Fish assemblages in littoral areas of the upper Paraná river floodplain, Brazil

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ABSTRACT. Fish assemblages in littoral areas of rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) on the upper Paraná river floodplain were evaluated in their composition, length structure, abundance and species dominance and diversity patterns. Samplings were carried out in March 1999, with single (for the rivers) and triple (for the lagoons) 5mm-mesh seine nets. Results amounted to the catch of 10,517 individuals belonging to 51 species. There were significant differences between the mean standard lengths of the assemblages in the different environments. Pousada lagoon registered high density in number of fish, as well as a high α-diversity value, whereas in Figueira lagoon a high biomass per unit of area was registered. The most abundant species in these environments were *Cheirodon notomelas* (Eigenmann, 1915) (Baía and Figueira), *Bryconamericus stramineus* Eigenmann, 1908 (Paraná), *Steindachnerina insculpta* (Fernándes-Yépez, 1948) (Genipapo) and *Moenkhausia intermedia* Eigenmann, 1908 (Pousada). There were few similarities between the littoral zones of the lagoons due to the pattern of connectivity of the environments and to the abrupt interruption of the floodplain pulse in the 1998/1999 hydrologic cycle. This interruption was caused by the closure of the Porto Primavera Hydroelectric Plant. Lagoons became more differentiated and their heterogeneity increased.

Key words: neotropical fish, littoral zone, floodplain, diversity, Paraná river, Brazil.

RESUMO. Assembléia de peixes em áreas litorâneas da planície de inundação do alto rio Paraná, Brasil. A assembléia de peixes em áreas litorâneas de rios (Baía e Paraná) e lagoas (Figueira, Genipapo e Pousada) da planície de inundação do alto rio Paraná foi avaliada quanto à composição, estrutura em comprimento, abundância e padrões de dominância e diversidade de espécies. As amostragens foram realizadas em março de 1999, com o uso de redes de arrastes simples (rios) e triplos (lagoas) de 5mm de malha, resultando na captura de 10.517 indivíduos pertencentes a 51 espécies. Houve diferenças significativas entre as médias de comprimento-padrão das assembléias nos diferentes ambientes. Na lagoa Pousada registrou-se a maior densidade em número de peixes, bem como o maior valor de diversidade α, enquanto na lagoa Figueira verificou-se a maior biomassa por unidade de área. As espécies mais abundantes nesses ambientes foram *Cheirodon notomelas* (Eigenmann, 1915) (Baía e Figueira), *Bryconamericus stramineus* Eigenmann, 1908 (Paraná), *Steindachnerina insculpta* (Fernándes-Yépez, 1948) (Genipapo) e *Moenkhausia intermedia* Eigenmann, 1908 (Pousada). As zonas litorâneas das lagoas apresentaram baixas similaridades entre si, o que pode estar relacionado com o padrão de conectividade dos ambientes e a forte interrupção do pulso de inundação na planície no ciclo hidrológico de 1998/1999. Esta interrupção foi provocada pelo fechamento da UHE de Porto Primavera, tornou as lagoas mais diferenciadas neste ciclo e aumentou a heterogeneidade entre elas.

Palavras-chave: peixes neotropicais, zona litorânea, planície de inundação, diversidade ictiofaunística, rio Paraná, Brasil.

River–floodplain systems are molded by the hydrologic regime which makes possible the occurrence of distinct aquatic and transitional habitats and allows the maintenance of high productivity and diversity of these environments (Junk *et al*., 1989; Thomaz *et al*., 1997). The fish

assemblage of the upper Paraná river floodplain is composed of resident forms whose entire life cycles occur in the area and of migrators that use the floodplain during part of their lifetime (Agostinho and Zalewski, 1996). In this context, the remaining floodplain areas of this stretch of the Paraná River have fundamental importance in the establishment of viable populations of species already eliminated from the stretches upstream, impacted by numerous dammings.

