VERTICAL SEGREGATION OF *SERRAPINNUS PIABA* AND *SERRAPINNUS HETERODON* (CHARACIFORMES: CHARACIDAE) IN A RIVER STRETCH IN NORTHEASTERN BRAZIL

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Abstract - The objective of this study was to evaluate the occupation in the water column by the fish species *Serrapinnus piaba* ***and*** *S. heterodon* ***and test for correlations between abundance and environmental characteristics. The study was conducted in a tributary of the Curu river, in semi-arid Northeastern Brazil. Snorkelers made day-time observations of behaviors: water column occupation, foraging, social organization, syntopy and agonism. The environmental characteristics included river depth, width and current speed in sampling areas dominated by*** *Ceratophyllum demersum* ***beds. The two species differed significantly with regard to the frequency of all behaviors, and presented inverse, though not statistically significant, correlations with environmental characteristics. The absence of statistical significance may be explained by the presence of abundant*** *C. demersum* ***beds favoring the heterogeneity of current speed and microhabitats. In conclusion, vertical segregation was observed between S. piaba (n=45) and S. heterodon (n=93) in an environment attenuated by the presence of macrophytes; however, further studies are required to determine the original cause of this segregation.***

Keywords - Cheirodontinae. Foraging. Social organization. Syntopy.

I. INTRODUÇÃO

Animal species are distributed variably in ecosystems, in terms of both quality and quantity, due to a range of environmental factors (RINCÓN 1999, KAUFMANN and PINHEIRO 2009). Many studies have demonstrated the influence of biotic and abiotic variables on diversity and abundance of aquatic animals, including hydrodynamic conditions (MARCHETTI and MOYLE 2001), substrate (VLACH et al. 2005, HUMPL and PIVNICKA 2006), riparian vegetation (GROWNS et al. 2003) and water temperature and chemical composition (LAPPALEINEN and SOININEN 2006, BUISSON et al. 2007). Biotic variables include macrophyte beds which form a complex habitat colonized by a great variety of organisms (JUNK 1973, GREGG and ROSE 1982, SÁNCHEZ-BOTERO and ARAUJO-LIMA 2001, LIMA et al. 2008). In a study on the effect of beds of anchored water hyacinth (*Eichhornia azurea*) on predator-prey interactions, Padial et al. (2009) found that the latter are influenced by the structural heterogeneity provided by the roots. Macrophytes also serve as refuge for invertebrates, increasing the heterogeneity of the habitat, and as spawning grounds for fish, in addition to contributing to the distribution and interactions of colonizing species (SAVINO and STEIN 1982, AGOSTINHO et al. 2003, PADIAL et al. 2009, BULLA et al. 2011). Thus, the spatial aspects of the habitat may be considered a key factor in the structuring of communities in which species interact dynamically and often compete for space (SCHOENER 1974, 1983, CUNHA and VIEIRA 2004).

The genus *Serrapinnus*, of the subfamily Cheirodontinae, one of the best known subfamilies of Characidae in terms of taxonomy and phylogenetics (MALABARBA 2003), is represented by three species in the middle and eastern part of Northeastern Brazil (ROSA et al. 2003). Considering the phylogenetic proximity of the species *S. piaba* (LÜTKEN 1875) and *S. heterodon* (EIGENMANN 1915) and their coexistence in a tributary of the Curu river, a perennial lotic ecosystem in semi-arid Northeastern Brazil, we expect that these species show some degree of resource partitioning. Thus, we investigated their resource use patterns for these two species in light of Schoener's (1974) concept of resource partitioning and Abrams' (1983) concept of limiting similarity. In addition, the abundance of each species was correlated with the physical characteristics of the ecosystem.

II. MATERIAL AND METHODS

Observations were made along a stretch of a tributary of the Curu river between 3°48′6.10″S 39°19′4.82″W and 3°49′2.66″S 39°19′9.92″W, located within the confines of the Vale do Curu research farm of the Federal University of Ceará, in the municipality of Pentecoste (Figure 1). The study was conducted in the end of the dry season (December) (ZANELLA 2005) to obtain the greatest possible visibility between observer and fish (the visibility was until four meters of distance).

