Evaluation of the Index of Biotic Integrity in the Sorocaba River Basin (Brazil, SP) Based on Fish Communities.

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ABSTRACT: Evaluation of the Index of Biotic Integrity in the Sorocaba River Basin (Brazil, SP) based on Fish Communities. Riverine habitats, such as creeks, rivers and contiguous lagoons, have special importance in tropical and sub-tropical natural systems. The Sorocaba River, in São Paulo State, Brazil, is an example of such systems, and presents an environmental mosaic constituted of distinct ecological conditions. An ichthyologycal study was conducted in seven tributaries of the Sorocaba River, comprising three different orders, so as to characterize habitats through an index of biotic integrity (IBI), thus providing relevant ecological information on the river basin. Field sampling was conducted to evaluate biological variables during dry and wet seasons in 1999-2000. Eleven variables indicating health and social levels of organization of the Fish communities were measured to obtain an IBI of the aquatic habitats under study so as to detect impacts on community structure. Thus, richness, total abundance of the species, intolerance, and trophic guilds were investigated. The health and organization variables for fish communities are the most important in formulating an IBI for 2nd, 3rd , and 4th order streams. In general, the Sorocaba river basin has altered with respect to fish community standards established in the last decade, which indicates some degree of degradation in the system.
Key-words: ichthyology, index of biotic integrity (IBI), Sorocaba River, environmental degradation.

RESUMO: Avaliação do índice de integridade biótica na bacia do rio Sorocaba (Brasil, SP) com base na comunidade de peixes. Dentre os sistemas naturais de regiões tropicais e sub-tropicais destacam-se os ambientes aquáticos que são representados por diferentes tipos de habitats como rios, riachos e lagoas marginais. A bacia do rio Sorocaba é um exemplo destes sistemas, sendo constituída por ambientes variados e, portanto, por condições ecológicas distintas. Tendo em vista a necessidade de caracterizar tais habitats por meio de índice de integridade biótica (IBI) e de prover informações ecológicas nesta bacia, foi realizado um estudo ictiológico em sete tributários do rio Sorocaba de três ordens diferentes. Foram realizadas coletas para avaliação das variáveis biológicas nas épocas de cheia e seca, nos anos de 1999 e 2000. Onze variáveis relacionadas à organização e saúde da comunidade de peixes foram avaliadas para análise do índice de integridade biótica dos habitats aquáticos em estudo, sendo essas variáveis selecionadas de maneira a detectar impactos sobre a estrutura da comunidade. Para tanto, verificou-se a riqueza e a abundância total das espécies, além da intolerância e categoria trófica dos indivíduos. Os resultados indicaram que a organização e a saúde da comunidade de peixes foram as variáveis mais importantes para composição do índice de integridade biótica nas três diferentes ordens de rio estudadas (2ª, 3ª e 4ª). De maneira geral, a qualidade ambiental da bacia do rio Sorocaba apresentou-se alterada em relação aos padrões estabelecidos para comunidade íctica nesta última década, o que é indicativo de degradação no sistema.
Palavras-chaves: ictiologia, índice de integridade biótica (IBI), rio Sorocaba, degradação ambiental.

Introduction

The Sorocaba river basin (São Paulo State, Brazil) is composed of various environmental types and distinct ecological conditions. This river, supplies water for eleven municipalities in the region, also does so for crop irrigation. Furthermore, it receives domestic and industrial wastewaters, which affect the aquatic environment. In relation to this problem, Karr (1981) stated that evaluation of ecosystem health on the basis of structure and organization of biotic communities may be one of the more efficient means of establishing the total impact of human activities that contribute to aquatic environment degradation.

From an anthropological point of view, preserving conditions which ensure ecosystem health, is to indirectly maintain functions crucial to the survival of human society (Cairns & Niederlehner, 1995). It is well known that fish communities respond to changes in abiotic (habitat and water quality) as well as biotic factors in addition to their interactions, by composition and organization variation (Karr, 1981; Hughes, 1985; Leonard & Orth, 1986; Ross, 1991; Angermeier & Schlosser, 1994; Simon & Lyons, 1995).

