FISH DIVERSITY OF FLOODPLAIN LAKES ON THE LOWER STRETCH OF THE SOLIMÕES RIVER

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ABSTRACT

The fish community of the Solimões floodplain lakes was studied by bimonthly samples taken from May 2001 to April 2002. These were carried out at lakes Maracá (03º51'33"S, 62º35'08,6"W), Samaúma (03º50'42,1"S, 61º39'49,3"W), and Sumaúma and Sacambú (03º17'11,6"S and 60º04'31,4"W), located between the town of Coari and the confluence of the Solimões and Negro rivers. Collections were done with 15 gillnets of standardized dimensions with several mesh sizes. We collected 1,313 animals distributed in 77 species, belonging to 55 genera of 20 families and 5 orders. Characiformes was the most abundant Order, with a larger number of representatives in the Serrasalmidae and Curimatidae. The most abundant species in the samplings were *Psectrogaster rutiloides* (132 individuals), *Pigocentrus nattereri* (115 individuals), and *Serrasalmus elongatus* (109 individuals). Lakes Samaúma, Sacambú, and Sumaúma were adjusted to logarithmic and lognormal series. The diversity exhibited an inverse gradient to the river flow, showing the highest diversity at Lake Sumaúma, followed by Samaúma, Sacambú, and Maracá. Species richness estimated through the jackknife technique ranged from 78 to 107 species.

Key words: fish, community, diversity, floodplain, Amazônia.

RESUMO

A diversidade de peixes em lagos de várzea no Baixo Rio Solimões

O estudo das comunidades de peixes dos lagos de várzea do Rio Solimões foi realizado no trecho compreendido entre o município de Coari e a confluência com o Rio Negro, nos Lagos Maracá (03º51'33"S e 62º35'08,6"W), Samaúma (03º50'42,1"S e 61º39'49,3"W), Sumaúma e Sacambú (03º17'11,6"S e 60º04'31,4"W), no período de maio de 2001 a abril de 2002, por meio de coletas bimensais realizadas com 15 redes de espera de dimensões padronizadas, com diversos tamanhos de malhas. Foram capturados 1.313 indivíduos distribuídos em 77 espécies, pertencentes a 55 gêneros de 20 famílias e 5 ordens. Characiformes foi a ordem mais abundante, com maior número de representantes nas famílias Serrasalmidae e Curimatidae. As espécies mais freqüentes foram: branquinha *Psectrogaster rutiloides,* com 132 indivíduos*,* piranhas *Pigocentrus nattereri,* com 115 indivíduos, e *Serrasalmus elongatus,* com 109 indivíduos. Os Lagos Samaúma, Sacambú e Sumaúma ajustaram-se aos modelos Série Logarítmica e Lognormal. O Lago Sumaúma apresentou maior diversidade, seguido de Samaúma, Sacambú e Maracá. A riqueza de espécies estimada oscila entre 78 e 107 espécies.

Palavras-chave: peixes, comunidade, diversidade, várzea, Amazônia.

INTRODUCTION

There is an abiding interest in the number of species in local communities, because species are the fundamental particles of biodiversity (Bisby, 1995). There are approximately 8,500 freshwater fish species (Lowe-McConnell, 1999), most of which occur in rivers and connected alluvial floodplains. These communities show a dynamic structure that reflects characteristics and alterations that interact with biotic processes, specially predation and competition (Perrson, 1997; Jackson *et al.*, 2001).

The Amazonian floodplain is a highly dynamic environment. The strongly defined aquatic and terrestrial phases produce several patterns of behavioral, morphological, anatomical, and physiological adaptations in organisms inhabiting those areas (Junk *et al.*, 1989). The high spatial heterogeneity of this mobile ecotone creates conditions that maintain rich natural communities. The present study attempts to characterize the fish communities living in the Amazonian floodplain lakes of the lower stretch of the Solimões River in relation to richness, diversity, species composition, and occurrence frequency. The study also theorizes on the factors that determine its organization.

