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Ichthyofauna of Rio Jurubatuba, Santos, São Paulo: a high diversity refuge in impacted lands

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Abstract: Ichthyofaunistic surveys in the Atlantic Rainforest have been published in relatively few works, in spite of the major biological importance of this once vast biome which is rapidly vanishing due to disordered human population growth and natural resources overexploitation. The present study aimed to access the fish fauna of a relatively well preserved basin between the cities of Santos and Cubatão (SP), an area highly modified by human activities where recent ichthyofaunistic surveys are still missing. Collections were made during three field trips in Rio Jurubatuba, a medium sized costal river, and Riacho Sabão, one of its main tributaries. A total of 2773 specimens were sampled, representing 25 species from 14 families. Six species were primary marine using the upper reaches of Rio Jurubatuba. Twelve of the 19 freshwater species are endemic of the Atlantic Rainforest and four are present in regional lists of endangered species. Only five species occurred in both Rio Jurubatuba and Riacho Sabão. The most diverse family was Characidae, followed by Poeciliidae, Rivulidae and Heptapteridae. *Phalloceros caudimaculatus* was the most abundant species, followed by *Poecilia vivipara* and *Geophagus brasiliensis*. The study area is considered well preserved and due to its critical location, urges for conservation policies to protect its fish diversity.

Keywords: Atlantic Rainforest, conservation, endangered species, endemism, stream fishes.

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Resumo: Levantamentos ictiofaunísticos na Mata Atlântica tem sido publicados em relativamente poucos trabalhos, apesar da grande importância biológica deste bioma que, mais vasto no passado, vem rapidamente desaparecendo por causa do crescimento desordenado das populações humanas e super exploração dos recursos naturais. O presente estudo objetivou acessar a fauna de peixes de uma bacia relativamente bem conservada entre as cidades de Santos e Cubatão (SP), uma área muito alterada pela atividade humana e carente de levantamentos ictiofaunísticos recentes. Coletas foram realizadas durante três campanhas no Rio Jurubatuba, um rio costeiro de médio porte, e no Riacho Sabão, um de seus afluentes. Foram amostrados 2773 indivíduos pertencentes a 25 espécies de 14 famílias. Seis espécies são primariamente marinhas e utilizam a porção mais alta do Rio Jurubatuba. Doze das 19 espécies de água doce são endêmicas da Mata Atlântica e quatro estão relacionadas em listas regionais de espécies ameaçadas. Apenas cinco espécies ocorreram no Rio Jurubatuba e Riacho Sabão concomitantemente. A família mais diversa foi Characidae, seguida de Poeciliidae, Rivulidae e Heptapteridae. *Phalloceros caudimaculatus* foi a espécie mais abundante, seguida de *Poecilia vivipara* e *Geophagus brasiliensis*. A área de estudo é considerada bem preservada e por causa de sua localização crítica, necessita de políticas conservacionistas para proteger sua diversidade de peixes.

Palavras-chave: Mata Atlântica, conservação, espécies ameaçadas, endemismo, peixes de riacho.

Introduction

Fishes constitute more than one half of the vertebrate diversity, with around 28.000 species and estimates pointing to more than 32.000 in total. Approximately 12.000 species, 43% of the whole fish diversity, live exclusively in freshwater environments which, on their turn, represent 1% of the surface of the Earth (Nelson 2006). The Neotropical Region is known to harbour the richest freshwater fish fauna in the world (Géry 1969, Böhlke et al. 1978, Lowe-McConnell 1999) but knowledge regarding its real diversity is far from completed (Vari & Malabarba 1998).

The Atlantic Rainforest is one of the richest biomes in the Neotropical Region mainly due to the variety of habitats throughout the range of the forest, which originally covered a wide stripe of coastal Brazil from Piauí to Rio Grande do Sul States. This includes a span of almost 30° of latitude distributed in a rather hilly terrain, crossed by several independent hydrological drainages flowing to the Atlantic Ocean, known as the Eastern Basins (Géry 1969, Bizerril 1994, Sazima 2004, Menezes et al. 2007).

Despite of not being vastly explored from an ichthyofaunistic point of view, the Atlantic Rainforest is known to possess a fish fauna characterized by a high level of endemism (Bizerril 1994, Mazzoni & Lobón-Cerviá 2000, Sazima 2004, Menezes et al. 2007). The high number of endemic fish species in the coastal rivers of the Atlantic Forest is an aggravating factor in respect to the conservation policies of these areas as this biome is located in the most populated regions of the country, making these rivers especially vulnerable to anthropogenic impacts (Bizerril 1994, Mazzoni & Lobón-Cerviá 2000, Gerhard et al. 2004, Menezes et al. 2007).

