PANAMJAS
Pan-American Journal of Aquatic Sciences

Factors affecting the distribution and abundance of freshwater stingrays (Chondrichthyes: Potamotrygonidae) at Marajó Island, mouth of the Amazon River

MAURICIO PINTO DE ALMEIDA[1], RONALDO BORGES BARTHEM[2], ANDERSON DA SILVA VIANA[3] & PATRICIA CHARVET-ALMEIDA[4]

[1] Post-Graduate Program in Zoology, Federal University of Pará (UFPA) and Emílio Goeldi Museum, Pará (MPEG). Av. Perimetral, 1901 - Terra Firme. CEP: 66077- 830 - Belém - PA - Brazil. E-mail: maupalms@gmail.com
[2] Emílio Goeldi Museum, Pará (MPEG). Zoology Dept. / Ichthyology. P.O. Box: 399. CEP 66017- 970. Belém-Pa. E-mail: barthem@superig.com.br
[3] Federal University of Para (UFPA/ICEN). Av. Augusto Correa, 1. CEP: 66075-110. Belém - PA - Brazil. E-mail: andviana@ufpa.br
[4] Collaborating Researcher, Emílio Goeldi Museum, Pará (MPEG). Av. Perimetral, 1901 - Terra Firme. CEP: 66077-830 - Belém - PA - Brazil. E-mail: pchalm@gmail.com

Abstract. Experimental fisheries were carried out at Marajó Island in regions with different environmental characteristics and using various fishing gears. A total of 344 specimens belonging to five described species (*Plesiotrygon iwamae*, *Paratrygon aiereba*, *Potamotrygon motoro*, *Potamotrygon orbignyi* and *Potamotrygon scobina*) and to two undescribed species were captured. The specific abundance and biomass were related with the environmental characteristics of the sampling points. Number of specimens captured, catch per unit effort (CPUE) and total weight values indicated that *Potamotrygon motoro* is the predominant species in this region, especially in the center of the island. Larger specimens of *Potamotrygon motoro* were registered in Arari Lake, while smaller ones were present on the island's bordering areas. As other elasmobranchs, it is suggested that potamotrygonids present habitat occupation and use preferences related to environmental conditions.

Key words: species composition, experimental fishery, potamotrygonids, Amazon estuary.

Resumo: Fatores que afetam a distribuição e abundância de raias de água doce (Chondrichthyes: Potamotrygonidae) na ilha de Marajó, foz do rio Amazonas. Pescarias experimentais foram efetuadas na ilha de Marajó em regiões com características ambientais distintas e utilizando vários apetrechos de pesca. Um total de 344 espécimes, pertencentes a cinco espécies descritas (*Plesiotrygon iwamae*, *Paratrygon aiereba*, *Potamotrygon motoro*, *Potamotrygon orbignyi* e *Potamotrygon scobina*) e a duas não descritas foram capturados. A abundância e a biomassa por espécie foram relacionadas com as características ambientais dos pontos amostrais. O número de exemplares capturados, as capturas por unidade de esforço e peso total indicaram *Potamotrygon motoro* como sendo a espécie predominante nesta região, especialmente no centro da ilha. Exemplares maiores de *Potamotrygon motoro* foram registrados no lago Arari, enquanto que os menores estavam presentes nas bordas da ilha. Assim como observado em outros elasmobrânquios, é sugerido que as raias de água doce apresentam preferências quanto à ocupação e uso de habitat associados às condições ambientais.

Palavras-chave: composição de espécies, pesca experimental, potamotrigonídeos, estuário Amazônico.

Introduction

Freshwater stingrays belong to the Potamotrygonidae family, a monophyletic group of elasmobranchs restricted to most river basins of the Neotropical region (Rosa, 1985). The taxonomy and nomenclature of group remains unsolved but there are approximately 20 described species for the Neotropical region (Rosa 1985, Mould 1997, Carvalho *et al.* 2003, Rosa & Carvalho 2007).

Some Potamotrygonidae species previously considered stenohalines (Brooks *et al.* 1981, Thorson *et al.* 1983), have been observed in brackish waters of the Amazon River mouth region (Charvet-Almeida 2001, Almeida 2003).

Like other elasmobranchs, they have distinct environment occupation and habitat use patterns that include vertical and horizontal movements that may lead to spatial and sexual segregation processes (Carrier *et al.* 2004). Johnson (1980) recognized that habitat selection is a hierarchical process, with different factors acting at different scales. These factors include geographic range, home range, and use of habitats within the home range. Both physical and biotic factors may shape habitat use at all spatial scales (Simpfendorfer & Heupel 2004).

Fisheries in the Amazon River mouth are intensive and diversified, and the commercial fishing boats operating in the region (from canoes to trawlers) exploit these resources taken from different types of environments (Barthem 1985, Barthem & Goulding 2007). Freshwater stingrays were not considered a traditional widespread fishery resource in the Amazon (Ferreira *et al.* 1998, Charvet-Almeida 2001). However, the increasing fish demand by the urban and rural population have stimulated commercial fishermen to exploit freshwater stingrays as a food resource and consequently freshwater stingray landings began to appear in the fishing statistics (IBAMA 2002).

Elasmobranchs in general, including freshwaters stingrays, have low growth and fecundity, are long-lived, and mature late in life when compared with most bony fish (Camhi *et al.* 1998, Musick & Bonfil 2004). The sustainability of elasmobranch catches is uncertain and several species are considered threatened by fisheries (Holden 1974, Pratt & Casey 1990, Lessa *et al.* 1999, Musick & Bonfil 2004) and by habitat modification (Compagno & Cook 1995, Charvet-Almeida *et al.* 2002, Martin 2005, Charvet-Almeida 2006).

Adequate fishery management and conservation of freshwater stingray require knowledge on the biology and ecology of each species. Apart from natural history data, the understanding of habitat use and identification of critical habitats at different life stages (e.g. pupping, nursery and mating grounds) are essential too (Camhi *et al.* 1998, Simpfendorfer & Heupel 2004).

The regions in the Amazon River mouth may be grouped according to the predominance of four main water systems, which are: (i) the Amazon River, (ii) the Tocantins River discharge, (iii) the estuary, and (iv) the inner island swamps (Kempf *et al.* 1967, Mabesoone 1970, Goulding *et al.* 2003, Barthem & Goulding 2007). The present study seeks to understand the relationship between the freshwater stingray species composition and abundance and characteristics of the different habitats in the Amazon River mouth.

