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Fish distribution in watersheds of the eastern part of the Serra da Mantiqueira (state of São Paulo)

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Abstract

The present work aims to analyse jointly four contiguous watersheds in the eastern part of the Serra da Mantiqueira with respect to the distribution of fish fauna and physical structure. The watersheds of Piracuama river, Ribeirão Grande, Buenos and Guaratinguetá are located in Pindamonhangaba, Campos do Jordão and Guaratinguetá municipalities, in the state of São Paulo. Data were collected between the years 2001 and 2010, with collections distributed throughout the seasons, including sites located on the slope and piedmont. The limnological parameters analysed were different between watersheds and habitat structure was different only for the slope segments between Ribeirão Grande and Buenos watersheds, and between Ribeirão Grande and Piracuama watersheds. Thirty-five species of fish were caught, with the highest species richness found in the Ribeirão Grande watershed (30 species), followed by the Piracuama (23 species) and Buenos and Guaratinguetá (21 species each). The most abundant species in both the segments (slope and piedmont) was *Trichomycterus itatiayae*. The highest degree of species dominance occurred in the Guaratinguetá watershed and in the segment slope, being *T. itatiayae* the dominant species. Species diversity was lower at the slope than the piedmont, indicating variability in species abundance. Again *T. itatiayae* was the most abundant species in both segments, showing to be a well adapted species to these streams systems by presenting, as well as other species, morphological adaptations to the stream environment.

Keywords: icthyofauna, species diversity, altitudinal gradient.

Distribuição de peixes em microbacias da serra da Mantiqueira oriental (Estado de São Paulo)

Resumo

O presente trabalho tem por objetivo analisar conjuntamente quatro microbacias contíguas na serra da Mantiqueira oriental com respeito à distribuição da ictiofauna e estrutura física. As microbacias do rio Piracuama, do Ribeirão Grande, do ribeirão dos Buenos e do rio Guaratinguetá situam-se nos municípios de Pindamonhangaba, Campos do Jordão e Guaratinguetá, no estado de São Paulo. Os dados foram coletados entre os anos de 2001 e 2010, sendo as coletas distribuídas ao longo das estações e contemplando pontos localizados na encosta e no pediplano. Os parâmetros limnológicos analisados foram diferentes entre as microbacias e a estrutura de habitat foi diferente apenas para os segmentos de encosta entre as microbacias do Ribeirão Grande e Buenos, e entre Ribeirão Grande e Piracuama. Trinta e cinco espécies de peixes foram capturadas, sendo a maior riqueza de espécies encontrada na microbacia do Ribeirão Grande (30 espécies), seguida pela do rio Piracuama (23 espécies) e dos Buenos e Guaratinguetá (21 espécies cada). A espécie mais abundante tanto na encosta como pediplano foi *Trichomycterus itatiayae*. O maior grau de dominância de espécies ocorreu na microbacia do Guaratinguetá e no segmento de encosta, sendo *T. itatiayae* a espécie dominante. A diversidade de espécies para encosta foi inferior à do pediplano, indicando variabilidade na abundância das espécies. Novamente *T. itatiayae* foi a espécie mais abundante nos dois segmentos, espécie bem adaptada a esses sistemas de riachos por apresentar, assim como outras espécies, adaptações morfológicas ao ambiente de riachos torrentosos.

Palavras-chave: ictiofauna, diversidade de espécies, gradiente altitudinal.

1. Introduction

The Serra do Mar and Serra da Mantiqueira complex was formed from the reactivation of ancient faults in the early Tertiary (Petri and Fúlfaro, 1983). These faults formed the *graben* of the Paraíba Valley in the Oligocene-Miocene, an extensive sedimentation plain that gave rise to a large lake, that drained, formed the Paraiba do Sul river (Moraes, 1945).

The Serra da Mantiqueira is located between the states of São Paulo, Minas Gerais and Rio de Janeiro, being a watershed for the basins of the Paraiba do Sul river and Grande river. According to Ponçano et al. (1981), the Serra da Mantiqueira is comprised of two sections: mountains in the east and west, which have distinct geological features. The mountains of the eastern Mantiqueira comprise the Itatiaia massif (RJ) and plateau of Campos do Jordão (SP), extending to the locality of Monteiro Lobato (SP). This part of the mountains is characterised by elevations above 1,900 m in Campos do Jordão and 2,400 m in the highlands of Itatiaia. The face for the state of Minas Gerais constitutes the *mar de morros* (Ab'Sáber, 1966) while the side facing the Paraíba Valley is formed by steep cliffs and rugged formations (Ponçano et al., 1981). The Serra da Mantiqueira continues northeast towards Poços de Caldas presenting less steep topography and lower altitudes.

