

Fish diversity and community structure in two small tributaries of the Paraná River, Paraná State, Brazil

T. Penczak*, A. A. Agostinho & E. K. Okada

NUPELIA, Universidade Estadual de Maringá, Av. Colombo, 3890, Campus Universitario, CEP 87020-900, Maringá, PR, Brazil;

** Department of Ecology and Vertebrate Zoology, University of Łódź, 90-237 Łódź, Banacha 12/16, Poland*

Received 12 October 1993; in revised form 18 January 1994; accepted 21 January 1994

Key words: Brasil, small rivers, fish populations, diversity, coenological analysis, community

Abstract

In eleven sites on two small tributaries of the Paraná River (North-West Paraná State), 6.8 and 4.0 km in length, 1263 fish specimens of 28 taxons and 14 families were collected using electrofishing. Up to twelve years ago the catchments of the two rivers were covered by tropical jungle; this has now been replaced by pasture and arable fields. Mean diversity indices of Simpson and Shannon indices were close to 0.6, which would indicate that human impact affected fish populations although the river beds have retained their original shape, except cleared of riparian trees. Despite their close location (about 18 km), the two streams differed from each other in their fish faunal composition. The distinctive nature of the fish communities in the two streams was a result of: conductivity, pH, also hiding places, riparian vegetation, submerged macrophytes and depth and width of the rivers.

Introduction

In the laboratory, when sampled fish were identified and information on the biology of captured taxons collected, it became evident that the Neotropical fish fauna is still little known (Lowe-McConnell, 1987). Many species lack any data on growth, maturity, habitat preferences as well as separate names in the language of native inhabitants. The fish faunas of those small streams that are unexploited have not been studied as much as those of larger rivers where there are commercial fisheries (Agostinho & Julio, in print). Hence, the aim of this study is to provide some data on their fish diversity and community structure. At present the Paraná River catchment possesses a dense network of populated settlements, developed industry and agriculture and is 'the most intensively exploited region in the country' (Agostinho & Julio, in print). Hence, the attempt here was to investigate its fish fauna in riverbed conditions that are still similar to those of natural habitats.

Study area and methods

Study area

The study area comprised two small, left side tributaries of the Paraná River in the north-western corner of the Paraná State. The Caracu River, 6.8 km long, empties to the Paraná, and the Agua do Rancho River, 4 km long, empties to the Areia Branca River at 7.8 km from its mouth to the Paraná river (Fig. 1).

With the exception of one tributary, all those from the left margin of the Paraná River are very short in the north-west Paraná State, and their drainage basins are totally located over the eolic cretaceous sandstone from the Caiu Formation, in the deepest valleys and canyons, and over a sheet of alluvial sand on the plateaux. Structurally, the area is a high block that slopes gently to the Paraná River, and the rivers from the left margin are controlled by small fractures (Stevaux, 1991).

Six sites, along a river's course, were selected on the Caracu River, and five on the Agua do Rancho River (Fig. 1). The distance between sites was sometimes dependent on the possibility of access to the riv-