Monitoring fish community, organization, and health is a way to assess environmental degradation because these factors directly or indirectly reflect stresses on the whole ecosystem (Fausch et al., 1990). Fish community attributes have been used to measure ecosystem well-being since the 1900s, particularly within the last 20 years. According to Fausch et al. (1990), taxa have often been considered indicators easily used in semi-quantitative (relative abundance) or qualitative (presence or absence) interpretation of samples. Karr proposed the index of biotic integrity (IBI) in 1981 as a tool for analysis of environmental quality, in which community features of fish are evaluated (Saylor & Scott, 1987), e.g., structure, composition, and functional organization (Lyons et al., 1996). Thus, the original IBI (Karr, 1981) includes community attributes (richness, species composition, and trophic interactions), populations (abundance), and individuals (health), all of which are highly sensitive to different types of environmental degradation. A total of twelve Fish community attributes are compared to expected values for undisturbed streams having similar structure and located in the same eco-region. These twelve are given a score of from one to five, by which river sections are classified from excellent to very degraded. These attributes have been tested by several authors, such as Fausch et al. (1988), Leonard & Orth (1986), Steedman (1988) and Bowen et al. (1996), all of whom presented a modification to the original IBI, consisting of nine attributes distributed in the following categories: (i) species richness and composition; (ii) indicator species; (iii) trophic functions, and (iv) abundance. Recently, Ganasan & Hughes (1998) referred to an IBI that combines twenty fish assemblage attributes classified in three groups: (i) species richness and composition; (ii) trophic functions; and (iii) fish health and abundance.

The IBI can be adopted as a tool for monitoring and as a standard method (Saylor & Scott, 1987), since this index can identify measurements necessary for promoting habitat conservation (Lyons et al., 1995), and be used in biodiversity monitoring (Angermeier & Schlosser, 1994).

This paper applies an index of biotic integrity based on a study of the Fish communities to some tributaries of the Sorocaba river to assess their environmental degradation. Diversity, richness, and abundance of fish species, as well as intolerance and trophic guilds were the factors evaluated. Potential impacts and damages to the fish community were identified. A final ordering of the biotic integrity classes of the system is given.

Material and methods

Study area

The study area (Fig. 1) is located in southeastern São Paulo State (altitude: 1,028 m above sea level). The drainage area is 5,325km², covering 17 municipalities (São Paulo, 1990; Relatório de Situação dos Recursos Hídricos-UGRHI-10 - Sorocaba, 1997). The climate is predominantly tropical with dry winters. Average maximum and minimum temperatures are 26.6°C and 16°C, respectively. Average annual rainfall is 898.4mm (IBGE, 1958 apud Smith, 1999).

The Sorocaba River is formed by the junction of the Sorocamirim and Sorocabuçu at the entrance of the Itupararanga Reservoir (Fig. 1) from which it flows for about 200 km until reaching the Tietê River, the largest tributary on its left bank. Minimum discharge of the Sorocaba into the Tietê River is about 13 m^3/s which includes the outflow of $7m^3/s$ from the Itupararanga Reservoir. The long-term average discharge of the Sorocaba River is about $45m^3/s$ (Núcleo Engenharia Consultiva Ltda. Plano integrado de aproveitamento e gerenciamento dos recursos hídricos da bacia do rio Sorocaba, 1993). Important bank tributaries are the Tatuí and Sarapuí rivers besides the smaller Ipanema and Pirapora rivers.