In the plateau region of Campos do Jordão, from the slopes to the Paraíba Valley, Hueck (1972) identified several forest formations associated with altitude and rainfall. However, such vegetation is now restricted to only some areas as a result of deforestation that started in the nineteenth century as a result of coffee planting (Dean, 1996), and today from the expansion of grazing and urbanisation.

From the eastern slopes of the mountains of the Serra da Mantiqueira that face the Paraíba Valley, numerous streams will empty into the left bank of the Paraíba do Sul river. These streams form systems that are separated by ridges of hills. This relief is of recent configuration, resulting from seismic tremors that occurred between 10 thousand and three thousand years ago (Clapperton, 1993; Modenesi-Gauttieri et al., 2002). Braga (2004) defined these different river systems, separated by ridges of the hill, as watersheds. Over the past few years, several watersheds have been studied with a focus on fish fauna, resulting in works on distribution (Braga, 2004; Braga, 2005a; Braga and Andrade, 2005; Ingenito and Buckup, 2007; Rondineli et al., 2011), feeding (Braga, 2005b; Braga and Gomiero, 2009), and population biology (Braga et al., 2007; Braga et al., 2009).

The present work aims to analyse jointly four contiguous watersheds in the eastern part of the Serra da Mantiqueira in relation to the distribution of fish fauna and their physical structure.

2. Material and Methods

2.1. Study area

The watersheds studied are situated on the slopes of the eastern part of the Serra da Mantiqueira in the municipalities of Pindamonhangaba, Campos do Jordão and Guaratinguetá, in the state of São Paulo. The watersheds of Piracuama (164.43 km^2), Ribeirão Grande (133.76 km^2), Buenos (84.31 km^2) and Guaratinguetá (162.31 km^2) are distributed from west to east (Figure 1).

The local relief can be summarised in four configurations: plateau, hillslope, piedmont and valley. The plateau is

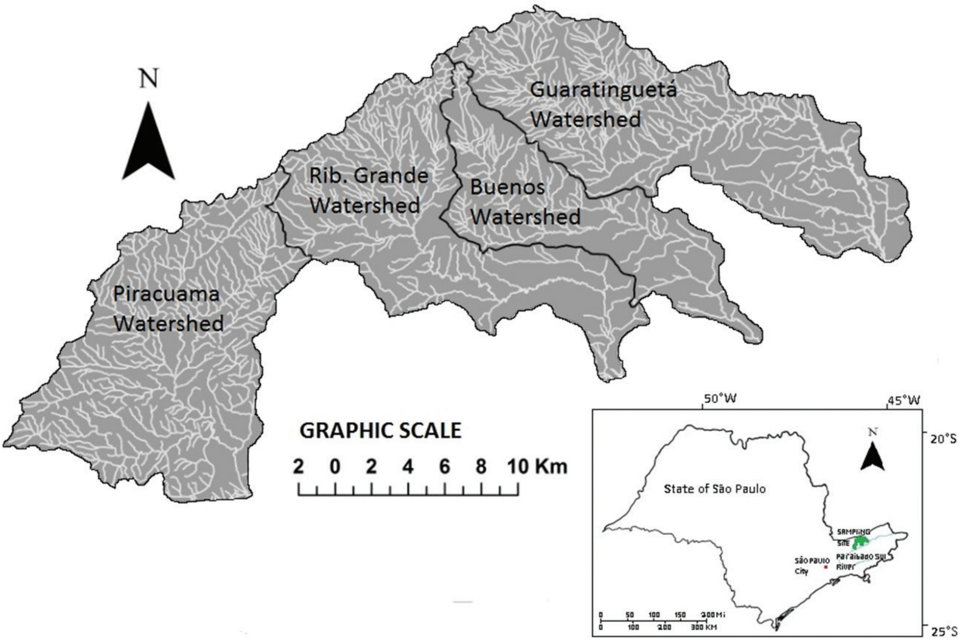

Figure 1. Watershed sites in the eastern parts of the Serra da Mantiqueira, state of São Paulo.

