Adaptation of a rapid assessment protocol for rivers on rocky meadows

Adaptação de um protocolo de avaliação rápida para rios em campos rupestres

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Abstract: This work aims to adapt a rapid river assessment protocol to be used in rocky meadows of Minas Gerais State highlands, taking as a "reference situation" the environmental conditions found inside the Itacolomi State Park in Ouro Preto (Minas Gerais, Brazil). Similar protocols have been used in the United States, Great Britain and Australia in water resources monitoring programs. The following parameters were proposed: substrates and/or habitats available; substrates in pools; embeddedness; speed/depth regimes; diversity of pools; sediment deposition; channel flow status; channel alteration; channel sinuosity; frequency of riffles; bank stability; vegetation protection and nearby channel vegetation status. For each parameter, a rank from 0 to 20, corresponding to the environmental condition, was attributed and the values were distributed according to the environmental stress gradient verified at the evaluation site, which varied from "poor", "regular", "good" to "excellent". After the adaptation of the protocol, an environmental monitoring workshop was offered to volunteer students. In order to evaluate applicability, clarity and possible inadequacy of the parameters proposed, 42 volunteers were selected in order to apply the protocol in two selected sections of the study area. The volunteers' response pattern was consistent, reflecting good understanding of the parameters proposed. In summary, adaptation and use of the protocol can be considered steps for the preservation of water resources. It can also be useful in environmental impact assessment studies of degraded areas (inserted in the studied environmental context) and as a tool to be used by the community in managing and monitoring of water resources.

Keywords: monitoring, environmental evaluation, management, water resources, habitat.

Resumo: Este trabalho visou adaptar um protocolo de avaliação rápida para trechos de rios de alto e baixo curso inseridos em campos rupestres tomando-se como "situação referência" as condições ambientais encontradas no interior do Parque Estadual do Itacolomi, Ouro Preto-MG. Protocolos similares têm sido empregados em programas de monitoramento de recursos hídricos em países como Estados Unidos, Grã-Bretanha, Canadá, Alemanha e Austrália. Os parâmetros propostos foram: substratos e/ou habitat disponíveis; substrato em poços; soterramento; regimes de velocidade/profundidade; diversidade de poços; deposição de sedimentos; condições de escoamento do canal; alterações no canal; sinuosidade do canal; freqüência de corredeiras; estabilidade das margens; proteção das margens pela vegetação e estado de conservação da vegetação do entorno. Para cada parâmetro uma pontuação, entre 0 e 20 pontos, correspondente à condição ambiental é atribuída e os valores são distribuídos de acordo com o gradiente de estresse ambiental verificado no local da avaliação, podendo variar desde uma condição considerada "ótima", até uma condição "péssima", passando por situações intermediárias "boa" e "regular". Após a adequação do protocolo foi realizada uma oficina de monitoramento ambiental em que 42 voluntários aplicaram o protocolo em dois trechos selecionados na área de estudo, a fim de realizar uma avaliação do método quanto à aplicabilidade, clareza e possíveis inadequações dos parâmetros propostos. A análise do padrão de respostas dos voluntários mostrou-se consistente, refletindo um bom entendimento dos parâmetros. A adequação e a utilização do protocolo podem ser consideradas etapas para a preservação de recursos hídricos, podendo ainda ser utilizado em estudos de avaliação de impacto ambiental em áreas degradadas (inseridas no contexto ambiental estudado) e como ferramenta que permite a participação social no processo de gerenciamento e monitoramento dos recursos hídricos.

Palavras-chave: monitoramento, avaliação ambiental, gerenciamento, recursos hídricos, habitat.

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1. Introduction

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) the Earth's freshwaters represent only 2.7% of the total water availability. Most part (77.2%) of this small value is found in polar caps, glaciers and icebergs, and the rest is distributed as follows: 22.4% stored in aquifers and groundwater; 0.36% in rivers, lakes and swamps, and 0.04% in the atmosphere. With the increase in population and consequently in pollution and degradation of existing water bodies, the amount of freshwater available for human use has been intensively and drastically decreased (Tundisi, 2003). According to the United Nations Organization (UNO), if urgent measures are not taken to rationalize the use of water resources, 60 countries will suffer from water scarcity in the year 2050 (PNUD, 2003).

The degradation of water resources has been detected and changes, both institutional and in the legislation, have been demanded. The indiscriminate use of river systems has ecological changes as direct consequence, causing serious modifications in the landscape and fluvial regime, besides altering the availability of habitats and the trophic composition of the aquatic environment (Brigante et al., 2003).

Pressed by this scenario, scientists have been developing assessment methods that are efficient both for the evaluation itself and the assistance for decision taking in the environmental management processes. The rapid river assessment protocols (RAP's) are inserted in this context and evaluate in an integrated form the characteristics of a river section according to the conservation or degradation condition of fluvial environment.

1.1. Rapid river assessment protocols (RAP's)

RAP`s were created in the mid-1980s in the United States, at a time when the environmental organizations noticed that qualitative evaluation methods should be established as an alternative to high cost and delay of the quantitative researches. In answer to the report from the US Environmental Protection Agency "Surface Water Monitoring: A Framework for Change" (EPA, 1987), which emphasized the reorganization of the monitoring programs in practice, a document by Plafkin et al. (1989) was published establishing the first protocols. According to the authors, these protocols aimed to provide basic data on the aquatic life to evaluate water quality and to assist in the management of water resources.

From 1989 on, discussions have intensified on the importance of the use of integrated criteria to evaluate the quality of water resources and use of methods that encompass these criteria. At present RAP's are used in Canada, Germany, Australia and Great Britain. The Australian government, for example, has developed a program called "Australian River Assessment System" (AusRivAS) to assess the "health" of Australian river systems, which included monitoring of lotic ecosystems by means of RAP`s (Parsons et al.., 2002). In Brazil, the technique is still restricted to projects developed in universities, e.g. Callisto et al. (2002), Ferreira (2003), Upgren (2004), Minatti-Ferreira and Beaumord (2006) and, Rodrigues (2008).