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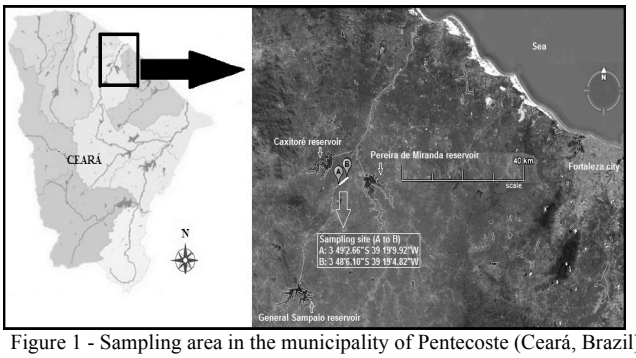

Figure 1 - Sampling area in the municipality of Pentecoste (Ceará, Brazil), showing location of the Vale do Curu Research Farm (Source: Adapted from GORAYEB et al. 2005; GOOGLE EARTH SOFTWARE 6.0.3.2197 Inc., 2011)

Day-time underwater observations were made by three snorkelers on December 6, 7 and 8, 2011. The individuals of *Serrapinnus* are usually found in the marginal areas of the stream, where the depth does not exceed 1.0 m and there are dense macrophyte stands. The chosen stretch of river presented a bottom of gravel and coarse sand and great abundance of hornwort beds (*Ceratophyllum demersum* L.), the macrophyte selected in this study for observation of associated fish fauna as a way to standardize the observations. The hornwort is a submerged free-floating macrophyte, though occasionally fastened to the substrate by rhizoids (DENNY 1987).

After approximately six hours of *ad libitum* exploration of different habitats along the river, 24 hornwort beds were selected at random for underwater observation of the species *S. piaba* and *S. heterodon* from the division of the total area in quadrants of 10 m². Thus, using the focal sampling method of Martin and Bateson (1993), twenty-four observation sessions, for 10 min each, were carried out, registering four variables: i) water column occupation (surface, middle or bottom layers), ii) foraging behaviors (food-seeking in the water column, in the substrate or in the hornwort canopy), iii) social organization (individuals solitary or in shoals of 2-5 or more than 5 individuals), and iv) syntopy (whether in the company of other species of *Serrapinnus*, observed within the same visual field). The presence of other species and agonistic behaviors were also registered. Following the *ad libitum* exploration required to locate the object of the study, hornwort beds were sampled with a dragnet to capture specimens of *S. piaba* and *S. heterodon*. Based on the literature, the specimens were identified taxonomically at the Research Farm in Pentecoste and deposited in the Coleção Ictiológica da Universidade Federal do Rio Grande do Norte (voucher codes: UFRN 934; UFRN 935).

Following each observation session, the physical characteristics (average depth, width and current speed) of the location were determined. The average depth was based on five probes within the observed hornwort bed. The average width was based on measurements of the two extremes encompassing the field of observation. The was determined by averaging the time required for a float to travel five meters downstream five times, according to the formula (1):

$$\textit{Current velocity} = d / \Delta t \qquad (1)$$

where d is the distance traveled and Δt is the average time elapsed.

Spearman correlations between abundance and habitat characteristics were analyzed with the software PAST 2.14 (HAMMER et al. 2001). Behavior-related data were analyzed with the software BioEstat 5.0 (AYRES et al. 2007) and compared with the G-test and the chi-square test, followed by Yates' correction. The level of statistical significance was set at 5% ($p < 0.05$).

III. RESULTS AND DISCUSSION

In all, 93 specimens of *S. heterodon* and 45 specimens of *S. piaba* were observed in or around the hornwort beds. Water column occupation differed significantly: *S. piaba* occupied the entire water column more frequently (63% of observations), while *S. heterodon* was mostly observed in the middle layer (66%) (Figure 2a). The existence of multiple microhabitats in the floating canopy of hornwort hypothetically favors the differential use of the water column, a question which could be further clarified in experiments involving the removal of one of the fish species.

The intraspecific social organization varied, but shoals of more than 5 individuals was the predominant pattern (*S. heterodon* = 94% vs. *S. piaba* = 73%) (Figure 2b). The latter species differed from the former as it was observed in shoals of 2-5 individuals in 27% of the observations. Syntopy was registered in 93% (*S. piaba*) and 59% (*S. heterodon*) of cases (Figure 2c). Thus, *S. heterodon* was syntopic with *Astyanax* gr. *bimaculatus* (Characidae), unlike *S. piaba* which was syntopic with *S. heterodon* only. Agonistic behaviors were observed between *S. piaba* and *Poecilia vivipara* (Poeciliidae) in the upper layers of the water column. Other species, such as *Astyanax* gr. *fasciatus*, *Leporinus* sp. and *Prochilodus brevis*, were sampled as bycatch and seen in the hornwort beds, but not in the same visual field as *Serrapinnus*.

