Fish assemblages in two sandy beaches in lower Purus river, Amazonas, Brazil

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ABSTRACT. Fish assemblages from two sandy beaches in the lower Purus river (Amazonas, Brazil) were compared. Four sampling groups were represented by: day and night samples in sandy beach inside the Reserva Biológica de Abufari (biological reserve) and day and night samples in the Reserva de Desenvolvimento Sustentável Piagaçu-Purus (sustainable development reserve). Samples were collected during low water levels (November) in 2007. The fish were sampled by means of seines with mesh size of 5 mm between opposing knots, 11 m long and 6 m wide. A total of 112 fish species belonging to nine orders and 27 families was captured. The vast majority of the dominant forms consisted of small fishes (< 100 mm SL) or juveniles. Samples collected in Abufari at night presented more specimens (3,540), higher richness (84 spp.), larger total biomass (76,614 g) and higher diversity (*H*'= 2.57) than the other groups. The composition of fish assemblages was significantly different among all analyzed groups (ANOSIM, p < 0.0001, R= 0.71). NMDS analysis also clustered all species in four distinct groups according to species composition per period and site. SIMPER analyses showed that 80% of variation of species composition among the groups examined was due to 12 species. However, fish composition did not show any correlation with the abiotic factors examined. Different levels of use in both reserves may explain differences in fish composition.

KEYWORDS. Amazon fish, nictemeral, protected areas, diversity, abundance.

RESUMO. Assembleias de peixes de duas praias no baixo rio Purus, Amazonas, Brasil. Foram comparadas as assembleias de peixes de duas praias arenosas localizadas no baixo rio Purus (Amazonas, Brasil). As amostragens foram delineadas representando quatro situações: amostras diurna e noturna na praia da Reserva Biológica de Abufari e amostras diurna e noturna na praia da Reserva de Desenvolvimento Sustentável Piagaçu-Purus. As coletas foram realizadas durante o período de seca (novembro) de 2007. Os peixes foram coletados utilizando rede de cerco com malha de 5 mm entre nós opostos, 11 m de comprimento e 6 m de altura. Um total de 112 espécies de peixes foram coletados pertencentes a nove ordens e 27 famílias. A grande maioria das formas dominantes compreendeu peixes de pequeno porte (< 100 mm CP) ou juvenis. A praia de Abufari a noite apresentou mais espécimes (3.540), maior riqueza (84 spp.), maior biomassa total (76.614 g) e maior diversidade (*H*' = 2,57) do que os demais grupos. A composição das assembleias de peixes foi significativamente diferente entre as quatro situações analisadas (ANOSIM, p < 0,0001, R = 0,71). Análises de NMDS também agruparam todas as espécies em quatro grupos distintos de acordo com a composição por período e local. A análise de SIMPER revelou que 80% da variação na composição entre os grupos analisados foi devido a 12 espécies. Entretanto, a composição de peixes não mostrou correlação com os fatores abióticos analisados. Diferentes níveis de uso de ambas as reservas são apontados como possíveis causas da diferença na composição de peixes.

PALAVRAS-CHAVE. Peixes da Amazônia, nictemeral, áreas protegidas, diversidade, abundância.

Much have already been said about the extreme richness of the ichthyofauna in the Amazon river *sensu latu* (Böhlke *et al.*, 1978; Goulding *et al*., 1988; Lowe-McConnell, 1999; Reis *et al.*, 2003). Diversity among different environments or even microhabitats within the large Amazon river drainage system is far from being satisfactorily assessed (Rapp Py-Daniel *et al*., 2007). Efforts to unravel the ichthyofauna in benthic habitats have been directed to sandy beaches along the margins of rivers (Stewart *et al*., 2002) or to the bottom of deep-river channel environments (Lundberg *et al.*, 1987; Cox-Fernandes, 1999; Cox-Fernandes *et al*., 2004). The literature on Amazon fishes present in sandy beaches is extremely poor (Goulding *et al*., 1988; Ibarra & Stewart, 1989; Jepsen, 1997; Stewart *et al*., 2002; Arrington & Winemiller, 2003). One of the possible reasons for the scarcity of information in this subject is the seasonality of the habitat: the vast majority of the sandy beaches are exposed only during three months of the year in the Amazon. Also, these habitats may show an incredibly high rate of dynamic faunal replacement, because rising and lowering waters occur on a weekly or even a daily basis.

Ichthyofauna composition has been shown to vary between periods and have been related to different fish activities, such as feeding, mating and moving (Matthews, 1998; Lowe-McConnell, 1999; Arrington & Winemiller, 2003; Pessanha & Araújo, 2003) and must play an important role in maintenance of diversity. Siluriformes and Gymnotiformes are more active at night whereas most of the Characiformes feed and migrate during the day (Matthews, 1998; Lowe-McConnell, 1999). There are also preferences among groups of fishes to look for shelter or protection in sandy beaches during different periods of the night (Goulding, 1997; Arrington & Winemiller, 2003; Pessanha & Araújo, 2003). Sandy beach dwellers have developed successful strategies to cope with fast lowering and rising of the waters, lack of places to hide, very high temperatures during the day, and an apparently extremely poor environment to look for food. Several forms adapted to sandy environments present translucent bodies almost without any coloration; others are creamy colored with dark small spots mimicking the sandy substrate; some present shiny surfaces in order to confound predators (Goulding, 1997; Zuanon *et al.*, 2006).