Fish species are distributed throughout various floodplain environments according to their ecological necessities and limitations. Some species occur mainly in the main river channel; others adapted themselves to medium-sized tributaries, streams, canals and permanent and temporary lagoons (Veríssimo, 1999). In the occupation of the physical space of the different floodplain environments by the fish, the littoral zones stood out by means of high spatial heterogeneity and productivity when compared to those of the pelagic areas, shown to be extremely important in the regulation of aquatic metabolism (Wetzel, 1979). It is fundamental to understand the structure and dynamics of the fish assemblages in these areas, usually colonized by juvenile fish and foragers. These species exploit the more structured environments, including the presence of macrophytes and a substrate composed of mud, sand and rocks (Welcomme, 1979; Delariva *et al*., 1994).

Taking as a hypothesis that the ichthyofauna similarity between the two biotopes investigated (rivers and lagoons) is high, this article analyzes the composition, length structure, abundance and dominance and diversity patterns of fish species in littoral areas of the upper Paraná river floodplain.

Material and methods

Samplings were carried out in March 1999, during daytime, in the littoral areas of the Baía and Paraná rivers and Figueira, Genipapo and Pousada lagoons on the upper Paraná river floodplain, between the states of Mato Grosso do Sul and Paraná, Brazil (Figure 1). Collections were made with single (for the rivers) and triple (for the lagoons) 5mm-mesh seine nets, 50m in length and 2.8 m in height. The physical characterization of the environments was based on data for depth, water column transparency, type of substrate, area sampled and percentage of macrophyte covering (Table 1).

After identification of fish species with the taxonomic keys proposed by Britski (1972) and Cetesb (1981), each specimen was weighed (g) and measured (standard length in cm). ANOVA was used to test the size differences of the individuals between the environments. Species abundance at each site was evaluated through density given in number of individuals or kg per 1,000 m^2 of dragged area.

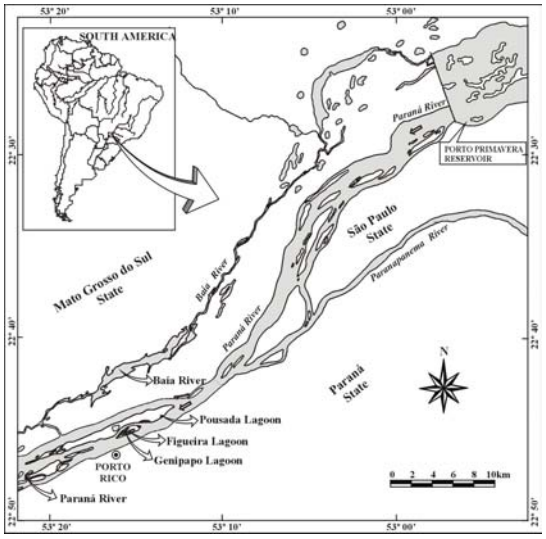

Figure 1. Location of the sampling sites

The dominance patterns between the sites were analyzed by species-abundance curves (Magurran, 1988) and local diversity (α) was based on Shannon's diversity index (H') (Pielou, 1975). Equitability in the distribution of the individuals caught among the species was based on the equation E = H'/logS, in which H' = diversity of Shannon and S = number of species. Community structure variables were estimated from species abundance by means of PC-ORD-v.3.0 (McCune and Mefford, 1997). Similarity in species abundance and composition was established by the Bray-Curtis index to obtain the distance matrix, and the Unweighted Pair-Group Method by Arithmetic Averages (UPGMA) as a method of connection. The cophenetic correlation coefficient (CCC) was applied to evaluate the adequacy of the method to obtain the dendrogram, using the program NTSYS-pc (Rohlf, 1994).

Results

10,517 individuals belonging to 19 families and 51 species were sampled (Table 2). Among the Osteichthyes, the Characiformes were represented by 35 species (70% of the total), varying from 60 to 90% in the different sites under analysis (Figure 2). The fish assemblage sampled in the littoral zone of the rivers and lagoons is constituted by small-sized

individuals; many with standard lengths between 1.0 and 8.0 cm (Figure 3). There were significant differences between the mean standard lengths of the fish assemblages from the different environments (ANOVA; F = 751.74; P<0.0001). Among the environments analyzed the largest individuals were collected in the Genipapo lagoon, with mean standard length close to 7.0 cm. On the other hand, the predominance of smaller individuals was verified for Figueira and Pousada lagoons, with mean SL close to 3.5 cm. In the rivers sampled, the amplitude of the standard length classes in the Paraná River was higher than that verified for the Baía River.

