HUMAN IMPACT ON TROPICAL FRESHWATER ENVIRONMENTS

Marcos Callisto and Marcelo S. Moretti
Universidade Federal de Minas Gerais, Instituto de Ciências Biológicas, Departamento de Biologia Geral, Laboratório de Ecologia de Bentos, Belo Horizonte, MG, Brazil

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Summary

This chapter approaches a series of aspects related to anthropic impact on continental aquatic ecosystems found in tropical regions: water usage policies, water resources degradation and loss of benefits, tropical diseases, water crisis, environmental biomonitoring programs, aquatic biodiversity, watersheds as the main focus for integrated intervention acts, reference sites for biomonitoring efforts, maintenance of gallery/riparian forests as intervention actions, and litter breakdown as a tool to assess human impacts.

1. Introduction

Water is, without doubt, an essential element for life. Today, even with all the technological advances of the modern world which provide comfort and practicality to our life, water continues to be one of our main concerns. As water availability is indispensable for the colonization and permanency in any environment, the lack of it can limit the distribution of living organisms, including human beings. Like our most primitive ancestors, we are still dependant on this resource that continues to be misused and wasted despite the fact that it is getting scarcer every day.

Despite some disagreements, the estimates of the relative distribution of the water between the several planet compartments point to (Von Sperling, 2006): 97.07526% in the oceans, 1.91523% in glaciers, 0.98828% in underground waters, 0.01646% in lakes, 0.00366% concentrated as soil moisture, 0.00095% in the atmosphere, 0.00009% in rivers and 0.00007% in living organisms. Thus, the freshwater available for human consumption found in rivers and lakes represents a percentage of around 0.01% of all water on the planet. Also, sources of freshwater are not homogeneously distributed around the planet's surface. There are clearly regions of the globe where freshwater is more abundant, such as the Amazon basin, and desert areas where this resource is more limited.

Currently, 11 countries in Africa and nine in the Middle East face severe water shortage problems. The situation is also critical in Mexico, Hungary, India, China, Thailand and the United States. Asia, Africa and Europe are the regions with less water available for human consumption (Table 1). On the other hand, Latin America has the greatest water availability per person in the world. However, the inappropriate distribution of this resource has caused shortage problems in several countries. For example, Brazil possesses 11.6% of the available world's freshwater but nearly 70% of it is in the Amazon basin while the other 30%, that supplies 93% of the Brazilian population, is unevenly distributed around the country.

Table 1. Water availability per habitant in the World regions (1000m^3).

The data found in Table 1 also show a tendency for decrease in water availability in all regions as time passes by. The superficial freshwater available (lakes, rivers and reservoirs) that is used for treatment and distribution has been suffering the effect of environmental deterioration processes (e.g. forest clearance and pollution). The intensive use of water resources has led to an adoption of measures, such as the regulation and modification of watercourses. These cause alterations in ecosystems and microenvironments as well as prejudice the fauna and flora. Increasing water pollution is one of the main characteristics of water usage around the world. In developing countries there are few cities that possess treatment stations for domestic, agricultural and/or industrial waste water, including the water contaminated with agrotoxics. As a result of spring water degradation, treatment to make it suitable for human consumption is becoming difficult and expensive.

The richness of water resources in Brazil does not imply that there is good water availability for the population. There are regions that are affected by droughts throughout almost all the year where access to the water is extremely difficult. In addition to this, in regions where water is abundant its quality can often be compromised by the lack of basic sanitation. According to the National Health Foundation (Fundação Nacional de Saúde, FUNASA), only 42% of Brazilian residences are provided with domestic waste water collection services. Besides this, the water distribution network is not evenly distributed among regions and between urban and rural population.

According to the Brazilian Institute of Statistics and Geography (Instituto

Brasileiro de Geografia e Estatística, IBGE), 77.8% of Brazilian residences have water distribution services. Nearly 6.97 million residences (15.6%) use wells and springs, and 2.95 million residences (6.6%) use other types of water supplies. Data from the World Health Organization (WHO) and the Pan American Health Organization (PAHO) showed that the improvement in water supply and the adequate collection and disposal of sewage and solid waste helped to prevent 80% of typhoid and paratyphoid fever cases and reduced more than 70% of trachoma and schistosomiasis cases. These actions also helped to prevent half of the occurrences of dysentery, amoebiasis, gastroenteritis and skin infections. Beyond the concerns about its distribution, there is also a strong concern about the quality of the water offered to the population. Research performed by the IBGE showed that in 1,974 Brazilian municipalities the water supplied by the public distribution service does not have any previous treatment. That means that 7.2% of the water provided to the Brazilian population is not submitted to any treatment or any disinfection process.

2. Water Usage Policy: From medieval civilizations to the present

There is a historical record that indicates that, apart from small springs and wells, the Tigris River was the main direct source of water for Rome during the first 441 years after the foundation of the city (Campos and Studart, 2001). In 312 BC the Romans began the construction of the *Aqua Appia* aqueduct and four decades later this was followed by the construction of the *Anio Vetus* aqueduct. In due course there were several aqueducts built, leading to the formation of a complex hydraulic network that provided all the water supply for the city. When there were crises because of the high demand for water supplies, the government searched for new sources that could provide high quality water in good quantities. These several aqueducts are historical monuments in modern Rome. To manage the system the Romans started organizing administration structure models and in 97 AC Julius Frontinus VI was nominated Rome's Water Deputy (*Curator Aquarum*) by Emperor Augustus Nerva. Frontinus had under his responsibility the functioning of a complex aqueduct system that collected water from sources far away from the city and transported it to various reservoirs distributed around the city.

The water was classified according to its usage as *nomine Caesari, privatis* and *usus publici*. The *usus publici* class was further subdivided as *castra*, *opera publica, munera* and *lacus*. The *nomine Caesari* was water reserved for the imperial palace and the buildings that were under direct control of the emperor. The *privatis* water was for citizens who had the emperor's grant (*principis* benefit) and its concession was dependant on the payment of a fee. The *usus publici* was the water provided for public buildings, bath houses, military and paramilitary buildings and activities, ornamental fountains and for emergency water reserves (Campos and Studart, 2001).

After the Middle Ages and until the late 18th century, hygienic habits and bathing were not popular and were infrequent. The use of perfumes during this period was a sign of prosperity.

After the Industrial Revolution the growth of cities brought serious problems linked to water quality and related to the lack of an adequate system for sewage disposal. As a result a continuous increase in pollution was observed and also an increase of the costs of obtaining water for human supply. Urban rivers began to receive sewage and effluents without treatment, becoming open channels for the transportation of pollutants.

Unfortunately in several Brazilian cities the disordered growth and the lack of government investment hampered the use of concepts and techniques fundamental for the implementation of an efficient system for water supply. These were:

- Extraction of raw water from rivers, wells, lakes, reservoirs, etc.
- Transport of raw water from the source of extraction to the points of consumption using channels, adductor systems, tunnels, etc.
- Treatment of raw water to improve its characteristics regarding physical, chemical and bacteriological aspects in order to make it suitable for human consumption.
- Distribution of treated water in the places of consumption using a pipe distribution system.
- Collection of used water and sewage using pipe networks to ensure their removal to safe places.
- Treatment of the used waters in order to produce water that can be assimilated by the final receptor water body.