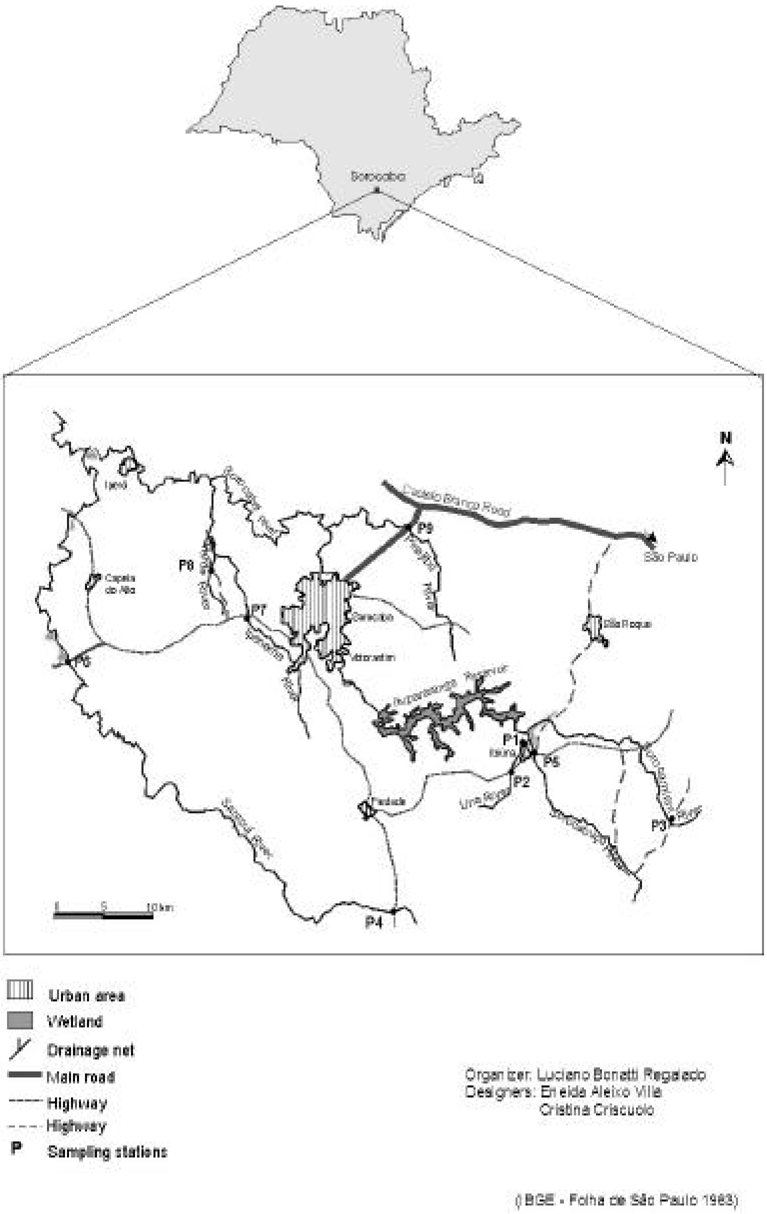


Figure 1: Location of study area and sampling stations.

Fish Catches

Fish catches were conducted at nine stations (Fig. 1), covering streams of the 2nd to 4th orders (Tab. I), distributed within the Sorocaba river basin during both dry and wet seasons (July-September 1999 and February-March 2000). Fish were collected in mesh gillnets (mesh, 3 to 12 cm between opposite knots) and strainers (to collect fish inhabiting shallow waters with dense submerged vegetation). Gillnets were set between 4:00 p.m. and 6:00 p.m. and maintained for a 12-hour minimum until the next morning. Collected fish were weighed, measured, and placed in small bags containing information on time caught, gear, and sampling station. They were immediately fixed in 10% formalin and stored in 70°GL alcohol. In the laboratory, fish were identified according to Britski et al., (1984), and confirmed by specialists of the Zoology Museum of the University of São Paulo (USP).

Table I: Sampling stations and their respective codes.

River	Station/stream order
Una Pt.2	1- 2nd
Una Pt.1	2- 2nd
Sorocamirim	3- 4th
Sarapuí. Pt.1	4- 4th
Sorocabuçu Pto.2	5- 4th
Sarapuí Pt.2	6- 4th
Ipanema	7- 4th
Verde	8- 3rd
Pirajibú Pto.2	9- 4th

Index of biotic integrity

The index of biotic integrity (IBI) proposed by Karr (1981) is adopted here as the well-being indicator of fish communities in the Sorocaba river basin. The community attributes included reflect structure and function at different trophic levels, so that the integrity classes have biological significance and sufficient sensitivity with respect to different perturbation sources.

Use of species richness and multivariate methods for analyzing biotic integrity is recommended when available data is restricted to species absence and presence (Ribeiro, 1994). When there are more complete samplings, the IBI should be modified in order to fit local situations. The present study follows modifications described by Ribeiro (1994), who established several criteria for (1) component selection (attributes); (2) attribution of weights to the components; (3) integration of components for estimating integrity levels to avoid repetition of mathematically inappropriate procedures for adding scores on an ordinal scale to obtain the overall average. Other modifications and adaptations were made based on study area characteristics.

Procedure for Determining a Biotic Integrity Index (IBI) Based on a Fish Community (Adapted from Ribeiro, 1994)

1.Selection of minimally impacted rivers in the basin under study. These areas shall serve as a reference for analyzing other areas for which an IBI is to be characterized.