The Purus river has always been considered an extremely rich environment, contributing significantly to the commercialized fish stocks in Manaus (Batista, 2003). The ichthyofauna of the Purus river has been recently assessed through different published surveys (Rapp Py-Daniel & Deus, 2003; Rossoni *et al.*, 2010; Silva *et al.*, 2010). The large size of the drainage and great diversity of environments, including many small tributaries and several lakes, in addition to the dramatic change in the landscapes between low and high waters, are essential for the maintenance of its organismic diversity and complex biological interactions.

The present work was conducted in two very different protected areas: the Reserva Biológica de Abufari (biological reserve), in which any kind of use of its biodiversity is forbidden, and the Reserva de Desenvolvimento Sustentável Piagaçu-Purus (sustainable development reserve), a reserve of sustainable use. Differently, in Abufari, all fishing, hunting and logging are forbidden. Even whole families were displaced from their houses to avoid confrontation with environmental agents. Abufari is an extremely rich area also known as point of egg deposition and hatching for Amazon turtles of the genus *Podocnemis* Wagler, 1830 (Vogt, 2003). On the other hand, Piagaçu Reserve has almost 60 communities that make their living through its biodiversity: all kinds of fishing (subsistence, commercial and ornamental), hunting (caimans, big mammals, birds and turtles), logging and planting are regular practices among locals.

We conducted the survey on two sandy beaches during low waters (November) in 2007. The beaches start to appear by the middle of September and reach their peak of exposed area by the end of November. In December, the water starts to rise again and the disappearance of the beaches happens in few weeks.

Our objectives were to investigate possible nictemeral differences in the composition, richness and biomass of the ichthyofauna between two sandy beaches (Abufari beach and Praia Grande).

MATERIAL AND METHODS

Study area. Sampling was conducted in November of 2007 (dry season) on two sandy beaches of the lower Purus River, one of the major white-water tributaries of the Amazon-Solimões System (Goulding *et al*., 2003). The first sandy beach is located in Abufari beach, in Reserva Biológica do Abufari (05°22'S 63°04'W), and the second in the Praia Grande, Reserva de Desenvolvimento Sustentável Piagaçu-Purus (04°30'S, 62°03'W) (Fig. 1).

Sampling methods. The sampling area covered approximately 3 km in each beach. We sampled 10 discrete patches of 100 m on each sandy beach only once. Each patch was considered a sample unit separated from the next by 100 m. On each patch three non-overlapping collections were made covering its whole area and combined to represent one sample. Samples were taken

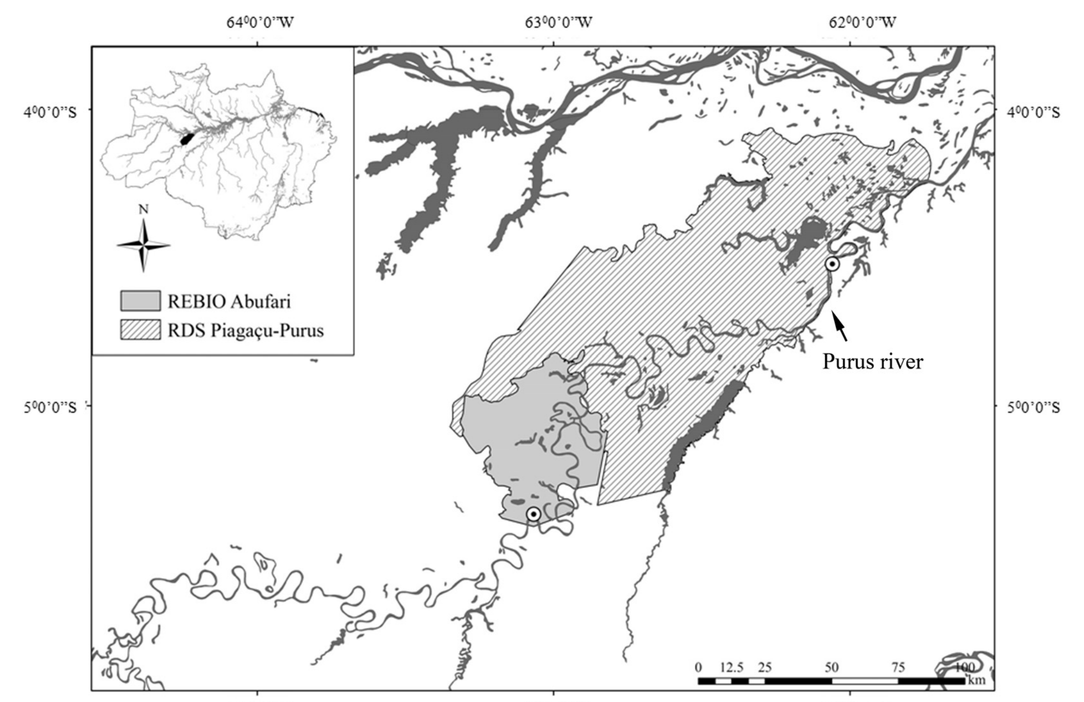

Figure 1. Study areas: Abufari beach, in the Reserva Biológica de Abufari (biological reserve - REBIO Abufari) and Praia Grande, in the Reserva de Desenvolvimento Sustentável Piagaçu-Purus (sustainable development reserve - RDS Piagaçu-Purus) in lower Purus river, Amazonas, Brazil.

during daylight (6:00-10:00 am) and at night (6:00-10:00 pm), with a 36-hour-minimum interval. Fish captures were made with an 11 m-long and 6 m-deep seine of 5 mm mesh size. During seine hauls, one end of the seine was pulled along the shoreline and the other end was pulled in a parallel direction offshore. At the offshore end of the seine the maximum depth was 1.5 m. Water temperature (^{0}C), conductivity (µS cm^{-1}), dissolved oxygen (%), pH and average depth of the first 10 m were measured (Tab. I). Depth measures were taken at each meter perpendicular to the shore.