Thus, the establishment of a policy for the management of water resources is fundamental in order to minimize water waste, to treat raw water, to guarantee the distribution of good quality water and to adequately treat sewage and effluents. It is mandatory that investments of this nature foresee: a) the objectives to be reached; b) the fundaments or principles of this policy; c) the mechanisms to implement it; d) a law or legal measurements that support it; and e) the institutions that will execute and accompany this policy. Campos (2001) emphasizes that these policies have to be designed taking into account the geographical space and local characteristics. Ideally, national policy has to be general enough to include aspects that can be applied in all states; afterwards these states have to develop a policy based around their individual needs whilst continuing to follow the national policy guidelines. All these policies have to follow the principle of decentralization, where the basin committees have to discuss the specific needs of each basin, respecting all the hydrologic, geomorphologic, cultural and economic peculiarities of the basin.

The basin committees are created in order to promote the management of the interventions made in each area. Usually, they are constituted by: a) representatives from the State's secretary or from organizations and entities from the administration that act in each basin and whose activities are related to water usage management strategic planning and financial management; b) representatives from the municipalities that compose the basin; c) representatives from the civil society such as universities, higher education institutions, institutions for research and technological development, water users, associations specialized in hydric resources, syndicates, regional councils and other community associations, all with headquarters inside the basin. In addition, the equal participation of all municipalities in each state has to be ensured. Usually the committees' functions are as follows:

- To approve the proposal for the basin in order to integrate the Water Resources Plan and its upgrades.
- To approve plans for upgrade, conservation and protection of the water resources of the hydrographic basin.
- To approve proposed annual and multi annual programs for the use of financial resources.
- To promote understanding, cooperation and conciliation between all users of the water resources.
- To study, divulge and debate in the region the priority programs for services and works that will be executed for the interest of the community and to define the objectives, goals, benefits, costs and the financial, environmental and social risks implied in these programs.
- To provide subsidies for the elaboration of the annual report on water resources in the hydrographic basin.
- To create an annual calendar of demands and events and to send them to the administrative organizations.
- To execute control actions at the hydrographic basin level.
- To ask, when needed, for support from the administrative organizations.

Brazilian Basin Agencies (as legal entities with administrative and financial structures of their own) are created in some hydrographic basins following the decision of the Committee and with the approval from the Water Resources Council. The Agencies' responsibilities would be to create future plans for the hydrographic basin and to manage the financial resources obtained from the financial charges imposed on water usage and other public services.

There is no consensus yet on the classification of water bodies for use as a management instrument. There is a necessity to classify water bodies in order to: a) ensure that they have a quality compatible with the uses that have been defined for them and b) to prevent over-use of financial resources in water treatment and pollution avoidance.

In Brazil, the classification of water bodies was initially instituted by the official document MINTER, GM 0013, in January 1976. It established the quality and emission standards for effluents in four classes.

This document was replaced by the Resolution of the National Council for the Environment (Conselho Nacional do Meio Ambiente – CONAMA) number 20, in July 1986. In this document, fresh, salt and brackish waters present in national territories were categorized in nine classes that were evaluated by specific parameters and indexes in order to define each class's potential main use. This is an instrument for the conservation of water quality levels in the water bodies. It states that health and well-being as well as environmental aquatic equilibrium cannot be achieved with deterioration of water quality. The classification of the water bodies is not necessarily based on their present state but on the quality levels that they have to achieve to fulfill the community needs.

The objective of this instrument is to ensure that water has a quality compatible with the purest type required, by the uses determined for it and to reduce, by implementing permanent prevention measures, the cost of the combat against water pollution. This mechanism also provides a link between water quality management and water quantity management. That is, it strengthens the relationship between water resources management and environmental management.

CONAMA RESOLUTION Nº 357, MARCH 17TH, 2005. *This determines classes of water bodies and the environmental guidelines for their classification, and establishes the conditions and standards for the emission of effluents and gives some other measures.*

Chapter II Regarding the Classification of Water Bodies

Article 3. The fresh, salt and brackish waters found in the national territories are classified according to the quality required based on the use for which they are going to be intended. There are 13 quality classes.

The better quality waters can be used for less exigent ends if they do not prejudice water quality and if they fulfill other pertinent requirements.

Section I – Regarding fresh waters

Article 4. Freshwater is classified in:

1. Special class: water appropriate for:

   a. Human consumption, after disinfection;
   b. Conservation of the natural equilibrium of water communities; and
   c. Conservation of aquatic environments in conservation units of the integral protection type.

2. Class 1: water appropriate for:

   a. Human consumption after simplified treatment;
   b. Protection of aquatic communities;
   c. Leisure activities of primary contact such as swimming, skiing and diving in agreement with the CONAMA resolution Nº 274, 2000;
   d. Irrigation of vegetables that are eaten raw and of fruits that grow in contact with the ground and that are eaten raw without peeling; and

e. Protection of aquatic communities found in indigenous lands.

3. Class 2: water appropriate for:

a. Human consumption after conventional treatment;
b. Protection of aquatic communities;
c. Leisure activities of primary contact such as swimming, skiing and diving in agreement with the CONAMA resolution Nº 274, 2000;
d. Irrigation of vegetables, fruiting plants, parks, gardens, sports and leisure fields that will be in direct contact with the public; and
e. Aquaculture and fishing.

4. Class 3: water appropriate for:

a. Human consumption after conventional or advanced treatment;
b. Irrigation of trees, cereals and forage plantations;
c. Amateur fishing;
d. Secondary contact leisure activities; and
e. Animal watering.

5. Class 4: water appropriate for:

a. Navigation;
b. Landscape harmony.

Water bestowal is an instrument for command and control, where a proportion of the water availabilities is conceded for a specific use, during a limited time, to a specific user. The main objectives of this bestowal are to ensure the qualitative and quantitative control of water usage and to provide the right to use the water.

Among the discussions and deliberations around water bestowal, the maximum bestowed values (volume or output, or both) have to be considered and also how the water will be allocated in times of drought. These decisions have a strong regional character and depend on the pluviometric regime in the basin and its affluents. Therefore, care has to be taken in the establishment of national general policies and the decision has to be based on the knowledge of different hydrologic and geomorphologic aspects, as well as on knowledge of the aquatic biodiversity found in different eco-regions, biomes and parts of hydrographic basins.

Countless dams were built during the twentieth century in tropical regions. In Brazil, since the 1950s and after the industrialization of the country, the use of hydroelectric dams was considered the most viable way to produce electric energy (Bortoleto, 2001). Today, reservoirs are used for several purposes such as water storage for public usage, fish farming, tourism and leisure, contributing also to regional development (Tundisi and Matsumara-Tundisi, 2003).

