Hydrobiologia **445:** 217–227, 2001.
© 2001 Kluwer Academic Publishers. Printed in the Netherlands.

Short Communication

Spatial patterns in fish distributions and structure of the ichthyocenosis in the Água Nanci stream, upper Paraná River basin, Brazil

Sara da Silva Abes & Angelo Antonio Agostinho
UEM – NUPELIA Bloco H90, Avenida Colombo, 5790, 87020-900 – Maringá (PR), Brazil
E-mail: sara@nupelia.uem.br
E-mail: agostinhoaa@nupelia.uem.br

Received 1 December 1998; in revised form 22 August 2000; accepted 4 December 2000

Key words: stream, ichthyocenosis, habitat complexity, tropical system, Paraná River

Abstract

Samples of fishes were collected quarterly at three reaches in the Água Nanci stream, upper Paraná River basin, Brazil: near the spring, in the middle course, and near the mouth. Richness and evenness of the fish fauna increased between reaches towards the river mouth showing a correlation with stream width, pH and the presence of riparian vegetation. These variations in species richness and evenness, verified through Principal Component Analysis and Pearson correlation, suggest relations to habitat complexity, especially characterized by both the degree of preservation of dense riparian vegetation and high width at the lower reaches of the stream, providing a wide variety of hiding places for fish. Abundant species showed correlations with some environmental factors, suggesting habitat preferences.

Introduction

Features of physical and chemical habitats have been thoroughly recognized as decisive factors in the distribution of species, and the organization of communities in streams (Huet, 1959; Hynes, 1970; Vannote et al., 1980). Variations in fish community composition and distributions of fish species have been associated with spatial and temporal changes in channel morphology and availability of resources (Schlosser, 1982), discharge patterns (Horwitz, 1978; Taylor et al., 1996), stream size and canopy openness (Angermeier & Karr, 1983), current velocity and stream size (Meffe & Sheldon, 1988), stream size and alkalinity (Peterson & Gale, 1991), gradual change in habitat, such as substrate composition, water depth, amount and type of cover available to fishes (Angermeier & Karr, 1984; Pusey et al., 1993 and Pusey et al., 1995), stream thermal regime, ecoregion, stream size and gradient (Lyons, 1996), presence of a barrier (falls) and minor differences in habitat structure (Pusey et al., 1998).

Some authors have also recognized the importance of biotic interactions in the structuring of the ichthyofauna (Ross, 1986; Gilliam et al., 1993; Taylor, 1996), and others have suggested that stochastic events such as small-scale floods and droughts (substantial effects of environmental unpredictability) may largely determine stream fish assemblage composition (Grossman et al., 1982, 1985).

In temperate latitudes, large rivers have been relatively little studied in comparison to small streams and lakes, mainly due to sampling difficulties in fast-flowing and deep waters (Casselman et al., 1990). On the other hand, in tropical systems, the ichthyofaunas of small streams have not been receiving the same attention as those of large rivers, where commercial fisheries occur (Agostinho & Júlio Jr., 1999). The present study focuses on a tropical stream, evaluating spatial patterns in fish distributions and structure of the ichthyocenosis relative to physical and chemical characteristics of the stream.

Study area

The prevailing climate of the study area is hot-temperate pluvial with rainfall all the year round, although dry winters occur in some years. Mean annual temperature is 20.8°C. The highest mean monthly temperature is 23.9°C and the lowest mean monthly temperature is 17.2°C. Annual rainfall total is 1558.9 mm. The rainiest month is January with 220 mm and the driest month is July with 46.7 mm (Maack, 1968).

The hydrological level of the Paraná River in 1996 was not pronounced, presenting the lowest values for floods intensity and mean level of the Paraná River in the last 5 years (Veríssimo, 1999).

Água Nanci stream is a small permanent tributary of 2nd order (Strahler, 1952), with a length of 8.5 km and situated on the east margin of the upper Paraná River. Its watershed is 34 km^2 and is located at 22° 46′ 52″ S and 53° 18′ 56″ W. Three sampling reaches were established along the stream's length, covering the spring, middle course and an area close to the mouth (Fig. 1). Near the spring, the riparian vegetation is rare, having been converted to pasture. Infrequently, some trees such as *Cedrela fissilis* (Meliaceae) and *Peschiera australis* (Apocynaceae) can be found. The emergent aquatic plants, such as Poaceae, Pteridophyta, Asteraceae and Cyperaceae, are prominent. At the spring reach, the narrow stream flows through a steep-sided valley, where pool-riffle sequences are common.

In the middle course, the riparian vegetation is moderate, with a predominance of trees, such as *Cecropia pachystachya* (Cecropiaceae), *Peltophorum dubium* (Caesalpiniaceae) and *Lonchocarpus* sp. (Fabaceae). The banks are also dominated by pasture, and *Panicum maximum* (Poaceae) occupies part of the banktop. The most common emergent aquatic plants are *Echinodorus* sp. (Alismataceae), Pteridophyta and *Polygonum punctatum* (Polygonaceae).

At the river mouth, a dense strip of riparian vegetation occupies the banks, consisting largely of trees, such as *Cecropia pachystachya* (Cecropiaceae), *Croton urucurana* (Euphorbiaceae), *Zygia cauliflora* (Mimosaceae), *Triplaris americana* (Polygonaceae), *Hymenaea courbaril* (Lecythidaceae) and *Inga* sp. (Mimosaceae). The characteristic emergent aquatic plants in the reach are composed of Poaceae and Pteridophyta. The widest stretch of the stream (close to the mouth) has a low and relatively consistent gradient compared with those of the upper reaches of the stream (Table 1).

Materials and methods

Fish samples were collected four times from May 1996 to January 1997, with the use of electrofishing and the technique of successive removal (Zippin, 1958). Electrofishing was conducted using full-wave rectified current (1 KW generator, output 220 V, 3 – 4 A) operated through two anode dipnets (Penczak, 1981). At each reach, a minimum of three successive catches with constant unit of effort (CPUE) were conducted over a stretch of 50 m, blocked by a net. Fishes were identified, measured (total length and standard length), weighed, preserved in 10% formalin solution and conserved in 70% alcohol solution. Measures of the area (m^2) and depth (m) of reaches were taken, the latter based on measuring at intervals along five cross sections.

