CHAPTER 4

Water Quality, Phytoplankton, and Benthic Invertebrates of the Upper and Lower Río Paraguay Basin, Paraguay

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Abstract

Water quality was assessed at 35 localities (Fig. 4.1). The waters of the Río Paraguay were generally slightly acidic (pH 6.0–6.5), with low oxygen levels (< 6.0 mg/L), low electrical conductivity (60–100 µS/cm), and temperatures ranging between 24–27° C. The waters of the Río Apa were neutral to slightly alkaline (pH 7.27–7.96), with variable levels of dissolved oxygen (4.2–7.13 mg/L), high electrical conductivity (163–376 µS/cm), and temperatures ranging between 22–29° C.

The phytoplankton communities were relatively diverse, and included representatives of several algae groups, including Chlorophyta, Euglenophyta, Chrysophyta, Bacillariophyta, and Cyanophyta. Benthic macro-invertebrates were collected at 33 sites. Chironomidae (Diptera) larvae and Oligochaeta were the dominant groups at 27 of the sites, representing 52% and 35% of the recorded organisms. Odonata, Trichoptera, Ephemeroptera, Chaoboridae, Ceratopogonidae, Corixidae, Conchostraca, Planaria, Nematoda, Hirudinea, Copepoda, Ostracoda, Bivalvia, and Gastropoda were collected less frequently.

Among the Chironomidae larvae, 26 taxa were identified. Some may be undescribed species. The diversity of benthic macro-invertebrates is high compared to other watersheds in South America. The majority of the genera are typical for herbaceous marshes, ponds, lakes, and slow moving portions of streams and rivers. Areas rich in decomposing vegetation exhibited a low diversity.

Overall, there was little evidence for direct contamination of the waters. The only exceptions were near Bahía Negra, where the burning and clearing of land could result in erosion and eutrophication.

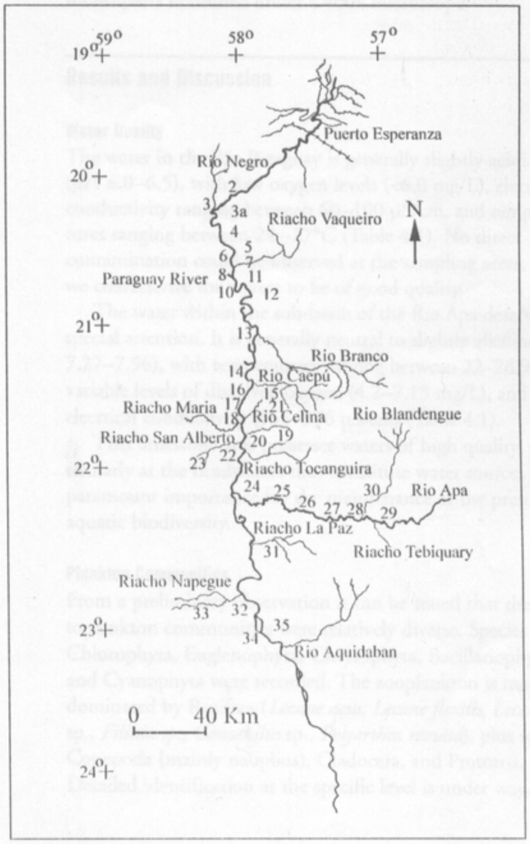

Figure 4.1. Map of the 35 stations sampled for water quality and benthic macro-invertebrates in the Upper and Lower Río Paraguay.

Introduction

The loss of biodiversity in aquatic ecosystems has received less attention than that in terrestrial ecosystems, despite knowledge of their physical, chemical, and biological degradation. The current state of aquatic habitats is clearly demonstrated by the increase in water-borne diseases (particularly in the tropics), decreasing fishery production, and diminishing water quality for human consumption, irrigation systems, and recreation. Furthermore, according to Master (1990), there are more aquatic organisms classified as rare to extinct (34% of fish, 75% of unionid mussels, and 65% of crayfish) than terrestrial ones (c. 11% to 14% of birds, mammals, and reptiles). Aquatic systems maintain a considerable biodiversity that is being lost mainly as a consequence of habitat deterioration.