To develop a RAP, a natural condition is firstly established, based on values obtained from localities considered the least perturbed and taken as "reference" (Plafkin et al., 1989). The starting premise takes into account that the less the water courses are affected by man the more favorable the environmental conditions will be (Minatti-Ferreira and Beaumord, 2004). Then, the parameters to be assessed, the environmental condition categories to be checked in the localities to be evaluated and the scores related to each parameter are established. After previous training, the evaluators go to the field and the protocols, adjusted to the regional particularities, are applied with no need of technological apparatus. The scores attributed to each parameter indicate the "condition" of the system. Higher scores reflect a good conservation state, whereas lower scores indicate degradation. The final result is obtained by adding the scores attributed to each parameter. It will reflect the level of environmental integrity of the section of the basin selected for study.

1.2. The quality of the habitat and biologic condition

The maintenance of an aquatic ecosystem structure depends, among others, on the water quality, energy sources, bankfull stage regime, biotic interactions and the quality of the habitats. A change in only one of these determinants will be able to reflect changes in others and modifications of the habitat structure, thus limiting the biotic integrity of these ecosystems (Gorman and Karr, 1978; Karr and Schlosser, 1978; Karr and Dudley, 1981).

Assuming that the water quality remains constant, a relationship between the quality of the habitat and the biologic conditions of a lotic ecosystem can be predicted. According to Barbour and Stribling (1991), this relationship can be easily detected by means of a graphic representation in which a sigmoidal curve indicates to which extent the quality of the environment is related to its biologic conditions or how much it can affect the aquatic communities.

The change in the quality of the habitat is represented by the x-axis of the graph, which can vary from "poor" to "excellent", according to a "reference" condition previously established. In the y-axis the change in the biologic condition corresponding to the quality of the habitat observed is represented. Thus, both the quality of the habitat and the biologic condition can vary from 0 to 100% in relation to the "reference" condition, being categorized in different environmental integrity levels (Figure 1).

The curve is divided in three 3 parts. The first, which is the upper part of the curve, reflects a situation in which the habitat physical quality and the biologic condition of the study section are considered "excellent" and undamaged

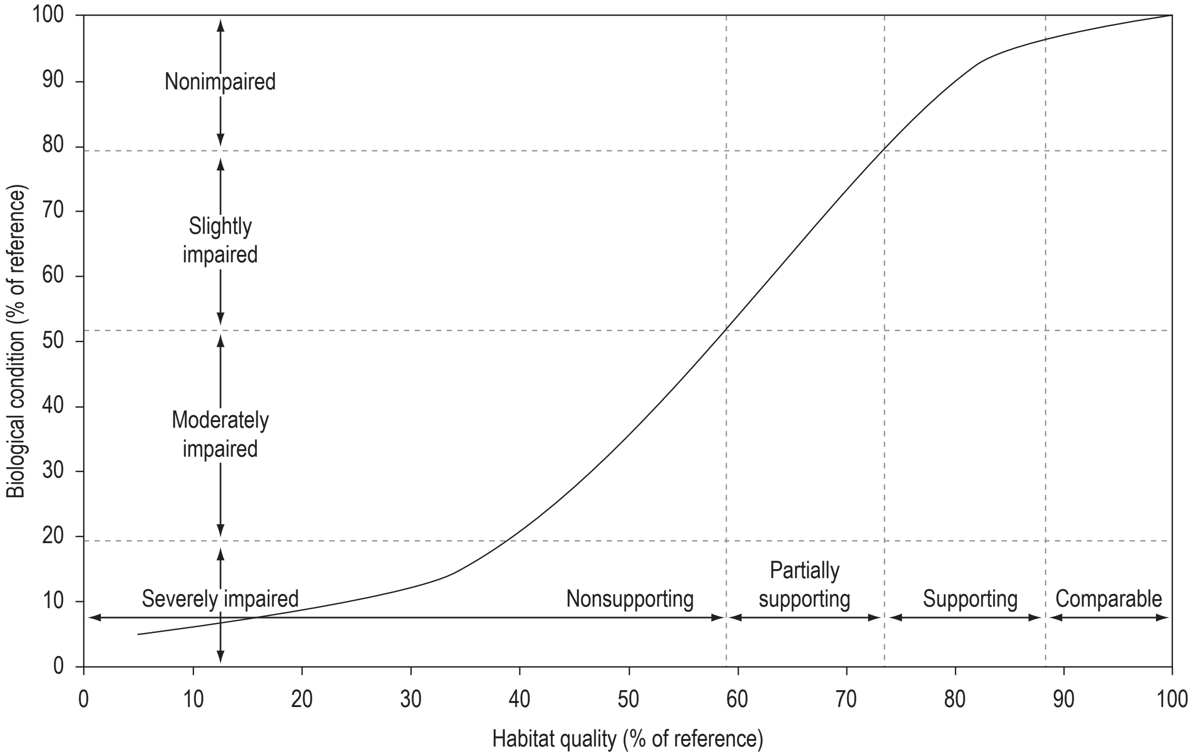

Figure 1. Relation between habitat physical quality and biologic condition of an aquatic ecosystem. Modified after Barbour and Stribling (1991).

when compared to the "reference" condition. In this case, minor variations can occur in the quality of the habitat without a significant reduction of the biologic condition. It is possible to observe in the second part or in the middle of the curve that a decrease in the biologic condition corresponds to a decrease in the quality of the habitat, in other words, as it decreases the biologic condition decreases concomitantly. In the lower part of the curve, the quality of the habitat is considered "poor", and the environmental degradation in the study section affects drastically the biologic condition. The biologic communities found in these situations are considered tolerant, opportunist and can resist to highly variable conditions.

