Marine Influence on Fish Assemblage in Coastal Streams of Itanhaém River Basin, Southeastern Brazil.

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ABSTRACT: Marine Influence on Fish Assemblage in Coastal Streams of Itanhaém River Basin, Southeastern Brazil. There are many studies of fish community in several estuaries around the world, but there is little information about the influence of marine-estuarine species on the structure of freshwater fish community in coastal streams. Our objective was to study the effect of marine-estuarine species on the structure of freshwater fish assemblage in coastal streams of Itanhaém River basin, Southeastern Brazil. Fishes were sampled with gill nets and dip nets in four sampling sites located 12, 14, 15, and 26 km from the mouth of estuary. Sampled fishes belonged to 19 species and 12 families. Five species were marine-estuarine: Centropomus pectinatus, Dormitator maculatus, Anchoa tricolor, Awaous tajasica, and Syngnathus folletti. The most abundant freshwater species were Hyphessobrycon reticulatus, Geophagus brasiliensis, Characidium lanei, and Phalloceros caudimaculatus. The sampling site closer to the estuary had the highest number of species and the highest abundance of marine-estuarine fishes that corresponded to 33% of species richness and 5% of the individuals. In other sites, marine-estuarine fishes were rare, and had a low contribution to increase species richness and diversity. They corresponded up to 13% of total number of species and 1.3% of total individuals sampled at each site. Their effect on the assemblage structure was qualitative and not quantitative. The abundance of marine-estuarine fishes was positively correlated with salinity and pH, and negatively correlated with the distance to the estuary. The majority of species was euryhaline and would not find any difficulty to enter streams with very low salinity, however most fishes were found next to the estuary. Probably this distribution is related to the fish life histories (catadromous or amphidromous), that keep them more tied to the estuarine environment. Despite the low abundance, predator fish from the estuary could be important in regulating the freshwater food web through top-down control and trophic cascade. Our findings indicate that marine-estuarine fishes play an important role in structuring the fish assemblages by increasing the species richness and the qualitative dissimilarity among sites.
Key-words: estuary, richness, diversity, distribution, similarity, salinity.

RESUMO: Influência marinha em assembléia de peixes em riachos costeiros da bacia do Rio Itanhaém, sudeste do Brasil. Há muitos estudos das comunidades de peixe em vários estuários no mundo, mas há pouca informação sobre a influência das espécies marinho-estuarinas na comunidade de peixes de água doce em rios costeiros. Nosso objetivo foi estudar o efeito das espécies marinho-estuarinas na estrutura da assembléia de peixes de água doce em rios costeiros da bacia do rio Itanhaém, Sudeste do Brasil. Os peixes foram coletados com redes malhadeiras e puçás em 4 pontos distantes 12, 14, 15 e 26 km da foz do estuário. Foram encontradas 19 espécies e 12 famílias. Cinco espécies foram marinho-estuarinas: Centropomus pectinatus, Dormitator maculatus, Anchoa tricolor, Awaous tajasica e Syngnathus folletti. As espécies de água doce mais abundantes foram Hyphessobrycon reticulatus, Geophagus brasiliensis, Characidium lanei e Phalloceros caudimaculatus. O ponto mais próximo do estuário possuiu o maior número de espécies e a maior abundân-

cia de peixes marinho-estuarinos correspondendo a 33% da riqueza de espécies e 5% dos indivíduos. Nos demais pontos, a ocorrência de peixes marinho-estuarinos foi rara, contribuindo pouco para o aumento da riqueza e diversidade de espécies, sendo que corresponderam no máximo a 13% das espécies ou 1,3% dos indivíduos amostrados em cada ponto. O seu efeito na estrutura da assembléia foi qualitativo e não quantitativo. A abundância dos peixes marinho-estuarinos se correlacionou positivamente com a salinidade e o pH, e negativamente com a distância ao estuário. A maioria das espécies foi eurihalina e não encontraria dificuldade para entrar em rios com salinidade extremamente baixa, entretanto a maior parte dos peixes foi encontrada próximo ao estuário. Provavelmente esta distribuição esteja relacionada à história de vida das espécies (catádromas ou anfídromas), que as mantêm mais ligadas ao ambiente estuarino. Apesar da baixa abundância, os peixes predadores do estuário podem ser importantes na regulação da cadeia alimentar de água doce através de controle topo-base e "cascata trófica". Os nossos resultados indicam que as espécies marinho-estuarinas desempenham um papel importante na estruturação da assembléia de peixes nos trechos baixos dos rios costeiros contribuindo principalmente para o aumento da riqueza de espécies e da dissimilaridade qualitativa.
Palavras-chave: estuário, riqueza, diversidade, distribuição, similaridade, salinidade.

