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Cover photo of this issue: A juvenile of Atlantic Green Turtle *Chelonia mydas* (Reptilia, Testudines, Cheloniidae) photographed *in situ* in the Barra Grande beach, state of Piauí, Brazil. Picture taken by Ana C. G. Mai.



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

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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, potamotrygonídeos, 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 km², 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° 09'S, 50° 23'W), situated in the northwest border of the Marajó Island, at the margin of the Amazon River; (2) Muaná (01° 31'S, 49° 13'W) located in the south border, on the margin

of the Tocantins River; (3) Soure (0° 42'S, 48° 31'W) situated at the east border, in the coast; (4) Arari (0° 39'S, 49° 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 cm² chunks) (*Anableps* 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*, *Hoplerhythrinus* 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

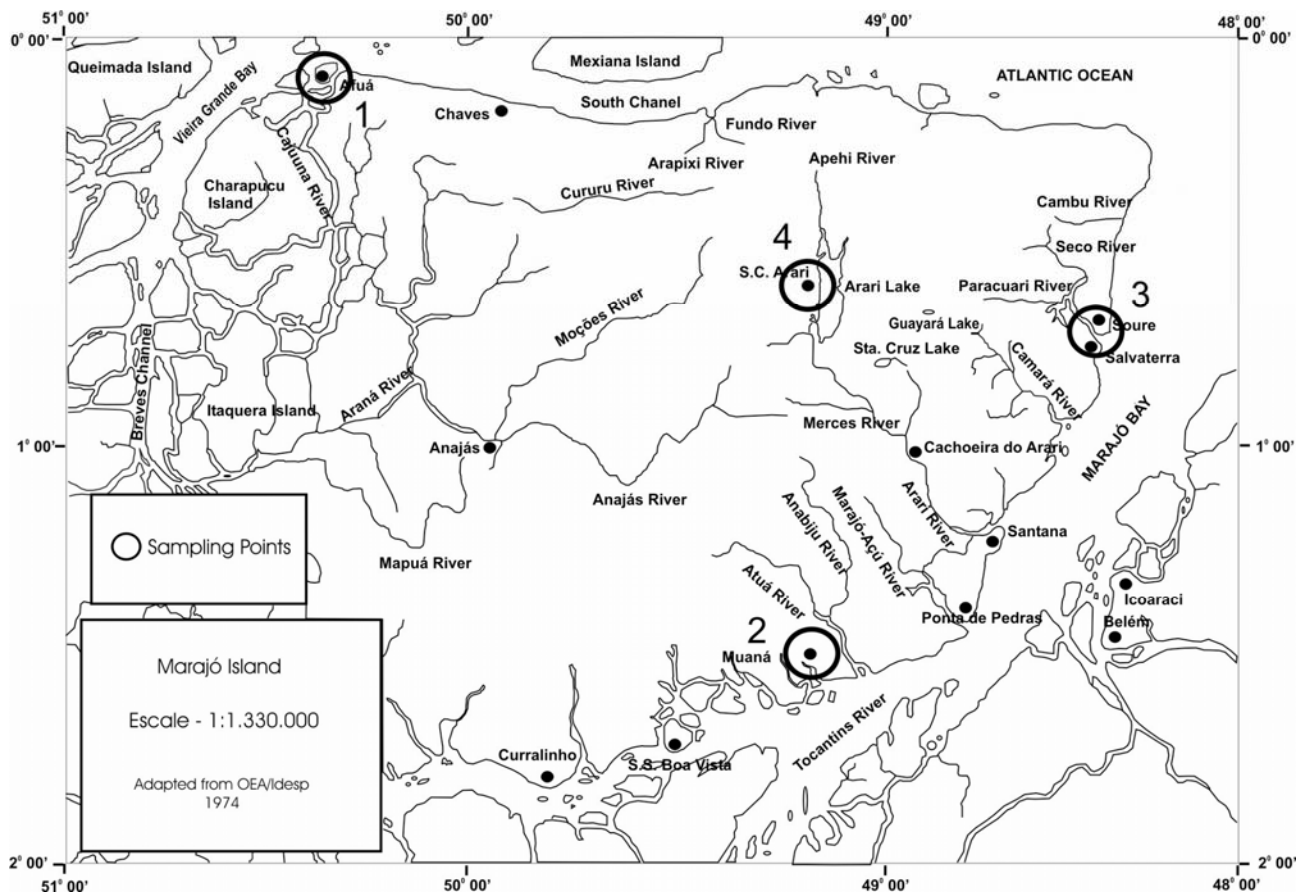


Figure 1 - Marajó Island map indicating the sampling points.

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 than 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	
<i>Paratrygon aiereba</i>	n	1	-	1	-	2
	w	28,000	-	8,400	-	36,400
<i>Potamotrygon n. sp. 1</i>	n	3	-	-	-	3
	w	7,140	-	-	-	7,140
<i>Plesiotrygon iwamae</i>	n	2	-	-	1	3
	w	14,200	-	-	4,900	19,100
<i>Potamotrygon n. sp. 2</i>	n	41	67	7	-	115
	w	81,400	388,260	14,770	-	484,430
<i>Potamotrygon motoro</i>	n	10	150	13	-	173
	w	10,559	909,570	29,252	-	949,381
<i>Potamotrygon orbignyi</i>	n	-	1	16	21	38
	w	-	1,050	11,510	30,810	43,370
<i>Potamotrygon scobina</i>	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 intermediate conductivity/salinity levels, with maximum values between 300-500 μ S/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	
<i>Paratrygon aiereba</i>	0.09	0	0.03	0	0.02
<i>Potamotrygon n. sp. 1</i>	0.27	0	0	0	0.03
<i>Plesiotrygon iwamae</i>	0.18	0	0	0.03	0.03
<i>Potamotrygon n. sp. 2</i>	3.73	1.63	0.24	0	1.03
<i>Potamotrygon motoro</i>	0.91	3.66	0.45	0	1.54
<i>Potamotrygon orbignyi</i>	0	0.02	0.55	0.68	0.34
<i>Potamotrygon scobina</i>	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 ($\mu\text{S}/\text{cm}$)	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 ($^{\circ}\text{C}$)	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 $\mu\text{S}/\text{cm}$ 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 $^{\circ}\text{C}$.

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*.

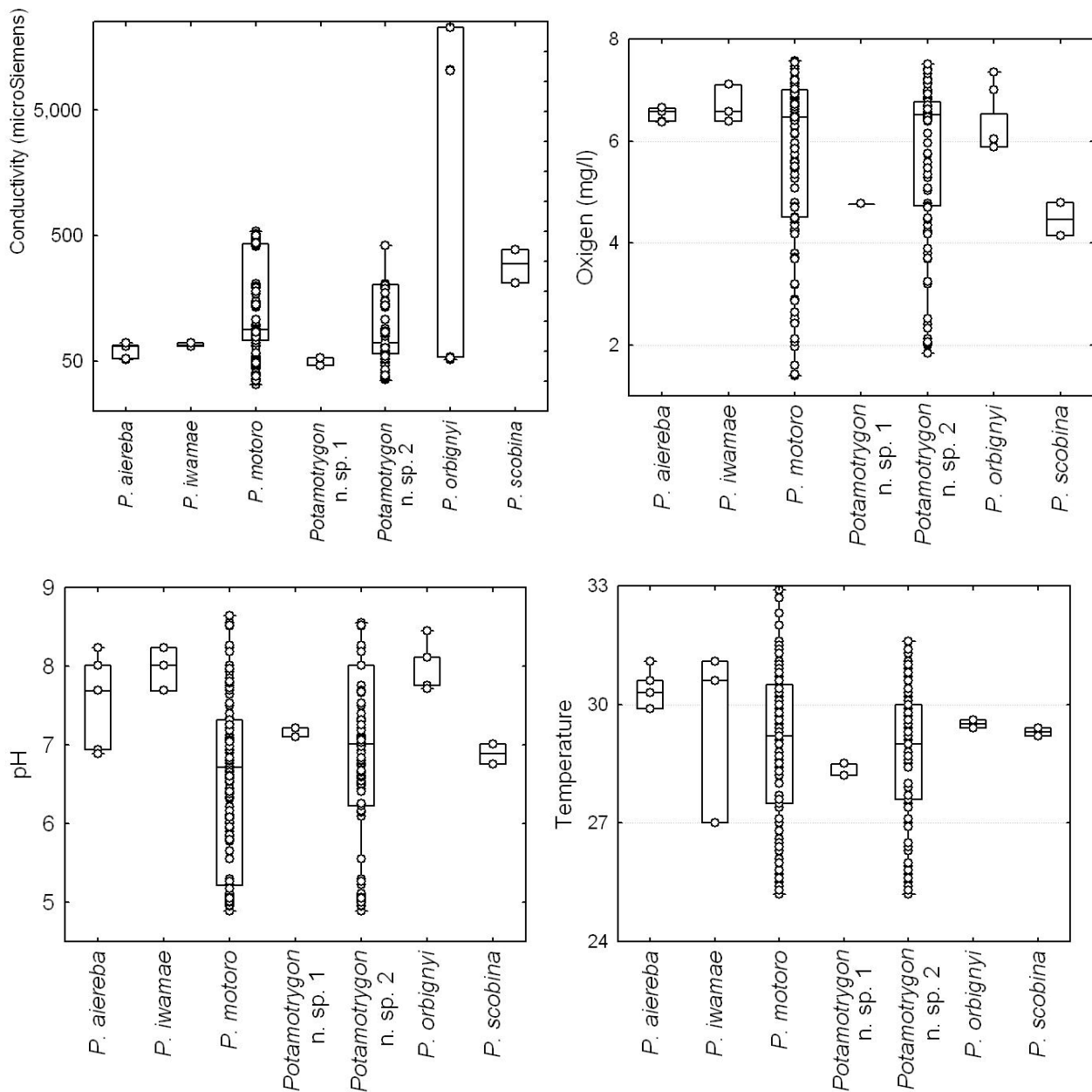


Figure 2. Box-plots indicating the water environmental characteristics in relation to the species occurrence for *Paratrygon aiereba*, *Plesioglyptodon iwamae*, *Potamotrygon motoro*, *Potamotrygon* n. sp. 1, *Potamotrygon* n. sp. 2, *Potamotrygon orbignyi* and *Potamotrygon scobina*.

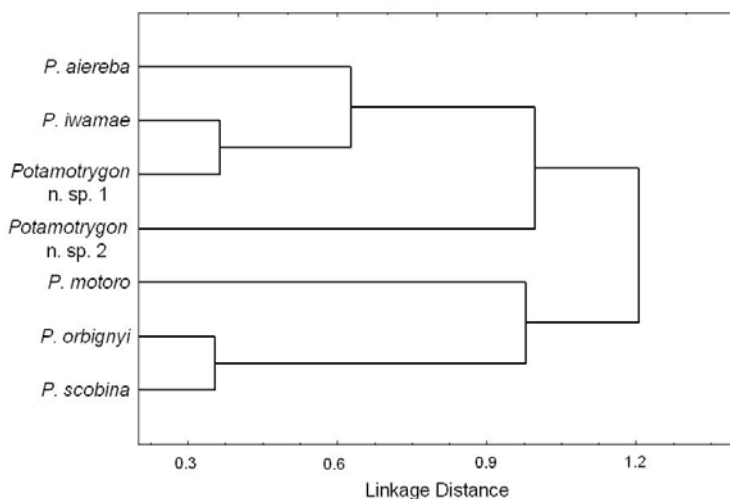


Figure 3. Freshwater stingray association based in the CPUE (number of stingrays caught / fishing day) of each fishery and cluster analysis of the CPUE for *Paratrygon aiereba*, *Plesioglyptodon iwamae*, *Potamotrygon* n. sp. 2, *Potamotrygon* n. sp. 1, *Potamotrygon motoro*, *Potamotrygon orbignyi*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

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Natural food resources and niche breadth of *Barilius bendelisis* (Hamilton) (Pisces, Cyprinidae) in river Dikrong, an upland riverine ecosystem in India

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Abstract. The food items and feeding habits of the Indian Hill Trout, *Barilius bendelisis* (Hamilton) from the River Dikrong in Arunachal Pradesh, India was examined between January and February of 2001. Fish samples were caught in the morning, noon, afternoon and evening, using cast net. Analysis of gut content revealed that the fish is periphytophagous and feeds mainly on bacillariophycean algae, showing more feeding intensity at noon hours of the day. The fish in general displayed wider niche breadth (around double) at noon (0.52) in comparison to morning (0.25) and also to evening (0.20) hours. Different size groups of *B. bendelisis* reflected resource selectivity in the same environment.

Key words: bacillariophyceae; gut analysis; periphyton; Arunachal Pradesh

Resumo. Recursos alimentares naturais e amplitude do nicho de *Barilius bendelisis* (Hamilton) no rio Dikrong, um ecossistema riverino de montanha na Índia. Os itens alimentares e os hábitos da alimentação da truta *Barilius bendelisis* (Hamilton) no rio Dikrong em Arunachal Pradesh, Índia foram examinados entre Janeiro e Fevereiro de 2001. As amostras foram coletadas pela manhã, meio-dia, tarde e noite usando uma tarrafa. Análise dos conteúdos estomacais revelou que a espécie é perifítófaga e que se alimenta principalmente de algas bacilariofíceas, apresentando uma maior intensidade na atividade alimentar no período do meio dia. A espécie apresentou em geral um nicho mais amplo (aproximadamente o dobro) no meio dia (0.52) em comparação com a manhã (0.25) e ainda com o anoitecer (0.20). Diferentes classes de tamanho de *B. bendelisis* refletiram seletividade dos recursos num mesmo ambiente.

Palavras chave: bacilariofíceas; análise do conteúdo estomacal, perifíton; Arunachal Pradesh

Introduction

Barilius bendelisis (Hamilton), commonly known as Indian Hill Trout, is an upland water fish of South East Asia. It belongs to the family Cyprinidae and dwells in shallow, clear and cold water (Gurung *et al.* 2005). It is highly endemic as well as endangered in the rivers of Himalayan region (Kurup *et al.* 2004). In northeastern India, it is commonly distributed in hilly streams and rivers (25°C) of Himalayan region. The fish plays significant role in the capture fishery in several parts of the Himalayan region of Arunachal Pradesh, inhabiting shallow lotic and seasonal lentic water bodies where Indian major carps and exotic carps cannot be raised successfully. Such areas include

shallow flooded watersheds, seasonal flood plains and smaller river-fed ponds. Though extensive studies have been done on food and feeding ecology of common carp (*Cyprinus carpio* L.) (Das *et al.* 2007, Saikia & Das 2008) in the rice fields from this part of Himalayan region, *B. bendelisis* being a demanding ornamental as well as potential food fish has hardly received any research attention for such studies.

Except from a few scattered reports on habitat characterization, no records on the feeding habits and food composition of *Barilius bendelisis* exists (Farswan *et al.* 1989, Shehgal 1999, Johal *et al.*, 2001). The present study is, therefore, an important contribution to the knowledge of the

feeding habit and food composition of this species, in order to develop a culture system in its natural environment. This paper deals with organisms found in the gut content of the fish collected directly from an eastern Himalayan river named *Dikrong* situated in the district of Papumpare, Arunachal Pradesh, India.

Material and Methods

The sampling of *B. bendelisis* was done between the months of January and February 2001. Random sampling in selected areas of Dikrong River was carried out once in a week using a cast net at morning (6:00 — 8:00), noon (12:00 — 13:30) and afternoon (14:45 — 15:00) hours of each day of sampling. The sampled fishes were identified using the taxonomic keys (Nath & Dey 2000) and immediately fixed in 8 % formalin. On an average 50 fishes were collected and examined during each sampling period. Total length of each fish was measured in centimeter and the gut was carefully dissected out. The gut was then cut lengthwise and gut contents were scraped gently using a soft brush. The gut contents were preserved in 5% formalin for further analysis. Microscopic observation and identification of food organisms was carried out up

to generic level following standard procedures (Turner 1978, Pantecost 1984, Edmondson 1992). The quantitative analysis of gut contents was done according to Windell and Bowen (1978) and Bowen (1983). Data were expressed in proportion as fraction of 1.0 (Haroon & Pittman 2000). Niche breadth (B) for the fish was determined using the following formula:

$$B = \frac{1}{\sum p_j^2} \text{ (Levins 1968)}$$

where, p_j = proportion of individuals found.

Fish samples were grouped in to two sizes vis-a-vis small sized fishes (SSF) which ranged between 6.0 and 10.0 cm and large sized fishes (LSF) ranging from 11.0 to 13.0 cm. Gut contents of SSF and those of LSF were examined separately. Temporal study on food organisms was done with all fishes sampled irrespective of the size groups.

Results

The qualitative and quantitative data of the gut contents for each size group was determined. These are presented in Table I, where can be seen that 10 genera of bacillariophyceae, 14 genera of chlorophyceae, 1 genus of protozoa and 3 genera of rotifers were observed in the gut of *B. bendelisis*.

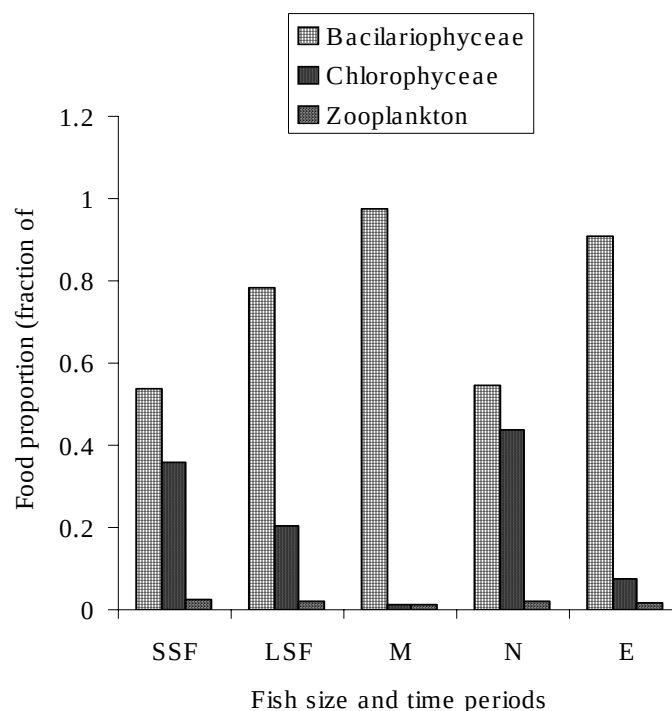


Figure 1. Proportion (fraction of 1.0) of available food organisms in the gut of *B. bendelisis* (Ham.) from Dikrong River, India. SSF, Small size fish; LSF, Large size fish; M, Morning; N, Noon; E, Evening

Table I. Proportion of available food organisms in the gut of *B. bendelisis* (Ham.) from Dikrong River, India

Genus	Size group		Time		
	SSF	LSF	Morning	Noon	Evening
(i) Bacillariophyceae					
<i>Navicula</i>	0.1566	0.3534	0.5364	0.1206	0.4512
<i>Pinnularia</i>	0.1897	0.0802	0.3180	0.0976	0.0731
<i>Gomphonema</i>	0.0772	0.0727	0.0920	0.1072	0.0558
<i>Melosira</i>	0.0290	0.0059		0.0080	0.0101
<i>Cymbella</i>	0.0793	0.0768	0.0249	0.0925	0.0774
<i>Tabellaria</i>	0.0069	0.0004		0.0022	
<i>Surirella</i>		0.0004	0.0057		0.0006
<i>Atthiya</i>		0.0017			0.0026
<i>Fragillaria</i>	0.0531	0.1279		0.1056	0.1430
<i>Amphora</i>	0.0241	0.0638		0.0134	0.0953
(ii) Chlorophyceae					
<i>Scenedesmus</i>		0.0104			0.0153
<i>Closterium</i>	0.0310	0.0234		0.0415	0.0185
<i>Euastrum</i>	0.1083	0.0025		0.0498	
<i>Cosmarium</i>		0.0231		0.0501	
<i>Spirogyra</i>	0.1359	0.0340		0.1018	
<i>Zygnema</i>		0.0087		0.0019	
<i>Ulothrix</i>	0.0372	0.0046	0.0115	0.0265	
<i>Microspora</i>	0.0241	0.0147		0.0469	
<i>Oedogonium</i>		0.0013		0.0032	
<i>Clostriopsis</i>		0.0277			0.0419
<i>Netrium</i>		0.0004		0.0096	
<i>Desmidium</i>	0.0041	0.0399		0.0987	
<i>Hyalotheca</i>		0.0059			
<i>Pleurotaenium</i>	0.0172	0.0059		0.0093	
(iii) Zooplankton					
<i>Diffugia</i>	0.0221	0.0084		0.0223	0.0069
<i>Keratella</i>	0.0041	0.0084	0.0115		
<i>Polyarthra</i>		0.0013			0.0020
<i>Testudinella</i>		0.0042			0.0064

Table II. Levins' niche breadth (B) of food organisms in the gut of *B. bendelisis* (Ham.) from Dikrong River, India

Size group		Time		
SSF	LSF	Morning	Noon	Evening
0.5012	0.1982	0.2519	0.5176	0.2014

The intensity of food consumption by fishes was higher in the morning (0.98) and evening (0.91) hours but moderate at noon (0.55) (Figure 1). Though *Navicula* was preferred by both SSF and LSF during morning (0.54) and evening (0.45) hours, the LSF showed comparatively more inclination (0.35) towards *Navicula* than to SSF. The proportion (fraction of 1.0) indicated that LSF

consumed more bacillariophyceae (0.7832) than SSF (0.5369). However, the fishes avoided *Surirella* (<0.006) irrespective of size groups and feeding hours. The SSF consumed Chlorophyceae mostly (0.36) in comparison to LSF (0.20). At noon hours, Chlorophyceae constituted a moderate proportion (0.44) of the gut content but a negligible proportion in the morning (0.01) and evening (0.08) hours. On the other hand, zooplankton represented a low poor proportion of gut content (<0.03).

The SSF exhibited wider niche breadth (0.5012) than the LSF (0.1982). The fish in general displayed wider niche breadth (around double) at noon (0.52) in comparison to morning (0.25) and also to evening (0.20) hours (Table II).

Discussion

Substrates like stones and rocks harbour the highest density of bacillariophyceae community in lotic systems (Nautiyal *et al.* 2000). Observation of higher proportion of bacillariophyceae in the gut of both size groups indicates that *B. bendelisis* browses on stone and rock substrate. Nautiyal *et al.* (2000) also reported *Navicula* as being common on such substrates thus explaining why the LSF might have preferred it to other food organisms. The narrow niche breadth indicates an increased specialization of the fish and this might be due to increased size and competitive ability of the species (Haroon & Pittman 1998). In contrast, wider niche breadth of SSF displayed its opportunistic habit. However, both size groups consumed chlorophyceae moderately and periphyton less frequently. The moderate consumption of chlorophyceae may be due to their mixed form of occurrence (suspended/attached) while from the less frequent consumption of periphyton, it can be presumed that the fish nibbled only on the available periphytic forms. Similarly, zooplankton was scarcely seen in the gut. This may be explained either by its pseudoperiphytic nature (Sladeckova 1962) or by its accidental consumption.

The functions of Levin's niche breadth

against feeding time for *B. bendelisis* showed a high degree of specialization on natural food in the morning and evening hours. The fish specialized on bacillariophyceae (Fig. 1) where *Navicula*, *Pinularia* and *Fragillaria* species contributed significant fraction of the food composition. However, wider niche breadth at noon hours reflects maximum food selection and feeding activity of the fish on available food resources. The reason for variations of niche breadth could be due to the resource selectivity by the individual from the environment (Petraitis 1979). The peak feeding response at noon hours is in conformation with the findings of Haroon and Pittman (1998), thus supporting an environmental effect on the resource utilization by the fish. The low magnitude of difference (30%) of niche breadth between both size groups in the same environment at a given time is enough to consider them as non-competitors and is also indicative of differences in resource selectivity. Thus, a selection of these size groups for sequential stocking in experimental or cultural set up may not lead to intraspecific competition. However, the whole study could not reflect a generalized niche breadth for the fish because of limited replications, consideration of less variable size groups of fish and long time interval taken as feeding hours.

The results of the present matrices are 'virtual' since other competitions in the environment are usually considered close to absent during such types of study (Haroon & Pittman 2000). Thus, depending on the competitive stress in presence of other species of fish, this relationship may be subject to change.

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Distribuição espacial e temporal da guaiúba *Ocyurus chrysurus* (Bloch, 1791) (Teleostei, Lutjanidae) capturada pela frota pesqueira artesanal na região nordeste do Brasil

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Abstract: Spatial and temporal distribution of the yellowtail snapper *Ocyurus chrysurus* (Bloch, 1791) (Teleostei, Lutjanidae) caught by the artisanal fleet in northeastern Brazil.

Fish sampling activities were carried out between 1998 and 2000, accompanying the landings of bottom-line operations of the artisanal fleet in northeastern Brazil. In order to standardize mean abundance indexes based on catch and effort data regarding *Ocyurus chrysurus* and identify mean abundance tendencies in time and space, generalized linear models (GLMs) were used on 1556 fisheries recorded during the study period. A standard relative abundance index (CPUE) for the most frequent vessel in catches was estimated, using factors and coefficients generated in the GLMs. Mean abundance indexes indicate that the species has a greater yield in the state of Bahia, with a tendency toward lower values at lower latitudes in the study area. The highest mean CPUE values were estimated between depths of 25 and 50 m. Non-linear models applied for abundance in relation to distance from the coast demonstrate that *O. chrysurus* has a differentiated aggregation structure depending on the extension of the continental shelf throughout northeastern Brazil. There was a decline in mean abundance indexes throughout the study period, which may have been caused by the considerable fishing effort targeting this species.

Key words: Spatial Statistic; Generalized Linear Models; Northeastern fishes.

Resumo. Atividades de amostragem de peixes foram realizadas entre 1998 e 2000, sendo acompanhados os desembarques da frota pesqueira artesanal que opera com linha de fundo na região nordeste do Brasil. A fim de padronizar índices médios de abundância a partir de dados de captura e esforço do *Ocyurus chrysurus* e identificar tendências médias da abundância no tempo e espaço, Modelos Lineares Generalizados (GLM) foram utilizados em 1.556 pescarias registradas no período de estudo. Um índice de abundância relativo padrão (CPUE) para a embarcação mais freqüente nas capturas foi estabelecido, utilizando fatores e coeficientes gerados nos GLMs estabelecidos. Índices médios de abundância indicaram que a espécie apresenta os maiores rendimentos no estado da Bahia, com tendência de diminuição em direção a menores latitudes da área de estudo. Entre as profundidades de 25 e 50 m foram estimados as maiores CPUEs médias para o recurso. Modelos não lineares, aplicados para abundância em relação às distâncias da costa demonstraram que o *O. chrysurus* apresenta estrutura de agregação diferenciada, segundo a extensão da plataforma continental ao longo da região nordeste do Brasil. Houve declínio dos índices médios de abundância no período de estudo, o que pode estar sendo promovido pelo alto esforço direcionado a esse recurso.

Palavras chave: Estatística Espacial; Modelos Lineares Generalizados; Peixes do nordeste.

Introdução

Os ambientes marinhos da plataforma continental suportam a maior proporção da produção de recursos renováveis em todo o mundo. Segundo a FAO (Caddy 1997), 95% de todas as pescarias mundiais localizam-se em águas costeiras. A guaiúba *Ocyurus chrysurus* (Bloch, 1791) faz parte desse percentual, ocorre no Atlântico ocidental da Carolina do Norte até o sudeste do Brasil, incluindo Bermuda, Golfo do México e Antilhas (Allen 1985), sendo mais comum nas Bahamas, sul da Flórida e no Caribe (Fischer 1978). Indivíduos jovens habitam águas costeiras, comumente associadas a recifes. Exemplos adultos distribuem-se em águas mais profundas da plataforma continental interna e externa (Manooch & Drennon 1987).

Entre 1950 e 2006, as capturas desse recurso, a partir do sul dos estados Unidos até o sudeste do Brasil, aumentaram de 200 t para 8.153 t (FAO 2007). Entre 1978 e 2004 (SUDEPE 1978 a 1979, IBGE 1980 a 1989, IBAMA 1990 a 2004), o peso desembarcado da guaiúba no nordeste brasileiro (Piauí a Bahia) representou uma média de 25,3% do total capturado em toda sua área de ocorrência. Dentre os países que exploram esse recurso, destacam-se Cuba e México, os quais são responsáveis por 30% da produção mundial em 2001 (FAO 2001). Muller *et al.* (2003), relataram que entre 1997 e 2000 foi capturada uma média anual de 3.458 t no Caribe.

No Brasil, as estatísticas mais recentes divulgadas pelo IBAMA (2002 a 2004), estimaram capturas entre os estados do Piauí e Bahia de 2.655 t (2002), 3.640 t (2003) e 3.901 t (2004). Os estados do Ceará e Bahia contribuíram com os maiores volumes desembarcados no período, de 43,4% e 39,4%, respectivamente. Em 2004, de 15.194 t de peixes capturadas no estado do Ceará (IBAMA 2004), a guaiúba representou 10,8% (1.644 t). No mesmo ano, na Bahia, o recurso foi responsável por 4,6% (1.654 t) do total desembarcado de peixes (35.879 t).

Dados de captura e esforço (CPUE) de pescarias têm sido utilizados para estabelecer índices relativos de abundância. A habilidade para usar taxas de captura como um índice de abundância depende da utilização de um método que remova os impactos de fatores que influenciam as capturas (composição da frota, tempo e área), que não estão relacionados a variações reais da abundância (Maunder & Punt 2004). Vários métodos têm sido desenvolvidos para padronizar capturas (Gulland 1956, Beverton & Holt 1957, Robson 1966, Honna 1973). Modelos Lineares Generalizados

(McCullough & Nelder 1989) é atualmente o método mais aplicado para padronização de dados de CPUE (Helser *et al.* 2004).

Historicamente, aplicação de GLMs tem sido na padronização de índices de abundância baseados em dados comerciais de captura e esforço (Kimura 1981, Punt *et al.* 2000, Punt *et al.* 2001, Campbell 2004, Chen & Nishida 2004, Maunder & Punt 2004, Xiao 2004) ou dados de cruzeiros (Stefánsson 1996). Contudo, aplicações também têm incluído estimativas de seletividade de aparelhos de pesca (Myers & Hoenig 1997), estimativas de taxas de captura de *bycatch* (Ortiz *et al.* 2000, Ortiz & Arocha 2004) e em estudos de parâmetros biológicos, tais como crescimento (Bromley 2000) e muitos outros.

Estudo de pescarias, tradicionalmente, tem focalizado na abundância de peixes, morfologia, comportamento, crescimento e reprodução. Técnicas quantitativas de cruzeiros científicos incluem estudos de ovos e larvas, marcação e recaptura e cruzeiros de arrasto para projetar o tamanho da população (Foote 1996). Geralmente, problemas espacialmente explícitos não têm sido incorporados dentro desses estudos, exceto para associar o comportamento e a fisiologia com variações ambientais.

Recentemente, grande ênfase tem sido dada à importância do padrão espacial, sua escala e variação como um componente no processo ecológico (Petitgas 1993, Horne & Schneider 1995). A importância da heterogeneidade de recursos biológicos e físicos tem sido reconhecida como um fator crítico na manutenção de populações (Legendre & Fortin 1989).

Reconhecer e realizar previsões da relação entre a dinâmica de estoques de peixes e a ocupação do habitat é fundamental para a efetiva avaliação e manejo de populações de peixes marinhos (Rubec *et al.* 2001). Tomadores de decisões de pescarias comerciais e recreativas, atualmente, reconhecem a importância do habitat para a produtividade de estoques de peixes (Rubec & McMichael 1996). Mapas precisos de habitats, associados à distribuição espacial de populações de peixes estão se tornando importantes ferramentas para manejo e proteção desses habitats, promovendo pescarias sustentáveis (Rubec *et al.* 1998b, Ault *et al.* 1999a).

A necessidade para manejar pescarias de uma perspectiva espacial é clara (Hinds 1992). Avaliação de estoques espacialmente referenciada apenas recentemente vem sendo desenvolvida. Sistema de Informação Geográfico (SIG) caracteriza-se por sistemas que organizam, analisam

e representam grafi-camente complexos e diversos dados com atributos geográficos (Nishida & Booth 2001). Existe um interesse crescente no desenvolvimento de SIG na área marinha, principalmente para visualizar conjunto de dados espaciais e prover uma plataforma de avaliação de estoques.

A tecnologia do Sistema de Informação Geográfico é essencial para o sucesso e implementação de medidas de manejo em capturas de pescarias, particularmente na inicial caracterização do ambiente, na correlação espacial de potenciais ameaças ao habitat, na evolução de impactos acumulativos e no monitoramento da qualidade e quantidade do habitat. Mapeamento do ecossistema, modelagem e a determinação de ambientes essenciais de peixes são atualmente realizados com SIG (Booth, 1998; Fisher *et al.*, 2000; Ross & Ott, 2000).

O presente estudo teve por objetivos estabelecer um índice padronizado de abundância relativo (CPUE) a partir das capturas de *O. chrysurus* realizadas por diferentes embarcações da frota pesqueira artesanal de linha de fundo na região nordeste do Brasil, recorrendo a um conjunto de covariáveis em GLMs e avaliando o impacto sobre a CPUE convencional. Os índices de abundância padronizados foram ainda modelados espacialmente e representados num SIG.

Materiais e Métodos

Os dados do presente estudo são provenientes do Programa de Avaliação do Potencial Sustentável da Zona Econômica Exclusiva Brasileira (REVIZEE) e foram coletados pela sub-área de Dinâmica de Populações do nordeste. As atividades de amostragens de peixes dos desembarques da frota artesanal motorizada e a vela do nordeste foram desenvolvidas entre fevereiro de 1998 e abril de 2000. Os pontos de coleta ao longo de toda a região nordeste foram escolhidos com base no volume de pescado desembarcado (IBAMA 1991 a 1997).

Dados sobre as pescarias foram registrados e completados com as seguintes informações coletadas dos mestres das embarcações no momento dos desembarques: nome da embarcação; tipo e categoria da embarcação (classificadas segundo IBAMA 1997); total desembarcado (Kg) e por espécie; número de pescadores; tempo efetivo de pesca; período das pescarias (noturno, diurno e ambos); localização e profundidade dos pesqueiros (áreas de pesca), tipo e quantidades dos petrechos de pesca empregados nas capturas.