In view of the ecological, economic, and social characteristics, the continental aquatic environments are important. Therefore, is necessary to include comprehensive and interactive factors in the assessment of these environments, which aim to cover a wide range of river characteristics in analysis. Thus, this work presents a rapid river assessment protocol for physical aspects of the habitat adjusted to the water courses on rocky meadow, considered by some authors as a phytophysiognomy of the biome *savanna*. Considering the countless environmental degradation processes involving water resources, it is essential that a viable and low-cost tool is made available to the society, which can evaluate in an integrated form the "health" of a fluvial ecosystem. Such tool will also help to promote the insertion of the community in the management and monitoring of national water resources.

2. Study Area

To elaborate the RAP proposed in this study, the Itacolomi State Park (PEIT) was chosen as the "reference" area. PEIT was opened to the public in May, 2004 and is located in the southeastern region of Minas Gerais State, in the Ouro Preto and Mariana municipalities, between meridians 43° 32' 30" W and 43° 22' 30" W and parallels 20° 22' 30" S and 20° 30' 00" S. It covers 7,543 ha and includes the Itacolomi Ridge, which is part of the Espinhaço Chain (Figure 2).

Part of the watercourses that cross the park belong to Carmo River basin, which in turn is a tributary of the Doce River. The latter constitutes the fifth largest hydrographic basin of Minas Gerais, covering an area of 83,400 km^2. Several environmental degradation processes can be observed in the Doce river basin.

In phytophysiognomic terms, PEIT is characterized by the presence of rocky meadows composing the southern limit of the Espinhaço Chain. The predominant vegetation is dirty or clean prairie, depending on the soil, water availability, altitude and relief (Lima et al., 2007). The dirty prairie phytophysiognomy is characterized by a dense herbaceous cover, mainly grass, on which sub-shrubby, shrubby and also small, up to 3 m tall woody individuals occur. The clean prairie

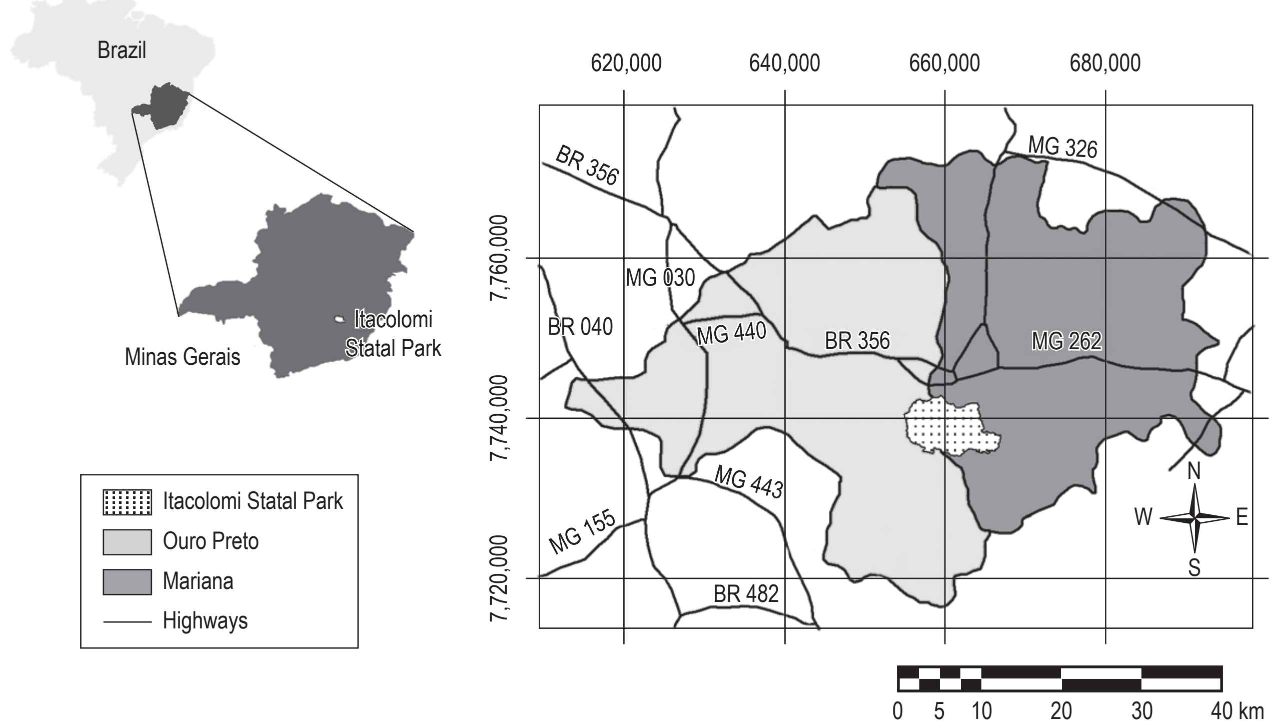

Figure 2. Map showing the location of the study area and the limits of the Itacolomi State Park, Ouro Preto/Mariana, MG. Modified after IBGE (2006).

phytophysiognomy is characterized by herbaceous vegetation with rare shrubs and no trees, and is found above 1,200 m a.s.l. (Rizzini, 1997; Tannus and Assis, 2004).

3. Material and Methods

3.1. Bibliographic and cartographic research on the study area

The first step comprised a bibliographic research on the study area involving: i) types of (natural or modified) plant cover; ii) water conditions; iii) morphopedologic, geologic and lithologic units; iv) agricultural and/or urban occupation; v) routes and vi) areas under environmental impact.

The cartographic analysis was based on aerial photographs in the 1:25,000 scale obtained from the cartographic collection of the Universidade Federal de Ouro Preto (UFOP), as well as (geologic, hypsometric, lithologic, declivity, vegetation and hydrologic) maps obtained from the (unpublished) PEIT Management Plan. This analysis helped the assessment of the geographic positions and geomorphologic and ecomorphologic aspects of the drainage basins and their watercourses, besides the identification and selection of the sections of the rivers studied.

3.2. Selection of points, application and adaptation of the model protocol

During the bibliographic research, a document by Barbour et al. (1999) was analyzed and taken as a model of compilation of several rapid assessment methods of existing rivers used throughout the United States by several state environmental agencies. Thus, this paper was adopted as a model protocol for this study.