Materials and Methods

The Amazon River mouth is formed by the confluence of the Amazon and Tocantins River with the Atlantic coast. The seasonal discharges of those rivers cause a displacement of the salt wedge along the 340 km extension of the river mouth. In this area water becomes brackish in the south during the dry season and freshwater is observed throughout its extension in the rainy season. It is not considered a true delta, however, there are several island aggregations that partially form an internal delta. The Marajó Island is the biggest one, with almost 50,000 km^2, followed by the Caviana, Mexiana, and Gurupá islands. Large extensions of the Marajó Island lowlands are seasonally flooded by the tide on its borders, or by rainfall in its inner portions, forming temporary and permanent swamps. The rainwater accumulates during the rainy season, in the first half of the year, especially in march, and floods vast areas of grasslands. There are several temporary and permanent lakes, where the biggest one is the Arari Lake. The accumulated water drains to the outside of the island by few meandering rivers. The bad drainage and tide action are factors, which retain the water that contributes to floods swamps and maintain the grass fields flooded along 5-7 months per year. The main discharge of the Amazon River flows towards the north of the Marajo Island, and all discharge of the Tocantins River flows towards the south into the Marajó Bay. The west side of the Marajo Island is crossed by several narrow channels, which connect the Amazon and Tocantins River waters. The estuarine waters influence the east side of the Marajo Island, especially during the dry season, when salinity level reaches over 10 psu (Teixeira 1953, Sioli 1966, Barthem & Schwassmann 1994, Roosevelt 1991, Costa *et al.* 2003, Goulding *et al.* 2003, Barthem & Goulding 2007).

The sampling points were established near four villages at the Marajó Island. These points were chosen considering the four different water systems defined *a priori*. Three points were in the border of the island and one was an inner point. The sampling points were: (1) Afuá (0^o 09'S, 50^o 23'W), situated in the northwest border of the Marajó Island, at the margin of the Amazon River; (2) Muaná (01^o 31'S, 49^o 13'W) located in the south border, on the margin of the Tocantins River; (3) Soure (0º 42'S, 48º 31'W) situated at the east border, in the coast; (4) Arari (0º 39'S, 49º 10'W) situated in the inner portion of the island, by the Arari Lake (Figure 1).

The specimens were sampled during 17 fishing trips carried out in 2005, 2006 and 2007. The trips were grouped according to seasonal phases, which were defined by rainfall. The first semester was considered the rainy season and the second the dry season. Each region was sampled at least once in each season. Depth ranges varied a lot (mostly from 0.5 to 6 m) according to daily tidal variation and seasonal phases.

The habitat diversity demanded a multi-gear fish sampling strategy. The fishing gears used were bottom long lines, beach trawl nets, hand-lines, and tidal traps. Each longline had 25 hooks (sizes 6/0 measuring 5 cm, 7/0 measuring 5.5 cm, 8/0 measuring 6 cm and 10/0 measuring 7.5 cm) and usually four longlines were set each day. Beach trawl net was 100 m long and had 30 mm mesh size. Each fishermen used one hand-line at time, with one or two hooks (hook size 7/0 measuring 5.5 cm and 0.100 mm nylon line).

Traps were employed in the tidal zone partially fencing a stream or a beach line (strategies known locally as "pari" and "zangaria"). The "pari" barrier was made of wood sticks, 2 m height and length varying from 500 to 1,000 m and the "zangaria" barrier was made of nylon nets, mainly 35 mm mesh size, 1.5 - 2.0 m height, length varying from 5 to 200 m. The fences were extended during the high tide and the fish were collected in the low tide. Cast nets were used too, but with no efficiency for potamotrygonids.

The longline and hand-line baits were fish of the local fauna (approximately 1 to 3 cm size or cut to 2 cm^2 chunks) (*Anaplebs* spp., *Mugil* spp., *Pellona* spp., *Arius* spp., *Leiarius* sp., *Hypophthalmus* spp., *Crenicichla* spp., *Gobioides* spp., *Plagioscion* spp., *Hypostomus* spp., *Symbranchus* sp., *Hoplosternum littorale*, *Schizodon* spp., *Trachycorystes galeatus*, *Hoplerythrinus* sp., *Tetragonopterus* sp., *Pimelodus* sp., *Farlowella* sp., several families of Gimnotiformes, *Hoplias malabaricus*), shrimps (approximately 5 cm total length) (*Machrobrachium* spp.) and crabs (approximately 4 - 6 cm carapace size) (*Dilocarcinus* sp.).

In this study the fishery unit was considered the fishing activity made by locality and trip. The locality was a place of the region with apparently similar environmental conditions. More than one fishing locality could be visited at the same day and trip. One or more fishing gears were used in each