Different aspects of the biology of a few fish species from the Atlantic Rainforest coastal streams have been approached in the literature, such as their reproduction (e.g. Menezes & Caramaschi 1994, Aranha & Caramaschi 1999, Mazzoni & Iglesias-Rios 2002a, 2007, Mazzoni et al. 2002, 2005, Mazzoni & Silva, 2006 Vitule et al. 2007, 2008a, Braga et al. 2008), feeding habits (e.g. Aranha & Caramaschi 1999, Aranha et al. 2000, Vitule & Aranha 2002, Mazzoni & Rezende 2003, Rezende & Mazoni 2003, 2006, Barreto & Aranha 2006, Leitão et al. 2007, Mazzoni & Costa 2007, Vitule et al. 2008b), population structure (e.g. Braga et al. 2007) and spatial distribution (e.g. Aranha & Caramaschi 1997, Menezes & Caramaschi 2000, Mazzoni & Iglesias-Rios 2002b, Mazzoni et al. 2004). Besides these studies, an important volume was published around ten years ago (Caramaschi et al. 1999) which included seminal papers regarding the origin and evolution of this ichthyofauna (Castro 1999), aspects of its historical biogeography (Buckup 1999), trophic structure (Esteves & Aranha 1999) and fish production (Mazzoni 1999), among others. Nevertheless, studies aiming to survey the ichthyofauna of certain portions of the biome and produce list of species in the Atlantic Forest coastal streams are still not as common as they should be given the accelerating process of environmental degradation influencing these watersheds.

This unique system represents a highly threatened environment whose ichthyofauna was not frequently explored by ecological studies focusing on the whole fauna, yielding a still poor knowledge of its stream fishes (Castro & Menezes 1998, Vilella et al. 2004, Menezes et al. 2007, Serra et al. 2007). Detailed publications regarding fish communities of the Atlantic Rainforest include basins from the states of Bahia, Rio de Janeiro, São Paulo, Paraná and Rio Grande do Sul (Costa 1987, Buck & Sazima 1995, Araújo 1996, Aranha et al. 1998, Mazzoni & Lobón-Cerviá 2000, Esteves & Lobón-Cerviá 2001, Fogaça et al. 2003, Vilella et al. 2004, Barreto & Aranha 2005, Mazzoni et al. 2006, Ribeiro et al. 2006, Sarmiento-Soares et al. 2007, 2008, 2009, Serra et al. 2007, Abilhoa & Bastos 2009). In the State of

São Paulo, ichthyofaunistic surveys were conducted more oftenly in the far north and southern regions of its range, including small streams in Ubatuba, Juréia-Itatins Ecological Station and Rio Ribeira de Iguape basin (Sabino & Castro 1990, Uieda, V.S. & Uieda, W. 2001, Sabino & Silva 2004, Oyakawa et al. 2006), leaving a lack in the knowledge regarding the vast central portion, highly impacted by human activities. The cities of Santos, one of the oldests human settlements in Brazil, and Cubatão, a highly polluted city due to its various industries operating since the early XX century, are located in the middle of this vast area. The survey presented herein is an attempt to increase our knowledge on the ichthyofauna of this region by presenting a list of species sampled in a rather well preserved river basin located in the municipality of Santos near its border with Cubatão and kept by the Santa Casa de Misericórdia de Santos.

1. Study area

The area around Santos is characterized by a wet tropical weather, with rains reaching 2.200 mm.year⁻¹ and concentrated during summer, but a distinct dry season is not evidenced. Temperatures are warm throughout the year, but a cooler weather is found during winter from June to August (Sant'Anna Neto & Nery 2005). The Atlantic Rainforest of this region is set upon a cristaline terrain with granite-gnaissic outcrops whose slopes advance towards the coast line and form a mountain chain approximately 800 m tall delimiting a relatively broad coastal plain (Villwock et al. 2005). Although many different vegetal domains are present in the Atlantic Forest, the study area is included in a Dense Ombrophilous Forest region (Ávila 2004).