To check the applicability of this model protocol to regional phytophysiognomic particularities, intensive field work was carried out in order to establish the environmental stress gradient to be used for the assessment of the river sections.

A total of 32 points were chosen based on their ecomorphologic characteristics – including local geology, vegetation, relief and the gradients of the water courses – and on their environmental conditions. The accessibility to the sections was a determining criterion for their selection. Once inadequacies of certain factors considered in the model protocol were identified, which included the descriptions of some parameters, the form to assess the physical aspects of the river section habitat inserted in regional phytophysiognomic particularities, or the need to include other parameters, adaptations were made and a new protocol was proposed.

3.3. Environmental monitoring workshop

After the adjustment of the model protocol, an environmental monitoring workshop was offered at the Exact and Biologic Sciences Institute – ICEB/UFOP and at PEIT involving the application of RAP's. The results from the workshop were used to calibrate and evaluate the applicability of the adjusted protocol. 42 volunteers (University students from several courses) attended the workshop and applied the adjusted RAP's to two different river sections inside PEIT. 21 evaluators applied the adjusted protocol to the upper- and other 21 to the lower-river sections.

3.4. Data analysis of the environmental monitoring workshop

To consolidate the adjusted protocol the analysis and interpretation of the response pattern obtained during the environmental monitoring workshop were carried out. The analysis of a pattern of similar responses was carried out in order to define the convergence of the evaluators' responses. Thus, the data were submitted to the test for equal variances, using Bartlett's and Levene's tests, to evaluate whether the variations in the volunteers' responses were significant or not (95% significance level). Differences were considered statistically significant at $P < 0.05$.

4. Results and Discussion

4.1. Presentation of the proposed parameters and categories of environmental conditions

Considering the adaptation of the model protocol to the regional phytophysiognomic particularities, the proposed parameters in the global assessment of the habitat of the upper (a) or lower (b) course of rivers are: (a, b) Substrates and/or habitats available; (b) Substrates in pools; (a) Embeddedness; (a, b) Speed/depth regimes; (b) Diversity of pools; (a, b) Sediment deposition; (a, b) Channel flow status; (a, b) Channel alteration; (b) Channel sinuosity; (a) Frequency of riffles; (a, b) Bank stability; (a, b) Protection of the banks by vegetation; (a, b) Vegetation protection and nearby vegetation status.

To each parameter a score between 0 and 20 is attributed, which corresponds to its environmental condition category. The values must be distributed according to the environmental stress gradient verified in the assessment location (Table 1). Score increases proportionally to the quality of the habitat and can vary according to the observation site. When the canal banks are involved in the assessment of the parameters a separate score is attributed to each (left/right) bank. In this case, the banks may present differing environmental conditions and the result for that section is the total of both scores.

The final result of the proposed protocol is the sum of the values attributed to each parameter evaluated. The final score reflects the level of environmental integrity of the sections of the basins studied. The total score intervals corresponding to the situations verified in the sections to be evaluated are presented in Table 1.

Table 1. Categorization of the environmental conditions to be considered according to the evaluated river sections.[1]

Categories of the conditions	Partial scores	Total scores	
		Lower course	Upper course
Excellent	16 to 20	166 to 220	151 to 200
Good	11 to 15	111 to 165	101 to 150
Regular	6 to 10	56 to 110	51 to 100
Poor	0 to 5	0 to 55	0 to 50

[1] To the assessment of the Parameter *"Speed/Depth Regimes"*, of the upper course of a river, only conditions "excellent", "good" and "regular" were considered. For parameter *"Channel flow status"*, evaluated during dry periods, only conditions "excellent", "good" and "poor" will be considered.

4.2. Description of the proposed parameters

4.2.1. Parameter 1: substrates and/or habitats available

According to Barbour et al. (1999), this parameter includes the number and relative variety of the river natural structures such as: pebbles, boulders, fallen tree trunks and branches, besides excavated banks available to the aquatic biota as shelter and site for nourishment and laying of eggs. According to Allan (1995), the diversity and abundance of aquatic communities are strictly related to a higher substrate stability and the presence of organic matter in the river bed. Several studies that deal with the "substrate-organism" relation state that the substrate is a fundamental aspect of the physical environment, being important to the maintenance of the aquatic ecosystem and local biota (Cummins, 1962; Hynes, 1970; Minshall, 1984).

The changes to adjust this parameter to regional characteristics consisted in the modification of the relative proportions established for each situation verified in the Barbour et al. (1999) model protocol (Panel 1).

4.2.2. Parameter 2: substrates in pools

This parameter, applied only to lower-course river sections, evaluates the type and the condition of the bottom substrate of the pools. According to Beschta and Platts (1986), firm substrates with rooted aquatic plants support a wider variety of organisms than the substrates where clay predominates or are rocky and devoid of plants.

Allan (1995) states that the great variety of substrates with mineral composition, form, size, superficial area, texture and interstitial spaces have a direct influence on the distribution and abundance of organisms. Organic detritus, in association with inorganic particles and clastic material, offer varied substrates for the fixation and colonization of plants and invertebrates, creating habitats favorable to reproduction, protection and shelter for the aquatic biota (Gore and Shields, 1995).

In this case, no change was necessary to adjust this parameter, which could be applied as proposed in the Barbour et al. (1999) protocol (Panel 2).

4.2.3. Parameter 3: embeddedness

"Embeddedness" refers to the degree to which rock, gravel, pebbles, clast particles and branches are covered or submerged in the bottom of the river in the sand, silt or clay

fraction, reducing the surface area available for the aquatic biota. Sylte and Fischenich (2002) state that its visual evaluation provides useful information according to the monitoring proposal. According to the authors, *"embeddedness"* can be used to evaluate the habitats available for macroinvertebrates and fish reproduction, being also a measure of water quality. High embeddedness levels are correlated with a low biotic productivity (Barbour and Stribling, 1991).