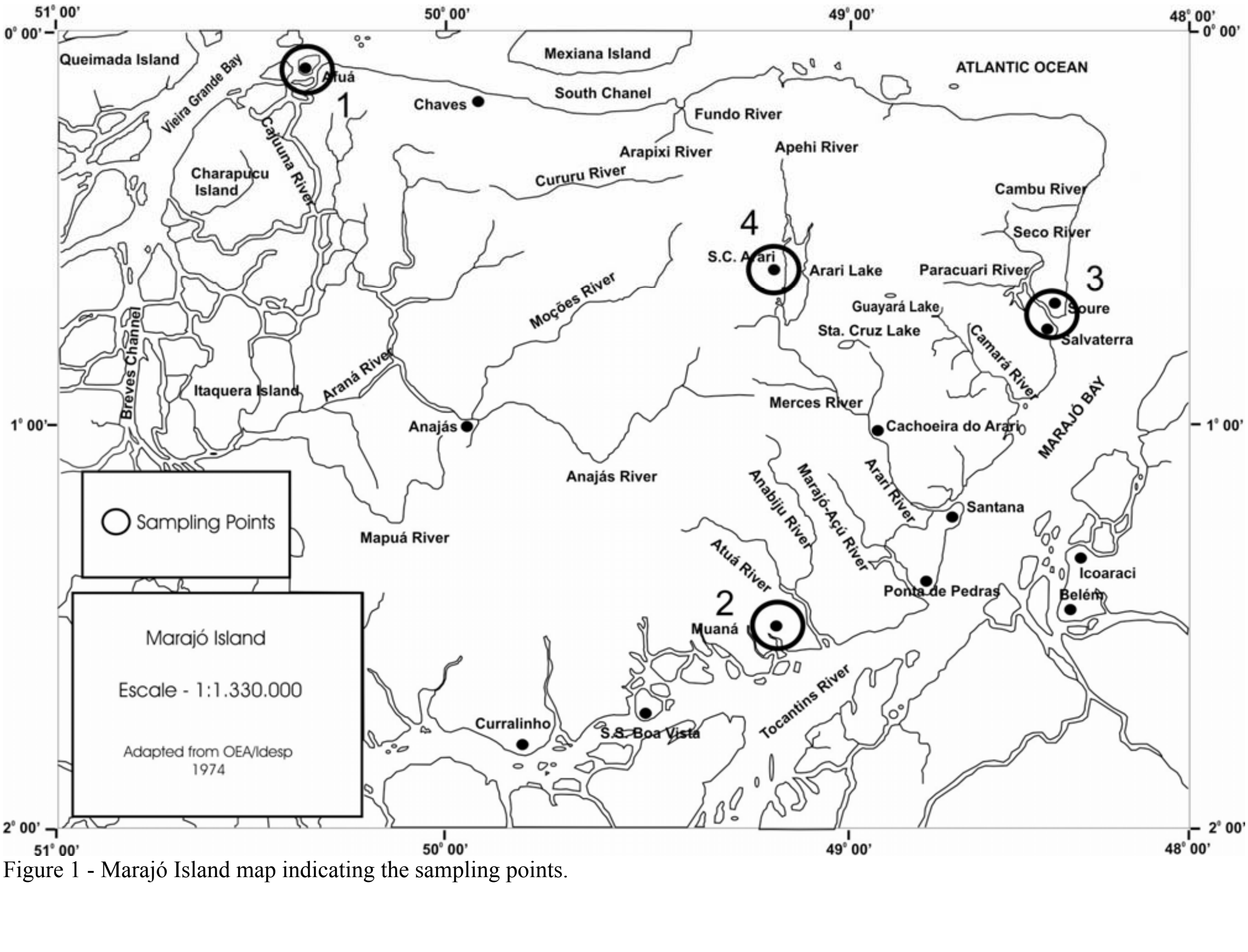

Figure 1 - Marajó Island map indicating the sampling points.

fishery, according the environmental conditions. The fishery effort unit was measured by the number of fishing days of each fishery, independent of the numbers or the kind of fishing gears used.

The geographical position of each fishing gear was taken by a GPS (Garmin MAP76). The water environmental characteristics were measured on each fishing day in terms of temperature, conductivity, salinity (YSI 30), pH (Oakton pH/Con 10 series), and dissolved oxygen (YSI 550A).

All specimens were subject to anesthesia and then had their fresh weight registered using field scales (Ohaus LS2000 and Pesola).

The Analysis of Covariance ANCOVA was used to test the relationship between the number of stingrays caught with the fishing effort and the seasonal and regional factors. The catch and effort variables were transformed into logarithm+1 (log+1) in order to normalize the data. The catch per unit effort (CPUE) was estimated as the ratio between the number of rays caught and number of fishing days.

Freshwater stingrays were the target-species of all fisheries carried out during this study but many other by-catch species were captured (mainly small catfish). Other fish species and invertebrates were neither preserved, nor studied and did not have CPUE values calculated.

The freshwater stingray species associations were determined by a Pearson r correlation coefficient and by cluster analysis using the complete linkage and 1-Pearson r distance.

The CPUE of the most abundant stingray species was correlated with the average, minimum and maximum values of conductivity, salinity, oxygen, temperature and pH measurements taken during the fisheries.

The Analysis of Variance ANOVA was used to test the differences of the stingray size of most abundant species in relation to the sex and sampling point factors. It was used the disc width size logarithm (logDW) as a size measured. The Fisher Least Significant Difference Test (LSD) was used as post-hoc comparison between the means.

Results

During the 17 trips a total of 44 fisheries were carried out. The duration of each trip ranged from 1 to 15 days. The average effort of each fishery was 2.7 fishing days, varying from 1 to 11. In 60% of the fisheries, only one fishing gear was used, whereas the maximum number of fishing gears used by fishery was four. Longline was the most frequent fishing gear used; it was employed in 88% of the 44 fisheries. The fishing localities number within each of the four sampling points was used as an indicator of the environmental heterogeneity. In total 24 localities were sampled, of which 54% were located in Muaná and 25% in Afuá.

A total of 344 specimens corresponding to 1,567,364 grams of freshwater stingrays were caught during the fisheries carried out in 112 fishing days. They belonged to seven species. Two of these were considered new species and are currently being described: *Potamotrygon* n. sp. 1 and *Potamotrygon* n. sp. 2 (Table I).

Afuá and Muaná were the most diversified regions, with five stingray species each. Arari and Soure presented three species each.

Muaná shared more species with other regions, three with Afuá, three with Arari and two with Soure. Afuá and Arari shared two species and the other combinations shared only one species.

Potamotrygon motoro (50%) and one of the new species *Potamotrygon* n. sp. 2 (33%) were the most abundant in the overall catches. Considering the overall catches in each sampling point, these species were also the most abundant in Afuá (90%), Arari (99%) and Muaná (46%) but were not observed in Soure. On the other hand, *Potamotrygon orbignyi* (11%) and *Potamotrygon scobina* (3%) represented less then 15% of the overall specimens collected. Nevertheless, these two were the most abundant species in Soure (96%) and Muaná (51%). *Paratrygon aiereba*, *Plesiotrygon iwamae* and the new specie *Potamotrygon* n. sp. 1 were rarely caught during the fisheries and only 8 specimens were captured.

In terms of weight, about 1.5 tons of stingrays were captured in all experimental fisheries. The sampling point with the highest biomass was Arari Lake and the one with the least was Soure. *Potamotrygon motoro* was the predominant species regarding number of specimens and total weight. *Potamotrygon* n. sp. 1 was the species with the lowest biomass.

The efficiency of the fishing gear was different in the four sampling points. Longlines caught 90% of the stingrays in Arari. However, traps caught 56% of the stingrays in the regions with tidal influence, such as Muaná (74%), Afuá (58%) and Soure (23%). The other fishing gears were responsible for 14% of the total catches.

The catch per unit effort (CPUE) per fishery in each sampling point ranged from 0 to 14.5 stingrays/fishing day, with an average of 2.3 stingrays/fishing day. The CPUE of Arari (average 4.9 stingrays/fishing day) in relation to the others regions was significantly higher (LSD Test, $p<0.05$). The CPUEs of the other regions were statistically similar: Afuá (2.7 stingrays/fishing day), Soure (1.6

Table I. Number (n) and weight (w, in grams) of freshwater stingrays caught per sampling point.