Modification of reservoir discharge alters the natural hydrologic regime of water bodies located downstream. It reduces the mean annual discharge rate and the seasonal discharge rate, alters the time of occurrence of extreme discharge volumes, reduces the magnitude of floods and/or inflicts non-natural outflows. These changes interfere with abiotic factors that are important for aquatic organisms (water speed, substrate type, temperature and oxygen). The consequences of these changes include variation in water quality, decrease in dilution and natural capacity for purification, exposure of the river bed, and interference with input of allochthonous material originating in vegetation at the margins (Poff *et al*. 1997; Limno-Tech and Slivitzky, 2002). Thus, these changes in reservoir discharge rate modify the structure of aquatic communities and interfere with spawning of migratory species, reducing the chance of larvae and eggs reaching developmental habitats (such as oxbow lakes). They also decrease the diversity of habitats and food available for invertebrates, amphibians, fish, birds and mammals.

The residual or remnant discharge of a river is the one that has to be guaranteed, downstream from any hydroelectric enterprise, in order to satisfy all the uses determined by the Water Resources National Policy. In other words, the residual discharge has to satisfy the following: sanitation, ecologic discharge (see below), human and industrial supply, animal watering, production of electrical energy, irrigation, navigation and leisure, among others.

After the 1990s, there has been an increase in the number of studies aiming to determine the volume of discharge that satisfies the socio-economic needs of rivers and reservoirs while maintaining viable habitat conditions essential to the preservation of the structure of natural biological communities related to the aquatic ecosystems.

In this context, the ecological discharge, also called residual or remnant discharge, is the volume of water needed to ensure the maintenance and conservation of natural aquatic ecosystems and their biota, the scenery characteristics and other economic, scientific and cultural interests (Alves and Bernardo, 2000).

The limitation of the methodologies used in the ecological discharge concept is that they focus on a minimal discharge without giving importance to other aspects related to ecosystem maintenance. The methods most used to determine ecological discharge were based on the need to maintain fish populations (especially those with economic importance) downstream from the reservoirs. These methodologies are based on the belief that if habitat conditions are suitable for fish populations to survive then they must be appropriate for the survival of other aquatic organisms. However, the reduction of the discharge downstream from reservoirs causes several impacts on aquatic communities and ecosystems that might not be detected by monitoring fish populations. Moreover, it is important to note that the response of fish communities might not represent responses to local alterations since these organisms are very mobile and can avoid unfavorable situations.

3. Water resources degradation and loss of benefits

The increase in anthropic impacts over aquatic ecosystems in recent decades is an aggravating circumstance that has demanded the attention of researchers and environmentalists. Every day there is an increase in freshwater extraction for diverse uses, as well as an increase of pollution in rivers and lakes caused by pouring of non-treated domestic and industrial waste into these water bodies. Water bodies have also suffered other types of impact such as margin modification, clearance of riparian vegetations, channeling of river beds and deposition and accumulation of sediments that can lead to river clogging (Table 2). This problem requires more attention in developing countries within tropical regions where population growth is higher and where fewer practical actions have been undertaken in order to minimize these impacts. Below, we will raise and discuss the main aspects related to anthropic impacts in tropical freshwater ecosystems.

Table 2: Main types of environmental impacts in tropical aquatic ecosystems (modified from Callisto *et al.,* 2005)

Lasting recent decades, freshwater ecosystems have been altered on varying scales and have registered various negative consequences of anthropogenic activities (e.g. mining, dam construction, artificial eutrophication, river canalization, and recreation). The detection of resulting impacts on streams depends on the use of biomonitors combined with physical (e.g. temperature, suspended solids) and chemical (e.g. nutrient levels, concentrations of potential toxins) data.

Water quality provides two broad classes of economic benefits: withdrawal benefits and instream benefits. Withdrawal benefits include municipal water supply and domestic use (e.g. household consumption, cooking, washing, and cleaning) benefits, agricultural irrigation and livestock watering benefits, and industry process waste benefits. If water quality is low, withdrawn water must be treated before it can be used and the economic benefits (net treatment costs) associated with its usage are lower. Instream benefits (i.e. the benefits of water quality arising from water left "in the stream" and not withdrawn) include two subcategories: usage benefits and non-usage benefits. Instream usage benefits include swimming, boating, and sport-fishing benefits. These type of benefits are associated with direct human interaction with water in the stream/river. Other instream usage benefits include the aesthetic value of water quality that may accrue to nearby picnickers, streamside trail hikers, and streamside property owners. Instream non-use benefits of water quality include stewardship value, altruistic value, bequest value and existence value. Non-use benefits accrue to individuals regardless of whether or not they have direct interaction with water. The stewardship value arises from a belief (often moral or religious) that humans are responsible for maintaining some level of water quality even in cases where no withdrawal or instream usage benefits result. The altruistic value arises from the enjoyment some people receive from simply knowing that other people enjoy withdrawal or instream use benefits. The bequest value arises from a belief that current human generations are responsible for maintaining some level of water quality to "bequest" to future human generations. Finally, the existence value arises from the enjoyment some people receive from simply knowing that some level of environmental quality exists. If water quality is allowed to deteriorate, then stewardship, bequest, and existence goals may not be met, and associated benefits fall (Dumas et al., 2005).

The impacts of urbanization on water quality benefits are mediated by aquatic ecosystems. Increases in stream nutrient levels that lead to algal blooms can reduce swimming and boating benefits while reductions in dissolved oxygen that lead to fish death can reduce fishing and streamside property value benefits. Meanwhile, the increases in disease-causing bacteria due to urban and suburban storm water runoff can increase water treatment costs and reduce swimming, fishing, and boating benefits. The reductions in aquatic species populations or diversity caused by stream sedimentation or toxic chemical discharges can reduce stewardship, altruistic, bequest, and existence values. Economic valuation methodologies typically trace changes in water quality variables through changes in aquatic ecosystem parameters to changes in economic benefits. Often, it is a change in an aquatic ecosystem parameter, such as a fish population, algae population, or disease-causing bacteria population, that is the ultimate cause of a change in economic benefits.

Conversions of rural and forested lands to urban areas degrade streams by altering the composition, structure and function of their aquatic ecosystems. Landscape changes associated with urbanization include terrestrial habitat loss, landscape fragmentation, increased impervious surface area, increased storm runoff, reduced groundwater recharge and riparian habitat loss. The urbanization process is consistently linked to stream degradation, which results from increased peak flows, stream power and stream sedimentation, reduced base flows, and modified instream habitat and substrate complexity. Riparian areas are particularly susceptible to urbanization impacts and habitat fragmentation. The loss of riparian vegetation can destabilize stream banks, increase summer water temperatures and daily fluctuations, alter the recharge of shallow aquifers, and reduce the effectiveness of these natural filters. This loss also results in increased surface runoff, increased erosion and sedimentation and reduced debris and leaf litter deposition. These organic matter deposits are used by many aquatic organisms for food and shelter. Declines of native fish, amphibian, and aquatic invertebrate assemblages have been linked to deterioration of riparian habitats (Kennen et al., 2005).