At each sampling reach temperature (°C), electrical conductivity (μS s^{-1}), dissolved oxygen (mg/l and % sat.), pH and current velocity (m/s) were measured. The canopy cover and emergent aquatic plants were visually estimated (in percentage terms) each 10 m section of the three sampling reaches. Rainfall and fluviometric level data (the latter for Paraná River) were obtained from the National Electric Energy and Water Department (1996). Types of substrates and hiding places for fish were quantified on a scale of 0 – 4, corresponding to absent, uncommon, common and very abundant, respectively (Pusey et al., 1998). Samples of sediment were taken in August 1996 to analyse the granulometric aspects and texture of the organic matter (Wentworth, 1922).

Evenness was derived from the Shannon–Wiener (H') index according to Pielou (1975). Inferences on richness were made on the basis of fish species number. The density and standing crop of fishes were calculated on the basis of three successive electrofishing removal runs at each sampling reach and the application of the Zippin (1958) method. The results were expressed as numbers of individuals or kilogrammes per hectare. Constancy was calculated as a percentage of the number of collections containing a given species relative to the total number of collections at each reach (Dajoz, 1983). The species were classed as constant (more than 50%), accessory (25% – 50%), and occasional (lower than 25%).

A Principal Component Analysis (PCA; Manly, 1995) was used to simplify and reduce the dimensionality of physical and chemical data comprising 11 variables obtained in four samplings at each reach. The scores for axes with an eigenvalue higher than 1

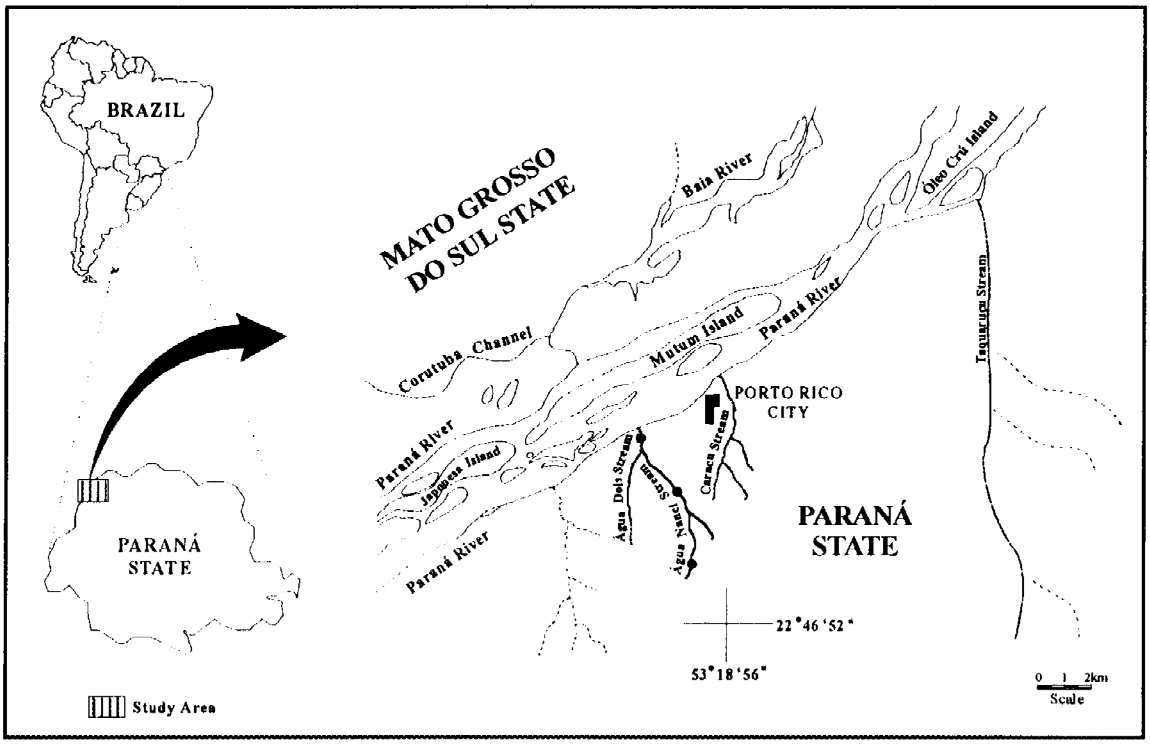

Figure 1. Location of the Água Nanci stream, showing the sampling reaches in the spring, middle course and mouth.

were correlated with the density and standing crop of the abundant species, as well as with species richness and evenness using the Pearson correlation coefficient (Sokal & Rohlf, 1981). All parameters were log-transformed before analysis, except pH. The objective was to determine whether aspects of the ichthyocenosis were related to the physical and chemical features of the stream.

Results

The physical and chemical features of the sampling reaches are presented in Table 1. The width of the bed and pH were more variable closer to the mouth than farther upstream. Values of water temperature, air temperature, current velocity and dissolved oxygen were higher in the rainy than in the dry season.

Canopy cover was most abundant near the mouth and the emergent aquatic plants exhibited the opposite pattern. Sand was the dominat substrate at the spring and mouth reaches, and gravel/sand was the predominant substrate at the middle course reach. Emergent aquatic plants and root masses predominated as fish hiding places at the spring reach, except in January, when leaf litter was more abundant. In the middle course, emergent aquatic plants and root masses dominated during the study period, but woody debris was very abundant in May and August, twigs in November and January, and holes in the stream bed in May. At the river mouth, woody debris, twigs and root masses were very abundant throughout the study period, as well as leaf litter in May, although it was common during the other sampling periods. Holes in the stream bed were very abundant in November at this reach.

In the Água Nanci stream, 1482 specimens of 35 fish taxa were captured. None of the 8 species captured in the spring (Table 2) were found exclusively at that reach, but six of them were found at all the sampling reaches (*A. bimaculatus*, *C. callichthys*, *G. carapo*, *H. derbyi*, *H. malabaricus* and *P. caudimaculatus*). On the other hand, of the 35 species collected in the whole stream, only five were not observed near the stream mouth. Among the total number of fish species sampled, 20% were classed as constant species, 31.4% as accessory species and 48.6% as occasional species. The average constancy of species appearing at a reach was highest in the middle course (75%) and lowest close to the mouth (30%).

