ICHTHYOFAUNA OF TWO STREAMS (SILTED AND REFERENCE) IN THE UPPER PARANÁ RIVER BASIN, SOUTHEASTERN BRAZIL

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(With 2 figures)

ABSTRACT

In this study the fish assemblages of the silted Águas Claras stream (AC) was compared with that of a reference, the São Carlos stream (SC), so as to identify potential fish indicators of integrity or degradation. Both streams, located about 5 km from one another, are part of the Upper Paraná river basin, Brazil, and present similar physiographical features. Twenty-one species were collected in AC (1,271 specimens) and 18 in SC (940 specimens). In AC, dominant species e.g., *Corydoras aeneus* (sandy pools), *Serrapinnus notomelas*, and *Pyrrhulina australis* (warm marginal shallow pools) were those favored by new microhabitats linked to siltation and removal of the riparian vegetation. Changes in the composition of the marginal vegetation resulted in dominance of species such as *Hisonotus francirochai* (marginal grasses). In SC the dominant species was *Phalloceros caudimacultus*, abundant in marginal shallow pools, and *Trichomycterus diabolus*. and *Hypostomus nigromaculatus*, exclusively riffle-dwelling species, which were absent in AC. Fish assemblage monitoring is recommended for use in riparian management programs in order to evaluate negative instream sedimentation effects.

Key words: stream fishes, agriculture, fish habitat, biotic integrity, siltation.

RESUMO

Ictiofauna de dois riachos (assoreado e referência) na bacia do Alto Rio Paraná, Sudeste do Brasil

Neste trabalho, a ictiofauna de um riacho assoreado (córrego Águas Claras – AC) foi comparada com a de um riacho referência (córrego São Carlos – SC), com o objetivo de identificar espécies potencialmente indicadoras de integridade ou degradação. Os riachos localizam-se na bacia do Alto Rio Paraná, Brasil, estão distantes cerca de 5 km entre si e apresentam características fisiográficas semelhantes. Foram coletadas 21 espécies no AC (1.271 indivíduos) e 18 no SC (940 indivíduos). No AC, as espécies dominantes foram aquelas favorecidas por microhabitats relacionados ao assoreamento e à remoção da vegetação marginal, como *Corydoras aeneus* (poços de fundo de areia), *Serrapinnus notomelas* e *Pyrrhulina australis* (poços rasos marginais), e por alterações na vegetação marginal, como *Hisonotus francirochai* (bancos de gramíneas marginais). No SC, a espécie mais abundante foi *Phalloceros caudimaculatus*, freqüentemente encontrada em poços rasos marginais, seguida por *Trichomycterus diabolus* e *Hypostomus nigromaculatus*, exclusivamente encontradas em corredeiras e que, em contraste, não foram registradas no AC. Recomenda-se o monitoramento das comunidades de peixes em programas de recuperação de vegetação ripária para que sejam avaliados os efeitos do assoreamento sobre essas comunidades.

Palavras-chave: peixes de riachos, agricultura, integridade biótica, assoreamento.

INTRODUCTION

Among several consequences of streamside vegetation removal, siltation is one that most directly affects warmwater fish assemblages (Rabeni & Smale, 1995). A variety of mechanisms by which siltation affects fishes have been described, including physiological stress from clogged gills, egg and larvae smothering, changes in normal feeding, and other activities that depend on vision (Rabeni & Smale, 1995). At broader temporal and spatial scales, siltation can cause local extinction of species that depend on coarse substrates for reproduction and feeding, and also nektonic species that require a minimum water volume for foraging.

As has occurred worldwide (Rabeni & Smale, 1995), siltation in Brazilian water courses has followed agriculturalization with neither environmental planning or preservation (Rodrigues & Gandolfi, 2000). Traditional water protection for human uses does not necessarily protect biological diversity and integrity of aquatic ecosystems (Hughes & Noss, 1992). To better assess the loss of aquatic biological diversity and integrity, biological indices have been drafted to assess water quality programs worldwide (Karr, 1981; Hughes & Oberdorff, 1999). Appropriate applications of such indices require knowledge of many biological and ecological attributes of fish assemblages.