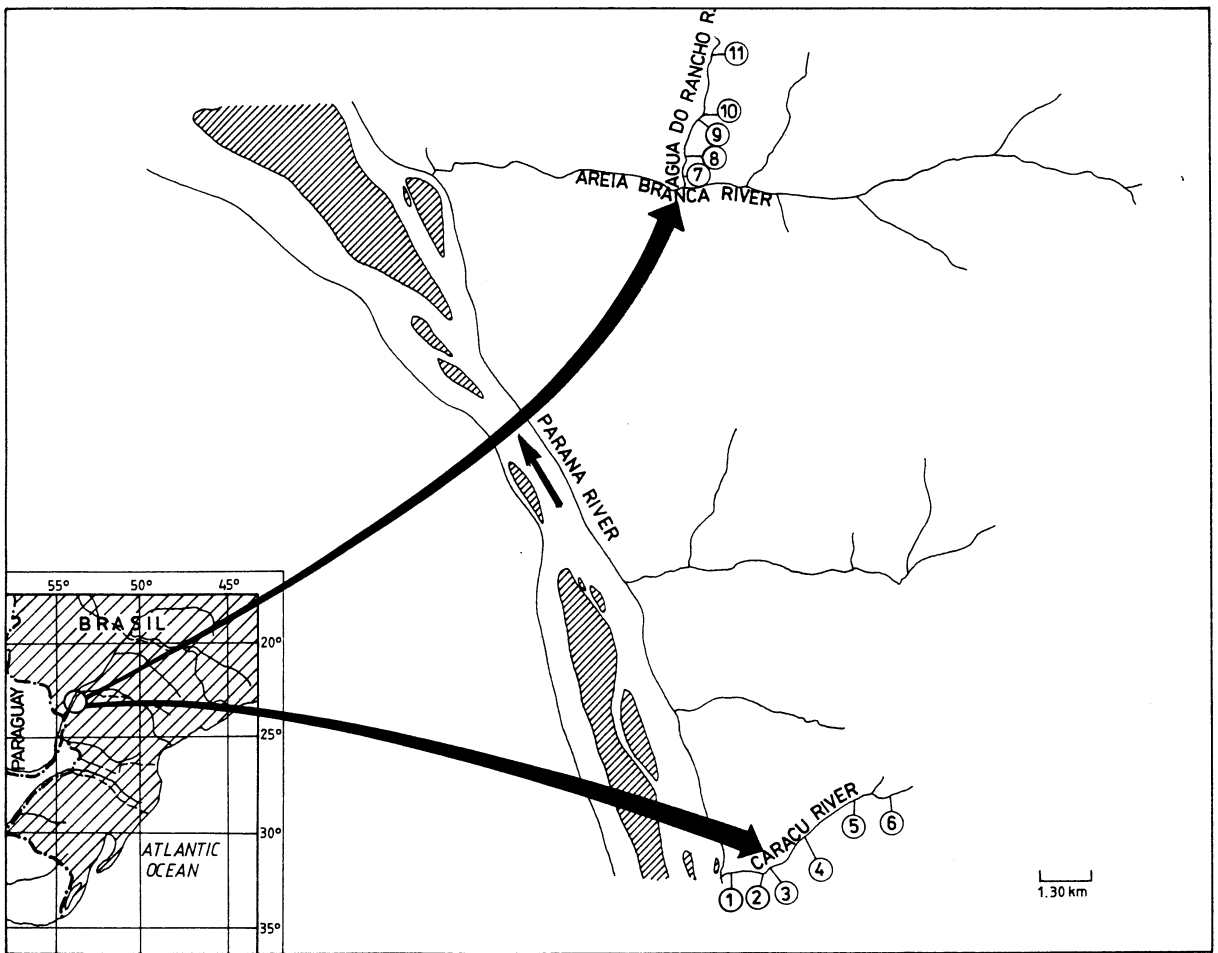


Fig. 1. Map of the study area with sites indicated.

er bank (lack of road, remnants of jungle). Site length (60 ± 15 m (mean \pm S.D.)) was river width dependent.

The sites' morphology was described on the basis of bathymetric maps developed at each site (Penczak *et al.*, 1985). Width of a river bed and average water depth were measured for every 10 m of river site. At each such cross-section, covered by submerged macrophytes, hiding places (as %) and their types, trees along banks (%) and adjacent areas were recorded for mean characteristics which are employed in the final diagram or in the text. Also velocity, measured at three points on a site, conductivity and pH were measured.

Sampling procedure

Fish were caught while wading upstream, using a full-wave rectified pulsed DC electroshocker (1.5 kW, 220 V, 4 A) operated through two anode dipnets

(Penczak *et al.*, 1981). At each site a minimum of three successive catches per constant unit of effort (CPUE) were conducted to estimate total populations of each species and the site downstream was tightly blocked by a net (Penczak, 1985). Stunned fish were anaesthetised and all fixed in 4% formalin, because identification in field conditions was rarely possible. In the laboratory, fish from each site separately were identified, counted and weighed. Total catch numbers, both by electroshocker and net, were used for creating the initial table, which was used for diversity and community study.

Diversity

Species diversity was assessed using the Simpson index (D) and the Shannon index (H):

$$D = \sum (p_i)^2 \text{ and } H = - \sum p_i \ln p_i,$$

where p_i is the proportion of individuals in a community, which are members of the i th species. For comparison, both indices were rescaled from 0 to 1, where 0 is the lowest possible diversity and 1 is the highest diversity (Odum, 1980).

Coenological analysis

Number data rather than biomass data were used to study fish community relationships, even when both were available, because species do not differ much in size in these two streamlets.

Similarity between sites (columns) and species (rows) was calculated using the Marczewski and Steinhaus (1958) equation:

$$s = \frac{w}{a + b - w} 100,$$

where s is similarity of two collections (two sites or two species), w is the total of the lower numbers of specimens of each pair of species common for two given analysed sites ('columns') (or the total of the lower numbers of sites of each pair of two given analysed species occurring in them ('rows')), a is the total number of specimens of a species at the site (or the total number of sites with species) A, and b is the total number of specimens of a species in site (or the total number of sites with species) B.

