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Scientific Note

Vertical segregation of two species of *Hyphessobrycon* (Characiformes: Characidae) in the Cabiúnas coastal lagoon, southeastern Brazil

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Segregation in the use of the water column by two congeneric species of Characidae, *Hyphessobrycon bifasciatus* and *H. luetkenii*, was investigated through underwater observations in the Cabiúnas coastal lagoon in northeastern Rio de Janeiro, Brazil. The use of the water column by the two species differed significantly. *Hyphessobrycon luetkenii* occupied mainly the uppermost stratum, with 79% of the observations within 20 cm of the surface; whereas *H. bifasciatus* was more common between 20 cm and 40 cm below the surface (55% of the observations). Predation pressure, macrophyte cover and nutrient distribution may influence this vertical segregation.

A segregação na coluna d'água por duas espécies congenéricas de caracídeos, *Hyphessobrycon bifasciatus* e *H. luetkenii*, foi investigada através de observações subaquáticas na lagoa costeira Cabiúnas, nordeste do Rio de Janeiro. O padrão do uso da coluna d'água diferiu significativamente. *Hyphessobrycon luetkenii* ocupou principalmente o estrato superior, com 79% das observações até 20 cm da superfície, enquanto *H. bifasciatus* foi mais comum entre 20 e 40 cm abaixo da superfície (55% das observações). Pressão de predação e distribuição das macrófitas e dos nutrientes são fatores que poderiam influenciar a segregação vertical entre as espécies de Hyphessobrycon.

Key words: Habitat use, Spatial segregation, Underwater observations, Restinga de Jurubatiba National Park.

The use of space seems to be the main factor explaining species richness and community structure (MacArthur, 1958; Schoener, 1974, 1983; Cunha & Vieira, 2004 and references therein). Differences in the pattern of use of space are especially important in complex or three-dimensional environments, and their study is a basic requisite for understanding species coexistence. Studies of the use of microhabitats by fish in lotic ecosystems suggest that depth, substrate composition, and water velocity determine the distribution of species (Daniels, 1987; Grossman *et al*., 1987; Bührnheim, 1999; Rincón, 1999). In lentic freshwater systems, the spatial distribution of fish is influenced in pelagic zones by factors associated with depth, such as temperature, light, dissolved oxygen, food type, and food abundance (McKaye, 1977; Seehausen & Bouton, 1997); and in the littoral and demersal zones by microhabitat heterogeneity (Diehl & Eklöv, 1995).

Ross (1986) reviewed different fish communities and taxa levels, and showed that spatial segregation is the main factor

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that explains the coexistence of phylogenetically related fishes. Studies on fish communities have shown that use of space or microhabitats distinguish species, often congeneric ones; whereas other dimensions of the ecological niche, such as diet and morphology, may overlap considerably (see Bouchon-Navaro, 1986 for reef fishes; Kohda & Yanagisawa, 1992 for lake cichlids; Ornellas & Coutinho, 1998 for marine-grass inhabitants; Nico & Thomerson, 1989 for annual killifishes; and Sabino & Zuanon, 1998 for Amazon stream fishes). Differentiation in microhabitat use is a key factor structuring fish communities (Junk *et al*., 1983; Fernandes, 1997; Bührnheim, 1999; Rincón, 1999).

The coastal lagoons of Parque Nacional da Restinga de Jurubatiba (PNRJ) in Rio de Janeiro State, Southeastern Brazil, have a rich macrophyte community supporting a great variety of microhabitats (Henriques *et al*., 1988; Esteves, 1998). We assume that differentiation in the use of space could be an important factor in structuring the fish communities of these lagoons, allowing closely related species to coexist. In PNRJ lagoons, the genus *Hyphessobrycon* Durbin is represented by two species, *H. bifasciatus* Ellis, 1911 and *H. luetkenii* (Boulenger, 1887), which occur together only in Cabiúnas Lagoon. We made direct observations by snorkeling to investigate water column use by these species in Cabiúnas Lagoon.

The Restinga de Jurubatiba National Park is located in the northeastern part of Rio de Janeiro State, Brazil, between 22°17'- 22°18' S and 41°39' - 41°40' W (Fig. 1). The climate is tropical ("AW" in the Köppen classification), with rainy periods in summer and dry periods in winter (Henriques *et al*., 1988). The fish community of seven coastal lagoons of the park is composed of 39 species, and species of *Hyphessobrycon* occur in four (Caramaschi *et al*., 2004). Cabiúnas Lagoon has an area of 0.34 km^2 and 2.37 m mean depth (Panosso *et al*., 1998). The community of aquatic macrophytes harbors 15 species in the nearshore parts of the lagoon (Henriques *et al*., 1988). In this area, the stands were dominated by the submersed macrophyte *Potamogeton stenostachys* K. Schum. and the emergent *Typha domingensis* (Pers.) Kunth. The members of *Hyphessobrycon* are usually found in the marginal areas of the lagoon, where the depth does not exceed 1.20 m and there are dense macrophyte stands. Three stands of macrophytes with similar composition were used in the study (Fig. 1).

