

Diversity of the ichthyofauna in the Serra do Mar State Park- Núcleo Santa Virgínia, São Paulo State, Brazil

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ABSTRACT. The aim of this work was to assess and compare the diversity of the ichthyofauna in three headwater rivers of Paraíba-do-Sul basin in the Serra do Mar State Park, Núcleo Santa Virgínia. A total of 1,774 specimens of 16 species of fishes belonging to 6 families were caught. Characiformes were the most abundant fish at all three sites, followed by Cyprinodontiformes, Siluriformes, and Perciformes. The Shannon index (H'), evenness (E), and the Jaccard and Morisita-Horn similarity indexes were low, indicating both low diversity and low similarity of species among the three streams. The values of these indexes should be evaluated according to the biotic and abiotic conditions in each environment. It is clear that in mountain streams of the Atlantic Forest, these low values occur because of the presence of a few abundant and many rare species.

Key words: diversity, similarity, fish, Atlantic Forest, Brazil.

RESUMO. Diversidade da ictiofauna no Parque Estadual da Serra do Mar-Núcleo Santa Virgínia, Estado de São Paulo, Brasil. O objetivo deste trabalho foi o de apresentar a diversidade da ictiofauna de três rios de cabeceira da bacia do Paraíba-do-Sul no Parque Estadual da Serra do Mar, Núcleo Santa Virgínia, caracterizando assim as similaridades ictiofaunísticas entre os diferentes locais. Foram capturados 1.774 exemplares de 16 espécies de peixes pertencentes a seis famílias. Os Characiformes foram os peixes mais abundantes nas capturas dos três locais, seguidos por Cyprinodontiformes, Siluriformes e Perciformes. O índice de Shannon (H'), a equitabilidade (E) e os índices de similaridade de Jaccard e de Morisita-Horn foram baixos, mostrando assim a baixa diversidade e similaridade de espécies entre estes locais. Estes valores devem ser avaliados de acordo com as condições bióticas e abióticas preponderantes em cada ambiente, ficando claro que em riachos de encosta da Mata Atlântica isto ocorre devido à ocorrência de algumas espécies abundantes e de muitas espécies raras.

Palavras-chave: diversidade, similaridade, peixes, Mata Atlântica, Brasil.

Introduction

The Atlantic Forest is invariably considered one of the most important areas of biodiversity on Earth. Its fauna is composed of a few, exceptionally abundant species, and many species with only a few individuals (Tonhasca Jr., 2005).

As in most South American hydrographic basins, little is known of the ichthyofauna of the Atlantic Forest. Although it represents a mosaic, the composition of the ichthyofauna is influenced by environmental factors intrinsic to the region (Buckup, 2003). The main aspect of this fauna is its high degree of endemism, resulting from the historical evolution of the species in an area which remained geomorphologically isolated from the other Brazilian hydrographic basins (Menezes, 2003).

In the higher parts, naturally protected by the

altitude, the headwater regions support low diversity and high endemism of fishes. Because of this, these regions are biologically important and their exploration should be a priority (Castro and Menezes, 2001; Menezes, 2003; Benedito-Cecilio *et al.*, 2004).

The Neotropical region contains 4,475 species of freshwater fishes (Reis *et al.*, 2003). 261 species are found in São Paulo State, where the Siluriformes comprise 53%, Characiformes 35%, Gymnotiformes 4%, Cyprinodontiformes 15%, and Perciformes 3% (Castro and Menezes, 2001). The fish diversity is distributed in several aquatic environment types, but mainly in small streams and headwaters (Langeani *et al.*, 2005). The freshwater fish fauna in Brazilian streams includes 34 families of teleost fishes (Buckup, 1999), of which the dominant phyletic lineages are the orders Characiformes and Siluriformes (Castro, 1999).

The Paraíba-do-Sul basin supports 22 families and 166 species of freshwater fishes (Castro and Menezes, 2001). This hydrographic system demonstrates a high degree of endemism (Ribeiro, 2006) although it has suffered impacts since the region was first occupied in the colonial period, and it has become the most densely populated and industrialized region in the country (Hilsdorf and Petrere Jr., 2002).

