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Habitat use and food partitioning of the fishes in a coastal stream of Atlantic Forest, Brazil

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Abstract: We analysed the fish assemblage in the "Mergulhão" stream (southern Brazil) with underwater observations for habitat use, considering water depth, current velocity, bottom type, shadow from vegetation cover, distance of stream-edge, and vertical position. Stomach contents or foregut content samples of the most abundant species were collected from 26 species (10 families). The fish assemblage occupied the bottom stream. The similarity analysis of spatial occupation of species grouped four habitat use guilds: A) "lambaris" (*Astyanax* sp. and *Deuterodon langei*), *Characidium* spp. (*C. lanei* and *C. pterostictum*) and *Rineloricaria kronei* used the bottom in deep sites and waters with middle current; B) *Pimelodella pappenheimi* and *Corydoras barbatus* used the bottom in sites with lower current; C) *Mimagoniates microlepis* used the surface of the water column; and D) *Phalloceros caudimaculatus* used shallow sites and waters without current. Species with few records were analysed descriptively. Diet similarity suggested seven trophic guilds: *Microglanis* sp. and *Pimelodella pappenheimi:* omnivorous/carnivorous guild; *Corydoras barbatus:* omnivorous/insectivorous guild; *Characidium lanei:* aquatic insectivorous guild, mainly aquatic insects; *Mimagoniates microlepis:* terrestrial insectivorous guild, mainly terrestrial insects; *Deuterodon langei* and *Astyanax* sp.: omnivorous/herbivorous guild; *Rineloricaria kronei, Kronichthys subteres, Schizolecis guntheri, Hisonotus leucofrenatus* and *Pseudotothyris obtusa:* herbivorous guild; and *Phalloceros caudimaculatus:* algivorous guild. When the guilds were similar, the species were generalists in diet and in habitat use.

Key words: Habitat use, feeding, resource partitioning, Atlantic Forest, coastal stream, Brazil.

Neotropical freshwater fishes are very diverse and fish assemblages are quite rich in this region. So the interspecific relationships are intricate in these communities (Lowe-McConnell 1987).

Several researchers believe that competition would be an important ecological and evolutionary factor (*e.g.* Schoener 1974, Yant *et al.* 1984). Nevertheless, others believe that the environmental instability of the abiotic factors would reduce the importance of the competitive relationships (*e.g.* Connor & Simberloff 1979, Strong 1980, Grossman *et al.* 1982, Wiens 1977).

The resource partitioning in a community may be important to the knowledge of the nature of these interrelationships (Schoener 1974). The most important dimensions of resource partitioning for fish assemblages are the habitat and trophic segregation (Ross

1986), being the habitat segregation most important in freshwater than it is in marine environments (Horn 1972).

In Brazil, studies of microhabitat and/or trophic structure of freshwater fish assemblages have been increasing during the last few years, but few studies have been conducted in coastal streams (*e.g.* Costa 1987, Teixeira 1989, Sabino & Castro 1990).

In this paper, the microhabitat use and trophic structure in guilds of the fishes were analysed in a coastal stream of the Atlantic Forest in Paraná State.

MATERIALS AND METHODS

The "Mergulhão" stream is a second order stream Atlantic Forest coastal stream in Antonina municipality (Paraná State, Brazil; 25°17'S, 48°44'W), with very clear water, which allows underwater observations. In the studied area the contiguous vegetation is composed of trees and shrubs on the left edge and herbaceous plants on the right. The average depth is one meter, and the average distance between the edges is 5m.

This research was conducted in daylight in September and October 1993, and January and March 1994.

A grid with ten transects (adapted from Gorman & Karr 1978; Fig. 1) with 80-130 point-samples was used for measuring four habitat variables and for observation of the fishes. The habitat variable measurements were the depth of water, current velocity, bottom type and shadow of vegetation cover. The depth was measured in centimeters and classified in categories of ten of centimeters (1= 0-10 cm to 9= 80-90 cm). The current velocity was measured with a Pitot tube at two centimeters under the surface and classified in four categories: 0, imperceptible; 1, slow (0.00-0.25 m.s^{-1}); 2, moderate (0.25-0.50 m.s^{-1}); and 3, fast (0.50-0.75 m.s^{-1}). The substrate or bottom type was classified in eight categories: 1, sand; 2, gravel; 3, pebble; 4, stone (less than 10 cm of diameter); 5, rock (10-25 cm); 6, large rock (more than 25 cm); 7, litter and 8, trunk and branches. The shadow of the vegetation cover was recorded by the presence (1) or absence (0) of the vegetation itself or branches over the point-sample.

