Effects of types of aquatic macrophyte stands and variations of dissolved oxygen and of temperature on the distribution of fishes in lakes of the amazonian floodplain

Efeitos dos tipos de estandes de macrófitas aquáticas e variações do oxigênio dissolvido e da temperatura na distribuição de peixes em lagos da várzea amazônica

Sánchez-Botero, JI.[1], Araujo-Lima, CARM.[2] and Garcez, DS.[3]

[1]Laboratório de Ecologia de Peixes, Departamento de Ecologia, Universidade Federal do Rio de Janeiro – UFRJ, Ilha do Fundão, CEP 21941-970, Rio de Janeiro, RJ, Brazil
e-mail: jisbar@gmail.com

[2]Curso de Pós-graduação em Biologia de Água Doce e Pesca Interior – BADPI, Laboratório de Ecologia de Peixes II, Instituto Nacional de Pesquisas da Amazônia – INPA, Av. André Araújo, 1756, CEP 69011-970, Manaus, AM, Brazil
e-mail: calima@inpa.gov.br

[3]Laboratório de Geografia Marinha, Departamento de Geografia, Universidade Federal do Rio de Janeiro – UFRJ, Ilha do Fundão, CEP 21945-970, Rio de Janeiro, RJ, Brazil
e-mail: dsgarcez@gmail.com

Abstract: It has been suggested that the distribution and abundance of fishes in Amazonian lakes are influenced by dissolved oxygen concentration, temperature, and macrophyte composition. We tested the influence of these variables in fish assemblages in Amazonian floodplain lakes. Sampling yielded 3910 individuals belonging to 93 fish species in four aquatic macrophyte stand types, composed by 12 replicates of *Paspalum repens*, *Echinocloa polystachya*, *Eichhornia* spp. and stands of decomposing grass species (totalizing 48 sampled stands) at three floodplain lakes (Janauacá, Camaleão and Rei) near Manaus, Amazonas State, Brazil. Results indicate that fish assemblages that inhabit different aquatic macrophyte stands in the studied lakes are not randomly distributed. Dissolved oxygen and water temperature did not affect fish distribution, abundance or biomass at the different stands. However, fish abundance, biomass, the number of hypoxia-resistant and non-migratory species were dependent on macrophyte stand type. Fish species richness was significantly lower under stands of *Eichhornia* spp. Average fish size did not differ between stand types. Migratory fish species differed among the sampled lakes. These results indicate that another key factor, associated to macrophyte stand type, possibly related to the location or morphological characteristics of the stands, influences the fish assemblages distribution in Amazonian lakes.

Keywords: fish assemblage, herbaceous vegetation, central Amazonia.

Resumo: Considera-se que a distribuição e abundância de peixes em lagos amazônicos estão influenciadas pelo oxigênio dissolvido, temperatura e estande de macrófita aquática. Neste estudo foram testadas a influência destas três variáveis na assembléia de peixes, em lagos de várzea do rio Amazonas. Foram coletados 3910 indivíduos de 93 espécies de peixes em quatro tipos de estandes de macrófitas aquáticas, compostos por 12 réplicas de *Paspalum repens*, *Echinocloa polystachya*, *Eichhornia* spp e gramíneas em decomposição (totalizando 48 estandes amostrados), em três lagos amazônicos (Janauacá, Camaleão e Rei) próximos a Manaus, Amazonas, Brasil. Os resultados indicaram que as assembléias de peixes que habitam diferentes estandes de macrófitas nos lagos amostrados não apresentaram distribuição aleatória. O oxigênio dissolvido e a temperatura não afetaram a distribuição, abundância ou biomassa de peixes entre os diferentes estandes. Entretanto, a abundância e a biomassa total de peixes, assim como o número de indivíduos resistentes à hipóxia e não migradores foram dependentes do estande de macrófita e a abundância de peixes migradores foi diferente entre os lagos amostrados. A riqueza de espécies foi significativamente menor em *Eichhornia* spp. O tamanho médio dos peixes não foi diferente entre os tipos de estandes de macrófitas aquáticas. Estes resultados indicam que outro fator associado ao tipo de estande de macrófita aquática, possivelmente relacionado à localização ou características morfológicas do estande, estruturam as assembléias de peixes em lagos da Amazônia.

Palavras-chave: assembléia de peixes, vegetação herbácea, Amazônia central.

