S7C-1 In: Proc. of the 8th Insternat. Symp. On Conservation and Management of Lakes: S7.C-1, ILEC, Copenhagen. 1999

Human impacts and freshwater biodiversity in the Rio Doce, south-east Brazil: the watershed as the study unit.

Para o Dr Callisto

Barbosa, F.A.R., Maia-Barbosa, P.M., Rocha, L., Marques, M.M. & Callisto, M.

Federal University of Minas Gerais-Institute of Biological Sciences-P.O. Box 486
30161-970 Belo Horizonte, Minas Gerais-Brazil.

Introduction

Although suggested since 1968, the adoption of the hydrographic basin as the unit for intervention/conservation has been very recent in Brazil with only few examples of integrated studies within a watershed considering simultaneously the major human activities and their impacts on the aquatic biodiversity (Paula et al., 1997).

In the present study, the major human activities on the middle Rio Doce basin were analyzed along seven sub-basins in order to determine their potential impacts on the water quality and the biodiversity of the benthic, planktonic and fish communities and to provide reliable tools for the monitoring of the physical, chemical and biological conditions. The results of a pioneering environmental education program were also summarized.

The Rio Doce basin is one of the most important watersheds in SE Brazil (83,000 km^2; 3.1 million inhabitants; 124 inhabitants/Km^2) representing an important segment of the economy (mining, iron/steel plants, *Eucalyptus* plantations, cellulose industry) developed recently and which was accompanied by accelerated urbanization lacking almost completely basic sanitation resulting in an increasing degradation of the aquatic ecosystems. The economic activities moved from the initial gold mining boom initiated in 1720, and coffee/sugar-cane plantations in 1861, to the implementation of iron/steel plants in the late 1930s, culminating with large reforestation projects mainly with *Eucalyptus* spp. from the end of the 70s. Nowadays, mining is one of the most important economic activities in the area, consuming considerable amounts of water and degrading extensive areas, including those containing the headwaters of the major rivers of the region.

The original Mata Atlântica was reported as possessing high diversity and endemism levels (Muller, 1973; Haffer, 1974) nowadays reduced to no more than 7% of the original vegetation of which less than 1% are primary forests (Fonseca, 1985). The botanical diversity in the area is *ca.* 10,000 species of which 53% of the trees, 74% of the bromeliads and 64% of the palms are endemic. Of the present 940 species of birds, 214 are restricted to the area, as well as 73 out of the 260 recorded species of mammals, and 92% of the known amphibians. Apart from a few inventories for certain groups (e.g. fishes), there is very scarce information on the aquatic biodiversity for the majority of the area (IEF, 1994).

The waters in the middle Rio Doce basin (Minas Gerais State) were grouped in seven sub-basins: Caraça, Santa Bárbara, Piracicaba, Peixe, Severo, Ipanema, and Rio Doce within which 20 sampling stations were investigated during the dry and rainy seasons of the period 1993-1995. The Piracicaba has been the most affected basin by human activities, receiving in 1992 alone some 80,000 m^3 of untreated effluents and 93,205 Kg/day of total suspended solids resulting in a chemical oxygen demand of 71,855 kg/day, a biochemical oxygen demand of 9,558 kg/day, and a toxicity of 7,500 kg Equitox/day (Cetec, 1988).

The major human activities are: a) mining, mainly in the upper basin; b) large and continuous areas of *Eucalyptus* plantations (1/3 of the area of the basin); c) agro-forestry and animal husbandry, causing widespread erosion, and a considerable loss of fertile soils, a progressive silting up and deterioration of water quality); and d) the contribution of untreated solid and liquid domestic wastes from the majority of the municipalities along the river banks, which are discharged into the waters, resulting in high organic pollution.

Results

Table 1 summarizes the number of taxa recorded for the studied communities along the sub-basins.