Rio Jurubatuba (23° 51' 50" S and 46° 17' 51" W) is a typical Atlantic Forest river, with upper reaches located in the Parque Estadual da Serra do Mar in the coastal slopes forming the Serra do Mar. It flows from the mountain chain through a steep portion forming waterfalls and rapids on a rocky bottom gathered to form the main river. Its medium portion crosses a less steep terrain and covers a wider area where sampling efforts were focused. Some smaller streams enter Rio Jurubatuba along its medium portion, and efforts were also concentrated on its largest tributary, Riacho Sabão. The lower portion of Rio Jurubatuba reaches a large estuary receiving waters from several other drainages and is located between the coastal slopes with its jungle and the coast line occupied by part of the city of Santos (Figure 1).

The sampled area in Rio Jurubatuba (Figure 2) is approximately one meter deep in average and 10-15 m wide. Bottom is covered by rocks and large stones near its upper reaches and gradually covered by sand and sparse stones towards the estuarine portion. Riparian vegetation and macrophyte benches are abundant along the studied area. Some anostomosed channels with muddy bottoms are formed along the river, originating small islands and sandbanks. The portion studied was influenced by tidal fluctuations, with tidal ranges of approximately 1.5 meter per 6-hours cycle and a salt wedge detected by its warm temperature around half meter deep in a few collections.

Riacho Sabão (Figure 3) is one of the main tributaries of Rio Jurubatuba within the studied area. It is a course of water also coming from the coastal slopes of the Serra do Mar flowing through a river bend of rocks and stones. In the coastal plain, its slope is nearly flat, with low energy and sandy bottom. Much vegetal debris composes the landscape and large amounts of dead leaves gather along its curves. The stream is quite long and meanders through the plain until it reaches Rio Jurubatuba. Some areas are shallow with more water flow and approximately 50 cm deep while others are more than one meter deep and form natural pools. The stream average width is around 1-3 m, with some portions being less wide and fitting deeper in the terrain. Several small tributary channels a few centimeters deep flow into Riacho Sabão and some of them were

Fishes of Rio Jurubatuba, Santos, SP



Figure 1. Map of the region of Santos and Cubatão, southeastern coast of Brazil, State of São Paulo, with main cities and hydrographic features. Shaded areas represent urbanized centers. Larger arrow indicates area of study in Rio Jurubatuba and smaller arrow indicates approximate location of Riacho Sabão.

Figura 1. Mapa da região de Santos e Cubatão, costa sudeste do Brasil, Estado de São Paulo, com principais cidades e características hidrográficas. Áreas sombreadas representam centros urbanizados. A seta maior indica a área de estudo no Rio Jurubatuba e a seta menor indica localização aproximada do Riacho Sabão.



Figure 2. Aspects of Rio Jurubatuba, Santos, São Paulo. a) rapids near the upper reaches; b) rocky bottom portion; c) lateral channel with muddy bottom and stones; and d) sandy bottom portion with marginal vegetation.

Figura 2. Aspectos do Rio Jurubatuba, Santos, São Paulo. a) corredeiras próximas às cabeceiras; b) trecho com fundo de pedras; c) canal lateral com fundo lodoso e pedras; e d) trecho com fundo de areia e vegetação marginal.



Figure 3. Aspects of Riacho Sabão, Santos, São Paulo. a) rapids in the upper reaches; b) sandy bottom portion; c) pools with bottom covered by leaves and tree trunks; and d) area with dense riparian forest.

Figura 3. Aspectos do Riacho Sabão, Santos, São Paulo. a) região da cabeceira encachoeirada; b) região com fundo de areia; c) poções em remansos com fundo de folhagem e troncos; and d) áreas com vegetação ripária densa.

completely dry trenches in part of the year. Marginal vegetation is dense along most portions of the stream, which is partly obstructed by fallen tree trunks in several spots.

Materials and Methods

Three field trips were taken, each lasting five days, in March, October and December of 2007. Both water bodies, Rio Jurubatuba and its tributary Riacho Sabão, were sampled with nine sampling units each (three units in each river per month). Each sampling unit in Rio Jurubatuba was represented by an active search of four hours using two hand nets circa of half a square meter in area and a trawl seine of 3×1 m and 5 mm of internode distance. This part of the sampling unit was carried out by two persons during the daytime, who traded between hand nets and trawl seine aiming to explore the environment as a whole.

Each unit was complemented by three gill nets measuring 10, 10 and 15 m in length and with 25 mm of internode distance in the former and 50 mm of internode in the latter two, which operated during a 12 hour period during the night. The hand nets and trawl seine were used in the exact same manner for each sampling unit in Riacho Sabão. Due to its natural characteristics, however, gill nets were not used in this rather small stream, substituted by three fish traps baited with commercial dog and cat food operating during a 12 hour period.