1. Introduction

Herbaceous floating vegetation occupies an estimated 43% of the Amazonian floodplain and contributes to 65% of the floodplain net primary production (Melack and Forsberg, 2001). Junk and Piedade (1997) stated that 388 plant species from floating macrophyte habitats at Amazon floodplains are known, but only 12 are very abundant. Some characteristics of aquatic macrophyte stands, such as density and architecture (Dionne and Folt, 1991; Lillie and Budd, 1992) and water chemistry (Fodge et al., 1990; Miranda et al., 2000) may influence the organisms selection. Habitat complexity and density have also been reported as important factors in providing food resources and shelter from predation (Gotceitas and Colgan, 1987; Sabino and Stein, 1989; Dielh and Eklov, 1995; Chick and McIvor, 1997). Macrophyte stands are considered nurseries for juvenile fishes, and the fish community is predominantly composed by young fishes (Sánchez-Botero and Araujo-Lima, 2001; Sánchez-Botero et al., 2007). Many of these species are economically important when they reach adulthood (Sánchez-Botero and Araujo-Lima, 2001).

Macrophytes diversity is higher during the period of high water level (water level in the floodplain rises to 12 m during annual flooding), but there are few dominant plants in this community during this time. These include the species *Paspalum repens*, *Echinochloa polystachya* and the floating plants *Eichhornia* spp. Prior to the onset of flooding, lake beds are exposed, allowing the growth of *P. repens* and *E. polystachya* (Junk, 1970; Piedade et al., 1991). As water levels rise, wind and currents break the stalks of *P. repens* and the plants stay afloat, whereas *E. polystachya* remains rooted in the sediment during most of the flooding. Two species of *Eichhornia* occur in the Central Amazon: *E. crassipes* and *E. azurea*. The latter species is by far the most abundant in floodplain lakes and forms monospecific stands (Junk and Piedade, 1997).

Environmental conditions in macrophyte stands are variable. The lifespan of these stands is typically less than one year (Junk and Piedade, 1997). Water temperature and dissolved oxygen concentration change throughout the day and night within the stand and may be related to water currents, macrophyte stand types and depth (Junk, 1973; Jedicke et al., 1989). Water temperature in any stand may vary daily from 27 to 40 °C and dissolved oxygen may oscillate from 0.1 $mg.L^{-1}$ to 7.0 $mg.L^{-1}$ in less than 12 hours (Junk, 1973; Sánchez-Botero et al., 2001).

Many fish that live in these stands possess special adaptations in order to withstand the extreme environmental conditions (Junk et al., 1983; Val and Almeida-Val, 1995; Crampton, 1998). Variations in hypoxia resistance among species partially explains why low concentrations of dissolved oxygen have been reported as one of the main factors that affect fish distribution and community composition in the floodplains (Junk et al., 1983; Soares, 1993). The extreme temperatures reported for macrophyte stands approach the lethal temperature reported for neotropical fishes (Rietzler et al., 1981; Rantin et al., 1985), and this variable may also lead to different fish distributions.

This study tested the influence of the dissolved oxygen, water temperature and macrophyte stand types on the density, diversity and richness of fish assemblages in the Amazon floodplain. An "aquatic macrophyte stand type" is defined in this study as a portion of an area section covered by aquatic plants, mainly composed by one species, being considered in this case as a monospecific stand.

1.1. Study area

The floodplain Lakes Janauacá (67.71 km^2 in surface area), Camaleão (7.29 km^2) and Rei (277.57 km^2) are located in central Amazon near Manaus, Amazonas State, Brazil (Figure 1). During high water season, many lakes are interconnected by the flood waters. However, Camaleão, Rei and Janauacá Lakes are not interconnected. All three lakes possess extensive macrophyte stands. Free-floating plants (*Eichhonia* spp.) normally occur on the outer edge of macrophyte stands and rooted emergent grasses (*Echinochloa polystachya*) occur on the inner side of the stands. During high water season, broken or rotting stalks of the semi-aquatic plants form a mass of decomposing grasses that floats on the outer edge of macrophyte stands.