MATERIAL AND METHODS

The study area comprises the floodplain environment of Solimões River, between the town of Coari and the mouth of the Negro River (Fig. 1). Six experimental fisheries were made at 2-month intervals at 4 sampling sites: Maracá Lake, located in the municipality of Coari; Samaúma Lake, located near the city of Anori; and Sacambú and Sumaúma, located in Paciência Island in the neighborhood of Costa do Baixio, both within the municipality of Iranduba. The samples were collected between May 2001 and April 2002. All the lakes are typically Amazonian floodplain lakes, areas covered with water even during the dry period (Junk & Howard-Williams, 1984).

To minimize gear selectivity effects on the samplings, two groups of gillnets with different mesh size were used. Each gillnet was of standard size: 20.0 m in length and 2.0 m in height. Each group was formed by seven gillnets with mesh sizes of 30, 40, 50, 60, 70, 80, 90, and 100 mm between adjacent knots. The gillnets were randomly placed throughout the total lake areas, except for seasonally affected sites, such as flooded forest (*igapó*). Fishes were identified, measured, and weighed soon after being caught. After formalin fixation, fishes were stored and transported to the laboratory, where identifications were corroborated with the aid of taxonomic keys or by specialists.

The taxonomic list of the collected species followed the organization proposed by Nelson (1994), as well as the modifications suggested by Fink & Fink (1981) and Lauder & Liem (1983).

We measured fish diversity for the studied lakes using two commonly employed indices: the Simpson dominance index (Magurran, 1988) and the Shannon index (Shannon & Weaver, 1949), both with numerical abundance data. Species richness was estimated by jackknife methodology, which isbased on single species frequency (Heltske & Forrester, 1983). Evenness was calculated according to Magurran (1988).

Abundance data obtained for the species of each lake were adjusted to the models of logarithmic and lognormal series and fitting goodness was tested through χ^2 (Zar, 1999).

RESULTS

After 6 samplings, 1,313 fishes were collected, distributed in 77 species, 55 genera from 20 families and 5 orders, of which the Characiformes (Fig. 2) was the major group, accounting for 44 species from 9 families. The most diverse family was the Serrasalmidae, with 15 species, followed by Anostomidae, with 5 species (Fig. 3). *Psectrogaster rutiloides*, *Pigocentrus nattereri*, and *Serrasalmus elongatus* were the most abundant species, with 132, 115, and 109 individuals respectively.

Maracá Lake showed a pattern of high abundance of few species, an intermediate abundance of few species, and many rare species (Fig. 4). The other lakes showed some very abundant species, a few species of intermediate abundance, and many rare species (Fig. 4).

Fish communities from Samaúma, Sacambú, and Sumaúma lakes were fitted to the logarithmic series and lognormal distribution models (Table 1). Data from Maracá Lake did not fit any of these models.

The estimators of α of the logarithmic series were 15.84 for Samaúma Lake, 17.12 for Sacambú Lake, and 18.11 for Sumaúma Lake. Species richness (S) estimated by adjustment of lognormal distribution was 62.7 for Samaúma Lake, 54.2 for Sacambú Lake, and 51.9 for Sumaúma Lake.