2.Preparation of an integrity matrix containing only variables common to the reference area and the other areas under study.

3.Application of multivariate variance analysis (MANOVA) using variables of the biotic integrity matrix as the dependent variables, and later testing possible environmental influences on the community under study (univariate test). Examples of such influences are: river order, seasonality, water depth, number of tributaries, etc.

4.If a variable tested in the previous item yields a significant result ($p<0.05$) in the integrity matrix, new matrices are prepared considering this result. For example, if seasonality is found to be significant, separate analyses of the wet and dry periods would be required prior to preparing two new matrices.

5.Application of principal component analysis (PCA) to arrange hierarchically the indicators composing the integrity matrix (or matrices) obtained as a result of MANOVA and the univariate test.

6.Utilization of the scores reached by PCA to obtain clusters. Appropriateness of these clusters has to be checked using the cophenetic correlation coefficients. This step is necessary to verify similarity between reference area groups and areas under study. Some authors suggest as acceptable cophenetic index values greater than 0.8 (Legendre & Legendre, 1983).

7.Flow diagram or a decision tree containing the integrity classes is constructed using the distance matrix calculated from the PCA scores. This matrix helps in determining the range of distances corresponding to IBI classes (excellent, good, regular, bad, and worst).

Selection of minimally impacted areas (item 1 above) is made by analysis of biotic composition, which should include abundance of invertivorous species, top carnivorous species, species intolerant to pollution, and others (Karr, 1981; Steedman, 1988). In this regard, some guilds (intolerant and exotic species) are considered good indicators for biotic integrity evaluation (Ribeiro, 1994).

The Sorocaba river basin presents intense urban, industrial, and agricultural activity with few undisturbed areas to serve as references. Furthermore, no data sets exist and fish research is rare for the region. Therefore, we chose to use data from studies conducted in river basins in the region near the Sorocaba River, which also lies in the Paraná river basin (Gery, 1969). This choice is reasonable given that the dendritic pattern of streams in the reference areas chosen is similar to that in the Sorocaba river basin, and, therefore, probably has similar fish community composition, and, thus, is adequate for purposes of comparison.

Six reference areas (RA) were selected from three studies conducted within the last decade: a) two sampling stations in a study by Barrella (1989) of the biotic community of 2nd and 3rd order streams; b) a station included in Barrella (1998) representing 4th order streams; and c) three stations from a study by Smith (1999) for 3rd and 4th order streams.

After reference area selection, an integrity matrix containing information on species richness, diversity, trophic category, and tolerance or intolerance to water pollution (particularly to high concentrations of total and dissolved nutrients and low dissolved oxygen (DO) was generated. Intolerant species are those that disappear rapidly in response to environmental degradation due to urban and agricultural development, high suspended solids concentration, increase in water temperature, sediment siltation, and DO drop (Steedman, 1988; Karr et al., 1986 apud Ganasan & Hughes, 1998). Besides these factors, intolerant species include those that normally occur in places with good quality water and habitat structure. On the other hand, tolerant species proliferate in waters with low DO concentration, high organic pollution, sedimentation, high turbidity, and very degraded habitats in general (Ledesma-Ayala, 1987 apud Lyon et al., 1995). As few studies exist on eco-toxicology of Paraná river basin fish, it was necessary to adopt an alternative criterion for classifying fish species tolerance/intolerance to pollution.

Based on the studies of Barrella (1989, 1998) and Smith (1999), all species occurring in large abundance in locations not used as references, were classified as tolerant. The remaining species were, occurring in locations used as references, classified as intolerant to pollution.

As for trophic guilds, carnivores were considered top because they decline and disappear as water quality deteriorates (Karr, 1981). In order to complement trophic guild classification, omnivores abundance was used to detect decline of the representativeness of normal trophic guilds (those expected to be normal). These guilds are associated with availability of terrestrial and benthic invertebrates, which justifies the use of invertivorous species as stream degradation indicators. In general, samples with less than 20% of omnivorous individuals are considered representative of good water quality while those with 45% reflect degradation (Karr, 1981; Steedman, 1988). All procedures applying to the reference areas were also used for the species sampled at the various stations.