Linking the effects of landscape fragmentation in a spatial context to ecological consequences is often a difficult task for aquatic ecologists. Moreover, translating the effects into procedures that can be used in management is even more complicated because ecological complexity tends to blur results with patterns and processes that can be difficult to distinguish because of the high level of variability inherent in aquatic ecological data (Kennen et al., 2005).

4. Schistosomiasis – Efforts to control this tropical disease

The rapid urbanization rate of Brazilian cities has resulted in progressively deteriorating sanitary conditions and increased poverty levels of the human population. This situation has greatly challenged public health authorities, created new health problems, and increased the demand for public health services (Callisto et al., 2005). The spread of human schistosomiasis is attributed not only to migration of infected people into non-infected areas, but also to invertebrate host (*Biomphalaria* spp. -A snail (*Mollusca, Gastropoda*)) dispersion. Epidemiological studies often fail to consider the social, economic, and behavioral characteristics of the region when, in fact the watershed should be considered as the study unit (Barbosa et al., 2000).

The natural infestation rates of *Biomphalaria* spp. by *Schistosoma mansoni* oscillates in freshwater ecosystems from 4% in *Biomphalaria straminea* up to 52% in *Biomphalaria glabrata.* The overall infestation rate is related to the abundance of *Biomphalaria* in the area (Favre *et al.,* 2002). A promising new path for biological control of the snail intermediate hosts of human schistosomiasis is the introduction of other snail species, such as *Melanoides tuberculatus* (Pointier, 2001; Giovanelli *et al.*, 2002), that acts only as a natural competitor, and whose competitive pressure on *Biomphalaria* spp. can lead to the latter's extinction. *M. tuberculatus* and *Biomphalaria* spp. have similar diets, feeding on detritus, associated micro-organisms (microalgae and bacteria), and fine particulate organic matter (Pointier *et al.,* 1991; De Marco, 1999). *M. tuberculatus* is an exotic species from Asia that has adapted very well to the climatic conditions of Brazil and can now be found in the benthic malacofauna of many permanent and stable lentic ecosystems. In Minas Gerais State, the introduction of *M. tuberculatus* has resulted in strong competitive pressure for space, as observed in Dom Helvécio Lake at Rio Doce State Park (De Marco, 1999) and in Lagoa Santa Lake in the karstic region (Lagoa Santa Municipality) (Freitas *et al.,* 1994). Recently, Guimarães (2001) observed the reduction and extinction of the *B. straminea* population in a small lagoon in the Municipality of Esmeraldas (metropolitan region of Belo Horizonte) after the appearance of *M. tuberculatus.*

5. What to do to minimize water crisis?

Currently, the world population is growing at a rate of around 1.3% every year, which represents an addition of around 80 million people each year. This growth has caused a significant increase in the demand for water both for direct consumption and for indirect usage (irrigation, industry, sanitation, etc.). To illustrate this better, water consumption in the world doubled between 1940 and 1980, and only 20 years later it doubled again. A visible consequence of this increase is that 40% of the world's population (around 80 countries) has a limited access to this resource. This has generated a series of social problems and conflicts related to hydric resources usage and distribution all over the world. Some pessimistic political scientists already affirm that if some measures are not undertaken, water shortage could be the cause of new world conflicts in a few decades.

The protection of springs and other sources of water needs to be a high priority in the modern society. These sources are streams, rivers, lakes, lagoons and underground aquifers that are used to supply water for human population activities (domestic, agricultural and industrial). The avoidance of pollution of freshwater sources is important for public health since it reduces the costs of treating waterborne diseases and also guarantees wildlife integrity and maintenance (Table 2). The treatment of one cubic meter of good quality water is four times cheaper than the treatment of one cubic meter of water from a polluted river. Furthermore, each dollar invested in water resources usage and treatment saves US$4.3 for the health sector. This certainly would help to reduce the mean of 238 deaths per day caused by polluted water and two thirds of the hospital admissions (including adults) registered by the National Health Service (SUS, Sistema Único de Saúde) (Information from Dr. M. Chiaperini published in the newspaper O Tempo on August 24th, 2003, in Belo Horizonte). Unfortunately, it has been observed that there is an increase in the amount of pollution sources, especially the pouring of sewage and industrial waste into the rivers, which consequently increases the economic resources that the Brazilian society has to spend in the treatment of polluted waters.

Another critical environmental problem that is observed along streams and river courses, especially those located in the floodplains, is the clearance of riparian vegetations. This clearance eliminates the natural barriers that prevent the carriage of fertilizers and herbicides into the water, exposes the river margins to erosion, and increase sediment transport and its deposition and accumulation on the river bed. Moreover, it increases the water flow, reduces the ability of the water to infiltrate and be retained into the ground and increases the effects of floods and inundations.

To manage these numerous anthropogenic pressures and to search for sustainable solutions it is fundamental that all social segments work together to establish political joints capable to ensure that actions are being focused on in order to accomplish the goals defined. It is necessary for these partnerships to discuss the best alternatives that fit the current legislation, use the technical and scientific regional knowledge and promote conferences and multidisciplinary discussions among professionals from different areas. With the involvement of the public administration, non-governmental organizations and natural resources managers it is possible to define priority strategic investments that will minimize the negative impacts affecting continental aquatic ecosystems. The main and most urgent priority is to make all existing information readily available since information is the base of any decision making process.

For water management it is fundamental to join together all the reliable information available that reflects reality in real time. The main sources of this information are (Souza Filho and Gouveia, 2001):

- Compilations in the hydrographic basin plans.
- Requirements monitoring, usage measurements and estimates of the needs concerning industrial, agricultural, tourist and urban usage (among others).
- Information regarding the bestowal system and the monetary charges imposed upon water usage.

- Information regarding the licensing processes for the implantation of new hydric works (e.g. wells and river dams, etc.)
- Data regarding the operation of hydric systems.
- Data regarding the participation of the public administration organizations and the civilians in the management of hydric resources.
- Hydroenvironmental monitoring (fluviometric parameter measurements, data about water socks, pluviometric data, data regarding aquiferous, climatic parameters and superficial and underground water quality).

6. Environmental Biomonitoring Programs

The development of ecological or biological evaluations, commonly called *Biomonitoring*, is fundamental for the sustainable management of hydric resources in several countries. In the European Union the law that establishes the guidelines for water management (2000) indicates that hydric resources have to be biomonitored and that the information obtained by this process has to be stored in databases that facilitate discussion and decision-making regarding the definition of the priorities for its usage. In Australia water quality has been evaluated since 1990 using biological indicators in order to guide the actions of environmental management agencies, and in the United States the same has been done since 1987 (Marchant et al., 2006).

The final price of water has increased rapidly in the last few years. In the main Brazilian cities the cost of a cup of water could reach half the price of a liter of petrol (US$ 0.50). This overprice reflects the shortage of water, especially when considering that petrol is a derivative of the petroleum industry that has to be exploited, refined, transported and distributed whilst mineral water only has to be bottled and transported to be sold.