The fish were observed during daylight by snorkeling dives on April 27, 2003, and from April 8 to 10, 2004. To assess the use of water column by one of the species when the other was absent, additional snorkeling observations were made in Carapebus Lagoon, where only *H. bifasciatus* occurs (Caramaschi *et al*., 2004). Each observation session lasted for five minutes, and was based on a focal individual approach (*sensu* Altman, 1974). Observers (AAC, SMQL, and JISB) remained in the same place during the diving sessions. Because of low visibility, focal individuals were followed for 15 seconds at most. The behavior of each focal individual was recorded on a plastic slate with a pencil, based on four variables: (a) Depth - the most frequent stratum occupied during observation (0-20 cm, 20-40 cm, > 40 cm below surface); (b) Forage – records of foraging events (biting particles in the water column, at the surface, or on macrophytes); (c) Social organization (solitary, schooling with fewer than five conspecific individuals, schooling with more than five individuals); (d) Syntopy – when

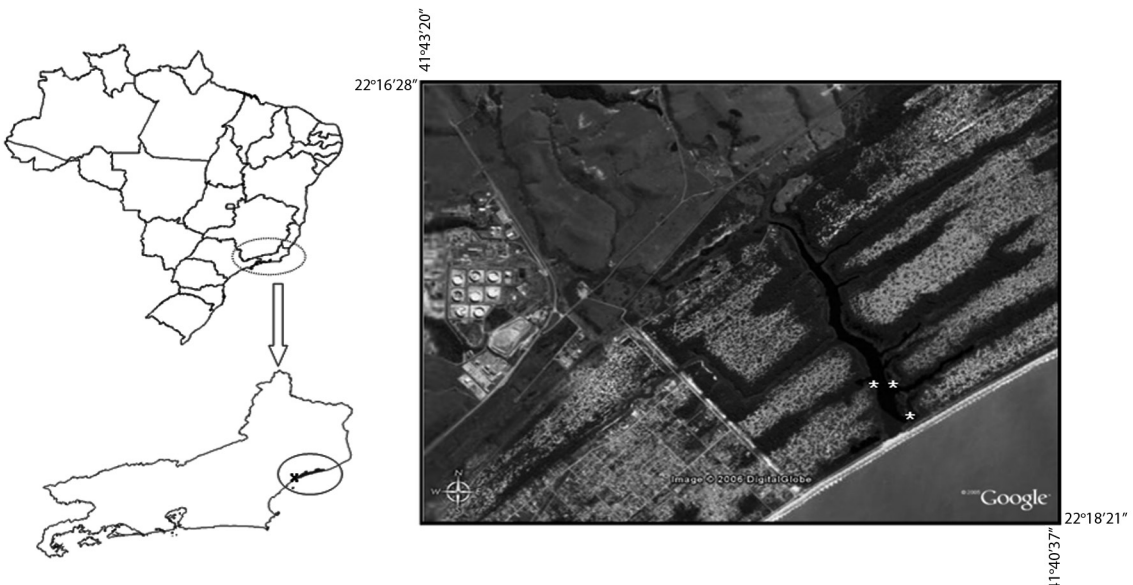

Fig. 1. Parque Nacional da Restinga de Jurubatiba (shaded area within the circle) in Rio de Janeiro State, southeastern Brazil. The satellite image shows Cabiúnas Lagoon, located in the southern part of the park. Asterisks indicate observation sites in the lagoon.

swimming, or not, with the other species of *Hyphessobrycon*, in the same visual field. The significance of the differences in frequency of each category within each variable between species was tested with one-tailed chi-square tests and Yates correction when necessary, assuming as significant values of $P < 0.05$ (Zar, 1984). We recorded the presence of individuals of other fish species, their identity, position in water column, and the occurrence of agonistic behavior. Voucher specimens of *H. bifasciatus* and *H. luetkenii* were deposited in the collection of the Laboratório de Ictiologia Geral e Aplicada, Universidade Federal do Rio de Janeiro (UFRJ 7284-7287).