located at the top of the slopes, at altitudes between 1,900 and 1,700 m, with the characteristic landscape of high mountain grasslands, wetlands and floodplains (Modenesi-Gauttieri et al., 2002). The streams that form the watersheds have their sources in these areas of wetlands. The hillslope is located between 1,700 and 800 m, being generally steep and rugged. In the higher parts, where the humidity is higher, *mata de neblina* occurs, which is replaced in the lower parts by *mata pluvial* (Hueck, 1972). At the base of the hilllslope in the transition area to the plain of the valley, at an altitude of 800-600 m, piedmont occurs, an ecotone area characterised by flat hills and currently being taken over by agricultural areas. The next configuration is the plain of the Paraiba Valley, situated around 500 m altitude. This region is densely populated, but relicts of semi-dry forests of Paraíba Valley still remain in some places.

2.2. Data collection

The data were collected in 2001 and 2002, in streams of the Ribeirão Grande watershed (Braga and Andrade, 2005), in the years of 2008 and 2009, in streams of the Buenos and Guaratinguetá watersheds (Rondineli, 2010), and in the years of 2009 and 2010 in streams of the Piracuama watershed (Carmassi, 2012). The samples were distributed over the years during the spring, summer, autumn and winter (Table 1).

Each sampling lasted five days. Every stream in each watershed was sampled using an electric fishing machine, which produced a direct electric current from 300 to 500 V and 8.7 A. The sampling was made in a stretch of 50 metres with just one repetition. The specimens collected were placed in 10% formalin in the laboratory and transferred to 70% alcohol, identified and quantified.

At each sampling site and during each sampling period data were obtained for the physical and chemical variables of water such as conductivity, water temperature, dissolved oxygen and pH. Dissolved oxygen was determined in the laboratory by the Winkler method (Moraes, 2001) and the other variables measured with electronic water analysers.

The variables of habitat structures such as depth, current velocity and substrate type were made using methods described in Gorman and Karr (1978). During the dry season (July) stretches of 50 m in an upstream-downstream direction were sampled. At each 5 m, on the left to right margin, on sites with an interval of 1 m in the width of the stream, the depth with a ruler in centimetres, current speed with a mechanical flowmeter and the type of substrate of visual form (Table 2) were measured. Landscape physiographic features were observed and recorded during all sampling periods.

2.3. Data analysis

The assessment of watershed areas was accomplished through the construction of the delimited polygons from the watersheds found on topographical maps of the Brazilian Institute of Geography and Statistics - IBGE (Brasil, 1971a, b, 1974a, b, 1975, 1982) that were digitally geo-referenced and processed in the Geographic Information System-GIS ArcGis 9.3 based on the procedures adopted and described by Lourenço (2009) who also used GIS tools in the study of fish ecology in the Buenos watershed. After generating a database in the GIS, the areas were obtained and it was possible to prepare and present maps (layouts).

The physical and chemical variables of water between watersheds were analysed using the non-parametric test of Kruskal-Wallis test (Siegel, 1975) followed by the "a posteriori" Dunn test (Vanzolini, 1993), when there was significance in test ($P < 0.05$).

The analysis of the habitat characterisation between watersheds was performed using the Friedman non-parametric test for related samples (Siegel, 1975), comparing the numerical frequencies of each structural category between

Table 1. Sample sites in Piracuama (P). Ribeirão Grande (RG), Buenos (B) and Guaratinguetá (G) watersheds, state of São Paulo; monitored stream, geographic coordinates and segment of the collection site.

Site	Stream	Coordinate	Segment
P1	Piracuama	22°49'43"S 45°35'31"W	Hillslope
P2	Piracuama	22°50'57"S 45°36'04"W	Piedmont
P3	Piracuama	22°52'04"S 45°35'07"W	Piedmont
P4	Oliveiras	22°48'36"S 45°31'33"W	Hillslope
P5	Oliveiras	22°48'51"S 45°32'28"W	Hillslope
P6	Oliveiras	22°50'42"S 45°34'55"W	Piedmont
RG1	Cedro	22° 45'02"S 45°27'58"W	Hillslope
RG2	Cedro	22°46'24"S 45°27'50"W	Hillslope
RG3	Canjarana	22°46'07"S 45°27'52"W	Piedmont
RG4	Ferraz	22°47'48"S 45°28'59"W	Piedmont
RG5	Ribeirão Grande	22°48'25"S 45°26'56"W	Piedmont
RG6	Ribeirão Grande	22°48'59"S 45°25'22"	Piedmont
B1	Buenos	22°46'31"S 45°24'44"	Hillslope
B2	Buenos	22°47'43"S 45°17'53"	Piedmont
G1	Taquaral	22°43'29"S 45°20'37"	Hillslope
G2	Pirutinga	22°44'25"S 45°22'24"	Piedmont

the watersheds. For significant difference ($P < 0.05$) a "a posteriori" test was used (Campos, 1983). In this analysis the sites situated on the slope and piedmont were considered separately.