Besides the rise in the price of potable water, another problem is that sometimes the mineral water offered as potable is not pure. Some commercial brands that provide mineral water use springs that are contaminated by heavy metals, organochlorides and organophosphorates, which are pollutants that are very difficult to detect by basic monitoring methodologies. In other words, sometimes people can consume mineral water polluted by substances that can potentially cause illnesses, several types of cancer and other diseases that result from processes such as bioaccumulation and biomagnification.

Rosenberg and Resh (1993) define biomonitoring as "the systematic use of biological responses to evaluate environmental changes and the use of that information in programs to control environmental quality. These changes most of the times are caused by anthropic actions". In general, an environmental monitoring program has to answer two main questions (Callisto and Gonçalves, 2005): (1) Which is the present functioning state of the ecosystem and where is the resource will be taken from it?, and (2), For what purpose is possible to use this resource (and how much of it?) without modifying the ecosystem functioning?.

Biological monitoring is based on the observation of the changes in the structure and composition of communities of aquatic organisms (Box 1). Benthic macroinvertebrates have been used as indicators of environmental conditions in biodiversity inventories. They have also been used as indicators when biodiversity indexes are used, in "in situ" experiments and in Environmental Biomonitoring Programs.

Box 1: Environmental Biomonitoring Program steps (modifyed from Callisto et al 2005).

7. Freshwater Biodiversity in Tropical Areas

The fundamental constraint for biodiversity conservation is poor knowledge of the existing biodiversity (one cannot effectively protect what is unknown). This is a question particularly important in the tropics since these areas possess the highest estimated biodiversity (hotspots) and, while being, at the same time, the most poorly assessed areas in terms of species inventories (Barbosa and Callisto, 2000). The classic use of species number as the diversity unit is another serious constraint for conservation purposes, particularly in the tropics where there is a general shortage of experts able to identify taxa to species level coupled with the highest number of species found in world ecosystems. In the tropical regions there are around 1.4 million known species (Parker, 1982), a figure that could grow to more than 30 million (Erwin, 1983). Furthermore, other categories may also be useful in determining biological diversity (e.g. functional groups). A more practical approach was suggested by Barbosa and Galdean (1997) as a way to allow joint efforts between taxonomists and ecologists to overcome this barrier.

The loss of biodiversity in aquatic ecosystems has been receiving much less attention despite the wide knowledge of their physical, chemical, and biological ongoing degradation. This degradation is clearly demonstrated by the increase in waterborne diseases (particularly in the tropics), the decrease in fishery production, and the reduction of the quality of water used for supply, irrigation systems and recreation. However, aquatic systems maintain a considerable biodiversity which is being lost mainly as a consequence of habitat deterioration and also due the introduction of exotic species (globally the second cause of biodiversity loss). Threats to the global freshwater biodiversity can be grouped under five interacting categories: overexploitation; water pollution; flow modification; destruction or degradation of habitats and invasion by exotic species (e.g. Allan and Flecker, 1993, Naiman et al., 1995; Naiman and Turner, 2000; Jackson et al., 2001; Malmqvist and Rundle, 2002; Rahel, 2002; Revenga et al., 2005). The environmental changes occurring in a global scale, such as nitrogen deposition, warming, and shifts in precipitation and runoff patterns (e.g. Galloway et al., 2004), are superimposed upon all of these threat categories. Overexploitation primarily affects vertebrates, mainly fishes, reptiles and some amphibians; whereas the other four threat categories have consequences for all freshwater biodiversity from microbes to the megafauna. Pollution problems are pandemic and although some industrialized countries have made considerable progress in reducing water pollution from domestic and industrial point sources, the threats derived from excessive nutrient enrichment (e.g. Smith, 2003) and the environmental accumulation of other chemicals such as endocrine disrupters are growing (e.g. Colborn *et al.*, 1996). Habitat degradation is caused by an array of interacting factors. It may involve direct impacts over the aquatic environments (such as river sand extraction) or indirect impacts that result from changes within the drainage basin. For example, forest clearance is usually associated with changes in surface runoff and increase in sediment loads that can lead to habitat alterations such as shoreline erosion, smothering of coastal habitats, clogging of river bottoms and floodplain degradation.

The use of biological indicators in monitoring programs provides a more exact measure of the anthropogenic impacts affecting the aquatic ecosystems (Callisto and Esteves, 1995; Callisto *et al.*, 2001a; Callisto et al., 2005). Biological indicators have the advantage of allowing the monitoring of water quality over long periods of time, providing a more adequate picture of the effects of pollutants on the ecosystem than traditional chemical methods, which provide only point evidence for water quality in a specific period of time (Tundisi and Barbosa, 1995). Within the organisms commonly used as biological indicators, the benthic macroinvertebrates stand out as biological models due to (Rosenberg and Resh, 1993):

- Their relatively low mobility and long life cycles that reflect temporal patterns and local conditions;
- Their high diversity and abundance that provide a wide range of responses to different environmental pollution agents;
- Their large size and easy identification by non-specialists at high taxonomic level (such as family) resolution;
- The well standardized and low-cost methodologies used to study them; and
- Their temporal and spatial stability that can reflect changes in ecosystem processes .

Microbiological monitoring of organisms, important for determining the levels of water contamination, is accomplished by using fecal pollution indicators represented by bacteria counts of coliform groups (Ceballos *et al.*, 1995). This parameter is used by government agencies to classify water bodies into different use and sanitary levels (balneability and potability). Aquatic bacteria and fungi feed on dissolved organic matter, multiplying rapidly under favorable conditions. Some authors suggest that the number and composition of yeast species present in rivers and lakes can be used as organic enrichment indicators in water bodies (Rosa *et al.*, 1995; Morais *et al.*, 1996). Species within the genera *Cryptococus*, *Debaryomyces*, and *Rhodotora* are characteristically found in non-polluted waters, while *Candida* and *Saccharomyces* species can be frequently found in eutrophic waters (Hagler *et al*., 1986; Rosa *et al.*, 1995).

8. Watersheds as the main focus for integrated intervention acts

Rivers have an important role in the biosphere, channeling water, nutrients, sediments, vegetal debris and biota from the continents to the sea. They are used by humans for transportation, fisheries, hydropower, and as domestic, industrial and agricultural water supplies. Rivers also support unique and complex ecological communities and often influence the structure and functioning of the surrounding terrestrial ecosystem (Pompeu et al., 2005). Because of all this and the critical role of freshwater as a human resource, ecologists are increasingly asked to assess or monitor river "health", "status" or "condition" (Bailey et al., 2004).

Changes in environmental factors often initiate qualitative modifications in species composition and biodiversity. For example, eutrophication may cause a shift in the primary producer species, which in turn may change faunal species composition. Through time, a sequence of modifications may give rise to strongly altered trophic network structures and functions (Marques et al., 2002). Many rivers, streams, lakes, and reservoirs have been damaged as a consequence of the increasing impact of human activities (McAllister et al., 1997). This situation is particularly noticeable in areas of dense human population, especially in the urban environment, where watercourses show highly degraded water quality, receiving not only a great amount of domestic and industrial wastewater, but also sediments and trash. Thus, urban rivers have been transformed, losing their natural characteristics and usually preserving little of their original biological diversity (Pompeu et al., 2005).

