Habitat assessment in evaluating the river health: what is and why is it important?

Aline Sueli de Lima Rodrigues

Engenheira Ambienta. Doutoranda do Programa de Pós-Graduação em Evolução Crustal e Recursos Naturais, Departamento de Geologia (DEGEO), Universidade Federal de Ouro Preto (UFOP)-MG.

E-mail contato: aline@degeo.ufop.br

RESUMO

Os agentes estressores dos ecossistemas fluviais são de natureza e intensidade variada e tem na destruição e degradação dos habitats papel de relevância. As alterações físicas e morfológicas dos rios, além de afetarem o regime da vazão, reduzem o corredor fluvial e degradam a zona ripária com consequentes perdas na biodiversidade e na integridade ecológica desses ambientes. Nesta perspectiva, este artigo discute os fatores físicos do habitat que influenciam a saúde dos rios e destaca a importância da avaliação destes fatores para a conservação da biodiversidade fluvial. A avaliação dos aspectos físicos do habitat disponibiliza informações adicionais que associadas às condições físicas, químicas e bacteriológicas das águas possibilitam avaliar a integridade ecológica dos sistemas fluviais sem limitar-se a visão antropocêntrica de padrões de uso das águas.

Palavras-chave: habitat físico, rios, saúde dos rios, avaliação ambiental, biodiversidade, biota aquática, integridade ecológica,

ABSTRACT

The agents of stress of fluvial ecosystems have many origins and intensity and play important role in the destruction and degradation of habitats. The physical and morphologic alterations of the rivers, besides affecting the flow regime, reduce the fluvial corridor and degrade the riparian zone with consequent losses in the biodiversity and the ecological integrity of fluvial environments. In this perspective, this paper discussed the physical factors of habitat that influence the river health and distinguish the importance of assessment these factors for conservation of fluvial biodiversity. The physical habitat assessment to become available additional information that associates to the bacteriological
physical-chemical conditions of water that turn possible to evaluate the ecological integrity of the fluvial systems without limiting it to anthropocentric vision of standards of use of water.

Key-words: physical habitat, rivers, river health, evaluation environment; biodiversity; biota aquatic; ecological integrity

1) Introduction

It is known that society benefits immeasurably from rivers. Yet over the past century, humans have changed rivers dramatically, threatening river health. As a result, societal well-being is also threatened because goods and services critical to human society are being depleted. Rivers throughout the world have suffered a long history of degradation through direct and indirect human influence.

In function of this, the notion of water resources has been extensively debated lately. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) the superficial freshwater represent only 2.7% of the total water available. The major part (77.2%) of this small value is found in polar caps, glaciers and icebergs, the rest being 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 decreasing (Tundisi, 2003). According to the United Nations Organization, 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).

As discussed for Rodrigues (2008), channel modification has been both widespread and intensive as streams and rivers have been aligned for farming convenience, to aid navigation, to achieve the engineering objectives of flood alleviation and agricultural drainage or straightened adjacent to roads and railways. As a consequence many rivers have a canalized nature with straight,
trapezoidal channel sections, clear of river bank trees and hedges and with uniform bed morphology.

In addition, the agents of stress of fluvial ecosystems are large origin and intensity and play important role in the destruction and degradation of habitat. The physical and morphologic alterations of the rivers besides affecting the flow regime reduce the fluvial corridor and degrade the riparian zone with consequent losses in the biodiversity and the ecological integrity of fluvial environments. In some situations the agent stress can overshadow the researches of the effect of the toxicity and the pollution of the waters (Karr et al. 1986). In others, they can evidence that the way adopted in the evaluation and monitoring of the quality of waters, tough valid and viable, are weak and insufficient to promote the sustainable use of the water resources (Ferreira & Castro, 2005).

The fact is that changes in both, amount and quality water and the physical structure of the channel have almost without fail led to changes in the composition of the biotic community inhabiting the river, usually with a reduction in the biological diversity of the aquatic ecosystem (Boon, 1992).