A total of 194 **phytoplankton** taxa were identified of which Cyanophyceae (28), Euchlorophyceae (45), Zygophyceae (67), Ulothricophyceae (8), Centrophycideae (3), Pennatophycideae (27), Dinophyceae (2), Euglenophyceae (10) and Chrysophyceae (3). Qualitatively Zygophyceae is the dominant group followed by Euchlorophyceae. Quantitatively Pennatophycideae is the dominant group. The **zooplankton** was dominated by Protozoa (*Arcella vulgaris* and *Vorticella* sp.), rotifers (*Bdelloidea*) and nematodes, particularly in areas of high organic polluted waters. Santa Bárbara is the sub-basin showing the highest diversity (2.81) and Piracicaba the lowest one (1.18). Rotifers constitute the most diverse group, representing 43% of the recorded organisms, followed by protozoans & copepods (20%), and cladocerans (17%).

Table 1. Number of taxa for each studied community and sub-basin, during the period 1993-1995

Sub-basin	Zooplankton	Phytoplankton	Benthos	Fishes
Caraça	25	53	18	-
Sta. Bárbara	52	74	60	-
Piracicaba	45	66	34	17
Peixe	19	55	28	12
Severo	31	65	20	-
Ipanema	12	34	11	-
Doce	53	54	38	17

The **benthic** community is formed by 84 taxa (70 Insecta, 9 Mollusca, 5 other groups). Among the Insecta, Chironomidae (Diptera) showed the highest frequency of occurrence, being present at all sampling stations. Other families with wide distribution were Hydrophilidae (Coleoptera), and Gomphidae (Odonata). On the other hand, 19 insect families were recorded at only one station. Among the Annelidae, Oligochaeta was common to all the sampling stations while Hirudinea was recorded in 11 of the sampling stations. Among the mollusks Physidae and Sphaeriidae showed a wide distribution while Planorbidae was present in 7 stations only. The **fish** diversity is represented by 25 species including five species exotic to the basin (*Pygocentrus nattereri, Hoplias lacerdae, Lophiosilurus alexandri, Tilapia cf. rendalli, and Poecilia reticulata*). Among the species with wide distribution were *Hoplias malabaricus, Astyanax bimaculatus, Oligosarcus artenteus* and *Geophagus brasiliensis*. In broad terms the recorded fish fauna can be considered as not very diversified, being comprised of species of broad geographical distribution and tolerant to environmental disturbances.

The waters are well oxygenated (> 80% saturation), with neutral pH, low to medium total alkalinity (0.5-1.0 mEq.CO_2 /L) and conductivity of 117-123 $\mu S.cm^{-1}$. NH_4-N is the major nitrogen form and, except for the Caraça sub-basin, inorganic P and soluble "reactive" Si are not limiting nutrients although concentrations < 10 $\mu g.l^{-1}$ of soluble reactive P have been recorded during the rainy periods.

Physico-chemical and biological indices were developed using multivariate statistical techniques. For the physico-chemical index, data of temperature, pH, alkalinity, conductivity, dissolved O_2, Si, NH_4-N, NO_2-N, NO_3-N, inorganic-P, total-P and total-N were used. For the biological index the following variables of the benthic community were used: number of taxa, total density, density of Ephemeroptera, Plecoptera and Trichoptera (EPT) % of dominant taxa, % of EPT, and % of Chironomidae + Oligochaeta.

From the correlation matrix of the variables the following generic formula was developed:

$$PCI / BI = a_1\left[\frac{(x_1 - \hat{\mu}_1)}{\hat{\sigma}_1}\right] + a_2\left[\frac{(x_2 - \hat{\mu}_2)}{\hat{\sigma}_2}\right] + a_3\left[\frac{(x_3 - \hat{\mu}_3)}{\hat{\sigma}_3}\right] + \ldots$$

Where: a_i = weight of variable i ; $\hat{\mu}_i$ = estimated average of variable i ; $\hat{\sigma}_i$ = estimated standard deviation of variable i ; x_i = empirical values of variable i ; i = 1, 2, 3, ...,p

This formula was then used to develop both, a physico-chemical index and a biological index, with the above listed variables. A water quality index was then developed (composite index), considering the combination of the physical, chemical and biological aspects, taking the benthic community as a reliable representative of the present biota. The following general formula was developed:

$$WQI_{d,r} = w\left(\frac{PCI_{d,r}\hat{\mu}_{WQI}}{\hat{\sigma}_{PCI}}\right) + w\left(\frac{BI_{d,r} - \hat{\mu}_{BI}}{\hat{\sigma}_{BI}}\right),$$

where $WQI_{d,r}$ = The water quality index for the dry (d) or rainy (r) period; w = weight of the principal component; $\hat{\mu}_{WQI}$ = estimated average of the physico-chemical index ; $\hat{\mu}_{BI}$ = estimated average of the biological index; $\hat{\sigma}_{PCI}$ = estimated variance of PCI, $\hat{\sigma}_{BI}$ = estimated variance of BI

Considering that the sampling distribution of the indices for dry and rainy periods is close to the normal, with an average of 0 and a variation of 2.7, five classes of water quality were identified as: Excellent, Good, Acceptable, Bad, Very Bad (Fig. 1).