OSTEICHTHYES ACTINOPTERYGII OSTARIOPHYSI	Mar	Sam	Sac	Sum	Σ
CLUPEIFORMES					
CLUPEIDAE					
Pellona castelnaeana	4	4	–	11	**19**
Pellona flavipinnis	3	3	6	12	**24**
OSTEOGLOSSIFORMES					
OSTEOGLOSSIDAE					
Osteoglossum bicirrhosum	3	3	–	2	**8**
CHARACIFORMES					
ERYTHRINIDAE					
Hoplias gr. malabaricus	1	–	6	–	**7**
ANOSTOMIDAE					
Leporinus friderici	3	2	11	4	**20**
Leporinus trifasciatus	1	–	–	3	**4**
Rhytiodus microlepis	1	10	–	1	**12**
Schizodon fasciatum	12	31	6	10	**59**
Schizodon vittatum	–	–	1	1	**2**
HEMIODONTIDAE					
Anodus elongatus	2	–	–	–	**2**
CURIMATIDAE					
Curimata vittata	–	2	–	–	**2**
Curimata ocellata	1	–	–	–	**1**
Potamorhina altamazonica	82	16	4	1	**103**
Potamorhina latior	70	6	19	7	**102**
Potamorhina pristigaster	2	40	1	–	**43**
Psectrogaster rutiloides	22	39	40	31	**132**
Psectrogaster amazonica	3	–	2	–	**5**
PROCHILODONTIDAE					
Prochilodus nigricans	1	26	1	3	**31**
Semaprochilodus insignis	4	–	–	–	**4**
Semaprochilodus taeniurus	–	–	–	1	**1**
GASTROPELIEIDAE					
Carnegiella strigata	–	–	–	1	**1**
SERRASALMIDAE					
Catoprion mento	1	–	1	–	**2**
Colossoma macropomum	–	2	–	2	**4**
Metynnis albus	–	1	–	–	**1**
Mylesinus sp.	–	3	–	–	**3**

OSTEICHTHYES ACTINOPTERYGII OSTARIOPHYSI	**Mar**	**Sam**	**Sac**	**Sum**	**Σ**
Myleus sp.	2	1	–	–	**3**
Mylossoma aureum	7	22	1	19	**49**
Mylossoma duriventri	5	56	3	19	**83**
Mylossoma sp.	–	–	1	1	**2**
Piaractus brachypomus	–-	1	1	1	**3**
Pristobrycon serrulatus	–	1	–	–	**1**
Pygocentrus nattereri	46	45	17	7	**115**
Serrasalmus elongatus	76	21	8	4	**109**
Serrasalmus robertsoni	23	7	1	1	**32**
Serrasalmus rhombeus	–	32	7	5	**44**
Serrasalmus spilopleura	2	6	3	2	**13**
CHARACIDAE					
Acestrorhynchus falcatus	4	–	–	–	**4**
Acestrorhynchus falcirostris	9	8	–	1	**18**
Astyanax sp.	–	3	–	–	**3**
Brycon cephalus	1	–	1	–	**2**
Rhaphiodon vulpinus	2	6	4	5	**17**
Roeboides myersi	2	2	–	1	**5**
Triportheus albus	–	–	–	1	**1**
Triportheus angulatus	2	6	10	5	**23**
Triportheus elongatus	–	1	–	3	**4**
Triportheus sp.	1	–	1	–	**2**
CYNODONTIDAE					
Hydrolycus scomberoides	–	–	1	–	**1**
SILURIFORMES SILUROIDEI					
DORADIDAE					
Anadoras grypus	–	–	1	–	**1**
Lithodoras dorsalis	–	–	–	2	**2**
Oxydoras niger	–	2	–	2	**4**
Pterodoras lentiginosus	–	6	14	10	**30**
AUCHENIPTERIDAE					
Auchenipterus nuchalis	–	1	1	4	**6**
Parauchenipterus galeatus	–	1	6	–	**7**
PIMELODIDAE					
Brachyplatystoma vaillantii	–	1	–	–	**1**
Calophysus macropterus	2	6	1	3	**12**
Hemisorubim platyrhynchos	–	1	–	–	**1**