Similarity calculated for sites ('columns') is included as an example (Table 1), which is then used for constructing a branched, two-dimensional dendrite of sites, which, on the same figure, is then transformed into a linear dendrite (Fig. 2). To construct the initial, two-dimensional dendrite, only the highest values of similarity (bold numbers) from Table 1 are used for connecting sites (Fig. 2). To change it into a linear dendrite, the weakest connections must be 'broken' to insert between the sites connected by weaker connections others with higher similarities to them; arrows show how to do it. Quotients calculated between the decreasing similarities of neighbouring sites (Fig. 2), except the border ones, differ slightly and if in between their series there happen to occur a quotient differing from the neighbouring ones (1.41) then its dividend (37.5) constitutes the lower bound of a similarity for defining clusters. All clusters below that value of similarity are considered separately.

The linear dendrite of species was constructed in the same way and both linear dendrites, that of sites and that of species, were used to derive a synthetic diagram which in Polish literature is named 'Roman-

iszyn's diagram' to distinguish its author (Romaniszyn, 1970).

Species represented by one specimen at one site only were omitted from investigations of similarity as well as from the procedure of preparing the synthetic diagram.

The whole procedure of how to construct the synthetic diagram, starting from the initial table is exemplified step by step by Romaniszyn (1970) on the basis of data on *Tendipodidae* (Diptera) sampled by Brundin (1949). The method was employed in fishery papers by Penczak (1972), Balon & Stewart (1983), Witkowski (1984), Zalewski *et al.* (1990), Penczak *et al.* (1991) and Przybylski *et al.* (1991). In the above papers a way of constructing the dendrites and Romaniszyn's diagram is showed in an abbreviated form.

Results

In 11 sites of the above mentioned two small streams 1263 fish specimens of 28 species ascribed to 14 families, including two probably new for science were identified (Fig. 2); the taxons of *Phenacorhamdia sp* and *Microlepidogaster sp* are a subject of separate taxonomic study. Most of the species were small body sized and non-migratory, while of the migratory ones mostly young individuals were captured. Information on the biology of the recorded species proved scarce (Table 2) while for several of them only the description of their taxonomic characters was obtained.

Catches at each site are collected in Table 3. The data were used to estimate diversity, using purposefully two indices, because the Simpson index is weighed in favour of dominant species, while the Shannon index of rare species (Table 4).

The linear dendrite of sites and linear dendrite of species were used to order the initial table (Table 3). The numerical values in the ordered table were substituted with their square roots, which were then employed to draw the sides of rectangles whose lengths equalled the square root values of the Romaniszyn synthetic diagram (Fig. 3), which is a reliable representation of the ordered table.

The dendrite of the investigated sites has fallen into two clusters of sites (X – 3 sites, and Y – 4 sites, Fig. 2 and 3), and 4 separate sites. The dendrite of species, which due to its dimensions is not presented in this study, has fallen into two clusters of 3 species each (A and B, Fig. 3) and 14 species not displaying pro-

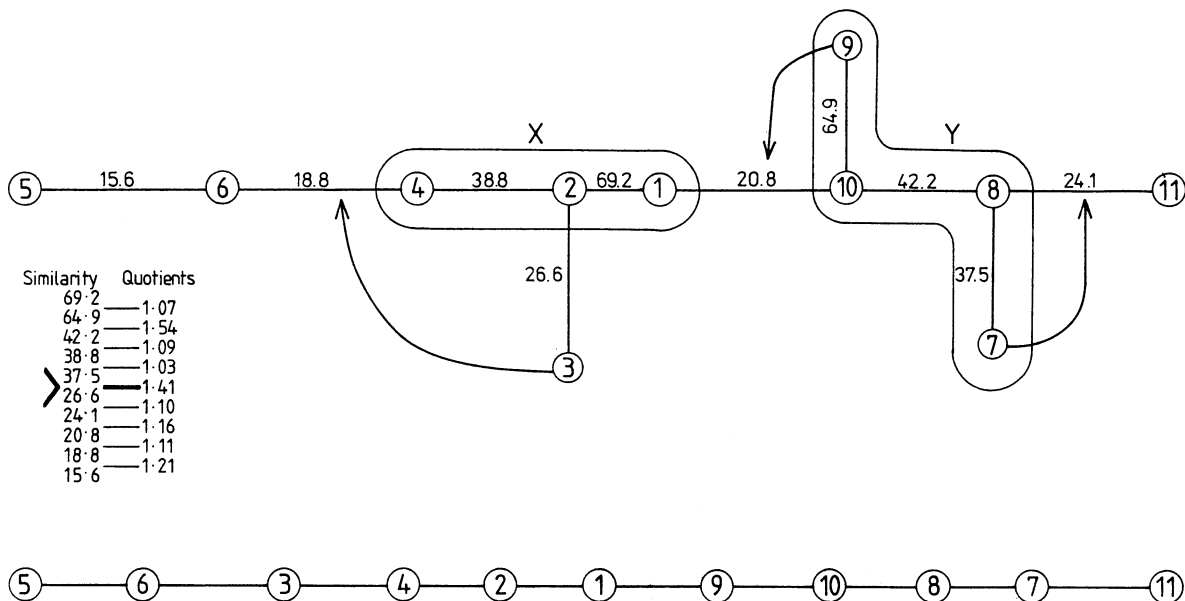


Fig. 2. The two-dimensional dendrite of sites, with distinguished two groups of sites (X, Y) on the basis of a quotient of 1.41. Below it the linear dendrite (see text for explanations) is presented.