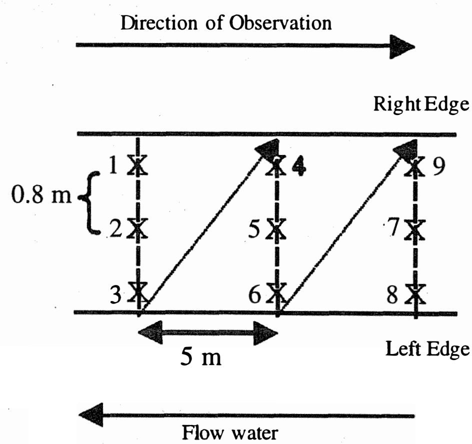

Fig. 1. Location of the sample-points in transects for measurement of variables of habitats and observation of habitat use. The grid has ten transects at 5 m intervals.

The underwater observations were done with mask and snorkel during 6 min in each point-sample, where we noted the number of fishes of each species, their distance from the water's edge and their vertical position. The distance from the water's edge was classified in three categories: 0, nearest to right edge; 1, mid-stream and 2, nearest to left edge. The vertical position was categorized as 1 (upper third of the water column), 2 (middle third), 3 (lower third) and 4 (bottom).

During the underwater observation, the feeding behaviour of the species was noted, and grouped using the same foraging tactic categories described by Sazima (1986).

After the observation, fishes were collected with fishing-nets, casting nets and sieves to study the fish assemblage and their diet.

The stomach or samples of the foregut contents of the most abundant collected species (when individuals were over ten) were examined, under estereoscopic microscope and optical microscope, to assign the feeding guilds by analysis by the occurrence methods, which the percent composition of each food item in the total number of the items found (Hyslop 1980).

Data Analysis: Chi-square goodness-of-fit-test was used to compare frequency distributions of habitat use in relation to the availability of each resource. Calculations of expected frequencies were based on the environmental features and the sample sizes were standardized to a total of 100, as suggested in Gorman (1988). For this purpose, we used the data for each species and for all species together. All species analysis provided an assessment of how the assemblage used the available resources.

The similarity in the habitat use by species was estimated by the Morisita's measure (Smith & Zaret 1982). A cluster analysis with UPGMA method (Romesburg 1990) was applied using the similarity data. The similarity of the percent composition of each food item was calculated using the Morisita's measure modified by Horn (Smith & Zaret 1982) and the results were grouped by UPGMA method (Romesburg 1990) to determine the feeding guilds.

RESULTS

We collected 26 species belonging to 10 families in the "Mergulhão" stream (Table 1).

The underwater observations totalized 14 hours and 2462 observation records of *Mimagoniates microlepis*, *Phalloceros caudimaculatus*, *Corydoras barbatus*, *Pimelodella pappenheimi*, *Rineloricaria kronei*, *Astyanax* sp., *Deuterodon langei*, *Characidium lanei* and *C. pterostictum*. The accurate specific differentiation of *Astyanax* sp. and *Deuterodon langei* was impossible to do during the observations and they were treated together and designated here by "lambaris". Likewise, *C. lanei* and *C. pterostictum* were treated as *Characidium* spp.

The habitat variables that prevails in the "Mergulhão" stream were the sand-type substrate (category 1), current velocity till 0.5 $m.s^{-1}$ (categories 1 and 2) and depths between 40 and 60 cm (categories 5 and 6).

The significant differences in the habitat use, by species and by assemblage, in each environmental variable category and its mainly occurrence is showed in Table 2. The habitat use by the fish assemblage was significant to vertical position and the tendency to occupy the bottom was corroborated. "Lambaris" tended to occupy the bottom of deep stretches with moderate and fast current velocity. *Mimagoniates microlepis* preferred sites in the left edge with litter and trunk/branch substrate type, water surface and shaded areas. *Characidium* spp. preferred water with current more than 0.25 m/s in deeper sites and occupied the bottom in unshaded areas. *Pimelodella pappenheimi* occupied the stream bottom in areas with sand, gravel and litter substrate types, water with current untill 0.25 $m.s^{-1}$ in unshaded areas with moderate depths. *Corydoras barbatus* occupied almost exclusively the stream bottom mainly the right edge, in litter and trunk/branch substrate type and waters whose current was lower than 0.25 $m.s^{-1}$. *Rineloricaria kromei* occurred in the right edge in unshaded deeper areas with sand substrate type and water currents moderate and fast. *Phalloceros caudimaculatus* occupied shallow and shaded areas with litter substrate type, and waters with slow current in the right edge of the stream.