In Cabiúnas Lagoon, we observed 185 individuals of *H. luetkenii* and 180 of *H. bifasciatus* in 74 dive sessions, totaling more than six hours of underwater observations. Patterns of water-column use differed significantly (Fig. 2a). *Hyphessobrycon luetkenii* occupied mainly the upper strata, with 79% of the observations within the uppermost 20 cm, 20% in the second stratum, and less than 1% below a depth of 40 cm. Individuals of *H. bifasciatus* were more common between 20 cm and 40 cm (55% of the observations), and less frequent toward the water surface (29%) and lagoon bottom (16%) (Fig. 2a).

The species did not differ significantly in foraging tactics (Fig. 2b), feeding mainly on items in the water column (76% and 54% of the observations for *H. bifasciatus* and *H. luetkenii*, respectively, Fig. 2b).

The intraspecific social organization differed between the two species (Fig. 2c). *Hyphessobrycon luetkenii* swam primarily in groups of 2-5 individuals (51% of the observations), whereas individuals of *H. bifasciatus* were more frequently (54%) observed alone. Groups with more than five individuals were less frequent for both species (approximately 10%, Fig. 2c). Syntopy was recorded in 38% and 19% of the observations of *H. luetkenii* and *H. bifasciatus*, respectively (Fig. 2d).

No agonistic behavior was observed between the species of *Hyphessobrycon*. The associated fish fauna was composed of *Poecilia vivipara* (Poeciliidae) at the surface and *Geophagus brasiliensis* (Cichlidae), *Hoplias malabaricus* (Erythrinidae), and *Oligosarcus hepsetus* (Characidae) at the bottom. The latter was occasionally observed attacking *H. luetkenii* from bottom to surface, in our above-surface observations, between diving sessions.

In Carapebus Lagoon, we observed 138 focal individuals of *H. bifasciatus* in 24 diving sessions, totaling two hours of underwater observation. All individuals were observed below 40 cm and in small groups (45% of the time with five or fewer individuals, 43% of the time alone, and only 12% in larger groups), and foraging among the macrophytes (83% *versus* 17% in the water column).

Vertical segregation in the use of space seems to allow different species to coexist in complex three-dimensional

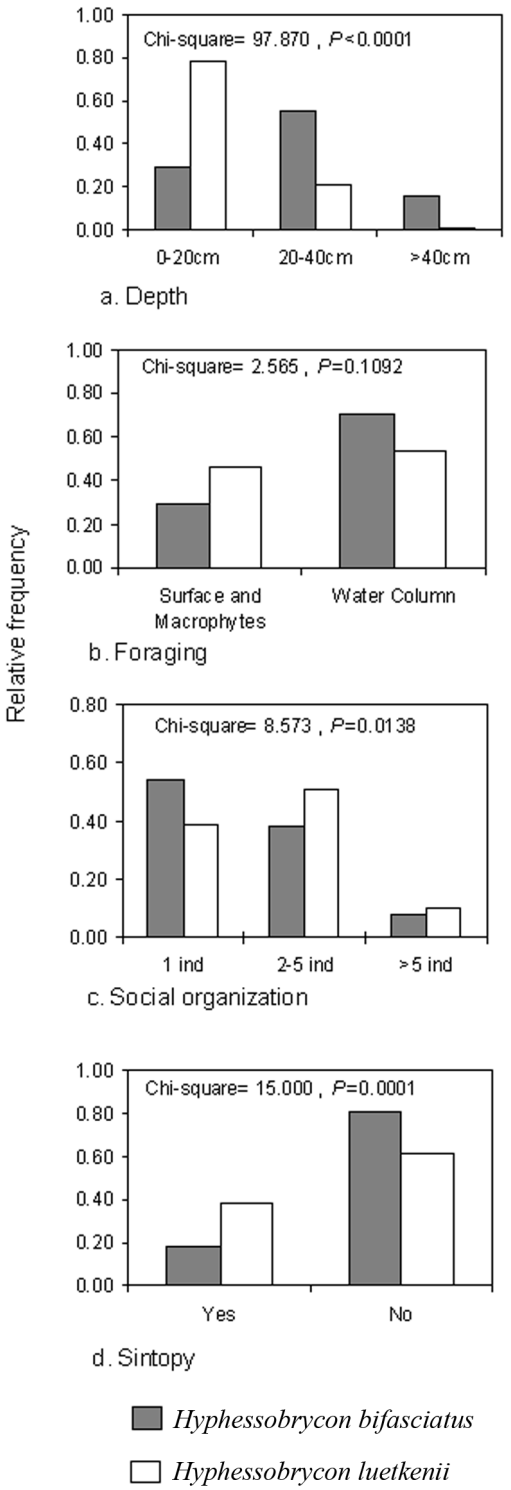

Fig. 2. Relative frequency and significance (Chi square) of the variables. In parentheses number of observations for *Hyphessobrycon bisfasciatus* and *H. luetkenii* in each analysis: (2a) depth (n=180/ 185), (2b) foraging (n=48/ 56), (2c) social organization (n=180/ 185), and (2d) syntopy (n=174/ 175), for focal individuals observed in Cabiúnas Lagoon, State of Rio de Janeiro, southeastern Brazil.