Data collected in this study were analyzed in various ways. Care was taken to apply the IBI in three different stream orders (2^{nd}, 3^{rd}, and 4^{th}) in both seasons studied. The multivariate of variance analysis (MANOVA) was applied using dependent variables from the biotic integrity matrix, and later separately testing the influence of stream order (factor one of MANOVA) and seasonality (factor two of MANOVA) on the community under study (Univariate Test). For the cluster analysis in step 6, we opted for the method of the unweighted pair-group method using averages (UPGMA) and mean Euclidean distance (MED), recommended by Romesburg (1984). This attributes similarity to pairs of groups in a less extreme manner than the other methods, besides permitting the use of any association coefficients (Ribeiro, 1994). The procedure of clustering and association results in a cophenetic matrix. A comparison between this matrix and the association matrix permits evaluation of the degree of distortion introduced by the original data analysis.

Finally, in order to construct the decision tree containing integrity classes, a distance matrix calculated from the PCA scores for factors 1 and 2, was employed, which explained more than 80% of the observed total variance. This ordination helped to evaluate the distances between reference and study areas with respect to the two PCA axes. Consequently, the integrity classes could be identified, for each sampling station, of the 2^{nd}, 3^{rd}, and 4^{th} order streams for both wet and dry seasons.

Results

A total of thirty four species were caught in the Sorocaba River (List 1), distributed among five orders, three sub-orders, fourteen families, and seven sub-families. The families Anostomidae and Characidae presented greater richness (six and seven species, respectively), whereas greater abundance of individuals captured during the study period, occurred in the families Characidae, Curimatidae, Loricariidae, and Callichthyidae.

Integrity matrices of reference and study areas (Tab. II) were prepared using abundance, species richness, Shannon's diversity index, and abundance and richness of species tolerant and intolerant to water pollution, besides trophic categories classified as omnivores, invertivorous, predators (top), and detritivores. Effects of seasonality and stream order factors were tested on MANOVA with an acceptance probability (p) of 5%. Both seasonality and river orders were not significant ($p= 0.725$ and $p=0.07$), respectively. Despite this result, we decided to analyze biotic integrity matrices according to the similarity between river orders because spatial distribution of fishes is strongly influenced by longitudinal variation in river characteristics: "The branching of dendritic drainages into many tributaries of varying sizes offer much heterogeneity of habitat and could increase the number of species occurring in the watershed" (Matthews, 1998).

The PCA was performed using individual stream order matrices in order to pinpoint the variables determining biotic integrity classification for each order (2^{nd} , 3^{rd}, and 4^{th} orders; Tab. III). In the case of 2^{nd} order streams, the first two components together explained 91% of the total variance of observed data. Variables contributing most to forming the first component were the Shannon diversity index, abundance and total richness of tolerant and intolerant species, besides the abundance of detritivores and omnivores (all with loadings greater than 0.7). For 3^{rd} order streams, the first two components explained 88% of the total variance of all variables with the exception of abundance of omnivores, all of which were correlated with loadings greater than 0.7, and were correlated with community organization and health, as in the previous case. For 4th order streams, 85% of variance was explained by the first two components. Again, all variables, except % of tolerant species, were correlated with the first component. Therefore, this result supports the characteristics revealed in the cases of 2nd and 3rd order streams.

List 1: List of fish species in the study region

Order CHARACIFORMES **Sub order CHARACHOIDEI**	
Family ERYTHRINIDAE	Hoplias malabaricus
Sub family SALMINIDAE	Salminus hilarii
Family CURIMATIDAE	Cyphocharax modesta Steindachnerina insculpta
Family PROCHILODONTIDAE	Prochilodus cf. lineatus
Family ANOSTOMIDAE	Leporinus cf. friderici Leporinus lacustris Leporinus sp. Leporinus cf. microcephalus Leporinus obtusidens Schizodon nasutus
Family CHARACIDAE Sub family TETRAGONOPTERINAE	Astyanax fasciatus Astyanax altiparanae Astyanax cf. eigenmanniorum Oligossarcus paranaensis Oligossarcus cf. pintoi
Sub Family ACESTRORHYNCHINAE Sub family TRIPORTHEINAE	Acestrorhynchus lacustris Triportheus sp.
Family SERRASALMIDAE Sub family SERRASALMINAE	Serrasalmus spilopleura
Family PARODONTIDAE	Apareiodon cf. affinis
Order SILURIFORMES Sub order SILUROIDEI	
Family CALLICHTHYIDAE	Hoplosternum littorale Corydoras aeneus
Family LORICARIIDAE	Hypostomus sp1 Hypostomus sp2 Hypostomus ancistroides
Family PIMELODIDAE Sub family PIMELODINAE	Pimelodus maculatus Pimelodella sp. Rhamdia quelen
Sub family SORUBIMINAE	Iheringichthys labrosus
Order GYMNOTIFORMES Sub order GYMNOTOIDEI	
Family GYMNOTIDAE	Gymnotus sp.
Family POECILIIDAE	Phalloceros caudimaculatus Poecilia vivipara
Order CYPRINIFORMES	
Family CYPRINIDAE	Cyprinus carpio
Super order ACANTHOPTERIGII Order PERCIFORMES	
Family CICHLIDAE	Geophagus brasiliensis