Species	Number and weight	Sampling Points				Total
		Afuá	Arari	Muaná	Soure	
Paratrygon aiereba	n	1	-	1	-	2
	w	28,000	-	8,400	-	36,400
Potamotrygon n. sp. 1	n	3	-	-	-	3
	w	7,140	-	-	-	7,140
Plesiotrygon iwamae	n	2	-	-	1	3
	w	14,200	-	-	4,900	19,100
Potamotrygon n. sp. 2	n	41	67	7	-	115
	w	81,400	388,260	14,770	-	484,430
Potamotrygon motoro	n	10	150	13	-	173
	w	10,559	909,570	29,252	-	949,381
Potamotrygon orbignyi	n	-	1	16	21	38
	w	-	1,050	11,510	30,810	43,370
Potamotrygon scobina	n	-	-	6	4	10
	w	-	-	3,293	24,250	27,543
Total	n	57	218	43	26	344
	w	141,299	1,298,880	67,225	59,960	1,567,364

stingrays/fishing day) and Muaná (1.2 stingrays/ fishing day).

The average CPUEs per species in each sampling point varied from 0 to 3.73. The highest value of a single species and point corresponded to *Potamotrygon* n. sp. 2. The overall highest value was attained by *Potamotrygon motoro* (1.54). The species that presented the lowest overall average CPUE value was *Paratrygon aiereba* (Table II).

The ANCOVA analysis ($p<0.01$, $r=0.85$) showed the overall stingray abundance was significantly related to the number of fishing days (as fishing effort) ($p<0.05$) and to the effect of the sampling points ($p<0.01$). The seasonal effect and number of gears were not significant ($p>0.05$) and those variables were not considered in the following analyses (Table III).

Water environmental characteristics variation measured in the fisheries when stingrays were caught are shown in Table IV. Average, minimum (min.) and maximum (max.) values were calculated. Soure was the sampling point where salinity and conductivity values were higher. The maximum and average conductivity values found in Arari are much higher than the ones observed in Afuá and Muaná. The minimum conductivity value registered in Arari is lower than the minimum values observed in other regions.

The register of occurrence of each species was related to the water environmental characteristics and indicated as a box-plot (Figure 2).

Potamotrygon orbignyi was captured in the highest conductivity/salinity levels, occurring in brackish water (maximum of 20.8 mS/cm conductivity and 12.4 psu salinity), but the average was of 4.7 psu or 8 mS/cm. *Potamotrygon motoro, Potamotrygon scobina* and *Potamotrygon* n. sp. 2 were sampled in ntermediate conductivity/salinity levels, with maximum values between 300-500 µS/cm or 0.2-0.3 psu. The other species occurred in

Table II. Average CPUE (number of stingrays caught / fishing day) per species in each of the sampling points.

Species	Sampling Points				Total
	Afuá	Arari	Muaná	Soure	
Paratrygon aiereba	0.09	0	0.03	0	0.02
Potamotrygon n. sp. 1	0.27	0	0	0	0.03
Plesiotrygon iwamae	0.18	0	0	0.03	0.03
Potamotrygon n. sp. 2	3.73	1.63	0.24	0	1.03
Potamotrygon motoro	0.91	3.66	0.45	0	1.54
Potamotrygon orbignyi	0	0.02	0.55	0.68	0.34
Potamotrygon scobina	0	0	0.21	0.13	0.09
Total	5.18	5.32	1.48	0.84	3.07
Fishing days	11	41	29	31	112

Table III. Analysis of Covariance (ANCOVA) testing the relationship between the number of stingrays caught with the fishing effort (number of fishing days and fishing gears employed) and the seasonal and regional factors (catch and effort variables transformed into log+1, numbers in bold correspond to statistically significant values).

Results/Tested parameters	Sum of Squares (S)	Degree of freedom	Mean Square (MS)	F value	p
Intercept	0.26677	1	0.266767	0.451458	0.506621
LogDays	3.95301	1	3.953011	6.689795	**0.014616**
LogGear	0.06627	1	0.066269	0.112150	0.739965
Seasonal Phases	2.41286	1	2.412859	4.083351	0.052018
Sampling Point	14.02767	3	4.675889	7.913142	**0.000463**
Season*Sampling Point	2.92703	3	0.975676	1.651164	0.197816
Error	18.31795	31	0.590902	-	-

Table IV. Water environmental characteristics measured during the fisheries (Min. = minimum and Max. = maximum).

Environmental Characteristics		Sampling Points			
		Afuá	Arari	Muaná	Soure
Salinity (psu)	Average	0.0	0.1	0.0	8.5
	Min.	0.0	0.0	0.0	0.1
	Max.	0.0	0.3	0.0	12.4
Conductivity (µS/cm)	Average	57.6	203.8	47.5	14,420.1
	Min.	43.6	29.3	36.9	198.3
	Max.	67.7	523.0	51.1	20,790.0
Oxygen (mg/l)	Average	6.5	5.6	5.7	5.6
	Min.	4.8	1.4	4.2	4.1
	Max.	7.1	7.6	7.0	7.4
pH	Average	8.1	6.4	7.3	7.9
	Min.	6.7	4.9	6.1	6.8
	Max.	8.6	8.6	7.8	8.5
Temperature (°C)	Average	29.5	28.6	29.6	29.5
	Min.	27.0	25.2	28.0	28.8
	Max.	31.1	32.9	30.9	29.9

freshwater with less than 60 µS/cm and 0 psu. *Potamotrygon motoro* and *Potamotrygon* n. sp. 2 were found in poorly oxygenated and acid waters, with less than 2 mg/l of oxygen and pH 5, while the others species were caught in water with at least 4 mg/l of oxygen and pH 6. The average water temperature where the stingrays were caught ranged between 28-30 °C.

The correlation between each species' CPUE and fishery was positive and significant at $p<0.05$ (n = 26) for *Potamotrygon motoro* and *Potamotrygon* n.sp. 2 (r = 0.43), *Paratrygon aiereba* and *Plesiotrygon iwamae* (r = 0.52), *Plesiotrygon iwamae* and *Potamotrygon* n. sp. 2 (r = 0.64), and *Potamotrygon scobina* and *Potamotrygon orbignyi* (r = 0.65). The cluster analysis shows the graphic representation of this freshwater stingray association (Figure 3).

