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Rapid assessment of water quality and diversity of benthic macroinvertebrates in the upper and middle Paraguay River using the Aqua-Rap approach

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Introduction

The fundamental constraint for biodiversity conservation is the poor knowledge of existing biodiversity (one cannot effectively protect what is not known). This is a question particularly important in the tropics since these areas possess the highest estimated biodiversity (hotspots) and, at the same time, the most poorly assessed. 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 and because the tropics have the highest number of species – there are ca. 1.4 million known species (PARKER 1982), a figure which could grow to ca. 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 & GALDEAN (1997) as a way to allow joint efforts between taxonomists and ecologists to overcome this barrier.

The creation of parks and natural reserves has been the major adopted action to avoid mass species extinction, and presently only ca. 5% of the Earth's surface is under protection, in approximately 5,000 areas worldwide. However, the effectiveness of this practice is arguable – how big must these areas be to be effective (SOULÉ & SANJAYAN 1998) and huge species extinction outside these areas will occur due to present deforestation rates and habitat destruction (SOULÉ 1991, SOULÉ & SANJAYAN 1998, PIMM & LAWTON 1998). According to these authors, the majority of extant species are living in tropical rain forests, most of which are under severe threat. Deforestation alone should be responsible for the elimination of most of the surrounding areas not under protection by the year 2100 or before (HOUGHTON 1990 apud SOULÉ 1991). Furthermore, according to SIMBERLOFF (1986), and SOULÉ & SANJAYAN (1998) up to 50% of the world's species are likely to disappear in the 21st century or sooner.

The loss of biodiversity in aquatic ecosystems has been receiving much less attention despite the wide knowledge of their physical, chemical, and biological degradation, clearly demonstrated through the increase in water borne diseases (particularly in the tropics), decreasing fishery production, and diminishing water quality for supply, irrigation systems, and recreation. However, aquatic systems maintain a considerable biodiversity which is being lost mainly as a consequence of habitat deterioration.

The introduction of the watershed as the unit for studies (RIGLER & PETERS 1995) was of paramount importance in the demonstration that the implementation of conservation practices for terrestrial environments does not automatically include adequate protection of aquatic habitats, as pointed out previously (JUNK 1983, BARBOSA 1994). The proposed areas for conservation in the Brazilian Amazon provide an example of the major constraints of this approach (see RYLANDS 1990).

Despite it being unclear if the best conservation option is to consider the protection of total diversity of an area or the highest possible number of rare species (see PIMM & LAWTON 1998) it is important to consider diversity in a dynamic context, including not only the preservation of the biotic elements but also the basic processes responsible for their maintenance (NORTON & ULANOWICZ 1992). Furthermore, as suggested by TUNDISI & BARBOSA (1995), for conservation purposes the adoption of the watershed as the conservation unit is fundamental. This unit integrates the multiple uses of natural resources and their surrounding social, economic, and cultural factors.

The Aqua-Rap approach

Taking as a basis the hierarchical strategic approach to establish investment priorities for conservation, Conservation International (CI) identified, at a global scale, areas named "hotspots" (15 of which are in tropical regions). These areas contain at least one

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third of the Earth's biodiversity, much of which is under threat. These regions were considered to represent the major "virgin" areas in the world, and the concept of "megadiversity countries" was developed. The hotspots, however, represent only 3–4% of the Earth's surface and only some of these areas have been assessed through the Rapid Assessment Programme (RAP) for Biodiversity (MITTERMEIER & FORSYTH 1992). In short, the RAP approach constitutes a powerful tool used to select important areas for the conservation of biodiversity, a selection made by a concentrated effort of specialists aiming to sample the highest possible number of sites in the shortest possible time. These areas will then be evaluated and selected for further detailed studies.

As an extension of the "rapid assessment programme", a protocol for aquatic systems – Aqua-Rap (CHERNOFF et al. 1996) was developed, which is based on the hydrographic basin as the unit for conservation. It concentrates on three main objectives: i) to develop interdisciplinary criteria and protocols to obtain information needed to select priority aquatic ecosystems for conservation; ii) to promote international collaboration and the development of research programmes, mainly in watersheds possessing international resources; and iii) to stimulate the exchange of scientific specimens and ideas in order to reduce "parochial systematics", hopefully resulting in a broader accepted taxonomy of biotic resources. This approach should be able to provide, in the shortest possible time, basic information to help governments and conservationist groups in defining conservation policies related to the aquatic biodiversity in these areas.

To date, two expeditions have been completed, one to the Bolivian Amazon area (basins of the Tahuamano and Nareuda Rivers) in 1996, and one to the Upper Paraguay basin (covering a considerable area of chaco in Paraguay) in 1997.

In this paper, we report the first results on water quality and the macroinvertebrate benthic fauna in the Paraguay basin, aiming to demonstrate their importance for conservation of aquatic biodiversity in South America. Furthermore, we intend to provide further basic elements that call attention to the urgent need to accelerate biodiversity assessment, and thus contribute to the enhancement and implementation of actions preserving the existing biodiversity.