The introduction of the watershed as the unit of study (Rigler and Peters, 1995) was of paramount importance in demonstrating that the implementation of conservation practices for terrestrial environments does not automatically include adequate protection of aquatic habitats (Junk, 1983; Barbosa, 1994). Despite this focus on watersheds, it is still unclear if the best conservation option is to consider the protection of total diversity of a given area or to focus on the highest possible number of rare species (see Pimm and 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 and Ulanowicz, 1992). Furthermore, as suggested by Tundisi and Barbosa (1995), the adoption of the watershed as the conservation unit is fundamental since it integrates the multiple uses of natural resources and their surrounding social, economic, and cultural factors.

The primary objective of this paper is to summarize limnological data recorded during the 1997 AquaRAP expedition to the Upper and Lower Río Paraguay (20°09'7.9"S, 58°10'11.4"W) and to the sub-basin of the Río Apa (22°06'S, 57(55'W) (Fig. 4.1, Appendix 7). Small tributaries within these areas, namely the Arroyos Blandengue, Tebicuary, and Riacho La Paz, were also sampled. A total of 35 localities were visited during this period for which water temperature, pH, dissolved oxygen and electrical conductivity were measured *in situ*. Benthic macro-invertebrates were collected at 54 sampling stations.

The Upper Río Paraguay is characterized by the presence of several types of habitats among which floating meadows formed by several aquatic macrophytes, coastal areas dominated by flooded palms (*Copernicia alba*), and litoral vegetation dominated by *Schinopsis balansae* are the most common. The Lower Río Paraguay is dominated by floating meadows as well, but there were also vegetated sandy banks, small streams, and sandy/muddy beaches.

Material and Methods

Except for total alkalinity measurements and benthic organism identification, all variables were measured *in situ*. The samples for the physio-chemical measurements were collected at each site from below the surface (0.20 meter depth) with a plastic jar. The type of water, distance from the shore, depth, substrate type and vegetation were recorded. For the physio-chemical (water quality) characterization of the waters, the following variables were measured: water temperature (°C), electrical conductivity (µS/cm), pH, and dissolved oxygen (mg/L and % saturation). Total alkalinity was determined after titration with 0.1N H_2SO_4.

For the plankton samples, a 20 µm plankton net was used to filter 2 x 40 liters of sub-surface water at each site. Sediment samples were collected in triplicate using an Ekman-Birge dredge in such a way that 1 meter² was covered at each site. Samples were then rinsed through a 250 µm mesh and fixed in formalin. In the laboratory, the samples were washed through 1.0 and 0.50 millimeter mesh sieves, sorted under a stereomicroscope, and the organisms preserved in 70% ethanol. For identification, chironomid larvae were prepared using 10% lactophenol slides and their mouthparts examined under a 400x microscope.

Results and Discussion

Water Quality

The water in the Río Paraguay is generally slightly acidic (pH 6.0–6.5), with low oxygen levels (<6.0 mg/L), electrical conductivity ranging between 60–100 µS/cm, and temperatures ranging between 24–27°C (Table 4.1). No direct contamination could be observed at the sampling areas, thus we characterize the waters to be of good quality.

The water within the sub-basin of the Río Apa deserves special attention. It is generally neutral to slightly alkaline (pH 7.27–7.96), with temperatures varying between 22–28.9°C, variable levels of dissolved oxygen (4.2–7.13 mg/L), and high electrical conductivity (163–376 µS/cm) (Table 4.1).

This limestone area possesses waters of high quality, particularly at the headwaters that constitute water sources of paramount importance for the maintenance of the present aquatic biodiversity.

Plankton Communities

From a preliminary observation it can be stated that the phytoplankton communities were relatively diverse. Species of Chlorophyta, Euglenophyta, Chrysophyta, Bacillariophyta and Cyanophyta were recorded. The zooplankton is mainly dominated by Rotifera (*Lecane acus, Lecane flexilis, Lecane* sp., *Filinia sp.*, *Conochilus* sp., *Polyarthra remata*), plus some Copepoda (mainly nauplius), Cladocera, and Protozoa. Detailed identification at the specific level is under way.

Table 4.1. Physico-chemical characteristics of the waters within the Upper/Lower Río Paraguay basin, September 1997. See Appendix 7 for site descriptions and locations.