Fish samples were coded and separated in plastic bags. All fishes were preserved in 10% formalin, posteriorly washed in water and conserved in 70% ethanol for identification. Voucher specimens were deposited in the Instituto Nacional de Pesquisas da Amazônia fish collection, Manaus, AM, Brazil (INPA 34629-34970).

Four groups of samples were compared: fishes sampled in Abufari during the day and during the night, and fishes from Praia Grande during the day and during the night. Fish composition was compared between both beaches regardless the period, between periods in the same beach, and between periods in the different beaches.

Statistical Analysis. Fish composition, richness, total abundance and biomass were determined for each beach and collecting period. Species richness was compared between groups by using rarefaction of individuals and species diversity was measured using the Shannon-Wiener Diversity Index (*H*') (Krebs, 1989), tested for significant differences between samples with Hutcheson's method (Hutcheson, 1970). We estimated the Evenness (Shannon's equitability) species and the Dominance, using Simpson's index (Simpson, 1949). The Shannon diversity index is calculated as: $H' = -\sum (p_i)(\log_2 p_i)$, where p_i is the proportion of individuals in the *i* th species. For the application of Hutcheson's method it must be calculated the variance in the diversity, the *t* test and the degrees of freedom.

Variance is estimated by: $\mathrm{VarH'} = \frac{\sum \mathrm{pi}(\log_2 \mathrm{pi})^2 - (\sum \mathrm{pilog}_2 \mathrm{pi})^2}{\mathrm{N}} - \frac{\mathrm{S}-1}{2\mathrm{N}^2}$ where *S* is the number of species and *N* is the total number of individuls. The *t* statistic is calculated as: $t = \frac{H'_1 - H'_2}{(VarH'_1 + VarH'_2)}$ where H'_1 is the diversity of site 1 and $VarH'_1$ is its variance. The degree of freedom is calculated by: $df = \frac{(VarH'_1 + VarH'_2)^2}{\left[(VarH'_1)^2 / N_1\right] + \left[(VarH'_2)^2 / N_2\right]}$. Evenenss was calculated as $E = H'/\log_2 S$, where *S* is species richness; and Dominance with the formula: $D = \sum \frac{(n_i(n_i - 1))}{(N(N-1))}$, where n_i is the number of individuals per species *i* and *N* is the total number of individuals. Calculations of Evenness, Dominance and Biomass were made with logarithmized data and their scores were compared through analyses of variance (ANOVA), followed by *a posteriori* Tukey test at a significance level of 95%.

A Non-metric Multidimensional Scaling ordination analysis (NMDS) was constructed with abundance data (log 10). To compare assemblages by beach and by period we used Analysis of Similarity ANOSIM (Clarke, 1993). ANOSIM is a nonparametric procedure for testing hypothesis of non-similarity between two or more groups of entities (McCune & Grace, 2002). This procedure uses the statistic test (R) based on the difference between the average of all the ranks dissimilarities between objects-between-groups (r_B) and the average of all the ranks dissimilarities between objects-within-groups (r_W) (Quinn & Keough, 2002), based on the formula: $R = \frac{\bar{r}_B - \bar{r}_W}{n(n-1)/4}$, where *n* means the total number of sample units. R varies from +1 to -1. R values greater than 0 mean more dissimilarity between groups than within groups, R values of zero indicate that there is no difference, and negative values of R mean that dissimilarities within groups are greater than dissimilarities between groups. To calculate the dissimilarity matrices we used Bray-Curtis index, a test considered most appropriate for biotic data (Bray & Curtis, 1957). Pairwise comparisons were conducted through analyses of the R value, as a *pos-hoc* test, and p Bonferroni corrected values (which are multiplied by the number of comparisons) (Clarke, 1993). In addition to that, a SIMPER analyses (percent of similarity) was used to evaluate the principal taxa responsible for the observed differences between the sampled groups. All the analyses were done using the free software PAST 2.03 (Hammer, 2010).

To test for possible correlation between abiotic factors and fish composition, Canonical Correspondence Analysis (CCA) was conducted using fish species abundances and temperature, dissolved oxygen, pH, conductivity, and average depth. For this analysis, we used PC-Ord (McCune & Mefford, 1997). All data were logarithmized using [log10 (n+1)] for abundance and (log 10) for abiotic values.

Table I. Abiotic factors values, minimum and maximum, mean and standard deviation (Sd), by site (Praia Grande and Abufari) and by period (day and night) on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007.