Table 1. Physical and chemical features in the Água Nanci stream, upper Paraná River basin. Symbols: (-) absent, (+) uncommon, (++) common, (+++) very abundant, Al-Alismataceae, As-Asteraceae, Cy-Cyperaceae, Po-Poaceae, Pt-Pteridophyta, Pl-Polygonaceae, *-Paraná River

Reach		Spring				Middle Course				Mouth			
Gradient (%)		1.43				0.82				0.48			
		May	August	November	January	May	August	November	January	May	August	November	January
Width (m)	mean	1.39	1.95	1.12	1.30	1.81	2.02	2.08	2.70	5.43	3.86	4.19	3.64
	(±S.E.)	0.28	0.48	0.38	0.26	0.37	0.43	0.50	0.38	0.84	0.57	0.63	0.43
	max	1.70	2.95	1.90	1.70	2.20	2.73	2.80	3.40	6.80	4.60	4.87	4.00
	min	0.90	1.50	0.80	0.85	1.10	1.50	1.36	2.25	4.40	2.85	3.15	2.90
Depth (m)	mean	0.20	0.13	0.20	0.22	0.39	0.24	0.29	0.22	0.19	0.26	0.29	0.32
	(±S.E.)	0.10	0.07	0.08	0.10	0.14	0.12	0.11	0.09	0.10	0.12	0.12	0.16
	max	0.35	0.35	0.35	0.40	0.65	0.46	0.60	0.41	0.50	0.56	0.55	0.60
	min	0.03	0.02	0.10	0.03	0.05	0.07	0.10	0.01	0.02	0.06	0.10	0.07
Canopy cover	%	3	2	2	2	39	26	50	47	64	78	80	85
Emergent aquatic plant		Po-Pt	Po-Pt	Po-Pt	As-Cy-Po-Pt	Al-Po-Pt	Al-Po-Pt	Al-Po-Pt	Al-Po-Pt Pl	-	-	-	Po-Pt
	%	40	40	45	50	47	49	60	60	0	0	0	2
Hiding places	woody debris	++	++	++	++	+++	+++	+	+	+++	+++	++	+++
	leaf litter	+	+	+	+++	+	+	+	++	+++	++	++	++
	twigs	++	++	+	++	++	++	+++	+++	+++	+++	+++	+++
	root masses	+++	+++	+++	+++	+++	+++	+++	+++	+++	++	+++	+++
	emergent aquatic plants	+++	+++	+++	+++	+++	+++	+++	++	-	-	-	−+−
	pebbles	+	+	++	+	++	++	++	+	-	-	-	-
	holes in the stream bed	++	++	++	++	+++	++	++	+	++	++	+++	+
Temperature (°C)	air	18	19	23	25	23.5	10.5	24	28	23	8	21	25
	water	21	18	25	26	21.5	15.5	23	25.50	21	16	22	25
Current speed (m/s)		0.32	0.33	0.62	0.51	0.48	0.60	0.51	0.65	0.58	0.44	0.39	0.80
Dissolved oxygen	mg/l	8.10	8.41	11.69	9.46	8.69	9.28	9.28	8.30	8.45	9.28	11.09	8.39
	%sat.	85.50	100.10	148.30	123.10	101.50	102.10	116.70	104.30	102.50	96.90	134.40	107.40
pH		6.84	6.68	6.77	6.93	7.05	6.94	7.18	7.13	7.18	7.10	7.51	7.23
Conductivity (μS^{-1})		70	49	68	69	73	51	72	89	58	49	63	70
Rainfall (mm)	weekly	0	0	0	17.80	0	0	0	0.50	0	0.30	0	15.40
	monthly	90.70	35.80	164.30	213.50	90.70	35.80	164.30	213.50	90.70	35.80	164.30	213.50
Fluviometric level* (cm)	mean	303	267	288	520	303	267	288	520	303	267	288	520
	max	336	290	311	742	336	290	311	742	336	290	311	742
	min	279	211	264	290	279	211	264	290	279	211	264	290
Substrates	sand	+++	+++	+++	+++	++	+++	+++	+++	+++	+++	+++	+++
	rocks	+	++	++	+	+	+++	++	-	-	-	-	+
	mud	++	-	+	-	-	+	-	-	-	++	-	-
	pebbles	-	-	+	-	+++	++	++	-	-	-	-	-
Granulometric texture (%)	pebbles	-	0	-	-	-	45.48	-	-	-	0	-	-
	granules	-	0	-	-	-	6.36	-	-	-	0	-	-
	very coarse sand grain	-	0	-	-	-	5.99	-	-	-	0	-	-
	coarse sand grain	-	0.90	-	-	-	5.28	-	-	-	0.19	-	-
	medium sand grain	-	28.47	-	-	-	21.07	-	-	-	53.09	-	-
	fine sand grain	-	59.65	-	-	-	12.79	-	-	-	43.40	-	-
	very fine sand grain	-	10.22	-	-	-	2.49	-	-	-	3.11	-	-
	mud	-	0.76	-	-	-	0.54	-	-	-	0.21	-	-
Organic matter (%)		-	0.69	-	-	-	0.58	-	-	-	0.18	-	-

The seven most abundant species contributed 82.4% of the total density in the ichthyocenosis, those being *H. derbyi*, *A. bimaculatus*, *G. carapo*, *P. caudimaculatus*, *C. zebra*, *B. stramineus* and *P. gracilis*. The first four, although present at all reaches sampled, showed well differentiated density patterns. Thus, *H. derbyi* and *G. carapo* were more abundant in the spring and middle course, while *A. bimaculatus* was most abundant at the lower reaches and *P. caudimaculatus* at the spring reach. The last three abundant species were restricted to one or two segments of the stream.