Site	Air Temperature (°C)	Water Temperature (°C)	pH	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% sat)	Alkalinity (meqCO_2/L)
1	28.9	27.0	6.35	97.2	—	—	383.0
2	35.9	26.3	6.36	59.2	—	—	261.9
3	—	28.2	6.29	64.1	—	—	—
4	27.6	27.4	6.19	61.1	—	—	252.3
5	33.2	27.3	6.52	63.0	—	—	233.6
6	30.6	27.4	6.36	61.9	—	—	238.6
7	30.7	27.5	6.40	63.3	—	—	234.6
8	28.2	28.0	6.25	62.6	—	—	188.6
9	32.8	27.9	6.46	67.6	—	—	225.1
10	30.5	27.2	6.25	63.1	—	—	236.7
11	29.9	27.5	6.47	61.7	—	—	225.7
12	30.2	27.8	6.34	61.1	—	—	228.3
13	27.0	27.8	6.04	74.2	—	—	226.6
14	21.6	25.8	6.26	64.3	—	—	256.1
15	22.3	25.7	6.01	63.9	—	—	255.3
16	21.9	24.4	5.54	63.4	—	—	130.2
17	24.2	26.9	6.35	64.8	—	—	235.4
18	20.1	24.4	6.06	71.0	—	—	243.4
19	29.4	26.6	6.45	68.5	—	—	243.6
20	26.4	25.1	6.84	62.8	—	—	251.9
21	24.2	24.6	6.06	66.5	—	—	265.6
22	31.1	27.0	6.58	68.5	—	—	223.5
23	31.3	25.4	6.35	61.5	—	—	256.2
24	31.4	26.1	7.27	163.9	4.20	55.1	677.6
25	—	27.6	7.66	167.0	6.84	93.6	733.8
26	29.3	28.2	7.74	165.4	5.42	75.4	695.7
27	33.4	28.9	7.80	172.2	6.02	82.5	729.2
28	28.0	27.4	7.59	167.6	6.66	91.7	759.4
29	29.6	27.8	7.81	168.5	7.02	95.2	690.1
30	28.1	22.1	7.88	376.0	7.13	85.3	1790.6
31	29.0	24.3	7.96	375.0	6.30	80.9	1870.8
32	35.1	25.7	6.32	71.5	3.36	44.1	572.3
33	30.4	26.0	6.55	68.5	4.23	51.5	557.7
34	23.1	24.8	6.20	71.7	3.89	50.1	503.1
35	24.7	25.9	6.94	89.1	7.52	100.6	663.9

Table 4.2. Comparative information about taxa richness and number of chironomid (Diptera) genera in different watersheds in South America.

Taxa Richness	Number of Chironomidae genera	Watersheds in South America	References
16	26	Río Paraguay (present data)	Barbosa and Callisto (2000)
06	18	Upper Rio Doce (Serra do Cipó National Park, Brasil)	Galdean, Callisto, Barbosa, and Rocha (1999)
84	23	Río Piracicaba (Middle Doce River, Brasil)	Marques et al. (1999)
15	19	Headwaters of Rio São Francisco (Serra da Canastra National Park, Brasil)	Galdean, Callisto, and Barbosa (1999)
?	21	Río Paquequer (Rio de Janeiro State, Brasil)	Nessimian and Sanseverino (1998) Sanseverino and Nessimian (1998)
29	31	Río Negro (Patagonia, Argentina)	Wais (1990)
14	17	Río Gravataí (Rio Grande do Sul, Brasil)	Bendati et al. (1998)
80	35	Upper Río Paraná (Brasil)	Takeda et al. (1997)
11	15	Río Trombetas (Brazilian Amazonia)	Callisto et al. (1998)

Benthic Macro-invertebrates

A total of 2,213 benthic macro-invertebrates specimens were recorded from 33 sampling stations (Appendix 8). Chironomidae larvae and Oligochaeta were the dominant groups in 27 stations, representing respectively 52% and 35% of the recorded organisms. Other groups collected in smaller numbers include Odonata, Trichoptera (*Oxyethira*), Ephemeroptera, Chaoboridae, Ceratopogonidae, Corixidae, Conchostraca, Planaria, Nematoda, Hirudinea, Copepoda, Ostracoda, Bivalvia, and Mollusca (*Pomacea*) (Appendix 8). Among the Chironomidae larvae, 26 taxa were identified. The most common (listed from most to least abundant) were *Nimbocera paulensis, Polypedilum, Chironomus, Ablabesmyia, Goeldichironomus, Fissimentum desiccatum, Harnischia, Nilothauma, Parachironomus, Stenochironomus, Asheum, Coelotanypus,* and *Djalmabatista.* At lower densities there were recorded larvae of *Axarus, Beardius, Cladopelma, Cryptochironomus, Phaenopsectra, Denopelopia, Labrundinia, Macropelopia, Tanypus, Corynoneura, Cricotopus, Nanocladius* and *Thienemanniella,* along with specimens belonging to the many yet undescribed, endemic species of South America (see Fittkau and Reiss, 1973).