Abiotic factors	Praia Grande day min/max (mean±Sd)	Praia Grande night min/max (mean±Sd)	Abufari day min/max (mean±Sd)	Abufari night min/max (mean±Sd)
Temperature (^{0}C)	30.1 - 32.1 (31.2±0.60)	31.1 - 33.1(32.1±0.59)	30.2 - 32.8 (31.2±0.77)	30.3 - 31.5 (30.6±0.38)
Conductivity (µS cm^{-1})	61.5 - 69.4 (67±2.21)	60.2 - 71.9 (66.9±3.62)	60.9 - 70.4 (66.8±3.17)	60.9 - 77,8 (67.8±5.06)
Dissolved oxygen (%)	5.23 - 7.06 (6.1±0.63)	5.24 - 7.28 (6.5±0.57)	5.09 - 6.68 (5.9±0.48)	4.95 - 6.05 (5.6±0.38)
pH	6.1 - 7.56 (7±0.43)	6.9 - 8.33 (7.3±0.39)	6 - 6.8 (6.4±0.27)	6 - 6.75 (6.5±0.28)
Average depth (cm)	25 - 48 (±7.8)	27.1 - 49 (±7.7)	37 - 69 (±10)	38.1 - 70.6 (±10.1)

RESULTS

Samples from both beaches resulted in 10,065 specimens, representing nine orders, 27 families and 112 species (Tab. II). Praia Grande during the day produced 37 species, Praia Grande at night 62, Abufari beach had 60 species during the day and 84 during the night (Tab. III). Considering all samples together, Characiformes were by far the richest group with 53 species (47% of the total), followed by Siluriformes with 39 species (35%) and Gymnotiformes with seven species (6%). Numerically, Characiformes were also more abundant, with 3,369 (34% of the total number of specimens), followed by Siluriformes with 2,849 (28%), and Tetraodontiformes with 1,542 (15%). Characiformes and Siluriformes were dominant in all analysed groups (Abufari day, Abufari night, Praia Grande day and Praia Grande night); Gymnotiformes were the third more dominant group only during night samples (Tab. II). The richest family was Characidae, with 27 species, followed by Pimelodidae, with 12 species (Tab. II).

Fish composition between beaches, independent of the period, showed 57 species (51%) in common to both beaches, whereas 38 (34%) were exclusive to Abufari beach and 17 (15%) exclusive to Praia Grande (Tab. II). Comparing fish composition during the periods, regardless of the beach, 60 species were found during day and night; 42 only at night and 10 species only during the day (Tab. II). Comparing periods and beaches, 44 species were found in common during the night in both beaches, but only 27 were common to both beaches during the day. Abufari beach had 49 species occurring day and night, whereas Praia Grande had only 25 (Tab. II).

According to the rarefaction curves, Praia Grande showed that the expected richness of a standard sample of 958 specimens was 37 species for the daily period and 42 for the nocturnal period. For Abufari, expected richness for daily and night period were 45 and 57 species respectively (Fig. 2). Abufari at night presented more specimens (3,540), higher number of species (84 spp), larger total biomass (76,614$\pm$3,831 g) and higher diversity (H'= 2.57$\pm$0.21) than the other groups. On the other hand, Praia Grande during the day had the lowest number of individuals (958), least richness (37 spp), lowest total biomass (3,589$\pm$184 g) and least diversity (H'= 2.048$\pm$0.22) (Tab. III). Shannon indices were significantly different between all groups ($p < 0.001$), except between Abufari beach by day and Praia Grande by night (Tab. IV). ANOVA results for Equitability and Dominance were not different ($p > 0.05$) among beaches and periods. However, total biomass was significantly different between all groups ($p = 0.000$), except between Abufari beach by day and night (Tukey test, $p = 0.5954$).

Composition of fish assemblages was significantly different among sites and periods (ANOSIM, $p < 0.0001$, R= 0.71, Tab. V). NMDS analysis also clumped all the species in four distinct groups according to species composition per site and per period (Fig. 3). ANOSIM and NMDS results revealed a greater similarity between Praia Grande day and night (R= 0.4756, p= 0.0006) and between Praia Grande night and Abufari beach day (R= 0.6232, p= 0), as well as a lesser similarity between Praia Grande day and Abufari beach night (R= 0.9613, p= 0).

SIMPER analyses showed that 80% of variation of species composition among the analyzed groups was due to 12 species (marked with an asterisk in table II). Some of these species were very abundant on both beaches and periods: *Pimelodus* gr. *blochii* and *Colomesus asellus* (Müller & Troschel, 1849) were the most abundant species in Abufari beach, representing 43% of all collected specimens and *Triportheus* **cf.** *albus*, *Geophagus* cf. *proximus* and *Moenkhausia* gr. *lepidura* were the most abundant species in Praia Grande, representing 57.5% of the total (Tab. II). Night samples represented 63% of the total sample with 102 species (Tab. II) and 6,335 specimens (Tab. III). *Eigenmannia macrops* (Boulenger, 1897) was one of the most abundant species on both beaches (1,264 specimens collected), but only during the night (12.5% of total number of specimens collected) (Tab. II). The vast majority of the dominant forms was comprised of small fishes such as *Moenkhausia* gr. *lepidura*, *Moenkhausia* **cf.** *jamesi*, *Aphyocharax alburnus* (Günther, 1869), *Colomesus aselus* (< 100 mm SL; these four species comprised of 2,803 specimens) or juveniles, especially of *Triportheus* **cf.** *albus*, *Plagioscion* **cf.** *squamosissimus* and *Geophagus* **cf.** *proximus* (2,150 specimens altogether). The majority of species present in both beaches and periods was clearly more abundant in Abufari, especially Siluriformes. Few Characiformes species were more abundant in Praia Grande than in Abufari. Despite of a larger number of some characins in Praia Grande by night, Siluriformes and Gymnotiformes were largely more abundant in Abufari beach by night. Within Siluriformes, all big catfishes were collected only in Abufari (day and night) (see table II for comparisons).