Sampled fishes were collected and fixed in 4% formalin for 72 hours, transferred to 70% ethanol, identified and counted. Identifications followed the works of Britski (1972), Géry (1977), Figueiredo & Menezes (1978, 1980), Menezes & Figueiredo (1985), Barletta & Corrêa (1992) and Menezes et al. (2007). Classification of species follows Menezes et al. (2003), Nelson (2006) and Buckup et al. (2007). Samples were deposited

Table 1. Classification of species sampled in Rio Jurubatuba (JUR) and Riacho Sabão (SAB), Santos, SP, with total number of individuals from each species sampled in the whole study, including the Frequency of Occurrence (%) of each species. One asterisk after name indicates Atlantic Rainforest endemic species and three asterisks indicate primary marine species.

Tabela 1. Classificação das espécies amostradas no Rio Jurubatuba (JUR) e Riacho Sabão (SAB), Santos, SP, com número total de indivíduos de cada espécie amostrados no estudo como um todo e Frequência de Ocorrência (%) de cada espécie. Um asterisco após o nome indica espécie endêmica de Mata Atlântica e três asteriscos indicam espécies primariamente marinhas.

Taxon	March 2007		October 2007		December 2007		Total	%
	JUR	SAB	JUR	SAB	JUR	SAB		
Characiformes								
CHARACIDAE: <i>Astyanax taeniatus</i> (Jenyns, 1848) *	12	10	-	52	24	11	109	83.4
<i>Hollandichthys multifasciatus</i> (Eigenmann & Norris, 1900) *	-	10	-	22	-	6	38	50.0
<i>Hyphessobrycon bifasciatus</i> Ellis, 1911 *	4	-	7	-	6	-	17	50.0
<i>Hyphessobrycon griemi</i> Hoedeman, 1957 *	20	-	30	-	2	-	52	50.0
<i>Oligosarcus hepsetus</i> (Cuvier, 1829) *	3	-	-	-	-	-	3	16.7
ERYTHRINIDAE : <i>Hoplias malabaricus</i> (Bloch, 1794)	-	-	1	-	-	-	1	16.7
Siluriformes								
LORICARIIDAE: <i>Schizolecis guntheri</i> (Miranda Ribeiro, 1918) *	-	25	-	83	-	65	173	50.0
HEPTAPTERIDAE: <i>Acentronichthys leptos</i> Eigenmann & Eigenmann, 1889*	-	3	-	4	-	1	8	50.0
<i>Rhamdia quelen</i> (Quoy & Gaimard, 1824)	-	-	-	2	-	1	3	33.4
<i>Rhamdioglanis transfasciatus</i> Miranda Ribeiro, 1908 *	-	1	-	4	-	1	6	50.0
ARIIDAE: <i>Genidens genidens</i> (Cuvier, 1829) ***	1	-	-	-	-	-	1	16.7
Gymnotiformes								
GYMNOTIDAE: <i>Gymnotus pantherinus</i> (Steindachner, 1908)*	-	2	-	4	-	5	11	50.0
Cyprinodontiformes								
RIVULIDAE: <i>Kryptolebias caudomarginatus</i> (Seegers, 1984) *	9	-	9	-	8	-	26	50.0
<i>Kryptolebias ocellatus</i> (Hensel, 1868)	-	-	3	-	-	-	3	16.7
<i>Rivulus santensis</i> Köhler, 1906 *	-	1	-	-	3	-	4	33.4
POECILIIDAE: <i>Phalloceros caudimaculatus</i> (Hensel, 1868)	105	25	658	73	517	86	1464	100.0
<i>Phalloptychus januarius</i> (Hensel, 1868) *	39	11	83	-	106	-	239	66.7
<i>Poecilia vivipara</i> Bloch & Schneider, 1801	19	-	52	-	207	-	278	50.0
Gasterosteiformes								
SYNGNATHIDAE: <i>Microphis lineatus</i> (Kaup, 1856) ***	-	-	5	-	-	-	5	16.7
<i>Pseudophallus mindii</i> (Meek & Hildebrand, 1923) ***	20	-	17	-	10	-	47	50.0
Synbranchiformes								
SYNBRANCHIDAE: <i>Synbranchus marmoratus</i> Bloch, 1795	-	1	-	-	-	-	1	16.7
Perciformes								
CENTROPOMIDAE: <i>Centropomus parallelus</i> Poey, 1860 ***	24	-	2	-	1	-	27	50.0
CICHLIDAE: <i>Geophagus brasiliensis</i> (Quoy & Gaimard, 1824)	98	-	65	5	76	-	244	66.7
ELEOTRIDAE: <i>Dormitator maculatus</i> (Bloch, 1792) ***	3	-	1	-	3	-	7	50.0
GOBIIDAE: <i>Awaous tajasica</i> Lichtenstein, 1822 ***	3	-	-	-	3	-	6	33.4