Os dados analisados são provenientes da frota que operou com linha de fundo no período.

O esforço de pesca empregado nas capturas por distintas embarcações foi considerado o número de anzóis multiplicado pelo tempo efetivo de pesca (tempo de imersão dos anzóis na água em dias). As áreas de pesca (pesqueiros) foram regionalizadas (latitude e longitude) e um mapa foi estabelecido no Software ArcView GIS 3.1 (1999), apresentando espacialmente as áreas onde a frota de linha atuou nas capturas.

Modelos Lineares Generalizados ou GLMs foram formalmente introduzidos por Nelder & Wedderburn (1972). Posteriormente foram expandidos por McCullagh & Nelder (1989) e incorporados em avaliações de recursos pesqueiros (Helser *et al.* 2004, Maunder & Punt 2004, Venables & Dichmont 2004). Duas classes de modelos GLM foram utilizados neste trabalho. A primeira foi ajustada a todos os dados (pescarias da frota de linha de fundo), considerando a variável resposta (Y) como variável dicotômica, denotando presença ou ausência de *O. chrysurus*. O modelo de distribuição de probabilidade utilizado $f(Y)$ foi o binomial e a função de ligação logística ($\delta(\mu) = \log(\mu/(1-\mu))$). O modelo proposto apresentou a seguinte estrutura em suas covariáveis:

Presença $\sim \beta + \text{embarcação} + \text{período de pesca} + \text{profundidade} + \text{latitude} + \text{distância da costa} + \text{mês} + \text{embarcação} \cdot \text{esforço}$.

Onde: β é o termo intercepto.

A segunda classe de modelo GLM foi ajustada exclusivamente aos dados em que houve captura da guaiúba e considera como variável resposta (Y) o peso (Kg) total da captura. Neste caso, foram utilizados os modelos de probabilidades $f(Y)$ normal e gama, e como função de ligação às funções identidade ($\delta(\mu) = \mu$) e logarítmica ($\delta(\mu) = \log(\mu)$). As unidades amostrais são pescarias. Essa classe de modelo apresentou a seguinte estrutura:

Peso esperado $\sim \beta + \text{embarcação} + \text{período de pesca} + \text{profundidade} + \text{latitude} + \text{ano} + \text{embarcação} \cdot \text{esforço}$

Onde: β é o termo intercepto.

As escolhas do modelo de probabilidade, da função de ligação e das covariáveis explicativas importantes foi realizada pelo critério de informação de Akaike (AIC) (Akaike 1973) (1). A escolha do melhor modelo entre um conjunto de possíveis modelos se dá em função do menor valor de AIC (Burnham & Anderson 2002).

$$AIC = 2k - 2\ln(L) \quad (1)$$

Onde: k é o número de parâmetros do modelo; L é o valor maximizado da função de verossimilhança do modelo estabelecido.

Após a seleção do melhor modelo GLM (i.e., a combinação mais adequada entre distribuição de probabilidade para a variável resposta, função de ligação e conjunto de covariáveis), foram verificados quais os níveis dos fatores e das interações foram estatisticamente significativas para explicar a variabilidade das variáveis respostas. O nível de significância de 0,05 (valores de P), foi utilizado na análise dos coeficientes estimados nos GLMs.

Após ter estimado os parâmetros nos dois modelos, estes modelos foram utilizados para estimar uma captura padronizada por unidade de esforço, procedendo conforme descrito a seguir. Fixamos um tipo de embarcação (bote motorizado) e uma unidade de esforço (Kg/anzol/dia), e estimamos para todos os pontos amostrais (pescarias realizadas pela frota de linha de fundo) da seguinte forma: a) a probabilidade de presença da espécie no modelo do primeiro tipo; denotando essa estimativa por $\hat{\mu}_{(1)}$; b) a captura esperada média para uma unidade de esforço de botes motorizados, condicionado a presença da espécie. Denominamos essa estimativa por $\hat{\mu}_{(2)}$. Bote motorizado foi escolhido para criação da CPUE padrão porque representa a embarcação mais freqüente em número e em peso desembarcado na região (Nóbrega & Lessa, 2007).

Finalmente, a captura padronizada por unidade de esforço, $\hat{U}$ é o produto das duas estimativas anteriores (2). Dessa forma, a CPUE padronizada para botes motorizados foi estabelecida, visando minimizar variações da abundância que podem ser causadas pela frota pesqueira, tempo e espaço.

$$\hat{U} = \hat{\mu}_{(1)} \cdot \hat{\mu}_{(2)} \quad (2)$$

Para avaliar o impacto dos GLMs sobre a padronização da CPUE, uma CPUE convencional (U_c) utilizando as mesmas unidades (Kg/anzol/dia) também foi calculada para os lances positivos da guaiúba, usando a seguinte equação: $CPUE = (\text{peso total capturado por pescaria} / (\text{n}^\circ \text{ anzóis} \cdot \text{tempo de imersão na água}))$, sendo medido o tempo de imersão dos anzóis na água em dias de pesca. Para possibilitar a comparação entre as duas CPUEs em relação aos meses e anos do período de estudo, variáveis normalizadas Z_1 (U_c) e Z_2 ($\hat{U}$) foram calculadas.

$$Z_1 = \frac{U_c - \text{média}(U_c)}{dp(U_c)} \quad \text{e}$$

$$Z_2 = \frac{\hat{U} - \text{média}(\hat{U})}{dp(\hat{U})}$$

Modelos de regressões lineares (3), quadráticos (4) e cúbicos (5) (Seber & Wild 2003) foram testados para identificar tendências da CPUE padronizada de botes motorizados em relação à distância da costa, profundidade e latitude. Para modelar a abundância relativa em função da distância da costa, a área de estudo foi dividida em duas partes: 13°S a 4°S e 4°S a 2°S. A separação desses intervalos de latitude foi realizada mediante análise das distâncias da costa de captura em relação à latitude, onde se verificou que a partir de 4° S a plataforma continental é acentuadamente mais extensa.

Foi ainda testada uma regressão não linear (6) para CPUE padronizada em relação à profundidade e distância da costa, desenvolvida pelo Dr. Eduardo Ferrandis (co-autor do presente estudo) para modelar a abundância dos recursos demersais em relação à profundidade no Mediterrâneo Espanhol. O nível de significância para a relação entre as variáveis foi de 0,05 e a seleção dos modelos foi feita mediante a comparação do

coeficiente de determinação ajustado ($\bar{R}^2$) (7) e AIC (8). Foi também utilizada como seleção dos modelos a significância a um nível de 5% para os coeficientes quadráticos e cúbicos gerados nos modelos polinomiais.

$$E(Y) = \beta_0 + \beta_1 x \quad (3)$$

$$E(Y) = \beta_0 + \beta_1 x + \beta_2 x^2 \quad (4)$$

$$E(Y) = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 \quad (5)$$

$$E(Y) = \frac{k * (x - \alpha) * (\beta - x)}{(x^2 - ax + b)} \quad (6)$$

Onde: $E(Y)$ = valor esperado da variável resposta;

β_0 = coeficiente linear; β_1 = coeficiente angular; β_2 = coeficiente quadrático; β_3 = coeficiente cúbico; x = distância da costa, profundidade ou latitude; k, a, b é um conjunto de parâmetros da regressão não linear, que descrevem as tendências da variável resposta em relação a x (profundidade, distância da costa); α e β é a variação de x do recurso estudado.

$$\bar{R}^2 = \frac{\frac{1}{n-2} SQR}{\frac{1}{n-1} SQT} \quad (7)$$

Onde: n = número de observações usadas na regressão; SQR = soma dos quadrados dos resíduos; SQT = soma dos quadrados totais.

$$AIC = n \log \left(\frac{SQR}{n} \right) + 2k \quad (8)$$

Onde: n = número de observações usadas na regressão; SQR = soma dos quadrados dos resíduos; k = número de parâmetros do modelo

As tendências de índices de CPUE padronizada identificadas nos modelos de regressão que apresentaram o melhor ajuste para profundidade e latitude foram combinadas em um “caminho multiplicativo”, para criação de um modelo geográfico (Journal & Huijbregts 2004), que descreve as tendências de índices de abundâncias médios para profundidade e latitude. Esse modelo geográfico foi estimado utilizando uma regressão não linear, com a seguinte equação: $K * \text{Modelo batimétrico} * \text{Modelo latitudinal}$, cujo K é um parâmetro desse modelo. Além do erro padrão e intervalos de confiança de 95% estimados pela regressão não linear para o parâmetro K , também foi utilizado um procedimento bootstrap (Gill *et al.* 1981) baseado em 10 amostras, para estimar um erro padrão e intervalo de confiança para K .

Para representar espacialmente (Journal & Huijbregts 2004) o modelo geográfico, estabelecido para a CPUE padronizada da guaiúba, foi utilizado a interface do Sistema de Informação Geográfico ArcView GIS 3.1 (1999). Um mapa da área de estudo foi construído, utilizando dados regionalizados (latitude e longitude) digitalizados da linha de costa (19.177 pontos), das isóbatas de 50 m (5.626 pontos), 100 m (4.484 pontos), 200 m (4.225 pontos) e 1000 m (3.849 pontos). A partir dos pontos da linha de costa e isóbatas foram criadas linhas, posteriormente polígonos e, utilizando o módulo Spatial Analysis 1.0 do ArcView GIS 3.1 uma reticula foi interpolada para toda a área da costa até 1000 m de profundidade, criando um polígono com a batimetria e latitude em todos os pontos da área da costa até 1.000 m de profundidade.

Utilizando o módulo Spatial Analysis 1.0 do ArcView GIS 3.1, os modelos de abundância estimados para batimetria e latitude foram criados espacialmente, dentro do polígono (0 a 1000 m) para toda a área de estudo. Esses modelos foram combinados em um caminho multiplicativo através da seguinte equação: $K * \text{Modelo de batimetria} * \text{Modelo de latitude}$, cujo valor de K é aquele estimado na regressão não linear que estabeleceu o modelo geográfico. Dessa forma, o modelo geográfico do recurso foi criado no Sistema Geográfico de Informação, descrevendo espacialmente a abundância relativa média (CPUE padronizada) da guaiúba para o período de estudo.

Resultados

A guaiúba foi registrada em 754 pescarias (48,5%), de um total de 1.556 realizadas pela frota que operou com linha de fundo. O peso desembarcado no período de estudo totalizou 8,997 t, representando 9,4% das 95,953 t capturadas por essa frota. O peso capturado por desembarque variou entre 0,1 e 164,3 Kg (média=11,95 Kg; desvio padrão=18,75 Kg). Entre abril e outubro foram registrados os maiores pesos médios de captura (Tabela I).

Foram registrados 221 diferentes barcos que capturaram a guaiúba na região nordeste do Brasil, representando 56,7% do total das 392 embarcações que compuseram a frota de linha de fundo no período de estudo. Botes motorizados contribuíram com a maior parte (47,2%) das pescarias (Tabela II). Um total de 225 áreas de pesca foi identificado nas capturas da guaiúba, representando 63,6% do total de áreas utilizadas ($n=353$) pela frota de linha de fundo (Figura 1). As profundidades de captura da guaiúba variaram de 11 a 204 m (média=61,6 m; desvio padrão=26 m), enquanto a profundidade de captura da frota de linha variou de 7 a 340 m (média=64,7 m; desvio padrão=29,3 m). As distâncias da costa nas capturas da guaiúba foram de 3,28 a 92 Km (média=20,04 Km; desvio padrão=15,02 Km). Para a totalidade de pescarias da frota de linha, a distância da costa de captura variou de 2,45 a 92 Km (média=20,24 Km; desvio padrão=14,52 Km).

Todas as covariáveis inseridas no GLM para modelar as probabilidades de presença da guaiúba nas capturas da frota de linha de fundo foram estatisticamente significativas (Tab. III). Segundo esse modelo GLM, jangadas apresentam a maior probabilidade de presença da guaiúba nas capturas, já botes motorizados as menores, sendo os níveis dos fatores estimados para essas embarcações estatisticamente diferentes de saveiros motorizados (Tab. IV). A interação do esforço de canoas a vela, botes motorizados e a vela foram maiores em relação às outras embarcações, com diferenças significativas (Tab. IV). Pescarias realizadas no período diurno apresentaram as menores probabilidades de capturar a guaiúba, com diferença significativa em relação ao período noturno (Tab. IV).

No GLM calculado para modelar o peso esperado da guaiúba o modelo gama, com função de ligação identidade apresentou o melhor ajuste, resultando o menor valor de AIC. Todas as variáveis inseridas nesse modelo são estatisticamente significativas (Tab. V) e influenciam na variação do peso capturado da guaiúba.

Tabela I. Número total de pescarias, pescarias em que a guaiúba foi capturada, peso médio de captura e desvio padrão, esforço médio empregado para totalidade das pescarias realizadas pela frota de linha de fundo, nos meses agrupados de fevereiro de 1998 a abril de 2000.

Mês	Nº total de pescarias	Nº de pescarias com captura	Peso capturado Médio (Kg)	Desvio padrão do peso médio	Esforço médio p/ total pescarias
1	137	44	8,2	12,2	20,1
2	117	38	4,2	4,1	21,7
3	154	68	6,7	10,5	23,2
4	167	83	10,4	16,3	19,1
5	140	72	17,0	26,4	26,9
6	101	52	10,7	15,1	15,5
7	105	67	14,4	20,3	13,5
8	122	67	16,7	21,3	15,7
9	152	81	12,9	22,6	18,2
10	129	79	16,8	24,6	15,6
11	113	65	8,5	10,2	25,6
12	119	38	9,6	10,7	20,6

Tabela II. Número total de pescarias, pescarias em que a guaiúba foi capturada, peso médio de captura e desvio padrão, esforço médio empregado na totalidade das pescarias realizadas pela frota de linha de fundo.

Embarcação	Nº total de pescarias	Nº de pescarias com captura	Peso capturado Médio (Kg)	Desvio padrão do peso médio	Esforço médio p/ total pescarias
Bote motorizado	734	271	12,0	21	20,8
Bote a vela	91	26	27,2	26	42,4
Canoa a vela	33	15	17,9	13	36,9
Jangada a vela	171	105	3,8	6	28,6
Lancha motorizada	4	1	8,5		4,8
Saveiro motorizado	523	336	13,0	18	10,6

Tabela III. Graus de liberdade e valores de P para o intercepto e variáveis explicativas utilizadas no GLM para modelar a probabilidade de presença da guaiúba nas capturas da frota de linha de fundo, utilizando o modelo binomial e função de ligação logit.

Efeitos	GL	P
Intercepto	1	0,0000
Embarcação	5	0,0000
Período de pesca	2	0,0000
Profundidade	1	0,0000
Latitude	1	0,0000
Distância da costa	1	0,0001
Mês	1	0,0000
Embarcação*Esforço	6	0,0002

Canoas, jangadas e botes a vela apresentaram os maiores níveis dos fatores, sendo estatisticamente diferentes de saveiros, resultando nas embarcações com maior esperança de captura em peso desse recurso no nordeste (Tab. VI). Botes a vela e motorizados apresentaram a maior declividade da interação entre embarcação e esforço, com diferenças significativas em relação a outras embarcações (Tabela VI). As pescarias realizadas no período noturno são aquelas com maior esperança de captura em peso, sendo estatisticamente diferente das realizadas no período diurno.

A comparação da CPUE padronizada ($\hat{U}$) e CPUE convencional (U_c) normatizadas em variáveis Z_1 , (U_c) e Z_2 ($\hat{U}$) indicou declínio claro de Z_2 entre 1998 e 2000, já Z_1 , entre 1998 e 1999 apresentou valores médios semelhantes e declínio em 2000 (Figura 2a). Em relação aos meses, a CPUE padronizada apresenta tendências mais acentuadas de diminuição e aumento (Figura 2b), com algumas diferenças do padrão para os meses de setembro a dezembro de 1998, quando Z_1 apresenta baixos valores, enquanto Z_2 os mais altos valores de todo o período de estudo. A U_c demonstra de forma geral, semelhanças na magnitude dos valores médios para

um mesmo mês nos diferentes anos do período de estudo, já a $\hat{U}$ indica que houve diminuição dos valores médios de um mesmo mês para os diferentes anos.

Na modelagem da CPUE padronizada em relação às distâncias da costa, entre as latitudes de 13°S e 4°S o modelo não linear (Figura 3a) resultou o melhor ajuste ($R^2=0,559$; AIC=735; $P<0,001$) e a seguinte equação:

$$CPUE = \frac{3,014 * DistCost * (50 - DistCost)}{((DistCost^2) - (-2,316 * DistCost) + 32,268)}$$

Segundo esse modelo, as maiores abundâncias desse recurso encontram-se até aproximadamente 15 Km da costa (Figura 3b), com

tendência de declínio em direção às maiores distâncias.

Para as latitudes menores que 4°S, o modelo não linear (Figura 3c) também apresentou o melhor ajuste ($R^2=0,549$; AIC=359; $P<0,001$), resultando a seguinte equação:

$$CPUE = \frac{0,704 * DistCost * (100 - DistCost)}{((DistCost^2) - (51,992 * DistCost) + 978,274)}$$

Esse modelo descreve as maiores CPUEs entre 20 e 40 Km da costa (Figura 3d), apresentando o recurso nesse intervalo de latitude, uma distribuição até longas distâncias da costa, resultado da grande extensão da plataforma continental nessa região.

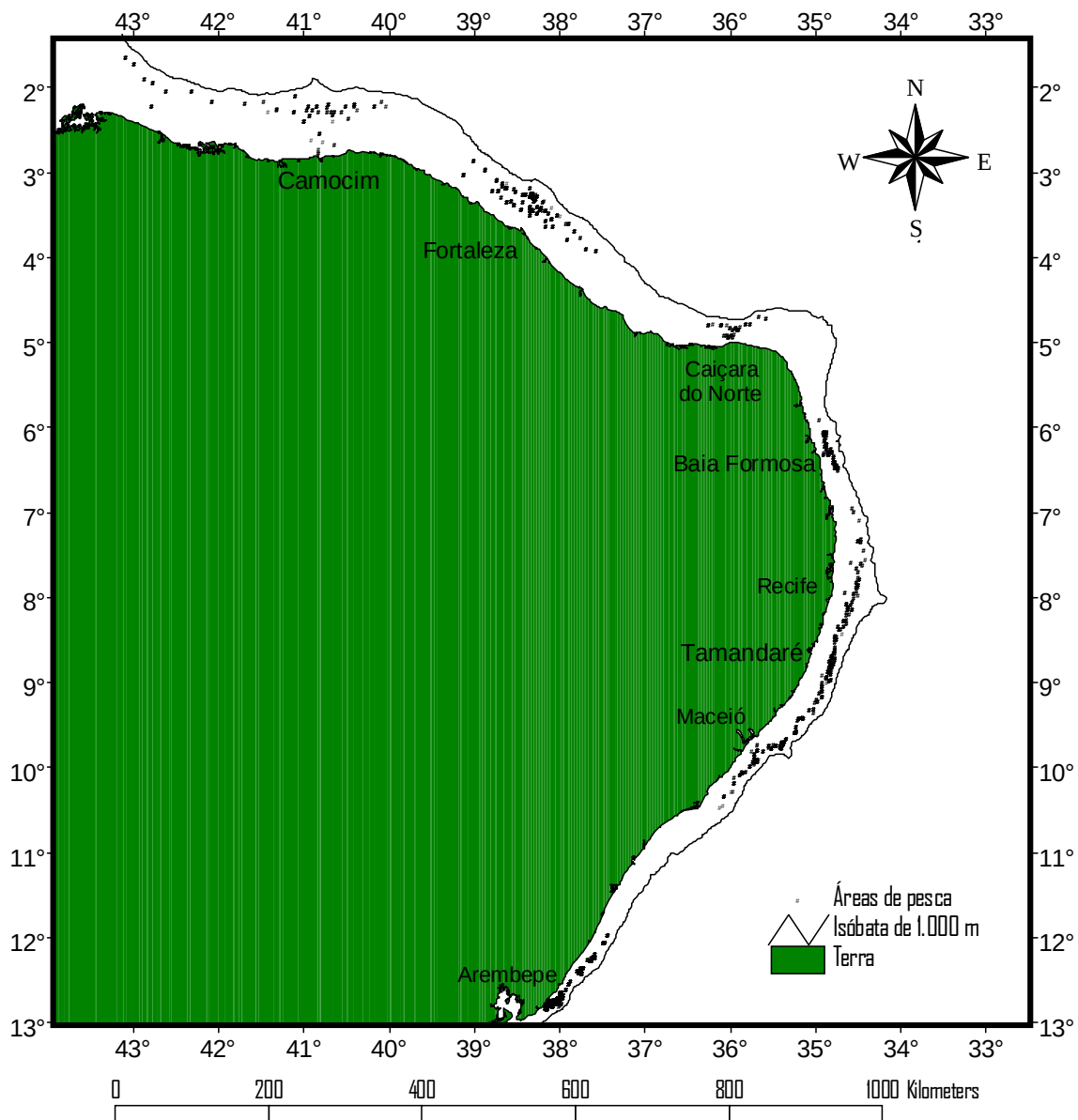


Figura 1. Localidades de amostragem dos desembarques e áreas de pesca identificadas nas pescarias realizadas pela frota de linha de fundo na região nordeste do Brasil.

Tabela IV. Resultados gerais da análise do GLM para variável resposta probabilidade de presença da guaiúba nas capturas da frota de linha de fundo, utilizando o modelo binomial e função de ligação logit.

Efeitos	B	Erro padrão	Intervalo de confiança 95%		P
			Inferior	Superior	
Intercepto	-3,7880	0,7092	-5,1781	-2,3980	0,0000
Bote motorizado	-0,9024	0,2224	-1,3383	-0,4665	0,0000
Bote a vela	0,1062	0,4574	-0,7903	1,0027	0,8164
Canoa a vela	0,3757	0,8067	-1,2054	1,9569	0,6414
Jangada a vela	2,3939	0,4818	1,4495	3,3383	0,0000
Lancha motorizada	1,1791	2,7876	-4,2846	6,6428	0,6723
Saveiro motorizado					
Período de pesca (ambos)	0,0648	0,1789	-0,2858	0,4154	0,7173
Período de pesca (diurno)	-1,0295	0,2119	-1,4448	-0,6142	0,0000
Período de pesca (noturno)					
Profundidade	-0,0180	0,0023	-0,0225	-0,0135	0,0000
Latitude	-0,3952	0,0496	-0,4923	-0,2981	0,0000
Distância da costa	0,0355	0,0088	0,0182	0,0528	0,0001
Mês	0,0781	0,0171	0,0446	0,1117	0,0000
Bote motorizado*esforço	0,0184	0,0055	0,0077	0,0291	0,0007
Bote a vela*esforço	0,0135	0,0053	0,0030	0,0239	0,0114
Canoa a vela*esforço	0,0332	0,0155	0,0028	0,0637	0,0324
Jangada a vela*esforço	-0,0109	0,0077	-0,0260	0,0042	0,1577
Lancha motorizada*esforço	-0,6144	0,7462	-2,0769	0,8481	0,4103
Saveiro motorizado*esforço	-0,0097	0,0085	-0,0264	0,0069	0,2527

Tabela V. Graus de liberdade e valores de *P* para o intercepto e variáveis explicativas utilizadas no GLM para modelar o peso esperado da guaiúba nas capturas da frota de linha de fundo, utilizando o modelo gama e função de ligação identidade.

Efeitos	GL	P
Intercepto	1	0,0003
Embarcação	5	0,0000
Período de pesca	2	0,0000
Profundidade	1	0,0032
Latitude	1	0,0000
Ano	1	0,0003
Embarcação*Esforço	6	0,0000

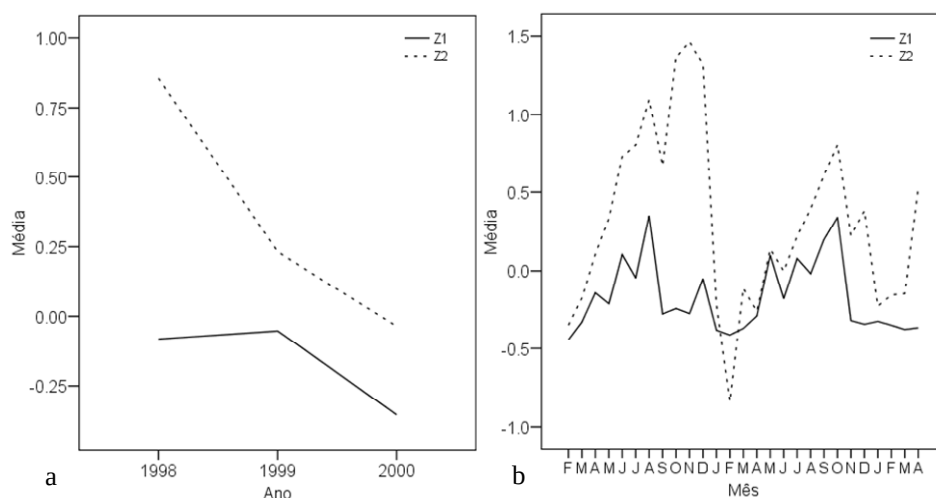
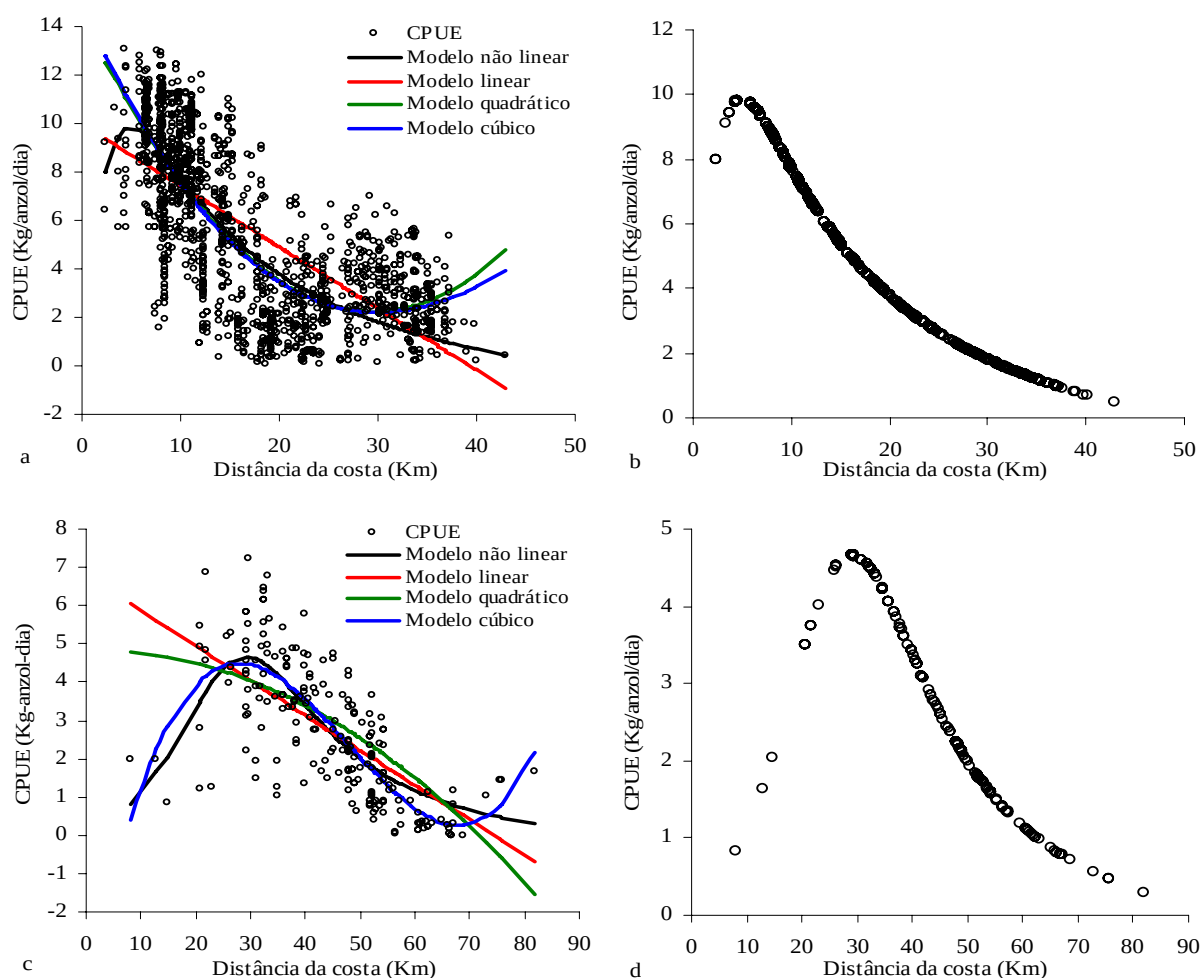
**Figura 2.** Valores médios para variável normalizada Z1 (CPUE convencional) e Z2 (CPUE padronizada), estimados para guaiúba capturada pela frota de linha no nordeste entre 1998 e 2000 (a), e nos meses de fevereiro de 1998 a abril de 2000 (b).

Tabela VI. Resultados gerais da análise do GLM para variável resposta peso esperado da guaiúba nas capturas da frota de linha de fundo, utilizando o modelo gama e função de ligação identidade.

Efeitos	B	Erro padrão	Intervalo de confiança 95%		P
			Inferior	Superior	
Intercepto	3,186	881	1,459	4,914	0,0003
Bote motorizado	0,0584	1,3419	-2,5718	2,6885	0,9653
Bote a vela	11,3716	1,5244	8,3838	14,3594	0,0000
Canoa a vela	22,6387	7,0350	8,8505	36,4270	0,0013
Jangada a vela	16,2663	1,6693	12,9946	19,5380	0,0000
Lancha motorizada	6,1995	9,1121	-11,6600	24,0590	0,4963
Saveiro motorizado	-	-	-	-	-
Período de pesca (ambos)	-1,7768	1,3349	-4,3932	0,8397	0,1832
Período de pesca (diurno)	-10,6648	1,2683	-13,1506	-8,1791	0,0000
Período de pesca (noturno)	-	-	-	-	-
Profundidade	0,0550	0,0186	0,0184	0,0915	0,0032
Latitude	-2,3570	0,1816	-2,7129	-2,0011	0,0000
Ano	-1,6034	0,4407	-2,4672	-0,7396	0,0003
Bote motorizado*esforço	0,1404	0,0387	0,0646	0,2162	0,0003
Bote a vela*esforço	0,3522	0,0842	0,1873	0,5171	0,0000
Canoa a vela*esforço	0,1104	0,1353	-0,1548	0,3757	0,4146
Jangada a vela*esforço	-0,0424	0,0140	-0,0698	-0,0150	0,0024
Lancha motorizada*esforço	0,0368	0,0334	-0,0287	0,1022	0,2712
Saveiro motorizado*esforço	0,0117	0,0615	-0,1088	0,1323	0,8486

**Figura 3.** Modelos testados para CPUE e distância da costa de captura da guaiúba, entre as latitudes de 13°S e 4°S (a) e valores estimados pelo modelo não linear (b). Modelos testados para CPUE e distância da costa entre 4°S e 1,68°S (c) e valores estimados pelo modelo não-linear (d).

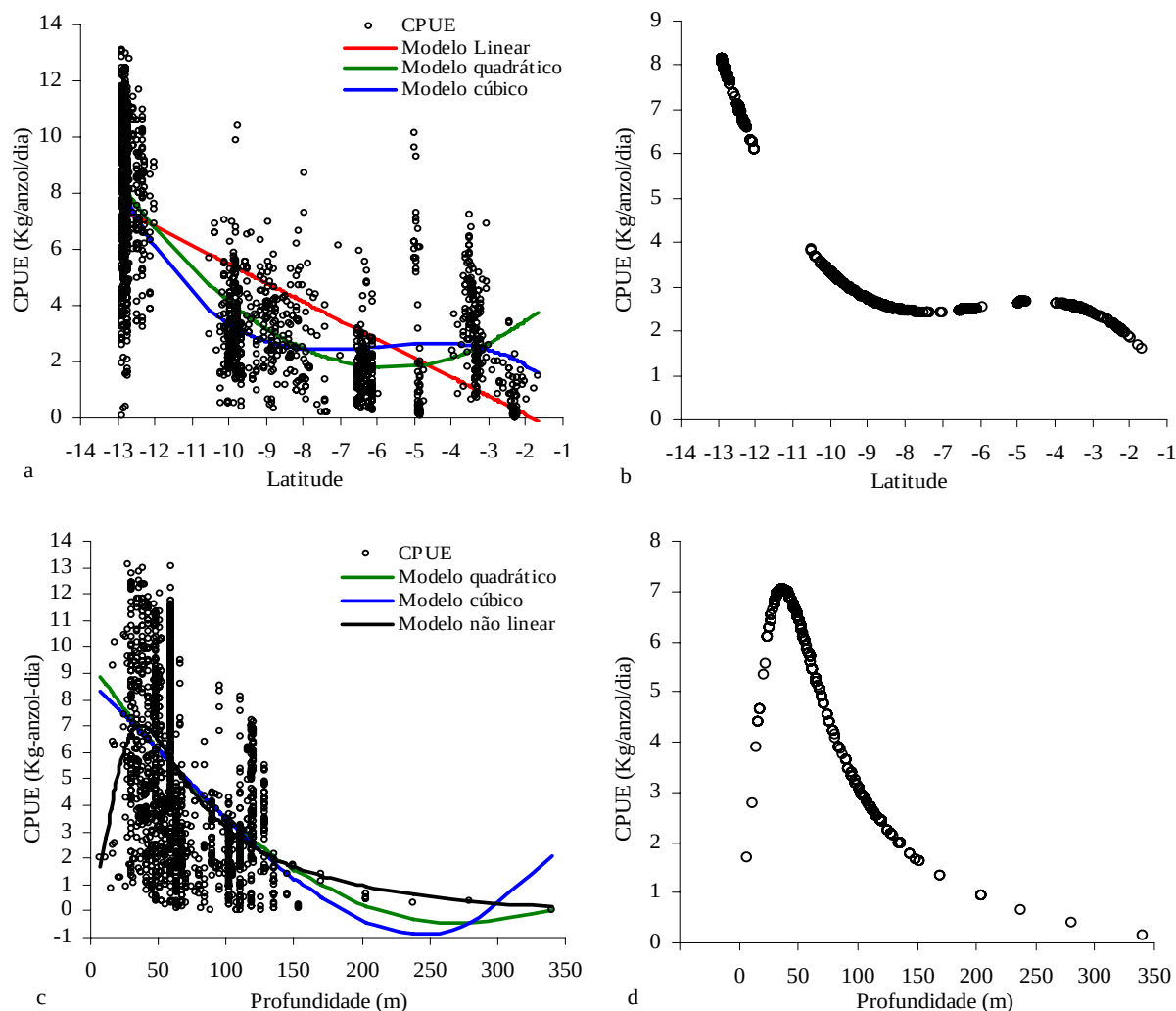


Figura 4. Modelos testados para CPUE e latitude (a) de captura da guaiúba e valores estimados pelo modelo parabólico cúbico (b). Modelos testados para CPUE e profundidade de captura da guaiúba (c) e valores estimados pelo modelo não-linear (d).