A great part of the impacts affecting hydrographic basins of the main rivers in the tropical region is a direct consequence of the high demographic densities that characterize these regions. The disordered occupancy of river margins, in addition to riparian vegetation clearance, the construction of river dams for water supply and electric energy production and the pouring of sewage into the water bodies without any previous treatment are examples of impacts that degrade the aquatic environments. These activities not only affect the environment but also the economy of a country by raising the cost of water treatment for human consumption. As pointed out before, the cost of treating good quality water is of US$2/1000 m^3 while to treat the same amount of degraded water this cost can rise to US$8/1000 m^3.

The high population densities observed in hydrographic basins are also responsible for the geographical expansion of waterborne sicknesses. In Brazil, these sicknesses are responsible for around 80% of the registered hospital admissions. Several experts have suggested that this expansion is directly related to the construction of reservoirs, to population migration and also to water quality decline.

Economic activities are another source of impact in tropical hydrographic basins. Most of the developing countries base their economies on agriculture, mineral and vegetal extraction, iron and steel works, etc. All these activities significantly contribute to the degradation of aquatic ecosystems since they cause accumulation and deposition of sediments in water bodies coupled with increasing levels of nutrient concentration and water pollution.

The Doce River basin, one of the most important basins in the south-east of Brazil (83 000 km^2), possesses areas where the demographic densities can reach 124 persons per km^2. This basin represents an important part of Brazilian economy (mining, iron and steel works, *Eucalyptus* plantations and cellulose industries) that have developed recently along with an accelerated urbanization process. However, this urbanization was not accompanied by a growth of basic sanitary services leading to a decrease in the water quality of the lakes and rivers of the region.

It is easy to perceive that aquatic environments are not isolated ecosystems that have little interaction with their surroundings. On the contrary, they are strongly associated with their drainage basin, constituting landscape entities that possess their own mechanisms responsible for their particular structure and functioning. Most of the time, the sources of the impacts suffered by aquatic environments (eutrophication, contamination, pollution, etc.) are located in their surroundings, originating outside of the aquatic environment. In consequence, proposals for the conservation of aquatic ecosystems have to adopt the entire hydrographic basin as their study and intervention unit, since it integrates the terrestrial and aquatic ecosystems as well as the socio-economic aspects, while being a natural limit for habitats, ecosystems and biota (Barbosa, 1994).

9. Reference Sites for Biomonitoring Efforts in Tropical Watersheds

It is necessary to first define and characterize the natural status of each water body type. This is usually designated as the reference condition (RC). The RC will consequently provide the baseline against which to measure anthropogenic impacts, describe the biological community potential and define the spatial and temporal natural variability (Reynoldson et al., 1997; Bailey et al., 2004). Nevertheless, RC do not necessarily equate to totally undisturbed pristine conditions. They might include very minor disturbances. Human pressure is allowed to be present in a RC as long as a high ecological status is still achieved (Bailey et al., 2004). A RC represents information from numerous similar sites. Establishing type-specific RCs and accordingly, setting type-specific ecological class boundaries, allows an accurate ecological evaluation of each site by comparison with very similar places presenting no or only very minor anthropogenic disturbances. Hydromorphological and physicochemical attributes characterizing the RCs should meet criteria of minimal disturbances to support reference biological communities. Five different approaches and/or combinations of them are currently suggested when determining the RC for biological criteria: (1) extensive spatial surveys, (2) predictive modelling, (3) historical data, (4) paleo-reconstruction and (5) expert judgment, the last being implicit to all four former procedures. In order to establish a RC based on an extensive survey, it is necessary to find sites that are supposed to have been minimally or never exposed to the stressor(s), but also to be representative of each water body type. In relatively unperturbed areas, if undisturbed or minimally disturbed sites are available and numbers are adequate for determining a reliable measure of the mean, median or mode and the distribution indicator values (i.e. percentiles and confidence limits), then the use of survey data is one of the most straightforward methods available for establishing the RC (Barbour et al., 1996; Bailey et al., 2004; Nijboer et al., 2004) (Tables 3 and 4). If reference sites were easily distinguished from disturbed sites, impairment could be assessed without any measurement (Resh et al., 1995). However, the assessment of aquatic ecosystem integrity should no longer be based on subjective criteria, and the reference sites must fulfill specific operational criteria that easily indicate the absence of exposure to stressors. A first classification, using clearly defined *a priori* criteria for human-generated disturbances, and based on several physical/social/biotic features, is becoming commonly used in order to preliminarily assign a sampling site to a degradation class (Hering et al., 2003) and thus, distinguish the reference sites from stressor exposed sites.

Table 3: Criteria for selection of reference sites.

Table 4: Examples of fundamental characteristics.

Recommendations (Bailey et al 2004):

- The objectives of the study have to be defined with the contribution of all the interested parties;
- The size of the studied area has to be determined taking into account that reference areas have to be located out of the impacted area but affected by the same variation in conditions;
- A set of environmental variables has to be chosen for the different scales studied;
- The criteria for the definition of the reference criteria have to be clear and applied rigorously (probably including revision processes);
- The sampling effort has to be standardized and equivalent in the reference and in the impacted locals;
- Create a database (quality control, reliability and safety).

Reference Condition approach in tropical watersheds (according to Bayley et al., 2004).

- First stage: Define the objectives;
- Second stage: Determine the spatial and temporal scale;
- Third stage: Determine the acceptable criteria for the reference areas;

- Fourth stage: Determine the adequate location and the number of reference areas;
- Fifth stage: Choose the parameters that will describe the biological communities and the abiotic variables;
- Sixth stage: Plan the structure of the data base or the system for data management;
- Seventh stage: Develop the certification protocols.

10. Maintenance of riparian vegetation as an intervention action

Riparian vegetation is characterized by being associated with watercourses. It acts like a physical barrier that regulates the exchange processes between terrestrial and aquatic environments by propitiating conditions that are favorable for infiltration of the water to the soil. Its presence significantly reduces the possibility of contamination of water bodies by sediments, fertilizer residues and pesticides in surface water runoff. These zones can be excellent nutrient consumers, acting as a buffer zone for input to the water body of nutrients from agroecosystems (Figure 1).

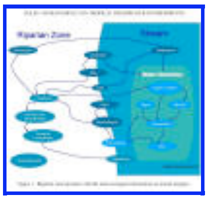

Figure 1: Riparian zone dynamic with the main ecological interactions at stream margins.

Frequently, riparian forests are impacted by forest clearance, mining and fires. For example, in the Brazilian savanna (Cerrado) there have been disorganized large scale forest clearance activities that included the actions of agriculturalists, livestock farmers, miners and woodsmen as well as the use of wood for charcoal production. The absence of plant cover provided by these forests alters local conditions and generates great ecological disequilibria. One of the most serious problems caused by the destruction of these habitats is increased surface runoff of nearby residues to the river. In the mid and long term, accumulation of these sediments causes lowering of the watershed, a process that causes floods and lowers the life span of dams and hydroelectric infrastructure. Clearance of riparian forests also leads to erosion processes, loss of soil fertility and agricultural lands, and disappearance of aquatic and terrestrial fauna.