The species diversity for the watersheds was analysed using the species dominance index of Berger-Parker (d) that also estimates the evenness (Magurran, 1991). Species diversity between the slope and piedmont was analysed using the Shannon index, which allows the use of t-test after the variance estimate (Magurran, 1991).

3. Results

Table 3 summarises the results found in the Kruskal-Wallis test for data of the physical and chemical variables of water in the watersheds analysed. The results showed significant differences ($P < 0.05$) in limnological parameters measured in the streams. The "a posteriori" Dunn test showed that in some cases the parameters were similar between watersheds while in others there was a significant difference, demonstrating a degree of heterogeneity among watersheds in relation to these limnological parameters.

Table 2. Description of categories (depth, current velocity and substrate) and the type and size used to describe the different habitats where fish were sampled in different streams.

Category	Type	Size
depth (cm)	shallow	between 0 and 30
	moderate	between 30 and 100
Current velocity (m/s)	very slow	< 0.05
	slow	between 0.05 and 0.2
	moderate	between 0.2 and 0.4
	fast	between 0.4 and 1.0
	torrent	> 1,0
substrate (mm)	sand	between 0.05 and 2.0
	gravel	between 2.0 and 10.0
	pebble	between 10.0 and 100.0
	stone	between 100.0 and 300.0
	boulder	> 300.0

The Friedman test applied to the structural characteristics of the streams located on the slope of the watersheds showed a significant result ($c^2 = 30.9$, $P < 0.001$). The "a posteriori" test showed no difference ($P < 0.05$) between structures of habitats in the segments of the slope for Ribeirão Grande and Buenos watersheds, and for Ribeirão Grande and Piracuama. The Friedman test applied to streams of watersheds located in piedmont was not significant ($c^2 = 4.48$, $P > 0.05$), indicating that there is no distinction of habitats in that segment.

Table 4 lists the 35 species of fish taken in the four watersheds. The highest species richness was found in the Ribeirão Grande watershed, with 30 species, followed by the Piracuama with 23 species and the Buenos and Guaratinguetá watersheds, with 21 species each. As for the abundance of individuals, the Ribeirão Grande watershed was the one with the largest number of individuals captured (2,792 individuals), followed by the Piracuama (1,641 individuals), Guaratinguetá (1,470 individuals) and Buenos (1,057 individuals).

Table 5 shows the occurrences of the 35 species collected at four watersheds studied in the segments of slope and piedmont. The most abundant species in both the segments was *Trichomycterus itatiayae* Miranda-Ribeiro, 1939. On the hillslope occurs 17 species and on the piedmont 33 species. Of these, 15 species were common to the slope and piedmont, while two species were unique to the slope and 18 for piedmont.

The results from the dominance index of Berger-Parker applied to the distribution of species in the four watersheds (Table 4) show that the highest degree of species dominance occurred in the Guaratinguetá watershed ($d = 0.692$) with the lowest equitability ($1 / d = 1.445$) where the dominant species was *Trichomycterus itatiayae*. The Ribeirão Grande watershed showed the lowest value of dominance ($d = 0.191$) and the highest value of evenness ($1 / d = 5.236$). When hillslope and piedmont were analysed, it was found that the Berger-Parker index value was greater on the slope ($d = 0.448$) showing lower values of evenness ($1 / d = 2.232$). Also in this case there was a preponderance of *T. itatiayae* in relation to other species (Table 5).

Table 6 presents the results of the Shannon index applied to the fish distribution into the watersheds considering the slope and piedmont segments. The index value estimated

Table 3. Results of Kruskal-Wallis test (H) for the physicochemical characteristics of the Piracuama (P), Ribeirão Grande (RG), Buenos (B) and Guaratinguetá (G) watersheds and the "a posteriori" Dunn test. $^*P < 0.05$. Values outside parentheses represent median values, inside parentheses represent the mean values of ordinations allocated and used in the test.