O modelo polinomial parabólico cúbico (Figura 4a) apresentou o melhor ajuste para CPUE e latitude ($R^2=0,628$; $AIC=369$; $P<0,001$). Esse modelo estimou as maiores abundâncias relativas no norte da Bahia (Figura 4b), resultando na seguinte equação:

$$CPUE = -0,677 - 1,872 * Lat - 0,377 * Lat^2 - 0,019 * Lat^3$$

As regressões testadas para CPUE e profundidade (Figura 4c) indicaram que o modelo não linear apresentou o melhor ajuste ($R^2=0,231$; $AIC=960$; $P<0,001$), sendo escolhido para descrever a variação da abundância relativa da guaiúba nas profundidades onde a frota de linha operou nas capturas, resultando na equação:

$$CPUE = \frac{0,831 * Prof * (400 - Prof)}{((Prof^2) - (36,162 * Prof) + 1.554,856)}$$

Segundo esse modelo (Figura 4d), entre 25 e 75 m de profundidade ocorrem as maiores

abundâncias da guaiúba dentro da área de estudo.

A regressão não linear utilizada para estabelecer o modelo geográfico se ajustou razoavelmente aos dados ($R^2=0,754$; $AIC=586$; $P<0,001$ - Tabela VII). Tendências médias para CPUE estimadas pelo modelo geográfico, indicam os maiores valores entre 25 e 50 m (Figura 5a), com declínio em direção a maiores profundidades e, praticamente, extinguindo-se das capturas da frota de linha de fundo do nordeste a partir de 200 m de profundidade. Em relação à latitude, no norte da Bahia foram verificados os maiores valores (Figura 5b), declinando em menores latitudes, com pequeno aumento entre $6^\circ S$ e $3^\circ S$.

O modelo geográfico estabelecido espacialmente, descreve as abundâncias médias relativas estimadas para CPUE padronizada de botes motorizados, desde $12,88^\circ S$ até $1,68^\circ S$, e entre as profundidades de 7 a 340 m (Figura 6). As maiores CPUEs médias são observadas nas proximidades de Salvador, com diminuição gradual em direção a

menores latitudes da área de estudo. Nota-se ainda, que entre 5°S e 3°S um pequeno aumento da CPUE é novamente visualizado, podendo ser também observado no modelo geográfico em relação a latitude (Figura 5b). A partir de 3°S em direção a menores latitudes as abundâncias relativas são baixas. Estimativas para esse modelo geográfico a partir de 2°S, em direção a menores latitudes devem ser interpretadas com cautela, devido ao reduzido número de pescarias que foram amostradas e

analisadas nessa área.

Tendências batimétricas da CPUE, entre 7 e 340 m de profundidade também estão incorporadas nessa cartografia, onde foram observados os maiores valores médios entre 25 e 125 m de profundidade (Figura 6), declinando em direção a maiores profundidades. Ainda, um gradiente latitudinal dentro da variação de abundância para batimetria, pode ser observado nas diferentes cores em relação a uma mesma profundidade ao longo da área de estudo.

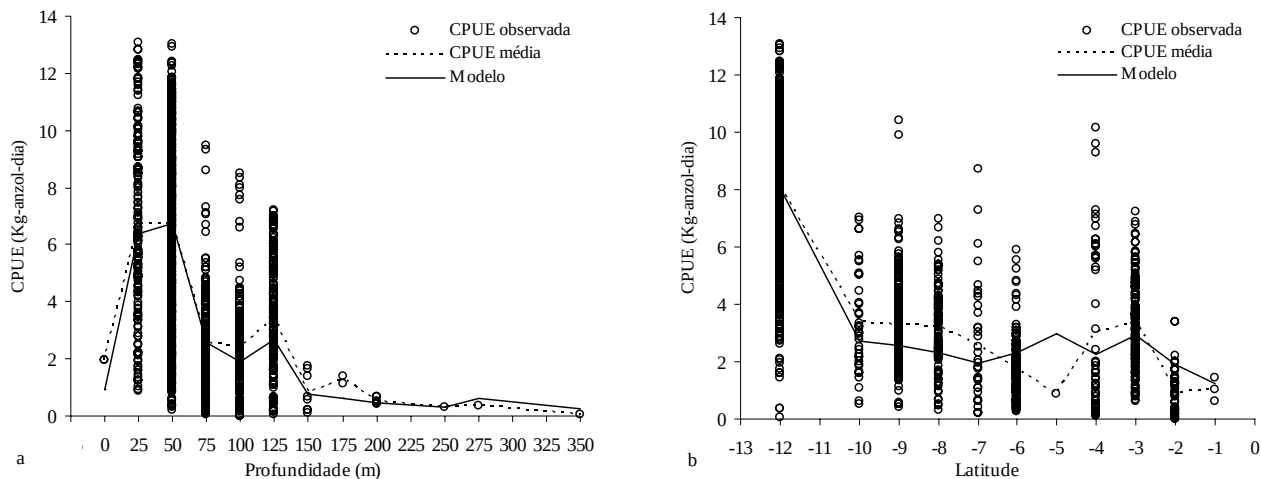


Figura 5. Modelo geográfico e CPUE média estimada em relação à profundidade (a) e latitude (b) em que a guaiúba foi capturada na região nordeste.

Tabela VII. Sumário dos parâmetros e estatísticas resultantes do modelo geográfico estimado para guaiúba (Bootstrap baseado em 10 amostras).

	Parâmetro	Estimado	Erro padrão	Intervalo de confiança	
				Inferior	Superior
Assintótico	K	0,1820	0,0013	0,1795	0,1846
Bootstrap	K	0,1820	0,0010	0,1797	0,1843

Discussão

A frota pesqueira artesanal de linha de fundo que capturou a guaiúba na região nordeste do Brasil é diversificada. Foram registrados no presente estudo seis tipos de embarcações motorizadas e a vela. Embarcações motorizadas são responsáveis pela maior parte dos desembarques (81,1%) e peso capturado (87,9%), provavelmente porque representaram 80,4% da frota de linha de fundo amostrada. Segundo Nóbrega & Lessa (2007), barcos motorizados contribuíram com 60,5% do peso total desembarcado pela frota artesanal no nordeste, entre 1998 e 2000.

Apesar de saveiros e botes motorizados serem responsáveis pelos maiores volumes desembarcados (85,2%) de *O. chrysurus*, capturas médias por desembarque indicam que botes e canoas a vela desembarcaram valores superiores (Tabela II). Botes e canoas a vela empregam altos esforços

médios (Tabela II), podendo estar relacionado a maiores capturas médias de *O. chrysurus*.

Canoas, jangadas a vela e lanchas motorizadas apresentaram, segundo o GLM, as maiores probabilidades de capturar a guaiúba na região nordeste. Examinando as profundidades médias em que atuam as embarcações da frota de linha de fundo, percebemos que essas embarcações operam entre profundidades médias de 25 e 50 m (Figura 7a), exatamente onde foram estimadas os maiores índices de abundância observados e estimados pelo modelo batimétrico e geográfico.

A padronização da CPUE, utilizando GLMs permitiu agregar às análises uma grande quantidade de informação, principalmente a inclusão das pescarias em que a guaiúba não foi capturada e os efeitos do tempo, espaço e frota pesqueira que foram inseridos nos modelos GLMs utilizando variáveis estatisticamente significativas e que são importantes

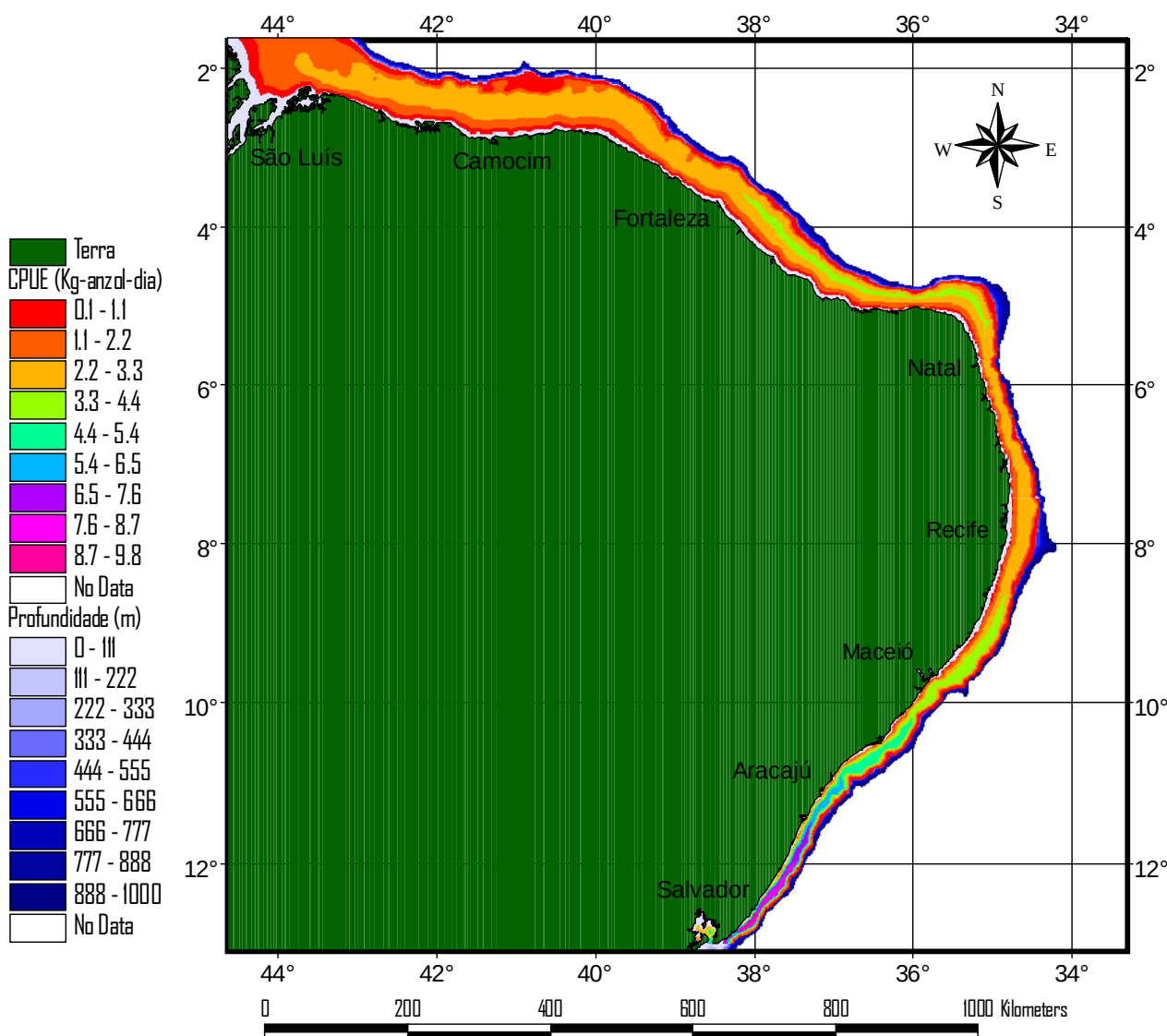


Figura 6. Cartografia de abundância relativa média estimada pelo modelo geográfico para CPUE da guaiúba, capturada pela frota de linha de fundo no nordeste brasileiro, entre fevereiro de 1998 e abril de 2000.

na explicação da variação das capturas da guaiúba no nordeste. A necessidade de padronizar índices de abundância pode ser verificada quando comparamos a CPUE convencional e aquela padronizada para botes motorizados, as quais demonstram diferenças entre os anos e meses do período de estudo. Existe uma tendência em todo mundo para padronização de índices de abundância de dados de captura e esforço de pescarias, utilizando principalmente GLMs (Helser *et al.* 2004, Maunders & Punt 2004, Nishida & Chen 2004, Venables & Dichmont 2004, Xiao 2004).

A metodologia de padronização de índices de abundância utilizada no presente estudo representa uma importante ferramenta, uma vez que permitiu identificar os fatores das diferenças do poder de pesca de distintas embarcações, do tempo e espaço. Uma vez identificado esses fatores foi possível criar uma CPUE padrão para a embarcação

mais freqüente na região, considerando dessa forma que todas as capturas foram realizadas por esse tipo de embarcação, minimizando as variações que não são devidas a reais mudanças da abundância da guaiúba. Capturas são padronizadas para remover o efeito de fatores como tempo, área, profundidade e composição da frota pesqueira (Hilborn & Walters 1992, Punt *et al.* 2000).

Os modelos de regressão ajustados para o índice de abundância padrão permitiram identificar tendências médias da distribuição de *O. chrysurus* no nordeste brasileiro. Os mais baixos níveis de abundância foram verificados a partir do estado do Ceará. Estatísticas divulgadas para a espécie na região (IBAMA 2002 a 2004) indicam que o Ceará contribui com a maior parte do peso desembarcado dessa espécie (43,4%). Altos níveis de esforço foram observados para a frota do estado do Ceará (Fig. 7b), podendo explicar os baixos níveis de abundância

estimados para o recurso nesse estado. Esses resultados sugerem que o grande volume capturado no Ceará está relacionado ao elevado esforço empregado, o que pode estar promovendo o declínio da abundância desse recurso na região.

Segundo Ferreira *et al.* (2004), o *O. chrysurus* capturado na região nordeste encontra-se sobreexplotado, necessitando redução da mortalidade por pesca. Klippel *et al.* (2005) também estimaram níveis de mortalidade por pesca acima do esforço máximo sustentável na costa central do Brasil. De acordo com a instrução normativa do Ministério do Meio Ambiente (IN MMA nº 05), medidas de manejo para a espécie devem ser implementadas, tendo em vista seu estado de espécie sobreexplotada. Especial atenção para essas medidas de manejo deve ser direcionada para a costa e frota pesqueira do Ceará, onde altos níveis de esforço e baixas abundâncias foram estimados no presente estudo. A diminuição da abundância média padronizada entre os anos de 1998 e 2000 (Figura 2a e b) pode estar relacionada à intensa exploração e declínio do estoque desse recurso. No estado da Bahia foram verificados os maiores volumes em peso desembarcado e índices de abundância. Esse recurso também é muito importante para a frota de linha na costa central brasileira (Salvador ao norte do Rio de Janeiro), onde representou 25% do total desembarcado por essa frota entre 1997 e 2000 (Costa *et al.* 2005).

Índices médios de abundância foram maiores entre 25 e 50 m de profundidade, segundo os valores médios e modelos batimétrico (Figura 4d) e geográfico (Figura 5a) estabelecidos. As pescarias realizadas entre essas profundidades somam 61% dos dados analisados no presente estudo. O esforço em pescarias comerciais é concentrado nas regiões onde os rendimentos dos recursos de maior valor econômico são maiores (Hart & Reynolds 2002). A distribuição dos estoques é limitada por fatores ecológicos, como nutrientes e relevo dos habitats, sendo escolhidos pelas espécies por características de sua alimentação, predação e reprodução (Helfman *et al.* 1997). Costa *et al.* (2005), estimaram maiores abundâncias médias de *O. chrysurus* na costa central do Brasil entre 20 e 60 m de profundidade, concordando com os resultados obtidos no presente estudo. Paiva & Fonteles-Filho (1995) também relataram que os rendimentos de peixes demersais são maiores entre 31 e 60 m de profundidade na área de Abrolhos, semelhante às profundidades em que a guaiúba apresentou as maiores abundâncias médias no nordeste brasileiro.

O modelo não linear utilizado no presente estudo apresentou bom ajuste aos dados de CPUE padronizada em relação à distância da costa e profundidade, apresentando relações estatisticamente significativas e caracterizando-se no modelo que melhor descreve as tendências médias da abundância em relação a essas variáveis. Modelos lineares, parabólicos quadráticos e cúbicos frequentemente utilizados em análises espacial de dados (Cressie 1993, Manly 2001, Fortin & Dale 2005) apresentaram também razoável ajuste aos dados de CPUE e distância da costa e profundidade, no entanto, estimaram valores negativos de CPUE em maiores distâncias da costa e profundidades (Figuras 3a, 3c e 4c). A utilização desses modelos acarretaria na necessidade de retirada de pescarias que atuaram nessas distâncias da costa e profundidades, resultando em significativa perda de informação da distribuição espacial da guaiúba.

O modelo não linear utilizado possui um termo em sua equação (6) que fornece o limite da distribuição em relação à distância da costa e profundidade de ocorrência do recurso, minimizando as possibilidades de estimativas de valores negativos. Apesar do baixo coeficiente de determinação observado ($R^2=0,231$) para a CPUE e profundidade resultante da utilização desse modelo não-linear (Fig. 4c), essa relação é estatisticamente significativa, os valores estimados de abundância descrevem de forma bastante razoável as tendências médias em relação à profundidade (Fig. 4c) e os resíduos apresentam distribuição aproximada a normal (Fig. 7c).

Os modelos não lineares estabelecidos para abundância em relação às distâncias da costa de captura indicam que a guaiúba possui uma distribuição diferenciada segundo a extensão da plataforma continental do nordeste. Na costa leste, o recurso está agregado em áreas mais próximas da costa, devido à menor extensão da plataforma continental nessa região, onde a distância da costa para isóbata de 200 m varia de 12,31 Km (12,88°S) a 63 Km (4,84°S). Já na costa norte do nordeste, a guaiúba apresenta maior concentração em áreas mais distantes da costa e distribui-se de forma mais dispersa, consequência da grande extensão da plataforma continental nessa área, onde dentro da área de estudo, a distância da costa para a isóbata de 200 m varia entre 48 Km (3,11°S) e 103,39 Km (2,08°S).

A guaiúba no nordeste brasileiro parece ter preferências por profundidades entre 25 e 50 m, que apresentaram as maiores abundâncias e provavel-

mente possuem as condições ambientais mais favoráveis para manutenção desse estoque. Em geral, os recursos biológicos apresentam uma distribuição com dependência espacial, já que argumentos ecológicos como a promoção da reprodução e controle da mortalidade natural frente à atuação de predadores, favorecem a agregação dos indivíduos (Helfman *et al.* 1997).

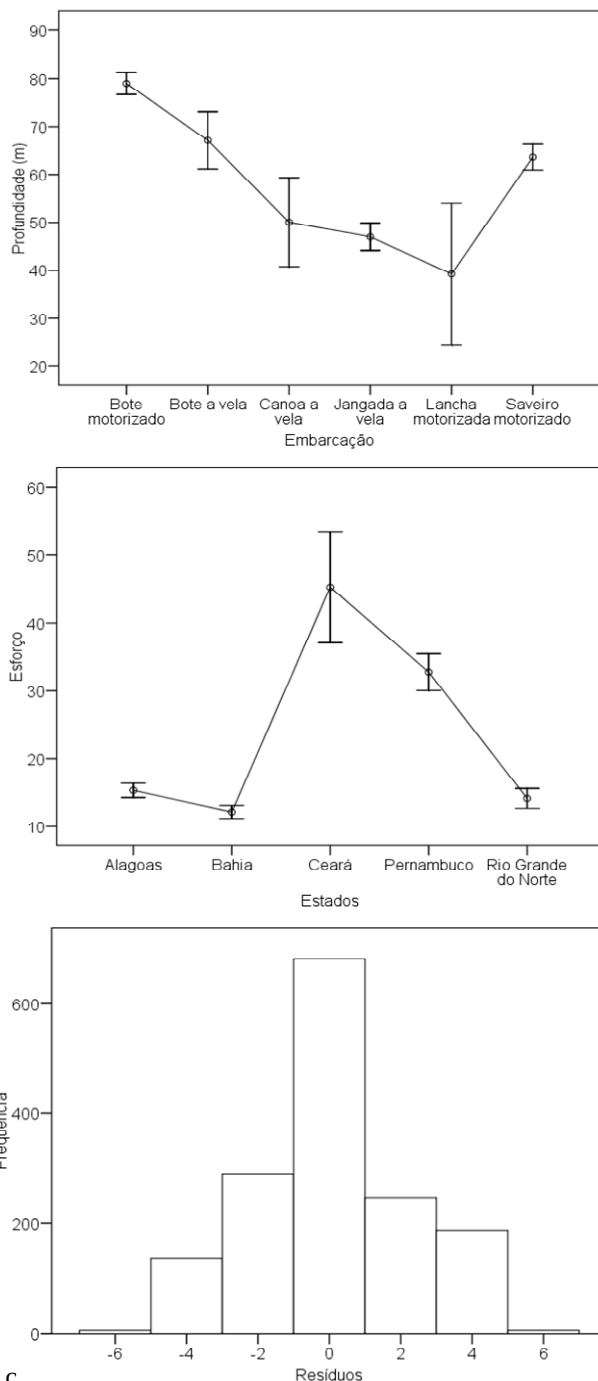


Figura 7. Profundidade média e intervalo de confiança em que atuam distintas embarcações da frota de linha de fundo (a); esforço médio e intervalo de confiança empregado pela frota nos diferentes estados do nordeste (b). Resíduos do modelo batimétrico estabelecido para CPUE e profundidade de captura da guaiúba (c).

Não foi observada distinção entre os índices de abundância em relação à profundidade para costa leste e norte do nordeste. Isso sugere que as diferenças na distribuição desse recurso em relação à distância da costa no leste e norte do nordeste, se devem à busca das profundidades que apresentam as condições hidrológicas e oceanográficas favoráveis à manutenção da espécie. A escolha de habitat é dinâmica para uma espécie, variando com a idade, tamanho, sexo, condições reprodutivas, áreas geográficas e condições ambientais (Karr 1981).

As áreas cujas profundidades variam entre 25 e 50 m na região nordeste constituem-se em um ambiente essencial para a manutenção do estoque da guaiúba. Atualmente, esse conceito tem sido muito discutido por autores que incluem a modelagem espacial de recursos em avaliações de estoques, os ambientes essenciais de peixes (Booth 1998, Fisher *et al.* 2000, Nishida & Miyashida 2000, Ross & Ott 2000). Medidas de manejo para a guaiúba no nordeste devem primordialmente considerar a criação de áreas de exclusão a pesca entre essas profundidades, o que pode permitir que a guaiúba e outros recursos desse habitat tenham uma chance de recuperar os níveis de biomassa do seu estoque.

A utilização da análise espacial, com desenvolvimento da técnica de geoestatística e posterior mapeamento, utilizando um SIG para identificar tendências médias de abundância do *O. chrysurus* devem contribuir para um melhor entendimento da correlação entre a distribuição e abundância desse recurso na região, assim como, para aplicação dessa metodologia na análise da distribuição espacial de outros importantes recursos pesqueiros da região. As possibilidades analíticas e funcionais oferecidas pelo SIG permitem aperfeiçoar a visualização, facilitar a investigação da dinâmica espaço temporal, associada com peixes, pescarias e seus ecossistemas (Nishida & Booth 2001).

Sistemas Geográficos de Informação são frequentemente utilizados por várias disciplinas e, não é surpresa, que atualmente essa tecnologia venha sendo incorporada dentro das investigações de pescarias (Giles & Nielsen 1992, Simpson 1992, Meaden 1996). Apesar de ainda pequena, a utilização de SIG tem aumentado em pesquisas de recursos pesqueiros. Aplicações pioneiras na área focalizaram o manejo de desembarques, pescarias costeiras (Caddy & Garcia 1986, Simpson 1992, Meaden 1996, Meaden & Do Chi 1996) e aquíicultura (Kapetsky *et al.* 1988, Meaden & Kapetsky 1991).

Num próximo artigo apresentaremos os resultados da distribuição espacial e temporal de

tamanhos e idades do *O. chrysurus* capturado pela frota de linha de fundo do nordeste. Acreditamos que com esses resultados contribuímos com as in-

formações necessárias, para um futuro ordenamento e criação de um plano de manejo do *O. chrysurus* capturado na região nordeste do Brasil.

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First case of an infection of the metacercariae of *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) in *Hypostomus regani* (Ihering, 1905) (Siluriformes: Loricariidae)

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Abstract. *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) was recorded infecting the eyes of a *Hypostomus regani* (Ihering, 1905) (Siluriformes: Loricariidae). This is the first report of a loricarid fish infected with *A. compactum*.

Key words: fish disease, diplostomid infection, new host, helminthology, Trematoda.

Resumo: **Primeiro caso de infecção por metacercárias de *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) em *Hypostomus regani* (Ihering, 1905) (Siluriformes: Loricariidae).** Relata-se a ocorrência de *Austrodiplostomum compactum* (Lutz, 1928) (Digenea, Diplostomidae) no olho de *Hypostomus regani* (Ihering, 1905) (Siluriformes: Loricariidae). Este é o primeiro registro de *A. compactum* infectando peixes da família Loricariidae.

Palavras-chave: doença em peixe, infecção por diplostomídeo, novo hospedeiro, helmintologia, Trematoda.

Austrodiplostomum compactum (Lutz, 1928) (Niewiadomska 2002a,b) has been previously reported in *Plagioscion squamosissimus* (Heckel, 1840), *Cichla ocellaris* (Schneider, 1801), *Cichla monoculus* Spix, 1831, *Crenicichla britskii* Kullander, 1982, *Cichlasoma paranaense* Kullander, 1983, *Hoplias malabaricus* (Bloch, 1794), *Satanoperca pappaterra* (Heckel, 1840) and *Geophagus brasiliensis* (Quoy & Gaimard, 1824) (see Machado *et al.* 2005 and references therein, Novaes *et al.* 2006) in Brazil. However, there are no reports on the occurrence of the metacercariae of this species infecting fishes in *Hypostomus* Lacépède, 1803. The aim of this study is to report the infection case of the metacercariae of *A. compactum* in the eyes of *Hypostomus regani* (Ihering, 1905).

The fish was collected on January 9, 2007, in the reservoir of Chavantes (23°43'36.32" S 049°43'52.94" W), medium Paranapanema river,

municipality of Fartura, São Paulo State, Brazil. Eighteen metacercariae (Figures 1 and 2) were removed from the vitreous humor and fixed in AFA solution under cover slip pressure. Ten specimens were stained with carmine and analyzed using a computerized system for image analysis (Qwin Lite 3.1 – Leica). The voucher specimens were deposited in the Coleção Helmintológica (CHIBB) of the Departamento de Parasitologia, Instituto de Biociências, Universidade Estadual Paulista - UNESP, Botucatu city, São Paulo State, Brazil, under register number CHIBB 3213.

The main characteristics of the observed metacercariae were: foliaceous body, slightly concave in the ventral face 1988 (1570-2281) µm long, 756 (543-864) µm wide; small conical segment in the posterior region 179 (73-335) µm long; small subterminal oral sucker 91 (69-102) µm long, 84 (75-99) µm wide; two lateral pseudosuckers in the anterior region – one 132 (93-148) µm long, 118

(68-157) μm wide and the other 131 (78-168) μm long, 119 (85-146) μm wide; oval pharynx, 73 (57-85) μm long, 64 (57-80) μm wide; esophagus, 111 (86-139) μm long; intestinal caeca ending near the posterior region; oval tribocytic

organ 373 (287-414) μm long, 243 (178-310) μm wide; gland cells occupying most of anterior region, extending from the beginning of intestinal caeca in the anterior region to the tribocytic organ (Figure 2).

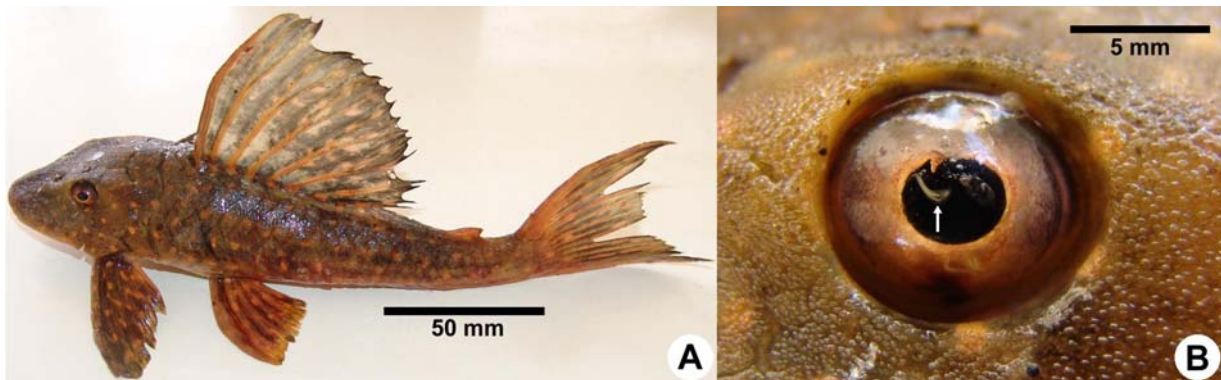


Figure 1. Metacercaria of *Austrodiplostomum compactum* (Lutz, 1928) Dubois, 1970 (Diplostomidae) in a specimen of *Hypostomus regani* (Ihering, 1905) (Loricariidae) from Chavantes reservoir, medium Paranapanema river, São Paulo State, Brazil. A) general view of the infected host; B) detail of a metacercaria of *A. compactum* in the eyes of the infected host (white arrow).

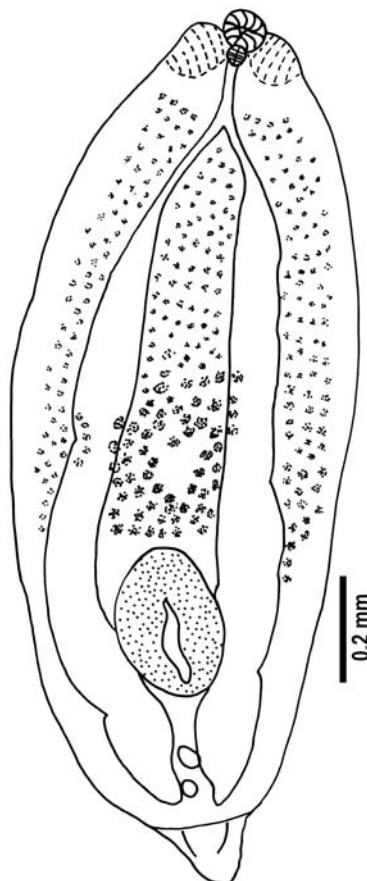


Figure 2. Metacercaria of *Austrodiplostomum compactum* (Lutz, 1928) Dubois, 1970 (Diplostomidae) found in the eye of *Hypostomus regani* (Ihering, 1905) (Loricariidae) from Chavantes reservoir, medium Paranapanema river, São Paulo State, Brazil.

Some studies have demonstrated that *P. squamosissimus* is highly susceptible to infection by *A. compactum* and the observed prevalence was higher than 90% while in *C. ocellaris* the prevalence

was lower (Santos *et al.* 2002). Kohn *et al.* (1995) found this infection in 100% of *P. squamosissimus* from the Paraná river. Machado *et al.* (2005) reported *A. compactum* infection in six fish species

from the Paraná river floodplain and the prevalence varied from 11.11 to 95.06% with the highest and lowest prevalence observed in *P. squamosissimus* and *H. malabaricus*, respectively.

These data demonstrate that infection by the metacercariae of *A. compactum* is frequently high but rarely observed in loricariid fishes. Amato *et al.* (2001) reported the only case of diplostomid metacercariae of an undetermined species found over and in the kidney ducts, over the liver and the peritoneum, in the abdominal cavity and in the brain of *Loricariichthys anus* (Valenciennes, 1840) from Rio Grande do Sul State, Brazil. *Hypostomus regani* is a new host recorded for *A. compactum*.

Austrodiplostomum compactum is generally located in the vitreous humor, but some larvae can also be found parasitizing the aqueous humor (Garcia *et al.* 1993) and the brain of their hosts (Conroy *et al.* 1985, Pineda-López 1985). According to Eiras (1994), the presence of this parasite in the eyes can cause blindness or harm vision, making the fish susceptible to predation that facilitates transmission of the parasite to the definitive host. For the diplostomids of *H. regani*, as the infection was observed in only one specimen, histopathological analyses were not accomplished. However, no morphological changes were noted by macroscopical examination.

Austrodiplostomum compactum metacercariae were found in the eyes of *H. regani* from the Chavantes reservoir, medim Paranapanema river. More than two thousand fish species have been described in Brazil (Buckup *et al.* 2007), however, only a few of them have been recorded as hosts for these metacercariae (Machado *et al.* 2005 and references therein, Novaes *et al.* 2006). These data suggest that other environmental features or the genetics of the hosts can contribute for the host-parasite interaction, in order to facilitate the infection for some fish species better than for others.

The species previously reported as hosts for *A. compactum* are mainly included in the Order Perciformes. *Hoplias malabaricus* is the only species of another order (Characiformes) parasitized by these diplostomid metacercariae. Pojmanska & Chabros (1993) demonstrated that the prevalence of diplostomids was significantly lower in native fishes and higher for the introduced species. These data were also observed by Machado *et al.* (2005) in Brazil. Probably, this metacercaria species was

introduced together with the hosts and has utilized native fish as the second intermediate hosts (Machado *et al.* 2005). The loricariid fishes are not phylogenetically related to Perciformes and

Characiformes. Thus, we suggest that the infection by metacercariae of *A. compactum* in these fishes may be associated with an environmental factor. Since the first intermediate host is an aquatic snail and the loricariid specimens are usually bottom fishes, the infection can occur because both use the same habitats, which increase the possibility of the encounter between host and parasite.