in the ichthyological collection of Museu de Zoologia da Universidade de São Paulo (MZUSP).

Simple fauna descriptors were calculated based on measures suggested by Magurran (1996) for this kind of ecological survey, namely the Margalef Diversity Index, Simpson Dominance Index and Jaccard Similarity between the two sampled rivers. Besides these indices, the Frequency of Occurrence Index (Sabino & Castro 1990) was also calculated for each species. In order to know if the collecting effort was enough to survey the ichthyofauna in the Rio Jurubatuba system, sample-based rarefaction curves were produced (Gotelli & Colwell 2001, Colwell et al. 2004) considering Rio Jurubatuba and Riacho Sabão both as a whole and as separate units, with the use of the software EstimateS 7.5 (Colwell 2005). As mentioned above, each site was sampled with three collecting units per month, resulting in nine collecting units for each stream for the entire period.

Results and Discussion

The list of species recorded in the Rio Jurubatuba system is presented in Table 1. A total of 2773 individuals were sampled, representing 25 species, 14 families and seven orders. The best represented orders in number of species were Cyprinodontiformes and Characiformes, followed by Siluriformes. The most diverse family was Characidae, followed by the cyprinodontiforms Poeciliidae and Rivulidae and the siluriform Heptapteridae. The most abundant species was the poeciliid *Phalloceros caudimaculatus*, followed by *Poecilia vivipara* and the cichlid *Geophagus brasiliensis*. *P. caudimaculatus* was the only species to occur in 100% of the sample units, followed in frequency of occurrence by *Astyanax taeniatatus*,

Phalloptychus januarius and *G. brasiliensis*. Six species showed low relative frequency of occurrence (16.7%), each only sampled once throughout the survey: *Hoplias malabaricus*, *Oligosarcus hepsetus*, *Genidens genidens*, *Kryptolebias ocellatus*, *Microphis lineatus* and *Synbranchus marmoratus* (Table 1). Six species (two characids, two poeciliids and two primary marine species) are illustrated in Figure 4.

Even after three field trips aiming to survey the ichthyofauna of Rio Jurubatuba system, the collector's curve for the whole area (Figure 5) shows just a little tendency towards an asymptote. The same can be said if Rio Jurubatuba and Riacho Sabão are considered separately (Figure 6), specially in regard to Rio Jurubatuba, which is both more diverse and unknown than its tributary Riacho Sabão. It is evident hence that although the ichthyofauna of this portion of Rio Jurubatuba can now be considered relatively known, further sampling efforts may increase this already enriched list of species.

The species richness registered in the Rio Jurubatuba system was relatively high with 25 species from 14 families. Excluding the primary marine fishes, 19 freshwater species from nine families were sampled. Studies conducted in similar systems in the Atlantic Rainforest accounted 15-26 freshwater species from 11 families (Costa 1987, Aranha et al. 1998, Mazzoni & Lobón-Cerviá 2000, Esteves & Lobón-Cerviá 2001, Vilella et al. 2004, Sarmento-Soares



Figure 4. Six of the species sampled in the present study, most of them observed exclusively in Rio Jurubatuba (except for *P. januarius*). All photos taken from aquarium a few hours after capture. a,b,f) Photos by Samuel E. Betkoviski and c,d,e) photos by Martha Lange. a) *Hyphessobrycon bifasciatus*; b) *H. griemi*; c) *Phalloptychus januarius*, female above, male below; d) *Poecilia vivipara*, male; e) *Microphis lineatus*; and f) *Dormitator maculatus*.