Characteristics	P	RG	B	G	H
Conductivity (µs/cm)	33.1 (50.2)	15.0 (17.8)	20.0 (35)	25.9 (42.7)	28.4*
	RG-G*, RG-P*				
Temperature (°C)	21.0 (30.6)	18.6 (22.4)	25.4 (3.2)	22.0 (2.8)	25.4*
	P-G*, P-B*				
Oxygen (mg/L)	9.7 (33.9)	9.4 (29.3)	9.1 (19.40)	8.8 (11.4)	16.8*
	RG-G*, P-G*				
pH	7.0 (26.5)	7.7 (51.6)	6.1 (7.8)	6.9 (17.8)	48.3*
	RG-G*, RG-G*, RG-P*				

Table 4. List of species caught in the four watersheds and their respective abundances and values of the Berger-Parker index (d) and evenness (1 / d).

Species	Piracuama	R.Grande	Buenos	Guaratinguetá	Total
Trichomycterus itatiayae Miranda-Ribeiro, 1939	636	500	311	1017	2464
Characidium lauroi Travassos, 1949	191	532	157	60	940
Neoplecostomus microps (Steindachner, 1877)	316	249	106	65	736
Characidium alipioi Travassos, 1955	26	520	43	12	601
Pareiorhina rudolphi (Miranda-Ribeiro, 1911)	71	277	2	60	410
Astyanax intermedius Eigenmann, 1908	102	213	5	15	335
Phalloceros caudimaculatus (Hensel, 1868)	10	17	280	3	310
Harttia carvalhoi Miranda-Ribeiro, 1939	118	46	13	69	246
Trichomycterus iheringi (Eigenmann, 1917)	10	30	41	42	123
Rineloricaria kronei (Miranda-Ribeiro, 1911)	0	85	15	17	117
Imparfinis minutus (Lütken, 1874)	0	100	0	0	100
Astyanax bimaculatus (Linnaeus, 1758)	5	24	50	11	90
Taunayia bifasciata (Eigenmann & Norris, 1900)	34	43	0	2	79
Pareiorhina brachyrhyncha Chamon, Aranda & Buckup, 2005	0	5	10	50	65
Geophagus brasiliensis (Quoy & Gaimard, 1824)	15	32	0	2	49
Hypostomus spp.	20	21	0	6	47
Trichomycterus immaculatus (Eigenmann & Eigenmann, 1889)	21	23	0	0	44
Ancistrus stigmaticus Eigenmann & Eigenmann, 1889	1	0	2	31	34
Astyanax fasciatus (Cuvier, 1829)	21	5	2	1	29
Oligosarcus hepsetus (Cuvier, 1929)	20	2	2	0	24
Gymnotus pantherinus (Steindachner, 1908)	0	12	10	0	22
Rhamdia quelen (Quoy & Gaimard, 1824)	12	6	0	2	20
Trichomycterus alternatus (Eigenmann, 1917)	5	13	0	0	18
Gymnotus carapo Linnaeus, 1758	0	5	1	3	9
Pimelodus maculatus Lacèpede, 1803	0	7	0	0	7
Rineloricaria steindachneri (Regan, 1904)	0	7	0	0	7
Synbranchus marmoratus Bloch, 1795	1	3	2	1	7
Hoplosternum littoralis (Hancock, 1828)	2	3	0	1	6
Rhamdia sp.	2	3	0	0	5
Hisonotus sp.	0	5	0	0	5
Hoplias malabaricus (Bloch, 1794)	0	4	0	0	4
Pimelodella sp.	0	0	3	0	3
Characidium cf. *pterostictium* Gomes, 1947	2	0	0	0	2
Oncorhyncus mykiss (Walbaum, 1792)	0	0	1	0	1
Pseudotocinclus parahybae Takako, Oliveira & Oyakawa, 2005	0	0	1	0	1
D	0.388	0.191	0.294	0.692	1.565
1/d	2.577	5.236	3.401	1.445	12.659
Total of individuals	1641	2792	1057	1470	6960
Total of species	23	30	21	21	35

for the slope was lower (H '= 1.645) to that estimated for the piedmont (H' = 2.559). The t test applied to these values showed significant difference (t = 34.3, P <0.001). The estimated values for evenness (E) were 0.581 for the slope and 0.732 for the piedmont. These values indicate the variability in species abundance which includes the preponderance of *T. itatiayae* in the two segments (Table 5).