The assessments were conducted at 33 sampling stations located in the upper-middle Paraguay River (Fig. 1). They aimed to characterise the basic water conditions and the structure and distribution patterns of the benthic communities, taking into consideration the existing trophic interactions, particularly the diversity of chironomids (Diptera), and the influence of abiotic features responsible for the quality and types of water and sediments.

The study areas

Samples were collected from the upper and middle Paraguay River, covering the contributions from the sub-basins of the Rivers Negro and Apa, and the La Paz Stream (20° 09' 7.0''–23° 6' 28'' S; 57° 34' 1.8''–58° 10' 11.4'' W), between 4 and 18 September 1997 (rainy season). These areas include several distinct types of habitats, namely wetlands and semi-lotic environments (corixes) with a diverse number of aquatic macrophytes (Dr. FATIMA MERELES personal communication, including: *Eichhornia cras-*

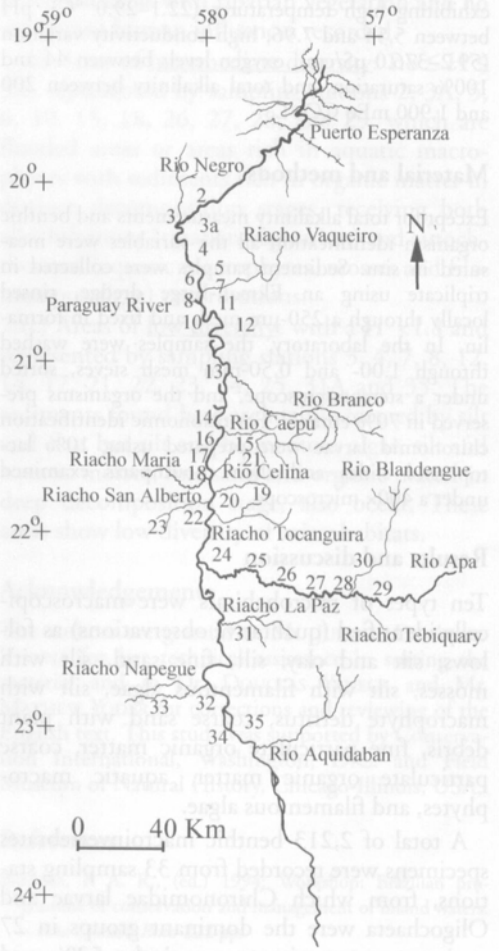

Fig. 1. Map of the sampled stations in the upper and middle Paraguay River.

sipes, E. azurea, Alternanthera philoxeroides, Salvinia sp., *Azolla* sp., *Ceratopteris* sp., *Ludwigia* sp., *Pontederia rotundifolia, Neptunia* sp., *Paspalum stoloniferum, Heteranthera* sp., *Spirodella* sp., *Pistia stratiotes, Wolffiella* sp., *Nymphaea* sp., *Cabomba* sp., *Utricullaria* sp., and *Nymphoides humboldtianum*), coastal-inundated areas largely covered with *Copernicia alba* (Palmares), riparian vegetation forming a mosaic with *Schinopsis balansae*, and *Copernicia alba* (higher areas), and flooded areas, vegetated sand banks, streams, and creeks with sandy or muddy beaches. In general terms, these areas appear to be well conserved except for the northern part where cattle ranching activities have been increasing considerably in the last decade.

The sampled waters are, in general, clear to dark, exhibiting high temperatures (22.1–29.0 °C), pH between 5.54 and 7.96, high conductivity variation (59.2–376.0 µS/cm), oxygen levels between 44 and 100% saturation, and total alkalinity between 200 and 1,900 mEq CO_2/L.

Material and methods

Except for total alkalinity measurements and benthic organism identification all the variables were measured in situ. Sediment samples were collected in triplicate using an Ekman-Birge dredge, rinsed locally through a 250-µm mesh and fixed in formalin. In the laboratory, the samples were washed through 1.00- and 0.50-mm mesh sieves, sorted under a stereomicroscope, and the organisms preserved in 70% ethanol. For taxonomic identification chironomid larvae were prepared using 10% lactophenol slides and their mouthparts examined under a 400× microscope.

Results and discussion

Ten types of microhabitats were macroscopically identified (qualitative observations) as follows: silt and clay, silt, fine sand, silt with mosses, silt with filamentous algae, silt with macrophyte detritus, coarse sand with plant debris, fine particulate organic matter, coarse particulate organic matter, aquatic macrophytes, and filamentous algae.

A total of 2,213 benthic macroinvertebrates specimens were recorded from 33 sampling stations, from which Chironomidae larvae and Oligochaeta were the dominant groups in 27 stations, representing, respectively, 52% and 35% of the recorded organisms. Other groups were also recorded in small numbers including: Odonata, Trichoptera (*Oxyethira*), Ephemeroptera, Chaoboridae, Ceratopogonidae, Corixidae, Conchostraca, Planaria, Nematoda, Hirudinea, Copepoda, Ostracoda, Bivalvia and Mollusca (*Pomacea*). Among the Chironomidae larvae 26 taxa were identified, with abundance in decreasing order as follows: *Nimbocera paulensis, Polypedilum, Chironomus, Ablabesmyia, Goeldichironomus, Fissimentum desiccatum, Harnischia, Nilothauma, Parachironomus, Stenochironomus, Asheum, Coelotanypus*, and *Djalmabatista*. At lower densities were larvae of *Axarus, Beardius, Cladopelma, Cryptochironomus, Phaenopsectra, Denopelopia, Labrundinia, Macropelopia, Tanypus, Corynoneura, Cricotopus, Nanocladius* and *Thienemanniella*, along with specimens belonging to the many Tanytarsini yet undescribed, endemic species of South America (see Fittkau & Reiss 1973).