OSTEICHTHYES **ACTINOPTERYGII** **OSTARIOPHYSI**	**Mar**	**Sam**	**Sac**	**Sum**	**Σ**
Pimelodella sp.	1	–	3	–	**4**
Pirinampus pirinampu	1	3	1	5	**10**
Pseudoplatystoma fasciatum	1	–	1	2	**4**
Pseudoplatystoma tigrinum	–	–	–	2	**2**
Sorubim lima	–	3	1	4	**8**
AGENEIOSIDAE					
Ageneiosus brevifilis	1	6	4	6	**17**
HYPOPTHTHALMIDAE					
Hypophthalmus edentatus	–	2	2	2	**6**
Hypophthalmus marginatus	–	3	–	2	**5**
Hypophthalmus sp.	–	2	–	–	**2**
CALLICHTHYIDAE					
Holplosternum litoralle	–	–	9	3	**12**
LORICARIIDAE					
Ancistrus spp.	–	–	1	–	**1**
Hypostomus emarginatus	1	4	4	1	**10**
Liposarcus pardalis	–	–	5	–	**5**
Loricariichthys maculatus	1	–	2	–	**3**
Pterygoplichthys sp.	–	–	1	1	**2**
ACANTHOPTERIGII **PERCIFORMES**					
SCIAENIDAE					
Plagioscion auratus	–	1	–	–	**1**
Plagioscion squamosissimus	2	2	4	14	**22**
Plagioscion sp.	–	–	1	–	**1**
CICHLIDAE					
Astronotus crassipinis	–	1	–-	–	**1**
Chaetobranchus flavescens	–	1	–	–	**1**
Cichla sp.	2	2	1	1	**6**

Samaúma Lake had the highest number of species collected. However, higher values for diversity index, Shannon index, and the Simpson index were recorded for Sumaúma and Sacambú lakes (Table 2). Maracá Lake showed the lowest number of species, as well as lowest values of diversity and evenness estimators (Table 2).

Using lakes for pseudovalue estimation, the species richness was estimated at 94 ± 4.06 species; confidence interval ranged from 81.1 to 106.9 ($p = 0.05$). On the other hand, using the 6 samplings for pseudovalue estimations, richness was estimated at 92.3 ± 5.58 species with a confidence interval of from 78 to 106.7 ($p = 0.05$).

DISCUSSION

Neotropical ictiofauna is characterized by a slight dominance of Characiformes over Siluriformes (Lowe-McConnell, 1999). However, in lakes and dams, a remarkable difference has been noticed (Veríssimo, 1994; Okada, 1995). Veríssimo (1994) related high dominance of small Characiformes in the floodplain of the Paraná River caused mainly, according to this author by the capacity of these species to use oxygen in the upper portion of the water column. In the present study, the high dominance of Characiformes suggests that the explanations given by Veríssimo (1994) can be extrapolated to fish communities of the Solimões river floodplains.

May (1975) explains that if a species pattern of relative abundance of a given community comes from an interaction of many independent factors, a lognormal distribution is expected to occur. But when one or few factors are dominant, resulting in unequal communities with few abundant species and many rare species, the data are more probably fitted to geometric or logarithmic series. The three lakes fit both lognormal and logarithmic distributions. The fit to logarithmic series probably happened due to dominance of the drying effect, since the bigger variation of periodicity and power occurs in the dry rather than the flood season (Irion *et al.*, 1997). On the other hand, competition, predation, and interactions of other biotic factors important to the Amazonian fish community dynamic induce lognormal distribution.

The absence of fitting of species-abundance models for Maracá Lake probably results from the small amount of species showing intermediate abundance and the strong dominance of *Potamorhina altamazonica*, *Serrasalmus elongates,* and *P. latior* that account for almost 50% of the total collected fishes. Merona & Bittencourt (1993) also noticed a decrease of intermediate abundance species in Lago do Rei. These authors point out that low species abundance in the samples can reflect low abundance in the environment or vulnerability of the fishing gear used. Junk *et al.* (1983) recorded a high occurrence of rare species in samplings at Camaleão Lake, and suggested that this was related to the fishing gear.