Figura 4. Seis das espécies amostradas no presente estudo, quase todas observadas exclusivamente no Rio Jurubatuba (com exceção de *P. januarius*). Todas as fotos obtidas em aquário algumas horas após a captura. a,b,f) Fotos de Samuel E. Betkoviski e c,d,e) fotos de Martha Lange. a) *Hyphessobrycon bifasciatus*; b) *H. griemi*; c) *Phalloptychus januarius*, fêmea acima, macho abaixo; d) *Poecilia vivipara*, macho; e) *Microphis lineatus*; e f) *Dormitator maculatus*.

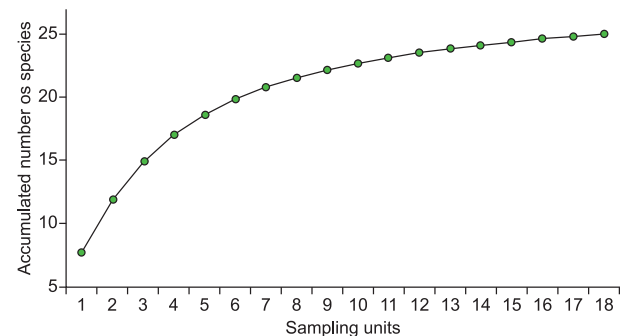


Figure 5. Sample-based rarefaction curve for samples from the whole studied area, Santos, SP.

Figura 5. Curva de rarefação baseada em amostragem para as coletas realizadas na área estudada, Santos, SP.

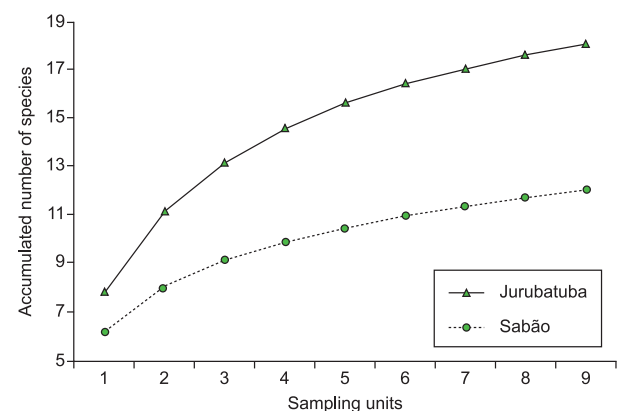


Figure 6. Sample-based rarefaction curves for samples from Rio Jurubatuba and Riacho Sabão considered separately, Santos, SP.

Figura 6. Curvas de rarefação baseada em amostragem para as coletas realizadas no Rio Jurubatuba e no Riacho Sabão consideradas separadamente, Santos, SP.

et al. 2007). Characiformes, Siluriformes and Cyprinodontiformes, the most diverse and dominant fish groups in South American freshwaters (Lowe McConnell 1999) were the most representative of the present study. It is worth highlighting the family Characidae, the most diverse in the present study, which holds great importance in streams of the Atlantic Rainforest (Menezes et al. 2007). The Margalef Diversity Index calculated for the whole study area was 3.15, while this value was 2.33 and 1.76 in Rio Jurubatuba and Riacho Sabão, respectively, when these streams are considered separately. These values are in accordance to what Gerhard et al. (2004) registered for the Rio Ribeira de Iguape system, with their highest value (3.14) obtained in the Rio Iporanga watershed.

The Simpson Dominance Index values were 0.31 for the whole area and 0.37 and 0.27 for Rio Jurubatuba and Riacho Sabão alone, respectively. In spite of the rather large population of *Phalloceros caudimaculatus* that apparently dominated the present study, other five species also accounted for high number of individuals in the samples (circa of 100-300 individuals each), although not as abundantly as *P. caudimaculatus*. There are seven other species following in number of individuals, with 10-55 specimens sampled each. Twelve species had less than ten specimens sampled, being *Hoplias malabaricus*, *Genidens genidens* and *Synbranchus marmoratus* the only species represented by a single individual sampled in the whole study. When both streams are considered separately, Rio Jurubatuba presented a higher dominance index value than Riacho Sabão, mainly reflecting the large population of *P. caudimaculatus* in that river. In Riacho Sabão, on the other hand, the sizes of the sampled populations of *P. caudimaculatus* and *Schizolecis guntheri* are similar, the two being the most abundant species in this stream.