In Brazil, the stream ichthyofauna is relatively well-known in the Upper Paraná river basin. This area is densely populated and has many degraded streams (although quantitative data corroborating this statement are lacking), mainly because of structural changes in drainage systems and agricultural modifications of the landscape usually linked to siltation in water courses.

Despite many studies of the ecological characteristics of fish assemblages in the Upper Paraná river basin (Garutti, 1988; Uieda, 1984; Uieda *et al*., 1997; Castro & Casatti, 1997; Pavanelli & Caramaschi, 1997), none have dealt with biological attributes in response to siltation. Another problem is that reference streams useful in comparisons with impacted streams are very rare in São Paulo State. The exceptions are those streams in the Morro do Diabo State Park that present pristine conditions and were recently studied by Casatti *et al*. (2001) and Casatti (2002, 2003). In the present investigation, the fish assemblages of a silted stream were compared with those of a reference stream, so as to identify potential fish indicators of integrity or degradation.

MATERIALS AND METHODS

Study sites

The studied streams (Fig. 1), which flow to the Paranapanema river, are located in the Upper Paraná river basin, municipality of Teodoro Sampaio, São Paulo State, Brazil. Águas Claras stream (AC), which in its entirety runs through pasture land, has degraded banks without riparian vegetation, and is intensely silted. According to local landowners, before 1970 AC had many riffles and runs, and pools deeper than 2 m. With progressive replacement of forest by pasture, siltation increased, resulting in a homogeneous channel $\leq$ 1.10 m deep, and having degraded banks and a sandy bottom. São Carlos stream (SC), completely surrounded by the semi-deciduous forest of Morro do Diabo State Park (Schlittler *et al*., 1993), is more sinuous and has a riffle-pool-raceway morphology. In the present study, these two streams presented similar water quality conditions, but AC was slightly deeper than SC (Table 1). In each stream, three 100 m long reaches were studied (upper, middle, and lower).

Regional soil, of the Caiuá formation, is mostly sandy and characterized by low water retention, low fertility, and high sandy composition (Schlittler *et al*., 1993). The climate is humid subtropical, with a dry season between April and September, and a wet one from October to March (Nimer, 1989). Monthly rainfall varied from 14.7 mm (May 2000) to 361 mm (December 2000) and temperature ranged from –1.2ºC (July 2000) to 37.8ºC (October 2000) (data provided by the weather station in the Morro do Diabo State Park).

Sampling and analyses

Fish assemblages were surveyed during the dry (June and September 2000) and the wet seasons (December 2000 and March 2001). Water temperature, pH, dissolved O_2, and conductivity were recorded with digital equipment (M-90 Checkmate Deluxe Field System, Corning).

Fish collection methods were selected to maximize yield according to the physical characteristics of each reach. In the upper reaches, two circular sieves (70 cm in diameter and 2.5 mm mesh) were placed close to the substrate, and fishes were chased into them for about 40 minutes. The same technique was used in the middle and lower reaches, and a seine (2 m x 1.5 m, 2.5 mm mesh) was used in the raceways for about 20 minutes. Each reach was blocked at its upper end by a net (2.5 mm mesh) and fishing proceeded in an upstream direction. Upon capture fishes were immediately preserved in 10% formalin. In addition, 17 hours (13 diurnal and 4 nocturnal) of snorkeling were put in in SC, according to the methodology described in Casatti (2002). Occurrence followed Dajoz (1983). Macroscopic identification of reproductive stages were based on Vazzoler (1996).

Shannon-Wiener (H') and Simpson (S) diversity indices were calculated through use of BioDiversity Pro Beta 2 version (McAlecee *et al*., 1997). Basic statistical tests were conducted with BioEstat 2.0 (Ayres *et al*., 2000). The pattern of variation in the species data along the longitudinal gradient was measured by detrended correspondence analysis (DCA) through the software PC-Ord, version 4.2 (McCune & Mefford, 1999), using downweight option and 26 segments. All specimens were deposited in the Laboratório de Ictiologia de Ribeirão Preto (LIRP), Departamento de Biologia, Universidade de São Paulo, Brazil.