An environmental education program jointly organized with local communities was conducted aiming to integrate environmental and social problems in the area. The following were the developed activities: an educational video on the major environmental problems of the basin; short and long courses on selected themes; mobilizing campaigns to enhance public awareness on the regional problems; a public poll on how the common citizens perceive their environment, and a specific long-term course aiming to form local environment monitoring groups capable of serving as nuclei for further activities. Furthermore, as a consequence of the above mentioned activities, local initiatives were supported in the organization of seminars and public discussions on specific environmental problems such as water quality, solid and liquid waste disposal, medicinal plants, among others. In a second phase, the program was concentrated within the primary and secondary schools of four municipalities for which a book based on regional relevant environmental questions was edited and distributed to all the schools within the area.

Conclusions and Perspectives

The recorded results constitute a reasonable foundation of data on the middle Rio Doce watershed, which should allow sound planning for restoration and management proposals in the near future. For the first time, limnological, ecological, and socio-economic aspects were considered together in order to clarify the regional environmental reality and to define policies and priorities for the actions to be taken. The use of the river as validation for the integrated analysis was a revelation: groups with perspectives other than the biological/ecological one became attracted to the idea of searching for common indicators to explain how different human actions affect the environment, thus changing the physical, chemical, and biological communities within the rivers. The general idea is as if each sampling station would expand itself to express the economic, cultural urban structure, political, and institutional activities. The joint participation of the scientific community, governmental segments, private initiatives and the local populations suggests a real possibility for the success of sound intervention in the area very likely to produce positive results. In the near future, planned actions will count on the present results in order to implement feasible proposals for the restoration and sustainable use of the natural resources of the area for the future generations.

It is very likely that the most significant contribution of the present project is the proposition of an interdisciplinary methodology, combining different views of the environmental question, thus constituting a real contribution towards changing the traditional mentality and attitudes of seeing the environment and its resources as simply a set of goods and services to be exploited by human populations. Furthermore, the results shall be used to propose a distinct mode of training people, assuming the need for interdisciplinary teams to deal with the environmental problems, and capable of promoting the sustainable use of the natural resources in the area.

The authors are grateful to the kindly contribution of the colleagues of the project Biodiversity, Population, Economy (PADCT/CIAMB), funded by the World Bank, CNPq, FINEP and CAPES. Special thanks to the comments and suggestions of DR Nicolae Galdean and the English revision of DR Douglas Yanega.

References

Centro de Tecnologia de Minas Gerais-CETEC. Levantamento da poluição hídrica da bacia do Rio Piracicaba. Relatorio Final, Belo Horizonte, 1983. FONSECA, G.A.B (1985): *Biol. conservation* 34: 17-340. -- HAFFER, J.J. (1974) Harvard: Nuttall Ornithological Club, Museum of Comparative Zoology/Harvard University, 1974. -- Instituto Estadual de Florestas-IEF (1994) Coletânea bibliográfica sobre o Parque Estadual do Rio Doce. Belo Horizonte, 61p. RIGLER, H.F. & PETER, R.H. (1995) in THIMME, O. (ed.). *Excellence in ecology*, vol 6. PAULA, J. A., A. F. BARBIERI, C. B. GUERRA, E. C. LANDAU, F. VIEIRA, F. A. R. BARBOSA, H. S. M. COSTA, L. P. GUERRA, R. L. M. MONTE-MOR, R. F. SIMÕES & T. M. BRAGA (1997) (org.). Biodiversidade, população e economia: uma região de Mata Atlântica. Rona Editora, Belo Horizonte, Brasil. -- VOLLENWEIDER, R.A (1968) ECO, Paris. OECD/DAS/SCI/.