2. Material and Methods

Janauacá, Camaleão and Rei Lakes were sampled during the high water period (May to June) of 1998. Forty-eight stands were sampled, formed by 12 replicates, each one composed mainly of *P. repens*, *E. polystachya*, *Eichhornia* spp. and stands of decomposing grass. Each stand type presented 80% of a dominant plant, estimated visually. Four replicates of each stand type were sampled in each lake and the results for each group of macrophyte stand type were considered separately. Each stand was sampled from at least a 100 m distant from its nearest neighbour. Dissolved oxygen concentration and water temperature were measured at the centre of each stand at vertical intervals of 10 cm from surface up to

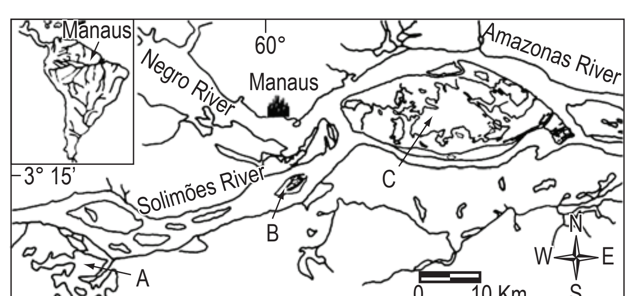

Figure 1. Map of the study area. A: Janauacá Lake; B: Camaleão Lake; C: Rei Lake.

1 m in depth with a YSI probe, and for analyses, they were represented by the mean value of the water column. Dissolved oxygen, water temperature and fishes were sampled randomly along the day hours in different stands of macrophytes, in order to maximize the range of these variables. The fishes were sampled with a seine net of 12 x 3 m, 5 mm mesh during daylight hours. The net was positioned in such a way as to enclose an average of 11 m^2 fraction of the macrophyte stand type. Once the patch was encircled, the lower end of the net was closed and pulled towards the boat. The captured fishes were separated from the plants and debris, fixed with 10% formalin and then preserved in alcohol at 70 °GL, and were measured the standard length (cm) and weight (g) of each individual. Rooted of *E. polystachya* and *Eichhornia* spp. were harder to sample due to the long stalks, which were cut with machete as the seine was pulled in. They were identified through specialized bibliography and by the help of specialists from the National Amazonian Research Institute (INPA), Amazonas State, Brazil. Fish voucher specimens were registered in the ichthyological collection of INPA, corresponding to the numbers: 14499 to 14505, for Janauacá Lake; 14506 to 14527, for Camaleão Lake; 14486 to 14498 and 16575, for Rei Lake.

Fish species richness in each macrophyte stand type (n = 12, sampled with a seine net for each stand type) was estimated by Jackknife approximation. The Shannon-Wienner diversity index was used and evenness was determined by Pielou index (Krebs, 1998). Analyses of variance (ANOVA) tested the mean value of dissolved oxygen, water temperature and standard length of fishes among the macrophytes stand types and lakes. Total fish abundance and fish biomass were analysed by a factorial design (ANCOVA) with two factors (lakes and macrophytes) and two covariates (dissolved oxygen and temperature). The abundance of fishes resistant to hypoxia (Val and Almeida-Val, 1995) as well as those with spawning migratory behaviour (Welcome, 1985; Vazzoler, 1992; Ruffino and Isaac, 1995) were also analysed. Data were transformed to log (x + 1) prior to analysis for correction of the heterocedasticity.

3. Results

The maximum variation per stand of dissolved oxygen and water temperature was 7 mgL^{-1} (range of 0.1-7.0 $mg.L^{-1}$) and 5 °C (range of 28-33 °C), respectively. Dissolved oxygen and temperature on the top meter of the macrophyte stands ranged from 0.2 to 6.2 $mg.L^{-1}$ and from 28.6 to 32.7 °C, respectively. Lakes were different in relation to mean dissolved oxygen (ANOVA; $F = 7.63$; $df = 2$; $p = 0.002$), but macrophyte stand types were not (ANOVA; $F = 2.17$; $df = 3$; $p = 0.10$). Camaleão Lake had lower dissolved oxygen average than the other lakes (Fisher's LSD; $p < 0.03$). Values considered hypoxic (less than 0.5 mgL^{-1} of dissolved oxygen) occurred in 15% of these samples. There was no difference in mean water temperature between lakes (ANOVA; $F = 0.73$; $df = 2$; $p = 0.48$) and macrophyte stand types (ANOVA; $F = 1.11$; $df = 3$; $p = 0.35$).