Table II: Integrity of reference and study areas (Ord.—stream order (S= dry period and C= wet period), Abun—total individual abundance, Riq—species richness, Diver—Shannon Diversity Index, Tol (N)—richness of tolerant species; Into (N)—richness of intolerant species, Tol %—abundance of tolerant species, Into %—abundance of intolerant species, Oni—abundance of omnivorous species; Inv—abundance of invertivorous species, Pred—abundance of predator species, Det—abundance of detritivorous species.

Stations	**Ord**	**Abun**	**Riq**	**Diver**	**Tol (N)**	**Into (N)**	**Tol %**	**Into%**	**Oni**	**Inv**	**Pred**	**Det**
Reference Areas 1	2	374	18	2.34	14	4	78	22	33	39	6	22
RA2	3	149	14	2.18	10	4	71	29	50	43	0	7
RA3	3	142	12	1.82	9	3	75	25	25	8	25	42
RA4	4	110	19	2.17	14	5	74	26	32	16	21	31
RA5	4	147	13	2.15	12	1	92	8	23	0	23	54
RA6	4	61	10	1.91	8	2	80	20	10	20	30	40
P1 (S)	2	55	9	1.64	7	2	78	22	22	34	22	22
P1 (C)	2	181	12	1.88	10	2	83	17	33	25	25	17
P2 (S)	2	106	6	1.24	5	1	83	17	50	17	33	0
P2 (C)	2	11	2	0.3	2	0	100	0	50	50	0	0
P3 (C)	4	115	10	1.46	9	1	90	10	30	20	30	20
P4 (S)	4	9	4	1.21	4	0	100	0	50	0	25	25
P4 (C)	4	4	1	0	1	0	100	0	100	0	0	0
P5 (S)	4	58	4	1.31	2	2	50	50	50	0	25	25
P5 (C)	4	160	14	2.01	11	3	79	21	43	21	14	21
P6 (S)	4	151	13	2.09	11	2	85	15	23	0	31	46
P6 (C)	4	99	13	1.86	10	3	77	23	31	15	23	31
P7 (S)	4	430	13	1.68	9	4	70	30	23	15	23	39
P7 (C)	4	133	13	2.03	11	2	85	15	31	8	23	38
P8 (S)	3	12	6	1.58	6	0	100	0	33	0	33	33
P8 (C)	3	95	7	1.31	7	0	100	0	43	0	14	43

