficient light. Furthermore, there is a remarkable quantity of fine and ultra fine particles accumulated on the surface layer of the sediments, which are used by the gathering and filtering collectors (Hydropsychidae, Leptophlebiidae, *Farrodes*) and detritivores (Chironominae). The Cipó river falls into this category, particularly the localities of Santana do Pirapama, Santana do Riacho, Duas Barras and Sumidouro.

Considering the economic development in the area and the recorded data, predictions on the ecological evolution of the studied rivers are possible and necessary for conservation purposes. Therefore, it can be asserted that if the present conditions of the biotopes are maintained (extension of riparian vegetation, used levels of fertilizers, impacts of tourism and cattle ranching) the lotic ecosystems in the area are very likely to remain relatively unchanged, particularly those included in Class 1 which are protected within the Serra do Cipó National Park. On the other hand, considering the likely changes due to the development of the surrounding villages, increased agricultural activities, pasture lands and growing water demands, a gradual increase in eutrophication of rivers or sectors of rivers in Classes 2 and 3 is likely to occur, with consequent reduction in water quality and threats to the present biodiversity through the promotion of opportunistic species capable of quickly using the available resources (e.g., algae, primary production, and ultra fine particulate organic matter).

Management of the aquatic resources is then a necessity in order to maintain water quality. The results of the present study can be used as an instrument to assess the present biodiversity and thus represents an aid in conserving the existing rivers' benthic fauna. Furthermore, this classification system, besides providing basic information on present environmental conditions, may also be a useful tool in defining a monitoring program for the area. It may also contribute to the definition of policies, and to assisting decision-makers in the selection of areas where sustainable uses of water resources are feasible, thus allowing for the preservation of 'quasi-pristine' water bodies for future generations.

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