The two species differed with regard to their feeding strategies: while *S. heterodon* was more frequently observed feeding on particles in the water column, *S. piaba* appeared to prefer the hornwort bed and the substratum (Figure 2d). According to Dias and Fialho (2009), both species are omnivorous and feed on detritus, fish scales, microcrustaceans, insects, algae and vegetable matter. The authors observed that *S. heterodon* and *S. piaba* were very predominant in hornwort beds in the Ceará Mirim river, an environment with microhabitats favoring species with generalist feeding strategies, but appeared to be segregated spatially or temporally due to the principle of competitive exclusion and were therefore not competing for food directly.

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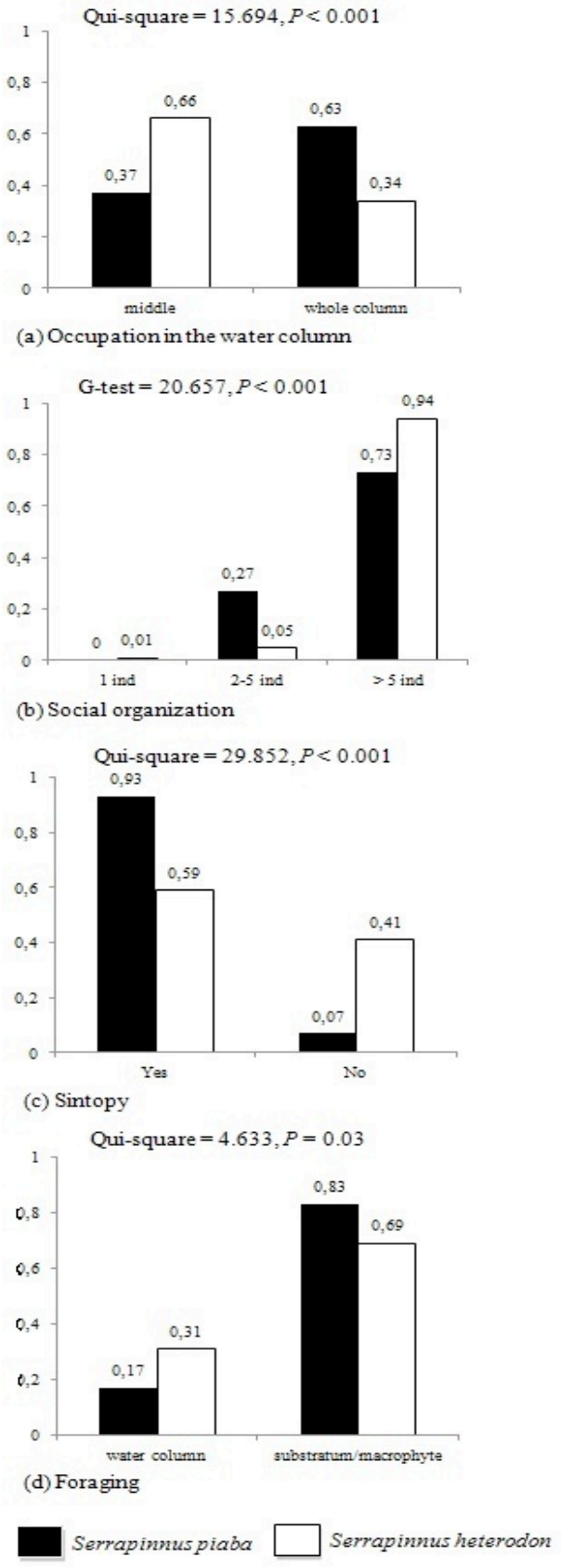

Figure 2 - Relative frequency and significance (chi-square and G-test) of study variables. In parenthesis, the number of observations for *Serrapinnus piaba* and *Serrapinnus heterodon* in each analysis: (a) occupation of the water column (n=45/93), (b) social organization (n=45/93), (c) syntopy (n=45/93) and (d) foraging (n=43/55) for individuals observed in a tributary of the Curu river (Ceará, Brazil).