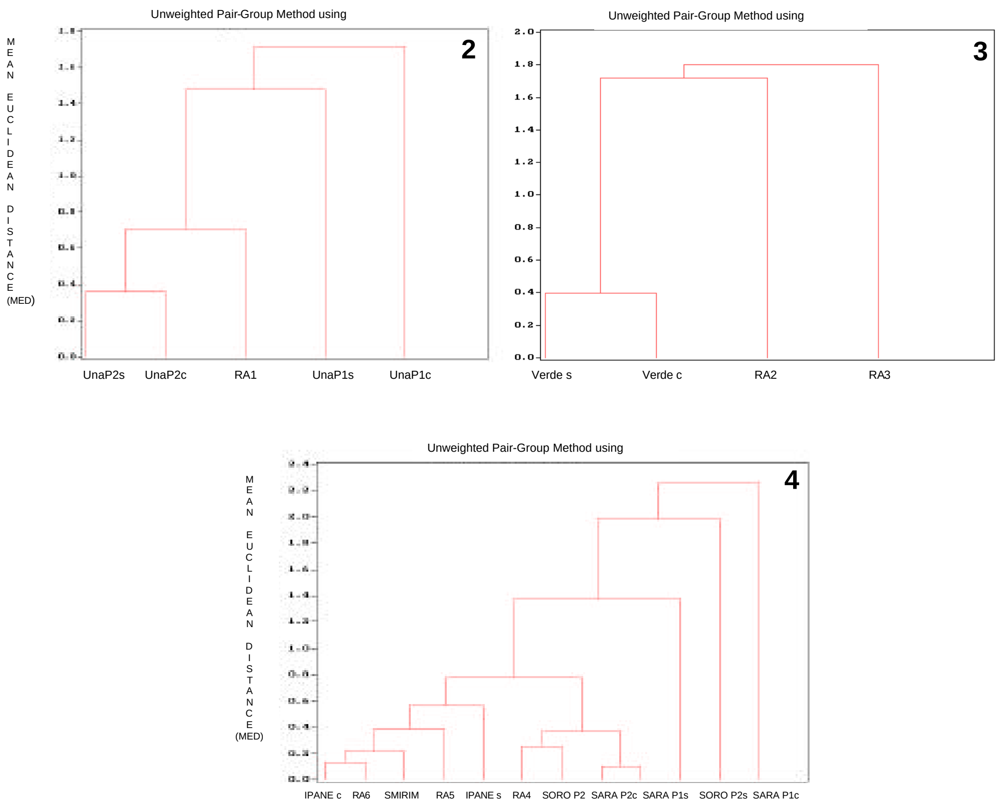
Table III: Results of principal component analysis for the stream groups.

SELECTED VARIABLES	**Component loading (2nd order streams)**		**Component loading (3rd order streams)**		**Component loading (4th order streams)**	
	Comp 1	Comp 2	Comp 1	Comp 2	Comp 1	Comp 2
Diversity of species	0.998	-0.005	0.855	0.096	0.954	0.185
% of tolerant species	-0.956	0.136	-0.956	-0.260	-0.466	0.860
Number of intolerant species	0.954	0.235	0.965	0.244	0.799	-0.412
% of intolerant species	0.951	-0.249	0.936	0.340	0.736	-0.665
Total richness of species	0.950	0.214	0.976	0.194	0.904	0.198
Number of tolerant species	0.939	0.215	0.925	0.165	0.837	0.396
Total abundance	0.905	-0.115	0.728	0.110	0.913	-0.072
Abundance of detritivores	0.834	0.469	-0.733	0.558	0.880	0.251
Abundance of omnivores	-0.709	-0.385	0.308	-0.900	-0.868	-0.276
Abundance of predators	0.587	-0.756	-0.789	0.592	0.794	0.173
Abundance of invertivores	-0.413	0.905	0.930	-0.165		
% of variance explained	73	18	72	16	68	17
Total	91		88		85	

*OBS: Results of PCA for 4th order streams with invertivores abundance excluded

Patterns of similarity between sampling stations (for each order) were sought in cluster analysis of the scores of mean Euclidean distance (MED) and UPGMA used as linkage (Fig. 2 to 4).

From the MED calculation, results for the two PCA factors associated to the interpretation of these axes together with the cluster analysis, the decision tree could be constructed containing the levels of biotic integrity for 2nd , 3rd, and 4th order streams.



Figures 2-4: Cluster of PCA scores to 2nd order rivers (rc=0.9062); Cluster of PCA to 3rd order rivers (rc=0.9747); Cluster of PCA scores to 4th order rivers (rc=0.9340).

An examination of the distance matrices for the various stream orders helped to establish the distance ranges between reference areas and stations sampled in this study. This allowed classification of all sampling stations into the following categories: excellent, good, regular, bad, and worst, as shown in Tab. IV.

Table IV: Classification of Water sampling stations according to biotic integrity.