It was sampled 3910 fish belonging to 93 species, 22 families and 8 orders. Twenty-three of the collected species show migratory behaviour. Thirty-six species, approximately 40% of all species, show some type of adaptation to low dissolved oxygen conditions (Appendix). Fish species richness predicted by the Jackknife procedure was significantly lower in stands of *Eichhornia* spp. No significant difference in diversity index was found between stand types of macrophytes (Table 1). Fishes standard length was not different between the macrophyte stand types (ANOVA; $F = 1.73$; $df = 3$; $p = 0.17$) and lakes (ANOVA; $F = 2.37$; $df = 2$; $p = 0.10$).

The total number of fishes (Nt), ichthyomass (W) and the number of hypoxia-resistant (Nhr) and non-migratory fishes (Nnm) were significantly lower in *Eichhornia* spp. stands. These stands, in general, showed fewer fish and lower biomass than other macrophyte stands, except for migratory and hypoxia sensitive species. Variations of dissolved oxygen and temperature had no effect on these fish assemblage parameters, whereas the migratory fish assemblage differed among the sampled lakes (Table 2, Figures 2 and 3).

On the whole, migratory fishes were less abundant or absent in Rei Lake and species such as *Cichla monoculus*, *Serrasalmus rhombeus*, *Moenkhausia* gr. *intermedia* and *Serrapinus* sp. were found mainly in Janauacá and Camaleão Lakes. Species caught frequently and with high abundance in Rei Lake included *Aphyocharax* aff. *alburnus*, *Apistogramma* aff. *cacatuoides*, *Brachyhypopomus brevirostris*, *Brachyhypopomus pinnicaudatus*, *Charax* sp. 2, Cheirodontinae, *Hoplias malabaricus*, *Moenkhausia* gr. *lepidura*, *Pterodoras granulosos*, *Synbranchus* sp. and *Trachelyopterus galeatus* (Appendix).

Table 1. Observed and estimated species richness (Jackknife), diversity (Shannon-Wienner index) and evenness (Pielou) of fish assemblages under four macrophyte stand types and their variances.

Macrophyte stand type	Observed and estimated species richness	S^2	Diversity	S^2	Evenness
Paspalum repens	58/84.6	24.33	2.78	0.05	0.68
Decomposing grass	61/81.2	25.67	2.51	0.06	0.61
Echinochloa polystachya	52/77.7	28.17	2.74	0.05	0.69
Eichhornia spp.	40/58.3*	30.56	2.22	0.06	0.60

* indicates means significantly different (Tukey post hoc test).

Table 2. Ancova results of the total abundance of fish (Nt), abundance of hypoxia-resistant species (Nhr), abundance of hypoxia-sensitive species (Nhs), biomass (W), abundance of migratory species (Nm) and abundance of non-migratory species (Nnm) in four macrophyte stand types and three floodplain lakes under different dissolved oxygen and water temperature. N = 48. MS: Mean Squares. F: Fisher's test. P: Probability ($p < 0.05$).

	Nt			Nhr			Nhs		
	MS	F	P	MS	F	P	MS	F	P
Factors									
Macrophyte stand	4.432	3.045	0.042	3.983	3.387	0.029	4.102	2.172	0.109
Lake	4.249	2.919	0.068	3.554	3.022	0.062	5.682	3.010	0.063
Residual	0.659	0.453	0.838	1.316	1.119	0.372	0.635	0.337	0.913
Covariable									
Oxygen	0.650	0.446	0.509	0.184	0.156	0.695	1.936	1.025	0.318
Temperature	2.048	1.407	0.244	2.205	1.875	0.180	2.076	1.100	0.302

	W			Nm			Nnm		
	MS	F	P	MS	F	P	MS	F	P
Factors									
Macrophyte stand	4.736	2.889	0.050	1.547	0.976	0.416	4.911	4.003	0.015
Lake	1.639	1.000	0.378	11.963	7.545	0.002	3.638	2.966	0.065
Residual	2.552	1.557	0.190	0.556	0.351	0.905	1.291	1.053	0.410
Covariable									
Oxygen	0.060	0.037	0.850	0.072	0.046	0.832	0.024	0.020	0.889
Temperature	0.730	0.445	0.509	0.003	0.002	0.964	1.800	1.467	0.234