Table 2. Fish Density (N.ha^{-1}), Standing Crop (Kg.ha^{-1}) and Constancy (%) in the three sampling reaches of the Água Nanci stream

Species	Density			Standing Crop			Constancy		
	Spring	Middle Course	Mouth	Spring	Middle Course	Mouth	Spring	Middle Course	Mouth
Characidae									
Apareiodon affinis		115.6	12.4		0.7	0.002		50	25
Aphyocharax nasutus			24.9			0.001			25
Astyanax bimaculatus	179.0	3375.3	1131.1	1.6	45.0	16.2	75	75	100
Astyanax fasciatus		138.7			1.2			50	
Bryconamericus stramineus		46.2	1317.6		0.1	1.1		25	75
Characidium aff *zebra*		1988.2	571.8		4.1	0.6		100	100
Cheirodon notomelas			24.9			0.02			25
Hyphessobrycon callistus			24.9			0.02			25
Hoplias malabaricus	35.8	46.2	24.9	0.6	1.6	0.04	25	25	25
Leporinus friderici		46.2	49.7		2.6	5.4		50	25
Leporinus obtusidens		23.1			0.9			25	
Moenkhausia sanctae-filomenae			111.9			0.1			50
Parodon tortuosus		92.5			0.3			25	
Callichthyidae									
Callichthys callichthys	35.8	184.9	12.4	0.06	2.6	0.1	25	75	25
Pimelodidae									
Cetopsorhamdia iheringi		971.0	323.2		2.1	0.1		100	50
Iheringichthys labrosus			136.7			0.1			25
Nannorhamdia schubarti	71.6	878.5		0.3	2.8		25	100	
Phenacorhamdia tenebrosa		161.8	149.2		0.3	0.3		75	25
Pimelodella gracilis			1143.5			8.4			75
Pimelodus maculatus			24.9			0.7			25
Rhamdia sp.		1456.5	12.4		21.6	0.2		100	25
Cichlidae									
Cichlasoma paranaense		23.1			0.9			25	
Crenicichla britskii		855.4	12.4		10.3	0.3		100	25
Loricariidae									
Farlowella sp.			87.0			0.2			50
Hypostomus aff *derbyi*	9557.9	7999.1	1814.8	17.4	30.6	6.8	100	100	100
Hypostomus sp.1		184.9	24.9		2.1	0.01		50	25
Hypostomus sp.2			24.9			0.1			25
Loricariichthys platymetopon			24.9			0.02			25
Gymnotidae									
Gymnotus carapo	2541.6	2057.6	708.5	35.7	32.8	9.4	100	100	100
Auchenipteridae									
Parauchenipterus galeatus			37.3			0.9			25
Tatia neivai			12.4			0.002			25
Poeciliidae									
Phalloceros caudimaculatus	5656.0	138.7	12.4	1.4	0.03	0.001	75	50	25
Potamotrygonidae									
Potamotrygon motoro			62.1			34.5			25
Potamotrygon sp.			12.4			33.1			25
Synbranchidae									
Synbranchus marmoratus	1360.3		24.9	13.8		0.8	100		25
Total	19438.0	20783.7	7955.1	70.9	162.9	119.6			

The largest contributions to the standing crop were *A. bimaculatus*, *G. carapo*, *P. motoro*, *Potamotrygon* sp., *H. derbyi* and *Rhamdia* sp.. *Rhamdia* sp. presented the largest standing crop in the middle course, while *P. motoro* and *Potamotrygon* sp. were exclusive to the mouth reach.

The first four principal components describing physical and chemical conditions were selected through PCA. However, only the first two (PCI and PCII) were significantly correlated with biotic variables and together they accounted for 67.7% of the total variability in abiotic data. The water temperature, electrical conductivity, current velocity, fluviometric level of the Paraná River and rainfall were positively correlated with PCI. PCII was negatively correlated with pH, the width of the bed and riparian vegetation cover, and positively related to emergent aquatic vegetation (Table 3a).

Richness and evenness were correlated negatively with PCII (Table 3b). Highest richness and evenness values were associated with low coverage of emergent aquatic plants, high pH, stream width and dense canopy vegetation (Fig. 2). Fish richness and evenness tended to increase towards the river mouth in all the sampling periods.

The density and standing crop of *A. bimaculatus* was positively correlated with PCI (Fig. 3), revealing that its highest abundance corresponded to warm temperatures, high conductivity, current velocity, rainfall and fluviometric level. In contrast, the density and standing crop of *H. derbyi* and *G. carapo* were correlated positively with PCII and, therefore, with the largest values of emergent aquatic vegetation, and with the smaller values of pH, width of the bed and covering of riparian vegetation. On the other hand, the density of *C. zebra*, *B. stramineus* and *P. gracilis*, and the standing crop of *P. gracilis* were negatively correlated with PCII, indicating opposed tendencies for those species and population parameters (Fig. 4).

Table 3. (a) Scores of the principal components analysis based on physical and chemical data with larger eigenvalues than 1.0. (b) Pearson correlations among those scores and the values, in logarithmic scale, of the richness, evenness, density and standing crop of the most abundant species in the Água Nanci stream, at the significance level $p < 0.05$. Symbols: *significant, **Paraná River (N=1482)

	PC I	PC II
(a) Variables/Components		
pH	0.450	−0.774
Dissolved Oxygen	0.015	−0.002
Water Temperature	0.909	0.278
Conductivity	0.842	0.332
Current Velocity	0.630	−0.172
Width	0.063	−0.936
Depth	0.364	−0.306
Emergent Aquatic Vegetation	0.105	0.874
Riparian Vegetation	0.270	−0.909
Fluviometric Level**	0.813	0.064
Rainfall	0.948	0.101
Eigenvalue	4.648	4.149
Explanation Percentage	35.756	31.914
(b) Pearson Correlation		
Log (Richness)	0.390	−0.580*
Log (Evenness)	0.150	−0.650*
Log (Density *H.* aff *derbyi*)	0.370	0.750*
Log (Standing Crop *H.* aff *derbyi*)	0.390	0.620*
Log (Density *A. bimaculatus*)	0.640*	−0.240
Log (Standing Crop *A. bimaculatus*)	0.590*	−0.310
Log (Density *G. carapo*)	0.180	0.620*
Log (Standing Crop *G. carapo*)	0.120	0.590*
Log (Density *P. caudimaculatus*)	0.080	0.530
Log (Standing Crop *P. caudimaculatus*)	−0.350	0.440
Log (Density *C.* aff *zebra*)	0.200	−0.620*
Log (Standing Crop *C.* aff *zebra*)	0.240	−0.080
Log (Density *B. stramineus*)	0.100	−0.700*
Log (Standing Crop *B. stramineus*)	0.160	−0.470
Log (Density *P. gracilis*)	−0.200	−0.820*
Log (Standing Crop *P. gracilis*)	−0.020	−0.690*