The Pearson r correlation of the CPUE of each specie and the water environmental characteristics (average, minimum, and maximum of conductivity, salinity, oxygen, pH, and temperature) of each fishery were significant at $p<0.05$ only for the minimal values of conductivity of *Potamotrygon motoro* (r=0.53).

The disc width size of *Potamotrygon motoro* was statistically significantly different in relation to sampling point ($P<0.01$) but not to sex ($P>0.10$). The Fisher LSD post-hoc test shows that the Arari disc width size is bigger than the Muaná and Afuá, indicating the smallest specimens are scattering around the island and the largest ones are in the Arari Lake. The disc width size of *Potamotrygon* n. sp. 2 was also statistically different in relation to sampling point ($P<0.01$) and sex ($p<0.01$). Females were bigger than males. The LSD post-hoc test indicates the stingrays of Arari Lake were bigger than the ones caught in Afuá and Muaná. On the other hand, there is no influence of the sex and sampling point (Muaná and Soure) on the disc width size of *Potamotrygon orbignyi*.

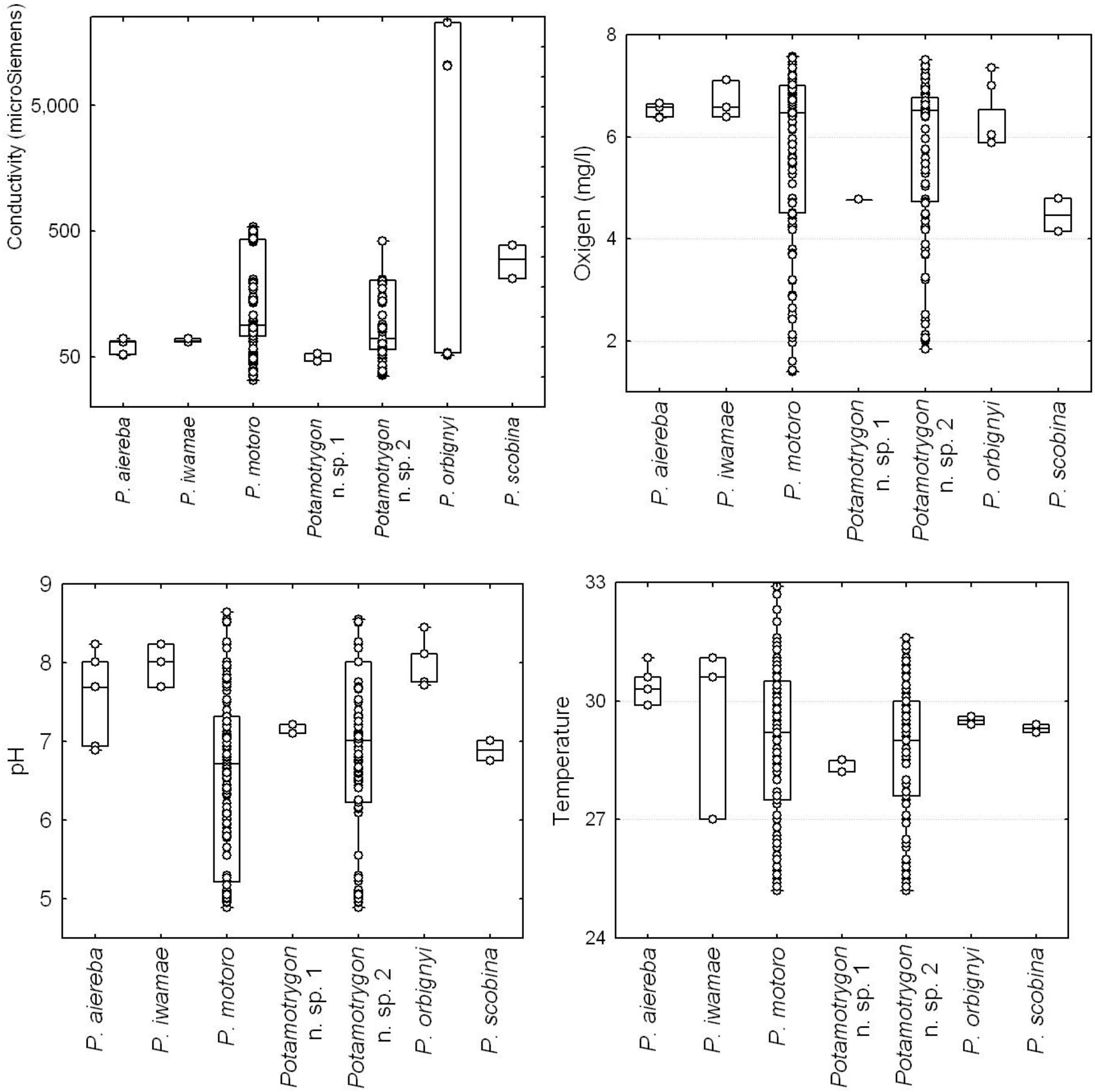

Figure 2. Box-plots indicating the water environmental characteristics in relation to the species occurrence for *Paratrygon aiereba*, *Plesiotrygon iwamae*, *Potamotrygon motoro*, *Potamotrygon* n. sp. 1, *Potamotrygon* n. sp. 2, *Potamotrygon orbignyi* and *Potamotrygon scobina*.

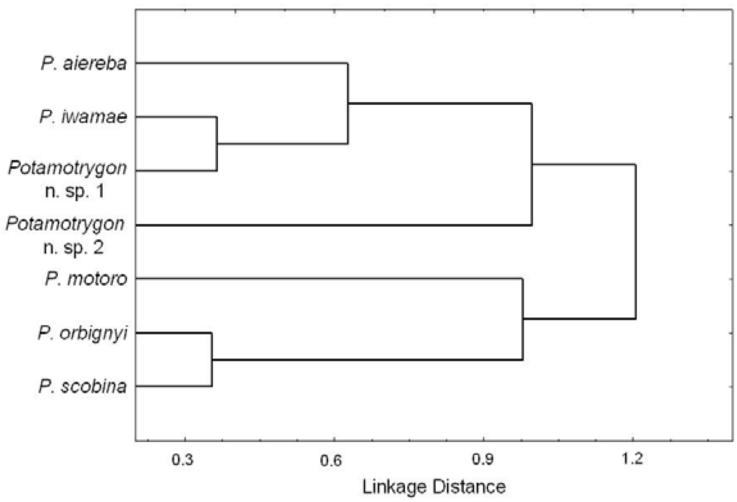

Figure 3. Freshwater stingray association based in the CPUE (number of stingrays caught / fishing day) of each fishery and cluster analysis of the CPUE for *Paratrygon aiereba*, *Plesiotrygon iwamae*, *Potamotrygon* n. sp. 2, *Potamotrygon* n. sp. 1, *Potamotrygon motoro*, *Potamotrygon orbignyi* and *Potamotrygon scobina*.