To make the assessment of this parameter more coherent with the environmental characteristics of the study area, the modifications consisted in the change of the relative proportions estimated for each condition characterizing the environmental stress gradient. Applicable only to upper-course river sections, the "embeddedness" should be preferentially estimated upstream and in areas where the substrate is pebbly (Panel 3).

4.2.4 Parameter 4: speed/depth regimes

This parameter measures the presence of different regimes in the rivers. The water courses that are characterized as having the best conditions in terms of this parameter are those that present a mixture of (1) fast/shallow, (2) slow/shallow, (3) fast/deep, and (4) slow/deep patterns (Barbour et al., 1999). Besides, the occurrence of the four patterns expresses the capacity of the aquatic ecosystem to provide and keep a stable aquatic environment. The modifications in this parameter consisted only in the form of assessment in the upper-course river sections. In this case, three possible environmental conditions are considered ("excellent", "good" or "regular") (Panel 4).

4.2.5. Parameter 5: diversity of pools

This parameter, which is assessed only in lower-course river sections, estimates the variability of pool types that occurs along the water course in relation to the pool size and depth. According to Minshall (1984), pools are determining formations in the quality of the substrate available for the aquatic communities and consequently determine the structure of the composition of these communities.

Panel 1. Parameter "Substrates and/or habitat available".

Upper course			
Excellent	Good	Regular	Poor
More than 70% of the study section presents substrates favorable to epifaune colonization and shelter for aquatic insects, amphibious animals or fish. A mixture of branches, excavated banks, pebbles or other available habitats are also observed.	50 to 70% of the study section presents substrates appropriate to epifaune colonization and maintenance. Additional substrates exist that are apt to colonization, for example, trunks or branches inclined on the water course, which still do not belong to the river substrate.	21 to 50% of the study section presents mixed stable habitats, appropriate to aquatic species colonization. In some parts the speed of the water makes the stabilization of the substrate impossible. The substrate can sometimes be removed.	The lack of habitats is obvious, or more than 80% of the study section presents monotonous or poorly diversified habitats. Gravel, pebbles and aquatic vegetation are lacking.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Lower course			
Excellent	Good	Regular	Poor
More than 50% of the study section presents varied substrate types and sizes favorable to epifaune colonization and shelter for aquatic insects, amphibious animals or fish. A mixture of submerged leaves, branches and trunks, excavated banks, pebbles or other stable habitats is also observed.	31 to 50% of the study section presents substrates appropriate to epifaune colonization and maintenance. There are some potential habitats such as trunks and branches inclined on the water course that still do not belong to the river substrate.	21 to 30% of the study section presents mixed stable habitats, appropriate to colonization. In some parts the speed of the water makes the stabilization of the substrate impossible. The substrate can sometimes be removed.	More than 80% of the study section presents monotonous or poorly diversified habitats. Branches, gravel, pebbles and aquatic vegetation are lacking.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Panel 2. Parameter "Substrates in pools".

Lower course			
Excellent	Good	Regular	Poor
Pools with varied substrate types and sizes, predominance of gravel and sand. The presence of interlaced roots and submerged vegetation is common.	At the bottom there is a mixture of loose sand and clay. Some interlaced roots and submerged vegetation can be observed.	Mud with some sand and clay predominate at the bottom of pools. A few interlaced roots and lack of submerged vegetation are also observed.	Pools with rocky or clayey bottoms. Lack of interlaced roots and submerged vegetation.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

The adaptation of this parameter consisted in changing the way the number of pools should be estimated. Whereas the Barbour et al. (1999) protocol considers as "deep pool" the one which is 1-m or more than 1-m deep, this study adopted a depth equal to or higher than 70 cm for a deep pool. In relation to the size of the pools, the values were kept as in the model protocol. A "large pool" is the one having width or length larger than half of the water course width (Panel 5).

4.2.6. Parameter 6: sediment deposition

This parameter, applied to upper- and lower-course river sections, measures the quantity of sediments that accumulates in pools and the changes that occur at the bottom of the water course as result of deposition. Based on the results obtained from the application of the model protocol, no changes were made to adjust this parameter, being applicable the one proposed by the Barbour et al., (1999) protocol (Panel 6).

According to França et al. (2006), sediments of the aquatic ecosystems are formed by a great variety of organic and inorganic materials of autochthonous and allochthonous origin, playing an important role in the structure of the lotic ecosystems, being the substrate responsible for the availability of habitats, nourishment and protection of local biota (Panel 6).

4.2.7. Parameter 7: channel flow status

This parameter evaluates the water course discharge conditions, which produce sites with more or less exposed substrates and consequently determine the quantity available for the aquatic biota. When water is not enough to cover the river floor, the local communities are threatened, once the number of substrates proper for the survival of organisms becomes limited (Hicks et al., 1991; MacDonald et al., 1991). To assess the type of flow in the canal is especially useful to interpret the biologic conditions in situations of very low or irregular flow (Barbour et al., 1999).

Panel 3. Parameter "Embeddedness".

Upper course

Excellent	Good	Regular	Poor
Less than 20% of the surface of gravel, pebbles, clast particles and branches are covered by fine sediment. Submerged pebbles supply great niche diversity.	20 to 40% of the surface of gravel, pebbles, clast particles and branches are covered by fine sediment.	60 to 80% of the surface of gravel, pebbles, clast particles and branches are covered by fine sediment.	More than 80% of the surface of gravel, pebbles, clast particles e branches are covered by fine sediment.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Panel 4. Parameter "Speed/depth regimes".

Upper course

Excellent	Good	Regular	
Presence of at least 2 regimes, being the fast/shallow regime compulsory.	Presence of two types of, lacking the fast/shallow regime.	Dominance of one of the existing regimes. If the slow-type regime prevails, the score is lower.	
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Lower course

Excellent	Good	Regular	Poor
The four types of regimes are present.	Presence of three regimes, being compulsory the presence of the fast/shallow regime.	Presence of two types of regimes. Should the fast/shallow or slow/deep regime lack, attribute a lower score.	Only one type of regime prevails, in general the slow/deep.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Panel 5. Parameter "Diversity of pools".