The biodiversity of the streams is altered by habitat degradation (pollution and deforestation of the riparian areas), by the presence of reservoirs with consequent regulation of streamflows, and also by overfishing (Dudgeon, 2000). The destruction of the Atlantic Forest is one of the principal factors in the elimination of species of fishes, as well as the introduction of species, and urban and industrial development (Buckup, 2003). The protective role of the forest is especially important along the watercourses, where erosion more easily causes silting. In addition to maintaining the soil structure, these gallery, ciliary, or riparian forests absorb and recycle nutrients and function as biological filters, preserving water quality and promoting the biodiversity of rivers and lakes (Tonhasca Jr., 2005).

In the present work, the diversity of three headwater rivers of the Paraíba-do-Sul basin in Serra do Mar State Park- Núcleo Santa Virgínia was assessed, characterizing the ichthyofaunal similarities among the different streams and the constancy of occurrence of the fish species.

Material and methods

A total of 12 samples were taken monthly from January to December 2004. Each sample period lasted four days. Three sites in the Paraíba-do-Sul basin were selected: the Paraibuna, Ipiranga, and Grande rivers. The rivers are typical hillside streams, which have riparian forest, pools and riffles, bed sediments of sand, gravel or rock, and clear shallow water. Sites are located within the Santa Virgínia Unit of the Serra do Mar State Park (23° 24' and 23° 17' South, 45° 03' West), municipality of São Luís do Paraitinga, São Paulo State, Brazil.

At each sample point, individuals were collected with gill nets with mesh sizes of 1.5; 2.0; 2.5; 3.0; 3.5, and 4.0 cm, measured between adjacent knots (10 m long and 1.5 m high), and totalizing 60 m. In addition to the nets, sieves (10 passages per site), and traps (three per site) were also used. Fish effort was standardized, keeping constant sampling time and the quantity of instruments employed at each point.

To identify fish species, contacts were made with expert on fish groups. Voucher specimens are

deposited in the Department of Zoology of the Universidade Estadual Paulista (Unesp), *campus* of Rio Claro, State of São Paulo.

Each species was classified according to constancy of occurrence (*c*), as: constant, when $c \geq 50\%$; accessory, when $25 < c < 50\%$; and accidental when $c \leq 25\%$ (Dajoz, 1983).

Diversity was calculated through the Shannon index (Magurran, 1991) for each sample point. This index assumes that each individual is sampled by chance from an indefinite large population and that all species are represented in the sample. The index (H') is given by:

$$H' = - \sum p_i \cdot \ln p_i$$

The sum p_i is the proportion of individuals found among these species. The equitability can also be calculated (Magurran, 1991), thus showing the abundance of species at each point. The equitability (E) is given by: $E = H'/\ln S$, where: H' : Shannon index; S : total number of species. The closer to 1, the greater will be the similarity among species abundances, and if the value reaches 1, the species abundances will be equal.

Besides this index, the Jaccard similarity index, which takes into account the presence or absence of the species, and the Morisita-Horn index, which also takes into account the species abundances, were used (Magurran, 1991).

The Jaccard index is used to compare species similarities between two sites. This index is given by: $C_j = J/(a+b-j)$, where: j : number of species found in both sites; a : number of species registered at site A; b : number of species registered at site B. This index assumes that if the calculated value equals 1, there is total similarity of species between both sites, and if the value is zero, there is no similarity. Estimated values of Jaccard's index lower than 0.60 indicate a substantial difference in the presence or absence of species (Rahel, 1990).

The use of the Morisita-Horn index is independent of sample size and species diversity (Wolda, 1981). This index is given by:

$$C_{M-H} = \frac{2 \sum (a_{ni} \cdot b_{ni})}{(da + db) aN \cdot bN}; \quad da = \frac{\sum a_{ni}^2}{aN^2} \quad e \quad db = \frac{\sum b_{ni}^2}{bN^2}$$

were:

aN : total number of individuals at site A; bN : total number of individuals at site B; a_{ni} : number of individuals of species (i) at site A; b_{ni} : number of individuals of species (i) at site B. Morisita-Horn indexes below 0.50 indicate low similarities in the

relative abundances of species, whereas indexes above 0.75 indicate high similarities (Matthews, 1986).