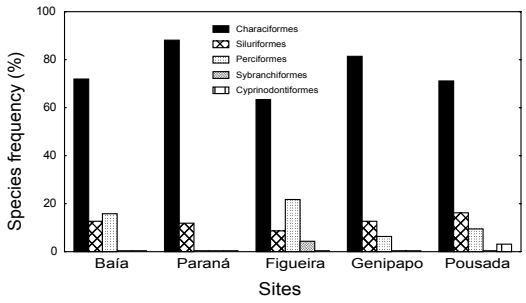

Figure 2. Proportion between orders of Osteichthyes registered in the littoral zones of rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) of the upper Paraná river floodplain

The highest densities in number of individuals and biomass were verified in the lagoons, with the exception of Genipapo, which had the lowest abundance in number among the sampling sites (Table 3). However, with regard to species dominance, specific patterns in the structure of the fish assemblages from the rivers and lagoons were not identified (Figure 4). The high abundance of *C. notomelas* was conspicuous in the Baía river, whereas *B. stramineus*, *S. insculpta* and *A. affinis* were dominant in the Paraná. Among the lagoons, the species-abundance curve tended towards high uniformity in Pousada, with the predominance of *M. intermedia*. In Genipapo lagoon, a strong dominance pattern was verified, with a high abundance of *S. insculpta*, in itself responsible for 77% of total catches at this site. In Figueira, a moderate pattern of dominance was noted, with intermediary uniformity between the lagoons studied and predominance of *C. notomelas* and *R. paranensis*. This last species was among the most abundant in Pousada lagoon. A high proportion of rare species characterizes the Baía River, including representatives from four of the six registered orders (Characiformes, Siluriformes, Perciformes and Rajiformes).

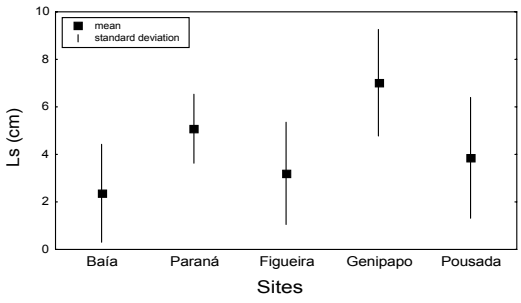

Figure 3. Mean standard length of fish assemblages in the littoral zones of rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) on the upper Paraná river floodplain

In spite of its high species richness, the Baía River showed reduced equitability in species distribution owing to the marked dominance of *C. notomelas*. On the other hand, although the richness in the Paraná river was lower, there was high equitability and this fact gave it a greater diversity than that verified for the Baía River (Table 4). So, α-diversity was higher in Pousada and Figueira lagoons, coinciding with the high densities in the number of individuals.

Table 1. Physical characterization of the sampling sites

	Rivers		Lagoons		
	Baía	Paraná	Figueira	Genipapo	Pousada
Maximum depth (m)	1.60	1.50	1.54	2.25	1.32
Transparency (cm)	-	-	65	90	35
Substrate type	sandy-clayey	sandy	sandy-clayey	sandy-clayey	clayey
Area sampled (m^2)	600	525	500	1,100	600
Proportion of plant cover	20% macrophytes (*Eichhornia azurea*, *Eichhornia crassipes*, *Salvinia* sp. and *Pistia stratiotes*)	20% banks of grasses	5% macrophyte (groupings of *Nympheaceae* sp.)	<5% macrophytes (*Salvinia* sp. and *Nympheaceae* sp.) and 80% grasses (*Cyperaceae* sp.)	70% macrophytes (*Eichhornia azurea*, *Paspalum* sp., *Polygonum acuminatum*, *Nympheaceae* sp., *Utricularia* sp. and *Salvinia* sp.) and grasses

Table 2. Systematic position of species collected during the study period in the littoral zones of rivers and lagoons on the upper Paraná river floodplain

CLASS CHONDRICHTHYES
- Order RAJIFORMES
  - Family POTAMOTRYGONIDAE
    - *Potamotrygon motoro* (Müller & Henle, 1841)