RESULTS

Twenty-eight species were collected, belonging to five orders and 13 families (Table 2). In AC, 21 species, 1,271 specimens, and 1,524.5 g were collected; in SC the results were 18 species, 940 specimens, and 1,671 g. Shannon and Simpson diversities were similar in both streams ($H'_{AC} = 0.85$, $H'_{SC} = 0.83$, $S_{AC} = 0.21$, $S_{SC} = 0.18$). In both AC and SC, Characiformes and Siluriformes dominated the number of species and individuals. Characiform abundance was significantly higher ($p < 0.0001$, $\alpha = 0.01$) in AC than in SC. In each stream, the number of individuals was significantly greater in the wet season than in the dry (Chi-square, $p < 0.0001$).

Fifteen species were resident in AC and 11 in SC. *Hisonotus* francirochai, *Corydoras aeneus*, and *Bryconamericus stramineus* were dominant in AC, whereas *Phalloceros caudimaculatus*, *Hypostomus nigromaculatus*, and *H. francirochai*. were so in SC. In AC, six species (28%) were rare (collected once); seven (38%) were so in SC (Table 2).

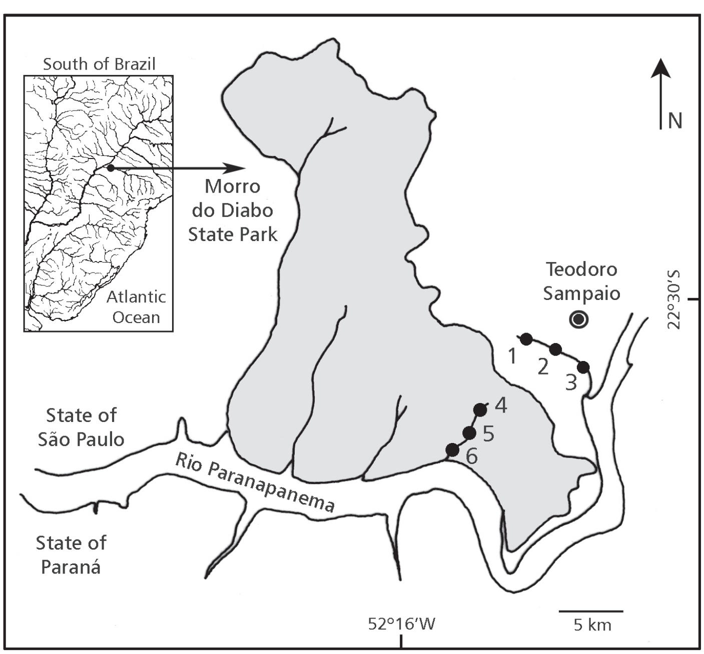

Fig. 1 — Locations of córrego Águas Claras (1-3) and córrego São Carlos (4-6), Upper Paraná river basin, Brazil.

TABLE 1
Major physical and chemical features of the study reaches in Águas Claras and São Carlos streams.

Features	Águas Claras			São Carlos		
	Upper	Middle	Lower	Upper	Middle	Lower
Order (1:50,000)	1st	2nd	2nd	1st	1st	1st
Coordinates	22º33'11.6"S 52º11'50.9"W	22º33'08.7"S 52º10'53.6"W	22º33'25"S 52º10'20.0"W	22º35'280"S 52º14'38.1"W	22º35'54.4"S 52º14'45.2"W	22º36'23.8"S 52º15'08.6"W
Altitude (m)	315	283	283	294	286	284
Bank stability	> 75% eroded	> 75% eroded	> 75% eroded	stable	stable	stable
Sediment deposition	heavy	heavy	heavy	little	little	little
Riffle-pool-raceway dominance	raceway	raceway	raceway	riffle	riffle-pool	riffle-pool-raceway
Riparian zone	absent	absent	absent	dense	dense	dense
Woody debris	absent	absent	absent	frequent	abundant	abundant
Substrate	sand	sand	sand	gravel/peebles	sand/gravel	sand/gravel
Habitat volume (m^3)	0.2	2.3	5.7	0.7	1.8	2.7
Maximum depth (m)	0.2	1.0	1.0	0.3	0.5	0.7
Water current ($m.s^{-1}$)	0.3	1.0	1.0	1.5	0.3	0.7
Mean water temperature (ºC)	18.3	20.6	21.0	20.9	22.2	21.0
Dissolved oxygen ($mg.L^{-1}$)	7.9	8.6	8.4	9.0	9.5	10.0
Conductivity ($\mu S.cm^{-1}$)	9.0	21.0	22.0	14.0	16.0	16.0
pH	6.7	7.5	7.7	7.6	6.8	8.0