Results

A total of 1,774 specimens belonging to 16 species and six families were captured and analyzed. *Astyanax* cf. *scabripinnis* *paranae*, *Phalloceros* sp., and *Brycon opalinus* were the species most often caught. At Point 1 (the Paraibuna River), 11 species were caught, 5 of them exclusive to this site: *Geophagus brasiliensis*, *Astyanax bimaculatus*, *Astyanax parahybae*, *Oreochromis* cf. *niloticus*, and *Cichlasoma facetum*. At Point 2 (the Ipiranga River), 6 species were caught, of which only *Trichomycterus* sp.2 was exclusive to that site. At Point 3 (the Grande River), 10 species were caught, four of which were exclusive: *Neoplecostomus microps*, *Pareiorhina* sp., *Harttia carvalhoi*, and *Trichomycterus* sp.1. In respect to constancy of occurrence, only *Brycon opalinus* was constant for all three sites. The Paraibuna River had 6 constant species (*B. opalinus*, *Oligosarcus hepsetus*, *A. bimaculatus*, *A. parahybae*, *Rhamdia quelen*, and *P. caudimaculatus*), 1 accessory, and 4 accidental species; the Ipiranga River had 2 constant species (*B. opalinus* and *Hemipsilichthys* sp.), 2 accessories, and 2 accidentals; and the Grande River had 5 constant species (*B. opalinus*, *Astyanax* cf. *scabripinnis* *paranae*, *Oligosarcus hepsetus*, *Rhamdia quelen*, and *Phalloceros* sp.), 1 accessory, and 4 accidental species (Table 1).

Table 1. Species captured and their occurrences at each sample site (1. Paraibuna River, 2. Ipiranga River, and 3. Grande River), and their constancy of occurrence.

Family	Species	N	1	2	3
Characidae	<i>Brycon opalinus</i> (Cuvier, 1819)	266	117c	116c	33c
Characidae	<i>Astyanax</i> cf. <i>scabripinnis</i> <i>paranae</i> (Eigenmann, 1914)	850	01ad	02ad	847c
Characidae	<i>Oligosarcus hepsetus</i> (Cuvier, 1829)	169	48c	03ac	118c
Characidae	<i>Astyanax bimaculatus</i> Linnaeus, 1758	19	19c		
Characidae	<i>Astyanax parahybae</i> (Eigenmann, 1908)	13	13c		
Pimelodidae	<i>Rhamdia quelen</i> (Quoy and Gaimard, 1824)	79	36c	04ac	39c
Loricariidae	<i>Hemipsilichthys</i> sp.	47	01ad	30c	16ac
Loricariidae	<i>Neoplecostomus microps</i> (Steidachner, 1877)	03		03ad	
Loricariidae	<i>Pareiorhina</i> sp.	02			02ad
Loricariidae	<i>Harttia carvalhoi</i> (Miranda-Ribeiro, 1939)	01			01ad
Trichomycteridae	<i>Trichomycterus</i> sp.1.	01			01ad
Trichomycteridae	<i>Trichomycterus</i> sp.2.	01		01ad	
Cichlidae	<i>Geophagus brasiliensis</i> (Quoy and Gaimard, 1824)	12	12ac		
Cichlidae	<i>Oreochromis</i> cf. <i>niloticus</i> Linnaeus, 1758	01	01ad		
Cichlidae	<i>Cichlasoma facetum</i> (Jenyns, 1842)	01	01ad		
Poeciliidae	<i>Phalloceros</i> sp. (Hensel, 1868)	309	135c		174c

c = constant; ac = accessory; ad = accidentals

The cumulative captures of species showed that during the course of the samples the number of species increased until the last three samples (October, November, and December), when the number of species remained constant (Figure 1).

The highest number of individuals caught occurred in the Grande River in the September and October collections, which were composed

principally of *A. cf. scabripinnis paranae*. In the Paraibuna River, the highest catch occurred in May and in the Ipiranga River in March (Figure 2).

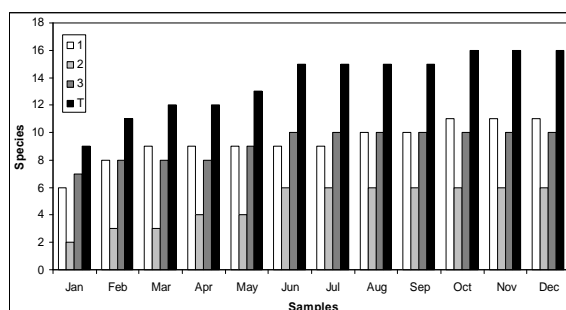


Figure 1. Cumulative captures of species at each sample site (1. Paraibuna River, 2. Ipiranga River, and 3. Grande River) and T. total.