CLASS OSTEICHTHYES
- Order CHARACIFORMES
  - Family CHARACIDAE
    - Subfamily TETRAGONOPTERINAE
      - *Astyanax altiparanae* Garutti & Britski, 2000
      - *Astyanax fasciatus* (Cuvier, 1819)
      - *Astyanax schubarti* Britski, 1964
      - *Bryconamericus stramineus* Eigenmann, 1908
      - *Hemigrammus marginatus* Ellis, 1911
      - *Hyphessobrycon eques* (Steindachner, 1882)
      - *Moenkhausia intermedia* Eigenmann, 1908
      - *Moenkhausia sanctae-filomenae* (Steindachner, 1907)
    - Subfamily APHYOCHARACINAE
      - *Aphyocharax nasutus* (Ahl, 1936)
    - Subfamily CHEIRODONTINAE
      - *Cheirodon notomelas* (Eigenmann, 1915)
      - *Cheirodon* sp.
      - *Odontostilbe microcephala* Eigenmann, 1907
    - Subfamily ACESTRORHYNCHINAE
      - *Acestrorhynchus lacustris* (Reinhardt, 1874)
    - Subfamily CHARACIDIINAE
      - *Characidium* aff. *zebra* Eigenmann, 1909
    - Subfamily CHARACINAE
      - *Roeboides paranensis* Pignalberi, 1975
    - Subfamily SALMININAE
      - *Salminus maxillosus* Valenciennes, 1840
      - *Salminus hilarii* Valenciennes, 1829
  - Family SERRASALMIDAE
    - Subfamily MYLEINAE
      - *Metynnis* sp.
      - *Myloplus levis* (Eigenmann & McAtee, 1907)
    - Subfamily SERRASALMINAE
      - *Serrasalmus marginatus* Valenciennes, 1847
      - *Serrasalmus spilopleura* Kner, 1860
  - Family ANOSTOMIDAE
    - *Leporinus friderici* (Bloch, 1794)
    - *Leporinus lacustris* Campos, 1945
    - *Leporinus obtusidens* (Valenciennes, 1847)
    - *Leporinus octofasciatus* Steindachner, 1817
    - *Schizodon altoparanae* Garavello & Britski, 1990
    - *Schizodon borellii* (Boulenger, 1895)
  - Family PARODONTIDAE
    - *Apareiodon affinis* (Steindachner, 1879)
  - Family CURIMATIDAE
    - *Steindachnerina insculpta* (Fernándes-Yépez, 1948)
    - *Cyphocharax modestus* (Campos & Fernándes-Yépez,1948)
  - Family PROCHILODONTIDAE
    - *Prochilodus lineatus* (Valenciennes, 1836)
  - Family ERYTHRINIDAE
    - *Hoplias* aff. *Malabaricus* (Bloch, 1794)
    - *Hoplerythrinus unitaeniatus* (Spix, 1829)
  - Family LEBIASINIDAE
    - *Pyrrhulina australis* (Eigenmann & Kennedy, 1903)
  - Family CYNODONTIDAE
    - *Rhaphiodon vulpinus* Agassiz, 1829
- Order SILURIFORMES
- Suborder GYMNOTOIDEI
  - Family STERNOPYGIDAE
    - *Eigenmannia* sp.
  - Family RHAMPHICHTHYIDAE
    - *Rhamphichthys rostratus* (Linnaeus, 1766)
- Suborder SILUROIDEI
  - Family AUCHENIPTERIDAE
    - *Parauchenipterus galeatus* (Linnaeus, 1766)
  - Family PIMELODIDAE
    - Subfamily PIMELODINAE
      - *Iheringichthys labrosus* (Kröyer, 1874)
      - *Pimelodella* sp.
      - *Pimelodus maculatus* Lacépède, 1803
  - Family LORICARIIDAE
    - Subfamily LORICARIINAE
      - *Loricariichthys platymetopon* Isbrücker & Nijssem, 1979
- Order CYPRINODONTIFORMES
  - Family RIVULIDAE
    - *Rivulus* sp.
- Order SYNBRANCHIFORMES
  - Family SYNBRANCHIDAE
    - *Synbranchus marmoratus* (Bloch, 1795)
- Order PERCIFORMES
  - Family SCIAENIDAE
    - *Plagioscion squamosissimus* (Heckel, 1840)
  - Family CICHLIDAE
    - *Cichla monoculus* Spix, 1831
    - *Cichlasoma paranaense* (Kullander, 1983)
    - *Crenicichla britskii* Kullander, 1982
    - *Satanoperca pappaterra* (Heckel, 1840)
    - *Laetacara* sp.