Water sampling stations (river)	**Stream order**	**Winter biotic integrity level (Dry season)**	**Summer biotic integrity level (Rainy season)**
Una 2	2nd order	Excellent (5)	Good (4)
Una 1	2nd order	Regular (3)	Bad (2)
Verde	3rd order	Good (4)	Good (4)
Ipanema	4th order	Good (4)	Excellent (5)
Sorocamirim	4th order	Missing data	Good (4)
Sarapuí 1	4th order	Regular (3)	Bad (2)
Sarapuí 2	4th order	Excellent (5)	Excellent (5)
Sorocabuçu 2	4th order	Regular (3)	Good (4)

The Una River (sampling stations 1 and 2) showed a decrease in IBI during the wet season when compared to the dry. The same result was observed for station 1 in the Sarapuí River. However, the Ipanema and Sorocabuçu rivers showed an opposite change, with IBI increasing from the dry to the wet season. The Verde and Sarapuí sampling stations showed the same IBI for both seasons.

Discussion

The Pirajibú River deserves special mention, as it produced no catch of fish of any species (indicates grave toxicity problem unidentified in the study), although nutrient concentrations were within acceptable limits as established by the state environmental agency (CETESB, 1998).

With respect to fish communities and their relation to the environment (Kuehne, 1962; Harrel & Dorris, 1968 and Platts, 1979) a direct relationship is expected between fish diversity and stream orders in view of different environmental fluctuation degrees or availability and community utilization of the habitat (Barila et al., 1981). In the Sorocaba river basin, this clearly did not occur, with 4th order streams showing smaller diversity than that of 2nd order streams. The lower diversity indices may have resulted from methodological problems in sampling or environmental stresses. Lower diversity and abundance of individuals was attributed (Osborne et al, 1979) to occurrence of ferric hydroxide deposits in the river heads streams. In all areas in the river basin, stream buffers were observed to be degraded or even to have been destroyed to accommodate agriculture. Comparative studies (Karr et al., 1985) have shown a strong influence of agriculture and urban land use on diversity of fish and other river biota, in addition to the effects of biogeography, competition, predation, physical disturbances, and other factors (Crowder, 1990). The IBI decrease for stations one Una and Sarapuí rivers may be due to organic loads discharged by adjoining cities as well as to allochthonous materials or runoffs carrying organic fertilizers.

The rare occurrence or complete absence of intolerant species and of invertivorous species from some sampling stations indicate the altered state of the study areas. Substitution of sensitive species by those more tolerant of environmental disturbances frequently occurs in response to stress situations (Scott et al., 1986).

During the classification of the sampling stations, large amplitudes variations in the matrices were observed, showing distance between reference and study areas of 3rd and 4th order rivers. These variations may be due to structural differences in the physical habitat such as width and depth of the stream channel, substrate type, and current velocity, which were not measured.

It should be noted that in São Paulo State, there are few hydrographic basins in undisturbed pristine condition, i.e., undisturbed in the structural patterns of biotic communities and physical habitats expected in any sustainable habitat, thus making it difficult to evaluate index of biotic integrity. A possible alternative to reference areas would be simulation models that would admit a wide range of variation within the reference areas, and thus lead to a better basis for constructing decision trees and acceptable levels of biotic diversity.

Conclusions

This ecological and ichthyological study was conducted on a seven tributaries of the Sorocaba River and covered three geomorphological orders. The objective was to characterize the encountered habitats by an index of biotic integrity (IBI) and to provide relevant ecological information for this basin. Eleven variables with respected to fish community health and social organization were observed to compose the IBI for analyzing the aquatic habitats under study, for the purpose of detecting impacts community structure. The results showed health and organization of fish communities to be the most important

IBI variables in the 2nd, 3rd, and 4th order streams. In general, the Sorocaba river basin presented an altered state with respect to the fish community standards established within the 1990s, which indicates degradation in the system. The degradation, made clear by the IBI, in some rivers of the Sorocaba river basin may be traced to buffer zone vegetation degradation and to the increased nutrient loads on the river system. This situation may lead to extinction of some native fish species.

Although studies on fish communities help to evaluate biotic integrity, some precautions are necessary. In analyzing various stream orders, availability of reference areas should be considered. From the conservation point of view, studies of physical and chemical parameters in monitoring programs are necessary, in addition to measures aimed at controlling land use so that water resources can be efficiently managed.

Acknowledgments

The authors would like to thank The National Council for Scientific and Technological Development (CNPq), technicians of Water Resources Center and Applied Ecology (CRHEA), from the Engineering School of São Carlos (USP), and of the Brazilian Institute of Geography and Statistics (IBGE) – Brasilia.

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Received: 25 August 2003
Accepted: 11 June 2004