environments such as freshwater ecosystems (see Sabino & Zuanon, 1998; Esteves & Aranha, 1999, and this study). The syntopic species of *Hyphessobrycon* clearly segregate from each other in the water column in Cabiúnas Lagoon. Similar patterns of vertical segregation have been observed for other congeneric fish species (Mendelson, 1975; Surat *et al*., 1982; Moyle & Senanayake, 1984, Aranha *et al*., 1993).

Both species are suspension feeders, and available data on their diets suggest that they are generalists (Aguiaro & Caramaschi, 1998). Microhabitat structure may influence the differential use of the water column by the two species. The macrophyte stands where the observations were made in both lagoons were dominated by *Potamogeton stenostachys* and *Typha domingensis*. However, the richness and structure of macrophytes can differ with depth in Cabiúnas Lagoon, as suggested by Henriques *et al*. (1988). Preferences to use the interface of open area and thickly vegetated areas, or the inner spaces of the macrophyte stands should be evaluated experimentally. In this approach, preferential use of the water column by *H. luetkenii* may be evaluated by experimentally excluding *H. bifasciatus*. Likewise, the availability of resources such as suspended particles, which were not measured during this study, may vary with depth (Spence, 1967) and thus influence the distribution of the two species throughout the water column.

Hyphessobrycon bifasciatus, even when living without the presence of the congeneric *H. luetkenii* as in Carapebus Lagoon, still occupies the lagoon bottom. This suggests, as established in previous studies (Ross, 1986; Peres-Neto, 1999; Casatti *et al*., 2005), that the use of habitat and microhabitat *per se*, rather than competition, must be the main factor in resource partitioning between fish species.

Predation is another factor that must affect the distribution of *Hyphessobrycon* species in these coastal lentic environments. Power (1984) demonstrated the importance of aerial predation in modifying the vertical pattern of fish distribution in a clear tropical stream. Ardeidae birds are commonly seen foraging in the PNRJ lagoons (Alves *et al*., 2004), but there are no studies on diet or hunting behavior of birds in southern Brazilian coastal lagoons. However, Carvalho & Del-Claro (2004) studying the effects of the avian predation pressure on *Hyphessobrycon eques* suggested that the avoidance of the surface by the fishes in the presence of a predator could be an evolutionary response to this pressure. It could also explain why *H. bifasciatus* occupies only the lagoon bottom even without *H. luetkenii* presence. The piscivorous fish species found in Cabiúnas Lagoon and observed in the macrophyte stands were *Oligosarcus hepsetus* and *Hoplias malabaricus*. Data for five piscivorous fishes (n=151 for all species) from Cabiúnas Lagoon showed that only *O. hepsetus* preyed upon *Hyphessobrycon* species (Rafael Leitão, pers. comm.). *Oligosarcus hepsetus* is a diurnal ambush predator, which suddenly attacks its prey from the bottom to the water surface (Sabino & Silva, 2004). It is possible that *H. bifasciatus* occupies the lagoon bottom in part to avoid predation by *O. hepsetus*, since occupying a position in the same stratum may allow it to perceive and escape from the predator. Since *H. bifasciatus* is more abundant than *H. luetkenii* (2.0 individuals/m^2 *vs*. 1.26 individuals/m^2, from Sanchéz-Botero, 2005), the former may be excluding the latter from the potentially less-dangerous area. Sympatry between *H. bifasciatus* and *H. luetkenii* with other species of *Oligosarcus* is also reported in the Patos (Garcia & Vieira, 1997; 2001) and Taim (Garcia *et al*., 2006) lagoons in southern Brazil, but no data on the use of space are available.

Overall, processes related to the spatial segregation between these species are still not clear, which provides impetus to search in detail for factors, such as predation, suspended particles distribution in the water column, and microhabitat characteristics, such as heterogeneity and complexity of macrophyte distribution, that may influence water-column segregation in this community.

We hypothesize that the observed pattern of vertical segregation was produced by a combination of predator avoidance and differential evolutionary adaptation, rather than by direct interspecies competition for space.

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