Species of *Biomphalaria* Preston, 1910 have aquatic environments with muddy or stony, shallow river-beds, with vegetation rooted closer to the banks as their preferential habitats (Neves *et al.* 2005). Lutz (1928) *apud* Amarista *et al.* (2001) observed that *B. prona* could be found on aquatic plants such as *Potamogeton* sp. Linnaeus, 1753 and species of Characeae Linnaeus, 1763. Amarista *et al.* (2001) reported that this mollusk was observed on *Eichhornia crassipes* (Martius, 1823) Solomons-Laubach, 1883 (Pontederiaceae Kunth), but it was more frequent on sandy and stony substrata. The fishes previously reported as hosts for metacercariae of *A. compactum*, occupy the same habitat, at least in some stage of their biological cycle, or use it as site for food intake (*P. squamosissimus*, *C. monoculus*, *C. britski* and *H. malabaricus*) (Almeida *et al.* 1997, Novaes *et al.* 2004) or as shelter for young specimens (*G. brasiliensis* and *C. paranaense*) (Bialetzki *et al.* 2002). *Hypostomus regani* also occupies these areas of the reservoir as a place for food and refuge (Delariva & Agostinho 2001). We conclude that all host species, including *H. regani*, are exposed to infection by *A. compactum* in that habitat, which would explain the eye infection only in a few fish species of the reservoir. Further studies will be carried out to investigate the prevalence of this infection in *Hypostomus* species in the reservoir at Chavantes, São Paulo State, Brazil.

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Feeding of *Farfantepenaeus paulensis* (Pérez-Farfante, 1967) (Crustacea: Penaeidae) inside and outside experimental pen-culture in southern Brazil

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Abstract. We assessed the value of benthic macroinvertebrates to the diet of *Farfantepenaeus paulensis* juveniles in experimental pen-cages after three independent rearing periods of 20, 40 and 60 days each. For each time period we initially stocked 3 pen-cages with 60 shrimps m⁻² supplemented with ration (treatment RS), and 3 pen-cages with 60 shrimps m⁻² without ration (WR). The diet of captive shrimps was compared with the diet of free shrimps (C). Shrimps fed preferentially on benthic preys. Captive shrimps extended their activity to daylight hours and consumed a significant amount of vegetation, likely in response to a severe decrease of macroinvertebrate density passed 20 and 40 days. After 60 days, the diet of the few survivors of *F. paulensis* in pen-cages without ration (WR) approached the diet of shrimps in the natural environment (C). These similarities were explained by the recovery of macroinvertebrates populations to relaxation from high predation pressure during the last 20 days of the experiment in WR pens. Considering the strong predatory control of *F. paulensis* over the benthic invertebrate assemblages we concluded that the value of natural production as food source for shrimps reared in pens is limited to the initial stage of the culture.

Key words: *Farfantepenaeus paulensis*; Penaeid shrimp; prawn predation; diet; pen culture; benthic invertebrate.

Resumen: Alimentación de *Farfantepenaeus paulensis* (Pérez-Farfante, 1967) (Crustacea: Penaeidae) dentro y fuera de corrales de cultivo experimentales en el sur de Brasil. Comparamos la importancia de macroinvertebrados bentónicos en la dieta de juveniles del camarón *Farfantepenaeus paulensis* en corrales de engorde experimentales tras tres periodos independientes de cultivo de 20, 40 y 60 días cada uno. Al inicio de cada período se incluyeron 60 camarones m⁻² en 3 corrales suplementados con ración (tratamiento RS), y 60 camarones m⁻² en 3 corrales sin la provisión de ración (WR). La dieta de los camarones cautivos se comparó con la de camarones capturados en el ambiente natural (C). Los camarones consumieron preferentemente presas bentónicas. Los camarones cultivados extendieron la búsqueda de alimento durante horas de luz y consumieron una fracción importante de vegetación, probablemente en respuesta a una fuerte reducción de la densidad de macroinvertebrados al cabo de 20 y 40 días de experimento. Luego de 60 días de cultivo, la dieta de los pocos camarones supervivientes en los corrales sin suplemento alimenticio (WR) se aproximó a la de los camarones en el ambiente natural (C). Estas similitudes fueron atribuidas a la recuperación de las poblaciones de macroinvertebrados, liberadas de la fuerte presión de depredación de los camarones durante los últimos 20 días en los corrales WR. Considerando el fuerte control de depredación de *F. paulensis* sobre las asociaciones de macroinvertebrados concluimos que el valor de la producción natural como fuente de alimento para camarones en sistemas de engorde está limitado a la etapa inicial del cultivo.

Palabras clave: *Farfantepenaeus paulensis*; camarón; depredación; dieta; acuicultura en corrales; invertebrado bentónico.

Introduction

Aquaculture development is particularly useful as an alternative source of food production for commercially important species that are subjected to intense fishing practices. This is the case of the shrimp *Farfantepenaeus paulensis*. An increase of small-scale fishing on juvenile populations of this species in Patos Lagoon is partly responsible for the depletion of resources (D'Incao 1991, D'Incao *et al.* 2002). This circumstance, in conjunction with the unpredictability of the shrimp harvests in the region (Castelo & Möller 1978, Reis & D'Incao 2000), emphasized the need for repopulation studies, as well as the improvement of low cost technologies for the culture of shrimps in estuarine inlets of Patos Lagoon (*e.g.* pens and cages) (Wasielesky *et al.* 1995).

Unlike cages, pens allow direct contact of shrimps with sediments in aquatic systems. These sediments provide refuge by promoting burrowing (Moller & Jones 1975), and offer a source of natural food available within culture environment (Wickins 1976, Angell 1989). Even with ration addition, the shrimps consume and use natural sources of carbon for their growth (Nunes *et al.* 1997, Nunes & Parsons 1999, Soares *et al.* 2005). Contributions of commercial ration usually constitute a small fraction of shrimps diet (Reymond & Langardère 1990) though it may slightly increase during growth (Soares *et al.* 2005). In contrast, benthic invertebrates can particularly play an important role in penaeid nutrition (Rubright & Harrell 1981, Moriarty *et al.* 1983, Soares *et al.* 2005).

For shrimp growth, the availability and use of the natural food and the environmental conditions originated in the culture will be of importance in the evaluation of the rearing method. The penaeid shrimps have been broadly classified as omnivorous and detritus feeders (Dall 1968), although some genus (*e.g.* *Metapenaeus*) were considered more vegetarian than *Farfantepenaeus* (Hall 1962). Studies analyzing stomach content of both free and captive *F. paulensis* supported the omnivorous diet described for other penaeids, since it has been reported that *F. paulensis* feeds on algae, live plant tissues and detritus, besides crustaceans, mollusks, polychaetes, and others invertebrates (Asmus 1984, Silva & D'Incao 2001, Albertoni *et al.* 2003, Soares *et al.* 2005). However, variations in the proventriculus contents of *F. paulensis* are likely influenced by variations in composition and abundance of benthic macrofauna (Asmus 1984).

Population densities of benthic invertebrates may be strongly reduced by shrimp predation (Leber

1985, Nelson & Capone 1990, Beseres & Feller 2007), potentially limiting shrimp growth and survival under pen-culture. Hence, the capacity of *F. paulensis* to overcome reductions in the availability of animal food sources would be critical to the success of culture methods such as pens. To assess the degree of dependence on prey availability and the importance of omnivory in the trophic behavior of *F. paulensis* we compared the diet of shrimps in their natural environment and inside experimental pen-cultures simultaneously.

Experiments designed to assess culture methods at relatively large spatial scales in the field usually suffer of statistical dependence problems, segregation of sample units, etc. (see Hurlbert 1984). In the present study we assessed the potential contribution of natural production to the diet of *F. paulensis* in a replicated experiment. We reinforced conclusions from parallel results that advised on poor shrimp growth and survival in highly stocked pens supplemented with low quality rations (Jorgensen & Bemvenuti 2001), explained by the drastic reduction of benthic invertebrate populations through shrimp predation within pen-cages (Jorgensen 1998).

Material and methods

Study area: The study was carried out in the estuarine region of Patos Lagoon, located in Rio Grande do Sul's coastal plain at southern Brazil (Fig. 1a, b). In this region there are shallow, semi-closed and vegetated areas locally known as "sacos". The Saco do Justino is a small mixohaline inlet of 2 km diameter and an approximate surface of 250 ha (Fig. 1c). Maximum depth in its central part is 1.5 m. Sandy and sand-muddy sediments constitute its bottom. Unlike other sectors of the lagoon, the inlet is unaffected by direct input of any anthropogenic nutrients (Baumgarten *et al.* 2005).

High levels of primary and secondary production in the "sacos" envisioned the aquaculture potential of the region for commercial rearing of native penaeid shrimps (*e.g.* Jorgensen & Bemvenuti 2001, Soares *et al.* 2006). However, precipitation produce abrupt variations of salinity in the Patos Lagoon (Garcia *et al.* 2004), and may affect growth and survival of shrimps (Tsuzuki *et al.* 2003, Soares *et al.* 2006). Environmental conditions during the present study were summarized in Jorgensen and Bemvenuti (2001). For the study season (Summer 1997), low salinities (< 5) were rare and never occurred during long periods (> 5 days). Furthermore, the total production of *Farfantepenaeus paulensis* for 1997 was the highest reported for the period 1989-1999 (D'Incao *et al.*

2002). Thus, it is inferred that growth and survival were not affected by environmental parameters in this study (Jorgensen 1998, Jorgensen & Bemvenuti 2001).

Experimental procedure: The population of *F. paulensis* included in the pens had an initial mean individual biomass of 4.25 g ($\pm$ 0.40 s.e.) (Jorgensen & Bemvenuti 2001). Cage inclusions were prolonged for three different periods, or stages, of 20, 40 and 60 days length (herein referred to as Period 1, Period 2 and Period 3 respectively), all initiated on February 1st, 1997. The following treatments were applied independently for each period: RS, 1 m⁻² pens stocked with 60 shrimps supplemented with a daily ration of by-catch local fishing (80% fish + 20% crustaceans) that amounted to about 10% the initial shrimp biomass in the pens; WR, pens with 60 shrimps but without ration addition; C, shrimps captured in the natural

environment (uncaged areas), as control of the general conditions of the experiment. Three replicates for period-treatment combination were disposed in the field following a totally randomized design. Additional details are available in Jorgensen and Bemvenuti (2001).

The shrimps included in the pens were captured in the natural environment the night before the beginning of cultures. Between 5 and 6 pm of the corresponding sampling day of each period, 6 pens were retired from the initial 18 pens (three for each treatment) and the shrimps collected were fixed and preserved in 5% formalin for ulterior analysis of their stomach content. This experimental procedure ensured the complete independence of treatment means (Underwood 1997). The same days of samplings, but at night (10 pm), shrimps were collected in the natural environment with a beam-trawl net.

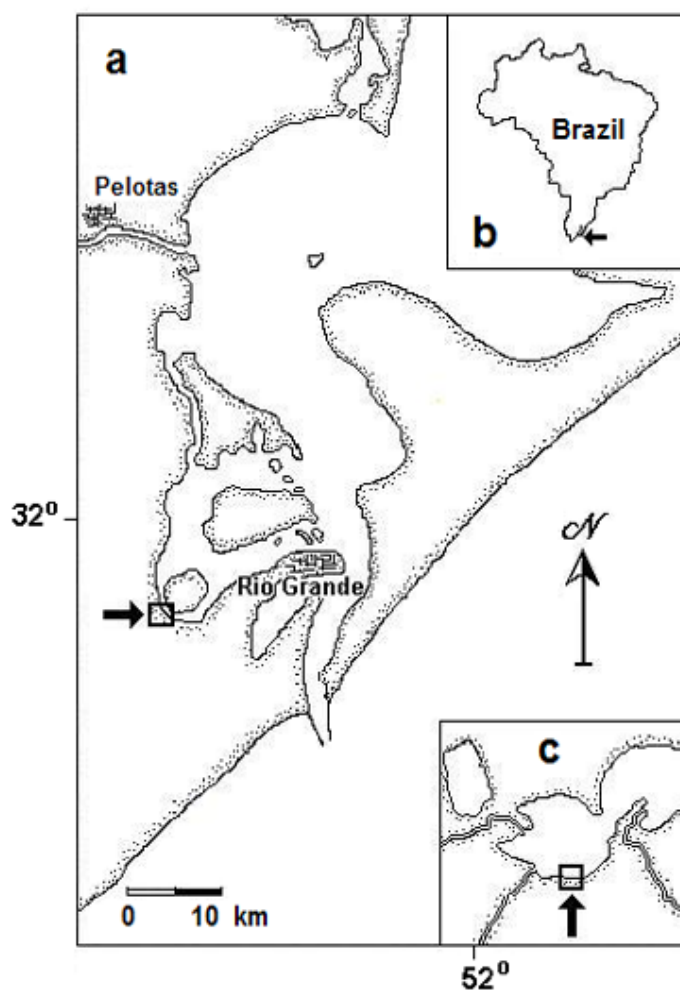


Figure 1. Geographic location of the sampling area within the Patos Lagoon estuary (a), at southern Brazil (b). The experimental units were located in an embayment known as Saco do Justino (c).

Content analysis of the anterior proventriculus: Five shrimps per pen and 15 among those captured in the natural environment in each sampling period were randomly chosen prior stomach content analysis. During dissection, the anterior proventriculus was separated and weighted; then, it was emptied and the wall of the proventriculus was weighted. The content mass was quantified by difference (error = 0.001 g). The percentage of stomach repletion index, R(%), was estimated from the categorical visual inspection of the proventriculus volume occupied by food, *sensu* Nunes *et al.* (1997). Finally the percentage frequency of food items occurrence, FO(%), was calculated on a total of 15 individuals analyzed for all period-treatment levels combinations.

The number of survival shrimps per pen did not reach in the third period the quantity fixed for the comparisons of weight content, R(%) and FO(%) among the experimental treatments. After 60 days of culture, only 1 individual was captured in one of the enclosures belonging to the treatment RS. In the same sampling period (Period 3), 3, 3 and 1 shrimp were collected in the three WR pens, respectively. Estimates of variables in this last period were then carried out basing on the number of survivors.

Data analysis: The comparative analysis of the growth in weight of cultured shrimps (RS and WR enclosures) was carried out through a 3-way nested ANOVA (treatment-period-pen) by Jorgensen and Bemvenuti (2001), so the observed results will be synthetically referred here. Variations in the content weight and in the repletion percentage, R(%), of the shrimps proventriculus among treatments RS, WR and C were estimated in a similar way. The factor 'pen' was nested in the factor 'treatment' and was ignored only after differences among the replicated pens were found to be not significant, justifying the use of the shrimps as experimental units in the comparisons (Underwood 1997). Statistical comparisons of the mentioned variables were limited to the periods 1 and 2 as a consequence of the reduced number of shrimps that survived after two months of culture. The relationship among the proventriculus-wall weight and the shrimp biomass was studied by a regression analysis.

The significance level of the statistical tests performed was preset at 5% ($\alpha = 0.05$). Cochran's test was used to test homogeneity of variances; data normality was verified through diagrams of observed and expected residuals for a normal distribution and box-plots of the medians distribution of the samples groups. When necessary,

were carried out the transformation of variables to $x' = \log_{10}(x+1)$, or to $x' = \arcsin(x\%/100)^{1/2}$ in the case of data expressed in percentages (Sokal & Rohlf 1981). *A posteriori* multiple comparisons of means among periods-treatments combinations were analyzed with Tukey's HSD test when significant differences were indicated by general ANOVA.

Differences in the diet of shrimps were evaluated by applying multivariate methods in non-transformed data of percentage frequency of food items occurrence in stomachs contents. In order to assess that a sufficient number of proventriculus were analyzed for each period-treatment combination, we plotted the cumulative number of species per number of proventriculus examined (*i.e.* species accumulation curves). We performed hierarchical classification of the samples by the use of UPGMA algorithm on the Bray-Curtis similarity matrix. The contribution of the items in the formation of groups defined by the classification analysis was determined through the SIMPER method (Clarke & Warwick 1994). The result of the groups' formation was evaluated by a samples ordination plot using NMDS (Non-metric Multidimensional Scaling) (Clarke & Warwick 1994). Ordinations were based on the rank similarity matrix among pairs of samples, defined by the Bray-Curtis index, and assessed through the stress value. Stress is a measure of quality of the ordination in the representation of the dissimilarity of matrix. Stress values < 0.1 indicate a good representation of the structure of the community without real risk of misinterpretation. The stress value interval 0.1 - 0.2 indicate a useful ordination, although little emphasis should be put on details for values of stress close to the upper limit of the interval (0.2). Computational routines used in multivariate analysis are part of statistical package PRIMER (Clarke & Gorley 2001).

Results

The mean shrimp weight increased significantly with time, and particularly during the first 20 days of the experiment ($p = 0.006$, Table I). Although the mean final growth was greater in the pens with food supply (Table II), this difference was not significant ($p = 0.212$, Table I). However, general differences among treatments were detected when the weight of the empty proventriculus of the shrimps was compared (RS = 0.233 g > C = 0.166 g and WR = 0.163 g; $F = 18.81$, $p = 0.000$). We found a significant direct relationship between the proventriculus-wall weight and the shrimp biomass ($n = 123$; $r = 0.7$; $p = 0.000$).

Table I. Summary of the 3-way nested ANOVA for differences among periods (Period 1: 20 days; Period 2: 40 days; Period 3: 60 days) and experimental treatments (RS: shrimps supplied with ration; WR: shrimps without ration supply; C: natural environment) in the mean weight of shrimps, stomach repletion index R(%), and weight of proventriculus content in *Farfantepenaeus paulensis*; n = 15 for period-treatment combination, except in Period 3; factor cage nested in factor treatment (see Material and methods). Significant values at $p < 0.05$ in bold.

Variable	Source	gl	MS	F	p
Shrimp weight ¹	Period	2	0.37	5.35	0.006
	Treatment	1	0.11	1.58	0.212
	Period x Treatment	2	0.15	2.12	0.126
	Residual	102	0.07		
R(%)	Period	1	1173.6	4.13	0.045
	Treatment	2	1265.6	4.46	0.014
	Period x Treatment	2	158.0	0.56	0.575
	Residual	84	284.0		
Proventriculus content	Period	1	0.000014	1.99	0.162
	Treatment	2	0.000025	3.47	0.035
	Period x Treatment	2	0.000053	7.37	0.001
	Residual	84	0.000007		

¹ shrimp weight comparisons among initial weight (day 0) and periods 1 and 2, and treatments RS and WR.

The amount of material ingested by *F. paulensis* (Tables III and IV) varied significantly across experimental treatments (R(%): $p = 0.014$; proventriculus content: $p = 0.035$, Table I). Shrimps included in WR pens, in which the only source of available food was the natural production of the system, consistently presented fuller proventriculus than in the other treatments (R(%), Period x Treatment: $p = 0.575$) (Table I). Furthermore, measures of stomach repletion, R(%), tended to decrease with the amount of time under captivity ($p = 0.045$, Tables I and III). In contrast with R(%), differences in the mass of material ingested by *F. paulensis* among treatments levels depended on the length of time under culture (Period x Treatment: $p = 0.001$, Table I). However, shrimps within RS pens presented both the lowest values of R(%) and mass content in their proventriculus after 60 days of culture ($40\% \pm 21$ s.e., Table III; $0.006 \text{ g} \pm 0.003$ s.e. Table IV).

Samples classification and ordination based on frequency of occurrence of food items ingested by *F. paulensis* reflected important differences in the

diet of shrimps under treatments RS, WR and C (Fig. 2). Species accumulation curves indicated that the number of proventriculus analyzed was adequate to characterize the diet of *F. paulensis* in the experimental treatments (Fig. 3). Indeed, in most situations the analyses of additional proventriculus would provide only small increases in the number of items (species) ingested.

Two homogeneous groups of samples were defined in the dendrogram at 75% similarity cut level in response to natural (group I) and culture (group II) conditions predefined in the experimental treatments (Fig. 2). Group I showed an average similarity of 83.3% and was constituted by animals captured in the natural environment, independently of the period of sampling, plus those belonging to WR pens subjected to two months of rearing. Group II (similarity average = 81.0%) was conformed by individuals in both pens RS and WR sampled at the end of the first two experiment periods (20 and 40 days of culture). Shrimps maintained in pens with food supply (RS) after two months of culture did not conform any group (Fig. 2).

Table II. Mean (s.e.) weight (g) of *Farfantepenaeus paulensis*, among periods (Period 1: 20 days; Period 2: 40 days; Period 3: 60 days) and experimental treatments (RS: shrimps supplied with ration, WR: shrimps without ration supply); n = 15 for period-treatment combination, except in Period 3 (see Material and Methods). Initial mean weight (s.e.): 4.25 g (0.40).

Shrimp weight	RS	WR
Period 1	5.49 (0.46)	5.62 (0.36)
Period 2	5.68 (0.38)	4.33 (0.38)
Period 3	6.99 (0.79)	5.27 (0.55)

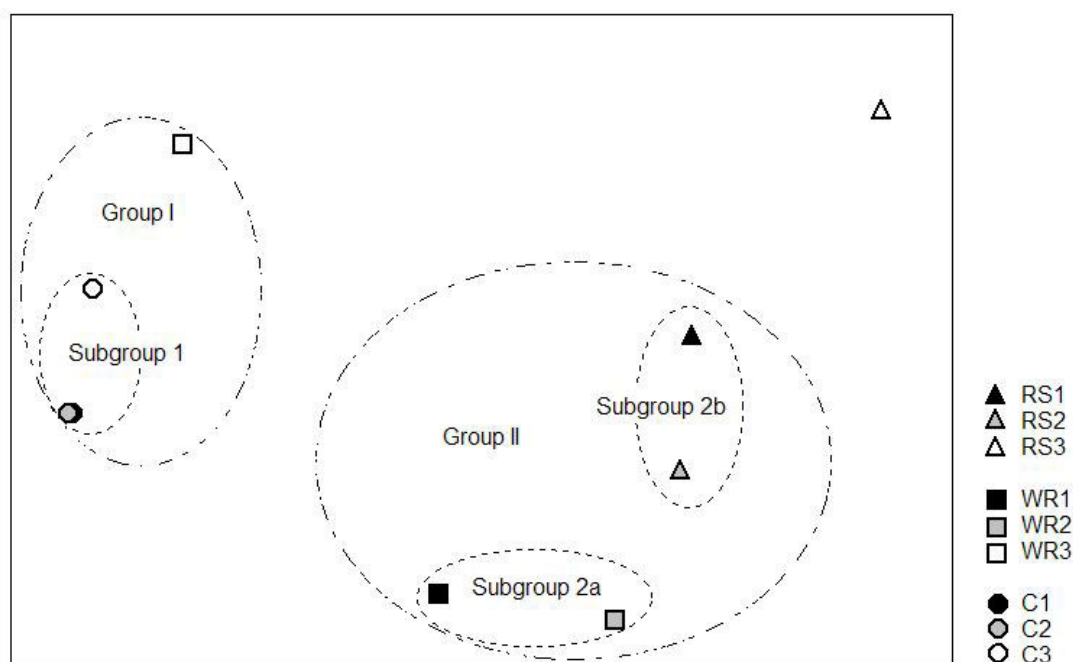


Figure 2. Non-metric Multidimensional Scaling (NMDS) ordination of the samples by frequency of food items occurrence, FO(%), in the anterior proventriculus of *Farfantepenaeus paulensis* (stress = 0.017). Letters and numbers of samples code (e.g. RS1) identifies experimental treatments (RS: shrimps supplied with ration, WR: without ration supply; C: natural environment) and period (Period 1: 20 days; Period 2: 40 days; Period 3: 60 days), respectively. The dotted lines define the groups and subgroups discriminated by the analysis of classification (dendrograme not shown).

Table III. Mean (s.e.) repletion, R(%), of the anterior proventriculus of *Farfantepenaeus paulensis*, among periods (Period 1: 20 days; Period 2: 40 days; Period 3: 60 days) and experimental treatments (RS: shrimps supplied with ration; WR: shrimps without ration supply; C: natural environment); n = 15 for period-treatment combination, except in Period 3 (see Material and methods).

R(%)	RS	WR	C
Period 1	64.2 (4.2)	77.5 (5.0)	61.7 (4.6)
Period 2	56.7 (5.1)	65.8 (1.7)	59.2 (3.6)
Period 3	40.0 (20.5)	71.4 (24.6)	61.7 (3.0)

Table IV. Mean (s.e.) wet weight content (g) in the anterior proventriculus of *Farfantepenaeus paulensis*, among periods (Period 1: 20 days; 2: 40 days; 3: 60 days) and experimental treatments (RS: shrimps supplied with ration; WR: shrimps without ration supply; C: natural environment); n = 15 for period-treatment combination, except in Period 3 (see Material and methods).

Weight (g)	RS	WR	C
Period 1	0.013 (0.001)	0.020 (0.004)	0.010 (0.002)
Period 2	0.014 (0.002)	0.011 (0.000)	0.012 (0.001)
Period 3	0.006 (0.003)	0.026 (0.010)	0.013 (0.001)

Table V. Frequency of food items occurrence, FO(%), in the anterior proventriculus of *Farfantepenaeus paulensis*, and their contribution to mean global dissimilarity (δ_{global}) among groups I and II, discriminated by the classification of samples in the dendrogram; $\delta_i\%$: percentual of dissimilarity contribution of the item *i* to the mean global dissimilarity among the two groups.

Item	FO(%)	FO(%)	$\delta_i\%$	$\delta_i\%$ Acumulated
	I	II	I-II	I-II
Vegetation	7.5	100.0	24.1	24.1
Insect eggs	12.5	76.7	16.5	40.6
<i>Laeonereis acuta</i>	65.0	16.7	13.1	53.7
Ration	0.0	41.7	11.2	64.9
Ostracoda	43.3	55.0	5.7	70.6
<i>Tanais stanfordi</i>	0.0	20.0	5.2	75.8
Nematoda	21.7	6.7	4.9	80.7
Unidentified	15.0	21.7	4.5	85.2
Foraminifera	25.0	33.3	4.3	89.5
<i>Kalliapseudes schübartii</i>	92.5	78.3	4.1	93.6
<i>Heleobia australis</i>	0.0	6.7	1.6	95.2
Sand	94.2	98.3	1.5	96.7
<i>Nephtys fluviatilis</i>	8.3	5.0	1.5	98.2
Detritus	100.0	95.0	1.3	99.5
Decapoda	0.0	1.7	0.5	100.0
δ_{global}			33.7	

The NMDS successfully depicted details on subgroups discrimination in response to the inclusion of high initial densities of *F. paulensis* (RS and WR vs. C), the addition of ration (RS vs. WR), and the length of time under culture (represented by periods 1, 2 and 3) (Fig. 2). During periods 1 and 2 the samples of treatments RS and WR presented separately a similar disposition in the plane defined by the multivariate analysis. In contrast, RS and WR samples in the third period showed a different location compared with the position of the samples of the respective treatments in the previous periods (Fig. 2). Differences in samples disposition among periods 1 and 2 relative to period 3 indicated that an important change in the *F. paulensis* diet took place when shrimps at initial densities were subjected to more than 40 days of culture.

The degree of percentage dissimilarity among the groups discriminated by the classification analysis was useful in the identification of the variables that had a major contribution to the observed results (Table V). This method showed that the vegetation was the most important item in the differentiation among the group conformed by treatments RS and WR (groups II), on one hand, and the group of control samples (group I) on the other. Still green vegetal remains (mainly from fanerogame *Ruppia maritima*) and insect eggs were frequently observed inside the proventriculus of animals in

captivity (treatments RS and WR of the first and second periods, and RS of the third). In contrast, these items were ingested with low frequency by shrimps in the natural environment or under treatment WR after 60 days of culture (Table VI).

Among animal preys, the polychaete *Laeonereis acuta* and the tanaid *Kalliapseudes schübartii* presented high frequencies of occurrence inside the proventriculus of the penaeid and were in general consumed in higher proportion by the shrimps captured in the natural environment (Tables V and VI). Meiofauna components did not show clear patterns of occurrence in the proventriculus during the first two experimental periods. Only in period 3 foraminifers and nematodes were present in higher frequency in the ration addition treatment (Table VI).

Detritus fragments and sand grains were identified in most of the proventriculus examined, both in captivity and control C. On the other hand, the ingestion of the ration given in RS was verified. The presence of this item was observed in more than 80% of the proventriculus of the shrimps maintained in RS pens (Tables V and VI). Other items were less important in the diet of *F. paulensis*. *Nephtys fluviatilis*, *Heleobia australis* and decapods were consumed occasionally because of their low palatability, or else in function of their availability or accessibility.

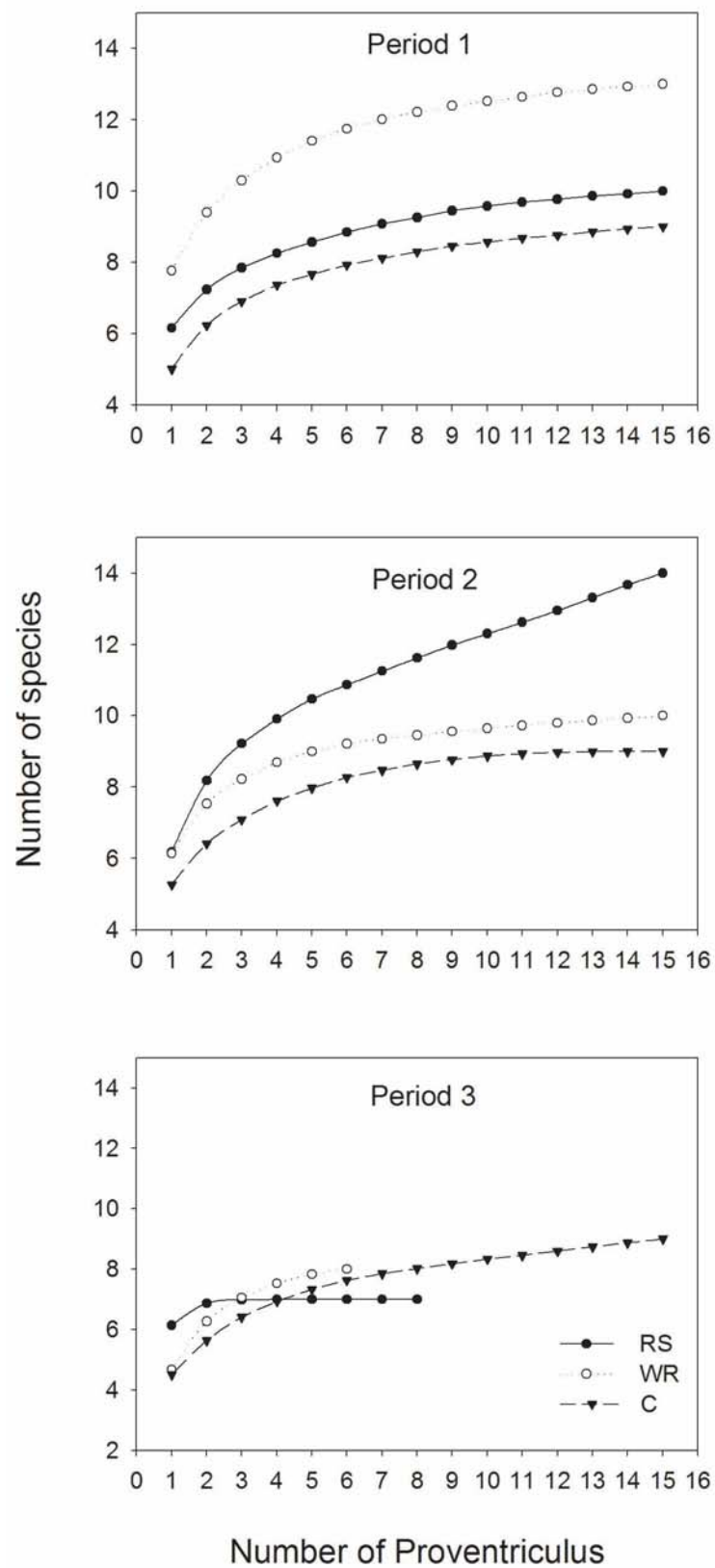


Figure 3. Cumulative number of items ingested (species) relative to the number of anterior proventriculus of *Farfantepenaeus paulensis* analyzed for the three periods, Period 1: 20 days; Period 2: 40 days; Period 3: 60 days, and experimental treatments RS: shrimps supplied with ration; WR: without ration supply; C: natural environment.

Table VI. Frequency of the food items occurrence, FO(%), in the anterior proventriculus of *Farfantepenaeus paulensis*, among periods (Period 1: 20 days; Period 2: 40 days; Period 3: 60 days) and experimental treatments (RS: shrimps supplied with ration; WR: shrimps without ration supply; C: natural environment); n = 15 for period-treatment combination, except in Period 3 (see Material and Methods).

Item	Period 1			Period 2			Period 3		
	RS	WR	C	RS	WR	C	RS	WR	C
Vegetation	100.0	100.0	6.7	100.0	100.0	0.0	100.0	16.7	6.7
Insect eggs	73.3	100.0	0.0	53.3	80.0	0.0	75.0	50.0	0.0
<i>Laonereis acuta</i>	13.3	53.3	73.3	0.0	0.0	73.3	0.0	66.7	46.7
Ration	93.3	0.0	0.0	73.3	0.0	0.0	87.5	0.0	0.0
Ostracoda	33.3	86.7	46.7	60.0	40.0	66.7	0.0	33.3	26.7
<i>Tanais stanfordi</i>	0.0	26.7	0.0	6.7	46.7	0.0	0.0	0.0	0.0
Nematoda	0.0	13.3	0.0	6.7	6.7	20.0	62.5	33.3	33.3
Unidentified	0.0	40.0	26.7	26.7	20.0	33.3	0.0	0.0	0.0
Foraminifera	20.0	40.0	46.7	33.3	40.0	20.0	87.5	0.0	33.3
<i>Kalliapseudes schubartii</i>	73.3	93.3	93.3	66.7	80.0	100.0	0.0	83.3	93.3
<i>Heleobia australis</i>	0.0	20.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0
Sand	100.0	100.0	93.3	93.3	100.0	100.0	100.0	83.3	100.0
<i>Nephtys fluviatilis</i>	6.7	6.7	13.3	6.7	0.0	13.3	0.0	0.0	6.7
Detritus	100.0	93.3	100.0	86.7	100.0	100.0	100.0	100.0	100.0
Decapoda	0.0	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0

Discussion

The trophic habit of penaeid shrimps have been broadly classified as omnivorous and detritivorous (Dall 1968). In the present study, developed between mid summer and the beginning of autumn, detritus particles occurred on average in more than 90% of the examined contents, both in the natural environment and under culture. Though we did not quantify the volumetric contribution of ingested items, detritus is usually in relatively constant low amount in guts of free *Farfantepenaeus* (e.g. Schwamborn & Criales 2000, Albertoni *et al.* 2003). Larger amounts of detritus may be observed, however, in response to low prey abundance (Stoner & Zimmerman 1988). This seems to be the case for *F. paulensis* in Patos Lagoon, where variability in their proventriculus content is strongly influenced by variations in composition and abundance of benthic macrofauna. For example, organic detritus only comprised a large proportion in the diet of free shrimps when prey availability diminished during winter, while in summer *F. paulensis* consumed mainly ostracodes and the digger polychaete *Laonereis acuta* (Asmus 1984). Similarly, detritus was the main food component of *F. paulensis* diet inside pen-cultures, likely in response to a severe decline of prey availability through consumption (Soares *et al.* 2004, Soares *et al.* 2005).