Finally, CCA did not show any correlation between species composition and abiotic factors (MONTE CARLO Test, $p > 0.01$). Abiotic factors were quite similar between both beaches; Abufari beach presented deeper areas (Tab. I).

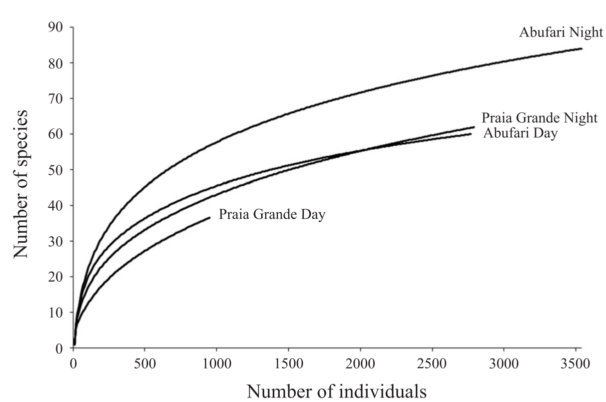

Figure 2. Individual-based rarefaction curves by site (Praia Grande and Abufari) and by period (day and night) for species richness on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007.

Table II. Species list with number of collected specimens by site (Praia Grande and Abufari) and by period (day and night) on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007 (* stands for most abundant species based on SIMPER analysis).

Taxa	Praia Grande day	Praia Grande night	Abufari day	Abufari night	Total
OSTEOGLOSSIFORMES					
OSTEOGLOSSIDAE					
Osteoglossum bicirrhosum (Cuvier, 1829)			1	3	4
CLUPEIFORMES					
ENGRAULIDIDAE					
Anchoviella **cf.** *carrikeri*	1		71		72
Jurengraulis juruensis (Boulenger, 1898)	6			1	7
Lycengraulis batesii (Günther, 1868)	9		20		29
PRISTIGASTERIDAE					
Ilisha amazonica (Miranda Ribeiro, 1920)		16		39	55
Pristigaster whiteheadi Menezes & de Pinna, 2000		11		51	62
CHARACIFORMES					
ACESTRORHYNCHIDAE					
Acestrorhynchus falcirostris (Cuvier, 1819)	1				1
A. microlepis (Schomburgk, 1841)	1	1	1	2	5
ANOSTOMIDAE					
Leporinus trifasciatus Steindachner, 1876	1				1
Rhytiodus argenteofuscus Kner, 1858		1	1		2
R. microlepis Kner, 1858		3	2	1	6
Schizodon fasciatus Spix & Agassiz, 1829	1	31		6	38
CHARACIDAE					
Aphyocharax alburnus (Günther, 1869)*	22	43	104	93	262
Astyanax sp.		1		5	6
Bryconops **cf.** *alburnoides*			1		1
Clupeacharax anchoveoides Pearson, 1924			2	1	3
Ctenobrycon hauxwellianus (Cope, 1870)	1	7	53	23	84
Hyphessobrycon sp.				1	1
Leptagoniates pi Vari, 1978		1		2	3
Microschemobrycon casiquiare Böhlke, 1953	4	21	21	32	78
Microschemobrycon sp.				2	2
Moenkhausia "aff. *megalops*"		2	3	2	7
M. **cf.** *browni*		2	46	28	76
M. **cf.** *ceros*		1			1
M. **cf.** *jamesi**	7	41	33	29	110
M. **cf.** *megalops*		24		12	36
M. gr. *lepidura**	163	320	271	135	889
Myleus torquatus (Kner, 1858)	1				1
Mylossoma aureum (Agassiz, 1829)		1	7	11	19
M. duriventre (Cuvier, 1818)				1	1
Prionobrama filigera (Cope, 1870)	1	5	3		9
Pygocentrus nattereri Kner, 1858	1	2			3
Roeboides affinis (Günther, 1868)		3	8	47	58
R. myersii Gill, 1870		3		9	12
Serrasalmus eigenmanni Norman, 1929		1			1
Tetragonopterus argenteus Cuvier, 1816		4		2	6
Triportheus angulatus (Spix & Agassiz, 1829)	1	8	3	12	24
T. auritus (Valenciennes, 1850)		1		1	2
T. **cf.** *albus**	207	942	95	210	1454
CTENOLUCIIDAE					
Boulengerella cuvieri (Agassiz, 1829)	1	2	4	4	11
CURIMATIDAE					
Curimata aspera (Günther, 1868)			5	5	10
Curimatella dorsalis (Eigenmann & Eigenmann, 1889)		3		1	4
Cyphocharax spiluropsis (Eigenmann & Eigenmann, 1889)			1	2	3
Potamorhina altamazonica (Cope, 1878)		1		1	2
P. latior (Spix & Agassiz, 1829)	3	31			34
Psectrogaster amazonica Eigenmann & Eigenmann, 1889	1	2		1	4
P. rutiloides (Kner, 1858)	8	10	1		19
Steindachnerina bimaculata (Steindachner, 1876)		1	2	1	4
CYNODONTIDAE					
Hydrolycus scomberoides (Cuvier, 1816)				1	1
Rhaphiodon vulpinus Spix & Agassiz, 1829				2	2
ERYTHRINIDAE					
Hoplias malabaricus (Bloch, 1794)	3	1	1		5
HEMIODONTIDAE					
Hemiodus argenteus Pellegrin, 1908		1			1
H. immaculatus Kner, 1858			1		1
H. microlepis Kner, 1858			1	10	11
Hemiodus sp.	1				1
GASTEROPELECIDAE					
Thoracocharax secures De Filippi, 1853	3		7	1	11
T. stellatus Kner, 1858			4	8	12

Tab. II (cont.)