Thus, in this paper will be explore initially the links between the quality of the habitat and biologic condition, as well as the analogy between methods of diagnosing river health and methods commonly applied to human health assessment. In the second part of the paper will be discussed the importance of the evaluation of the physical habitat and which parameters can be evaluated. As discussed for Rodrigues & Castro (2008), the habitat assessment supports understanding of the relationship between habitat quality and biological conditions. Such assessment identifies obvious constraints on the attainable potential of the site, assists in the selection of appropriate sampling stations and provides basics information for interpreting biosurvey results.
2) The quality of the Habitat and Biologic Condition

The maintenance of an aquatic ecosystem structure depends 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 reflected in the changes of the others and in the modifications of the habitat structure, thus limiting the biotic integrity of these ecosystems (Gorman & Karr, 1978; Karr & Schlosser, 1978; Karr & 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 & 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 (to see Figure 1).
The curve is divided in three 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 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, opportunistic and can resist to highly variable conditions.
2) Diagnostic Tools for Assessing River Health

Based in the premise of that the condition or health may be influenced by a number of factors relating to the river, including its ecological status, water quality, hydrology, geomorphology and physical habitat, Maddock (1999), proposed the existence of an analogy.

According to Maddock (1999), an analogy can be drawn between methods of diagnosing river health and methods commonly applied to human health assessment. For example, a doctor wishing to assess the health of a patient may check several indicators, such as pulse, breathing, temperature and the blood content. The doctor will use a specific measure of each indicator, such as the pulse rate per minute, or the oxygen levels, sugar levels and red blood cell count of a blood sample, and compare the measurements against the expected normal or healthy values (bench-marks). It can also expect the doctor to diagnose the likely source of the problem when certain indicators are not normal, and prescribe a course of treatment to improve the health state of patients. Therefore, a proper review requires a check on not just one but a number of these diagnostic tools.

The same is true for assessing river health. The indicators include the ecological status, water quality, hydrology, geomorphology and availability of physical habitat. To check these indicators of rivers health, specific measures must be addressed within each, such as biotic diversity, flow regime or evidence of channel instability (Figure 2). Assessing physical habitat is an important member of this suite of indicators.

Appraisals of the condition of a river may incorporate an evaluation of its ecological status, i.e. the presence and condition of the biota in the river. Three general outcomes are possible when comparing ambient stream stations to a reference (expected normal or healthy values): i) no biological effects, or effects due to habitat degradation; ii) effects due to water quality or iii) an artificial elevation of the perceived condition of the community beyond the expected relationship because of mild enrichment effects.
According to Barbour & Stribling (1991), Barbour et al. (1999) and Rodrigues & Castro (2008), the accurate determination of these possible outcomes is supported by a reference database adequate to defining the expected relationship between habitat quality and biological integrity. The theoretical regression line between habitat quality and biological condition should be substantiated with a larger database than is currently available. Establishing the reduction of habitat quality may be all that is needed to judge impairment. The quantification of habitat quality may be as important as measuring in stream communities in documenting nonpoint source impact.

![Figure 2: The analogy between diagnostic tools for assessing human health (A) and river health (B). (Modified after Maddock, 1999).](image)

3) Physical Habitat: Definition, Importance and as to Evaluate

Jowett (1997) suggested that the generic term “habitat” is used to describe the physical surroundings of plants and animals, and therefore aquatic habitat can be defined as the local physical, chemical and biological features that provide an environment for the in stream biota. Currently, as discussed for Booker & Acreman (2007), physical habitat is increasingly used worldwide as a measure of river ecosystem health when assessing changes to river flows, such as those caused by abstraction.
The importance of physical habitat in determining the condition of the river ecosystem is implicit in its definition, because without a suitable “living space” a given species is unlikely to exist at that particular location. Physical habitat is a particularly useful element to be considered for evaluating river health since it provides the natural link between the physical environments and their inhabitants. This was illustrated by Harper et al. (1992) who identified physical habitats as fundamental units on which to base river conservation recommendations (Figure 3).