It is now apparent from stable isotope studies tracing food webs of coastal ecosystems that penaeids are mainly carnivorous and not detritivorous (Stoner & Zimmerman 1988, Primavera 1996, Schwamborn & Criales 2000), in contrast to earlier conclusions on penaeid diets. In our study *F. paulensis* consumed food of animal origin whenever it was available, even in culture conditions when macrobenthic preys density was reduced in 80% as a consequence of the high number of shrimps included initially in the pens (Jorgensen 1998). However, diet differences among captive shrimps and those from the natural environment were clearly reflected in our study, for example, through differences in the frequency of vegetation ingestion. These contrasts could hardly have originated from discrepancies in the hour of sampling of shrimp populations. Instead, we think the major reason for the frequent consumption of vegetation observed in the culture environment derived from the significant reduction of the density of macrobenthic invertebrates in pens RS and WR. The ingestion of vegetation likely occurred as an opportunistic feeding strategy to overcome deficiencies in the diet due to shortage of animal preys. Similarly, Soares *et al.* (2005) reported consumption of plant material by *F. penaeus* under culture conditions. Weidenbach (1980) showed that increases in vegetal material consumption by

shrimps of considerable size occurred under the absence of balanced food.

The ingestion of vegetation does not imply that its digestion really happens (Dall *et al.* 1990). It is possible that epibionts in *Ruppia maritima* are in fact the source of nutrition. A recent stable isotopes study indicated that microorganisms living in the organic matrix attached to submersed surfaces enhanced growth of *F. paulensis* kept in floating cages and unable to feed on benthic invertebrates (Abreu *et al.* 2007). Hence, omnivory (*i.e.* consumption at more than one trophic level) such as detritivory appears to be important only when the abundance of primary consumers is low, such as in least productive seasons (*e.g.* Asmus 1984), or when the predation pressure reduce availability of invertebrates to sustain the shrimps stocked in rearing systems (*e.g.* Soares *et al.* 2005, this study). In fact, wild *F. paulensis* in Saco do Justino have a high trophic position in the food chain, as indicated by a stable isotopic study that positioned the shrimp in a similar trophic level as predatory fishes (Abreu *et al.* 2006).

The ingestion of vegetation was not the only difference between the trophic habits of captive and free shrimps. The observation of *F. paulensis* behavior inside the pens during the experiment showed surprisingly high activity levels during the day (mainly in treatment WR). Daytime feeding of juveniles of free *F. paulensis* in the Patos Lagoon estuary has been described, although feeding activity mostly occurs during the dark period (Santos 2003). In densely stocked cultures, shrimps increased their feeding frequency in the unavailability of food of high nutritious quality (Reymond & Langardère 1990). Increments of activity, described as a tendency of shrimps to emerge off the substratum during daylight hours, were observed in *F. esculentus* after six days of starvation (Hill & Wassenberg 1987). A similar behavior was reported for *Metapenaeus macleayi* (Racek 1959). The extension of shrimp activity to daylight hours in our study was likely related to an increase in food search time in response to the reduction of benthic preys density (Jorgensen 1998). This would also explain why the animals included in the non-supplemented treatment (WR) showed consistently fuller proventriculus.

Inclusion of *F. paulensis* in cages or pens indicated that the shrimp functions at a predator level, having its greatest effect on benthic invertebrates (Jorgensen 1998, Soares *et al.* 2004, Rodríguez-Gallego *et al.* 2008). In parallel studies Jorgensen (1998) and Jorgensen and Bemvenuti (2001) showed that the densities of benthic

macroinvertebrates within enclosures were significantly depressed soon after introduction of shrimps, and depletion of prey populations derived in their low survival, particularly in WR cages. The extremely low survival of *F. paulensis* in WR cages (7%) determined the recovery of some invertebrate populations, and the structure of the macrobenthic assemblage approached that of the natural environment during the last twenty days of culture (Jorgensen 1998, Jorgensen & Bemvenuti 2001). The numerical response of prey populations to relaxation of the predation pressure associated with a severe reduction in *F. paulensis* density was also reflected in the proventriculus content of shrimps (Table VI). The tight relationship between the macroinvertebrates species abundance matrix in the pen-cultures, and the matrix of benthic invertebrates frequency inside the anterior proventriculus of *F. paulensis* was indicated by a multivariate correlation analysis performed by the RELATE routine, included in PRIMER (Clarke & Gorley 2001). The null hypothesis of non-existence relationship between both groups of variables was rejected with a probability error below 0.1% ($\text{Rho} = 0.405$, $p < 0.001$). The vicinity of samples WR of the third period with the samples C (natural) in the NMDS plane (Fig. 2) could then be explained as a return to the 'natural conditions' in the availability of the preys preferred by *F. paulensis* in its diet.

The marked preference of *F. paulensis* for benthic invertebrate preys contrasts with least carnivorous habits of other penaeid species, such as *Litopenaeus vannamei* (see references in Lemos *et al.* 2004). The dominant carnivorous behavior of *F. paulensis* explained the high protein demand of this species in captivity, and why the commercial culture of *F. paulensis* in ponds drastically decreased due to the lack of adequate feeds to sustain profitable growth (references in Lemos *et al.* 2004). Hence, the trophic preferences and the strong functional role of *F. paulensis* must be considered when determining the density of shrimps to be included in culture pens and in the adoption of rations of high nutritional value (*i.e.* protein content and digestibility). Although preys population recover may be possible at densities $< 10 \text{ ind. m}^{-2}$, dominance of the macrobenthic assemblage of Saco do Justino by preys with direct development (*e.g.* *K. schubartii*) would retard recovery time.

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Remediation of eutrophied water using *Spirodela polyrrhiza* L. Shleid in controlled environment

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Abstract. The range of pH from 6.5 to 6 and temperature of 25 to 30°C were the most suitable environmental condition for remediation of eutrophic water using giant duckweed. When harvested regularly duckweed plants may be of use in counteracting eutrophication in affected water bodies.

Key words: controlled environment, eutrophied water, growth, remediation, *Spirodela polyrrhiza*

Resumo: Tratamento de água eutrofizada usando *Spirodela polyrrhiza* L. Shleid em ambientes controlados. A faixa de pH entre 6,5 e 6 e temperatura entre 25°C e 30°C foram as condições ambientais mais adequadas para a remediação da eutrofização da água usando *Spirodela polyrrhiza*. Quando colhidas regularmente, as “lentilhas d’água” podem ser usadas no controle da eutrofização em corpos de água afetados.

Palavras chave: ambiente controlado, água eutrofizada, crescimento, remediação, *Spirodela polyrrhiza*

The physiochemical processes within a water source have major implications for controlling eutrophication in aquatic bodies (Khan & Ansari 2005). The free-floating members of family Lemnaceae may be of use in phytoremediation of eutrophic waters (Ansari & Khan 2008). In the present study growth response of *Spirodela polyrrhiza* at various temperature and pH levels was investigated for its possible use and application for remediation of eutrophic waters.

The experiments were conducted in small polyvinyl pots (maintained in triplicate) containing 500 ml of fresh water with nutrient solution (1ml l⁻¹) (Mahadevan & Sridhar 1986) inoculated with 1g of *S. polyrrhiza*. Growth of duckweed plants were tested at various temperatures (15° 20°, 25° 30°, 35° and 40° C) and pH levels (6, 6.5, 7, 7.5, 8 and 8.5) by placing pots for 20 days in a growth chamber in a light of 36 μ mol m⁻² s⁻¹. For all temperature treatments the sets were maintained at pH 7.0 measured with a pH meter (Elico Limited,

Hyderabad). NaOH or HCl were added to growth medium to maintain the specific pH. For all sets with various pH levels was maintained at 30°C temperature. Standard deviation and least significant difference at 5% level of significance were calculated using three replicates for each treatment following Dospekhov (1984).

The chlorophyll-*a* content in plants was estimated following the method of Zhao (2000a). The nitrogen and phosphorus contents were determined using the method of Lindner (1944) and Fiske & Subba Row (1925) respectively. Potassium was determined with a Flame photometer (AIMIL). Soluble protein was extracted following the method of Lazan *et al.* (1983) and Lowery *et al.* (1951). For peroxidase (POD) assay used the technique of Kar & Mishra (1976) and the activity was determined as described by Putter (1974). Catalase (CAT) activity was estimated following Lu (2002). Melanodialdehyde (MDA) contents were estimated according to the

Table I. Growth response of giant duckweed at various temperatures. (FW = Fresh weight, U = Unit, LSD = Least significant difference, % = level of significance)

	Temperature						LSD at 5 %
	15oC	20°C	25°C	30°C	35°C	40°C	
Dry weight mg g-1 FW	125.4±3.3	130.7±2.8	134.6±3.4	141.2±4.6	132.3±2.1	118..4±2.5	2.5
Chlorophyll mg g-1 FW	1.182±0.015	1.218±0.021	1.242±0.019	1.259±0.013	1.238±0.017	1.203±0.021	0.017
Nitrogen mg 100mg-1	3.10±0.18	3.47±0.13	3.69±0.15	3.87±0.16	3.61±0.12	2.96±0.10	0.19
Phosphorus mg 100mg-1	0.268±0.022	0.285±0.020	0.312±0.027	0.343±0.031	0.327±0.032	0.287±0.021	0.021
Potassium mg 100mg-1	1.65±0.26	1.89±0.22	2.10±0.27	2.29±0.31	2.15±0.11	1.91±0.13	0.17
Soluble protein mg g-1 FW	1.21±0.09	1.32±0.12	1.55±0.14	1.67±0.16	1.49±0.14	1.36±0.15	0.13
POD U mg1protein min-1	431±7	414±5	395±4	371±5	406±5	427±6	8
CATU mg-1protein min-1	117±3	103±4	85±2	74±2	88±4	105±5	12
MDA µmol g-1 FW	2.89±0.17	2.75±0.14	2.59±0.12	2.40±0.11	2.55±0.16	2.68±0.13	0.15

Table II. Growth response of giant duckweed at various pH levels. (NS = Not Significant, FW = Fresh weight, U = Unit, LSD = Least significant difference, % = level of significance)

	pH levels						LSD at 5 %
	6	6.5	7	7.5	8	8.5	
Dry weight mg g-1 FW	138.9±3.4	135.8±3.1	131.6±2.8	128.2±2.2	123.3±2.3	119.6±2.1	2.8
Chlorophyll mg g-1 FW	1.246±0.013	1.231±0.011	1.214±0.014	1.195±0.012	1.69±0.016	1.136±0.06	0.015
Nitrogen mg 100mg-1	3.87±0.22	3.65±0.31	3.40±0.34	3.22±0.24	2.91±0.32	2.79±0.26	0.16
Phosphorus mg 100mg-1	0.381±0.013	0.364±0.012	0.339±0.011	0.309±0.017	0.272±0.021	0.285±0.022	0.019
Potassium mg 100mg-1	2.35±0.10	2.29±0.09	2.22±0.05	2.17±0.09	2.12±0.08	2.06±0.11	NS
Soluble protein mg g-1 FW	1.39±0.06	1.32±0.10	1.27±0.13	1.20±0.09	1.15±0.08	1.07±0.07	0.05
POD U mg-1protein min-1	347±7	352±8	349±6	356±9	361±7	365±5	NS
CAT U mg-1protein min-1	82±5	80±4	86±3	88±3	93±6	95±5	NS
MDA µmol g-1 FW	2.35±0.20	2. 38±0.17	2.42±0.22	2.48±0.31	2.52±0.30	2.55±0.22	NS

method of Zhao (2000b).

Dry matter and chlorophyll-*a* accumulation were significantly higher at 25°C to 30°C (Table I). The optimum uptake of nitrogen, phosphorus and potassium was noted at 30°C. The temperatures of 15° and 40°C significantly reduced the nutrient uptake, dry matter and chlorophyll-*a* concentration. POD, CAT and MDA were higher at 15°C but maximum was at 40°C. The temperature regulates cell division, enzyme activity, translocation of food and photosynthesis in plants. 30° C is the optimum temperature for most of the biochemical processes (Devlin and Witham 1986). Lower temperature (10°C) retarded cell growth, synthesis and the absorption of nutrients from the water by duckweed (Ansari & Khan 2006).

The variation in pH (Table II) did not affect potassium, POD, CAT and MDA in plants. The plants grow well at all the tested pH levels. However, with the dry matter determination it was found that the nitrogen, phosphorus and protein contents of plants were significantly higher at acidic pH. It is known that the pH regulates origin, mobility and availability of ions and their different forms (Devlin & Witham 1986).

This study indicated that, under controlled conditions (at acidic pH and temperature between 25° and 30°C) of water and by harvesting regularly, giant duckweed may be used for removing high nutrient levels in eutrophic water.

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Analysis of fluctuating asymmetries in marine shrimp *Litopenaeus schmitti* (Decapoda, Penaeidae)

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Abstract. Fluctuating asymmetries (FA) are associated to instability in organism development caused by environmental and genetic factors that act during the first stages of ontogenesis. Analysis of bilateral morphometries in commercial Penaeidae stocks has shown a high AF frequency in stocks submitted to several generations in captivity. With the objective of determining a basal level of fluctuating asymmetries found in natural populations of the *Litopenaeus* genus and determine which segments are most informative in the expression of these asymmetries, 18 parameters were measured obtained from 15 bilateral segments of a sample of 40 specimens of *L. schmitti* collected along the coast of Rio Grande do Norte state, northeastern Brazil. The analysis indicated the presence of asymmetries in 27.7% of the segments measured, corresponding to segments of the pereopods. The fluctuating asymmetries indexes observed are significantly smaller than those shown in captive stocks of *L. vannamei*, under high density and endogamy. Low fluctuating asymmetry indexes suggest an active role of the stabilizing selection in this natural population.

Key words: bilateral asymmetries, Crustacea, carciniculture, developmental instability.

Resumo. Determinação da assimetria flutuante no camarão marinho *Litopenaeus schmitti* (Decapoda, Penaeidae). Assimétrias flutuantes (AF) estão associadas à instabilidade no desenvolvimento de organismos em decorrência de fatores genéticos e ambientais que agem durante os primeiros estágios da ontogênese. Análises da morfometria bilateral em estoques comerciais de Penaeidae têm mostrado uma alta frequência de AF em estoques submetidos a várias gerações de cultivo. Com o objetivo de determinar o nível basal de assimetria flutuante em populações naturais de espécies do gênero *Litopenaeus* e determinar quais segmentos são mais informativos na expressão destas assimétrias, 18 parâmetros foram mensurados, obtidos de 15 segmentos bilaterais de uma amostra de 40 espécimes de *L. schmitti* coletados ao longo da costa do Rio Grande do Norte, nordeste do Brasil. As análises indicaram a presença de assimétrias em 27,7% dos segmentos mensurados, correspondendo aos segmentos dos pereiópodos. Os índices de AF observados são significativamente menores que aqueles apresentados por estoques cativos de *L. vannamei*, sob intenso confinamento e endogamia. Os baixos valores de AF sugerem um papel ativo da seleção estabilizadora na população nativa desta espécie.

Palavras-chave: Crustacea, carcinicultura, instabilidade do desenvolvimento, assimetria bilateral.

Introduction

The white shrimp, *Litopenaeus schmitti* (Pérez-Farfante & Kensley 1997), is distributed in the Western Atlantic from the Antilles to the

extreme south of Brazil and is found inhabiting localities up to 47 m deep (Pérez-Farfante 1970). Marine shrimp cultivation is one of the most important activities in economy of several countries.

Because of this, various genetic and morphological data need to be obtained in *L. schmitti* stocks, an important cultivated native species in Brazil.

Fluctuating asymmetry frequencies have been used extensively as an indicator of the quality of ontogenetic development in many species. It can be translated as morphological reflex to disturbances, either genetic or environmental in natural conditions (Rayman & Utter 1987, Parsons 1990, 1992, Sarre *et al.* 1994, Houle 2000), identified by measuring of bilateral traits.

The determination of the fluctuating asymmetry indexes under different conditions, especially involving Penaeidae species, performs an important function because they are very practical for monitoring the quality of native and/or exotic stocks. Fluctuating asymmetry studies on *L. vannamei* under different generations of cultivation identified a high degree of asymmetry in stocks, possibly linked to the existence of extensive endogamy caused by management (Silva 2001).

The basal fluctuating asymmetry values are not yet known in any natural stocks of *Litopenaeus* species without environmental or genetic stress. Thus the present study aimed to determine for the first time the FA levels in a wild population of a representative of the genus, *L. schmitti*, native to the Brazilian coast under natural selection, by analysis of the measure means obtained in segments of locomotors appendix pairs and establish the sex interaction.

Material and Methods

A sample of forty *L. schmitti* individuals (20 males and 20 females) were collected using trawling nets along the shore in the Baía Formosa beach (6° 22' 10" S, 35° 00' 28" W), Rio Grande do Norte state, Northeast Brazil. After collection, the animals were stored at -20°C until measurement.

To establish comparison with previous data obtained for *L. vannamei*, the following measurements were chosen for analysis: length of ischium (I), mero (M), carpo (C), and propod (P) of the three first pairs of pereopods and scaphocerytes (S) and the length and width of the side and median uropods (UL and UM). The appendixes were carefully dissected, spread out on a flat surface and measured with one replication, using a digital caliper (precision 0.01 mm) under a stereomicroscope.

Two methods of analysis were used to estimate the fluctuating asymmetries. The first consisted of the analysis of multivariate variance with repeated measurements, considering the effects of the sex, segment and side factors. Another approach was the use of the method to estimate the

fluctuating asymmetry established by Palmer & Strobeck (1986) represented by the formula $FA_i = (R_i - L_i) / (R_i + L_i) / 2$ indicated by eliminating the influence of individual size from the segment analyzed, where R_i is the mean of the right side and L_i is the mean of the left side. The mean of the two measurements of each individual was calculated and the Multivariate analysis of variance (MANOVA) (significant at $p < 0.05$) test was applied to repeated data on the response vector formed by the 10 pairs of means obtained.

Results

Effects and interaction among the sex, segment and side factors. The analyses of the segments from the 1st, 2nd and 3rd pereopods, scaphocerytes and uropods (analyzed jointly) indicated a significant effect for segment and sex parameters and depending on the segment, a significant or discrete interaction between them. The side factor showed no significant effect or interaction with the other factors, indicating the possibility of analysis of fluctuating asymmetry. Regarding the third pair of pereopods the interaction of the variables side and segment presented a result fairly close to the level of significance ($p = 0.0541$; Table I). In this case, there was an indication that the variables sex and side may influence the segment size but the other interaction did not present a significant effect.

Effects and interactions between sex and segment, using weighted fluctuating asymmetries. When the same methodology was applied to the weighted fluctuating asymmetry means the effect of size was eliminated from all the segments (Table II), and the non significant effects of the factors sex, segment and the their interaction were observed, indicating the possibility of analysis of the occurrence of fluctuating asymmetries regardless of sex.

Statistics of the fluctuating asymmetries distribution in the segments. Table III shows the kurtosis for all the segments. In the first pair of pereopods, the distributions of the mero and carpo segments presented significant asymmetry but bimodality (antisymmetry) was not detected. This fact invalidated the hypothesis of normality of the distributions confirmed in the Kolmogorov-Smirnov and Lilliefors tests. It was ascertained in the second pair of pereopods that the mero segment presents cryptic level of asymmetry ($p = 0.0589$) in its distribution, however it is significant in the propod segment. The mero, carpo and propod segments of the third pair of pereopods also showed significant

values. The analysis carried out on the scaphocerytes indicated that the width and length parameters showed significant effect by their isolated estimative suggesting that fluctuating asymmetries can be analyzed without considering the sex. The fluctuating asymmetries distribution and the kurtosis obtained for the uropods revealed significant values. All the distributions for kurtosis were leptokurtic.

Fluctuating asymmetries by appendixes.

Table IV shows the distribution normality by the Kolmogorov-Smirnov and Lilliefors test. On the 1st and 2nd pair of pereopods normality was shown in the distributions of the propod, ischium and mero,

respectively, and the others were rejected. On the third pair of pereopods the ischium and mero showed normal distribution. In the median and side scaphocerytes and uropods, the Kolmogorov-Smirnov and Lilliefors normality test rejected the distribution of the width and length means. There was no indication of other forms of asymmetry in any of the segments analyzed where normality was rejected.

The results presented in Table IV show that only 27.7% of the segments studied expressed fluctuating asymmetries although 67.7% had significant effects.

Table I. Test of effects and interactions among the sex, segment and side factors of *Litopenaeus schmitti* by MANOVA with repeated measurements, to compare means of the different segments.

Factors	Factors Effects		Experimental Error		F	p
	D.F.	M.S	D.F.	M.S		
1 st Pereiopod Segment	3	138.5485	114	0.2978	465.2488	0.0000*
Sex	1	77.7461	38	6.8259	11.3899	0.0017*
Side	1	0.0167	38	0.0086	1.9385	0.1719 ^{NS}
Sex X 1 st Pereiopod Segment	3	0.7078	114	0.2978	2.3767	0.0736
2 nd Pereiopod Segment	3	672.2859	114	0.5321	1263.4208	0.0000*
Sex	1	176.2695	38	12.8097	13.7606	0.0007*
Side	1	0.0017	38	0.0049	0.3426	0.5618 ^{NS}
Sex X 2 nd Pereiopod Segment	3	7.1315	114	0.5321	13.4021	0.0000*
3 rd Pereiopod Segment	3	2740.2278	114	1.7819	1537.8445	p<0.0001*
Sex	1	246.0827	38	25.7700	9.5492	0.0037*
Side	1	0.0002	38	0.0011	0.1720	0.6806 ^{NS}
Segment x Side	3	0.0059	114	0.0023	2.6222	0.0541
Sex X 3 rd Pereiopod Segment	3	17.2367	114	1.7819	9.6734	p<0.0001*
Scaphoceryte	1	6492.8135	38	2.1576	3009.2852	0.0000*
Sex	1	123.2888	38	11.7025	10.5352	0.0024*
Side	1	0.0018	38	0.0024	0.7524	0.3912 ^{NS}
Sex X Scaphoceryte	1	27.7889	38	2.1576	12.8796	0.0009*
Uropod	3	4822.9624	114	2.0075	2402.4592	0.0000*
Sex	1	172.2464	38	17.2538	9.9831	0.0031*
Side	1	0.0025	38	0.0277	0.0905	0.7651 ^{NS}
Sex X Uropod	3	19.9961	114	2.0075	9.9606	0.0000*

NS - not statistically significant; * - statistically significant

Discussion

The level of fluctuating asymmetries can be estimated from the analysis of bilateral appendixes of individuals in natural populations revealing valid data on environmental and genetic stability to which that group is submitted. Although fluctuating asymmetry has been used successfully in plants and animals (Galhardo 1995, Evans & Marshall 1996, Møller *et al.* 1999), there are few reports of its use in

marine shrimps (Clarke 1993, Silva 2001).

Asymmetries presenting heredity components, such as directional asymmetry and antisymmetry, can harm fluctuating asymmetry analysis (Palmer & Strobeck 1992). However, analyzes carried out on *L. schmitti* did not show the presence of either of these asymmetries in spite of the heterogeneity in the size of the individuals. This variability in size of individuals motivated the use of

relative fluctuating asymmetry formula (Palmer & Strobeck 1986). In the two forms of analysis applied to the data, the occurrence of fluctuating asymmetries could be observed, a situation previously identified in *L. vannamei* (Silva 2001).

An important question in the study of fluctuating asymmetries is the choice of the

structures to be used. In shrimp, the reduced size of the appendices and ill-defined landmarks can favor imprecise results significantly. For this reason, the rigid pereopod, scaphoceryte and uropod segments were chosen in this study, in detriment to membranous structures such as pleopods, whose measurement is less accurate (Silva 2001).

Table II. Test of effects and interaction among the factors sex and segments of *Litopenaeus schmitti*, by MANOVA with repeated measurements using weighted fluctuating asymmetries as response.

Factors	Factors Effects		Experimental Error		F	p
	D.F	M.S	D.F	M.S		
Sex	1	0.0010	38	0.0006	1.6190	0.2110 ^{NS}
1 st Pereiopod Segments	3	0.0003	114	0.0003	1.0589	0.3695 ^{NS}
Sex X 1 st Pereiopod Segment	3	0.0001	114	0.0003	0.3623	0.7803 ^{NS}
Sex	1	0.000005	38	0.0002	0.0305	0.8622 ^{NS}
2 nd Pereiopod Segment	3	0.000017	114	0.0002	0.1064	0.9562 ^{NS}
Sex X 2 nd Pereiopod Segment	3	0.000061	114	0.0002	0.3894	0.7608 ^{NS}
Sex	1	0.00005	38	0.00002	2.7530	0.1053 ^{NS}
3 rd Pereiopod Segment	3	0.00009	114	0.00004	2.0241	0.1145 ^{NS}
Sex X Segment	3	0.00001	114	0.00004	0.2957	0.8284 ^{NS}
Sex	1	0.00012	38	0.00005	2.4695	0.1244 ^{NS}
Scaphoceryte	1	0.00038	38	0.00014	2.7020	0.1085 ^{NS}
Sex X Scaphoceryte	1	0.00034	38	0.00014	2.4242	0.1278 ^{NS}
Sex	1	0.00000	38	0.00020	0.0017	0.9676 ^{NS}
Uropods	3	0.00057	114	0.00127	0.4508	0.7172 ^{NS}
Sex X Uropods	3	0.00175	114	0.00127	1.3819	0.2519 ^{NS}

NS - no statistically significant; * - statistically significant

The pereopods perform the functions of food manipulation, locomotion and defense. While the scaphocerytes act in feeding, the uropods are used for defense and swimming (Narchi 1973). These appendices and segments of the crustaceous can show some degree of variability. A morphometric study on the pink Mediterranean shrimp, *Aristeus antennatus*, showed that the scaphocerytes, uropods and the carpo of the third pair of pereopods show adaptive plasticity (Sardà *et al.* 1998).

Structures with large functional importance are normally subject to strong selective pressure in natural populations. Thus the presence of the significant fluctuating asymmetry indexes in such structures may reflect the maximum degree of tolerability permitted by environmental pressures.

Characteristics with weak stabilizing selection are less stable and therefore can develop a wide range of phenotypes and show high levels of fluctuating asymmetry (Balmford *et al.* 1993). This can result in the characteristics that are functionally

important presenting extremely restricted development ways, revealing lower fluctuating asymmetry levels (Møller & Swaddle 1997, Kodrick-Brown 1997). In birds, the wings have more stable development than the tails due to their greater aerodynamic importance (Møller & Höglund 1991, Balmford *et al.* 1993, Anciães 1998). Apparently a similar situation was identified here among the pereopods and uropods in *L. schmitti* with marked asymmetries in the first and absence of asymmetries in the latter. But the hypothesis cannot be disregarded that structures with segments in series such as the pereopods can suffer a greater degree of asymmetry during development than simpler structures such as the uropods and scaphocerytes.

The level of asymmetry fluctuates within populations (with approximately normal distribution) indicating that is a property of the population. Some individuals tend to present some level of asymmetry that reflects how much its genotype can express the ideal phenotype in given

conditions. This can lead to rejection of the normal distribution, although the segment analyzed is statistically significant (Galhardo 1995), as observed in all the *L. schmitti* appendixes and segments.

Thus, considering the fluctuating asymmetry properties (Palmer & Strobeck 1992, Møller 1997), the occurrence of fluctuating asymmetries could only be identified in the propod (1st pair), ischium (2nd and 3rd pairs) and mero (2nd pair) segments. For the other segments the pereopods and the measurements (width and length) of scaphocerytes (WS and LS) and of lateral and medial uropods (WLU, width of lateral uropod, LLU, length of lateral uropod, WMU, width of medial uropod, LMU, length of medial uropod) fluctuating asymmetry was not considered to exist because it

did not fit in fluctuating asymmetry properties.

Markow (1995) considered fluctuating asymmetries as a random flight from a predicted bilateral symmetry, so that one group of differences between the sides creates a normal distribution. One level of fluctuating asymmetries that is relatively higher than the level found in an appropriate control group reflects the reduced homeostasis of development. Bearing in mind the optimum environmental conditions available for *L. schmitti*, the reduced fluctuating asymmetry indexes might be considered as base levels of the population. Given the phylogenetic proximity with congeneric species, these data could be a comparative parameter for others penaeid species, populations or cultivated stocks.

Table III. Statistics of the fluctuating asymmetry distribution in the segment measurements (ischium, mero, carpo and propod) in *Litopenaeus schmitti*

Segments	Average	Confidence Interval 95%		Asymmetry Coefficient	<i>p</i> asymmetry	Kurtosis Coefficient	<i>p</i> Kurtosis
		Low range	High range				
1 st pereiopod							
I	0.0009	-0.0087	0.0104	-0.3356	0.3806 ^{NS}	8.7194	p<0.0001 [*]
M	-0.0025	-0.0055	0.0006	-3.6569	p<0.0001 [*]	17.5976	p<0.0001 [*]
C	-0.0055	-0.0120	0.0009	-2.9157	p<0.0001 [*]	9.0407	p<0.0001 [*]
P	-0.0014	-0.0033	0.0005	-0.6713	0.0884 ^{NS}	2.0727	0.0107 [*]
2 nd pereiopod							
I	-0.0007	-0.0062	0.0048	-0.1831	0.6299 ^{NS}	5.4760	p<0.0001 [*]
M	0.0000	-0.0024	0.0024	-0.7511	0.0589 ^{NS}	7.2738	p<0.0001 [*]
C	-0.0014	-0.0057	0.0030	0.6367	0.1048 ^{NS}	7.9385	p<0.0001 [*]
P	-0.0001	-0.0029	0.0028	-2.2742	p<0.0001 [*]	12.2844	p<0.0001 [*]
3 rd pereiopod							
I	-0.0008	-0.0031	0.0015	-0.1362	0.7196 ^{NS}	-0.1693	0.8197 ^{NS}
M	0.0013	-0.0003	-0.0003	0.9157	0.0242 [*]	2.6072	0.0021 [*]
C	-0.0011	-0.0025	0.0004	-1.4651	0.0009 [*]	6.7600	p<0.0001 [*]
P	0.0020	-0.0003	0.0042	2.6668	p<0.0001 [*]	9.6223	p<0.0001 [*]
Scaphoceryte							
WS	-0.0027	-0.0068	0.0014	-1.3319	0.0021 [*]	8.4406	p<0.0001 [*]
LS	0.0016	-0.0002	0.0035	1.6978	0.0002 [*]	3.6421	p<0.0001 [*]
Uropods							
WLU	-0.0028	-0.0067	0.0012	-2.3601	p<0.0001 [*]	7.4722	p<0.0001 [*]
LLU	-0.0033	-0.0169	0.0103	-4.6449	p<0.0001 [*]	28.8452	p<0.0001 [*]
WMU	0.0005	-0.0070	0.0080	2.8156	p<0.0001 [*]	13.3322	p<0.0001 [*]
LMU	0.0049	-0.0076	0.0174	4.8598	p<0.0001 [*]	29.1741	p<0.0001 [*]

NS- no statistically significant; * - statistically significant; Assimetry coefficient – differences between left (-) and right (+) sides; WS – width scaphoceryte; LS – length scaphoceryte; WLU- width lateral uropod; LLU – length lateral uropod; WMU- width medium uropod; LMU- length medium uropod.

Table IV. Presence of fluctuating asymmetries (FA) in the parameters measured in each appendix of *Litopenaeus schmitti* specimens.

Appendix	Segments	Average	<i>p</i>	K - S	Results
1 st pereopod	I	0.0009	0.3806 ^{NS}	-	~FA
	M	- 0.0025	<i>p</i> < 0.0001*	-	~FA
	C	- 0.0055	<i>p</i> < 0.0001*	-	~FA
	P	- 0.0014	0.0884 ^{NS}	+	FA
2 nd pereopod	I	- 0.0007	0.6299 ^{NS}	+	FA
	M	0.0000	0.0589 ^{NS}	+	FA
	C	- 0.0014	0.1048 ^{NS}	-	~FA
	P	- 0.0001	<i>p</i> < 0.0001*	-	~FA
3 rd pereopod	I	- 0.0008	0.7196 ^{NS}	+	FA
	M	0.0013	0.0242*	+	FA
	C	- 0.0011	0.0009*	-	~FA
	P	0.0020	<i>p</i> < 0.0001*	-	~FA
Scaphoceryte	WS	- 0.0027	0.0021*	-	~FA
	LS	0.0016	0.0002*	-	~FA
Uropods	WLU	-0.0028	<i>p</i> < 0.0001*	-	~FA
	LLU	-0.0033	<i>p</i> < 0.0001*	-	~FA
	WMU	0.0005	<i>p</i> < 0.0001*	-	~FA
	LMU	0.0049	<i>p</i> < 0.0001*	-	~FA

NS - not statistically significant; * - statistically significant; K-S – Kolmogorov-Smirnov test; (+) normal; (-) not normal; ~ despite statistically significant were rejected the FA; I – ischium; M – mero; C – carpo; P – propod; WS – width scaphoceryte; LS – length scaphoceryte; WLU - width lateral uropod; LLU – length lateral uropod; WMU - width medium uropod; LMU - length medium uropod.