In the spatial context, Rio Jurubatuba presented higher number of species and abundance of individuals (18 and 2259, respectively) than its tributary, Riacho Sabão (12 and 514, respectively). In Rio Jurubatuba, the most abundant species were *Phalloceros caudimaculatus*, *Poecilia vivipara* and *Geophagus brasiliensis*. Six primary marine species were registered in Rio Jurubatuba: the marine catfish *Genidens genidens*, the pipe-fishes *Microphis lineatus* and *Pseudophallus mindii*, the gobiid *Awaous tajassica*, the eleotrid *Dormitor maculatus* and the snook *Centropomus paralellus* (Table 1). They are all typically estuarine species that use the upper freshwater reaches in parts of their life cycles benefiting from the salt wedge formed from time to time (Figueiredo & Menezes 1978, 1980, Menezes & Figueiredo 1985). Riacho Sabão had no primary marine fishes, with the most abundant species being *P. caudimaculatus*, *Schizolecis guntheri* and *Astyanax taeniatus*. Both Rio Jurubatuba and Riacho Sabão had seven freshwater species sampled exclusively in each area. Among the 25 species sampled, only five occurred in both Rio Jurubatuba and Riacho Sabão: *A. taeniatus*, *P. caudimaculatus*, *Phalloptychus januarius*, *Rivulus santensis* and *G. brasiliensis*. This was responsible for the low value in Jaccard Similarity Index calculated between both rivers: 0.20.

The distribution of species in the seasonal context revealed groups of species exclusive of a given period (Table 1). *Oligosarcus hepsetus*, *Genidens genidens* and *Synbranchus marmoratus* were only sampled in March, a transition between the rainy summer and beginning of fall, while *Hoplias malabaricus*, *Kryptolebias ocellatus* and *Microphis lineatus* were found exclusively in October, during spring time. It should be noted, however, that the seasonal pattern described above involves species with low abundance which may be naturally more difficult to sample and, therefore, must be used with caution when associated with a given pattern. Expansions of populations were also related to season. *Phalloptychus januarius* and *Geophagus brasiliensis*, two of the most common species in Rio Jurubatuba, were only sampled in the tributary Riacho Sabão in

March, being restricted to the larger river in the remaining sampled periods. It is also worth noticing the abundance fluctuation of the three poeciliids. *Phalloceros caudimaculatus*, the dominant species in this study, shows a prominent increase in number of individuals sampled in October, which may indicate that the spawning season for this species is somewhere between March and October. As for *Phalloptychus januarius* and *Poecilia vivipara*, both species show a gradual increase in number of individuals culminating in high values in December. This increase was a little more pronounced in *P. vivipara* than in *P. januarius*. Live-bearers poeciliids such as these (especially *P. caudimaculatus* and *P. vivipara*) are commonly known to adopt r-strategies in their life-cycles, which can be related to their dominant nature in many streams of the Neotropical region. The same was detected in the Rio Jurubatuba system.

Twelve out of the 19 freshwater species sampled in the present study are endemic of the Atlantic Rainforest, a rather large proportion of the whole diversity registered. It is outstanding that all sampled Characidae species, for instance, are restricted to these coastal drainages. Almost all Siluriformes sampled are also endemic of the Atlantic Rainforest. This well illustrates the high endemism of fishes in this biome pointed out by many authors (Bizerril 1994, Mazzoni & Lobón-Cerviá 2000, Sabino & Silva 2004, Sazima 2004, Oyakawa et al. 2006, Menezes et al. 2007). Besides the high endemism of the ichthyofauna in the study area, four species are listed as vulnerable or in danger in local lists, including *Hollandichthys multifasciatus* (Rio Grande do Sul), *Acentronichthys leptos* (Rio de Janeiro and Espírito Santo), *Kryptolebias caudomarginatus* and *K. ocellatus* (both in Rio de Janeiro) (Buckup et al. 2007).

Historically, the coastal rivers of São Paulo State were explored by the first naturalists to set foot in the region. This is reflected in the description of some species based on material collected from these areas that grants them the status of type-localities. *Hollandichthys multifasciatus*, for instance, was first described in 1900 from coastal streams in Cubatão. *Gymnotus pantherinus* and *Rivulus santensis* were both described from coastal streams of Santos (Menezes et al. 2007). This represents the great historical importance of these areas, and measures to protect them are strongly recommended.

The study area includes a high amount of endemic species (two-thirds of the freshwater fishes) and four species listed as vulnerable in regional lists. Allied to these facts is the geographic location of the study area, which is in the vicinities of a major industrial pole and one of the oldest cities in Brazil. These stand as good enough reasons to implement conservation measures to the study area as soon as possible, as it represents an island of diversity in a nearly deserted land.

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