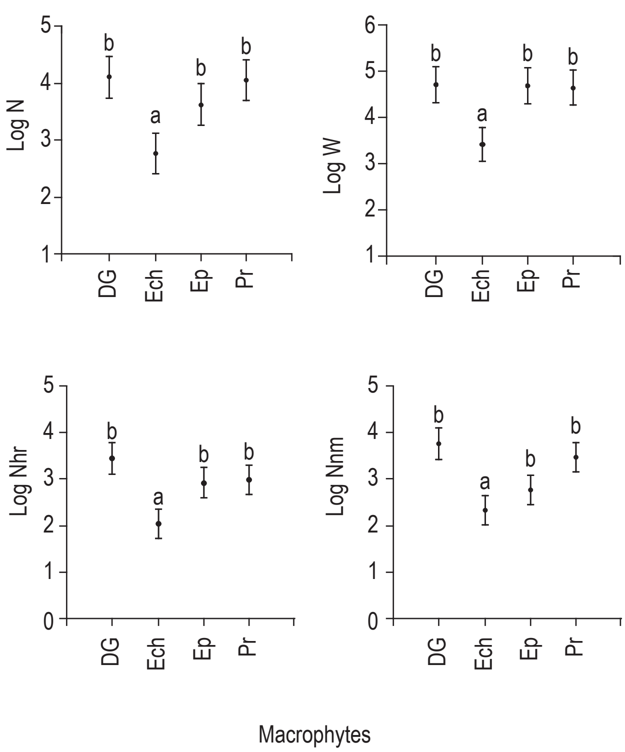

Figure 2. Variation of the total abundance of fishes (Log N), ichthyomass (Log W), abundance of hypoxia-resistant species (Log Nhr) and non-migratory species (Log Nnm) in relation to macrophyte stand types. Mean values (dots) and standard error (bars) are shown. Significantly different means are shown with a different letter (Tukey test); DG = decomposing grass, Ech = *Eichhornia* spp., Ep = *E. polystachya*, Pr = *P. repens*.

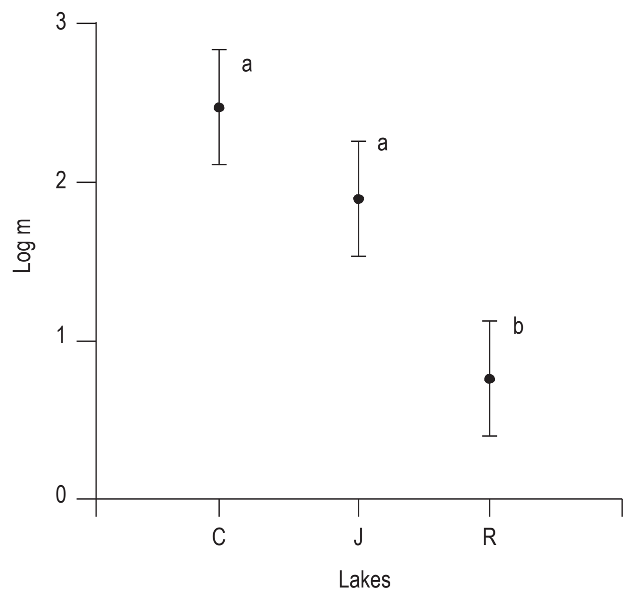

Figure 3. Variation in the abundance of migratory fish species (Log m) in three floodplain lakes. Mean values (dots) and standard error (bars) are shown. Significantly different means are shown with a different letter (Tukey test). C = Camaleão Lake; J = Janauacá Lake; R = Rei Lake.

4. Discussion

Amazonian macrophyte stand types normally form a landscape composed by patches of habitats that influence on fish distribution (Araujo-Lima et al., 1986; Henderson and Hamilton, 1995; Petry et al., 2003; Sánchez-Botero et al., 2003). According to Petry et al. (2003) predation pressure was an important factor for fish habitat selection in the Amazon floodplain. This study showed that the abundance and biomass of fishes are significantly influenced by the types of aquatic macrophytes. Areas of the floating vegetation dominated by *E. polystachya* and *P. repens* exhibited a significantly higher fish density and richness than areas dominated by *Eichhornia* spp. or decomposing grasses.