The distribution of differences between the left and the right sides measures presented leptokurtic distribution, indicating FA (Møller 1996). The preponderance of the leptokurtic distribution presented in results is consistent with some models presented (Møller 1997, Vøllestad *et al.* 1999) showing that the differences inherent to ability of individuals control the development process invariably implies this type of distribution.

The comparative FA study in *L. schmitti* revealed the occurrence of fluctuating asymmetries in a non preferential form between the sexes. These results differ from those obtained with stocks of *L. vannamei* (Silva 2001) whose females were more asymmetric than males.

For various authors (Jones 1987, Thornhill 1992, Möller 1995), natural selection acting on morphological characteristics such as the sensor pores and the number of rays in fish fins would act equally in males and females since less stable genotypes would have less survival. The effect of stabilizing selection on fluctuating asymmetries in a *Cyprinodon pecosensis* population influenced the degree of fluctuating asymmetry of the characteristic in both sexes as well as in the reduction of its

variability indicating that the modal phenotypes would be more symmetrical than those more extreme, suggesting that the individuals with values close to the mean of the group represent highly stable genotypes (Kodric-Brown & Hohmann 1990, Kodric-Brown 1997).

The low indexes of fluctuating asymmetries obtained for the natural *L. schmitti* population showed the stability of the population in the face of the deviation of development, permitting the establishment of maximum tolerance values under natural conditions. These results would permit the use of this methodology to monitor other natural Penaeidae populations, and the applied use in stock control under cultivation conditions.

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Size-related changes in diet of the slipper sole *Trinectes paulistanus* (Actinopterygii, Achiridae) juveniles in a subtropical Brazilian estuary

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Abstract. Size-related changes in the diet of the slipper sole *Trinectes paulistanus* juveniles were described based on the stomach content analysis of 105 specimens (9 – 55 mm standard length) collected in an oligohaline habitat of the Paranaguá Bay estuarine complex (southern Brazil). From multivariate analyses, an ontogenetic diet shift was detected at about 25 mm standard length. Chironomidae larvae were the most important prey for the smaller fish (≤ 25 mm), and the tanaid *Kalliapseudes schubarti*, for the larger ones (> 25 mm). Results of feeding strategy analyses revealed a trophic specialization toward a single prey and, consequently, the trophic niche was narrow within each size class. We discussed such size-related dietary patterns in light of ontogenetic changes in mouth gape size.

Key words: feeding habits, population feeding specialization, Paranaguá estuarine complex, flatfish, *Leptocheirus spinicoxa*

Resumo. Mudanças ontogenéticas na dieta de juvenis do linguado *Trinectes paulistanus* (Actinopterygii, Achiridae) em um estuário subtropical do Brasil. Variações ontogenéticas na dieta de juvenis do linguado *Trinectes paulistanus* foram descritas a partir da análise do conteúdo estomacal de 105 espécimes (9 – 55 mm comprimento padrão - CP) coletados em um habitat oligohalino do complexo estuarino da baía de Paranaguá (Sul do Brasil). Análises multivariadas detectaram uma mudança na dieta em 25 mm de CP. Larva de Chironomidae e *Kalliapseudes schubarti* dominaram as dietas dos menores (≤ 25 mm CP) e maiores peixes (> 25 mm CP), respectivamente. Os resultados de análises de estratégia alimentar revelaram especialização em uma particular presa e um conseqüente nicho trófico reduzido dentro de cada classe de tamanho. Discutiram-se tais padrões ontogenéticos de dieta à luz de mudanças ontogenéticas na abertura oral em *T. paulistanus*.

Palavras-chave: hábito alimentar, especialização trófica da população, complexo estuarino de Paranaguá, linguado, *Leptocheirus spinicoxa*

Introduction

The Achiridae are moderately small flatfishes which are principally marine and estuarine, although some species occur in freshwater (Munroe 2002). The slipper sole, *Trinectes paulistanus* (Miranda-Ribeiro, 1915), is a small (max 180 mm standard length - SL), marine demersal species that is widely distributed along the Eastern South American coast, from Colombia to southern Brazil (Munroe 2002). It exhibits negligible commercial importance and is commonly caught and discarded

as by-catch in crustacean trawl fisheries operating in estuaries and shallow coastal areas (Munroe 2002). *T. paulistanus* larvae and juveniles appear to occupy shallow estuarine areas (Bonecker *et al.* 2007, Michele & Uieda 2007) and adults, main channels of estuaries (Maciel 2001), bays (Azevedo *et al.* 2007), beaches (Godefroid *et al.* 2004), and inner shelf habitats (Santos 2007).

Michele & Uieda (2007) found *T. paulistanus* juveniles feeding on insects, polychaetes, isopods, and amphipods in a

southeastern Brazilian mangrove river. Despite abundant in estuaries of the subtropical Brazil (Maciel 2001), the species' biology and ecology are poorly described. Further, there is no information on ontogenetic dietary shifts, which may reduce intra-specific competition for food resources especially when various size classes occur at same general habitat (Ward-Campbell & Beamish 2005). Changes in gape size facilitate intra-specific partitioning of food as gape constraints the size of the ingested prey (Ward-Campbell & Beamish 2005).

Within size-structured fish populations, individual specialization may be a conspicuous phenomenon (Svanback & Persson 2004) and thus is necessary to be estimated for characterizing the feeding niche width precisely (Bolnick *et al.* 2003).

This study deals with the diet of *T. paulistanus* juveniles of an oligohaline habitat within the estuarine complex of Paranaguá Bay (southern Brazil). Our specific goal is to examine size-related shifts in diet composition in light of the mouth dimensions changes and individual trophic specializations.

Materials and Methods

The study took place in the upper estuary of Guaraguaçu River, a large tributary located on the

southern part of the Paranaguá Bay estuarine complex, Brazil (Fig. 1). Three continuous stations within the river's oligohaline zone were selected for sampling (Fig. 1). Sampling was monthly conducted from February-2006 to April-2006. Fish were caught by a 15 m x 2 m seine-net with a uniform mesh size of 5 mm. During each survey, one 20 m-tow was performed parallel to the river's course at each station, fishing to depth of ca. 1.5 m. Fish were stored and transported on ice to the laboratory.

In laboratory, the vertical (MV) and horizontal (MH) mouth openings (0.1 mm - using a caliper) and SL (mm) were taken of each fish before its stomach was removed and preserved in 10% formalin. Stomach fullness was estimated visually on a scale of 1 (10% full) to 10 (100% full; Sarre *et al.* 2000). Prey items from each stomach were identified to the lowest taxonomic level and quantified by: (1) percentage volume (%V - by spreading all stomach contents in counting cell chamber with uniform depth and then calculating $\text{area of prey item } j / \text{total item area} \times 100$; modified from Hellowell & Abel 1971); and (2) percentage abundance (%N) as $\text{number of prey item } j / \text{total number of prey} \times 100$ (Hyslop 1980). To preserve individual variation, stomach contents were not pooled in the following analyses (Ley *et al.* 1994).

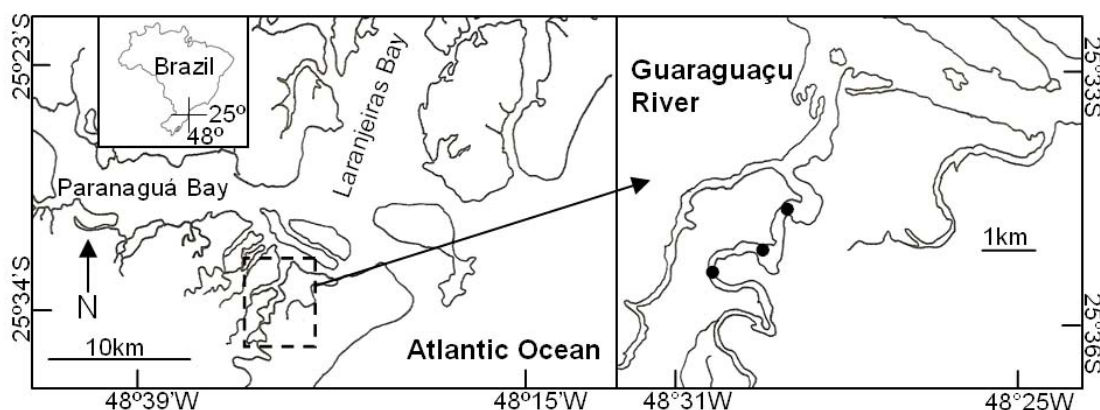


Figure 1. Map of the estuarine complex of Paranaguá Bay and its location on the southern Brazilian coast. The Guaraguaçu River Estuary and the capture stations (●) are shown in detail.

A group average hierarchical cluster analysis, using the Bray-Curtis similarity index, assessed size-related variations in diet. It based on individual stomach content data, which were described by %V values only. Due to heterogeneous size range of the diet components, %N values are less suitable in similarity analysis (Baldó & Drake 2002) and thus were not used. %V values were root-square transformed prior analysis. Analysis of similarity (ANOSIM; Clarke & Warwick 1994)

tested for differences in diet between resultant clusters (size groups) and month of captures.

To synthesize the size group diet information, the frequency of occurrence (%F - percentage of fish containing a given prey item *j*), the mean %V and mean %N values, and the index of relative importance $[IRI_j = (\%N_j + \%V_j) \times \%F_j]$ were computed for each prey item (Hyslop 1980).

The Costello graphical method (Costello 1990), modified by Amundsen *et al.* (1996), was

employed to look for general trends in feeding behavior of *T. paulistanus*. To identify individual specialization, the proportion similarity index was calculated following Svanback & Persson (2004):

$$PS_i = \sum_j \min(p_{ij}, q_j), \text{ where } p_{ij} \text{ is the proportion}$$

volumetric of prey item j in the individual i 's diet and q_j is the volumetric contribution of j in the diet of the population as a whole. For individuals that specialize on a single diet item j , PS_i takes on the value q_j . For individuals that consume resources in direct proportion to the population as a whole, PS_i will equal 1 (Svanback & Persson 2004). The overall prevalence of individual specialization (IS) in the population can be expressed by the average PS_i value: $IS = 1/n \times \sum_i PS_i$ (Svanback & Persson

2004). Note that if all individuals have the same diets then IS will be 1, indicating no individual specialization, while values close to 0 indicate strong individual specialization (Svanback & Persson 2004).

Finally, mouth dimensions (MH and MV) were regressed against SL (either linearly or log-linearly, based on the r^2 value) (Karpouzi & Stergiou 2003). One-way ANOVA tested the association between SL and dependent variables.

Results

Caught fish ranged from 9 to 55 mm SL (mean size = 26.9 mm SL), with the best represented class being the 15-25 mm SL (Fig. 2). Of the 105 individuals caught, 88 (83.8%) contained food in the stomachs and were used in diet analysis.

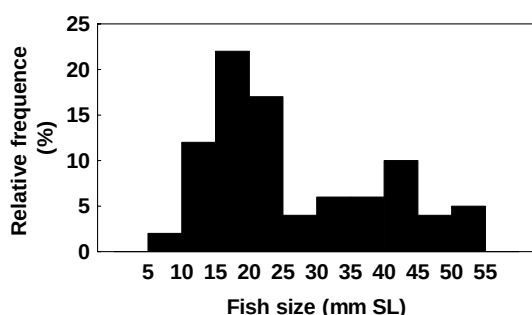


Figure 2. Size-frequency distribution of *T. paulistanus*, collected in the Guaraguaçu River Estuary. SL = Standard Length

Month of capture did not appear to have significant effect on diet compositions (ANOSIM, $R = 0.106$, $p > 0.09$).

Two size groups with similar dietary pattern were identified (Fig. 3): group 1 ($n = 38$) pooled almost all fish smaller than 26 mm SL, and group 2

($n = 50$), mainly those larger than 25 mm SL. The diet composition of the groups were significant different (ANOSIM, $R = 0.544$, $p < 0.01$) and the mean stomach fullness of both was relatively high and similar (> 6 , Table I). According to the diet indices (Table I), and the feeding strategy diagram (Fig. 4a), chironomid larva was the major prey within the group 1, followed by the tanaid *Kalliapseudes schubarti*. Some individuals specialized on the latter and also another tanaid *Sinelobus stanfordi* (Fig. 4a). The diets of the larger fish (group 2) were by far dominated by *K. schubarti*, and secondly by chironomids and polychaetes on which some fish specialized (Fig. 4b and Table I). Remaining prey items can be considered occasional.

Within each size group, the predominance of high PS_i -values (Fig. 5), the high IS -values ($IS_{\text{GROUP1}} = 0.68$, $IS_{\text{GROUP2}} = 0.76$), and a restrict point in the upper right of the diagram (Fig. 4 a, b) represent a predator population's specialization (thus a low individual specialization) as well as a population's narrow niche. MH related log-linearly ($\ln MH = \ln 1.1072SL - 3.1667$, $r^2 = 0.84$) and MV linearly ($MV = 0.0965SL - 0.0247$, $r^2 = 0.92$; Fig. 6) with SL. The slopes of the regressions were all statistically significant ($p < 0.0001$).

Discussion

Comparing our data to those of other areas reveals that benthivory appears to be common in *T. paulistanus*, despite some differences in terms of prey composition. While it feeds on polychaetes, amphipods, and aquatic insects in the Rio da Fazenda Estuary (Michele & Uieda 2007), in the Sepetiba Bay its diet is dominated by polychaetes (Guedes & Araújo 2008). The congeneric *T. maculatus* also consumes mainly benthic invertebrates, such as polychaetes and amphipods (Derrick & Kennedy 1997). In the oligohaline zone of the Guaraguaçu, *T. paulistanus* preyed heavily on chironomids and *K. schubarti*, probably due to their high availability. Chironomid larvae seem to be common in low-salinity upper estuaries (Corrêa & Uieda 2008) and *K. schubarti* is an abundant macrofauna component in the Paranaguá Bay (Lana *et al.* 1989; Lana & Guiss 1991).

Within each size group, almost all individuals fed mostly upon a dominant prey taxon (either *K. schubarti* or chironomid larvae), some specialized on specific items, and few included small proportions of other prey types occasionally. Such a strong feeding specialization of the groups resulted in narrow trophic niche widths, which differ

from those with high within- or between-phenotype component (Amundsen *et al.* 1996). Narrow trophic niche was also reported by the population from Sepetiba Bay (Guedes & Araújo 2008).

The observed size-related diet shift may be related to ontogenetic shifts in gape size that grew consistently with increasing body size in *T. paulistanus*. Ontogenetic gape increase (among other factors) allows growing predators to ingest

more elusive, larger prey successfully (Karpouzi & Stergiou 2003; Ward-Campbell & Beamish 2005). In fact, chironomid larva is a small, slow-moving prey, while *K. schubarti* is relatively larger and more elusive, despite its tubicolous life style (Lana & Guiss 1991). Similar predator-prey size relationships also were detected in other flatfish (Scharf *et al.* 2000) and other estuarine fishes (Scharf & Schlicht 2000; Contente *et al.* in press).

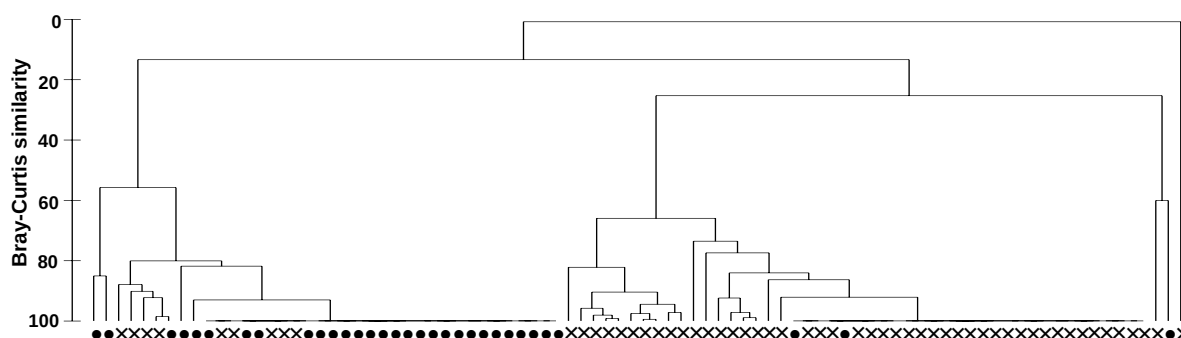


Figure 3. Hierarchical cluster analysis based on percentage by volume (%V) of the *T. paulistanus* individual diets from the Guaraguaçu River Estuary. ● = fish > 25 mm standard length; x = fish ≤ 25 mm standard length.

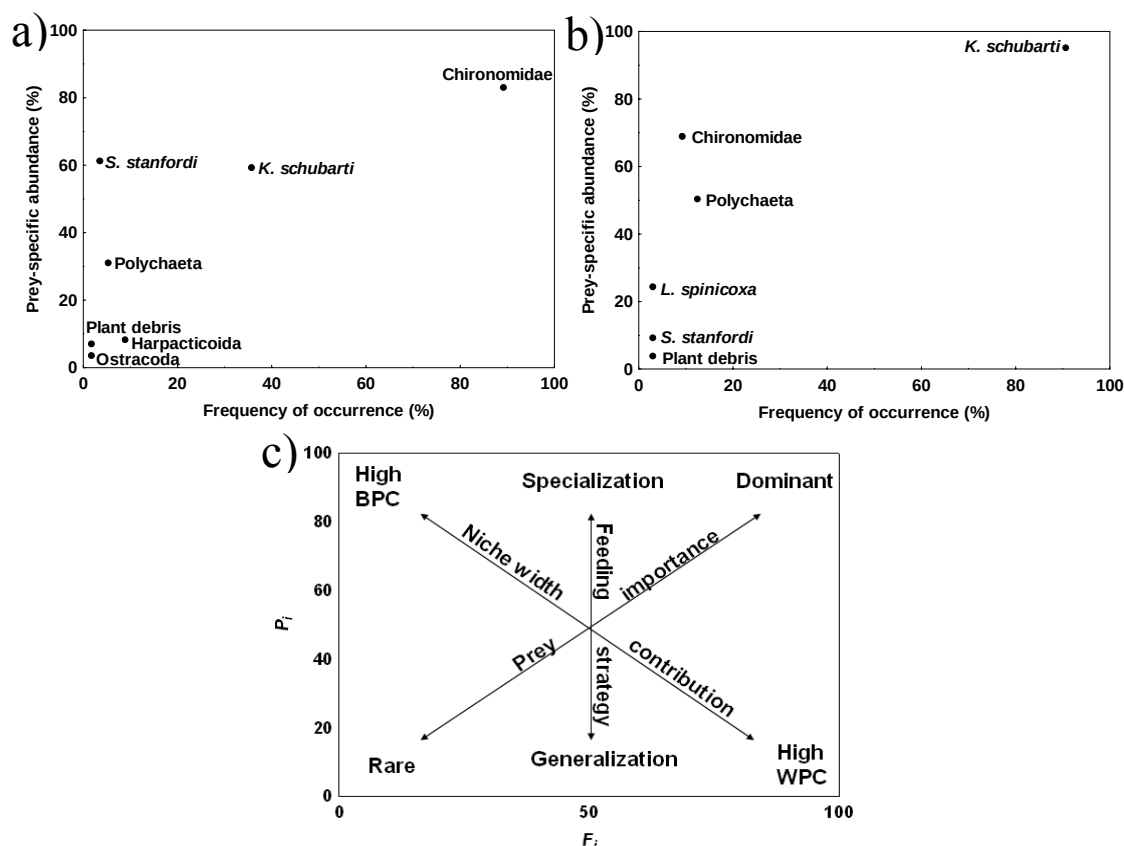
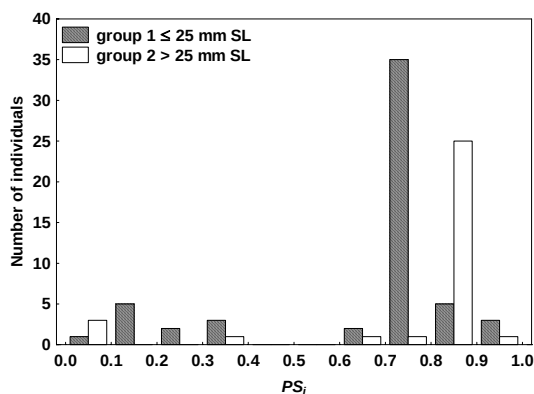
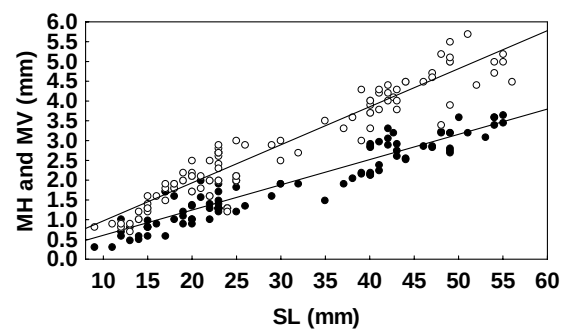


Figure 4. Relationship between prey-specific abundance (P_i) and frequency of occurrence (% F_i) of prey items in the diet of *T. paulistanus* size groups, collected in the Guaraguaçu River Estuary. [(a) ≤ 25 mm standard length group; (b) > 25 mm standard length group]. (c) explanatory diagram modified of Amundsen *et al.* (1996).

Table I. Prey items of two *T. paulistanus* size groups from the Guaraguaçu River Estuary. SL = Standard Length, %F = frequency of occurrence, %V = percentage by volume, %N = numeric abundance, and %IRI = index of relative importance. Mean stomach fullness also is given.

Prey item	≤25 mm SL group size				>25 mm SL group size			
	%F	%V	%N	%IRI	%F	%V	%N	%IRI
Insecta								
Chironomidae larva	89.29	78.75	90.17	94.46	9.38	6.98	8.57	0.91
Crustacea								
Tanaidacea								
<i>Kalliapseudes schubarti</i> Mañe-Garzon, 1969	35.71	17.53	5.94	5.25	90.63	85.88	87.15	98.36
<i>Sinelobus stanfordi</i> (Richardson, 1901)	3.57	0.74	0.52	0.03	3.13	0.15	0.71	0.02
Amphipoda								
Gammaridea								
<i>Leptocheirus spinicoxa</i> Valerio-Berardo & Wakabara, 2003					3.13	1.24	0.71	0.04
Ostracoda	1.79	0.07	0.26	< 0.01				
Copepoda								
Harpacticoida	8.93	0.53	2.33	0.16				
Polychaeta	5.36	2.18	0.78	0.10	12.50	5.67	2.86	0.67
Plant debris	1.79	0.20		< 0.01	3.13	0.08		< 0.01
Mean stomach fullness (mean ± SD)	6.5 ± 0.28				6.1 ± 0.27			

Considering the overlap between coexisting individuals of different sizes and such abundant prey, smaller fish may have restricted themselves to smaller prey (chironomids) due to gape limitations, while larger ones preferred more profitable, larger prey (*K. schubarti*). This narrows the feeding niche in each ontogenetic stage, which may be a potential mechanism of intra-specific partitioning of food. Such a hypothesis must be tested by future investigations taking into account prey size, prey abundance-availability, and predator's preference through size groups. Moreover, for a complete knowledge of the trophic ecology of *T. paulistanus*, future studies should focus on the description of ontogenetic patterns beyond the limits examined in this study.

**Figure 5.** Frequency distribution of proportion similarity (PS_i) index values of *T. paulistanus* from the Guaraguaçu River Estuary.**Figure 6.** Vertical (MV - ○) and horizontal (MH - ●) mouth opening relation with standard length (SL) of *T. paulistanus* from the Guaraguaçu River Estuary.

Finally, this is the first record of *Leptocheirus spinicoxa* (Corophiidae) (Table I) for the southern Brazilian coast. It has been previously only reported in the northeastern coast (Valerio-Berardo & Wakabara 2003). Due to high mobility, fish may display a higher prey detection rate than conventional samplers (Raddum & Fjellheim 2003) and this may lead to new records of taxa not detected in previous fauna surveys (Fjellheim *et al.* 2007).

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Morphological data, biological observations and occurrence of a rare skate, *Leucoraja circularis* (Chondrichthyes: Rajidae), off the northern coast of Tunisia (central Mediterranean)

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Abstract. This paper presents information on a rare skate, *Leucoraja circularis* (Couch 1838), from off the northern coast of Tunisia (central Mediterranean), based on 11 specimens, 5 males, 6 females, captured from 1971 to date. Morphological data such as morphometric measurements and meristic counts were recorded. Additionally, biological observations showed that females were larger than males. The largest adult male and the largest adult female were 450 and 620 mm disc width (DW), respectively, while the largest juvenile male and the largest juvenile female were 400 mm and 420 mm DW, respectively. The largest adult female exhibited yolky oocytes ready to be ovulated, measuring between 25 and 29 mm in diameter (mean = 27.8 ± 1.4), and weighing between 2.9 and 3.5 g (mean = 3.3 ± 0.2). Two egg cases were found in this female, one in each uterus, measured 109-111 mm in length with horns, 88-89 mm in length without horns, 55-60 mm in width, and weighed 28-32 g. *Leucoraja circularis* is locally very rare as well in other Mediterranean regions. However, it is suggested that a population could inhabit a limited area, southern Italian Seas -Strait of Sicily- northern Tunisian coast, but such hypothesis needs further confirmation.

Key words: disc width-total mass relationship, mucous pores, competition pressure, migration.

Resumo. Dados morfológicos, observações biológicas e ocorrência de uma raia rara, *Leucoraja circularis* (Chondrichthyes: Rajidae), águas fora da costa norte da Tunísia (Mediterrâneo central). O presente trabalho proporciona informação sobre uma espécie de raia rara, *Leucoraja circularis* (Couch 1838), em águas fora da costa norte da Tunísia (Mediterrâneo central), baseado em 11 espécimes, 5 machos e 6 fêmeas, capturados desde 1971 até o presente. Dados morfológicos, medições morfométricas e contagem merística foram analisados. Adicionalmente, observações biológicas mostraram que as fêmeas foram maiores do que os machos. O maior macho adulto e a maior fêmea adulta tiveram largura de disco de 450 e 620 mm respectivamente, enquanto que a o maior macho juvenil e a maior fêmea juvenil mediram 400 mm e 420 mm de largura de disco, respectivamente. A maior fêmea adulta apresentou folículos vitelogênicos prontos para serem ovulados, com diâmetros de entre 25 e 29 mm (média = 27.8 ± 1.4), e peso de entre 2.9 e 3.5 g (média = 3.3 ± 0.2). Duas cápsulas ovíferas foram encontradas nesta fêmea, uma em cada útero, com comprimento de 109-111 mm considerando os chifres; 88-89 mm de comprimento sem considerar os chifres; 55-60 mm de largura e peso de 28-32 g. *Leucoraja circularis* é localmente muito rara assim como em outras regiões do Mediterrâneo. Porém, se presume que a população possa habitar uma área limitada, o Estreito de Sicília, nos Mares italianos do sul, ao norte da costa da Tunísia, mas esta hipótese precisa ser confirmada.

Palavras-chave: relação largura de disco-peso total, poros mucosos, pressão de competição, migração.

Introduction

The sandy ray *Leucoraja circularis* (Couch 1838) is occasionally caught in the northern North Sea and Celtic Sea at depths of 108-432 m according to Ellis *et al.* (2005). The species was known around the British Isles (Wheeler 1969), along the French Atlantic shore (Quéro *et al.* 2003), the Atlantic coast of Spain (Ortea & De La Hoz 1979, Rodríguez-Cabello 2005) and off Portugal (Albuquerque 1954, 1956). South Strait of Gibraltar, *L. circularis* was reported off Morocco by Collignon & Aloncle (1972).

Leucoraja circularis is only reported in the western Mediterranean Basin (Quignard & Tomasini 2000), being mostly recorded in the Strait of Sicily (Ragonese *et al.* 2003) and in Italian Seas (Consalvo *et al.* 2008). Moreau (1881) recorded the species for the first time off southern coast of France, and then Quignard (1965) reported it as rather common in the Gulf of Lion. However, since 1965, no record of the sandy ray was done in the latter area according to Capapé *et al.* (2006). The Greek waters seem to be its easternmost range extension (Economidis 1973, Mytilineou *et al.* 2005) being the species not

reported to date in the Levant Basin (Golani 2005).

Of the fourteen skate species reported off the Tunisian coast (Capapé 1987, Bradaï *et al.* 2004), *L. circularis* is locally considered as rare such as in other Mediterranean areas (Consalvo *et al.* 2008). The species was only recorded to date off the northwestern area from the Algerian border to Bizerte (Fig. 1). It was firstly recorded by Le Danois (1925), then by Bourgois & Farina (1961) and Quignard & Capapé (1972) who recorded two specimens. Eight other sandy rays were collected between 1973 and 1982, and a single specimen in 2007 (Fig. 2).

The purpose of this paper is to present, since 1972 to date, all available data concerning some morphological data such as morphometric measurements and counts, and biological observations carried out in sandy rays caught in Tunisian waters and to assess the real status of the species in the region to prepare a national plan for elasmobranch species in the same region. Additionally, the distribution of *L. circularis* in the Mediterranean Sea is commented and discussed.

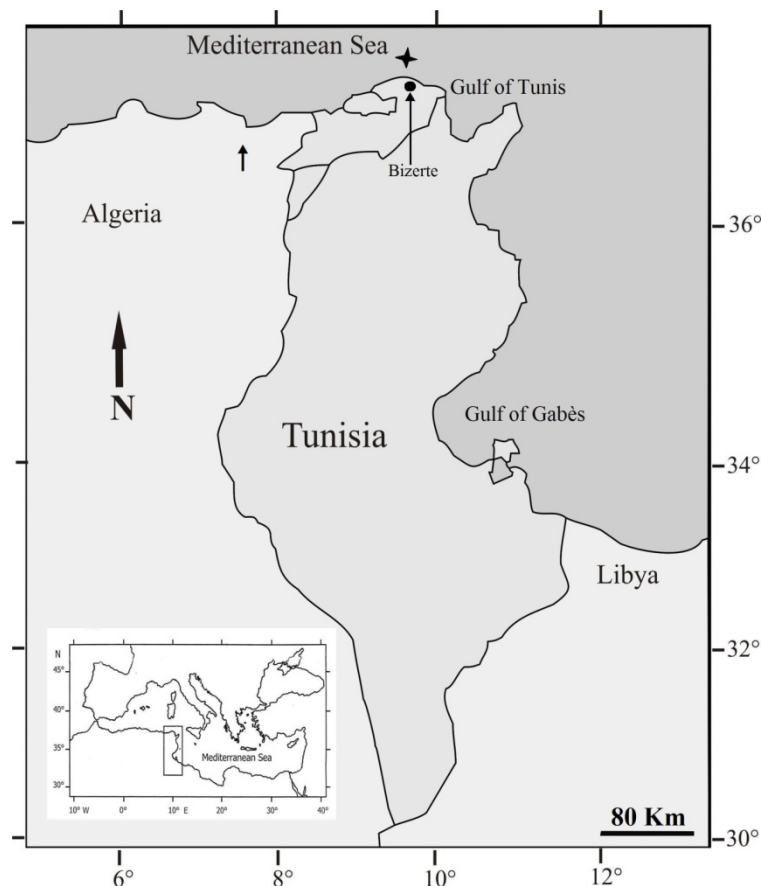


Figure 1. Map of the Mediterranean showing the Tunisian coast and pointing out the capture sites of *Leucoraja circularis* off Bizerte (black star).



Figure 2. Adult female of *Leucoraja circularis* (ref. FSB Raj – circ 01), captured on 26 June 2007, off Bizerte, scale bar = 100 mm.

Material and Methods

At all, 11 specimens were examined, caught by bottom trawler operating off Bizerte in northern Tunisia, at depths between 150 and 350 m, on sandy-muddy bottoms. The specimens were captured between 1971 and 2007. The last specimen was caught off the northern Tunisian coast on 25 June 2007. This specimen was preserved in 5 % buffered formaline and deposited in the Ichthyological Collection of the Faculté des Sciences of Bizerte (Tunisia) under the catalogue number FSB- Raj- circ 01 (Fig. 2).

Disc width (DW) and other morphometric measurement were carried out following Clark (1926), Mejri *et al.* (2004) and Consalvo *et al.* (2008), while meristic counts followed Quignard (1965), such as tooth rows, truncal vertebrae, pectoral fin rays, pseudo-branchial lamellae, and Capapé & Quignard (1981) such as nictitating lamellae. Additionally, Aloncle (1966) suggested the use of the external distribution of the mucous pores (ampullae of Lorenzini) in ventral surface, for taxonomy of rajid species. Similar pattern was also used by Bini (1967) and Gomes & Parago (2005) for distinguish some skate species from off Italian Seas and Brazil, respectively. Aloncle (1966) draws a line subdivided in three different regions (see Fig. 6): wing, curve and point, presenting interspecific variations in skate species from off the Moroccan coast.

Total mass (TM) was recorded to the nearest gram. Developing and yolky oocytes were firstly

counted on each ovary; then they were removed and measured to the nearest millimeter and weighed, when possible, to the nearest decigram. Egg cases were extracted from the oviducts and weighed to the nearest decigram after removal of surface water by blotting on tissue paper and were measured to the nearest millimeter; three measurements were considered: length with horns not including filaments, length without horns and width.

Male reproductive condition was assessed by examination of claspers, following Collenot (1969), while some aspects of the testes and other reproductive organs were given following Hamlett *et al.* (1999) and Capapé *et al.* (2004). In juveniles, testes and genital ducts were membranous and inconspicuously developed, while in adults, testes were well-developed and exhibited spermatocysts externally visible. The genital duct was twisted and sperm was observed in the seminal vesicles. Size at sexual maturity was determined in females from the condition of ovaries, the reproductive tract morphology and the mass of the oviducal glands (see Capapé *et al.* 2004, Callard *et al.* 2005). Both male and female specimens were divided in two categories: juvenile and adult.

The relationship between DW and TM was calculated, this relationship being useful as an indication of species for condition or for stock assessment (Petrakis & Stergiou 1995, Froese 2006). The linear regression was expressed in decimal logarithmic coordinates. Correlations were assessed by least-squares regression.

Results

Main morphometric measurements were carried out on 6 specimens, 2 males and 4 females, and given in Table I.