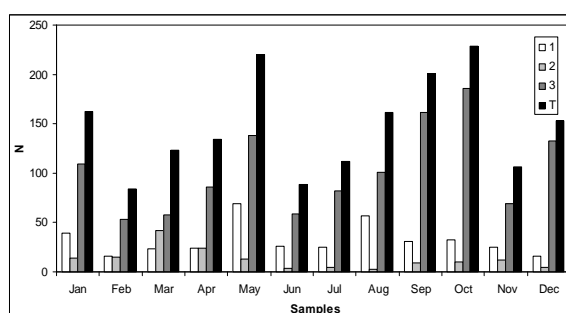


Figure 2. Number of individuals sampled at each site (1. Paraibuna River, 2. Ipiranga River, and 3. Grande River) and T. total.

Characiformes were the most abundant fishes in all three streams, followed by Cyprinodontiformes, Siluriformes, and Perciformes (Figure 3).

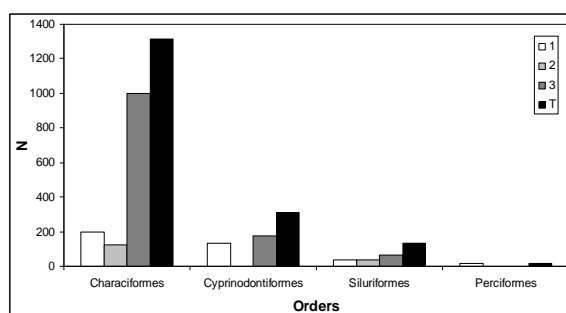


Figure 3. Numeric frequency of Orders of species captured at each sample site (1. Paraibuna River, 2. Ipiranga River, and 3. Grande River) and T. total.

The Shannon index (H') and evenness (E) were relatively low. Both diversity and evenness were highest in the Paraibuna River. Diversity was higher in the Grande River than in the Ipiranga (Figure 4).

The Jaccard and Morisita-Horn similarity indexes were always lower than 0.6, reflecting the low species similarity among the sites. Jaccard's

index indicated that similarity was highest between the Paraibuna and Ipiranga rivers and between the Ipiranga and Grande rivers. The Morisita-Horn index between the Paraibuna and Ipiranga rivers was above 0.50, indicating that the relative abundances among species were similar (Figure 5).

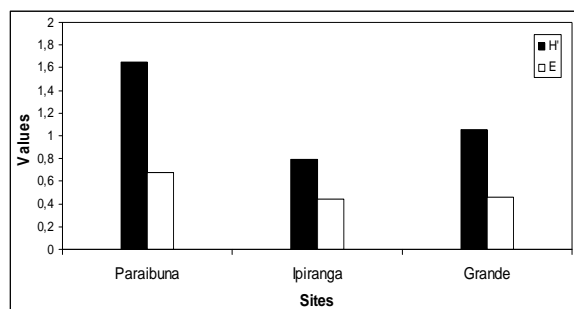


Figure 4. Shannon diversity index (H') and equitability (E) at each sample site.

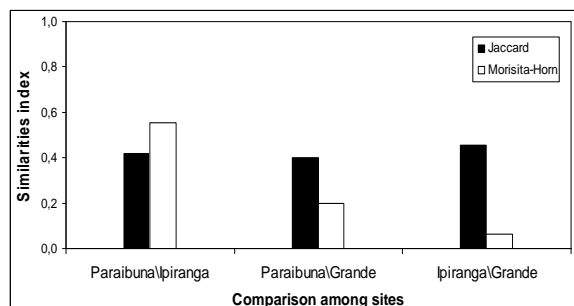


Figure 5. Jaccard and Morisita-Horn similarities index for all the sites.

Discussion

In general, species richness in freshwater and marine environments declines with increasing latitude, depth, and altitude (Wootton, 1992). In addition to these factors, diversity can be influenced by the number of predators (Paine, 1966), by the gradient of increase in habitats from the headwaters toward the mouth (Sheldon, 1968; Peres-Neto *et al.*, 1995; Uieda and Barreto, 1999), and with the food and anti-predation requirements of the species (Mazzoni and Iglesias-Rios, 2002).

The sampled rivers show the same abiotic and biotic patterns of most streams in the East Basin (Sabino, 2003). Some species were abundant and constant in the majority of samples. However, most species were present in low abundance and appeared in only a few samples. The indexes of diversity of all three sites were relatively low due to the occurrence of a few abundant species and many rare species.

The cumulative captures of species showed that no species were added in the last sample, which may

indicate that the fishing equipment used was efficient for sampling the ichthyofauna in these sites.