In AC almost all species abundances increased from headwaters to the mouth. In SC, this pattern was also noted, except for *Trichomycterus diabolus* and *H. nigromaculatus*, which were progressively less abundant downstream. The resident species occupied eight microhabitats as foraging and shelter sites, and their longitudinal distributions were related to the longitudinal availability of these microhabitats. *Astyanax altiparanae*, *Moenkhausia sanctaefilomenae*, and *B. stramineus* are nektonic and occurred mostly in raceways. *Corydoras aeneus* and *Geophagus brasiliensis* occurred on sandy bottoms. *T. diabolus* and *H. nigromaculatus* were restricted to riffles. *Pyrrhulina australis*, *Serrapinnus notomelas*, and *P. caudimaculatus* occurred mostly in shallow pools, whereas *Oligosarcus pintoi*, *Rhamdia quelen*, and *Crenicichla britskii* occurred in deeper pools. *Eigenmannia virescens*, *Sternopygus macrurus*, and *Gymnotus carapo* were most frequent in marginal shelters. *Hypostomus ancistroides* was abundant in areas with woody debris, whereas *H. francirochai* occupied marginal submerged vegetation.

In both streams, all resident species had mature, maturing, and juvenile specimens. Both assemblages were dominated by species that were small as adults, with 92% of specimens being ≤ 150 mm in standard length in AC, and 87% in SC. Wet season samples yielded the smallest specimens (20-30 mm standard length); this difference was significant (Kolmogorov-Smirnov Test, $p < 0.0001$).

Ordination results (Fig. 2) showed a pattern of species distribution closely related with longitudinal environmental gradients. In SC the upper stretch was characterized by riffle-dwelling species whereas in the lower stretch pools and nektonic species occurred. In AC, where the bottom is completely sandy, no riffle-dwelling species were registered and the pattern of species distribution followed water volume increase.

TABLE 2
Fish species collected in Águas Claras and São Carlos streams, including their occurrence and number of specimens.

Species	Occurrence (%)		Águas Claras			São Carlos		
	AC	SC	upper	middle	lower	upper	middle	lower
Characiformes								
Erythrinidae								
Hoplias malabaricus	25	25	–	–	2	–	–	1
Lebiasinidae								
Pyrrhulina australis	50	–	–	–	26	–	–	–
Characidae								
Astyanax altiparanae	50	75	–	–	3	–	–	7
Astyanax sp.	–	25	–	–	–	–	–	1
Moenkhausia sanctaefilomenae	–	100	–	–	–	–	–	14
Bryconamericus stramineus	100	–	–	13	169	–	–	–
Hemigrammus marginatus	25	–	–	–	3	–	–	–
Hyphessobrycon eques	25	–	–	–	1	–	–	–
Oligosarcus pintoi	25	100	–	1	1	–	2	17
Serrapinnus notomelas	100	–	–	–	89	–	–	–
Crenuchidae								
Characidium sp.	–	25	–	–	–	–	–	1
Siluriformes								
Pimelodidae								
Imparfinis mirini	25	25	–	2	1	–	–	2
Phenacorhamdia hoehnei	–	25	–	–	–	–	–	1
Rhamdia quelen	75	50	–	3	9	4	9	4
Pimelodella aff. *gracilis*	–	25	–	–	–	–	–	1
Trichomycteridae								
Trichomycterus diabolus	–	100	–	–	–	107	20	–
Loricariidae								
Hisonotus francirochai	100	100	–	111	388	2	23	141
Hypostomus ancistroides	100	100	–	18	36	2	21	65
Hypostomus nigromaculatus	–	100	–	–	–	163	32	10
Callichthyidae								
Corydoras aeneus	100	100	–	105	101	–	2	17
Gymnotiformes								
Sternopygiidae								
Eigenmannia virescens	75	–	–	–	4	–	–	–
Sternopygus macrurus	50	–	–	–	6	–	–	–
Gymnotidae								
Gymnotus carapo	50	–	–	12	15	–	–	–
Cyprinodontiformes								
Poeciliidae								
Phalloceros caudimaculatus	50	100	9	3	63	33	135	92
Synbranchiformes								
Synbranchidae								
Synbranchus marmoratus	50	25	–	2	2	–	1	–
Perciformes								
Cichlidae								
Cichlasoma paranaense	25	–	–	2	5	–	–	–
Crenicichla britskii	100	75	–	18	30	–	–	10
Geophagus brasiliensis	75	–	–	2	16	–	–	–
Total			**9**	**292**	**970**	**311**	**245**	**384**