The environmental impacts caused by human beings over the basins' ecosystems can be the product of practices such as: long-term soil fertilization, systematic application of pesticides and herbicides, organic waste management, garbage recycling and management practices and development projects that use the water. The continuous application of chemical nitrogen-based fertilizers or cow dung can contaminate groundwater with nitrate, elevating its concentrations to more than 10 mg/l. The expansion of urban areas over agricultural lands and forested microbasins can cause increase in peak flow and modify the river's physical characteristics. Interactions between forest management and agricultural areas need to be evaluated, first at the microbasin level and then at the level of entire basins, especially with regard to the quality and quantity of water available in the extant watercourses.

To date, there is little information in the literature regarding the relationships between hydrographic basin management and riparian forest maintenance or between riparian forests and soil management and conservation. Understanding of these relationships involves the understanding of the inherent link between human systems and the natural environment. First, it is necessary to understand the relationship between the riparian forest and the watercourse. It is probable that these forests were established as a consequence of the moisture and fertility conditions that prevail in the river margins; these conditions are adequate for the germination and establishment of dispersing plant species. However, in an established system, both parts (the watercourse and the riparian forest) are mutually dependant on each other and both can suffer when one is altered or suppressed.

The terrain located at the margins of rivers and reservoirs has great importance because it is usually covered by natural vegetation that has to be permanently preserved. This vegetation protects the soil against erosive processes, prevents sediment accumulation and deposition, guarantees the permeation of storm waters, and creates buffer zones against floods and barriers for surface and sub-surface runoff of polluting agents into the watercourses. It is also necessary that areas located in floodplains have a restricted usage in order to maximize their preservation. These areas must have low occupancy rates in order to allow water permeation to the ground and consequently reduce the runoff of unwanted substances to the watercourses. In those areas the terrain has to be permeable at least in 50% of the surface.

Forests and other natural vegetation formations that are located along rivers are thus considered by the Brazilian Forestry Code as Permanent Protection Areas (Areas de Proteção Permanente) where the minimum zone width accepted by the legislation for the marginal vegetation that has to be preserved depends on the size of the water body as follows:

- 30 meters for rivers less than 10 meters wide;
- 50 meters for rivers between 10 and 50 meters wide;
- 100 meters for rivers between 100 and 200 meters wide;
- 200 meters for rivers between 200 and 600 meters wide; and
- 500 meters for rivers with more than 600 meters from margin to margin.

For lakes, lagoons and natural and artificial reservoirs, the CONAMA

Resolution Nº 04/85 establishes as ecological reserves any forests and adjacent vegetation in a marginal zone of different sizes according to the following:

- 30 meters in urban areas
- 50 meters for water bodies located in rural areas that are less than 20 hectares in size (surface area);
- 100 meters for hydroelectric dams and water bodies located in rural areas and with more than 20 hectares of surface area.

11. Litter Breakdown as a tool to assess Human Impacts

The assessment of ecosystems condition is a critical prerequisite for alleviating effects of multiple anthropogenic stresses imposed on them. For freshwaters, a multitude of approaches has been proposed for this purpose. However, they all rest on assessment of structural attributes, even though it is generally recognized that adequate characterization of ecosystems requires information on both their structure and functioning (Gessner and Chauvet, 2002).

The functional processes in temperate rivers are relatively well described, based on the large number of studies already performed. The increase on the knowledge of river ecology is basic for the proposal and application of water resources conservation and management measures. Although rivers in tropical and sub-tropical regions can transport greater water volume than those in temperate regions, studies into the energy transfer that maintains the metabolism of these lotic ecosystems are still scarce. Tropical and sub-tropical rivers are probably less impacted than those in temperate regions, but increases in urbanization, industrialization, and agricultural and forestry enterprises tend to alter this situation.

Litter breakdown rate is a good alternative to assess ecosystem-level processes in addition to structural biological parameters where the input of allochthonous organic matter is the main energy source for aquatic communities in environments that have margins shaded by riparian vegetation (Webster and Meyer, 1997). Litter breakdown experiments are simple to set up and have been done in many aquatic ecosystems in recent decades, especially in North America and Europe. As yet, however, little is known about litter breakdown in tropical streams (Moretti *et al.*, 2007), but recently many researchers have become interested in the patterns that regulate this process and in its use to assess stream integrity in the tropical region, which occupies about 25% of the planet area.

Leaf breakdown in streams is governed by a variety of internal and external factors that may complicate the separation of effects due to anthropogenic stress and natural processes, thus potentially limiting the sensitivity and robustness of the methods. However, many confounding factors can be controlled by standardizing the assessment procedures, including such measures as the use of litter from specified reference leaf species, stream classification, and/or comparative approaches. In addition, if breakdown rates *per se* are not sensitive enough, one may resort to composite parameters such as ratios of breakdown coefficients in coarse mesh and fine-mesh bags. Furthermore, the analyses may be extended to a wide range of both structural and functional parameters associated with the breakdown process.

Adding to biological communities' structural parameters, the information obtained with litter breakdown experiments can be useful for companies and environmental bodies to take important decisions for the maintenance of the health of aquatic ecosystems (mainly for ecosystems in which previous studies on biological communities and physicochemical variables have already been carried out). This kind of approach allows researchers to obtain precise evaluations about the vulnerability of the lotic ecosystems and the impacts that they are subjected to. This information is also relevant to discussions about preservation, refining more effective methodologies to be used in restoration projects, and in implementation of management policies by public institutions and potentially polluting industries.

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Glossary

Agrotoxics	**:** Chemical products used in agriculture. In most cases, agrotoxics refers to the broad range of insecticides, herbicides, and fungicides, but it may also include synthetic fertilizers, hormones and other chemical growth agents, and concentrated stores of raw animal manure. *Agrochemicals*.
Allochthonous organic matter	**:** Organic matter entering a stream, lake or ocean but derived from an adjacent terrestrial system.
Aquifer	**:** An underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be usefully extracted using a water well.
Balneability	**:** The quality of waters for recreational use, for instance, to the bath, swimming and other sportive issues.
Benthic zone	**:** The lowest level of a body of water, such as an ocean or a lake. It is inhabited by organisms that live in close relationship with (if not physically attached to) the ground, called benthos or benthic organisms. Generally, these include life forms that tolerate cool temperatures and low oxygen levels, but this depends on the depth of the water.
Bioaccumulation	**:** The increase in concentration of a substance in an individual' tissues due to uptake from food and sediments in an aquatic milieu. It is a process that occurs within a trophic level.