Discussion

The small rivers and streams in the upper Paraná River basin present a fish fauna composed of small-bodied fish, some of which are typical of this kind of environment, whereas others have wide distribution. However, juveniles of medium sized and large species that inhabit the floodplain can temporarily be present in the lowest reaches of streams, making use of river habitat and food resources during the high water season (Agostinho & Júlio Jr., 1999). Nevertheless, some species are common throughout the streams of the Paraná River basin: *A. bimaculatus*, *G. carapo*, *P. caudimaculatus*, *C. notomelas*, *Characidium* sp. and *Hypostomus* sp. (Uieda, 1984; Caramaschi, 1986; Garutti, 1988; Penczak et al., 1994; Pavanelli & Caramaschi, 1997; Castro & Casatti, 1997).

The species classed as constants totalled 20% of the ichthyocenosis, a value similar to that registered by Pavanelli & Caramaschi (1997) for the Caracu stream,

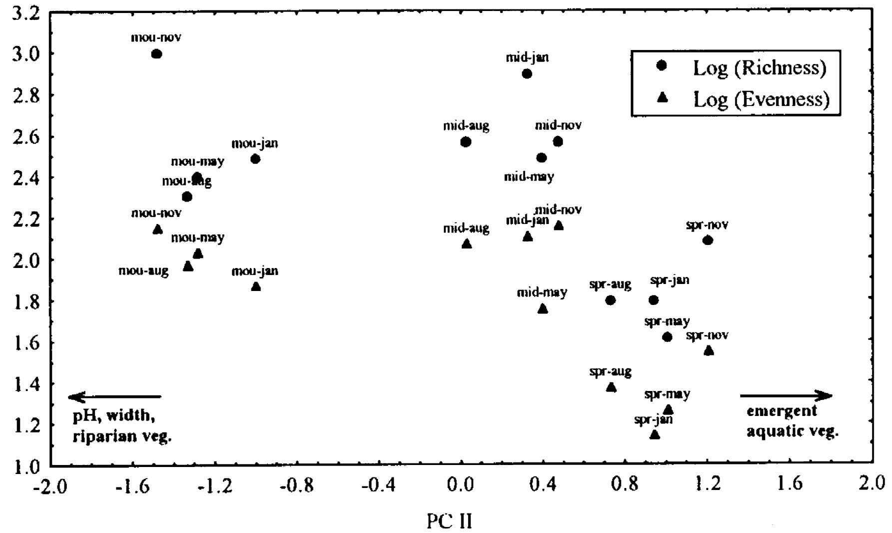

Figure 2. Correlations among the scores of the principal component II (PC II) and the logarithmic values of the richness and evenness. The arrows show the direction of the increase in the values of the standardized variables. Abbreviation: spr – spring, mid – middle course, mou – mouth, may – May, aug – August, nov – November, jan – January, veg – vegetation.

located near the Água Nanci stream and Caramaschi (1986) in streams of the Pardo River and Paranapanema River, São Paulo State. That proportion has varied from 10.6% (Caramaschi, op. cit.) to 52% (Garutti, 1988) in the streams of the Paraná River basin.

Richness and evenness of the fauna increased towards the mouth of the Água Nanci stream, in agreement with results of other works in tropical and temperate streams (Sheldon, 1968; Horwitz, 1978; Schlosser, 1982; Garutti, 1988; Reyes-Gavilán et al., 1996).

The Principal Component Analysis and the Pearson correlation suggested variations in species richness and evenness related to habitat complexity, especially characterized by both the degree of preservation of dense riparian vegetation and the highest values of the width at the lowest reaches of stream, providing a wide variety of hiding places to fish, such as woody debris, twigs and root masses (Table 1). Similar relationships between habitat structure and fish assemblage structure have been reported by Schlosser (1982), Angermeier & Karr (1983), Angermeier & Karr (1984), Pusey et al. (1993), Pusey et al. (1995) and Pusey et al. (1998).

Woody debris plays a multidimensional role in the structure and function of stream ecosystems (Angermeier & Karr, 1984). Cover available to fish was significantly correlated with the mean species richness of each site located in the Mary River drainage system of south-east Queensland, Australia (Pusey et al., 1993). A gradual downstream change in fish assemblage structure, correlated with gradual changes in habitat, substrate and type of in-stream cover was observed by Pusey et al. (1995) in the Mulgrave River of northern Queensland, Australia. Schlosser (1982) suggested that species additions from upstream to downstream areas were associated with changes in habitat complexity, when the habitats become deeper. Similar statements are made by Reyes-Gavilán et al. (1996), Angermeier & Karr (1983) and Peterson & Gale (1991). Taylor (1996) suggests that the species number per unit area tends to be reduced in smaller streams, with population density exhibiting the opposite pattern.

Complexity of habitat structure is considered an important predictor of species richness (Pusey et al., 1995). However, in the present study, the abundance of emergent aquatic vegetation, a component that increases habitat complexity, correlated negatively with richness. Other aspects of complexity, especially the stream width and riparian vegetation covering (providing a wide variety of hiding places for fish), were more important at the river mouth where emergent aquatic vegetation was not present. On the other hand, at near the spring, where emergent aquatic vegetation is abundant, the upper reach is subjected to large seasonal fluctuations because it has a smaller width and dense canopy vegetation has been removed, supporting fewer species.