Table 1. Similarity of sites in terms of fish species abundance. Bold numbers signify the highest similarities chosen for fractional dendrites' connections.

Site	Site	1	2	3	4	5	6	7	8	9	10	11
1	100.00	69.23	23.90	33.33	11.59	7.92	10.22	15.94	17.86	20.81	6.09	
2		100.00	26.62	38.82	13.64	8.08	9.58	15.14	16.67	19.46	6.15	
3			100.00	20.39	5.26	5.52	7.09	8.59	10.13	11.98	3.03	
4				100.00	14.55	18.75	4.42	11.24	6.36	8.50	10.80	
5					100.00	15.56	1.41	2.18	2.92	3.36	2.70	
6						100.00	2.24	16.16	3.59	5.44	17.95	
7							100.00	37.53	27.81	33.45	5.00	
8								100.00	38.13	42.19	24.07	
9									100.00	64.86	9.20	
10										100.00	11.84	
11											100.00	

nounced coenological connections, *i.e.* not regularly cooccurring with one another.

Having marked the above mentioned clusters of sites and species on Fig. 3, we can see that it enriches our knowledge on the biology of these relatively poorly investigated species, and particularly on their mutual occurrence and habitat preferences.

Three species of cluster A, with one exception (site 8, *Phenacorhamdia sp*) occur in similar abundance to one another. They occurred together in the

sites of cluster Y, which is characterized by the lowest pH and lowest conductivity, with no exceptions. Furthermore they are characterized by, with one recorded exception, the highest river width, low depth, lack of macrophytes, rich canopy and a low number of hiding places (Fig. 3).

Another, also a three-species, cluster B, inhabits, with one exception (site 3), site cluster X, which is characterized by the highest pH, high water conductivity, abundance of hiding places, hardly any bank