Discussion

Freshwater stingrays, like other elasmobranchs, seem to have a distinct environmental pattern occupation determined by specie, size and sex factors (Carrier *et al.* 2004). This fact probably affected the fishery results (abundance and diversity) in this and other studies (Charvet-Almeida 2001, 2006, Rincon 2006).

Several factors might interfere in freshwater stingray species composition, such as prey-predator relations, competition, sexual and ontogenetic segregation. In general, temporal factors (diel effects and long-term effects), spatial factors (migratory movements), physical factors (tolerance levels of species) and biotic factors (prey distribution/reproductive aspects) acting isolated or combined in ways that affect elasmobranch distribution (Simpfendorfer & Heupel 2004).

In an area with dynamic environmental conditions, including tidal influence, dry and rainy well-defined seasons, floods and others, it is extremely difficult to isolate and test a single factor that is potentially related to potamotrygonid habitat occupation and distribution. The environments in such regions are heterogeneous, varying from wide and deep bays and channels to narrow and shallow lakes, streams or beaches (Teixeira 1953, Milliman 1973, Miranda-Neto 2005).

The areas influenced by the Amazon and Tocantins discharges (Afuá and Muaná) were the most diversified in number of species, with five species each. On the other hand, the swamp-like region of the Arari Lake was the sampling point where more specimens were capture. The Arari Lake seems to be a differentiated environment, presenting slightly acid waters, highest extreme temperatures and low levels of dissolved oxygen in the rainy season. The Amazon estuary is well-known for its high diversity and unique distribution of fish species (Barthem 1985).

One of the new species sampled (*Potamotrygon* n.sp. 2) was abundant in three of the four sampling points. This only reinforces the lack of knowledge, need of more systematic studies within this group and supports that there are many other species yet to be described (Zorzi 1995, Araújo 1998, Charvet-Almeida 2001, Rincon 2006). The sampling of two new species only highlighted the need of further fieldwork sampling with preservation of specimens to be studied.

One factor that may have contributed to the results observed was the fishing gear characteristics since they presented different sampling efficiency in different habitats. This factor, associated to species segregation processes probably generated differentiated results.

The fishing gears efficiency was distinct among the sampling points. The longlines were the most important in the lake habitat, while the traps were more effective in the habitats with tidal influence. However, the environmental pattern occupation is yet unclear for freshwater stingrays.

The CPUE analysis did not detect an overall seasonal significant effect, suggesting that there is stability in the stingray abundance among the sampling points. The overall average number of specimens captured in one fishing day (CPUE), considering all sampling points and species, was 3.07. This value was higher than the one (2.76 stingrays/day) observed by Rincon (2006) when using active harpoon fishery at night in the Paranã River.

The highest average CPUE per species was recorded for *Potamotrygon motoro* (1.54). The abundance of this species in the Arari Lake seemed higher than in the other sampling points.

Afuá and Arari were the sampling points with the best capture rates. In Arari this could be explained by the fact that the Arari Lake is an almost closed water system, especially in the dry season. As consequence, this would probably increase the abundance of freshwater stingrays in that area and their probability of being captured in relation to the other points. In Afuá captures were also high due to the habitat conditions that apparently favored a most efficient use of the “pari” fencing fishery. This gear proved to be efficient to capture smaller size stingrays and *Potamotrygon* n.sp. 2 specimens.

The lowest CPUE results were registered in Soure. This point had CPUE values lower than one capture per day for all species. In this sampling point the CPUE values observed for *Potamotrygon orbignyi* (0.68) were much lower than the one of 2.57 specimens/day registered in Paranã River (Rincon 2006) regarding this same species. This reduced CPUE in Soure is probably associated to the fact that *Potamotrygon orbignyi* is not commonly caught using longlines since it feeds predominantly on insects (Charvet-Almeida 2006, Rincon 2006) and was unlikely to be attracted by the fish, shrimp or crab-baited hooks. Apart from this fact, it is important to highlight that the high salinity levels also did not favor the presence of potamotrygonids in this sampling point.

Nevertheless, CPUE values observed were low (0.84 - 5.32) but not very different from ones obtained in other studies (overall range of 1 - 2.3) (Rincon 2006). Freshwater stingray abundance is usually low in most river basins probably because they often occupy a predator role in the trophic chain, as other elasmobranchs (Charvet-Almeida 2001, 2006). Bait competition and difficulties in operating the longlines in areas with strong tidal effects may have contributed to the low number of specimens caught per day.

Despite the considerable salinity variation in Soure (0.1 - 12.4 psu) possibly associated to dry and rainy periods, no statistically significant differences were noted between seasonal phases on the ANCOVA analysis. This result was possibly caused by the low number of specimens captured (CPUE = 0.84) in this sampling point or by the significance level of the statistical test used ($p<0.01$).

The highest pH average values were observed in Afuá and are probably related to the water characteristics of the Amazon River discharge. The high pH values registered in Soure are also probably related to the estuarine water influence.

Potamotrygon orbignyi was the most salt resistant specie found in the Amazon mouth. This possible salt tolerance contributed as an important factor to determine its abundance in Soure region, near the influence of estuarine waters, especially during the dry season. *Potamotrygon motoro, P. scobina* and *Potamotrygon* n. sp. 2 were sampled at intermediate conductivity/salinity levels and could be considered intermediately salt resistant.

According to the box-plot analysis, the abundance of *Potamotrygon motoro* was clearly associated to low conductivity values.

In Soure interviews with fishermen involving photo-identification of species indicated that *Potamotrygon motoro* and *Potamotrygon scobina* were frequently captured by their artisanal fisheries. The results of this study showed that these two species were collected in small quantities or were not even sampled. Nevertheless, the fishermen also mentioned that these species move to the inner portion of the island and Marajó Bay as the salinity levels rise during the dry season. This displacement is also detected by a seasonal increase in the number of accidents involving stingrays along the beaches.