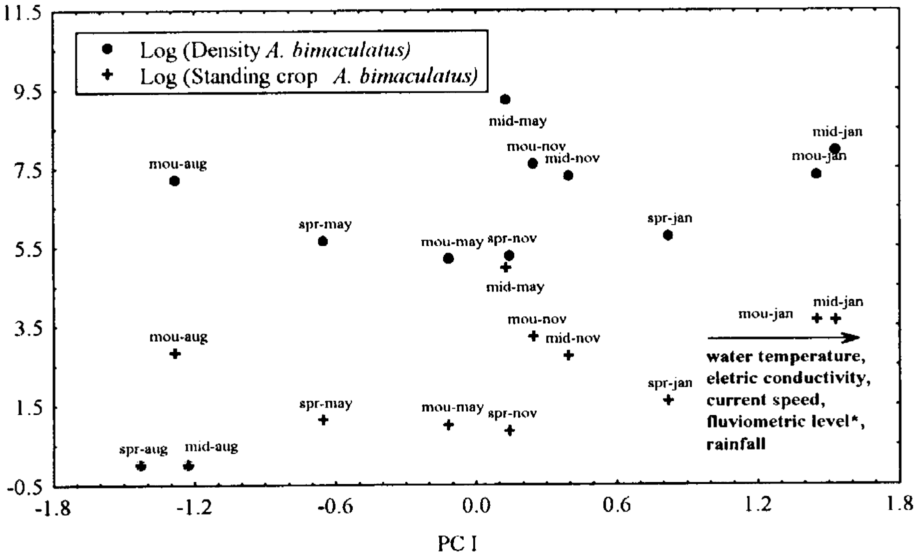

Figure 3. Correlations among the scores of the principal component I (PC I) and the logarithmic values of the density and standing crop of the *A. bimaculatus*. The arrow shows the direction of the increase in the values of the standardized variables. Abbreviation: spr – spring, mid – middle course, mou – mouth, may – May, aug – August, nov – November, jan – January, veg – vegetation. Symbols: *Paraná River.

The degree of preservation of riparian vegetation and the increasing pH in the direction of the river mouth correlated positively with species richness. Similar results, despite an inverse gradient in the distribution of emergent aquatic vegetation, were described by Penczak et al. (1994).

Clearly, the range of variations in fish distributions in streams cannot be attributed to a specific environmental factor (Horwitz, 1978). In the Água Nanci stream, another factor to consider is the influence of the Paraná River on its lower stretch and the role of a small tributary in contributing species. In general terms, it is believed that variations in species composition along the course of a river are more related to abiotic factors in upstream areas, and to biotic interactions in downstream areas (Reyes-Gavilán et al., 1996).

Most of the abundant species showed specific relationships with physical and chemical variables, following general patterns in richness and evenness, or maintaining other inherent demands for the best conditions, which demonstrates habitat preferences. *H. derbyi* and *G. carapo* were more abundant in the upstream reach and middle course, where the largest proportions of emergent aquatic vegetation were present, and lower values of pH, width and riparian vegetation covering were recorded. In the Caracu and Água do Rancho streams, Agostinho & Penczak (1995) found positive correlations between fish production and maximum depths and an abundance of hiding places, where *G. carapo* presented the third largest contribution. *Hypostomus* sp. feeds actively on algae attached to rocks (Power et al., 1989), but its occurrence in aquatic macrophyte banks or emergent aquatic vegetation has also been registered (Silva, 1995). *G. carapo* has been observed in backwaters, associated with the marginal aquatic vegetation (Soares, 1979; Uieda, 1984; Machado-Allison, 1990; Silva, 1995).

C. zebra, *B. stramineus* and *P. gracilis* had a clear preference for the middle course and river mouth, characterized by lower proportions of emergent aquatic vegetation, larger width, preserved riparian vegetation and slightly alkaline pH. Penczak et al. (1994) recorded similar preferences for *B. stramineus* and two species of Pimelodidae, but different ones for *Characidium fasciatus*, such as highly alkaline pH and abundance of macrophytes. *A. bimaculatus* is a species with a wide distribution in the Paraná River basin. In the Água Nanci stream, *A. bimaculatus* was classed as constant at all the sites, being more abundant in the lowest segments, especially in the summer and during floods. Garutti (1988) recorded an immediate repopulation for *A. bimaculatus*, *Cheirodon piaba* and *Pyrrhulina australis* in the upper segment of the Barra Funda stream after intense rains. In the Água Nanci stream, the combined effect of the increase of the discharge, integration of the new individuals from the Paraná River, and subsequent dis-