Lower course

Excellent	Good	Regular	Poor
The four types of pools present in similar proportions.	Large and deep pools predominate. A few shallow pools are observed.	In general, shallow rather than deep pools prevail.	Lack of pools or predominance of only one type of pool. In general small and shallow pools.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

To adjust this parameter, a difference in filling the canal with water during the rainy and dry periods was taken into account. This difference was not considered in the model protocol (Panel 7).

4.2.8. Parameter 8: channel alteration

This parameter assesses the anthropogenic changes that can be evidenced along the water course such as the presence of dikes, landfills, earth moving, dams, enrockments or other forms of artificial stabilization of the banks. Any action that changes the natural water course can cause damage to the local communities. Hannaford et al. (1997) state that the aquatic biota usually has specific habitat requirements, being sensitive to small flow alterations or to small increases in sediment load caused by anthropogenic changes. Rectification, canalization or imperviousness caused by engineering structures have a direct consequence to the reduction of the drainage area of the hydrographic basins, which cause a drastic reduction in density and diversity of aquatic species. To adjust this parameter, changes in the description of each established category were made (Panel 8).

4.2.9. Parameter 9: channel sinuosity

This parameter, assessed only in lower-course river sections, measures the meanders and the occurrence of curves along the water courses. According to Barbour et al. (1999), a high sinuosity grade provides varied habitats and fauna and the capacity of the water course to control wave movement is improved when flow fluctuates during strong rainfall, consisting in an important parameter to the environmental assessment. The absorption of energy by the curves protects the water course from excessive erosion and bankfull stage, and provides shelter for the biota during storm events (Gordon et al., 1992).

Considering that the protocol aims at a rapid assessment and that this attribute is important to define the quality of

Panel 6. Parameter "Sediment deposition".

Upper course			
Excellent	Good	Regular	Poor
Lack or small enlargement of isles or point bars. Less than 5% of the bottom is affected by sediment deposition.	Some recent additions in the formation of bars, predominance of gravel, sand or fine sediment. 5 to 30% of the bottom is affected by deposition. The weak deposition in the pools.	Moderate deposition of gravel, sand or fine sediment in recent and old bars. 30 to 50% of the bottom is affected by sediment deposition. The deposition in the pools is moderate.	High deposition of fine material and increased development of bars. More than 50% of the bottom is affected by deposition. Pools cannot be observed because of the substantial deposition in them.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Lower course			
Excellent	Good	Regular	Poor
Presence of small point bars or isles, which do not affect the normal course of the river. Less than 20% of the bottom is affected by sediment deposition.	Presence of gravel, sands or fine sediments in the recently formed bars. In the pools the sediment deposition is low. The bottom is affected from 20 to 50% by sediment deposition.	Moderate deposition of gravel, sand or fine sediment in existing bars or bars in formation. Deposition is moderate in pools and 50 to 80% of the bottom is affected by sediment deposition.	Evident development of bars caused by the high deposition of fine material. Pools practically lack due to the large quantity of material being deposited. More than 80% of the bottom is affected by sediment deposition.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Panel 7. Parameter "Channel flow status".

Upper and lower course			
Rainy period – From November to April			
Water reaches the lower base of both banks and a minimum of the substrates is exposed.	Water fills more than 75% of the canal and less than 25% of the substrates are exposed.	Water fills 25 to 75% of the canal, and/or the majority of the riffle substrates are exposed.	Very few water in the canal, most of the water stagnant in pools.
20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Dry period – from May to October			
Excellent	Good		Poor
Water reaches the lower base of both banks and a minimum of the substrates is exposed. Or, water fills more than 75% of the canal and less than 25% of the substrates are exposed.	Water fills 25 to 75% of the canal, and/or the majority of the riffle substrates are exposed.	Very few water in the canal, most of the water stagnant in pools.	The canal is completely dry.
20	19 18 17 16 15	14 13 12 11 10	0

the lotic ecosystem, the choice was to evaluate this parameter only by what is possible to be visually assessed (in the field), differently from the model protocol that, by means of calculations, estimates the environmental condition related to this parameter (Panel 9).

4.2.10.Parameter 10: frequency of riffles

This parameter measures the sequence of riffles that occur along the section under evaluation and evaluates the heterogeneity of the habitats in the water course (Barbour et al., 1999). Riffles indicate the high quality of the habitat and faunal diversity and consequently an increase in its frequency strongly enhances the diversity of aquatic communities (Barbour et al., 1999). In the headwaters, the riffles are usually continuous and the presence of waterfalls or pebbles provides a low channel sinuosity and enhances the water course structure, being measurable only in the upper course of a river. Gordon et al. (1992) state that a stable canal does not show progressive changes in declivity, contour or size, despite minor chances occur during bankfull stage. As with the previous parameter, the form of assessment of this parameter was changed to only visual (Panel 10).

4.2.11. Parameter 11: bank stability

This parameter, applicable to upper- and lower-course river sections is evaluated separately for the left and right banks. According to Barbour et al. (1999) it measures the erodibility of the banks (or potential to erosion). Steeper banks are more susceptible to fall and erosion (Minatti-Ferreira and Beaumord, 2006). According to Barrella et al. (2001), this parameter is related to the presence of vegetation on the banks. Its removal promotes favorable conditions to silting, as well as an increase in the concentrations of solids in suspension in the receptor body. Erosion signs include exposed banks or banks devoid of vegetation, collapse, roots and exposed soils. No change was made to adjust this parameter to the study region (Panel 11).