The diversity of benthic macro-invertebrates can be considered high when compared with other watersheds in South America (Table 4.2). Furthermore, the majority of the recorded genera are typical of herbaceous marshes, ponds, lakes, and the slower moving portions of streams and rivers. They apparently prefer soft waters of low alkalinity and slightly acidic to circumneutral pH.

On the other hand, areas rich in decomposing vegetation exhibited a low diversity of benthic organisms. Sampling stations 2 and 3 (west bank of the Río Paraguay, rich in aquatic macrophytes) and station 23 (Riacho San Alberto, flooded area covered mainly with *Copernicia alba*) are good examples, with each dominated (80-100%) by *Chironomus* larvae. These larvae prefer habitats rich in decomposing organic matter, low oxygen concentrations, and oftentimes waters of low quality.

Some of the recorded genera usually feed on macrophyte detritus, and others are characteristically miners of decomposing plant tissues (e.g., *Goeldichironomus, Polypedilum,* and *Stenochironomus*). Finally, some of these organisms 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 and Strixino (1991) and *Fissimentum desiccatum* Cranston and Nolte (1996). *Nimbocera paulensis* was first described as typical of rheolimnic conditions, shallow environments with sandy and organic sediments. *Fissimentum desiccatum* is a typical inhabitant of the potamal region, also areas with sandy and organic sediments but possessing decomposing aquatic macrophytes. According to Cranston and Nolte (1996), the larvae of *F. desiccatum* build galleries in the sediment that allow them to resist dry periods and return when the sediment is rehydrated. At sampling stations 24 and 35, intense predation by the carnivorous larvae of *Coelotanypus* on larvae of *F. desiccatum, N. paulensis* and *Phaenopsectra* was observed.

Cladopelma, Axarus, Harnischia, Nilothauma, Parachironomus, Corynoneura, Nanocladius and *Thienemanniella* have wide distributions, and were collected from all the existing microhabitats. The observed benthic macro-invertebrate communities possessed a 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 and Trivinho-Strixino, 1991; Higuti et al., 1993; Nessimian, 1995; Nessimian and Sanseverino, 1995; Callisto et al., 1998).

A tentative classification of the studied areas based upon benthic macro-invertebrate diversity

Although the present results were obtained from a single survey (at the end of the rainy season), they provide a first assessment of water quality as well as the structure and distribution of the benthic macro-invertebrate communities for the area. Furthermore, the study also allowed us to identify eleven types of microhabitats. They are 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. It must be pointed out that the sampling period was rather atypical, with higher water levels than usual for this time of the year.

Based on the diversity index (H; Shannon-Wiener) of Chironomidae larvae and the recorded substrate types (Appendix 9), Barbosa and Callisto (2000) suggested three major divisions along the Upper/Lower Río Paraguay in relation to their benthic macro-invertebrate community diversity. This information should be considered when making conservation decisions.

(a) Areas of **high diversity:** with an H' > 3.0 and represented in this survey by sampling stations 30 and 31, located respectively in the streams Blandengue and La Paz. Here the highest number of microhabitats was 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 allocthonous (riparian vegetation) and autocthonous (aquatic macrophytes, mosses and filamentous algae) contributions.

(c) Areas of **low diversity:** with an 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.

Recommended Conservation and Research Activities

- Overall, the Río Paraguay basin is relatively well preserved, with the exception of the northern part near Bahía Negra. This area is primarily threatened as a consequence of disorganized land use resulting in widespread deforestation in order to form pasture land. Erosion is a direct consequence, thus affecting the water and its living communities. Furthermore, the burning of natural vegetation, particularly large areas of *Copernicia alba* (palm trees), constitutes another considerable threat that may result in eutrophication of these waters. Habitat impact studies need to be conducted to determine how to manage the land properly.

- Limestone areas possess waters of high quality. Steps need to be taken to preserve these sites.

- The diversity of macro-invertebrates can be considered high when compared with other watersheds in South America. Most of these species are found in habitats created by seasonal flooding. Habitat modifications that disrupt the annual changes in water level should be prevented. An example of habitat modification is the Hidrovia Paraguay-Paraná, which will affect directly the seasonal flooding regime of the Río Paraguay and indirectly other streams within the watershed, resulting in the loss of certain habitats and their communities.

- The Río Verde is under severe threat of salinization.

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