Biodiversity	**:** An umbrella term to describe collectively the variety and variability of nature. It encompasses three basic levels of organization in living systems : the genetic, species, and ecosystem levels. Plant and animal species are the most commonly recognized units of biological diversity, thus public concern has been mainly devoted to conserving species diversity.
Biomagnifications	**:** The increase in concentration of a substance, such as the pesticide DDT, that occurs in a food chain as a consequence of (1) food chain energetics; and (2) low (or nonexistent) rate of excretion/degradation of the substance. It is a process that occurs across trophic (food chain) levels.
Biomonitor	**:** An organism that provides quantitative information on the quality of the environment around it. Therefore, a good biomonitor will indicate the presence of the pollutant and also attempt to provide additional information about the amount and intensity of the exposure.
Buffer zone	**:** The area of land adjacent to a wetland or water body. A buffer zone is generally thought of as a buffer against human generated disturbance in areas adjacent to the wetland.
Competitive pressure	**:** In biology, competition is an interaction between two (or more) organisms (or species), in which, for each, the birth and/or growth rates are depressed and/or the death rate increased by the other organisms (or species).
Conservation	**:** The science of analyzing and protecting Earth's biological diversity. Conservation biology draws from the biological, physical and social sciences, economics, and the practice of natural-resource management. It also means the scientific study of the phenomena that affect the maintenance, loss, and restoration of biological diversity.
Data base	**:** In computer science, a database is a structured collection of records or data that is stored in a computer system so that a computer program or person using a query language can consult it to answer queries. The records retrieved in answer to queries are information that can be used to make decisions.
Environmental monitoring	**:** The science of inferring the ecological condition of an area by examining the organisms that live there. Although environmental monitoring can occur in any ecosystem, it is most often used to assess water quality of rivers, lakes, streams, and wetlands. *Biomonitoring*.
Eutrophication	**:** An increase in chemical nutrients (typically compounds containing nitrogen or phosphorus) in an

	ecosystem. It may occur on land or in water. The term is however often used to mean the resultant increase in the ecosystem's primary productivity (in other words, excessive plant growth and decay) and even further impacts, including lack of oxygen and severe reductions in water quality and in fish and other animal populations.
Exotic species	**:** An organism that is not indigenous to a given place or area and instead has been accidentally or deliberately transported to this new location by human activity. Exotic species can often be damaging to the ecosystem it is introduced to. *Introduced species*, *alien species*.
Fertilizers	**:** Compounds given to plants to promote growth; they are usually applied either via the soil, for uptake by plant roots, or by foliar feeding, for uptake through leaves. Fertilizers can be organic (composed of organic matter), or inorganic (made of simple, inorganic chemicals or minerals).
Functional parameters	**:** Refers to the rates, patterns, and relative importance of different ecosystem-level processes.
Habitat fragmentation	**:** The emergence of discontinuities (fragmentation) in an organism's preferred environment (habitat). Habitat fragmentation can be caused by geological processes that slowly alter the layout of the physical environment or by human activity such as land conversion, which can alter the environment on a much faster time scale. The former is suspected of being one of the major causes of speciation. The latter is causative in extinctions of many species.
Habitat loss	**:** Is a process of land use change in which one habitat-type is removed and replaced with another habitat-type. In the process of land-use change, plants and animals which previously used the site are displaced or destroyed, reducing biodiversity.
Herbicides	**:** Compounds used to kill unwanted plants. Selective herbicides kill specific targets while leaving the desired crop relatively unharmed. Some of these act by interfering with the growth of the weed and are often based on plant hormones. Herbicides used to clear waste ground are nonselective and kill all plant material with which they come into contact.
Host	**:** In biology, a host is an organism that harbors a virus or parasite, or a mutual or commensal symbiont, typically providing nourishment and shelter.
Hydrographic basin	**:** A region of land where water from rain or snow melt drains downhill into a body of water, such as a river, lake, dam, estuary, wetland, sea or ocean. The hydrographic basin includes both the streams and rivers that convey the water as well as the land

surfaces from which water drains into those channels. The drainage basin acts like a funnel - collecting all the water within the area covered by the basin and channeling it into a waterway. Each drainage basin is separated topographically from adjacent basins by a ridge, hill or mountain, which is known as a water divide or a watershed. *Drainage basin, water basin*.

Litter breakdown **:** The decomposition of riparian organic matter (mainly dead leaves) in aquatic ecosystems. This process can be influenced by a variety of factors, specially leaching and presence of biotic decomposers (adapted microbial and invertebrate fauna).

Malacology **:** The branch of invertebrate zoology which deals with the study of mollusks, the second-largest phylum of animals in terms of described species. One division of malacology, conchology, is devoted to the study of shelled mollusks. Fields of malacological research include taxonomy, ecology, and evolution. Applied malacology studies medical, veterinary, and agricultural applications, for example mollusks as mediators of such diseases as schistosomiasis.

Microenvironment **:** The immediate surroundings and other physical factors of an individual plant or animal within its habitat. *Microhabitat.*

Overexploitation **:** The use of raw materials excessively without considering the long-term ecological impacts of such use.

Oxbow lake **:** A U-shaped lacustrine water body formed when a wide meander from the mainstem of a river is cut off to create a lake. This landform is called an oxbow lake for the distinctive curved shape that results from this process.

Potability **:** The quality of waters to serve as drinking water, which is intended to be ingested by humans.

Riparian vegetation **:** Plant communities living in a forested area of land adjacent to a body of water such as a river, stream, pond, lake, marshland, estuary, canal, playa or reservoir.

Riparian zone **:** The interface between land and a flowing surface water body. These zones are significant in ecology, environmental management, and civil engineering due to their role in soil conservation, their biodiversity, and the influence they have on aquatic ecosystems.

Stressor **:** An agent, condition, or other stimulus that causes stress to an organism or ecosystem.

Structural parameters **:** Refers to spatiotemporal patterns, particularly of biological communities and their resources.

Yeast **:** A growth form of eukaryotic microorganisms classified in the kingdom Fungi, with approximately 1,500 species described. Yeasts are unicellular, although some species with yeast forms may become multicellular through the formation of a string of connected budding cells known as *pseudohyphae*, or *true hyphae* as seen in most molds. Yeast size can vary greatly depending on the species, typically measuring 3–4 µm in diameter, although some yeasts can reach over 40 µm.

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Biographical Sketches

Marcos Callisto is a biologist, Master in Ecology, and PhD by Federal University of Rio de Janeiro, Brazil. He has been working at Federal University of Minas Gerais with benthic macroinvertebrate ecology in headwater streams, focusing on their importance as bioindicators of water quality in tropical ecosystems. His scientific interests include tropical freshwater conservation, leaf breakdown process, environmental education and interdisciplinary studies of watersheds. A summary of his activities is available at www.icb.ufmg.br/big/benthos.

Marcelo S. Moretti is a biologist, Master in Ecology, and conducting his PhD in Ecology at Federal University of Minas Gerais. His research is focused on the study of a typical tropical shredder using leaf detritus in laboratory and field experiments. Part of his research focus is on the microorganisms and invertebrates involved in leaf breakdown in tropical freshwater ecosystems.

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