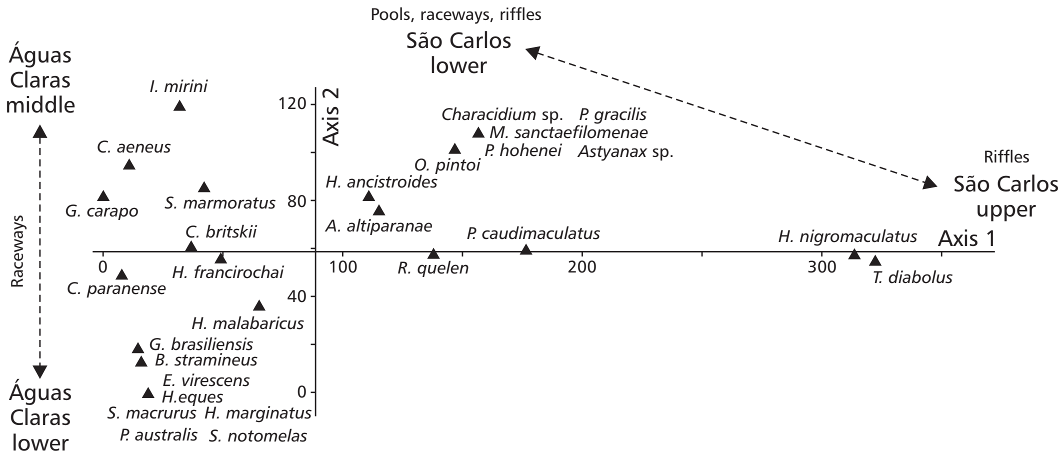

Fig. 2 — Detrended correspondence analysis plot of fish species abundance from the stretches sampled in the Águas Claras and São Carlos streams, southeastern Brazil (eigenvalues: axis 1 = 0.766, axis 2 = 0.110).

DISCUSSION

Freshwater integrity depends on processes at many spatial and temporal scales, from cellular mechanisms producing local and regional transformations of energy and materials to a transfer of energy and materials when fish or insects migrate upstream or onto floodplains (Karr & Chu, 1999). Understanding how changes in these processes affect aquatic ecosystem integrity is a great challenge for aquatic resource science and conservation because of the vital importance of high quality fresh waters not only for human consumption, recreation, and aesthetic needs, but also for entire aquatic biota.

The importance of a riparian buffer zone for reducing sediment inputs into water courses is relatively well-known (Rabeni & Smale, 1995; Joly *et al.*, 2000). But input effects on fish assemblages as ecological indicators are poorly documented in the literature. According to Rabeni & Smale (1995), fish responses to siltation are more evident at the assemblage level and, in both interregional or intraregional comparisons, herbivores, benthic invertivores, and lithophilous spawners are reliable indicators of siltation.

The presence of benthic species is considered an indicator of higher biotic integrity (Hughes & Oberdorff, 1999). Generally these species are sensitive to benthic habitat degradation because such species have specific reproduction and feeding requirements. Both benthic herbivores and invertivores, as well as lithophilous spawners, diminish with increased siltation levels (Rabeni & Smale, 1995). In AC, 16% of the collected specimens belonged to a single species, *C. aeneus*, a benthic invertivore (Aranha *et al.*, 1993; Casatti, 2002). This abundance, notably greater in AC than in SC (2%), can probably be related with the great availability in AC of shallow marginal sandy pools, the preferred microhabitat of *C. aeneus*, as also noted by Aranha *et al.* (1993). Thus, high percentages of benthic invertivores do not always indicate integrity. An alternative to this metric is use of riffle-dwelling species percentage (Harris, 1995) or, in the case of temperate regions, the percentage of sculpin individuals (McCormick *et al.*, 2001; Mebane *et al.*, 2003), because the term benthic does not distinguish silt-tolerant from silt-intolerant benthic species.