4.2.12. Parameter 12: protection of the banks by vegetation

This parameter estimates the quantity of vegetation available along the banks. Lima (1989) states that deforestation favors the loss of the buffer zone between the aquatic and adjacent terrestrial systems. According to Ferraz (2001), the riparian zone plays an important role in the protection of the headwaters and river-forming water courses. Banks plenty of natural vegetation grows offer better conditions

Panel 8. Parameter "Channel alteration"

Upper and lower course																				
Excellent					Good					Regular					Poor					
Lack or minimal presence of small canalizations and dredging. The water course follows a natural pattern.					Presence of some canalization, in general in an area to support bridges or evidence of old canalizations and dredging, but recent canalizations lack.					Presence of dikes, earth moving, landfills, dams, enrockments or contention structures on both banks. 40 to 60% of the canal is channeled and ruptured.					Banks covered with gabions or cement and *ca*. 80% of the water course is channeled and ruptured.					
20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	*0*

Panel 9. Parameter "Channel sinuosity".

Lower course																				
Excellent					Good					Regular					Poor					
The occurrence of curves is evident in the study section, promoting increased diversity of habitats for the local biota.					The channel sinuosity is not so evident; distant curves and the diversity of habitats for the local biota can be observed.					The section presents a few curves and the habitats are monotonous, with a few local places available for shelter and reproduction of the local biota.					The section is straight. If the canalization is the result of human activity, a lower score is to be attributed.					
20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Panel 10. Parameter "Frequency of riffles".

Upper course																				
Excellent					Good					Regular					Poor					
Frequent occurrence of riffles. Between the riffles small backwaters or pools are formed, with significant increase of the number of habitats.					The riffles are frequent, but there are not favorable conditions to the presence of diversified habitats.					In general the water surface is plain or with shallow riffles; scarce habitats.					Rare presence of riffles. In a great part of the section the water is still in the pools.					
20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

to biota than those devoid of vegetation or protected with concrete or enrockments.

According to Barbour and Stribling (1991; 1994), the results of the assessment of this parameter give important information on the capacity of the bank to resist to erosive processes, and also reveal information on the intake of nutrients by plants, the control of upstream flow and shadowing. To adjust this parameter, changes in the description of the assessment categories were made (Panel 12).

4.2.13. Parameter 13: vegetation protection and nearby vegetation status

This parameter evaluates the general conservation state of the surrounding vegetation (Panel 13). According to Rodrigues and Shepherd (2004), the environment surrounding a lotic system reflects the geologic, geomorphological, climatic, hydrological and hydrographic characteristics that act as elements which define the landscape and consequently the local ecological conditions.

Steinblums et al. (1984), Platts et al. (1987), Elmore and Beschta (1987), Magette et al. (1989), Gregory et al. (1992) and Bren (1993), among others, have demonstrated that the surrounding vegetation, also named riparian zone, has important hydrologic functions. The recovery of the surrounding vegetation contributes significantly to the increase of the water storage capacity of the microbasins along the riparian zone, which contributes to the flow increase during the dry season (Elmore and Beschta, 1987). The surrounding vegetation, which strategically isolates the water course from the higher terrains in the microbasins, acts as an efficient superficial sediment filtering (Magette et al., 1989) and therefore directly plays a role in the cycling of nutrients (Lima and Zakia, 2004). Besides, it establishes a direct interaction with the aquatic ecosystem, in special for the aspects related to the canal geomorphologic and hydraulic processes. This parameter substitutes the *"width*

Panel 11. Parameter "Bank stability".

Upper and lower course											
Excellent			Good			Regular			Poor		
Stable banks, lack or minimal evidence of erosion or faults in the banks; low potential for future problems. Less than 5% of the banks are affected.			Moderately stable banks, with healed erosion scars. 5 to 30% of the extension of the banks are eroded.			Moderately unstable banks. 30 to 60% of the extension of the banks are eroded and the erosion potential is high during bankfull stage.			Unstable banks and many eroded areas. Erosion is frequent along the straight section and curves. 60 to 100% of the extension of the banks are eroded.		
MD*	10	9	8	7	6	5	4	3	2	1	0
ME**	10	9	8	7	6	5	4	3	2	1	0

*Right margin, **Left margin.

Panel 12. Parameter "Protection of the banks by vegetation".

Upper and lower course											
Excellent			Good			Regular			Poor		
More than 90% of the surface of the banks and immediate riparian zone is covered by native vegetation. Lack of cultivated areas (agriculture) or pastures. Most of the plants can grow naturally.			70 to 90% of the marginal surface is covered by native vegetation; great discontinuities are not observed. Minimal evidence of cultivated areas or pastures.			50 to 70% of the marginal surface is covered by vegetation, with a mixture covered soil and areas lacking vegetation. Cultivated areas or pastures are observed.			Less than 50% of the marginal surface is covered by vegetation. The discontinuity of the surrounding vegetation is evident, being practically non existent.		
MD*	10	9	8	7	6	5	4	3	2	1	0
ME**	10	9	8	7	6	5	4	3	2	1	0

*Right margin, **Left margin.

Panel 13. Parameter "Vegetative protection and nearby vegetation status".

Upper and lower course											
Excellent			Good			Regular			Poor		
The surrounding vegetation is composed of well-preserved native species; it does not present signs of degradation caused by human activities.			The vegetation is composed not only of native but also of exotic species, and is well-preserved. Minimal evidence of impacts caused by human activities.			The vegetation is constituted by exotic species and native vegetation is scarce. Impacts caused by human activities are noticeable.			Surrounding vegetation is practically non existent and the soil is exposed to natural weathering. Human activities, such as fires and deforestation are evident.		
MD*	10	9	8	7	6	5	4	3	2	1	0
ME**	10	9	8	7	6	5	4	3	2	1	0

*Right margin, **Left margin.

of the riparian vegetation zone" of the model protocol, not applicable to the selected sections.

4.3. Environmental monitoring workshop

The environmental monitoring workshop took place in two stages. In the first stage, a theoretical approach was adopted, in which the rapid assessment method, relevance and definitions regarding the subject were presented to the volunteers. In the second stage (field work), half of the volunteers applied the protocol to an upper-course and the other half to a lower-course river section. Each evaluator applied the protocol individually.