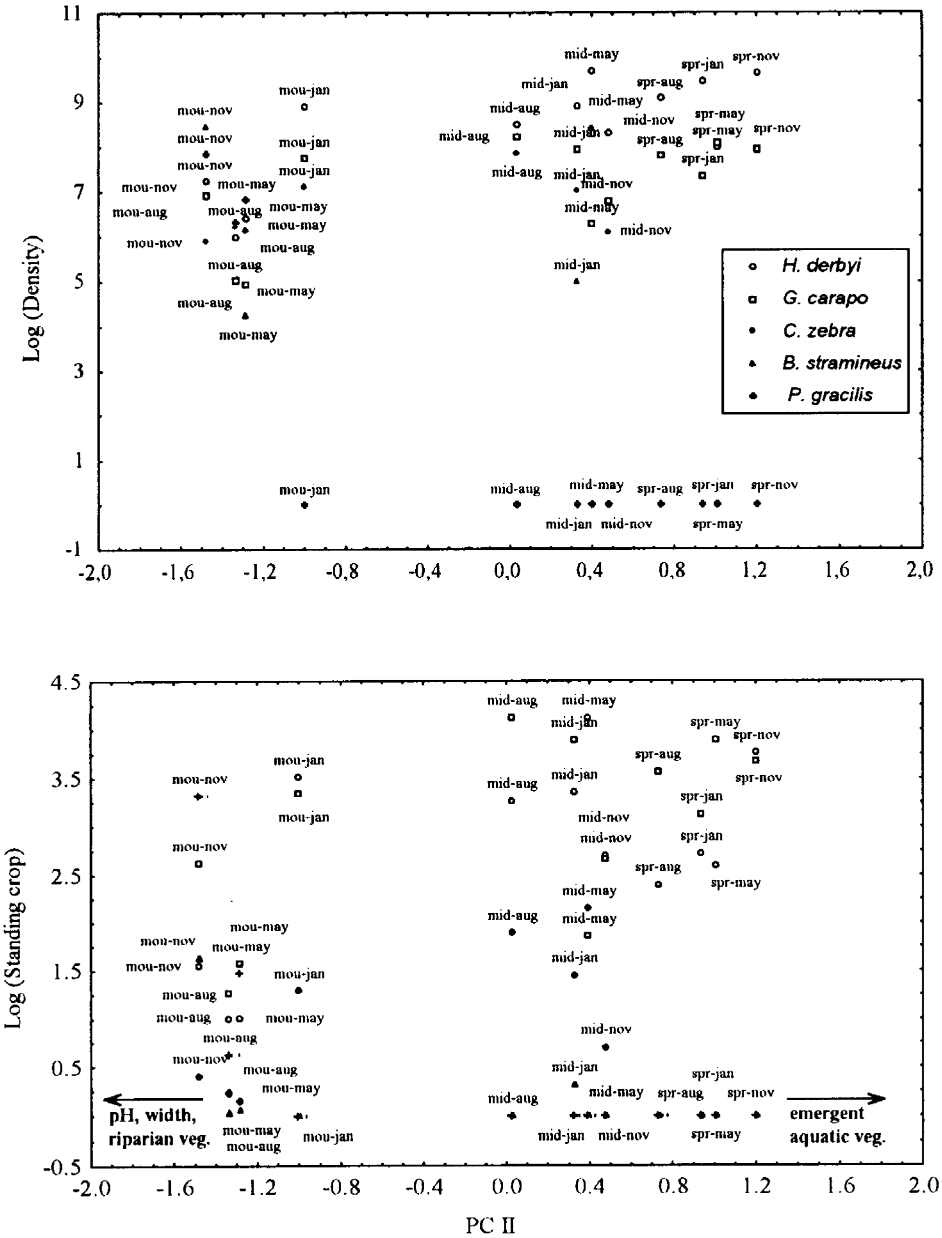

Figure 4. Correlations among the scores of the principal component II (PCII) and the logarithmic values of the density and standing crop of the *Hypostomus* aff *derbyi*, *Gymnotus carapo*, *Characidium* aff *zebra*, *Bryconamericus stramineus* e *Pimelodella gracilis*. The arrow shows the direction of the increase in the values of the standardized variables. Abbreviation: spr – spring, mid – middle course, mou – mouth, may – May, aug – August, nov – November, jan – January, veg – vegetation.

persion to the middle course of the stream may explain the high abundance of *A. bimaculatus* under the above conditions. Penczak et al. (1994) also reported that *P. caudimaculatus*, with its wide distribution in the Água Nanci stream, displays a notable preference for the upper reach. The fact that this segment is deforested, which favours the proliferation of filamentous algae, may have accentuated that preference, as already reported by Sabino & Castro (1990) for a stream in the Atlantic coastal forest, where the filamentous algae were very frequent in the diet of *P. caudimaculatus*.

In conclusion, richness and evenness of fish species in the Água Nanci stream increased progressively downstream in the three reaches, suggesting relations to habitat complexity, especially in providing a wide variety of hiding places for fish. The density and standing crop of the most abundant species showed specific correlations with some environmental variables, demonstrating habitat preferences.

Acknowledgements

This paper is a part of a Masters dissertation produced by Sara da Silva Abes at State University of Maringá, Paraná State, Brazil, conducted under the supervision of Dr Angelo Antonio Agostinho. Dr Luiz Carlos Gomes, Biologist João Dirço, Dr Carla S. Pavanelli, Dr Heraldo A. Britski, MSc. Cláudio H. Zawadzki, Dr Samuel Veríssimo, Dr Harumi I. Suzuki, MSc. Edson K. Okada, MSc. Angela M. Ambrósio and MSc Luiz M. Bini provided valuable contributions to this study. Thanks also to the Professors, Biologists, Technicians and Fishermen of NUPELIA group at State University of Maringá for their support, as well as Dr Nicholas C. Collins, MSc. Ariadne Angulo, Tanya Trivedi and Asha Gupta from the University of Toronto at Mississauga for their revision of the manuscript.

References

Agostinho, A. A. & H. F. Júlio Jr., 1999. Peixes da bacia do alto rio Paraná. In Lowe-McConnell, R. H. (ed.), Ecologia de Comunidades de Peixes Tropicais. A. E. A. M. Vazzoler and A. A. Agostinho & P. T. M. Cunninghan. EDUSP, São Paulo: 374–400.

Agostinho, A. A. & T. Penczak, 1995. Populations and production of fish in two small tributaries of the Paraná River, Paraná, Brazil. Hydrobiologia 312: 153–166.

Angermeier, P. L. & J. R. Karr, 1983. Fish communities along environmental gradients in a system of tropical streams. Envir. Biol. Fishes 9(2): 117–135.

Angermeier, P. L. & J. R. Karr, 1984. Relationships between woody debris and fish habitat in a small warmwater stream. Trans. Am. Fish. Soc. 113: 716–726.

Caramaschi, E. P., 1986. Distribuição da ictiofauna de riachos das bacias do Tietê e do Paranapanema, junto ao divisor de águas (Botucatu, SP). UFSCAR, São Carlos. Tese (Doutorado) – Departamento de Ciências Biológicas, Universidade Federal de São Carlos: 245 pp.

Casselman, J. M., T. Penczak, L. Carl, R. H. K. Mann, J. Holcik & W. A. Woitowich, 1990. An evaluation of fish sampling methodologies for large river systems. Pol. Arch. Hydrobiol. 37(4): 521–551.

Castro, R. M. C. & L. Casatti, 1997. The fish fauna from a small forest stream of the upper Paraná River basin, southeastern Brazil. Ichthyol. Explor. Freshwaters 7(4): 337–352.

Dajoz, R., 1983. Ecologia Geral. Vozes, Petrópolis: 471 pp.

Garutti, V., 1988. Distribuição longitudinal da ictiofauna em um córrego da região noroeste do estado de São Paulo, bacia do rio Paraná. Rev. Brasil. Biol. 48(4): 747–759.