Probably these two species in fact leave the area under greater influence of estuarine waters in the beginning of the dry season looking for better environmental conditions. It is possible that these movements are associated to their reproductive cycle as observed in *Plesiotrygon iwamae* (Charvet-Almeida 2001).

The Arari Lake was expected to have one of the lowest dissolved oxygen and highest average water temperature values. Curiously an opposite situation was observed due to the strong winds that form waves (up to 0.5 m high) mainly in the dry season. These waves revolve the water increasing the dissolved oxygen levels, lower water temperature and lead to higher conductivity values since the muddy bottom is stirred. Despite this, *Potamotrygon motoro* and *Potamotrygon* n. sp. 2 were found in critical conditions regarding pH, dissolved oxygen concentrations and extreme temperatures in the Arari Lake.

Potamotrygon scobina was found in association with *Potamotrygon orbignyi*, distributed mainly in the south and southeast regions at the Marajó Island. However, no environment factors seemed evident to clearly explain their abundance in these regions. *Potamotrygon scobina* apparently tolerated well low oxygen levels and preferred lower pH values.

The other species were so rare that it was not possible to relate their presence to environmental conditions. *Plesiotrygon iwamae* and *Paratrygon aiereba* were less abundant or captured in smaller proportions in other studies too (Charvet-Almeida 2001, Almeida 2003, Charvet-Almeida 2006, Charvet-Almeida & Almeida *in press*). They seem to prefer deeper channels or areas that are much more difficult to access and sample adequately with experimental fisheries.

The disc width distribution was not homogeneous for *P. motoro* and *Potamotrygon* n. sp. 2. The smaller specimens of these two stingray species apparently live scattered on the island's borders, unlike the larger specimens that were found closer to the center or inner portions at Marajó Island. The Arari Lake is likely to be the breeding grounds for these species, while the borders of the island apparently correspond to nursery areas. The inner areas present swampy conditions where predation and food availability does not seem to favor the permanence of smaller specimens. These factors possibly determine their movement away from the center of the island. At the island's borders the neonates and juveniles are likely to benefit from the daily tidal oscillations to move around and use shallow areas to seek protection and food.

It is unlikely that fishing gear selectivity biased these results since the same equipment was used at all four sampling points. Fishing gear selectivity was reported for other potamotrygonids in river systems and more restricted areas (Charvet-Almeida 2006, Charvet-Almeida & Almeida *in press*).

River beaches have been previously considered nursery grounds for freshwater stingrays (Araújo 1998, Charvet-Almeida 2001, 2006, Martin 2005, Rincon 2006) but size segregation following the island pattern observed in this study had never been recorded before for potamotrygonids.

Acknowledgments

The leading author is grateful to The National Council for Scientific and Technological Development (CNPq) for his doctorate study grant. The authors are also thankful to the fishermen that helped with the captures and provided helpful information.

References

Almeida, M. P. 2003. Pesca, Policromatismo e Aspectos Sistemáticos de *Potamotrygon scobina* (Chondrichthyes: Potamotrygonidae) da Região da Ilha de Colares - Baía de Marajó - Pará. **Master Thesis**. Universidade Federal do Pará & Museu Paraense Emílio Goeldi, Belém, 145 p.

Araújo, M. L. G. 1998. Biologia Reprodutiva e Pesca de *Potamotrygon* sp. C (Chondrichthyes - Potamotrygonidae), no Médio Rio Negro, Amazonas. **Master Thesis.** Instituto Nacional de Pesquisas da Amazônia & Universidade do Amazonas, Manaus, Brasil, 171 p.

Barthem, R. B. 1985. Ocorrência, distribuição e biologia dos peixes da baia de Marajó, estuário amazônico. **Boletim do Museu Paraense Emílio Goeldi** - Série Zoologia, 15: 49-69.

Barthem, R. B. & Golding, M. 2007. **An Unexpected Ecosystem: The Amazon revealed by the fisheries**. Lima Amazon Conservation Association (ACA) - Missouri Botanical Garden Press, 241 p.

Barthem, R. B. & Schwassmann, H. O. 1994. Amazon river influence on the seasonal displacement of the salt wedge in the Tocantins river estuary. Brazil. 1983-1985. **Boletim do Museu Paraense Emílio Goeldi** - Série Zoologia, 10: 119-130.

Brooks, D.R., Thorson, T.B. & Mayes, M.A. 1981. Freshwater stingrays (Potamotrygonidae) and their helminth parasites: testing hypotheses of evolution and coevolution. **Proceedings of the First Meeting of the Willi Hennig Society,** p. 147-175.

Camhi, M., Fowler, S., Musick, J., Bräutigam, M. & Fordjam, S. 1998. Sharks and Their Relatives: ecology and conservation. Occasional Paper of the IUCN Species Survival Commission (20). **Oxford Information Press**, p. 39.

Carrier, J. C., Musick, J. A. & Heithaus, M. R. 2004. **Biology of sharks and their relatives**. CRC Press LLC, London, 596 p.

Carvalho, M. R., Lovejoy, N. R. & Rosa, R. S. 2003. Family Potamotrygonidae (river stingrays). Pp 22-28. *In:* Reis, R. E., Kullander, S. O. & Ferraris Jr., C. J., (Eds). **Check List of the Freshwater Fishes of South and Central America**. EDIPUCRS, Porto Alegre, 729 p.

Charvet-Almeida, P. 2001. Ocorrência, Biologia e Uso das Raias de Água Doce na Baía de Marajó (Pará-Brasil), com ênfase na biologia de *Plesiotrygon iwamae* (Chondrichthyes: Potamotrygonidae). **Master Thesis**. Universidade Federal do Pará & Museu Paraense Emílio Goeldi, Belém, Brasil, 213 p.

Charvet-Almeida, P. 2006. História Natural e Conservação das Raias de Água Doce (Chondrichthyes: Potamotrygonidae) no Medio Rio Xingu, Área de Influência do Projeto Hidrelétrico de Belo Monte (Pará, Brasil). **Doctorate Thesis**. Universidade Federal da Paraíba, João Pessoa, Brasil, 475 p.

Charvet-Almeida, P., Araújo, M. L. G., Rosa, R. S. & Rincon, G. 2002. Neotropical freshwater stingrays: diversity and conservation status. **IUCN Shark News,** 14: 1-2.