In hillside areas of the Serra da Mantiqueira (Atlantic Forest), Braga (2004) collected 17 species by electroshocking; a high proportion of these species were relatively few in numbers. Mazzoni and Lobón-Cerviá (2000) collected 18 species in one river of the Serra do Mar. These numbers are quite close to that obtained in the study area (16), and thus indicate the similarities of these environments and the general characteristics of occupation of these niches.

Mountain streams are fragile environments, and support small populations in terms of numbers of species and abundance of individuals (Braga and Andrade, 2005). Areas on steeper slopes and nearer the headwaters support low diversity and species richness, with high levels dominance and endemism (Buckup, 1999; Uieda and Barreto, 1999).

Biodiversity is much used to quantify the ecological status of different biotopes (Izsák and Papp, 2000). Because of this, low values of diversity and similarity must be carefully analyzed and related to the biotic and abiotic conditions in each environment.

Species diversity in tropical areas depends on small periodic disturbances. The populations are normally small, and human disturbance, such as deforestation and pollution, can cause many species extinctions (Connell, 1978). In the Ombrophile Forest (Atlantic Forest), climate conditions vary little and there is practically no dry season, principally because of the buffer effect of the ocean (Tonhasca Jr., 2005). In these hillside environments, periodic high flows after the rains can cause the environmental variables which determine the abundance, occurrence, and adaptations of the fish species.

The Characiformes were the most abundant fishes in our collections from all three rivers, their small size conforming to the general pattern for stream fishes (Castro, 1999).

According to Bizerril (1994), the ichthyofauna in the East Basin is composed of 49.2% Siluriformes, 37.7% Characiformes, 4.9% Cyprinodontiformes, 4.9% Cichlidae, and 1.7% Gymnotidae. However, this author verified predominance of the Characiformes in his area of study, probably because the catches were made along the riverbanks, and the Siluriformes are typical of deeper waters. The same occurred during our samples, which were always made near the streambanks, in clear shallow water.

The family Characidae comprises 170 genera and 885 species, which are not exclusive to streams.

However, their members generally form the principal group of mid-water species, in contrast to the benthic catfishes (Buckup, 1999). The most abundant species in our collections was *Astyanax scabripinnis*, a typical fish of headwaters, but which also occurs in river stretches farther downstream (Castro, 1999; Uieda and Barreto, 1999). Other examples of characids were *Oligosarcus hepsetus*, which is endemic to the Coast Central region (Menezes, 1988 apud Buckup, 1999), and *Brycon opalinus*, also endemic to this basin (Hilsdorf and Petrere Jr., 2002) and presently threatened with extinction (Machado *et al.*, 2005).

According to Buckup (1999), the pimelodids include some stream species, being those adapted to life in torrent environments, where they live hidden among pebbles during the day. The trichomycterids include 155 species of 36 genera; the nonparasitic species are characteristic of mountain streams, where they generally occur buried in the sand and gravel of the riffles. The Loricariidae is the largest family of the Siluriformes, with about 550 species of 80 genera, representing an important component of the stream ichthyofauna. The Poeciliidae includes 293 species of 30 genera. They are very common in the coastal-plain streams, and their habitats range from marshes and small ponds to streams of the planalto (interior highlands). The density of poeciliids is related to the open areas of pools (Mazzoni and Iglesias-Rios, 2002). The family Cichlidae is also well represented in the streams of all regions of Brazil (Buckup, 1999).

Representatives of the family Cichlidae are usually introduced, purposely or not, into natural environments, in many cases causing irreversible damage (Gomiero and Braga, 2004). In the Paraíba River one generalist African cichlid, *Oreochromis cf. niloticus*, occurs. It may have arrived from pay-fishing ponds, and may potentially cause damage to the site ichthyofauna.

In the Paraíba-do-Sul basin, additional introduced species are found. The inadvisable practice of introducing species may have contributed to the reduction and even disappearance of local species (Hilsdorf and Petrere Jr., 2002). Problems with exotic species and habitat destruction are the principal causes of the growing number of threatened species (Tonhasca Jr., 2005).

Conclusion

The values of Shannon index (H'), evenness (E), and the Jaccard and Morisita-Horn similarity indexes were low in present study. These indexes should be evaluated according to the biotic and

abiotic conditions in each environment. It is clear that in mountain streams of the Atlantic Forest, these low values occur because of the presence of a few abundant and many rare species.

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