PROCHILODONTIDAE					
Semaprochilodus taeniurus (Valenciennes, 1817)		25			25
Prochilodus nigricans Agassiz, 1829			1	5	6
SILURIFORMES					
AUCHENIPTERIDAE					
Ageneiosus atronasus Eigenmann & Eigenmann, 1888		1	1		2
A. ucayalensis Castelnau, 1855		1			1
Auchenipterus fordicei Eigenmann & Eigenmann, 1888				1	1
Centromochlus heckelii (De Filippi, 1853)		2		1	3
ASPREDINIDAE					
Bunocephalus gr. *coracoideus*				1	1
DORADIDAE					
Doras carinatus (Linnaeus, 1766)		1			1
Hemidoras stenopeltis (Kner, 1855) *	1	10	80	20	111
Nemadoras trimaculatus (Boulenger, 1898)			6		6
Oxydoras niger (Valenciennes, 1821)			2	14	16
Trachydoras nattereri (Steindachner, 1881)	2	4	41	26	73
T. steindachneri (Perugia, 1897)			12	2	14
HEPTAPTERIDAE					
Pimelodella steindachneri Eigenmann, 1917		4	7	8	19
LORICARIIDAE					
Hemiodontichthys acipenserinus (Kner, 1853)	2		30	33	65
Hypostomus gr. *emarginatus*			24	41	65
Hypostomus sp.	2	5	2	3	12
Loricaria cataphracta Linnaeus, 1758	1		2	15	18
Loricariichthys nudirostris (Kner, 1853)		2			2
Pseudoloricaria **cf.** *punctata**	6	6	49	73	134
Rineloricaria sp.		1			1
Sturisoma guentheri (Regan, 1904)			5	6	11
PIMELODIDAE					
Calophysus macropterus (Lichtenstein, 1819)				2	2
Cheirocerus goeldii (Steindachner, 1908)*	5	41	71	97	214
Hemisorubim platyrhynchus (Valenciennes, 1840)		1	11	6	18
Hypophthalmus edentatus Spix & Agassiz, 1829		4			4
Leiarius pictus (Müller & Troschel, 1849)				2	2
Phractocephalus hemioliopterus (Bloch & Schneider, 1801)			5	8	13
Pimelodus gr. *blochii**	84	354	718	814	1970
Pseudoplatystoma punctifer (Castelnau, 1855)			4	4	8
P. reticulatum (Eigenmann & Eigenmann, 1889)			3	3	6
P. tigrinum (Valenciennes, 1840)				1	1
Sorubim elongatus Littmann, Burr, Schmidt & Isern, 2001		1			1
Sorubimichthys planiceps (Spix & Agassiz, 1829)			2	3	5
TRICHOMYCTERIDAE					
Henonemus punctatus (Boulenger, 1887)				1	1
Ochmacanthus reinhardtii (Steindachner, 1882)			7	5	12
Paravandellia sp.	1			4	5
Plectrochilus sp.				1	1
Pseudostegophilus nemurus (Günther, 1869)				4	4
Vandellia cirrhosa Valenciennes, 1846		15	1	8	24
V. sanguinea Eigenmann, 1917			1	1	2
GYMNOTIFORMESAPTERONOTIDAE					
Sternarchorhynchus **cf.** *oxyrhynchus*				1	1
STERNOPYGIDAE					
Distocyclus conirostris (Eigenmann & Allen, 1942)				1	1
Eigenmannia limbata (Schreiner & Miranda Ribeiro,1903)				2	2
E. macrops (Boulenger, 1897)*		232		1032	1264
Eigenmannia sp.				7	7
Rhabdolichops sp.1		3		3	6
Rhabdolichops sp.2		1			1
PERCIFORMES					
SCIAENIDAE					
Pachyurus **cf.** *gabrielensis*		1	12	31	44
Plagioscion **cf.** *squamosissimus**		45	1	62	108
CICHLIDAE					
Cichla monoculus Spix & Agassiz, 1831				1	1
Geophagus **cf.** *proximus**	217	310	30	31	588
BELONIFORMESBELONIDAE					
Pseudotylosurus sp.	1		2		3
PLEURONECTIFORMES					
ACHIRIDAE					
Hypoclinemus mentalis (Günther, 1862)	2	1	37	10	50
TETRAODONTIFORMES					
TETRAODONTIDAE					
Colomesus asellus (Müller & Troschel, 1849)*	186	176	832	348	1542
Total	958	2795	2772	3540	10065