Trophic features comprise other categories of biotic-condition indicators. One trophic metric often used is the percentage of omnivorous individuals, which often increases when a site declines in quality (Karr, 1981), as a consequence of their broad trophic amplitude. *Phalloceros caudimaculatus*, with 27% of the total specimens in SC, is omnivorous with a herbivorous tendency (Casatti, 2002). In AC this species, comprising 6% of the total specimens, fed on algae. In other Brazilian streams, this species was considered omnivorous with a tendency to herbivory (Sabino & Castro, 1990), insectivorous (Uieda *et al*., 1997), and herbivorous (Costa, 1987; Aranha & Caramaschi, 1999).

Its many feeding tactics (Sabino & Castro, 1990) suggesed a broad feeding niche. Because of its dominance in SC, *P. caudimaculatus* was not characteristic of sediment-degraded sites, but together with *Poecilia* spp., may be abundant in sites with poor water quality (Araújo, 1998). Omnivory in general indicates feeding opportunism but not necessarily environmental degradation, and its use as an integrity metric should be based on what is known about each species. McCormick *et al*. (2001) found that macrophagic omnivore percent was more responsive to sedimentation than total or microphagic omnivores. Together with the well-documented feeding opportunism, it is important to consider the livebearing condition of this species. In west-central Mexico, native livebearers were considered to be tolerant to environmental degradation (Lyons *et al*., 1995).

The number of water column or pool species is often considered an indicator of higher biotic integrity (Hughes & Oberdorff, 1999). The greater number of Characiformes in AC, represented mostly by *B. stramineus*, *P. australis*, and *S. notomelas* (which were absent in SC), is related to the presence of two microhabitats typical of this stream. *Bryconamericus stramineus* is nektonic and collects drifting prey from mid-channel areas with strong flow (Casatti & Castro, 1998). Although highly silted, AC still had sufficient habitat volume for active nektonic species. *Pyrrhulina australis* and *S. notomelas* are lentic species, often found in warm shallow marginal pools in lower stream reaches, where there is abundant filamentous algae on which they feed. This microhabitat is often linked to siltation and riparian vegetation removal, and a high percentage of fish species favored by such conditions can indicate degraded sites.

Although part of the original richness in AC probably has been lost because of siltation, the remaining resident fish species have conditions adequate for reproduction and growth, because specimens in all developmental stages were found. Reproduction occurs mainly during the wet season, when availability of food and shelter are high (Lowe-McConnell, 1987). In contrast, the absence of exclusively lithophilous spawners (*T. diabolus* and *H. nigromaculatus*) in AC indicates that these two species are riffle-siltation intolerant.

Hisonotus francirochai, as well as other Hypoptopomatinae species, occurs in association with leaves and branches of submerged marginal vegetation (Costa, 1987; Casatti & Castro, 1998) to which individuals often attached themselves. Higher abundance of this species in AC can be explained by the large amount of grasses (pasture) in contact with the water, which implies that this species is not a good indicator of bank conditions.

Recent studies in the Upper Paraná river basin have dealt with riparian restoration (Kageyama & Gandara, 2000; Joly *et al*., 2000). Because any change in the terrestrial ecosystem is reflected in the aquatic environment, it is wise to include fish assemblage monitoring in riparian management programs to properly evaluate the effects of instream sedimentation. However, it is necessary to evaluate all candidate metrics for their responses to a variety of known stressors before including them in a biotic integrity index (Hughes *et al*., 1998; McCormick *et al*., 2001; Mebane *et al*., 2003). Thus, in the silted AC the ichthyofauna was dominated by species associated with high availability of microhabitats linked to siltation and removal of riparian vegetation (sandy pools, marginal grasses, and marginal shallow pools) that, together with the absence of riffle-dwelling species, strongly evidence biological integrity decline in this stream.