4. Discussion

The streams which descend to the eastern parts of the Serra da Mantiqueira have their courses driven by joints that are positioned along the slopes and once reaching the region of the valley, the route is directed by the texture of the soil sediment (Braga, 2004). Thus,

Table 5. List of species occurring in the four watersheds considering events on the slope and piedmont. Values for the Berger-Parker (d) index and evenness (1 / d).

Species	Hillslope	Piedmont	Total
Trichomycterus itatiayae Miranda-Ribeiro, 1939	1,684	780	2,464
Characidium lauroi Travassos, 1949	774	166	940
Neoplecostomus microps (Steindachner, 1877)	444	292	736
Characidium alipioi Travassos, 1955	7	594	601
Pareiorhina rudolphi (Miranda-Ribeiro, 1911)	332	78	410
Astyanax intermedius Eigenmann, 1908	234	101	335
Phalloceros caudimaculatus (Hensel, 1868)	23	287	310
Harttia carvalhoi Miranda-Ribeiro, 1939	94	152	246
Trichomycterus iheringi (Eigenmann, 1917)	4	119	123
Rineloricaria kronei (Miranda-Ribeiro, 1911)	-	117	117
Imparfinis minutus (Lütken, 1874)	8	92	100
Astyanax bimaculatus (Linnaeus, 1758)	1	89	90
Taunayia bifasciata (Eigenmann & Norris, 1900)	58	21	79
Pareiorhina brachyrhyncha Chamon, Aranda & Buckup, 2005	48	17	65
Geophagus brasiliensis (Quoy & Gaimard, 1824)	-	49	49
Hypostomus spp.	-	47	47
Trichomycterus immaculatus. (Eigenmann & Eigenmann, 1889)	2	42	44
Ancistrus stigmaticus Eigenmann & Eigenmann, 1889	-	34	34
Astyanax fasciatus (Cuvier, 1819)	-	29	29
Oligosarcus hepsetus (Cuvier, 1829)	-	24	24
Gymnotus pantherinus (Steindachner, 1908)	4	18	22
Rhamdia quelen (Quoy & Gaimard, 1824)	-	20	20
Trichomycterus alternatus (Eigenmann, 1917)	18	-	18
Gymnotus carapo Linnaeus, 1758	-	9	9
Pimelodus maculatus Lacèpede, 1803	-	7	7
Rineloricaria steindachneri (Regan, 1904)	-	7	7
Synbranchus marmoratus Bloch, 1795	-	7	7
Hoplosternum littoralis (Hancock, 1828)	-	6	6
Rhamdia sp.	5	-	5
Hisonotus sp.	-	5	5
Hoplias malabaricus (Bloch, 1794)	-	4	4
Pimelodella sp.	-	3	3
Characidium cf. *pterostictium* Gomes, 1947	-	2	2
Oncorhyncus mykiss (Walbaum, 1792)	-	1	1
Pseudotocinclus parahybae Takako, Oliveira & Oyakawa, 2005	-	1	1
Total	3,740	3,220	6,960
Number of species	17	33	
Number of common species	15		
Number of unique species	2	18	
d	0.448	0.242	
1/d	2.232	4.132	

there is a relationship between the physical aspects such as flow velocity, substrate and temperature of water, and chemical variables of water such as conductivity, pH and dissolved oxygen. In addition, the lithology, soil and covering vegetation area will play a fundamental role in the stream characteristics (Allan, 1995).

The recent history of paleoclimatic and geomorphological evolution of mountains of the Serra da Mantiqueira date from events that started in the Pleistocene and continued into the Holocene (Modenesi and Melhem, 1992; Modenesi-Gauttieri and Nunes, 1998; Modenesi-Gauttieri et al., 2002). Studies by Ebert (1960) in the highlands of Itatiaia showed evidence of altitude glaciation in the Pleistocene, but were questioned by Clapperton (1993) as having other origins (Modenesi-Gauttieri and Nunes, 1998).

In the terminal Pleistocene, 12,000 to 18,000 in recent years, southeastern Brazil was under the influence of a dry period that provoked a series of morphoclimatic mosaics

Table 6. Results of the Shannon diversity index applied to distributions of fish in the watersheds considering hillslope and piedmont. H '= index value, E = value of evenness, Var = variance of the index, t = t value of the statistic, P = significance.