Table I. Masses and main morphometric measurements recorded in six female *Leucoraja circularis* caught off northern Tunisian coast.

Sex	Male		Male		Female		Female		Female		Female	
Year of capture	1977		1979		1971		1973		1982		2007	
Total mass in gram	1250		2000		4930		4706		5650		4485	
Morphometric measurements	mm	% DW	mm	% DW	mm	% DW	mm	% DW	mm	% DW	mm	% DW
Total length	619	163.1	672	160.1	880	155.7	860	154.9	101	160.5	715 (?)	120 (?)
Disc length	300	78.9	332	79.1	445	78.8	430	77.4	490	79	475	79.2
Disc width	380	100	420	100	565	100	555	100	620	100	600	100
Disc-depth	26	6.8	28	6.7	38	6.7	36	6.5	42	6.8	40	6.6
Eyeball length	17	4.5	19	4.5	24	4.2	24	4.3	27	4.4	25	4.2
Cornea	11	2.9	12	2.8	16	2.8	15	2.7	18	2.9	16	2.7
Pre-orbital length	65	17.1	71	17.1	99	17.5	96	17.3	100	16.2	97	16.2
Inter-orbital width	24	6.3	26	6.2	35	6.2	33	5.9	40	6.5	38	6.3
Spiracle length	16	4.2	18	4.3	25	4.4	23	4.1	26	4.2	24	4
Spiracle width	-	-	-	-	-	-	-	-	-	-	17	2.8
Inter-nasal width	40	10.5	44	10.5	58	10.3	58	10.5	62	10	59	9.8
Nasal curtain	-	-	-	-	-	-	-	-	-	-	73	12.2
Inter-spiracular width	35	9.2	36	8.6	49	8.6	49	8.8	62	10	57	9.5
Pre-oral length	-	-	-	-	90	15.9	91	16.4	99	15.9	97	16.2
Mouth width	43	11.3	49	11.7	75	13.2	74	13.3	80	12.9	77	12.8
First gill slit	-	-	-	-	-	-	-	-	-	-	23	3.8
Second gill slit	-	-	-	-	-	-	-	-	-	-	22	3.7
Third gill slit	-	-	-	-	-	-	-	-	-	-	22	3.7
Fourth gill slit	-	-	-	-	-	-	-	-	-	-	22	3.7
Fifth gill slit	-	-	-	-	-	-	-	-	-	-	16	2.7
Width between first gill slit	-	-	-	-	-	-	-	-	-	-	135	22.5
Width between fifth gill slit	-	-	-	-	-	-	-	-	-	-	84	14
Snout tip to first gill slit	-	-	-	-	-	-	-	-	-	-	108	18
Snout tip to fifth gill slit	-	-	-	-	-	-	-	-	-	-	84	14
Snout tip to pelvic fin	-	-	-	-	-	-	-	-	-	-	165	27.5
Snout tip to vent	280	73.7	310	73.8	420	74.3	410	73.9	450	72.6	442	73.7
Pectoral fin anterior margin	238	62.6	270	64.3	365	64.6	360	64.9	390	62.9	370	62.7
Pectoral fin posterior margin	196	51.6	210	50.5	300	53.1	295	52.3	315	50.8	305	50.8
Pectoral fin inner margin	44	11.6	48	11.5	65	11.5	63	11.4	72	11.6	70	11.7
Pelvic fin anterior margin	-	-	-	-	-	-	-	-	-	-	77	12.8
Pelvic fin posterior margin	-	-	-	-	-	-	-	-	-	-	145	24.2
Pelvic fin inner margin	-	-	-	-	-	-	-	-	-	-	64	10.7
Span of pelvic fin	-	-	-	-	-	-	-	-	-	-	234	39
Tail base fin	33	8.7	37	8.8	50	8.8	48	8.7	56	9	53	8.8
Tail base depth	-	-	-	-	-	-	-	-	40	6.5	-	-
Tail length	280	73.7	310	73.8	420	74.3	410	73.9	460	74.2	-	-
Snout tip to first dorsal fin	-	-	-	-	-	-	-	-	862	139	-	-
Snout tip to second dorsal fin	-	-	-	-	-	-	-	-	880	141.9	-	-

Meristic counts were carried out on the eleven specimens of our sample (Table II), being compared

with previous data recorded from other Mediterranean areas.

Table II. Meristic counts recorded in 11 specimens of *Leucoraja circularis* caught off northern Tunisian coast, and compared with similar data previously recorded in specimens caught off other Mediterranean areas.

Authors	This study	Dieuzeide <i>et al.</i> (1953)	Tortonese (1956)	Quignard (1965)	Colligon & Aloncle (1972)
Marine area	Northern coast of Tunisia	Algerian coast	Italian Seas	Gulf of Lion	Atlantic coast of Morocco
Tooth rows	68-92/68-93	68-84/68-84	60-84	68-110/65-111	68-110/65-111
Truncal vertebrae	32-36	-	-	32	-
Pectoral fin rays	90-91	-	-	90	-
Pseudo-branchial lamellae	16-18	-	-	16-19	-
Nictitating lamellae	15	-	-	-	-

Of the 15 nictitating lamellae counted, 7 lamellae were more developed than the 8 others (Fig. 3). The sandy ray presented in Fig. 2 clearly exhibited 8 thorns on each external orbital ring, and 3 rows of nuchal thorns, 10 median and 8 on each side. Aloncle's line showed that the wing is rather narrow and sharpened in its distal end, the curve strongly rounded and the point larger than the wing (Fig. 4).



Figure 3. Nictitating lamellae removed from eye of *Leucoraja circularis*, scale bar = 3 mm.

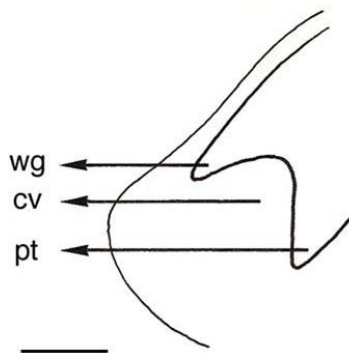


Figure 4. Line of Aloncle drawn from external distribution of mucous pores (ampullae of Lorenzini) on ventral surface of *Leucoraja circularis* showing wing (wg), curve (cv) and point (pt), scale bar = 100 mm.

Of the 11 specimens observed, 5 were males

and 6 females. Males ranged between 350 and 450 mm DW and weighed between 745 and 2560 g, while females ranged between 300 mm and 620 mm DW and weighed between 400 and 5650 g. The relationship between DW and TM, was given by: $\log TM = 3.45 \log DW - 5.85$; $r = 0.98$; $n = 11$ (Fig. 5).

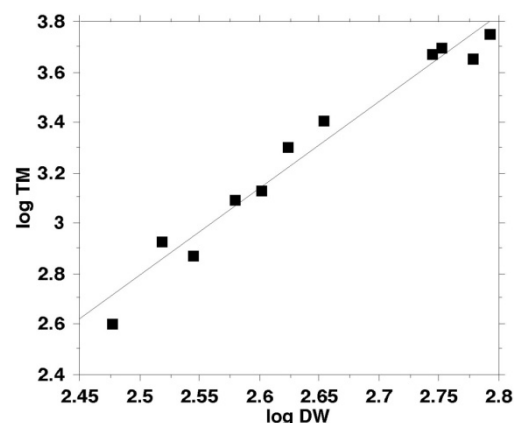


Figure 5. Relationship between disc-width (DW) and total mass (TM) expressed in decimal logarithmic coordinates in *Leucoraja circularis*

Among the males, a single specimen was adult, being the largest one, with 450 mm DW and weighed 2560 g. It exhibited rigid and calcified claspers longer than the pelvic fin. The testes were well-developed and the genital tract was convoluted and well-developed too. The largest juvenile male was 400 mm DW and weighed 1350 g.

The largest adult female weighed 5650 g. Additionally, it exhibited a batch yolk y oocytes ready to be ovulated and a batch of developing oocytes in each ovary. Eight largest oocytes were measured between 25 and 29 mm in diameter (mean = 27.8 ± 1.4), and weighed between 2.9 and 3.5 g (mean = 3.3 ± 0.2), the smallest oocytes ranged between 11 and 15 mm in diameter, being not

wieghed. This female also bore one egg capsule in each uterus (Fig. 6). Measurements recorded were as follows: 109-111 mm in length with horns, 88-89 mm in length without horns, 55-60 in width, 28-32 g in mass. The largest juvenile female was 420 mm DW and wieghed 2000 g TM.



Figure 6. Egg capsule of *Leucoraja circularis* removed from a female caught off northern Tunisian coast, showing horn (hr) and terminal filament (ft), scale bar = 10 mm.

Discussion

Biological observations, morphometric measurements and meristic counts carried out in the sandy ray caught off the northern Tunisian coast did not show differences with those specimens from other Mediterranean areas (Tortonese 1956, Bini 1967, Consalvo *et al.* 2008). However, Consalvo *et al.* (2008) recorded 7 nictitating lamellae in the male caught in the central Tyrrhenian Sea, probably considering the largest lamellae.

Our data suggest that females became adult at a larger DW, above 420 mm, reaching a larger maximal DW, 620 mm, than males, which were sexually mature with DW above 400 mm, attaining up to 450 mm DW. This is an additional instance in sexual dimorphism in size in oviparous elasmobranch species, similar patterns were commonly observed in other skate species from different marine areas (Capapé 1977a, Capapé *et al.* 2004, 2007, Mellinger 1989, Oddone & Velasco 2006). By contrast, males were larger than females in the oviparous smallspotted catshark *Scyliorhinus canicula* (Linnaeus 1758) according to Capapé *et al.* (2008).

Leucoraja circularis is rather considered as a rare species in the Mediterranean areas where it was generally reported. Moreover, it disappeared

from some areas, such as the Mediterranean coast of France where it was previously known (Capapé 1977b, Capapé *et al.* 2004, 2006). To date the species is rather known in the Italian Seas where only some specimens had been recorded (Consalvo *et al.* 2008), although it seems to be more abundant in the Ionian Sea (Bertrand *et al.* 2000). The rarity of the species in other areas such as the Adriatic Sea and its non-occurrence off the eastern Basin, suggests that the species inhabits a rather restricted Mediterranean region.

Additionally, competition pressure with other related predators such as shark species must be considered, as shown by tail broken *intra-vitam*, just before the first dorsal fin (Fig. 2), which did not allow to record some measurements (see Table I). Similar patterns was commonly observed in skates and rays (Clark 1926, Soto & Mincarone 2001). This fact explains why disc width could be more used as reference to measure these elasmobranch species rather than total length.

Although investigations were conducted during the last decade in the Tunisian waters, *L. circularis* appears to be relatively rare in the area. From 1971 to date, 11 specimens were recorded, and only a single one during 25 years, between 1982 and 2007. The relationship between disc width and total mass was positively correlated; moreover, captures of juveniles and adults of both sexes and one female bearing egg capsules in the genital tract allow to think that the species found in the area a favourable environment to develop and reproduce. The species is not completely extincted in the area, even if it is recorded in a limited area, off the northern coast from the Algerian border to Bizerte. Information about the close Algerian waters (Hemida, pers.comm., 2009) showed that the occurrence in this area remains doubtful, moreover, as no sandy ray was recorded since Dieuzeide *et al.* (1953).

Leucoraja circularis is considered as rather common off eastern European Atlantic (Quéro *et al.* 2003). Migration into the Mediterranean Sea through Strait of Gibraltar remains a suitable hypothesis that needs to be proved. However, the scarcity of the species in related areas such as the Spanish coast and the Algerian coast is not in agreement with such hypothesis. It could be also due to human impacts, *L. circularis* being particularly vulnerable to overfishing such as other skate species (Dulvy *et al.* 2003), as over-exploitation of marine waters unfortunately occurs in western Mediterranean countries, such as Spain (Pohl 2001).

Leucoraja circularis inhabits in temperate waters and the fact that the Mediterranean waters are becoming warmer (Francour *et al.* 1994) does not

favour a migration from the north-eastern Atlantic, through Strait of Gibraltar. Consequently, a core of a *L. circularis* population seems to be limited to southern Italia, Strait of Sicily and northern Tunisian coast. Nevertheless, the occurrence and the importance of this single and possible Mediterranean population remain questionable and require further investigations. Additionally, conservation actions are needed in order to avoid the drastic decline of *L. circularis* (Dulvy *et al.* 2003), prior its complete extinction in the area.

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Distribuição espacial e temporal da malacofauna no estuário do rio Ceará, Ceará, Brasil

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Abstract. Spatial and temporal distribution of malacofauna in estuary of Ceará River, Ceará, Brazil. The objective of this study is analyzing the different communities of mollusks along estuarine zone of the Ceará River, Ceará, Brazil, checking the richness and dominance of species on the raining and drying seasons. Three spots for collection were chosen along the estuary. To the quantitative analysis of the epifauna, a corridor of 6.75m² was used. To the infauna analysis, three transects of 10 m were made. A qualitative analysis was also performed, using a sampling effort of 30 minutes. The indexes of diversity of Shannon-Wiener, dominance of Simpson and similarity of Bray-Curtis were calculated. Six samples were carried out, between the years 2005 and 2006, with two Classes of Mollusca being found: Bivalvia and Gastropoda, comprehending 19 families, 21 genera and 31 species. The Bivalvia represented 54,84% of the species found, while Gastropoda represented 45,16%. Density, richness and dominance of the malacofauna suffered variation along the raining and drying seasons and some variation occurred along the estuary. Throughout this study, it is possible to conclude that the salinity was a structuring factor for the community of mollusks in the Ceará River estuary, since where salinity suffered less variation, a higher diversity occurred.

Key words: mollusks, mangrove, community, salinity.

Resumo. O objetivo deste trabalho é analisar as diferentes comunidades de moluscos ao longo da zona estuarina do rio Ceará, Ceará - Brasil, verificando a riqueza e a dominância das espécies nos períodos chuvoso e não-chuvoso. Foram escolhidas três áreas de coleta ao longo do estuário, onde foram feitas as amostragens. Na análise quantitativa da epifauna, foi utilizado um corredor de 6,75m². Na análise da infauna, foram feitos três transectos de 10m. Foi feita ainda uma análise qualitativa com esforço amostral de 30 minutos. Foram calculados índices de diversidade de Shannon-Wiener, dominância de Simpson e similaridade de Bray-Curtis. Foram realizadas 6 coletas, entre os anos de 2005 e 2006, tendo sido encontradas duas classes de Mollusca: Bivalvia e Gastropoda, compreendendo 19 famílias, 21 gêneros e 31 espécies. A classe Bivalvia representou 54,84% das espécies encontradas, enquanto Gastropoda representou 45,16%. Verificou-se que a densidade, a riqueza e a dominância da malacofauna variaram ao longo dos períodos chuvoso e não-chuvoso e que houve variação da malacofauna ao longo do estuário analisado. Através do estudo, foi possível concluir que a salinidade é um fator estruturador da comunidade de moluscos no Estuário do rio Ceará, pois onde a salinidade variou menos, houve uma maior diversidade.

Palavras-chave: Moluscos, manguezal, comunidade, salinidade.

Introdução

Dentre os grupos mais representativos do ecossistema manguezal estão os moluscos. Várias famílias pertencentes a duas classes desse grupo – Gastropoda e Bivalvia – estão representadas no

manguezal (Aveline, 1980). Os moluscos bivalves do manguezal – ostras, mexilhões e berbigões – representam uma das riquezas desse ambiente, possuindo tanto valor ecológico como sócio-econômico. *Anomalocardia brasiliiana* (Gmelin,

1791) (berbigão), *Crassostrea rhizophorae* (Guilding, 1828) (ostra), *Mytella falcata* (d'Orbigny, 1842) (mexilhão ou sururu), *Iphigenia brasiliana* (Lamarck, 1818) (tarioba), *Lucina pectinata* (Gmelin, 1791) (lambreta, marisco redondo) e *Tagelus plebeius* (Lightfoot, 1786) (unha-de-velho) são alguns exemplos de moluscos bivalves explorados comercialmente encontrados no manguezal (Por 1994, Grasso & Tognella 1995).

Estudos feitos por Dajoz (1972) e Brewer (1988) dizem que áreas estuarinas, devido a sua grande variabilidade, principalmente em relação à salinidade, possuem um baixo número de espécies e um alto número de espécimes, enquanto que em áreas com influência marinha ocorre o oposto.

O objetivo deste trabalho foi analisar as diferentes comunidades de moluscos ao longo da zona estuarina do rio Ceará, Ceará, Brasil, verificando a riqueza e a dominância das espécies de moluscos nos períodos chuvoso e não-chuvoso.

Material e Métodos

Área de estudo. A área de estudo situa-se no estuário do rio Ceará, que se localiza na divisa dos municípios de Fortaleza e Caucaia, Ceará, nordeste do Brasil (Fig. 1). O estuário do rio Ceará

abrange uma área de, aproximadamente, 500 hectares de manguezal, que se estende até, aproximadamente, 14 km de sua desembocadura.

Foram escolhidas três áreas para as coletas da malacofauna ao longo do estuário do rio Ceará: Área 1 (03°44'05,6"S; 038°37'48,6"W), Área 2 (03°44'11,1"S; 038°37'23,6"W) e Área 3 (03°42'06"S; 038°35'44"W). As Áreas 1 e 2 encontram-se mais a montante do rio (áreas tipicamente estuarinas), enquanto a área 3 se localiza próxima a foz do rio Ceará (forte influência marinha). As coletas para a análise quali-quantitativa da malacofauna e medição de salinidade foram realizadas nos meses de setembro, outubro e novembro de 2005 e fevereiro, março e abril de 2006.

Levantamento quali-quantitativo da malacofauna. Para a análise quantitativa da epifauna na zona entre-marés, em cada área de coleta, foi montado um corredor, perpendicularmente ao leito do rio, de 6,75 m², na área com vegetação. Os animais foram contados em campo. A análise qualitativa da epifauna foi feita de forma aleatória por uma pessoa através de esforço amostral de 30 minutos, dentro da área de manguezal.

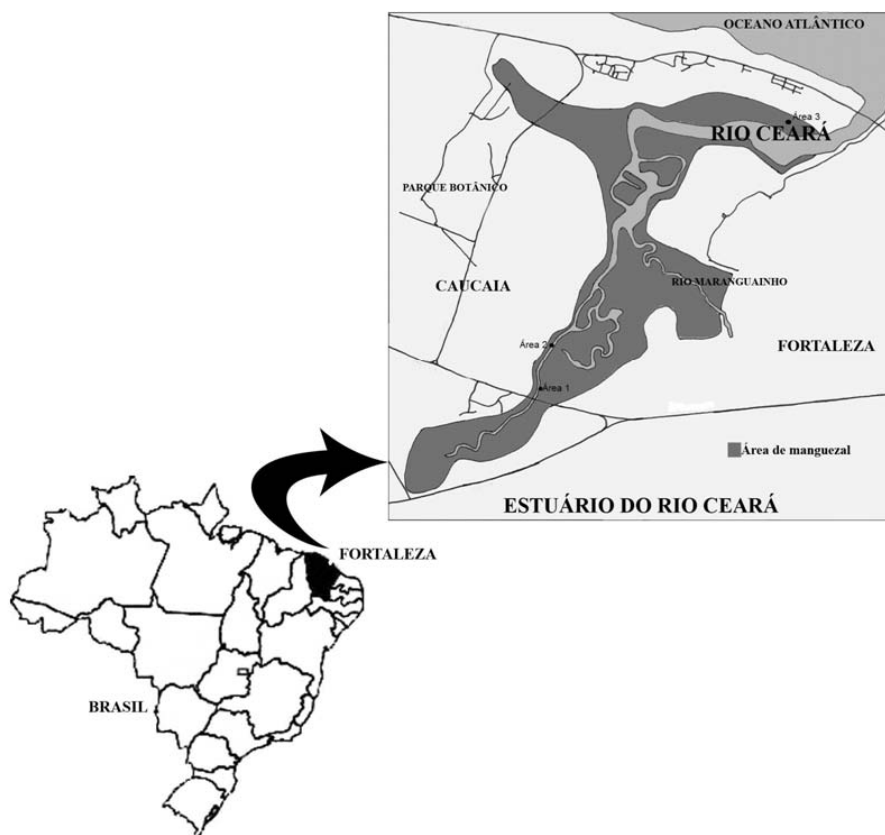


Figura 1. Área de estudo, no estuário do rio Ceará, Ceará, nordeste do Brasil.

Para a amostragem quali-quantitativa da infauna na zona entre marés, em cada estação de coleta, foi determinado um transecto de 10m perpendicular ao leito do rio, ao longo do qual foram tomadas amostras de sedimento, a cada 2 m, por meio de um amostrador cilíndrico de PVC ("core"), com 1177,5 cm³. Todas as amostras de sedimento coletadas foram triadas inicialmente por meio de peneiramento em malha de 0,5 mm de abertura. O sedimento retido foi conservado em álcool etílico 70% e corado com Rosa de Bengala, para que os organismos fossem evidenciados em meio ao sedimento. Em seguida, foi feita uma triagem mais refinada, sob microscópio estereoscópico. Após a triagem, os animais foram preservados em álcool etílico a 70%.

Medição da salinidade e dados de pluviometria. Em cada uma das três áreas, foram coletadas amostras de água da superfície do rio para a medição da salinidade com o auxílio de um refratômetro. Dados sobre a precipitação total mensal foram obtidos na Fundação Cearense de Meteorologia e Recursos Hídricos (FUNCEME).

Análise dos dados. Os dados obtidos com a análise feita com o auxílio do "core" (amostragem da infauna) foram inseridos em planilhas eletrônicas contendo os grupos encontrados na área de manguezal e suas respectivas abundâncias (número de indivíduos). Com estes dados foram calculadas a diversidade de Shannon-Wiener (H') e a dominância de Simpson (Λ') para cada área. Foi feita ainda a similaridade de Bray-Curtis em cada área de coleta, levando-se em consideração a presença ou

ausência de todas as espécies encontradas. As análises numéricas dos dados foram realizadas com o auxílio do pacote estatístico Primer 5.0.

Resultados

Levantamentos quali-quantitativos.

Considerando as três áreas de coleta, foram encontradas duas classes de Mollusca: Bivalvia e Gastropoda, compreendendo 19 famílias, 21 gêneros e 31 espécies. A classe Bivalvia representou 54,84% das espécies encontradas, enquanto Gastropoda representou 45,16%.

Nas Áreas 1 e 2, foram encontradas oito espécies em cada, enquanto que na Área 3, foram identificadas 23 espécies. O número de espécimes foi maior na Área 1, tendo sido coletados 3.456 indivíduos. Foram coletados 2.377 espécimes na Área 2 e 311 espécimes na Área 3.

Em relação ao número de espécies encontradas nos períodos não-chuvoso e chuvoso, não houve diferença estatisticamente significativa. As espécies encontradas em cada área de coleta nos períodos não-chuvoso (setembro, outubro e novembro de 2005) e chuvoso (fevereiro, março e abril de 2006) estão representadas na Tabela I.

Diversidade de Shannon-Wiener (H') e dominância de Simpson (Λ'). Os índices de diversidade de Shannon-Wiener (H') e de dominância de Simpson (Λ') variaram ao longo do trabalho nas três áreas estudadas (Fig. 2). A Área 3 foi a área que apresentou maior índice de diversidade de Shannon, enquanto que a Área 1 foi a que apresentou maior valor de dominância de Simpson.

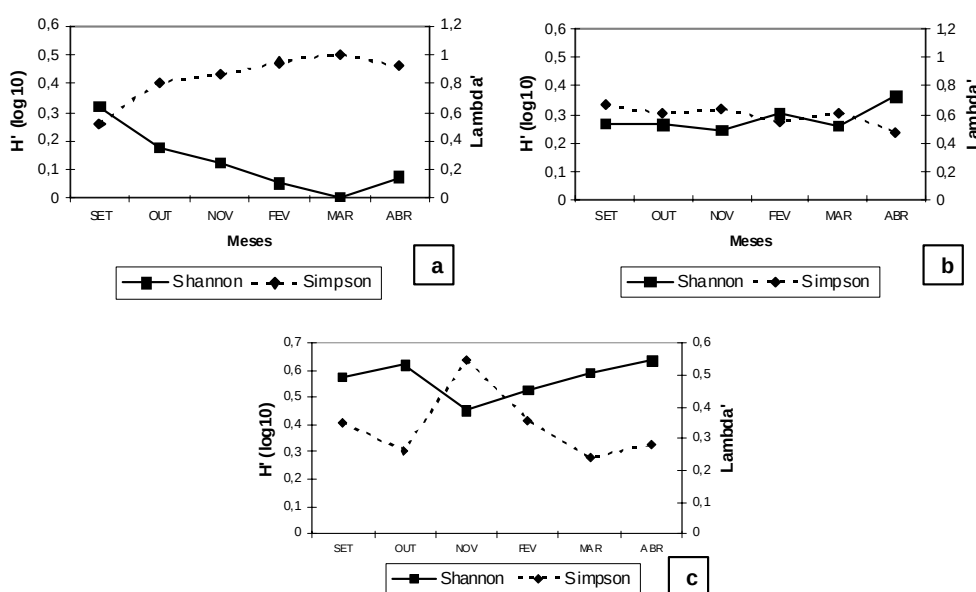


Figura 2. Índices de Diversidade de Shannon-Wiener (H') e dominância de Simpson (Λ'). a. Área 1; b. Área 2; c. Área 3.

Tabela I. Composição e distribuição dos táxons de molusco nos locais de coleta, no estuário do Rio Ceará, nos períodos não-chuvoso e chuvoso.

Táxons	ÁREA 1		ÁREA 2		ÁREA 3	
	Não-chuvoso	Chuvoso	Não-chuvoso	Chuvoso	Não-chuvoso	Chuvoso
BIVALVIA						
<i>Anomalocardia brasiliiana</i> (Gmelin, 1791)					X	X
<i>Codakia costata</i> (Orbigny, 1842)					X	X
<i>Corbicula largillierti</i> (Philippi, 1844)				X		
<i>Crassostrea rhizophorae</i> (Guilding, 1828)					X	X
<i>Diplodonta punctata</i> (Say, 1822)	X		X	X		
<i>Iphigenia brasiliiana</i> (Lamarck, 1818)					X	
<i>Lucina pectinata</i> (Gmelin, 1791)					X	X
<i>Tagelus plebeius</i> (Lightfoot, 1786)					X	X
<i>Tellina punicea</i> Born, 1778						X
<i>Tellina</i> sp. 1					X	
<i>Tellina</i> sp. 2					X	X
<i>Tellina</i> sp. 3					X	
<i>Tellina</i> sp. 4					X	
<i>Tellina</i> sp. 5						X
<i>Macoma</i> sp.						X
<i>Macoma constricta</i> (Bruguiere, 1792)						X
Mytilidae – Esp. 1						X
GASTROPODA						
<i>Bulla striata</i> Bruguiere, 1792						X
<i>Bursatella leachii</i> Blainville, 1817					X	
<i>Ellobium</i> sp.	X		X	X		
<i>Littoridina</i> sp.	X	X	X	X		
<i>Littorina angulifera</i> (Lamarck, 1822)		X			X	X
<i>Littorina flava</i> King and Broderip, 1832					X	X
<i>Melampus coffeus</i> (Linnaeus, 1758)	X	X	X	X		
<i>Melanoides tuberculatus</i> (Muller, 1774)	X	X	X	X		
<i>Nassarius vibex</i> (Say, 1822)					X	X
<i>Neritina virginea</i> (Linnaeus, 1758)			X	X	X	X
<i>Neritina zebra</i> (Bruguière, 1792)	X	X	X	X		
<i>Pugilina morio</i> (Linnaeus, 1758)					X	X
<i>Solariorbis</i> sp.					X	
Vitrinellidae – Esp. 1	X					

Similaridade de Bray-Curtis. Através da análise de similaridade entre as áreas puderam-se obter dois grupos: um formado pelas Áreas 1 e 2 (similaridade de 75%) e outro formado pela Área 3. A similaridade entre esses dois grupos foi de 6,25% (Fig. 3).

Pluviometria e salinidade. As precipitações pluviométricas e a salinidade variaram ao longo dos meses de estudo, estando a diminuição da salinidade nas áreas de coleta (Áreas 1 e 2, principalmente) diretamente relacionada com o aumento da precipitação na área do estuário do rio Ceará (Fig. 4).

Discussão

Tipicamente, a riqueza de espécies declina do oceano para as águas com baixa salinidade, freqüentemente chegando a um mínimo nas salinidades próximas de 4-6, e depois crescendo novamente em direção as condições de água doce (Lercari & Defeo 2006). Em seus estudos sobre a malacofauna presente no estuário do rio Paraíba do Norte (PB), Petraglia-Sassi (1986) observou que uma maior diversidade de espécies ocorreu em áreas de maior influência marinha e que houve uma diminuição progressiva na quantidade de espécies à medida que se aproximava do extremo estuarino superior.

Os resultados obtidos neste presente estudo corroboram a afirmação feita pelos autores citados acima, pois um número maior de espécies ocorreu na área em que houve uma menor variação de salinidade (Área 3, que possui uma forte influência marinha), acontecendo o oposto com o número de espécimes, ou seja, áreas com maior variação de salinidade apresentaram um maior número de espécimes (Áreas 1 e 2, tipicamente estuarinas).

Devido às variações na abundância (número de indivíduos) e na ocorrência das espécies ao longo

dos meses estudados, na amostragem da infauna, houve variações na riqueza e na dominância nas áreas de coleta.

A Área 1 apresentou o maior valor de dominância de Simpson, pois nesta área, *Melanoides tuberculatus* (Müller, 1774) foi a espécie predominante, com sua abundância aumentando ao longo dos meses de estudo até o mês de março de 2006, quando foi a única espécie que ocorreu na Área 1.

Na Área 2, houve um equilíbrio entre os índices de Shannon-Wiener e Simpson, pois, nesta área, a abundância de *Melanoides tuberculatus* foi contrabalanceada com a de *Diplodonta punctata* (Say, 1822).

A Área 3 apresentou altos índices de Shannon-Wiener e baixos valores de dominância de Simpson, quando comparada às outras duas áreas. Esses resultados mostram que esta região possui uma maior diversidade (em relação às outras) e uma melhor equitabilidade, com exceção do mês de novembro de 2005, quando apesar de terem sido encontradas oito espécies, houve dominância de *Anomalocardia brasiliiana* jovem.

A análise de similaridade de Bray-Curtis comprovou a alta similaridade entre as Áreas 1 e 2 (similaridade de 75%), que apresentaram comunidades de molusco muito parecidas, sendo áreas tipicamente estuarinas. A similaridade entre estas duas áreas foi fortemente influenciada pelas espécies *Neritina zebra*, *Melanoides tuberculatus* e *Littoridina* sp.. Já a Área 3, que possui uma forte influência marinha, apresentou uma malacofauna bem diferente, sendo esta composta, principalmente, por espécies de origem marinha, como por exemplo, *A. brasiliiana*, *C. costata*, *B. leachii* e as várias espécies de *Tellina*. Isso fez com que sua similaridade com as outras duas áreas fosse bem baixa (similaridade de 6,25%).

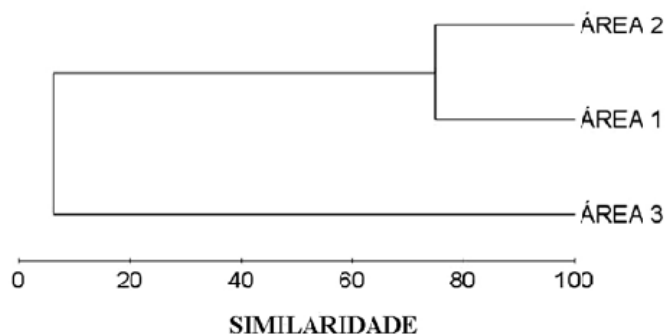


Figura 3. Dendrograma por agrupamento por similaridade das áreas de coleta.

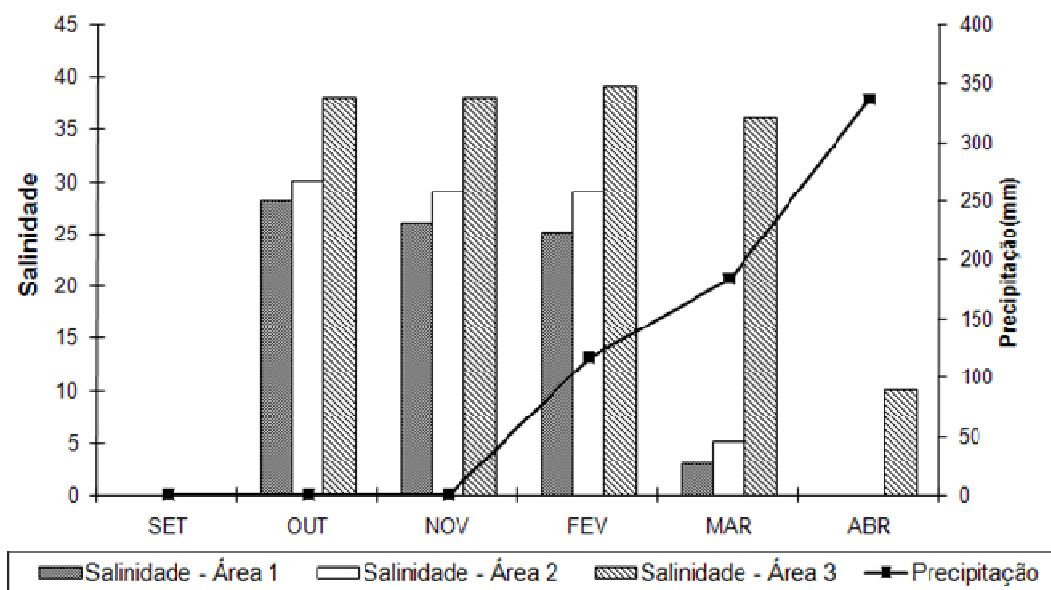


Figura 4 - Relação entre a salinidade nas áreas de coleta (barras) e a precipitação na área de manguezal do Estuário do rio Ceará (linha) entre os anos de 2005 e 2006.