The majority of the recorded genera are typical of herbaceous marshes, ponds, lakes, and the slow moving portions of streams and rivers. They apparently prefer soft waters of low alkalinity, slightly acidic to circumneutral pH.

On the other hand, areas rich in decomposing vegetation showed low diversity of benthic organisms, among which sampling stations 2 and 3 (right margin of the Paraguay River, rich in aquatic macrophytes) and station 23 (San Alberto Stream, flooded area of *Copernicia alba*) are good examples, being highly dominated (80–100%) by *Chironomus* larvae, organisms with a characteristic preference for habitats rich in decomposing organic matter, low oxygen concentrations, and (in general) water of low quality.

Some of the recorded genera are organisms typically feeding in macrophyte detritus and others are characteristically miners of decomposing plant tissues, e.g. *Goeldichironomus, Polypedilum*, and *Stenochironomus*. Finally, some typically live on periphyton (*Beardius, Asheum, Cryptochironomus*) or feed directly on filamentous algae (*Cricotopus*).

Two of the recorded species deserve special attention: *Nimbocera paulensis* Trivinho-Strixino & Strixino (1991) and *Fissimentum desiccatum* Cranston & Nolte (1996). *N. paulensis* was first described as typical of reolimnic condi-

tions, shallow environments with sandy and organic sediments. *F. desiccatum* is a typical inhabitant of the potamal region, also areas with sandy and organic sediments but possessing decomposing aquatic macrophytes. According to CRANSTON & NOLTE (1996), the larvae of *F. desiccatum* build galleries in sediment that allows them to resist dry periods and return when the sediment is re-hydrated. At sampling stations 24 and 35, an intense predation by the carnivorous larvae of *Coelotanypus* on larvae of *F. desiccatum*, *N. paulensis* and *Phaenopsectra* was observed.

Some of the recorded genera showed wide distribution, and were collected from all the existing microhabitats. These include *Cladopelma, Axarus, Harnischia, Nilothauma, Parachironomus, Corynoneura, Nanocladius* and *Thienemanniella*.

The observed benthic macroinvertebrate communities show high diversity and abundance of carnivorous larvae of the genera *Ablabesmyia, Coelotanypus, Labrundinia, Denopelopia, Macropelopia, Djalmabatista* and *Tanypus*. It is suggested that these carnivorous larvae are the major controlling agent of the richness of other chironomids, thus resulting in a rather high diversity in comparison with other aquatic systems in South America (e.g. NOLTE 1989, STRIXINO & TRIVINHO-STRIXINO 1991, HIGUTI et al. 1993, NESSIMIAN 1995, NESSIMIAN & SANSEVERINO 1995, CALLISTO et al. 1999).

A tentative classification of the studied areas based upon benthic macroinvertebrate diversity

Although the present results were obtained from a single field trip (end of the rainy season) they provide a first assessment of water quality and structure and distribution of benthic macroinvertebrate communities for the area. The study also provided the identification of a considerable diversity of microhabitats existing in the area, considering mainly the existing sediment types, and the presence of aquatic macrophytes and filamentous algae. Furthermore, the sampling period was rather atypical, showing higher water levels than usual for this time of the year.

Based on the diversity index (Shannon-Wiener) of Chironomidae larvae and the recorded substrate types, three major areas along the upper-middle Paraguay River, which can be identified in relation to their benthic communities diversity, could be considered for conservation purposes:

(a) Areas of high diversity: with a H' >3.0 and represented in this survey by sampling stations 30 and 31, located in the Blandengue and La Paz Streams, respectively. Here the highest number of microhabitats were found, including sand, gravel, periphyton, aquatic mosses, and a stand of *Cabomba* sp. These are relatively well protected areas with riparian vegetation and no significant human influences recorded.

(b) Areas of intermediate diversity: $1.8 \leq H' \leq 3.0$, represented by sampling stations 2, 3A, 5, 6, 10, 15, 18, 26, 27, 28, and 29, which are flooded areas or areas rich in aquatic macrophytes with sediments rich in organic matter in distinct decomposition stages, receiving both allochthonous (riparian vegetation) and autochthonous (aquatic macrophytes, mosses and filamentous algae) contributions.

(c) Areas of low diversity: with a H' <1.8 and represented by sampling stations 3, 4, 7, 8, 12, 14, 17, 21, 22, 23, 24, 25, 31A and 35. The sediments found here are mainly formed by silt and clay, but silt and filamentous algae, silt and aquatic mosses, fine sand and organic matter in deep decomposition stage, also occur. These areas show low diversity of microhabitats.

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