Segment	H'	E	Var	t	P
Hillslope	1.645	0.581	0.00031	34.3	<0.001
Piedmont	2.559	0.732	0.00040		

and phytogeographic patterns (Ab'Sáber, 1977, 1979, 1988). The weather was predominantly dry in the lowlands and humid in the highest. In the lowlands, the vegetation was xeromorphic due to the dry climate. Paleoclimatic evidence of this climate is the presence in the landscape of stone lines.

In the study area stone lines were identified in low and middle parts of the Piracuama watershed (Carmassi, 2012), in the medial portion of the Ribeirão Grande watershed (Braga, 2005a) and in middle parts of the Buenos and Guaratinguetá watersheds (Rondineli, 2010). The locations of stone lines follow a transect at the boundary between the valley and piedmont. Therefore it appears that the piedmont, the transition zone between the hillslope and the plain, is an ecotone that in the past separated a dry zone and a wet zone. In the early Holocene, with the end of the last glacial period the climate became warmer and wetter and forests began to occupy the lower parts of slopes (Ab'Sáber, 1977).

In a zoning plan for continental-scale of rivers, many streams have its segments in the slope, piedmont and plain (Matthews, 1998). In the slope, the segment of the stream alternates riffles and pools, whereas the plain stream segment becomes more voluminous (Allan, 1995). The upper parts of a stream are called rhithron and the lower parts, potamon, and fish that inhabit these segments tend to have adaptive features for these conditions (Wootton, 1992). In rhithron these adaptations are associated with the use of habitats, such as body shape and structures developed (fins, spines) to keep the fish in the riffle environment. In potamon, the lowest current velocity, the greater width of the stream, wetland margins and proliferation of aquatic weeds, cause the fish to develop morphological adaptations for continuous swimming and physiological adaptations to meet the depletion of dissolved oxygen. Braga (2004) studied the fish fauna in streams of the Ribeirão Grande watershed and found that many species that inhabit preferentially rhithron present a reduction in gonad size and loss of bladder as adaptive features for these environments.

The species composition and diversity are common patterns to be observed along a river gradient (Horwitz, 1978; Evans and Noble, 1979; Ostrand and Wilde, 2002). These patterns are occasioned by the action of biotic and abiotic factors that act in the assemblage structure of fish in the longitudinal direction (Taylor et al., 1993). Fish species that inhabit the headwaters are more tolerant of stressful conditions, while those that inhabit the lower parts are adapted to less extreme conditions (Lohr and Fausch, 1997). Several studies associate the seasonal environmental variations to climate factors influencing community and species diversity (Matthews, 1990; Meador and Matthews, 1992; Taylor et al., 1996).

Of the 35 species recorded in the studied watersheds of the eastern Serra da Mantiqueira, 15 are common to the hillside and piedmont segments, two are exclusive to the slope and 18 are exclusive to piedmont. According to Schlosser (1982) changes in the composition of the fish fauna and an increase in species richness upstream to downstream are associated with seasonal variability, channel morphology and available resources. Braga and Gomiero (2009) found that fish from the Ribeirão Grande watershed feed mainly on insect larvae and nymphs, and this source of food is available both on slopes and piedmont. Species that occurred on the slope, such as *Characidium lauroi* Travassos, 1949 and *C. alipioi* Travassos, 1955 which prevailed in piedmont, had similar diets based mainly on insect larvae and nymphs (Braga, 2005b).

Several studies suggest that environmental variability tends to decrease moving downstream, and that this decrease is associated with an increased diversity of species (Grossman et al., 1982; Poff and Allan, 1995; Ostrand and Wilde, 2002). In the watersheds of the eastern mountains of the Serra da Mantiqueira, the environmental variability was greater among slope streams than among the piedmont streams. On the other hand, the richness and diversity of species was greater in the piedmont segment, where environmental conditions tend to be more homogeneous.

Trichomycterus itatiayae was the most abundant species among the watersheds studied. It is a species well adapted to these streams by presenting morphological adaptations to the environment of riffles, as well as *Characidium* spp. and catfishes (Braga, 2004). In the lower parts, in the transition from the rhithron to potamon, there were species with morphological adaptations to this environment (Wootton, 1992), such as more active swimming in the water column (*Astyanax* spp.), respiratory adaptations to the fall in the level oxygen (*Synbranchus marmoratus* Bloch, 1795), associations with macrophytes (guppies, *Gymnotus* spp.), sucking habits (catfish) and carnivores (*Hoplias malabaricus* (Bloch, 1794)*, Oligosarcus hepsetus* (Cuvier, 1929)).

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