Table 3. Density (number of individuals and biomass) of fish assemblages in the littoral zones of rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) on the upper Paraná river floodplain

	Rivers		Lagoons		
	Baía	Paraná	Figueira	Genipapo	Pousada
Density (ind/1,000m^2)	3,039.0	2,321.7	4,086.7	984.8	5,604.0
Density (kg/1,000m^2)	7.9	8.1	12.5	11.0	10.6

Figure 5 shows the similarity between the sampling sites with regard to species abundance and composition. Three groups were close to the 0.52 level: (i) the Baía river and Figueira lagoon; (ii) Pousada lagoon; and (iii) the Paraná river and Genipapo lagoon. Since the Cophenetic Correlation Coefficient (r) was 0.96, the appropriateness of the methodology applied in the determination of the grouping of the sampling sites is confirmed (Everitt and Dunn, 1991).

Table 4. Structure variables of fish assemblages in the littoral zones of rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) on the upper Paraná river floodplain

	Rivers		Lagoons		
	Baía	Paraná	Figueira	Genipapo	Pousada
Number of species (S)	33	17	23	16	31
Equitability (E)	0.42	0.56	0.51	0.41	0.55
Diversity (H')	1.46	1.58	1.59	1.15	1.87

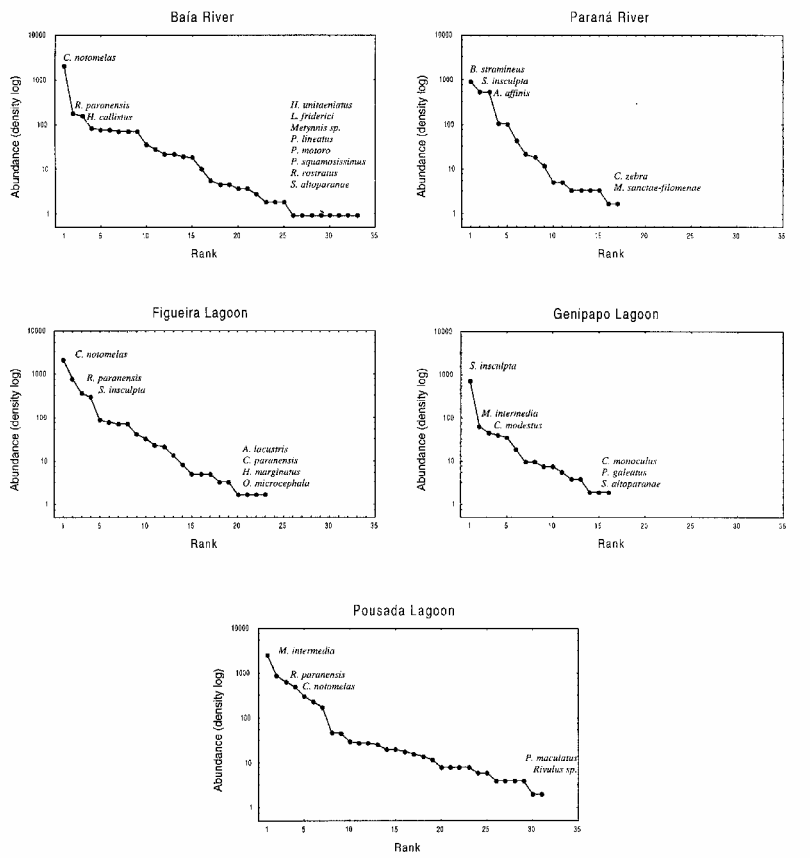

Figure 4. Species-abundance curve based on species density in the littoral zones of rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) of the upper Paraná river floodplain