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REFERENCES

ARANHA, J. M. R. & CARAMASCHI, E. P., 1999, Estrutura populacional, aspectos da reprodução e alimentação dos Cyprinodontiformes (Osteichthyes) de um riacho do sudeste do Brasil. *Revta. Bras. Zool.*, *16*: 37-651.

ARANHA, J. M. R., CARAMASCHI, E. P. & CARAMASCHI, U., 1993, Ocupação espacial, alimentação e época reprodutiva de duas espécies de *Corydoras* Lacépède (Siluroidei, Callichthyidae) coexistentes no rio Alambari (Botucatu, São Paulo). *Revta. Bras. Zool.*, *10*: 453-466.

ARAÚJO, F. G., 1998, Adaptação do índice de integridade biótica usando a comunidade de peixes para o Rio Paraíba do Sul. *Rev. Brasil. Biol.*, *58*: 547-558.

AYRES, M., AYRES Jr., M., AYRES, D. L. & SANTOS, A. A. S., 2000, *BioEstat: Aplicações estatísticas nas áreas das ciências biológicas e médicas*. Version 2.0, Sociedade Civil Mamirauá, Belém.

CASATTI, L., 2002, Alimentação dos peixes em um riacho do parque estadual Morro do Diabo, bacia do Alto Rio Paraná, sudeste do Brasil. *Biota Neotrop.*, *2*: 1-14.

CASATTI, L., 2003, Biology of a catfish, *Trichomycterus* sp. (Pisces, Siluriformes), in a pristine stream in the Morro do Diabo State Park, southeastern Brazil. *Stud. Neotrop. Fauna & Environm*, *38*: 205-210.

CASATTI, L. & CASTRO, R. M. C., 1998, A fish community of the São Francisco River headwater riffles, southeastern Brazil. *Ichthyol. Explor. Freshwaters*, *9*: 229-242.

CASATTI, L., LANGEANI, F. & CASTRO, R. M. C., 2001, Peixes de riacho do parque estadual Morro do Diabo, bacia do Alto rio Paraná, SP. *Biota Neotrop.*, *1*: 1-15.

CASTRO, R. M. C. & CASATTI, L., 1997, The fish fauna from a small forest stream of the upper Paraná river basin, Southeastern Brazil. *Ichthyol. Explor. Freshwaters*, *7*: 337-352.

COSTA, W. J. E. M., 1987, Feeding habits of a fish community in a tropical coastal stream, rio Mato Grosso, Brazil. *Stud. Neotrop. Fauna & Environm.*, *22*: 145-153.

DAJOZ, R., 1983, *Ecologia geral*. Editora Vozes, São Paulo, 472p.

GARUTTI, V., 1988, Distribuição longitudinal da ictiofauna de um córrego na região noroeste do Estado de São Paulo, bacia do rio Paraná. *Rev. Brasil. Biol.*, *48*: 747-759.

HARRIS, J. H., 1995, The use of fish in ecological assessments. *Austr. J. Ecol.*, *20*: 65-80.

HUGHES, R. M. & NOSS, R. F., 1992, Biological diversity and biological integrity: current concerns for lakes and streams. *Fisheries*, *17*: 11-19.

HUGHES, R. M. & OBERDORFF, T., 1999, Applications of IBI concepts and metrics to waters outside the United States and Canada, pp. 79-93. *In*: T. P. Simon (ed.), *Assessing the sustainability and biological integrity of water resources using fish communities*. CRC Press, Boca Raton, 672p.

HUGHES, R. M., KAUFMANN, P. R., HERLIHY, A. T., KINCAID, T. M, REYNOLDS, L. & LARSEN, D. P., 1998, A process for developing and evaluating indices of fish assemblage integrity. *Can. J. Fish. Aquat. Sci.*, *55*: 1618-1631.