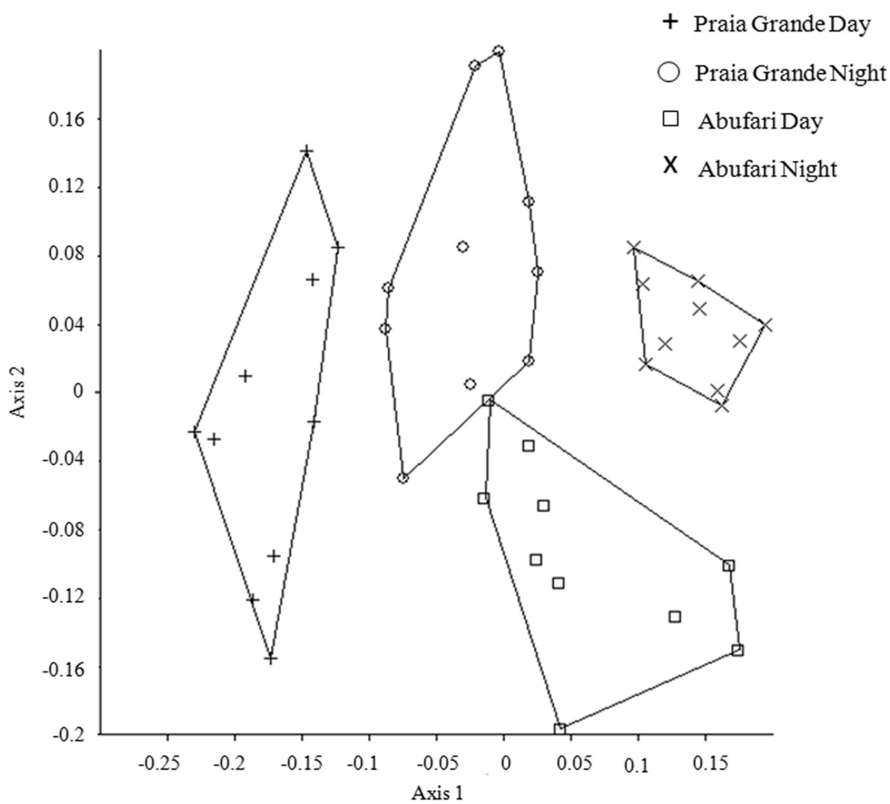

Figure 3. Non-metric Multidimensional Scaling (NMDS) representing the results for fish abundance by site (Praia Grande and Abufari) and by period (day and night) on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007.

Table III. Total number of individuals (N), number of species (S), total biomass (g), diversity Index (*H*'), evenness (*E*) and dominance (*D*), mean and standard deviation (in parenthesis), by site (Praia Grande and Abufari) and by period (day and night) on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007.

Beach/ period	N	S	Total biomass (g)	*H'*	*E*	*D*
Praia Grande day	958 (9.5%)	37	3,589 (358$\pm$184)	2.048 (1.62$\pm$0.22)	0.567 (0.71$\pm$0.06)	0.827 (0.73$\pm$0.05)
Praia Grande night	2,795 (27.8%)	62	24,404 (2,440$\pm$2,247)	2.333 (2.1$\pm$0.36)	0.565 (0.69$\pm$0.10)	0.833(0.8$\pm$0.1)
Abufari day	2,772 (27.5%)	60	60,025 (6,002$\pm$5,074)	2.4 (2.09$\pm$0.45)	0.586 (0.65$\pm$0.13)	0.826 (0.78$\pm$0.12)
Abufari night	3,540 (35.2%)	84	76,614 (7,661$\pm$3,831)	2.572 (2.24$\pm$0.21)	0.580 (0.65$\pm$0.05)	0.844 (0.81$\pm$0.05)
Total	10,065 (100%)		164,632			

Table IV. Hutcheson's method using Shannon-Wiener Diversity Index (*H*'), *t* values, df (degree of freedom) and p by site (Praia Grande and Abufari) and by period (day and night) on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007.

	Praia Grande day	Praia Grande night	Abufari day
Praia Grande night	t = 6.34 df = 1970 P< 0.001**		
Abufari day	t = 7.60 df = 2137 P< 0.001**	t = 1.73 df = 5528 P> 0.05	
Abufari night	t = 11.44 df = 2042 P< 0.001**	t = 6.31 df = 6272 P< 0.001**	t = 4.33 df = 6104 P< 0.001**

Table V. ANOSIM results - R values and p values Bonferroni-corrected (in parenthesis) for each pairwise comparisons between sites (Praia Grande and Abufari) and periods (day and night) on two sandy beaches in lower Purus river, Amazonas, Brazil, November 2007.

	Praia Grande day	Praia Grande night	Abufari day
Praia Grande night	0.4756 (0.0006)		
Abufari day	0.7696 (0)	0.6232 (0)	
Abufari night	0.9613 (0)	0.6907 (0.0006)	0.7751(0)

DISCUSSION

Sandy beaches can be considered a very species-rich environment for fish assemblies when compared to other environments (GOULDING *et al.*, 1988; RAPP PY-DANIEL *et al.*, 2007), especially concerning Characiformes (GOULDING *et al.*, 1988; IBARRA & STEWART, 1989; JEPSEN, 1997; STEWART *et al.*, 2002).

Our results showed difference in fish composition between the two beaches and between periods. Besides, Abufari beach presented a larger number of species during day and night. Fish assemblies of Abufari and Praia Grande showed a relevant abundance of young (or immature) specimens of *Triportheus* **cf.** *albus* and *Geophagus* **cf.** *proximus* and large numbers of *Pimelodus* gr. *blochii*, small characids (such as *Moenkhausia* gr. *lepidura*) and *Colomesus asellus*. Araújo-Lima *et al.* (2001), when studying nictemeral differences of fish larvae composition in Amazonas-Solimões and Negro Rivers, also noted a large number of *Colomesus asellus* in shallower waters at day and night. For *Colomesus* Gill, 1884 and the other small and more abundant forms, sandy beaches can be used for protection (too shallow for some larger predatory species) or also for foraging (GOULDING *et al.*, 1988; IBARRA & STEWART, 1989; GOULDING, 1997; SANTOS & FERREIRA, 1999; STEWART *et al*., 2002). Moreover, the large number of juveniles can indicate the role of this environment in nursery, as already observed for marine environments (PESSANHA & ARAÚJO, 2003; GAELZER *et al*., 2007). The abundance of these forms might be one of the reasons of the lack of significant difference between Dominance and Evenness in our results when comparing between beaches and periods.