Gilliam, J. F., D. F. Fraser & M. Alkins-Koo, 1993. Structure of a tropical stream fish community: a role for biotic interactions. Ecology 74(6): 1856–1870.

Grossman, G. D., P. B. Moyle & J. O. Whitaker Jr.,1982. Stochasticity in structural and functional characteristics of an Indiana stream fish assemblage: a test of community theory. Am. Nat., 120(4): 423–454.

Grossman, G. D., M. C. Freeman, P. B. Moyle & J. O. Whitaker Jr., 1985. Stochasticity and assemblage organization in an Indiana stream fish assemblage. Am. Nat. 126: 275–285.

Horwitz, R. J., 1978. Temporal variability patterns and the distributional patterns of stream fishes. Ecol. Monogr. 48: 307–321.

Huet, M., 1959. Profiles and biology of western European streams as related to fish management. Trans. Am. Fish. Soc. 88(3): 155–163.

Hynes, H. B. N., 1970. The Ecology of Running Waters. Liverpool University Press, Liverpool: 555 pp.

Lyons, J., 1996. Patterns in the species composition of fish assemblages among Wisconsin streams. Envir. Biol. Fishes 45: 329–341.

Maack, R., 1968. Geografia Física do Estado do Paraná. Max Roesner Ltda, Curitiba: 350 pp.

Machado-Allison, A., 1990. Ecologia de los peces de las areas inundables de los llanos de Venezuela. Interciencia 15(6): 411–423.

Manly, B. F. J., 1995. Multivariate Statistical Methods. 2. Chapman & Hall, London: 215 pp.

Meffe, G. K. & A. L. Sheldon, 1988. The influence of habitat structure on fish assemblage composition in southeastern blackwater streams. Am. Midl. Nat. 120(2): 225–240.

Pavanelli, C. S. & E. P. Caramaschi, 1997. Composition of the ichthyofauna of two small tributaries of the Paraná River, Porto Rico, Paraná State, Brazil. Ichthyol. Explor. Freshwat. 8(1): 23–31.

Penczak, T., 1981. Ecological fish production in two small lowland rivers in Poland. Oecologia 48: 107–111.

Penczak, T., A. A. Agostinho & E. K. Okada, 1994. Fish diversity and community structure in two small tributaries of the Paraná River, Paraná State, Brazil. Hydrobiologia 294: 243–251.

Peterson, R. H. & D. Gale, 1991. Fish species associations in riffle habitat of streams of varying size and acidity in New Brunswick and Nova Scotia. J. Fish Biol. 38: 859–871.

Pielou, E. C., 1975. Ecological Diversity. John Wiley & Sons, New York: 165 pp.

Power, M. E., T. L. Dudley & S. D. Cooper, 1989. Grazing catfish, fishing birds, and attached algae in a Panamanian stream. Envir. Biol. Fishes 26: 285–294.

Pusey, B. J., A. H. Arthington & M. G. Read, 1993. Spatial and temporal variation in fish assemblage structure in the Mary River, south-eastern Queensland: the influence of habitat structure. Envir. Biol. Fishes 37: 355–380.

Pusey, B. J., A. H. Arthington & M. G. Read, 1995. Species richness and spatial variation in fish assemblage structure in two rivers of the wet tropics of northern Queensland, Australia. Envir. Biol. Fishes 42: 181–199.

Pusey, B. J., A. H. Arthington & M. G. Read, 1998. Freshwater fishes of the Burdekin River, Australia: biogeography, history and spatial variation in the community structure. Envir. Biol. Fishes 53: 303–318.

Reyes-Gavilán, F. G., R. Garrido, A. G. Nicieza, M. M. Toledo & F. Braña, 1996. Fish community variation along physical gradients in short streams of northern Spain and the disruptive effect of dams. Hydrobiologia 321: 155–163.

Ross, S. T., 1986. Resource partitioning in fish assemblages: a review of field studies. Copeia (2): 352–388.

Sabino, J. & R. M. C. Castro, 1990. Alimentação, período de atividade e distribuição espacial dos peixes de um riacho da floresta Atlântica (sudeste do Brasil). Rev. Brasil. Biol. 50(1): 23–36.

Schlosser, I. J., 1982. Fish community structure and function along two habitat gradients in a headwater stream. Ecol. Monogr. 52(4): 395–414.

Sheldon, A. L., 1968. Species diversity and longitudinal succession in stream fishes. Ecology 49(2): 193–198.

Silva, C. P. D., 1995. Community structure of fish in urban and natural streams in the central Amazon. Amazoniana 13(3/4): 221–236.

Soares, M. G. M., 1979. Aspectos ecológicos (alimentação e reprodução) dos peixes do igarapé do Porto, Aripuanã, MT. Acta Amazonica 9(2): 325–352.

Sokal, R. R. & F. J. Rohlf, 1981. Biometry. 2. W. H. Freeman and Company, New York: 859 pp.

Strahler, A. N., 1952. Hypsometric (area-altitude) analysis of erosional topography. Bull. Geol. Soc. Am. 63: 1117–1142.

Taylor, C. M., 1996. Abundance and distribution within a guild of benthic stream fishes: local processes and regional patterns. Freshwat. Biol. 36: 385–396.

Taylor, C. M., M. R.Winston & W. J. Matthews, 1996. Temporal variation in tributary and mainstem fish assemblages in a great plains stream system. Copeia (2): 280–289.

Uieda, V. S., 1984. Ocorrência e distribuição dos peixes em um riacho de água doce. Rev. Brasil. Biol. 44(2): 203–213.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell & C. E. Cushing, 1980. The river continuum concept. Can. J. Fish. aquat. Sci. 37: 130–137.

Veríssimo, S., 1999. Influência do regime hidrológico sobre a ictiocenose de três lagoas da planície aluvial do alto rio Paraná. UFSCAR, São Carlos. Tese (Doutorado) – Departamento de Ciências Biológicas, Universidade Federal de São Carlos: 90 pp.

Wentworth, C. K., 1922. A scale of grade and class terms for clastic sediments. J. Geol. 30: 377–392.

Zippin, C., 1958. The removal method of population estimation. J. Wildl. Manag. 22: 82–90.