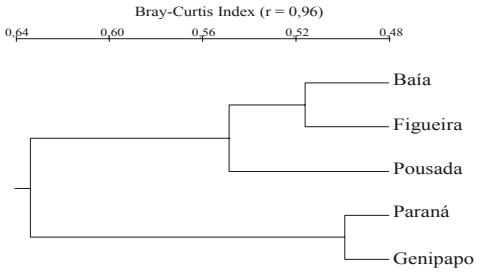

Figure 5. Dendrogram of similarity (Bray-Curtis) based on species abundance in rivers (Baía and Paraná) and lagoons (Figueira, Genipapo and Pousada) of the upper Paraná river floodplain (r = Cophenetic Correlation Coefficient)

Discussion

The broad diversity of Characiformes and Siluriformes in Neotropical environments has been attested by various authors, who refer to a slight predominance of Characiformes (Agostinho *et al*., 1997b; Pavanelli and Caramaschi, 1997; Lowe-McConnell, 1999). In the present study, restricted to littoral and shallow areas, Characiformes showed a very high participation, followed by Siluriformes and Perciformes.

In temporary lagoons in the upper Paraná river floodplain, Veríssimo (1994, 1999) also verified the predominance of Characiformes. Analyzing the ichthyofauna associated with macrophytes in various environments on the same floodplain, Delariva *et al*. (1994) also established high species richness in the order Characiformes. These authors associated their results with (i) the specificity of the biotope found in the macrophyte banks, with regard to space for refuge and oxygen availability (particular requirements of Characiformes); (ii) the fact that the collections have always been executed at the same time of day (at nightfall) and could have underestimated the catch of Siluriformes, which generally have nocturnal habits. Thus, in the present

work, the dial cycle played an important role on assemblage composition from the littoral areas.

Ichthyofauna from the littoral zones of the rivers and lagoons studied in this article was composed of small-sized species, predominantly Characidae (Tetragonopterinae and Cheirodontinae) and Curimatidae. Using the trophic classification of the species from the region (Agostinho *et al*., 1997a), a great many were small-sized foragers with insectivorous (*C. notomelas*, *M. intermedia*, *R. paranensis* and *B. stramineus*) and iliophagous (*S. insculpta* and *A. affinis*) habits. The large number of insectivores could be related to the large supply of available food resources (mainly insects) in the littoral zones, whose life cycles are intimately connected to these areas. The intrinsic food plasticity of the small foragers, exemplified by insectivores with omnivorous tendencies, allied to the large availability of preferential food items in the lagoons, certainly minimized the effect of competition among them within these environments (Veríssimo, 1999).

With regard to abundance of large-sized individuals, representatives of piscivores (*H.* aff. *malabaricus*), detritivores (*L. platymetopon*) and iliophagous (*S. pappaterra*, *S. insculpta* and *C. modestus*) were caught. Such richness of trophic categories could be related to the high spatial structuring of the marginal areas, generally with reduced depth, presence of fallen wood debris and various species of floating and rooted macrophytes that provide refuges for the ichthyofauna, with a subsequent reduction of predatory pressure. Habitats structurally more complex have a large variety of microhabitats which supporting more species than do simple habitats (Pianka, 1994).

As a rule, the abundance of individuals was higher in the lagoons than in the rivers, with the exception of Genipapo lagoon. Since the largest individuals of *S. insculpta* were caught in this lagoon, it gained enormous importance with regard to total biomass, in addition to the *P. lineatus*, *R. vulpinus* and *C. modestus* juveniles. This trend may be explained by the low connectivity between the lagoon and the river channel, since it permitted exchange of water and fish only during a short period. In banks of macrophytes from several environments in the same region, Delariva *et al*. (1994) verified that the fish assemblage was essentially composed of large-sized juveniles, including the above migrators.

Although the littoral zones of the rivers and lagoons had high richness, the diversity in these environments was low, due to the reduced uniformity in species distribution. The littoral zone is characterized by broad variations in the abiotic parameters (especially temperature and dissolved oxygen), causing the establishment of stressful conditions for the resident fish assemblages. These conditions may restrict the presence of species with specific demands. On the other hand, species highly tolerant to environmental variations may exploit with more efficiency the available resources and become abundant (Agostinho *et al*., 1997b).