Analyses of similarity showed a large similarity between periods in Praia Grande, but not in Abufari. ARRINGTON & WINEMILLER (2003), when studying nictemeral variance on fish assemblages in Cinaruco River, Venezuela, observed more similarity between nocturnal samples among different beaches than day-night samples in the same beach. Our different results could be related to a small number of sampled beaches to compare or, in Praia Grande, environmental conditions may be more constant during the whole day. In Abufari, on the other hand, more dramatic day-night changes may be occurring, causing a larger number of substitutions of fish species between periods. Abiotic conditions did not vary significantly to explain these differences.

The discrepancy on biomass values between both beaches observed in the present work is strongly related to the presence of big pimelodids, mainly predators, captured only on the Abufari beach in both periods, such as *Pseudoplatystoma punctifer* (Castelnau, 1855), *P. reticulatum* (Eigenmann & Eigenmann, 1889), *P. tigrinum* (Valenciennes, 1840), *Calophysus macropterus* (Lichtenstein, 1819), *Phractocephalus hemioliopterus* (Bloch & Schneider, 1801), and *Sorubimichthys planiceps* (Spix & Agassiz, 1829). Some big catfishes forage solitarily in the shallows (ZUANON & FERREIRA, 2008). BARTHEM & GOULDING (1997) suggested that *Pseudoplatystoma* Bleeker, 1862 species prey closer to the shore than other catfishes and, as many piscivores, move towards the shores at night to feed.

It has already been suggested that, on beach environments, habitat selection and structure of fish assemblies are influenced by predation (IBARRA & STEWART, 1989; JEPSEN, 1997; STEWART *et al.*, 2002; LAYMAN & WINEMILLER, 2004; ARRINGTON & WINEMILLER, 2003; 2006). The presence of large numbers of fish predators in sandy beaches has been cited before (GOULDING *et al*., 1988; PEREIRA *et al*., 2007), as well as the presence of fishes that prey on recently ecloded turtles (ALHO & PÁDUA, 1982; FACHÍN-TERÁN & VOGT, 2004). Sandy beaches are important sites for turtle-eggs deposition what might be a factor of attraction for these big predators (VOGT, 2008). Abufari beach is an important preserved site for egg deposition by different species of turtles, particularly, *Podocnemis expansa* (Schweigger, 1812) (*tartaruga da Amazônia*). Every year a large number of turtles lay their eggs in the Abufari beach. Praia Grande, on the other hand, has been subjected to continuous harvesting of turtle-eggs and it is not considered a turtle-egg deposition site for decades.

Abufari showed larger numbers and richness of Siluriformes and Gymnotiformes than Praia Grande. This difference could not be explained by abiotic factors (temperature, pH, dissolved oxygen, conductivity and mean depth), because our results showed that these parameters did not affect the composition of fish assemblages. STEWART *et al.* (2002) observed that differences between sandy beaches and river channels fish fauna could be related to depth. The beach-zone fish assemblage was strongly dominated by small characins, whereas the deep-river habitat was dominated by catfishes and weakly electric gymnotiforms. Praia Grande and Abufari did not show significant differences in depth, although Abufari showed the deepest areas. IBARRA & STEWART (1989) also related fish richness to latitude: beaches from lower latitudes would have a greater richness of fish than beaches at low altitude. Their work involved strong variation in altitudes, what is not the case of the Purus drainage which has its greatest stretch running on the sedimentary basin.

Nictemeral differences were not as remarkable as fish composition between both beaches. Larger biomass, more diversity and more species were clearly observed in Abufari beach and, as the abiotic factors did not have any influence in fish composition, the two beaches are structurally very similar, the main factor that might be influencing fish richness and abundance is the level of protection. Both beaches are located in protected areas under federal (Abufari beach) or state (Praia Grande) government protection. Despite its location in a protected area, where use is controlled, Praia Grande is subjected to some fisheries pressure. Abufari beach, on the other hand, is located in a full-protection unit, where fisheries are not allowed. This fact might have contributed for the maintenance of overall diversity and natural fish populations, as already observed in some marine environments (GAELZER *et al*., 2007), what reinforces the need of measures of environmental protection. Different levels of protection along creeks have been appointed as major causes for differences in fish species richness, diversity and abundance (DIAS & TEJERINA-GARRO, 2010; CASATTI *et al.*, 2010).

Our results raise the question of maintaining of fish diversity in areas with low levels of restriction of use and points out for the necessity to really develop management plans to keep fishing areas sustainable. Especially in sandy beaches, with very short period of exposition and high vulnerability to fisheries, more efforts should be directed to management plans. Praia Grande has already lost its status as an area for turtle egg-laying and hatching, due to strong predation by locals over the years. This kind of resource becomes unavailable for the locals, as well, and this situation can be seen along several sandy beaches on different tributaries of the Solimões-Amazonas system. To regain local sustainability, Praia Grande would have to go through a very objective management plan, what might be very uneffective these days due to the strong antropic activities in the area. However, our results could encourage that other sustainable reserves should work towards developing active management plans that could guarantee their sustainability.

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