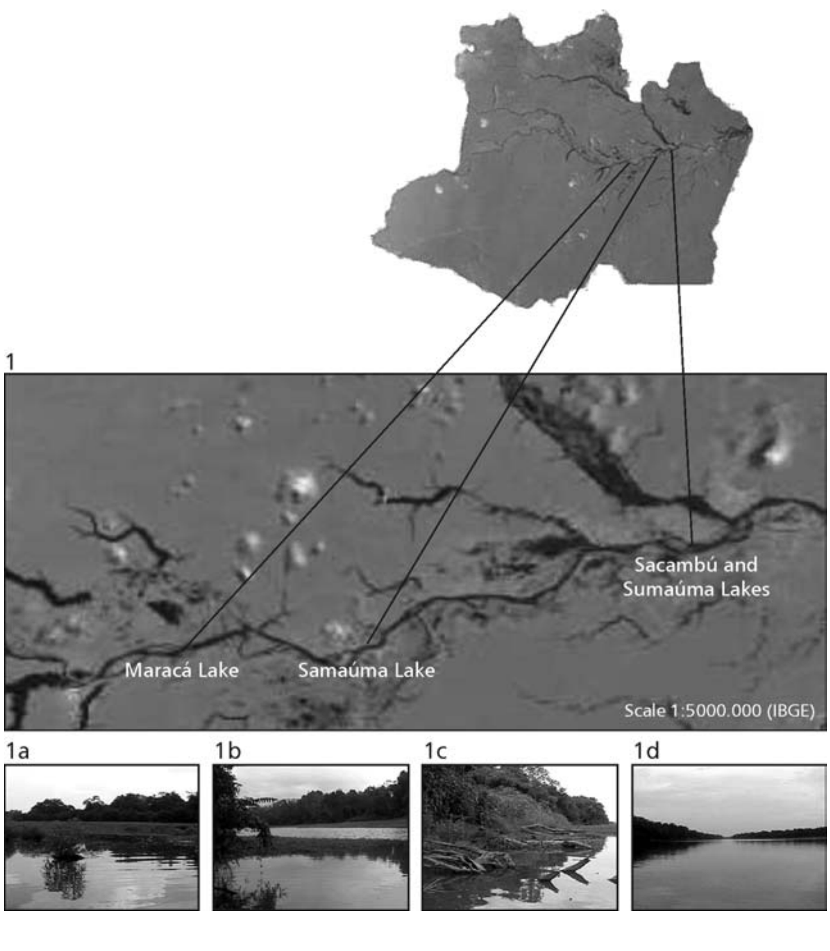

Fig. 1 — Satellite image of study area showing the sampling sites in the Solimões River floodplain. Figs. 1a. Maracá Lake; 1b. Samaúma Lake; 1c. Sacambú Lake; 1d. Sumaúma Lake.

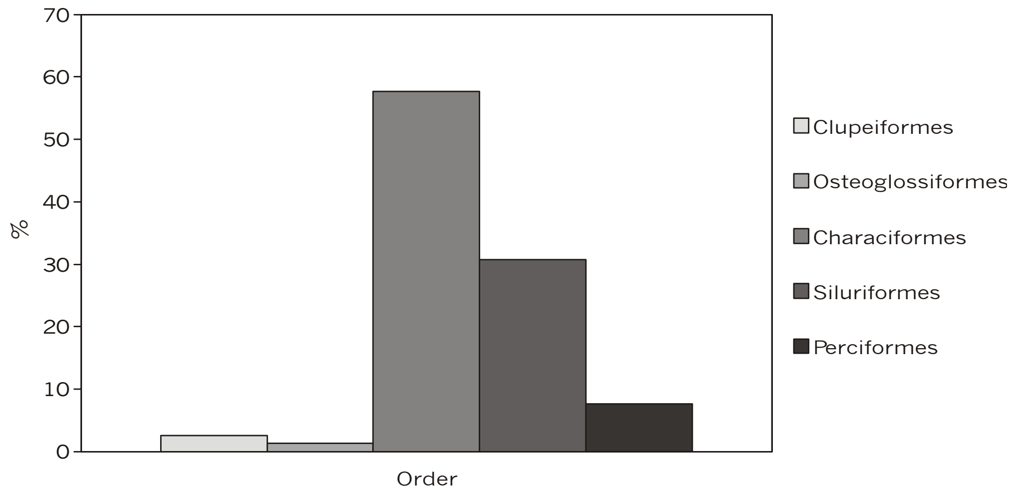

Fig. 2 — Relative abundance by orders.