The macrophyte stand types evaluated in this study were formed mostly by aquatic grasses in great abundance, but with different life forms and submerged structures (Junk, 1970; Piedade et al., 1991). On the other hand, in the evaluated lakes those species of *Eichhornia* normally occurred on the outer edge of macrophyte stands (pers. obs). This location could be affecting the assemblages' distribution and richness suggesting that the variation of fish species captured was related to their position in the macrophyte stand. So, fishes that inhabit *Eichhornia* stands could be suffering a kind of "edge effect" caused by disturbances from different origins, amplitudes, frequencies, time length and intensities, caused for being more exposed to the direct effects of material flow and water. According to Henry (2003), these situations of environmental stress at the earth-water ecotones could affect available resources and, consequently, the patterns of regional displacement of fish. This study showed the establishment of a poorer ichthyofauna in the limited vicinity between aquatic plants (where *Eichhornia* species happens) and limnetic area. The existence of different abundance distribution patterns in hypoxia-resistant, non migratory individuals, ichthyomass and fish richness suggests a selection tendency of these assemblages in some macrophyte stand types. This probably happens because of the stands distribution in floodplain lakes and the differences regarding to their complex structures, that might directly affect the availability of other resources, such as food or shelter, as a result of a particular association between fish and plants.

The effect of low oxygen concentration on fish populations has been reported by Junk et al. (1983) and Soares (1993) and was predicted in this study as well. Dissolved oxygen values lower than 0.5 $mg.L^{-1}$ (which occurred in 15% of the samples) are considered hypoxic and lead to responses and escape behavior in fish fauna (Soares, 1993). In this study, the most common adaptation was the aquatic surface breath (24.6% of the species) followed by the presence of accessory air-breathing organs (7.8% of the species), physiological adaptations (6.3% of the species) or change in behaviour (1.1% of the species). In the lakes near Manaus during the flood season values exceeding 0.5 mgL^{-1} of dissolved oxygen on the surface were rarely registered even during the day and in emergent aquatic grasses stands (Junk et al., 1983; Melack and Fisher, 1983). Small differences in these variables were observed among the studied aquatic macrophyte stands. Hypoxic values were less frequent at the surface (6% of the samples) and at a depth of 0.5 m (20% of the samples). However, it is suggested that the higher dissolved oxygen concentrations near the surface lead to higher fish abundance in this habitat stratum affecting fish vertical distribution more than segregation by size (Junk et al., 1983; Miranda et al., 2000). It is less probable that the differential size or maturity state distribution affected the samples in this study, considering that the net used tends to capture fishes that commonly inhabit up to a depth of two meters.

The temperatures found in the aquatic macrophyte stands were within the tolerance range for neotropical fish fauna (Brett, 1956; Rietzler et al., 1981; Rantin et al., 1985), with low frequencies of extreme values. Accounting for these arguments, the values of dissolved oxygen and water temperature evaluated at different macrophyte stand types were not significantly different and, thus, did not influence the fish assemblages' distribution.

The results suggest that a factor more related to particular characteristics of macrophyte stand types in the Central Amazonian lakes might alter fish assemblages distribution, indicating that there are no random associations between macrophytes and fishes.

The different frequencies in fish composition from the three sampled lakes were attributed to different geomorphological and limnological features: Camaleão Lake is anoxic for short periods of time in some areas, caused mainly by the high decomposition rates (Junk et al., 1983). In contrast with the other two lakes, this one is smaller and connected to the river by a short and wide channel (Sites: Agência Nacional de Águas – ANA; Google earth) which favors colonization by young migratory fish species. However, we observed that at Janauacá Lake, species of migratory Characiformes were frequently captured, while at Rei Lake, Gymnotiformes, Cichlidae and Siluriformes were the most frequent groups. The most frequently captured species at Camaleão Lake were *Ctenobrycon hauxwellianus*, *Serralpinus* sp. and *Hemigrammus* aff. *rodwayi*, considered as high plasticity (Winemiller, 1989) suggesting that this environment is submitted to oscillations of its biotic and abiotic conditions. Likewise, fluctuations in the number of some fish species are common in Amazonian floodplains from one year to the next, due to, for instance, the intensity and length of the rainy season (Lowe-McConnell, 1987). Due to the variation in biotic and abiotic characteristics of the lakes, resource availability is expected to cause fluctuations in the fish fauna of these environments. On the other hand, the connectivity between the river and lateral lacustrine environments at the floodplain areas could be a fundamental factor affecting the species richness (Ward et al., 1999). In addiction to this, Camaleão Lake possesses the higher specific richness (54 fish species) that may suffer an influence do to its location near the merger of the Negro and Solimões Rivers.