Charvet-Almeida, P. & Almeida, M. P. *in press*. **Contribuição ao Conhecimento, Distribuição e aos Desafios para a Conservação dos Elasmobrânquios (Raias e Tubarões) no Sistema Solimões-Amazonas**. Pp. 207-244. *In*: Albernaz, A. L. K. M. (Org.): Bases Científicas para a Conservação da várzea: Identificação e Caracterização de regiões biogeográficas. IBAMA/PROVÁRZEA. Brasília, 350p.

Compagno, L. J. V. & Cook, S. F. 1995. The exploitation and conservation of freshwater elasmobranchs: status of taxa and prospects for the future. **Journal of Aquariculture & Aquatic Sciences**, 7: 62-90.

Costa, M. H., Botta, A. & Cardille, J. A. 2003. Effects of large-scale changes in land cover on the discharge of the Tocantins River. Southeastern Amazonia. **Journal of Hydrology**, 283: 206-217.

Ferreira, E. J. G.; Zuanon, J. A. S. & Santos, G. M. dos. 1998. **Peixes Comerciais do Médio Amazonas: região de Santarém, Pará**. IBAMA, Brasília, p. 17 - 22.

Goulding, M., Barthem, R. B. & Ferreira, E. J. G. 2003. **The Smithsonian Atlas of the Amazon**. Washington Smithsonian Institution, 253 p.

Holden, M.J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. Pp. 117-137. *In*: Harder-Jones, F. R. (Ed). **Sea Fisheries Research**. New York: John Wiley & Sons, 510 p.

IBAMA PróVárzea. 2002. **Estatística Pesqueira do Amazonas e Pará-2001**. Ruffino, M. L. (coordenador). Manaus (Brasil), IBAMA PróVárzea, 76 p.

Jonhson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preferences. **Ecology**, 61: 65-71.

Kempf, M., Coutinho, P. N. & Morais, J. O. 1967. Plataforma continental do Norte e Nordeste do Brasil. **Trabalhos Oceanográficos da Universidade Federal de Pernambuco,** 9/11: 9-26.

Lessa, R.; Santana, F. M.; Rincón, G.; Gadig, O. B. F. & El-Deir, A. C. A. 1999. **Biodiversidade de Elasmobrânquios no Brasil.** *In*: Relatório e Ações Prioritárias para Conservação da Biodiversidade da Zona Costeira e Marinha. World Wide Web electronic publication, acessible at http://www.anp.gov.br/brasil-rounds/round6/guias/PERFURACAO/PERFURACAO_R6/refere/Elasmobranquios.pdf. (Acessed 19/08/2008)

Mabesoone, J. M. & Coutinho, P. N. 1970. Littoral and shallow marine geology of Nothern and Northeastern Brazil. **Trabalhos Oceanográficos da Universidade Federal de Pernambuco**, 12: 1-214.

Martin, R. A. 2005. Conservation of freshwater and euryhaline elasmobranchs: a review. **Jornal of the Marine Biological Association of the United Kingdom,** 85: 1049-1073.

Milliman, J. D., Barretto, H. T., Barreto, L.. A., Costa, M. P. A. & Francisconi, O. 1973. Surficial sediments of the Brazilian continental margin. **Proceedings of the XXVI Congresso Brasileiro de Geologia**: 30-44.

Miranda-Neto, M. J. 2005. **Marajó: desafio da Amazônia**. EDUFPA, Belém, 218 p.

Mould, B. 1997. **Classification of the Recent Elasmobranchii: a classification of the living sharks and rays of the world.** World Wide Web electronic publication, acessible at http://ibis.nott.ac.uk/elasmobranch.html. (Acessed 19/08/2008).

Musick, J. A. & Bonfil, R. 2004. **Elasmobranch Fisheries Management Techniques**. IUCN, APEC and VIMS. Singapore, 369 p.

Pratt, H. L. & Casey, J. G. 1990. Shark reproductive strategies as limiting factor in directed fisheries, with a review of Holden's method of estimating growth-parameters. Pp. 97-109. *In*: Pratt, H. L., Gruber, S. H. & Taniuchi, T., (Eds). **Elasmobranch as Living Resources: advances in biology, ecology and systematics, and the status of fisheries**. NOAA Technical Report. NMFS 90, U. S. Department of Commerce, 518 p.

Rincon, G., 2006. Aspectos Taxonômicos, Alimentação e Reprodução da Raia de Água Doce *Potamotrygon orbignyi* (Castelnau) (Elasmobranchii:Potamotrygonidae) no Rio Paranã - Tocantins. **Doctorate Thesis**. Universidade Estadual Paulista Julio de Mesquita Filho, Rio Claro, 132 p.

Roosevelt, A. C. 1991. **Moundbuilders of the Amazon: Geophysical Archaeology on Marajo Island, Brazil.** Academic Press. San Diego – California, 495 p.

Rosa, R.S. 1985. A Systematic Revision of the South American Freshwater Stingrays (Chondrichthyes: Potamotrygonidae). **PhD Thesis**. College of William and Mary, Williamsburg, 523 p.

Rosa, R. S. & Carvalho, M. R. 2007. Família Potamotrygonidae. Pp 17-18. In: Buckup, P. A., Menezes, N. A., Ghazzi, M. S. (Eds.). **Catálogo das espécies de peixes de água doce do Brasil.** Museu Nacional série livros 23, Rio de Janeiro, 149 p.

Simpfendorfer, C. A. & Heupel, M. R. 2004. Assessing Habitat Use and Movement. Pp. 553-572. *In*: Carrier, J. C., Musick, J. A. & Heithaus, M. R. (Eds). **Biology of sharks and their relatives**. CRC Press, New York, 618 p.

Sioli, H. 1966. General features of the delta of the Amazon. Humid Tropics Research. Scientific Problems of the Humid Tropical Zone Deltas and Their Implications. **Proceedings of the Dacca Symposium,** p.381-390.

Teixeira, J. F. 1953. **O Arquipélago de Marajó**. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística, 96 p.

Thorson, T. B., Langhammer, J. K. & Oetinger, M. I. 1983. Reproduction and development of the South American freshwater stingrays, *Potamotrygon circularis* and *P. motoro*. **Environmental Biology of Fishes,** 9 (1): 3-24.

Zorzi, G. 1995. The biology of freshwater elasmobranchs: an historical perspective. *In*: Oetinger, M. I. & Zorzi, G. (Eds). **Journal of Aquariculture & Aquatic Sciences,** p. 10-31.

Received August 2008
Accepted October 2008
Published online January 2009