When the ichthyofauna similarity was taken into account, three groups could be formed. The first group consisting of the Baía river and the Figueira lagoon, characterized by littoral zone shallows, sandy-clayey substrate and reduced plant covering in the sampling area, showed moderate abundance values, biomass and species diversity. These environments were constituted by small individuals with a strong pattern of dominance among the species, especially the insectivores *C. notomelas* and *R. paranensis*. In these two environments the species *H.* aff. *malabaricus* and *S. pappaterra* had the highest densities in biomass. *H.* aff. *malabaricus*, popularly called traíra, is a piscivorous species, which takes advantage of an environment with broad variations in oxygen concentration, such as the littoral zone, for physiological adaptations that allow its survival in hypoxic environments (Rantin and Johansen, 1984). Okada (1995) also verified the presence of *H.* aff. *malabaricus* in lagoons in the terminal phase of desiccation, with low concentrations of oxygen. The species *S. pappaterra* (ileophagous) may have benefited from the high supply of organic detritus, produced by large quantities of submerged vegetation, in the littoral zones of these environments. The second group, comprising the Paraná river and Genipapo lagoon, showed lower abundance, biomass and species richness rates. It was formed by individuals larger than those in the other two environments and with a strong pattern of equitability, in spite of the expressive abundance of *S. insculpta*, which assumed great importance in their total biomass. Due to the high availability of particulated sediment with microorganisms and unicellular algae, the above ileophagous species hardly ever presents alimentary restrictions in the littoral zone.

Pousada lagoon exhibited a series of characteristics that distinguish it from the other environments with regard to species occurrence and abundance: high abundance of individuals (35% of the total catch) and a strong pattern of α-diversity (high richness and diversity of Shannon). It should be emphasized that this lagoon was conspicuous for its extensive macrophyte cover (70% of the cover),

which may be related to small-sized individuals in this environment and to the dominance of the insectivore *M. intermedia*.

The pattern of connectivity between geographically close environments is fundamental to their high similarity (Agostinho *et al*., 1997b). The fact that the Paraná river is typically lotic and the Baía river seasonally presents the behavior of a semi-lentic system, depending on the hydrologic regime, might have been decisive in the low similarity between themselves. The isolation of the lagoons and the stressful conditions to which their fish assemblages have been submitted should have repercussions on the composition and abundance of the species in these environments, differentiating them. These factors might be important in the high dissimilarity that the lagoons presented.

It is expected that interspecies interactions (competition and predation) are intense and frequent in littoral zones, although the composition of the assemblages may be altered seasonally (Hall and Werner, 1977; Gelwick and Matthews, 1990). In the various environments that compose floodplains, species diversity and density are broadly controlled by the flood regime. Floods increase the homogenization of the environments in relation to their limnological characteristics (Thomaz *et al*., 1997), or rather, the environments start to respond to regional factors in an independent way and fauna heterogeneity increases to the extent the environments are isolated when the water recedes. Thus the degree of uniformity in the composition of the ichthyofauna after water recession affects directly the level of homogeneity reached in the previous pulse and indirectly its magnitude (Veríssimo, 1999).

During five years of studies on the upper Paraná river floodplain, Veríssimo (1999) verified that the duration of the floods, represented by days of flooding, was the most influential factor as regard to the different attributes of the ichthyofauna. According to this author, in the 1998/1999 hydrologic cycle, when samplings for the present study were carried out, the lagoons experienced a strong impact from the construction of the Porto Primavera Hydroelectric Plant upstream the floodplain, with a strong interruption of the flood pulse. For this reason, the lagoons may have presented a strong pattern of differentiation in this cycle, which led to their high heterogeneity. This would explain the great dissimilarity between the lagoons verified in this study.

Man's impact on nature has modified the greater part of the original course of the Paraná river in Brazilian territory. The regulation of the flow imposed by dammings, with the consequent alteration in the flood regime, is gradually changing the distribution patterns and structure of fish assemblages (Agostinho and Zalewski, 1995). In this context, registers on the ichthyofauna of the upper Paraná river floodplain should be monitored with other biotopes, not merely with descriptive characteristics, but to supply data for the best assessment of these impacts.

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