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Appendix

Table 1. List of the fish species observed in macrophyte stands in Amazonian floodplaind lakes. Number of individuals sampled for lake (J: Janauacá Lake, C: Camaleão Lake and R: Rei Lake) and ecological attributes - fish resistance to hypoxia (Val and Almeida-Val, 1995), and spawning migratory behaviour (Welcome, 1985; Vazzoler, 1992; Ruffino and Isaac, 1995) - are indicated by "x".

Classification	N of individuals/lake			Migratory behaviour	Hypoxia resistance
	J	C	R		
Clupeiformes					
ENGRAULIDAE					
Lycengraulis batesii (Günther, 1868)	2	-	-	x	-
Characiformes					
CURIMATIDAE					
Curimatella sp.	1	-	-	-	-
Cyphocharax sp.	-	-	1	-	-
Potamorhina altamazonica (Cope, 1878)	1	-	-	x	-
Potamorhina latior (Spix and Agassiz, 1829)	2	5	-	x	-
Psectrogaster amazonica Eigenmann and Eigenmann, 1889	3	-	-	x	-
Psectrogaster rutiloides (Kner, 1858)	3	-	1	x	x
Psectrogaster sp.	-	-	1	x	-
PROCHILODONTIDAE					
Prochilodus nigricans Agassiz, 1829	13	21	-	x	-
Semaprochilodus insignis (Jardine & Schomburgk, 1841)	6	96	-	x	x
Semaprochilodus taeniurus (Valenciennes, 1817)	4	-	-	x	x
ANOSTOMIDAE					
Leporinus fasciatus (Bloch, 1794)	-	2	-	x	-
Leporinus friderici (Bloch, 1794)	1	1	-	x	x
Laemolyta sp.	3	-	1	x	-
Rhytiodus microlepis Kner, 1858	22	1	1	x	x
Schizodon fasciatus Spix and Agassiz, 1829	11	36	7	x	x
CHARACIDAE					
Aphyocharax aff. *alburnus* (Günther, 1869)	-	2	37	-	-
Astyanax aff. *bimaculatus* (Linnaeus, 1758)	41	-	2	x	-
Brycon melanopterus (Cope, 1872)	-	1	-	x	x
Charax sp.1	1	3	-	-	-
Charax sp.2	3	5	85	-	-
Ctenobrycon hauxwellianus (Cope, 1870)	172	708	138	-	x
Gymnocorymbus thayeri Eigenmann, 1908	-	3	-	-	-
Hemigrammus belottii (Steindachner, 1882)	4	-	63	-	-
Hemigrammus aff. *rodwayi* Durbin, 1909	2	506	70	-	-
Hemigrammus sp.	-	1	1	-	-
Hyphessobrycon eques (Steindachner, 1882)	-	3	-	-	-
Hyphessobrycon sp.1	-	1	1	-	-
Hyphessobrycon sp.2	27	32	-	-	-
Moenkhausia gr. *dichroura* (Kner, 1858)	-	11	-	-	-
Moenkhausia gr. *intermedia* Eigenmann, 1908	67	147	16	x	-
Moenkhausia gr. *lepidura* (Kner, 1858)	-	10	28	-	-
Mylossoma aureum (Agassiz, 1829)	-	1	-	x	x
Mylossoma duriventre (Cuvier, 1818)	24	47	19	x	x
Odontostilbe sp.	21	411	15	-	-
Cheirodontinae	-	20	48	-	-
Prionobrama filigera (Cope, 1870)	-	-	9	-	-
Pygocentrus nattereri Kner, 1858	55	43	42	-	-
Roeboides affinis (Günther, 1868)	1	-	3	-	-

Table 1. Continued...