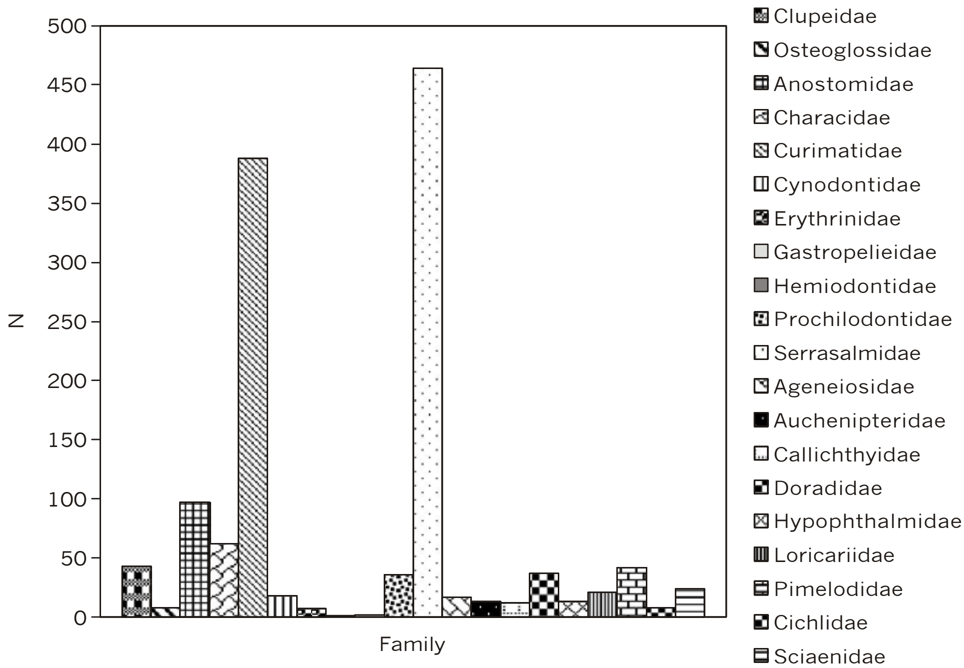

Fig. 3 — Numerical abundance by families.

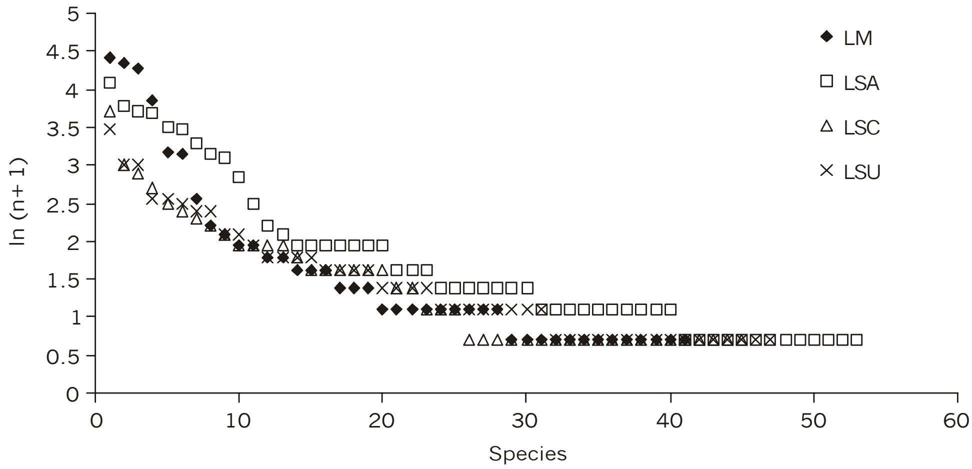

Fig. 4 — Whittaker plots of transformed data for the number of individuals, ln (n + 1), of the fish assemblages: LM – Maracá Lake; LSA – Samaúma Lake; LSC – Sacambú Lake; and LSU – Sumaúma Lake.