O presente estudo corrobora com as observações feitas por Fernandes (1990) e Rios (1994), pois no manguezal do rio Ceará, *Melampus coffeus* e *Neritina zebra* foram encontrados somente nas regiões mais superiores do rio (Áreas 1 e 2), onde a máxima salinidade foi de 30, entre os pneumatóforos de *Avicennia* sp. A não-ocorrência destas espécies na Área 3 (próxima a foz do rio) demonstra que elas não suportam salinidade marinha (35 ou mais), aparecendo com mais frequência em áreas estuarinas (água salobra), suportando salinidades que chegam a 0 no período chuvoso.

A ocorrência de *Neritina virginea* nas Áreas 2 e 3 no presente estudo mostra bem a capacidade que esta espécie tem de suportar amplas variações de salinidade, corroborando com a afirmação feita por Flores & Cárceres (1973) sobre a eurihalidade desta espécie. A sua ocorrência na Área 3 mostra que *N. virginea* suporta salinidades marinhas, ao contrário de *N. zebra*, que não ocorreu nesta área. Entretanto, a baixa densidade de *N. virginea* na Área 2 demonstra que *N. zebra* é mais bem adaptada a baixas salinidades.

No presente estudo, a ocorrência de *L. angulifera* nas Áreas 1 e 3 mostra a capacidade que esta espécie tem de suportar uma ampla variação de salinidade. Esta capacidade pode ser atribuída ao seu comportamento de se manter acima da linha da maré alta (Abbott 1954, Amos & Amos 1988, Rios 1994), que foi observado em campo durante os seis meses de coleta.

Melanoides tuberculatus é um tiarídeo afro-

asiático, comum de ambientes dulcícolas, que agora está presente em grande parte das regiões tropicais e subtropicais do Novo Mundo. Sua ocorrência já foi registrada em 17 estados brasileiros, incluindo o Ceará (Fernandez *et al.* 2003). Esta é a primeira ocorrência de *M. tuberculatus* em uma área estuarina no Estado do Ceará.

Anomalocardia brasiliana é um molusco bivalve que ocorre em toda a costa brasileira, sendo encontrado em bancos de areia e lama, em águas rasas (Rios 1994). A tolerância relativamente limitada de *A. brasiliana* a salinidades muito baixas, observada por Araújo (2004), pôde ser demonstrada no presente estudo, uma vez que essa espécie só ocorreu na Área 3 (de forte influência marinha), não ocorrendo nas Áreas 1 e 2, onde a salinidade variou de 0 a 30.

A grande ocorrência de indivíduos jovens da família Tellinidae, durante todo o período de estudo, principalmente no mês de abril de 2006, demonstra que o ambiente estuarino com forte influência marinha da Área 3 é favorável para o assentamento das larvas desta família.

Por ser uma espécie dulcícola e ter sido encontrada somente no mês de abril de 2006, a presença de *Corbicula largillierii* (molusco exótico) na Área 2 do manguezal do rio Ceará foi uma consequência do aumento da correnteza do rio, devido às chuvas, que acabou carreando alguns espécimes para as regiões mais inferiores do rio.

Crassostrea rhizophorae é um molusco bivalve sésil, comum em raízes de *Rhizophora*

mangle, rochas e substratos duros. Distribui-se desde a zona entre marés até 50 m e ocorre em toda costa brasileira (Rios 1994). A não-ocorrência de *C. rhizophorae* nas Áreas 1 e 2 deste presente estudo, mostra a pequena tolerância que esta espécie possui a baixas salinidades, que foi observada por Vilanova & Chaves (1988). A ocorrência desta espécie em construções (muros e pilares) na Área 3 corrobora com as observações feitas por Rios (1994) sobre seus locais de assentamento.

Bursatella leachii é um molusco gastrópode opistobrânquio, presente nas regiões entre marés e infralitoral, de ocorrência circuntropical (Rios 1994). A hipótese levantada neste presente estudo no estuário do rio Ceará é que *B. leachii* migraria para o estuário para sua reprodução, pois indivíduos desta espécie foram encontrados somente nos meses de setembro e outubro de 2005, estando estes em período de reprodução (observação de desovas e indivíduos desovando). Entretanto, não foram encontradas na literatura referências sobre migração de *B. leachii* para estuários para reprodução. Lowe & Turner (1976) afirmam que a agregação de vários indivíduos desta espécie muitas vezes não é para fins reprodutivos, mas simplesmente fazem parte do ciclo de vida do animal. Um grande número de véligers saíria do plâncton, se assentaria e encontraria condições ambientais ótimas para o desenvolvimento em determinados locais, como, por exemplo, um estuário ou em regiões mais profundas. No presente estudo, não foram encontrados indivíduos jovens desta espécie. Portanto, as observações feitas em campo não corroboram com as afirmações feitas por Lowe & Turner (1976). Ainda são necessários estudos sobre o comportamento reprodutivo desta espécie.

Por talvez se tratar de uma nova espécie, não são feitas aqui considerações ecológicas a respeito de *Littoridina* sp. Os indivíduos encontrados no rio Ceará ainda estão sendo avaliados por um especialista.

Miranda (1985) encontrou ampla variação na salinidade do estuário do rio Ceará, com valor mínimo de 17 no mês de março e máximo de 43, em outubro do mesmo ano. Alcântara-Filho (1978) encontrou variação de 0,2 a 39,5 na salinidade desta mesma área. Escouto (1996), estudando os nutrientes presentes neste estuário, encontrou variação de salinidade de 0,1 a 39,5. Segundo os estudos citados acima, os valores mínimos de salinidade aconteceram no período de alta precipitação.

De acordo com as pesquisas acima citadas e com o presente trabalho, pode-se concluir que o caráter sazonal da salinidade é regulado,

basicamente, pelas precipitações pluviométricas, observando-se também que este caráter sazonal da salinidade é oposto a precipitação pluviométrica.

Santos (2004), em seus estudos no estuário do rio Jaboatão (PE), concluiu que a salinidade e o tipo de sedimento foram os parâmetros ambientais que mais influenciaram a distribuição das espécies de molusco no estuário, não tendo sido a temperatura um fator relevante nesta distribuição. Petraglia-Sassi (1986) concluiu, com seus estudos no estuário do rio Paraíba do Norte (PB), que a salinidade poderia ser o fator principal que controlaria a distribuição dos moluscos ao longo deste ambiente. Ysebaert *et al.* (2003) observaram em seus estudos, numa região estuarina da Europa, que a salinidade foi o fator que mais afetou a distribuição das espécies da macrofauna e a estrutura da comunidade. O padrão de riqueza de espécies e a diversidade declinaram com a diminuição da salinidade.

Conclusão

Através deste estudo pôde-se concluir que a salinidade é um fator estruturador da comunidade de moluscos no estuário do rio Ceará, pois onde a salinidade variou menos, houve uma maior diversidade.

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Population features of the spider crab *Acanthonyx scutiformis* (Dana 1851) (Crustacea, Majoidea, Epialtidae) associated with rocky-shore algae from southeastern Brazil

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Abstract. *Acanthonyx scutiformis*, an endemic species in the Brazilian coast, is commonly found in intertidal rocky-shore algal communities. This study analyzes the population biology of *A. scutiformis* from Ubatuba region. A total of 371 specimens were collected over one year. Size range was 4.2–12.7 mm CW (carapace width) for females and 3.7–15.8 mm CW for males. Females predominated in intermediate size classes, whereas males prevailed in the largest ones. The estimated size when 50% crabs were mature was 10.7 mm CW for males and 8.9 mm CW for females. Sex ratio varied among the demographic groups. The processes that influence *A. scutiformis* population structure can be related to the different times males and females reach sexual maturity and probably to the distinct predation pressures on each sex during the adult phase.

Key words: *Acanthonyx*, spider crab, population structure, sex ratio, sexual maturity, growth.

Resumo. Aspectos populacionais do caranguejo-aranha *Acanthonyx scutiformis* (Dana 1851) (Crustacea, Majoidea, Epialtidae) associado às algas de costões rochosos no sudeste do Brasil. *Acanthonyx scutiformis* é uma espécie endêmica da costa brasileira, comumente encontrada na zona entre-marés de praias rochosas junto aos bancos de algas. Este estudo analisou a biologia populacional de *A. scutiformis* na região de Ubatuba. Um total de 371 espécimes foi coletado, durante o período de um ano. A amplitude de tamanho encontrada para as fêmeas foi de 4,2 a 12,7 mm de CW (largura da carapaça) e para os machos de 3,7 a 15,8 mm de CW. As fêmeas predominam nas classes de tamanho intermediárias enquanto os machos predominam nas maiores classes. O tamanho estimado em que 50% dos caranguejos encontram-se maduros sexualmente foi de 10,7 e 8,9 mm de CW para machos e fêmeas, respectivamente. A razão sexual variou entre os grupos demográficos. Os processos que atuam na determinação da estrutura populacional de *A. scutiformis* podem estar relacionados à aquisição diferencial da maturidade sexual entre machos e fêmeas e, provavelmente, à pressões de predação distintas sobre machos e fêmeas durante a fase adulta de suas vidas.

Palavras-Chave: *Acanthonyx*, Caranguejo-aranha, estrutura populacional, razão sexual, maturidade sexual, crescimento.

Introduction

In the southeast-south of the Brazilian coast, a region that extends from the border of Rio de Janeiro and Espírito Santo States to the extreme south of Rio Grande do Sul State, Brachyurans account for 189 species, of which 47 belong to the

Majidae family (Melo 1996). According to Ng *et al.* (2008), the taxon Majidae was transferred to the superfamily Majoidea, and up to eight families can be recognized, especially in the Americas. Thus, the genus *Acanthonyx* Latreille, 1825 is included in the family Epialtidae. Coelho & Torres (1994)

mentioned that the genus *Acanthonyx* is represented in the Western Atlantic by three species: *A. petiverii* in Florida, Antilles and north of South America, and *A. scutiformis* (Dana 1851) and *A. dissimulatus* Coelho, 1991-1993, in Brazil.

In the northern coast of São Paulo State, the spider crabs *A. scutiformis* and *Epialtus brasiliensis* are commonly found on algal banks including the genus *Sargassum*, *Padina*, *Laurencia* and *Hypneia* (Negreiros-Fransozo *et al.* 1994, Hiyodo & Fransozo 1995, Negreiros-Fransozo & Fransozo 2001). According to Howard (1981), crustaceans and gastropods frequently constitute the major densities of the benthic epifauna in algal and phanerogam communities.

The features on brachyuran populations from the northern coast of São Paulo State has been increasingly reported in the last decades both for species from non-consolidated sublittoral areas (Negreiros-Fransozo & Fransozo 1995, Mantelatto *et al.* 1995, Santos *et al.* 1995, Negreiros-Fransozo *et al.* 1999) and for estuarine species (Leme 2002, Costa & Negreiros-Fransozo 2003, Colpo & Negreiros-Fransozo 2004, Castiglioni & Negreiros-Fransozo 2005, Castiglioni *et al.* 2006, Silva *et al.* 2007). However, data on rocky-shore species are still scarce (*e.g.* Hiyodo & Fransozo 1995, Flores & Negreiros-Fransozo 1999, Fransozo *et al.* 2000). The available literature concerning the population biology of spider crab species from hard bottoms in São Paulo coast includes the studies of Negreiros-Fransozo *et al.* (1994) and Teixeira *et al.* (2008) with *Epialtus brasiliensis*, and Mantelatto *et al.* (2003) and Cobo (2006) with *Mithraculus forceps*.

Functional maturity can be assumed as the minimum size for each sex to be morphologically and physiologically able to reproduce (Mura *et al.* 2005). Generalizations about the dimensions of males and females of certain species when they reach sexual maturity are based on allometric technique, macroscopic gonad analysis, microscopic gonad analysis (histology), development of secondary sexual characters, or functional criterion, including behavioral patterns related to gamete transference.

Among brachyurans, spider crabs are mature only after the terminal molt (Hartnoll 1963). Thus, mature specimens cannot grow and their size distribution may depend mainly on some factors that influence the growth, survival and maturation of juveniles (Hartnoll *et al.* 1993).

In this study, the population biology of *A. scutiformis* from Ubatuba region was analyzed with emphasis on size distribution, sex ratio, and morphologic sexual maturity based on the

development of secondary sexual characters. *A. scutiformis* has a restrict distribution along the Brazilian southeastern coast, ranging from Espírito Santo to São Paulo States (Melo 1996). Features of natural populations are fundamental to the conservation of species such as this Brazilian endemic species, *A. scutiformis*.

Material & Methods

Spider crabs were manually sampled every month during low tide periods, from March/2003 to February/2004, by scanning the algae (*Sargassum* and *Hypneia*) on the rocky shores in Ubatuba (23°28'24"S; 45°04'00"W), São Paulo State, Brazil. The collected specimens and some algal portions were kept cold in thermo boxes during transportation. In the laboratory, crabs were counted, sexed, and checked for the presence of eggs on female's pleopods. Carapace width was measured under microscope stereoscope or using a caliper (0.1 mm accuracy).

All the obtained crabs were distributed into five demographic groups: young males, adult males, young females, adult females, and ovigerous females. Juvenile and adult specimens were sorted based on the examination of the secondary sexual characters such as pleopod morphology, free abdomen (*i.e.* the abdomen does not adhere to the thoracic sternites), convex abdomen (forming an incubator chamber) in the females, and distinct cheliped development in adult males when compared with juvenile males. Such changes associated with the sexual maturity attainment are similar to those described for the epialtid *Epialtus brasiliensis* by Negreiros-Fransozo *et al.* (1994). The identification of juvenile specimens based on the abdominal condition (sealed or not) has been widely used for Portunoidea (*e.g.* Taissoun 1969, Williams 1974, Pinheiro & Fransozo 1993, Santos & Negreiros-Fransozo 1996) and useful for the representatives of the superfamily Majoidea.

The present results were compared with those obtained by Hiyodo & Fransozo (1995), who analyzed the allometric patterns of the same *A. scutiformis* population. Although they used carapace length instead of width, the allometric relationship between carapace width and carapace length presented isometry. Utilizing the equations determined by those authors ($CW=0.71*CL^{0.99}$ for males and $CW=0.74*CL^{0.98}$ for females) and converting the CL data into CW, we could found the following values: 12.8 mm for the largest juvenile males; 8.9 mm for the smallest adult males; 10.8 mm for the largest juvenile females; and 8 mm for the smallest adult females. Such findings agree with the

separation of adults and juveniles already done in the analysis of secondary sexual characters. Crabs were distributed into 13 size classes of 1 mm amplitude. The male:female proportions in each size class were compared through the chi-square (χ^2) test ($\alpha = 0.05$). The population structure was analyzed by plotting in histograms the number of individuals per demographic category and size class. To determine sexual maturity, the relative frequency was expressed in percentage for each sex and size class and plotted in graphs. Data were fit to a sigmoid curve, according to the results of the logistic equation:

$$Y = \frac{1}{1 + e^{r(CW - CW_{50})}} ;$$

CW_{50} = carapace width when 50% of the crabs were

sexually mature; r = the curve slope. The equation was fitted by the least-squares regression method (Aguilar *et al.* 1995, Vazzoler 1996).

Specimens were deposited in the NEBECC (Crustacean Biology, Ecology and Culture Study Group), Department of Zoology, Institute of Biosciences, Unesp, Botucatu, São Paulo State, Brazil.

Results

A total of 371 *A. scutiformis* specimens were sampled during the study period, of which 165 were males (68 adults and 97 juveniles) and 206 females (63 non-ovigerous adults, 72 ovigerous adults, and 71 juveniles). The distribution of crab demographic groups into 13 size classes is presented in Table I. Size range was 3.7–15.8 mm CW in males and 4.2–12.7 mm CW in females.

Table I. *Acanthonyx scutiformis*. Distribution of individuals in size classes and demographic groups. N values in bold represent the size classes in which both adult and juvenile crabs can occur. ns = not significant.

Size class (mm)	Immatures			Matures			Total of crabs		
	Males	Females	χ^2	Males	Females	χ^2	Males	Females	χ^2
3.0--]4.0	3	0	* oos	0	0	-	3	0	* oos
4.0--]5.0	8	1	p<0.05	0	0	-	8	1	Ns
5.0--]6.0	10	3	ns	0	0	-	10	3	Ns
6.0--]7.0	13	13	ns	0	0	-	13	13	Ns
7.0--]8.0	17	18	ns	0	1	* oos	17	19	Ns
8.0--]9.0	12	20	ns	5	8	ns	17	28	Ns
9.0--]10.0	17	14	ns	3	40	p<0.05	20	54	p<0.05
10.0--]11.0	9	2	p<0.05	11	37	p<0.05	20	39	p<0.05
11.0--]12.0	6	0	* oos	10	41	p<0.05	16	41	p<0.05
12.0--]13.0	2	0	* oos	15	8	ns	17	8	Ns
13.0--]14.0	0	0	-	17	0	* oos	17	0	* oos
14.0--]15.0	0	0	-	4	0	* oos	4	0	* oos
15.0--]16.0	0	0	-	3	0	* oos	3	0	* oos
Total	97	71	p<0.05	68	135	p<0.05	165	206	p<0.05

* oos = only one sex

For females, the highest frequencies obtained for juveniles and adults were 8-9 mm and 11-12 mm CW, respectively (Fig. 1). For males, the highest frequencies obtained for juveniles and adults were from 7-8 to 10-11 mm and from 12-13 to 13-14 mm CW, respectively (Fig. 2).

The result of the logistic equation indicates that approximately 50% male crabs were sexually mature in the 10–11 mm CW size class, whereas for females this proportion was found in the 8–9 mm CW size class (Fig. 3).

Sex ratio for the total number of collected crabs was 0.8:1 (M:F); 0.5:1 for adult and 1.3:1 for

juvenile crabs ($p < 0.05$). In the sex ratio analysis according to size class, the χ^2 test indicates significant differences ($p < 0.05$) for adult animals in the size classes from 9-10 to 11-12 mm CW, with predominance of females. For juveniles, there were significant differences for males in the classes 4-5 and 10-11 mm CW (Table I and Fig. 4 a, b and c).

Discussion

In spider crabs, growth is interrupted when sexual maturity is reached (Elner & Beninger 1992). Thus, the age, stage and size at morphologic sexual

maturity are coincident events for a certain specimen (Orensanz *et al.* 2007). Such pattern is described as “determined growth”, remarkably differing from the

“undetermined growth”, in which successive molts, even after sexual maturity, allow the specimens to gradually grow until death (Hartnoll 1985).

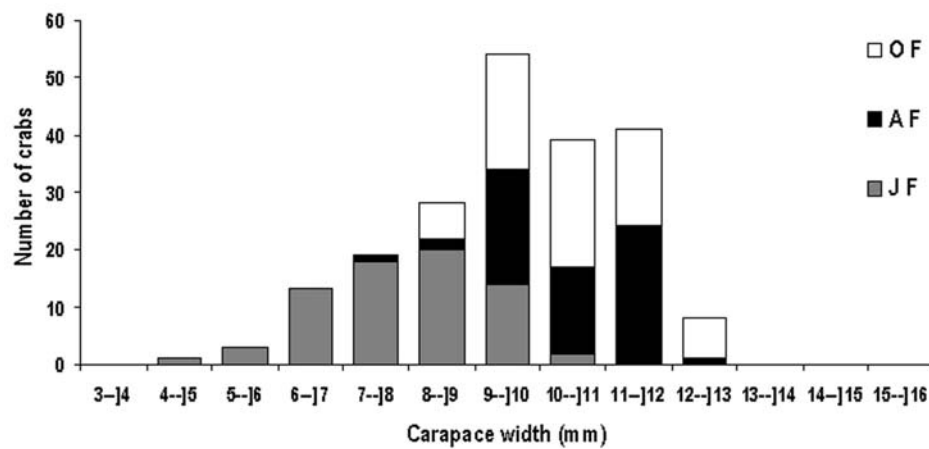


Figure 1. *Acanthonyx scutiformis*. Size frequency distribution of females (71 juveniles, 63 non-ovigerous adults and 72 ovigerous females). OF: Ovigerous Females; AF: Non-Ovigerous Adult females; JF: Juvenile females.

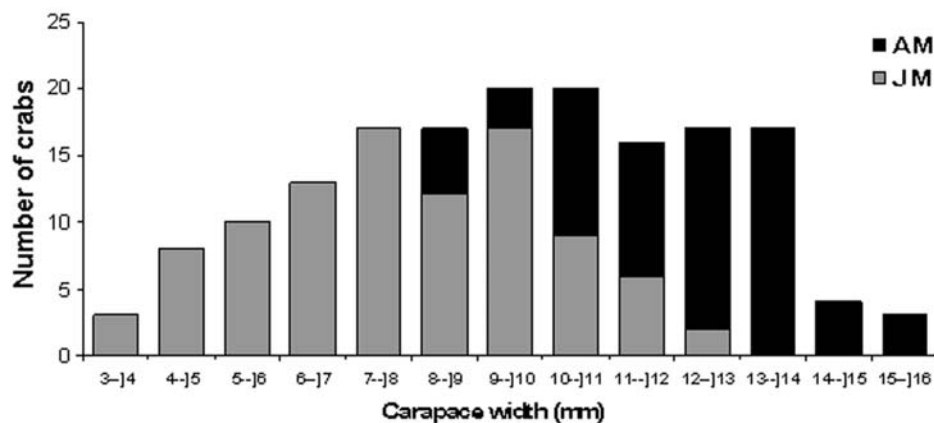


Figure 2. *Acanthonyx scutiformis*. Size frequency distribution of males (97 juveniles and 68 adults). AM: Adult males; JM: Juvenile males.

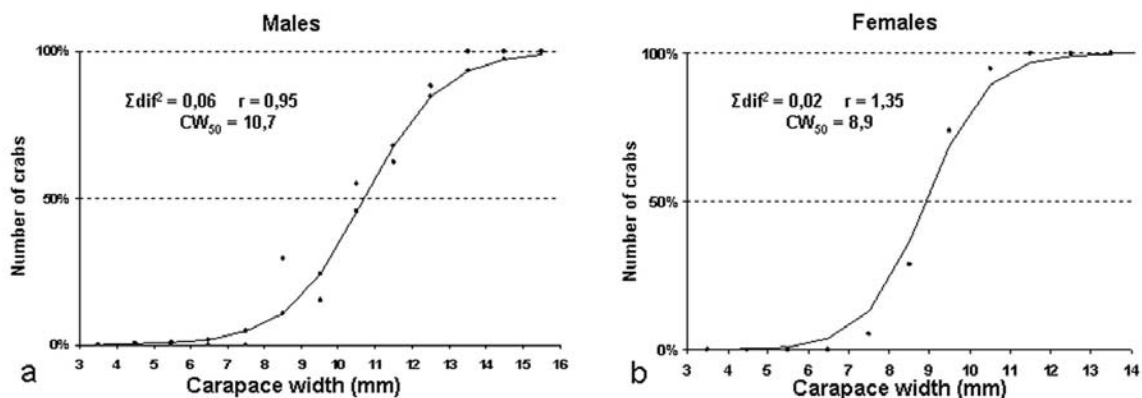


Figure 3. *Acanthonyx scutiformis*. Maturation curve for males (a) and females (b). According to the logistic equation, CW_{50} is 10.7 mm CW for males and 8.9 mm CW for females.

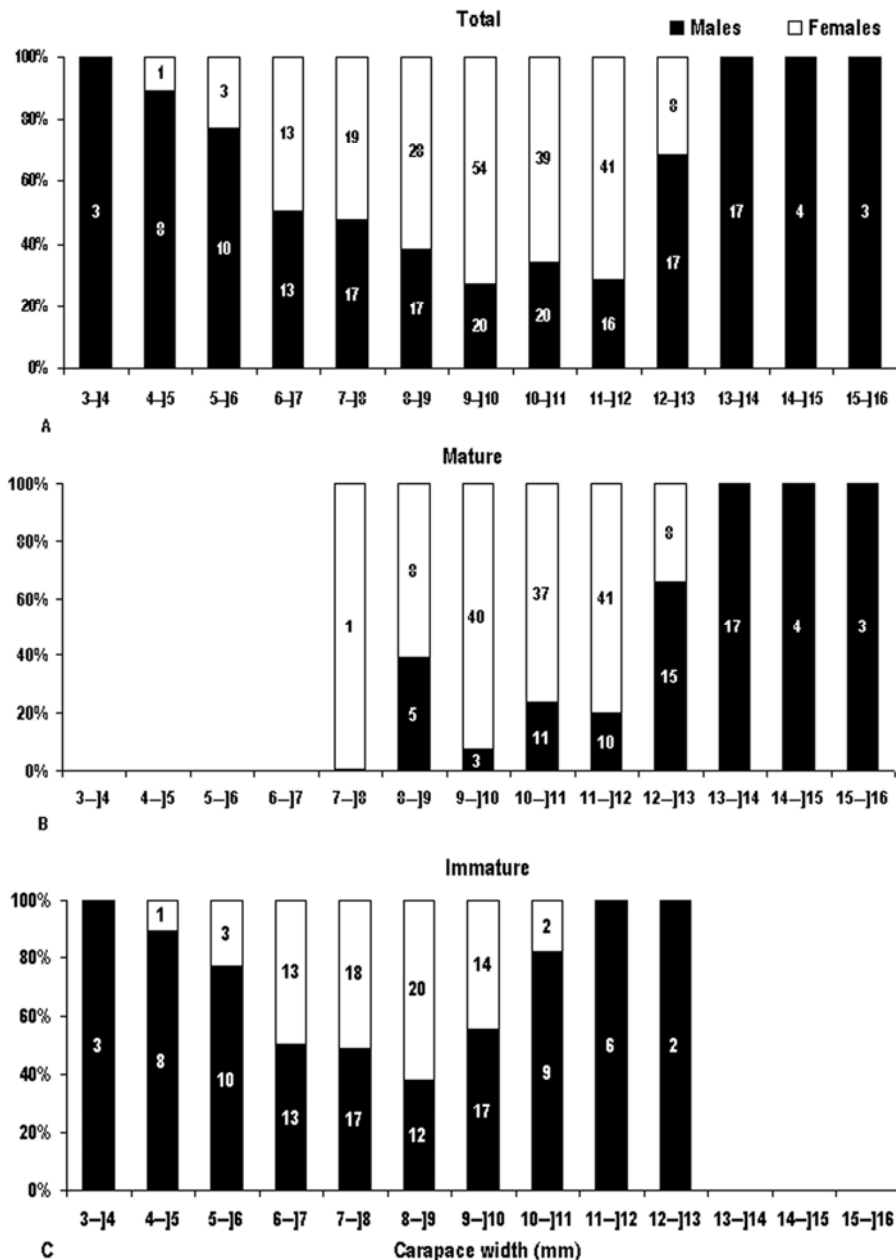


Figure 4. *Acanthonyx scutiformis*. Percentage of males and females per size class. 4a. Total of crabs; 4b. Adults; and 4c. Immatures.

The size of mature individuals of a certain spider crab species varied due to their size at terminal molt or puberty molt, which can be different for each specimen, but in a wide extension range of body size (Hartnoll *et al.* 1993).

Three growth stages can be recognized in Majoidea crabs: immature, pre-pubertal, and mature (Hartnoll 1963). Such stages are identified based on two important events during the animal's growth (Teissier 1935): pre-puberty molt, in which immature crabs begin their changes to become adults, and puberty molt or terminal molt (Carlisle 1957), in which crabs are completely mature.

Negreiros-Fransozo *et al.* (1994) analyzed in detail the morphologic changes that occur in *Epialtus brasiliensis* (Majoidea, Epialtidae) during its puberty molt and described a remarkable increase in the size of chelipeds and gonopods. Such size differences can be associated with necessary male behaviors during the adult life, such as territory defense, agonistic behavior against other individuals for food or females to copulate, and also mating. In this sense, the present results on the predominance of males in the largest size classes could be an advantage during many behavioral displays.

The considerable adult size extension in

both sexes was already recorded for a number of Majoidea species (Teissier 1960, Winget *et al.* 1974, Aldrich 1974, Hartnoll *et al.* 1993, Negreiros-Fransozo *et al.* 1994, Hiyodo & Fransozo 1995, Hartnoll & Bryant 2001). For males, such wide extension requires three successive molts, two of which are optional, as in certain crab species they can occur in several size categories, even before sexual maturity (Aldrich 1974).

The present analysis showed that mature females have from 7 to 8 mm CW, whereas males from 8 to 9 mm CW, although the latter reach larger size classes than females. For many brachyuran species, females can attain reproductive stages by accumulating energetic resources in size classes that are better for reproduction, delaying the somatic growth (Colby & Fonseca 1984, Conde & Diaz 1989, Diaz & Conde 1989).

The CW_{50} calculated for *A. scutiformis* females (8.9 mm CW) was lower than that obtained for males (10.7 mm CW). Such finding corroborates the results obtained by Hiyodo & Fransozo (1995). Studying another spider crab species, *E. brasiliensis*, in the same geographic area, Negreiros-Fransozo *et al.* (1994) also found smaller maturity sizes for females than for males.

As stated by Bernardo (1993), the phenotypic plasticity in the maturity transition can be associated with age, development (expressed by stage) and growth (expressed by body size). Such plasticity can be influenced by the interaction between the growth and the reproduction process, which compete for energetic resources and are thus antagonistic events. In this sense, the crabs could begin their reproductive season with reduced sizes due to a slow growth, providing reproduction in a situation of high mortality rate at the largest size classes (life-history tactics *r*, as mentioned by Stearns (1976)). The opposite strategy could be a rapid growth if the crab can only reproduce at larger sizes (life history tactics *k*, as mentioned by Stearns (1976)), providing a higher ability to produce gametes (Hartnoll & Gould 1988). In this last case, however, the animals would be more susceptible to predation before reproducing.

A different number of juvenile specimens between sexes was also verified by Negreiros-Fransozo *et al.* (1994) in *E. brasiliensis*. As regards adult crabs, females were more numerous than males, which can be explained by the higher survival rate of the former, whereas males with larger chelipeds could be more easily identified by predators (Diesel 1986). Besides, males are more active and present more notable behaviors when searching or fighting for females (Wirtz & Diesel

1983). Such factors can considerably increase their susceptibility to predation

Small herbivores usually look for shelter among algae and frequently choose those structurally complex or with morphologic or chemical features that prevent the presence of some predator fishes (Hay 1997). Cruz-Riviera (2001) described the decoration habit of the spider crab *Acanthonyx lunulatus* and other two Majoidea species as a strategy to reduce predation. The presently studied species, *A. scutiformis*, does not have an evident decoration habit; however, its coloration and body ornaments make it very misidentified with the algae and difficult to see with the naked eyes. Such behavior might have interfered in the number of collected specimens for each sex, which was reduced mainly in the two first classes ($N=12$). However, this differential distribution should not be disregarded, as discussed by Fransozo *et al.* (2000) concerning the Xanthoidea crab *Menippe nodifrons*. Such species has a differentiated habitat occupation during its juvenile phase as the young lives in worm colonies and the adults are found in the fissures and under rocks of the intertidal region.

Warner (1967) reported that, during the reproductive period of *Aratus pisonii* (H. Milne Edwards 1837), females migrate from the interior of the mangrove to the water edge, increasing the relative frequency of females. Thus, the deviation in the sex ratio per size class found in *A. scutiformis* could be due to the cryptic habit of such crabs, as they live among the branches of algae, which makes capturing difficult.

In marine crustaceans, as mentioned by Wenner (1972), sex-ratio patterns can vary with the size, and some inferences can be done about anomalous patterns based on the sexual reversion (disregarded in the case of *A. scutiformis*), besides the differences between sexes in relation to their longevity, migration, mortality and growth rate.

There is no report in literature about majid migration in the Brazilian coast. However, Furbock & Patzner (2005) observed non-directional maximum movements as far as 16 m in a 9-day period for *Maja crispata*. González-Gurriarán *et al.* (2002), studying *M. squinado*, detected directional movements as far as 100 m in short periods of time for adult crabs and more restricted and non-directional movements for juveniles. It is interesting to note, however, that such majid specimens are very large, relative to the genera *Epialtus* and *Acanthonyx*.

A. scutiformis dependence on algae for a favorable habitat can constitute an increasing

protection factor, favoring sex encounters for mating. On the other hand, the algal bank can easily be removed by strong marine currents during storms and crabs may present increased mortality risk or modified density due to seasonal variation in environmental factors.

The sex ratio obtained for the total sampled *A. scutiformis* was similar to that obtained by Negreiros-Fransozo *et al.* (1994) for *E. brasiliensis*, close to 1:1. However, those authors found more males in the immature demographic group and more females in the adult group. Both species of the Epialtidae family occur in sympatry and syntopy; they also present a great overlap of juveniles and adults in some size classes, and the same sex-ratio pattern, sexual dimorphism and life habits. Such data corroborate the hypothesis that population features are mainly determined based on the differential sexual maturity attainment between sexes and on the major predation susceptibility of adult males in algal banks on the rocky shores of the northern littoral of São Paulo State.

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Original Scientific Photographs

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Copepods are the most numerous among parasitic crustaceans and may be the most common group of fish parasites. They have been found parasitizing skin, gills, eyes, fins and even inside the mouth of fishes, near the palate and nostrils (Eiras 1994). Among the well known copepods in Brazil, the most observed species is the exotic *Lernaea cyprinacea* (Linnaeus, 1758), introduced during the 80's via the common carp *Cyprinus carpio* Linnaeus, 1758, at the northeast area, spreading to southeastern, mid-west and reaching the southern regions of Brazil (Fortes *et al.* 1998). The guppy *Poecilia reticulata* Peters, 1859 is an ovoviviparous freshwater fish of low waters native to northern South America and the Antilles (Rodríguez 1997). On December 13th, 2008 at 1 pm, in an artificial small tank (1 m²) at the Araçatuba city (21°12'50" S; 50°25'48" W), State of São Paulo, Brazil, two adult specimens of *Poecilia reticulata* (male and female, Fig. 1a, b) were observed being parasitized by the anchor worm *L. cyprinacea*. *Lernaea cyprinacea* is an important parasite to fish farming so much economically, due to the fish's bad appearance for commerce (after parasitized), as ecologically, since when introduced in the environment the parasite can cause mortality of other fishes due to secondary infections caused by fungi and bacteria (Querol *et al.* 2005). Pictures characteristics: Digital Machine model Sony DSC-R1, 3 Mp resolution (72 dpi), diaphragm aperture 4.8, time of exposition 1/125; Speed ISO-160.

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