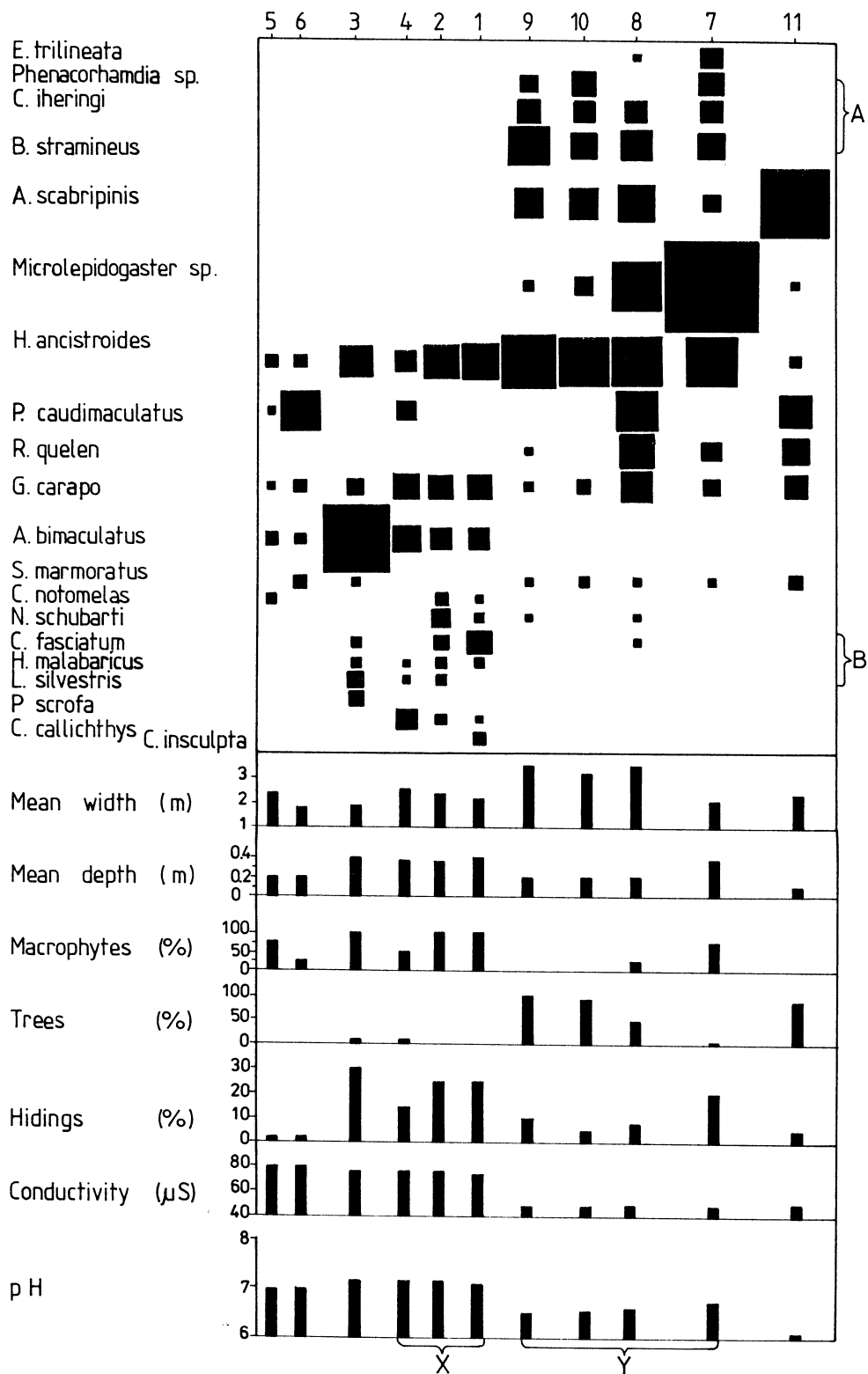


Fig. 3. Synthetic diagram showing quantitative species distribution in relation to sites (1-11). Basic habitat percentages are shown for each site. A and B are species groups; X and Y are site groups - distinguished on the basis of dendrites.

Table 2. Names, taxonomic position and biology of fish collected in two small tributaries of the Parana River. L_s - standard body length.

Family	Scientific name	Common name	First maturation (L_s in cm)	Migration
Characidae	<i>Astyanax scabripinis</i> (Eigenmann, 1927)	lambari	4.0	?
"	<i>Bryconamericus stramineus</i> (Eigenmann, 1908)	pequira	4.0	No
"	<i>Astyanax bimaculatus</i> (Linnaeus, 1758)	tambiu	4.6	Yes- short distance
"	<i>Astyanax schubarti</i> Britski, 1964	lambari		?
"	<i>Characidium fasciatum</i> Reinhardt, 1866	canivete	2.5	?
"	<i>Cheirodon notomelas</i> (Eigenmann, 1915)	pequira		No
"	<i>Roeboides paranensis</i> Pignalberi, 1975	dentudo	5.5	No
Pimelodidae	<i>Rhamdia quelen</i> (Quoy & Gaimard, 1824)	bagre	5.0	No
"	<i>Nannorhamdia schubarti</i> Gomes, 1956	bagre	4.0	No
"	<i>Cetopsorhamdia iheringi</i> Schubart & Gomes, 1959	bagre		No
"	<i>Phenacorhamdia</i> sp	mandi	4.0	No
Loricariidae	<i>Hypostomus ancistroides</i> Ihering, 1911	casculo	4.5	No
"	<i>Microlepidogaster</i> sp	casculo	2.5	No
"	<i>Loricariichthys platymetopon</i> Isbrucker & Nijssen, 1979	casculo-chinelo	15.0	No
Anostomidae	<i>Leporinus silvestris</i> Boulanger, 1902	piau	14.1	Yes
"	<i>Leporinus obtusidens</i> (Valenciennes, 1847)	piapara	15.0	Yes
"	<i>Leporinus friderici</i> (Bloch, 1794)	piau	15.0	Yes
Callichthyidae	<i>Corydoras aeneus</i> (Gill, 1864)	coridoras		No
"	<i>Callichthys callichthys</i> (Linnaeus, 1758)	tamboata		No
Poeciliidae	<i>Phalocerus caudimaculatus</i> (Hensel, 1868)	barrigudinho	1.5(female)	No
Synbranchidae	<i>Synbranchus marmoratus</i> (Bloch, 1795)	mussum		No
Sternopygidae	<i>Eigenmania trilineata</i> (Lopez & Castello, 1966)	tuvira		No
Gymnotidae	<i>Gymnotus carapo</i> (Linnaeus, 1758)	morenita	13.0	No
Erythrinidae	<i>Hoplias malabaricus</i> (Bloch, 1794)	traíra		No
Auchenipteridae	<i>Parauchenipterus galeatus</i> (Linnaeus, 1766)	cangati	10.8	No
Curimatidae	<i>Curimata insculpta</i> (Fernandes-Yepe, 1948)	saguiru	6.0	?
Prochilodontidae	<i>Prochilodus scrofa</i> Steindachner, 1882	curimba	24.4	Yes
Cichlidae	<i>Cichlasoma paranaense</i> Haseman, 1911	cará		No

Literature used for identification of the above data: Barbieri & Barbieri, 1984;

Britski, 1972; Godoy, 1975; "Itaipu Binacional", 1981; Mees, 1974; Nomura, 1975;

Ringuelet, Aramburu & Aramburu, 1967; Weber, 1986.

forestation, abundance of macrophytes and moderate river width (Fig. 3).