TABLE 1
Fit of logarithmic and lognormal distributions of the data of each lake.

Lakes	Logarithmic series			Lognormal distribution		
	df	χ^2	p	df	χ^2	p
Maracá	6	22.060	0.001	15	27.676	0.024
Samaúma	5	8.023	0.155	15	19.462	0.194
Sacambú	5	2.356	0.798	15	17.393	0.296
Sumaúma	4	1.920	0.750	15	7.088	0.955

TABLE 2
Diversity parameters for each lake.

	Maracá	Samaúma	Sacambú	Sumaúma
Species richness (S)	41	50	45	47
Numerical abundance (N)	410	454	220	229
Shannon (*H'*)	3.686	4.566	4.628	4.822
Evenness (E)	0.993	1.167	1.209	1.252
Simpson (D)	0.123	0.060	0.061	0.048
Inverse of Simpson (1/D)	8.157	16.750	16.332	20.818

During the flood period, the lakes are frequented by several species that come from the main river channel (Lowe-McConnell, 1999). When the water level recedes, species such as *Potamorhina* spp. and *Psectrogaster* spp. are predominant, feeding on a mix of perifiton and detritus. *Schizodon fasciatum* and

Rhytiodus spp. are also present. Carnivorous species such as *S. elongatus* and *Pygocentrus nattereri* swim in schools in these periods, feeding on preys near water surface (Queiroz & Crampton, 1999). This corroborates our results, since these species were the most abundant, specially in October and December, during the dry season.

The Shannon index estimated for fish diversity in Amazonian aquatic environments values ranging from 0.97 to 5.35 (Barthem, 1981; Merona, 1986/1987; Ferreira *et al*., 1988; Goulding *et al*., 1988; Santos, 1991). In Central Amazonian lakes, Barthem (1981) found variation in the Shannon index of from 2.2 to 3.2. Pereira (2000) used this same index to evaluate the diversity of Camaleão Lake, finding values varying from 3.9 to 4.1.

The Simpson index estimated the diversity for each sampling area based on dominance, and obtained a similar result when compared to Shannon index results. The strong dominance of some species in Maracá Lake is explained by Lowe-McConnell (1999). When high dominance of a given species is present, it may be due to the formation of large schools or because of human activities. In our case, the formation of schools is the most likely explanation.

Merona & Bittencourt (1993), observed that the diversity index found for Lago do Rei was higher than that found for African continental waters, but was similar to those found for the Tocantins River, a tributary of the Amazon, that has virtually no flood plain areas (Merona, 1986/87). These authors also point out that this high diversity is not directly related to environmental pecularities, but to the Amazon basin's global diversity.

Species richness in the Amazon basin is poorly known. Bohlke *et al*. (1978) suggests that the total number of species is approximately 2000, 30% of which have yet to be described. This regional richness has local reflexes and varies with the methodology used, sampling season, environmental conditions, etc. The jackknife estimation showed that there were enough samples to avoid seasonal/spatial patterns, since the number of species did not vary. Some studies corroborate our species richness estimative, e.g., Cox-Fernandes (1988) in studying lateral migrations in the Lago do Rei found 87 species. Junk *et al.* (1983) in 20 months, found 132 species in a study of seasonal movements. Merona (1988) found 164 species in Lago do Rei, and in the same area Merona & Bittencourt (1993) found 141 species.

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