![Diagram](image)

**Figure 3:** The definition of habitat as the natural link between the environment and its inhabitants (Modified after Harper et al., 1992).

Physical habitats typically are evaluated for two main reasons. The first is to provide additional explanatory variables for assessments of stream ecology or water quality. The second is to explore relations between the stream and drainage-basin characteristics, usually with the intention of understanding land-use effects. The first approach is optimized if the habitat variables measured relate spatially and temporally to the specific biological or water-quality samples, both of which can be heavily dependent on the stream discharge at the time of sampling. In contrast, the second approach seeks minimizing the effects of discharge and measure variables that are longer-term integrators of geomorphic responses.
Thus, ahead of these facts and due to his necessity to incorporate more including scales in the programs of evaluation and monitoring water resources, there had been developed two ways to interpret the structure of the habitat. The first one includes the characterization of the morphology and the margin of the canal, the physical structures of the sediments, the floodplain and the flow dynamics. The second way consists of a faster, semi-quantitative visual evaluation, that it makes possible to characterize, in situ, the global the physical quality of the habitat in the fluvial segments. In these cases, protocols have been proposed for evaluation of physical habitat and as example are distinguished the Rapid River Assessment Protocols (RRAP).

As discussed for Rodrigues (2008), the RRAP was 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 at providing basic data on the aquatic life as a means 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 RRAP 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 RRAP (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 & Beaumord (2006) and Rodrigues (2008).
To develop a RRAP, a “normal” limit 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 & 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.

4) Physical Habitat Parameters to be Evaluated

According to Rodrigues (2008), the following physical parameters are designed to assess habitat quality: 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 or riffles; bank stability; protection of the banks by vegetation and vegetation protection and nearby vegetation status.

According to Barbour et al. (1999), the “substrate and/or habitats available” 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 spawning of fishes. According to Allan (1995), the diversity and abundance of aquatic communities are strictly related to 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
The parameter “substrates in pools” applied only to lower-course river sections, evaluates the type and the condition of the bottom substrate of the pools. According to Beschta & 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.

“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 & 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 & Stribling, 1991).

The parameter “speed/depth regimes” 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.

“Diversity of pools”, 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.
The parameter “sediment deposition” measures the quantity of sediments that accumulate in pools and the changes that occur at the bottom of the water course as result of deposition. According to França et al. (2006) the 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 structuring of the lotic ecosystems, being the substrate responsible for the availability of habitats, nourishment and protection of the local biota.

“Channel flow status” 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).

The parameter “channel alteration” 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 as 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.

The parameter “channel sinuosity”, 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).

“Frequency of riffles” 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.

The parameter “bank stability” 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 & Beaumord, 2006). According to Barrella et al. (2001), this parameter is related to the presence of vegetation on the banks. Its removal promotes conditions favorable to silting, as well as 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.

“Protection of the banks by vegetation” is the parameter that 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 to biota than those devoid of vegetation or protected with concrete or enrocksments.

Finally, the parameter “Vegetation protection and nearby vegetation status” evaluates the general conservation state of the surrounding vegetation. According to Rodrigues & Shepherd (2004), the environment surrounding a lotic system reflects the geologic, geomorphologic, climatic, hydrologic and
hydrographic characteristics that act as elements that define the landscape and consequently the local ecological conditions.

Steinblums et al. (1984), Platts et al. (1987), Elmore & 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 & 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 & 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.

5) Concluding Remarks

Throughout this paper, was possible to perceive that the knowledge of the characteristics of the physical habitat is the best way to understand the factors that affect fluvial biodiversity. This implies that the studies of aquatic ecology must be act as basis in the process of understand the physical complexity of the systems. Moreover, it can aid for forming the set of more complex response of the biological system (and their relations) with chemical and physical factors. This understanding is an improvement of the knowledge of the attributes of the landscape in regional and local scale and contributes to explain the distribution and the biodiversity of rivers, between distinct ecoclimatic regions and ecorregions.

The development of new technologies particularly relating 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.

6) References


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