Although the order of the sites down each river has been rearranged in Fig. 3, it is clear that several sites were quite different from their neighbours; indeed, each site had a unique combination of taxa. Also, although only about 18 km apart, the two rivers had different fish communities. Only six taxa were common to both; fourteen occurred only in the Caracu and eight only in the Agua do Rancho.

While paying attention to particular sites and species we can see that only 2 of 20 species included in Fig. 3 occur always together in both streams, *H. ancistroides* being more abundant, and *G. carapo* forming numerically abundant populations in none of the sites.

Fewer species were present in the headwater sites of each stream (sites 5 & 6 and 11) than in sites in the middle and lower reaches.

Site 3, which was separated on the diagram, proved most abundant in hiding places formed of grass and

Table 3. Number of fish collected in sites 1-6 in the Caracu River, and in sites 7-11 in the Agua do Rancho River. * - species rejected from coenological analysis (see text for explanations).

Family	Scientific name	Caracu River						Agua do Rancho River						
		1	2	3	4	5	6	Σ	7	8	9	10	11	Σ
Characidae	<i>A. scabripinis</i>								5	25	16	18	93	157
"	<i>B. stramineus</i>								14	18	32	13		77
"	<i>A. bimaculatus</i>	8	9	90	15	3	2	127						
"	<i>A. schubarti</i>									1				1
"	<i>C. fasciatum</i>	12	4	2				18		1				1
"	<i>C. notomelas</i>	1	3			2		6						
"	<i>R. paranensis*</i>	1						1						
Pimelodidae	<i>R. quelen</i>								6	21	1		13	41
"	<i>N. schubarti</i>	2	7					9		1	1			2
"	<i>C. iheringi</i>								9	9	11	9		38
"	<i>Phenacorhamdia</i> sp								11		5	12		28
Loricariidae	<i>H. ancistroides</i>	27	25	21	9	3	3	88	50	48	60	48	2	208
"	<i>Microlepidogaster</i> sp								169	48	2	7	1	227
"	<i>L. platymetopon</i>	1						1						
Anostomidae	<i>L. silvestris</i>		2	5	1			8						
"	<i>L. obtusidens*</i>	1						1						
"	<i>L. friderici*</i>			1				1						
Callichthyidae	<i>C. aeneus*</i>	1						1						
"	<i>C. callichthys</i>	1	2		8			11						
Poeciliidae	<i>P. caudimaculatus</i>				7	1	30	38		32			19	51
Synbranchidae	<i>S. marmoratus</i>			1			4	5	1	1	1	2	4	9
Sternopygidae	<i>E. trilineata</i>								8	1				9
Gymnotidae	<i>G. carapo</i>	11	11	5	12	1	3	43	5	19	2	4	10	40
Erythrinidae	<i>H. malabaricus</i>	2	2	2	1			7						
Auchenipteridae	<i>P. galeatus*</i>	1						1						
Curimatidae	<i>C. insculpta</i>	3						3						
Prochilodontidae	<i>P. scrofa</i>			4				4						
Cichlidae	<i>C. paranaense*</i>		1					1						
Total		72	66	131	53	10	42	374	278	225	132	113	142	889

Table 4. Simpson (D) and Shannon (H) diversity indices calculated for fish species in the Caracu (sites 1-6) and the Agua do Rancho Rivers (sites 7-11).

Site	1	2	3	4	5	6	Mean±95%CL
D	0.79	0.79	0.50	0.80	0.76	0.47	0.69±0.16
H	0.74	0.81	0.50	0.87	0.93	0.61	0.74±0.17
Site	7	8	9	10	11		Mean±95%CL
D	0.59	0.85	0.70	0.76	0.54		0.69±0.16
H	0.59	0.80	0.66	0.82	0.59		0.69±0.14

tree branches. Its bottom was covered by numerous boulders and this habitat proved optimal for *A. bimaculatus*, whose abundance decided the separateness of this site from site cluster X, despite its similar fish fauna composition (Fig. 3). Following these steps, one can determine optimal habitats (sites) separately for any species.