It was not possible to do the x^2 test in the vertical position variable for *Characidium* spp., *Corydoras barbatus* and *Rineloricaria kronei* because these species used almost exclusively the stream bottom.

The similarity analysis of spatial occupation of species allowed us to determine four groups: "lambaris", *Characidium* spp. and *Rineloricaria kronei* (group A), used the bottom in deep sites and waters with current more than 0.25 $m.s^{-1}$; *Pimelodella pappenheimi* and *Corydoras barbatus* (group B), occurred the bottom in sites with lower current (until 0.25 $m.s^{-1}$) and litter substrate type; *Phalloceros*

TABLE 1

Fish species collected and/or observed in the "Mergulhão" stream during the study, and the codes used in the results of microhabitat or diet

Species	Microhabitat codes	Diet codes
Family Erythrinidae		
Hoplias malabaricus (Bloch, 1794)		
Family Characidae		
Characidium lanei Travassos, 1967	Cha	Chl
Characidium pterostictum Gomes, 1947	Cha	
Oligosarcus hepsetus (Cuvier, 1817)		
Mimagoniates microlepis (Steindachner,1876)	Mim	Mim
Astyanax sp.	Ast	Ast
Deuterodon langei Travassos, 1957	Deu	Deu
Family Pimelodidae		
Microglanis sp.n *	Mig	Mig
Heptapteros mustelinus Valenciennes, 1840		
Pimelodella pappenheimi Ahl, 1928	Pim	Pim
Rhamdia quelen (Quoy & Gaimard, 1824)		
Family Trichomycteridae		
Homodiaetus sp.n *		
Family Callichthyidae		
Corydoras barbatus (Quoy & Gaimard, 1824)	Cor	Cor
Family Loricariidae		
Hemipsilichthys sp.n *		
Kronichthys subteres Ribeiro, 1908	Kro	Kro
Hisonotus leucofrenatus (Ribeiro, 1908)	His	His
Pseudotothyris obtusa (Ribeiro, 1911)	Pse	Pse
Schizolecis guntheri Britski & Garavelo, 1984	Sch	Sch
Rineloricaria kronei (Ribeiro, 1911)	Rhi	Rhi
Ancistrus sp.		
Family Gymnotidae		
Gymnotus pantherinus Steindachner, 1908		
Family Poeciliidae		
Phalloceros caudimaculatus (Hensel, 1868)	Pha	Pha
Family Cichlidae		
Cichlasoma facetum (Jenyns, 1842)		
Crenicichla sp.n *		
Geophagus brasiliensis (Quoy & Gaimard, 1824)		
Family Synbranchidae		
Synbranchus marmoratus Bloch, 1795		

"*" new species that are being described.

caudimaculatus (group C) occupied shallow sites and waters with little current; and *Mimagoniates microlepis* (group D), the surface of water column.

Species with few records were not analysed statistically and their results were just descriptive.

Geophagus brasiliensis occurred in the left edge of the stream, upon litter and trunks and branches, in shaded areas.

Kronichthys subteres and *Microglanis* sp. were not seen during underwater observations. However, during the samplings, they always occupied microhabitats formed by branches, leaves and other accumulated materials in fallen branches in the water, which suggests their preference for these microhabitats. Furthermore, there were few individuals, in the right margin of the stream in the middle of the grass. *Hoplias malabaricus*, *Gymnotus*

TABLE 2

The significant differences in the habitat use, by species and by assemblage, in each environmental variable category, compared with the environmental availability, and its mainly occurrence

	Fish assemblage		"Lambaris"	
Categories	x^2	Mainly occurrence	x^2	Mainly occurrence
Depth			*	Deep sites (9)
Substrate				
Current			*	Faster (2, 3)
Shadow				
Edge distance				
Vertical position	*	Bottom (4)	*	Bottom (4)
	Mimagoniates microlepis		*Characidium spp.*	
Categories	x^2	Mainly occurrence	x^2	Mainly occurrence
Depth			*	Deep sites (7, 8, 9)
Substrate	*	Litter (7); trunk and branches (8)		
Current			*	Faster (2, 3)
Shadow	*	Presence (1)	*	Ausence (2)
Edge distance	*	Left edge (2)	*	No occuped the left edge (2)
Vertical position	*	Upper (1)	n/p	Bottom (4)
	Pimelodella pappenheimi		*Corydoras barbatus*	
Categories	x^2	Mainly occurrence	x^2	Mainly occurrence
Depth	*	Moderate deep (5, 6, 7)	*	Moderate (5, 6) and deep (8, 9)
Substrate	*	Sand (1), gravel (2), litter (7)	*	Litter (7); trunk and branches (8)
Current	*	Slow (1)	*	Slow (1)
Shadow	*	Ausence (2)		
Edge distance			*	Right edge (0)
Vertical position	*	Bottom (3,4)	n/p	Bottom (4)
	Rineloricaria kronei		*Phalloceros caudimaculatus*	
Categories	x^2	Mainly occurrence	x^2	Mainly occurrence
Depth	*	Deep sites (7, 8, 9)	*	Shallow sites (3, 4)
Substrate	*	Occurred: sand (1))	*	Occurred: litter (7)
Current	*	Faster (2, 3)	*	Very Slow (0, 1)
Shadow	*	Ausence (2)	*	Presence (1)
Edge distance	*	Right edge (0)	*	Right edge (0)
Vertical position	n/p	Bottom (4)	*	Bottom (4)