The differential availability of suspended particles in the water column (SPENCE 1967), as observed in the tributary of the Curu river in association with the presence and density of *C. demersum* in the water column, may in part account for the spatial segregation of the two species. In fact, greater differences in depth, water flow, light, nutrient availability and other variables related to the submerged macrophyte structures tend to lead to greater a diversity among associated organisms and particles (HENRIQUES et al. 1988, PIERINI and THOMAZ 2009, THOMAZ and ESTEVES 2011). Ibañez et al. (2007) looked at the importance of phylogenetic relationships between fish species, but stressed the role of ecomorphological characteristics in the establishment of feeding patterns, especially in their study from the Bolivian Amazon in which six ecomorphological characteristics (standard length, eye diameter, head length, mouth width, mouth position and gut length) were identified as relevant to analysis. Dias and Fialho (2009) made inferences regarding the existence of a common feeding pattern for *S. heterodon* and *S. piaba* based on their small size, similarities in trophic morphology and common ancestry.

Predator pressure may also affect the distribution of *Serrapinnus* in this environment. Several predators were observed or collected in association with the sampled hornwort beds, especially *Hoplias malabaricus*, an efficient ambush predator (WINEMILLER 1989), *Cichlasoma orientale* and *Crenicichla* sp. In most of our observations, both species of *Serrapinnus* were swimming in shoals of more than 5 individuals. As observed for other fish species, this behavior may reflect a strategy to prevent predation (BROCK and RIFFENBURGH 1960). The preference for hornwort beds may be justified by similar benefits, as previously demonstrated (SÁNCHEZ-BOTERO et al. 2007, PADIAL et al. 2009). However, in general, the processes related to spatial segregation between *S. heterodon* and *S. piaba* remain unclear. Further studies on microhabitat, predator pressure and particles suspended in the water column may shed light on these aspects (WARFE and BARMUTA 2006, PADIAL et al. 2009, PRADO et al. 2010).

On the average, the river stretch selected for the study was 0.35 ± 0.24 m deep and 6.6 ± 2.18 m wide. Depending on the location, the current speed varied from 0.20 to 0.50 ± 0.10 m/s. The river bed consisted of coarse sand and gravel, with a few scattered rocks (KRUMBEIN and SLOSS 1963).

When the abundance of *Serrapinnus* was analyzed in relation to the physical characteristics of the river (Table I), the abundance of *S. piaba* was positively correlated with depth and width. On the other hand, the abundance of *S. heterodon* was negatively correlated with depth and width and positively correlated with current speed only. In comparison, Leal et al. (2011) found that both *S. piaba* and *S. heterodon* prefer environments with low current speed. They added that *S. heterodon* was more abundant than *S. piaba* in open stretches of river, but less abundant on flooded plains, indicating that *S. heterodon* prefer lotic environments while *S. piaba* prefer lentic environments. This is supported by our findings, with emphasis on depth and current speed. According to Leal et al. (2011), the two species differ with regard to body type: the body shape of *S. piaba* is more compressed (better adapted to lentic systems) than that of *S. heterodon* (LANGERHANS et al. 2003). The absence of significant correlations is compatible with the observed coexistence of *S. piaba* and *S. heterodon* in the

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sampled hornwort beds, as these macrophytes attenuate the hydrodynamic properties of the river, favoring environmental heterogeneity (GREGG and ROSE 1982).

Table I - Correlations between physical variables of the sampling area in a tributary of the Curu river (Ceará, Brazil) and the abundance of *Serrapinnus piaba* and *Serrapinnus heterodon*. December 2011.

	Abundance	
	S. piaba	*S. heterodon*
Depth	$r =$ **+0.50**; $p = 0.31$	$r =$ **- 0.29**; $p = 0.47$
Width	$r =$ **+0.54**; $p = 0.26$	$r =$ **- 0.49**; $p = 0.21$
Current speed	$r =$ **- 0.56**; $p = 0.23$	$r =$ **+0.35**; $p = 0.39$

In conclusion, *S. piaba* and *S. heterodon* were found to coexist in beds of *C. demersum* in a perennial river in semi-arid Northeastern Brazil. However, it was not possible to ascertain whether the observed vertical segregation was due to competition for space or the evolutionary history of each species. Interestingly, all the species observed and collected in this study (n=9) were native (ROSA et al. 2003) and were reported for this ecosystem for the first time in the present study. The Curu river may be said to be better preserved than similar waterways in semi-arid Northeastern Brazil in which exotic species have already been introduced (MEDEIROS and MALTCHIK 2001, MALTCHIK and MEDEIROS 2006).

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