Discussion

Till today the Romaniszyn synthetic diagram has been used to examine fish community structures in Polish, Zambian, English, and Hungarian rivers (Penczak, 1972; Balon & Stewart, 1983; Witkowski, 1983/1984; Zalewski *et al.*, 1990; Penczak *et al.*, 1991; Przybylski *et al.*, 1991). We believe that the Romaniszyn synthetic diagram (Fig. 3) has helped our interpretation of the environmental preferences of individual species and species clusters in these two little studied rivers. Graphic pictures of physico-chemical characters of the sites added by Penczak *et al.* (1991) to the diagram allow immediate estimation of the habitat preferences of species clusters and of single species. The possibility of detecting the preferences is probably particularly important for little known regions, to which the Paraná River catchment, except the Paraná River itself, undoubtedly belongs in Brazil (Lowe-McConnell, 1987). From the diagram it is easy to discern which species may cooccur and which may not and which characters of a habitat condition the abundance or even lack of a given taxon.

It is interesting to separate both rivers on the basis of the similarity definition, although the geological structure of the catchments of both rivers and adjoining areas is similar (Stevaux, 1991). The surface formations of the stream valleys (alluvial sands) and the exploitation of both catchments were also similar. In view of this the separateness of communities in the two rivers appeared to be determined mainly by water quality and morphology of sites, because nobody exploits fish other than natural predators, due to their small size despite their high abundance, in the Paraná River (Agostinho & Julio, in print).

We think that the cutting out of jungle in the catchments of the investigated rivers and exploiting them as pastures trampled by herds of cattle, which particularly harmed the Caracu River basin, caused the erosion of soils, and thus decrease in the transparency of water and in the diversity of fish fauna.

According to Odum (1980) values of Simpson and Shannon indices ≤ 0.6 determine the lower level boundary bound of natural habitats, while several values (8) from Table 4 were at the same or even a lower level than that indicated by Odum, which would suggest that employing catchments as pastures for cattle or crop fields is stressogenous and limiting for fish.

Lowe-McConnell (1987) in a chapter 'Diversity: its maintenance and evolution' estimates diversity only with the number of species, hence it is difficult to determine if about a dozen of diversity indices that were collected in the present study are relatively high and characteristic for the Neotropical fish fauna. The characteristics of the small streams of Central Amazonia (Lowe-McConnell, 1987) are similar to those of the upper and middle courses of the Agua do Rancho River. The latter are also characterized by a full canopy, lack of aquatic plants and 'scarce nutrient salts' (conductivity was only 46–49 $\mu\text{S cm}^{-1}$), but despite this the number of species in none of the sites exceeded 10, while Lowe-McConnell (1987, 1987) proved that in the streams of Amazonia they are 'surprisingly abundant' and amount to 30–50 for one stream.

In the streams presently investigated, as in the streams of Amazonia, the family of Characidae was the most abundant one (Lowe-McConnell (1987, 1991).

Of the three stream sections mentioned for the Amazonia streams only the upper one of the streams presently investigated differed significantly in its species composition and fish numbers from the other two, while the middle and lower sections of the streams differed slightly from each other. The impact of the main river (Paraná) on the ichthyofauna of the investigated streams was more pronounced in the Caracu River, which is directly connected with the Paraná, this supporting Lowe-McConnell's (1987) conclusion on the easier migration of fish between the main river and its direct although small tributaries than the river and its large but indirect ones.

Acknowledgments

The authors are very grateful to R. H. Lowe-McConnell and anonymous reviewer for English and merit improvements and helpful, valuable pieces of advice on to the text. They also thank J. Lobón-Cerviá for reading the manuscript (and apologize him for not including all of his suggestions) and Ł. Głowacki for help in preparing the English version of the draft manuscript, H. F. Julio, C. S. Pavaneli, H. A. Brit-

ski for identification of fish species, G. Baungartner, E. E. Marques, R. Fugi, C. Deitos for help in catching, counting and measuring fish, S. Rodrigues and A. S. Silva for hard field work. The project was sponsored by ITAPU BINACIONAL (Brazil).