"*" denotes distributions significantly different from expected (a = 0.01).
"n/p" denotes that it was not possible to use chi-square test.

pantherinus and *Synbranchus marmoratus* preferred places next to the riparian vegetation.

Hisonotus leucofrenatus, *Pseudotothyris obtusa* and *Schizolecis guntheri* had few records during the observations. Nevertheless, they occupied the bottom, in depths varying from 40.5 to 88.0 cm and preferred the edges of the stream.

Crenicichla sp. and *Oligosarcus hepsetus* were observed in deep microhabitats in the middle of the water column.

Homodiaetus sp. was collected in a small area of rapids of the stream.

Feeding Behavior: The foraging tactic of *Mimagoniates microlepis* was considered as "surface picker", picking up floating organisms in the surface. *Characidium* spp. were considered as "sit-and-wait predators", sedentary fishes that ambush prey. *Corydoras barbatus* and *Rineloricaria kronei* were considered as "grubers", excavating the substrate and the characteristic "shallow environment" can have distinct magnitude.

P. caudimaculatus preferred to occupy the shallow edges of the stream almost without current. These results confirm the description made by Teixeira (1989), Sabino & Castro (1990) and Aranha & Caramaschi (in prep.) about the distribution of this species in coastal streams in Rio Grande do Sul, São Paulo and Rio de Janeiro, respectively.

The microhabitats occupied by "lambaris", *Characidium* spp. and *Pimelodella pappenheimi* were similar to those indicated by Sabino & Castro (1990) respectively for *Deuterodon iguape*, *Characidium* sp. and *Rhamdella minuta*. These pairs of species belonging to the same subfamilies, and may execute similar functions as a reflex of the common evolutionary history of these groups.

Loricariidae and Callichthyidae studied fishes occupied mainly the bottom of the stream and the edge with vegetation. These results agree with those from Teixeira (1989) for some loricariids and for *Corydoras paleatus*, and with those from Aranha et al. (1993) for two others *Corydoras* species. Probably, this preferential microhabitat is characteristic in these groups.

The study of stomach contents indicated high frequency of algae in most of the species. Probably it is due to the availability of this resource in the "Mergulhão" stream.

The collected number of *Hoplias malabaricus* and *Oligosarcus hepsetus* was quite small and the stomach contents of these species were not studied. In the literature, these species have been appointed as piscivorous (*e.g.* Costa 1987, Teixeira 1989). We suppose that these species, together with *Synbranchus marmoratus*, constitute a piscivorous guild in the "Mergulhão" stream.

The comparative analysis of the trophic and habitat use guilds showed that the grouping of species was different, suggesting resource partitioning by the species.

D. langei and *Astyanax* sp. were generalist in the food preference (omnivorous/herbivorous guild) and in the habitat use too.

Herbivorous guild occupied the bottom and the edge of the stream, except *K. subteres* (which used a microhabitat similar to *Microglanis* sp.) and *Rineloricaria kronei* (which occupied the bottom in deep sites in unshaded areas).

P. caudimaculatus was a specialist in the habitat use and food. It constituted a spatial and a trophic guild by itself.

These results did not elucidate the theoretical question if stream fish assemblages are organized by deterministic processes such as competition. However, the fish assemblage of the "Mergulhão" stream does not have a random pattern of the habitat use, in opposition to the random organization whose some authors believe in (*e.g.* Matthews 1982).

We conclude that the differences in the spatial and trophic guilds in the "Mergulhão" stream make possible the segregation of these resources. If the competition is an important ecologic factor in this stream, the spatial and food partitioning should guarantee the coexistence of these species in the "Mergulhão" stream.

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