Classification	N of individuals/lake			Migratory behaviour	Hypoxia resistance
	J	C	R		
Roeboides myersii Gill, 1870	2	1	2	-	-
Roeboides sp.	1	-	-	-	-
Serrapinnus sp.	30	70	-	-	-
Serrasalmus cf. *elongatus* Kner, 1858	1	3	2	-	-
Serrasalmus rhombeus (Linnaeus, 1766)	22	3	-	-	x
Serrasalmus spilopleura Kner, 1858	1	11	7	-	-
Serrasalmus sp.1	-	5	1	-	-
Serrasalmus sp.2	-	-	1	-	-
Triportheus albus Cope, 1872	-	2	-	x	x
Triportheus angulatus (Spix and Agassiz, 1829)	1	86	-	x	-
Triportheus auritus (Valenciennes, 1850)	2	-	-	x	-
ACESTRORHYNCHIDAE					
Acestrorhynchus falcirostris (Cuvier, 1819)	-	-	1	-	-
CYNODONTIDAE					
Rhaphiodon vulpinus Agassiz, 1829	3	-	-	-	-
ERYTHRINIDAE					
Hoplerythrinus unitaeniatus (Agassiz, 1829)	-	-	1	-	x
Hoplias malabaricus (Bloch, 1794)	12	18	21	-	x
LEBIASINIDAE					
Nannostomus eques Steindachner, 1876	-	-	1	-	-
Pyrrhulina brevis Steindachner, 1876	7	-	-	-	-
Siluriformes					
CALLICHTHYIDAE					
Corydoras hastatus Eigenmann and Eigenmann, 1888	-	1	-	-	x
Hoplosternum littorale (Hancock, 1828)	2	2	-	-	x
Megalechis thoracata (Valenciennes, 1840)	7	1	1	-	x
LORICARIIDAE					
Pterygoplichthys pardalis (Castelnau, 1855)	2	-	3	-	x
PIMELODIDAE					
Pimelodus aff. *blochii* Valenciennes, 1840	-	3	-	x	x
DORADIDAE					
Anadoras sp.	-	1	-	-	-
Opsodoras sp.	-	2	-	-	-
'Petalodoras' punctatus (Kner, 1853)	-	-	2	-	-
Pterodoras granulosus (Valenciennes, 1821)	-	11	12	-	-
AUCHENIPTERIDAE					
Trachelyopterus galeatus (Linnaeus, 1766)	-	21	30	-	x
Gymnotiformes					
GYMNOTIDAE					
Gymnotus cf. *carapo* Linnaeus, 1758	-	-	1	-	x
Gymnotus sp.	-	1	-	-	x
STERNOPYGIDAE					
Eigenmannia gr. *virescens* (Valenciennes, 1836)	-	1	3	-	x
Eigenmannia sp.	-	3	1	-	x
Sternopygus macrurus (Bloch & Schneider, 1801)	-	-	1	-	x
Sternopygus sp.	1	-	-	-	-
HYPOPOMIDAE					
Brachyhypopomus brevirostris (Steindachner, 1868)	-	2	12	-	x
Brachyhypopomus pinnicaudatus (Hopkins, 1991)	-	8	14	-	x
Brachyhypopomus sp.	-	1	2	-	x

Table 1. Continued...

Classification	N of individuals/lake			Migratory behaviour	Hypoxia resistance
	J	C	R		
APTERONOTIDAE					
Parapteronotus hasemani (Ellis, 1913)	1	-	-	-	x
Synbranchiformes					
SYNBRANCHIDAE					
Synbranchus sp.	13	16	47	-	x
Perciformes					
CICHLIDAE					
Aequidens sp.	2	-	-	-	-
Apistogramma aff. *cacatuoides* Hoedeman, 1951	-	-	5	-	-
Apistogramma agassizii (Steindachner, 1875)	-	-	4	-	-
Astronotus crassipinnis (Heckel, 1840)	1	-	-	-	-
Astronotus sp.	-	-	1	-	x
Chaetobranchus sp.	-	-	1	-	x
Chaetobranchopsis orbicularis (Steindachner, 1875)	1	-	-	-	-
Cichla monoculus Spix and Agassiz, 1831	7	-	-	-	x
Cichlasoma amazonarum Kullander, 1983	9	13	4	-	x
Crenicichla lugubris Heckel, 1840	3	-	-	-	-
Heros efasciatus Heckel, 1840	4	2	3	-	-
Mesonauta insignis (Heckel, 1840)	1	94	7	-	-
Pterophyllum scalare (Schultze, 1823)	-	-	1	-	x
Satanoperca jurupari (Heckel, 1840)	1	-	-	-	-
Tetraodontiformes					
TETRAODONTIDAE					
Colomesus asellus (Müller and Troschel, 1849)	2	-	-	-	-
Lepidosireniformes					
LEPIDOSIRENIDAE					
Lepidosiren paradoxa Fitzinger, 1837	-	1	-	-	x