References

- Agostinho, A. A. & H. F. Julio, Ecology of fishes of the Upper Paraná River basin, 1994.
- Balon, E. K. & D. J. Stewart, 1983. Fish assemblages in a river with unusual gradient (Luongo, Africa – Zaire system), reflections on river zonation, and description of another new species. *Envir. Biol. Fish.* 9: 225–252.
- Barbieri, G. & M. C. Barbieri, 1984. Crescimento de *Gymnotus carpo* (Linnaeus, 1778) na represa do Lobo, Estado de São Paulo, pelo método da distribuição da frequência de comprimento (Pisces, Gymnotidae). *Rev. Bras. Biol.* 44: 239–246.
- Britski, H. A., 1972. Peixes de Água Doce do Estado de São Paulo: Sistemática. In *Poluição e Piscicultura*. Faculdade de Saúde Pública da Universidade de São Paulo, Instituto de Pesca: 79–108.
- Brundin, L., 1949. Chironomiden und andere Bodentiere der südschwedischen Urgebirgssen. Ein Beitrag zur Kenntnis der bodenfaunistischen Charakterzüge südschwedischer oligotropher Seen. *Rep. Inst. Freshwat. Res. Lund.* 30: 1–914.
- Godoy, M. P., 1975. Peixes do Brasil. Ed. Franciscana, Piracicaba, vol. 4, 847 pp.
- Itaipu Binacional, 1981. Ictiologia. Complementação do Inventário Ictiofaunístico. CETESB, São Paulo, 89 pp.
- Lowe-McConnell, R. H., 1987. *Ecological Studies in Tropical Fish Communities*. Cambridge, London, Cambridge University Press: 1–382.
- Lowe-McConnell, R. H., 1991. Natural history of fishes in Araguaia and Xingu Amazonian tributaries, Serra do Roncador, Mato Grosso, Brazil. *Ichthyol. Explor. Freshwat.*, 2: 63–82.
- Marczewski, E. & H. Steinhaus, 1958. On a certain distance of sets and the corresponding distance of function. *Coll. Math.* 6: 319–327.
- Mess, G. F., 1974. The Auchenipteridae and Pimelodidae of Suriname (Pisces, Nematognathi). *Zool. Verhand.*, 132: 1–256.
- Nomura, H., 1975. Comparação da idade e crescimento de três espécies de peixes do gênero *Astyanax* Baird & Girard, 1854 (Osteichthyes, Characidae) do rio Mogi Guaçu, SP. *Rev. Bras. Biol.* 35: 531–547.
- Odum, E. P., 1980. *Ecology*. London, Holt-Saunders: 1–244.
- Penczak, T., 1972. Structure of fish groupings in the rivers and streams of the Nida drainage basin. *Ekol. pol.* 20: 327–344.
- Penczak, T., 1985. Influence of site area on the estimation of the density of fish populations in a small river. *Aquat. Fish. Mgmt* 1: 273–285.
- Penczak, T., I. Forbes, T. F. Coles, T. Atkin & T. Hill, 1991. Fish community structure in the rivers of Lincolnshire and South Humberside, England. *Hydrobiologia* 211: 1–9.
- Penczak, T., J. Jankov, Ts. Dikov & M. Zalewski, 1985. Fish production in the Mesta River, Rila Mountain, Samokov, Bulgaria. *Fish. Res.* 3: 201–221.
- Penczak, T. & C. Lasso, 1991. Problems of estimating population parameters and production of fish in a tropical rain forest stream, North Venezuela. *Hydrobiologia* 215: 121–133.
- Penczak, T., M. Zalewski, E. Suszycka & M. Molinski, 1981. Estimation of the density, biomass and growth rate of fish populations in two small lowland rivers. *Ekol. pol.* 29: 233–255.
- Przybylski, M., P. Biro, M. Zalewski, I. Tatrai & P. Frankiewicz, 1991. The Structure of fish communities in streams of the northern part of the catchment area of Lake Balaton (Hungary). *Acta Hydrobiol.* 33: 135–148.
- Ringuélet, R. A., R. A. Aramburu & A.A. Aramburu, 1967. *Los Peces argentinos de agua dulce*. La Plata – Comisión de Investigación Científica. Buenos Aires, 602 pp.
- Romaniszyn, W., 1970. An attempt at interpreting agglomerative tendencies of animals based on definition of similarity and distance. *Wiad. ekol.* 16: 306–321.
- Stevaux, J. C., 1991. Avaliação do potencial mineral do Grupo Bauru no Noroeste do Estado do Paraná. *Convenio UEM/MINEROPAR*, 200 pp.
- Weber, C., 1986. Les poissons-chat cuirassés de la sous-famille des Hypostominae du Paraguay. Nancy, Université de Nancy. Tese (Etude Supérieures), 96 pp.
- Witkowski, A., 1984. Structure of communities and biomass of ichthyofauna in the Biebrza River, its old river beds and affluents. *Pol. ecol. Stud.* 10: 447–474.
- Zalewski, M., P. Frankiewicz, M. Przybylski, J. Banbura & M. Nowak, 1990. Structure and dynamics of fish communities in temperate rivers in relation to the abiotic-biotic regulatory continuum concept. *Pol. Arch. Hydrobiol.* 37: 151–176.