4.3.1. The application of RAP to upper course river section

As shown in Figure 3, the results of the application of the adapted protocol to upper-course river sections rarely presented variations among evaluators. According to the statistical analysis, the small variations observed in the volunteers' response pattern did not correspond to significant statistical differences (P = 0.825 – Bartlett's test/P = 0.847 – Levene's test) (data not shown).

In relation to the time spent by the volunteers to apply the protocol, 35% spent less than 20 minutes and 65% spent from 20 to 40 minutes, thus showing that the proposed tool for monitoring and assessment of the environment is practical and fast.

4.3.2. Application of RAP to lower-course river section

Similarly to the results of the application of the protocol to upper-course river sections, divergence among volunteers' responses was rarely observed regarding the application of the protocol to lower-course river sections (Figure 4). After applying the statistical analysis, it was once again verified that the variations in the volunteers' response pattern were not statistically significant (P = 0.404 – Bartlett's test/P = 0.796 – Levene's test) (data not shown).

Regarding the time spent by the volunteers to apply the protocol, 90% of the volunteers spent 20 to 40 minutes and only 10% 40 minutes to an hour, demonstrating once again the practicability and quickness of the protocol applied as an environmental assessment tool. It is important to point out that when RAP was applied by more experienced people, the variation in the response pattern was smaller and the time spent to apply the protocol was shorter, which adds more efficiency to the method (data not shown).

The analysis of the response pattern obtained in this study demonstrates that, even though there are variations in the responses to some of the parameters evaluated, the results did not significantly diverge from one evaluator to another. The results validate the applicability of the protocol to water courses on rocky meadow of the study region. The variations observed in the response pattern can be minimized with more training and/or instructions regarding the assessment of the parameters.

5. Conclusions

Much wider components and processes integrate the aquatic ecosystems than an analysis focused only on the component water. The understanding of all these components and processes, as well as the global system quality is only possible from an analysis that integrates all the factors involved. This analysis must include, besides the characteristics intrinsic to the determination of the water quality, those which determine the environment quality and/or physical habitat characterization, as well as the relationship between these characteristics (Rodrigues et al., 2008).

The lack of proper indices for the assessment of the habitat biological and physical conditions has been an

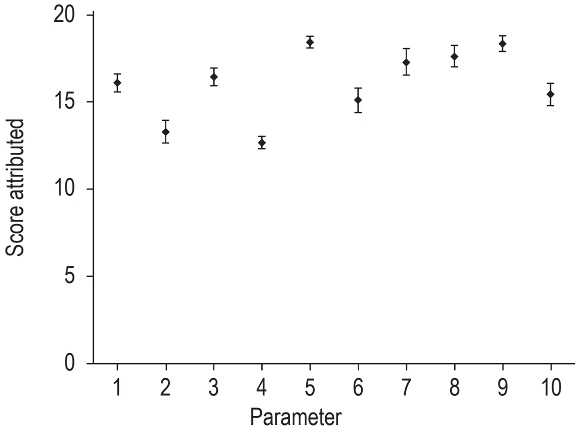

Figure 3. Variation of the score attributed to the parameters analyzed by 21 volunteers in an upper-course river section in the Itacolomi State Park, Ouro Preto, MG. The points in the graph represent the average +/- standard deviation of the scores attributed to each parameter of the modified protocol.

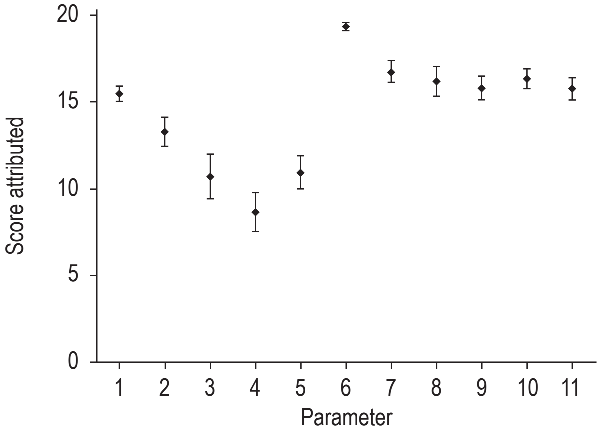

Figure 4. Variation of the score attributed to the parameters analyzed by 21 volunteers in a lower-course river section in the Itacolomi State Park, Ouro Preto, MG. The points in the graph represent the average +/- standard deviation of the scores attributed to each parameter of the modified protocol.

impediment to a more realistic evaluation of the biotic integrity of the aquatic ecosystems. The aquatic biota is affected structurally and functionally by variables associated with physical factors and therefore the availability of an indicator of the habitat physical or even structural aspects contributes to the improvement of the tools used to establish environmental quality indicators. The proposed protocol is a useful tool for rapid assessment of river systems and the data obtained in the research demonstrate the utility of the tool to environmental agencies, in the sense that people previously instructed are able to apply this tool and collaborate to the collection of data related to water resources monitoring of a study region.

To promote the participation of the society in environmental monitoring programs of river ecosystems, aiming at the identification of water courses that need recovery and revitalization, location and identification of polluting sources and irregular discharge points is extremely important to the success of the environmental managing process, especially considering the new perspective created by the institution of the hydrographic basin committees, which can contribute to a better practice of the administration of water resources.

Therefore, the development of simple and complementary assessment methods, as the one proposed here, can be considered useful tool in the preservation of lotic ecosystems, bringing, among other advantages, the improvement of the life quality and the insertion of the community in the management of national water resources.

The development of new technologies particularly related to survey methods should help improve the speed and level of detail attainable by physical habitat assessments. A better understanding of the ways in which the spatial and temporal dynamics of physical habitat determine stream health and how these elements can be incorporated into assessment methods, remains a key research goal.

In conclusion, the method presented in this study consists in a simplified but not simplistic tool, which can be used in activities that aim at promoting a quick and reliable assessment of the "health" of a river.

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