JOLY, C. A., SPIGOLON, J. R., LIEBERG, S. A., SALIS, S. M., AIDAR, M. P. M., METZGER, J. P. W., ZICKEL, C. S., LOBO, P. C., SHIMABUKURO, M. T., MARQUES, M. C. M. & SALINO, A., 2000, Projeto Jacaré-Pepira – o desenvolvimento de um modelo de recomposição de mata ciliar com base na florística regional, pp. 271-287. *In*: R. R. Rodrigues & H. L. Leitão Filho (eds.), *Matas Ciliares: conservação e recuperação*. EDUSP/FAPESP, São Paulo, 320p.

KAGEYAMA, P. & GANDARA, F. B., 2000, Recuperação de áreas ciliares, pp. 249-269. *In*: R. R. Rodrigues & H. L. Leitão Filho (eds.), *Matas Ciliares: conservação e recuperação*. EDUSP/FAPESP, São Paulo, 320p.

KARR, J. R., 1981, Assessment of biotic integrity using fish communities. *Fisheries*, *6*: 21-27.

KARR, J. R. & CHU, E. W., 1999, *Restoring life in running waters: better biological monitoring*. Island Press, Washington D.C., 206p.

LOWE-McCONNELL, R. H., 1987, *Ecological studies in tropical fish communities*. Cambridge University Press, Cambridge, 382p.

LYONS, J., NAVARRO-PÉREZ, S., COCHRAN, P. A., SANTANA, C. E. & GUZMÁN-ARROYO, M., 1995, Index of biotic integrity based on fish assemblages for the conservation of streams and rivers in West-Central Mexico. *Cons. Biol.*, *9*: 569-584.

McALECEE, N., LAMBSHEAD, P. J. D., PATERSON, G. L. J. & GAGE, J. G., 1997, *Biodiversity professional*. Beta-Version. The Natural History Museum and The Scottish Association for Marine Sciences, London.

McCORMICK, F. H., HUGHES, R. M., KAUFMANN, P. R., PECK, D. V., STODDARD, J. L. & HERLIHY, A. T., 2001, Development of an index of biotic integrity for the Mid-Atlantic Highlands. *Trans. Am. Fish. Soc.*, *130*: 857-877.

McCUNE, B. & MEFFORD, M. J., 1999, *PC-Ord: Multivariate analysis of ecological data*. Version 4.2. MjM Software Design, Gleneden Beach, Oregon.

MEBANE, C. A., MARET, T. R. & HUGHES, R. M., 2003, An index of biological integrity (IBI) for Pacific Northwest rivers. *Trans. Am. Fish. Soc.*, *132*: 239-261.

NIMER, E., 1989, *Climatologia do Brasil*. Secretaria de Planejamento e Coordenação da Presidência da República/IBGE, Rio de Janeiro, 421p.

PAVANELLI, C. S. & CAMASCHI, E. P., 1997, Composition of the ichthyofauna of two small tributaries of the Paraná river, Porto Rico, Paraná State, Brazil. *Ichthyol. Explor. Freshwaters*, *8*: 23-31.

RABENI, C. F. & SMALE, M. A., 1995, Effects on siltation on stream fishes and the potential mitigating role of the buffering riparian zone. *Hydrobiol.*, *303*: 211-219.

RODRIGUES, R. R. & GANDOLFI, S., 2000, Conceitos, tendências e ações para a recuperação de florestas ciliares, pp. 235-247. *In*: R. R. Rodrigues & H. L. Leitão Filho (eds.), *Matas Ciliares: conservação e recuperação*. EDUSP/ FAPESP, São Paulo, 320p.

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

SCHLITTLER, F. H. M., DEMARINIS, G. & CESAR, O., 1993, Produção de serapilheira na floresta do Morro do Diabo, Pontal do Paranapanema, SP. *Naturalia*, *18*: 135-147.

UIEDA, V. S., 1984, Ocorrência e distribuição dos peixes em um riacho de água doce. *Rev. Brasil. Biol.*, *44*: 203-213.

UIEDA, V. S., BUZZATO, P. & KIKUCHI, R. M., 1997, Partilha de recursos alimentares em peixes em um riacho de serra no sudeste do Brasil. *An. Acad. Bras. Cienc.*, *69*: 243-252.

VAZZOLER, A. E. A. M., 1996, *Biologia da reprodução de peixes teleósteos*. EDUEM, Maringá, 169p.