Introduction

The structure of fish communities in streams are influenced by a great number of factors that operate on different temporal and spatial scales (Moyle & Cech Jr., 1996). There are two temporal scales considered in fish research, one evolutionary and another ecological. Evolutionary scale refers to the processes from the past that determine the current fish assemblages of a stream or basin such as continental drift or glaciation, which influenced speciation events and dispersion of species (Moyle & Herbold, 1987; Pusey et al., 1998), whereas ecological scale refers to abiotic and biotic factors from the present that influence the fish assemblages (Matthews, 1998). There are fundamentally three spatial scales: global, regional and local. Global phenomena act on large areas of the Earth (e.g. continents) such as El Niño Southern Oscillation that causes droughts or high rainfall in different regions of the world altering the community structure of fishes in different aquatic ecosystems (Swales et al., 1999; Davis, 2000; Garcia et al., 2003). Regional processes operate on smaller scale, like drainage basins, that are generally recognized by ichthyologist as fundamental arrangement to understand a regional fauna (Koel & Peterka, 2003). The fish assemblages are generally more similar between streams of a same basin than streams of neighboring basins (Hugueny & Lévêque, 1994). Local traits that influence fish fauna are usually related to channel deep and width, type of riparian vegetation, bottom type, presence of logs and root wads, hydrologic channel process (erosional and depositional zones), and so forth (Matthews, 1998).

In coastal streams, the fish assemblages are affected by another factor - the marine influence. This influence is stronger in the lower part of a stream, in the estuary, a transition zone between the marine and freshwater ecosystems. Estuaries are generally highly productive (Day et al., 1989), functioning as nursery and feeding area for some marine fishes (Boesch & Tuner, 1984; Cabral & Costa, 1999; Churchill et al., 1999). They are links between marine and freshwater ecosystems for migratory fishes as observed for schools of manjuba Anchoviella lepidentostole which penetrate into rivers to spawn (Bendazoli & Rossi-Wongtschowski, 1990). Fish communities in estuaries are intensively studied, because of its importance for the recruitment of young individuals into adult populations (Day et al., 1989), and because of the impacts that the development of cities and economic activities could have on these ecosystems such as pollution, deforestation or urbanization (Tomlinson, 1986; Blanchard et al., 1999; Koening et al., 2003; Levings et al., 2004). There are many studies of fish communities in estuaries (Yáñez-Arancibia, 1985; Lonerangan et al., 1986; Humphries et al., 1992; Whitfield, 1999) as well as in coastal streams (Aranha et al., 1998; Mérigoux et al., 1998; Esteves & Lobón-Cerviá, 2001; Uieda & Uieda, 2001). However, there is not any research that attempted to quantify the impact of marine-estuarine fishes on the structure of freshwater fish community, despite the importance they could represent for coastal streams (Winemiller & Ponwith, 1998; Fitzsimons et al., 2002). The aim of this research was to study the effect of marine-estuarine species on the structure of freshwater fish assemblage in coastal streams of Itanhaém River basin, Southeastern Brazil. This river basin was chosen because most of the streams are conserved with a rich and diverse flora and fauna, and it has been the focus of several studies covering aquatic macrophytes (Camargo & Florentino, 2000), zooplankton (Pereira & Camargo, 2004), microbiology (Rizzo, 1994), and paleolimnology (Oliveira, 1999).

Material and methods

Study Area

The Itanhaém River basin is located in the Southeastern Brazil (23°50' S- 24°15' S; 46°5' W- 47°00' W) (Fig. 1). According to Ponçano et al. (1981), three major geomorphological units can be recognized: (I) high escarpment region in a mountainous area (700-800 m) on Pre-Cambrian terrain with steep slope (›30 %), high drainage density and high velocity streams surrounded by Atlantic rain forest;

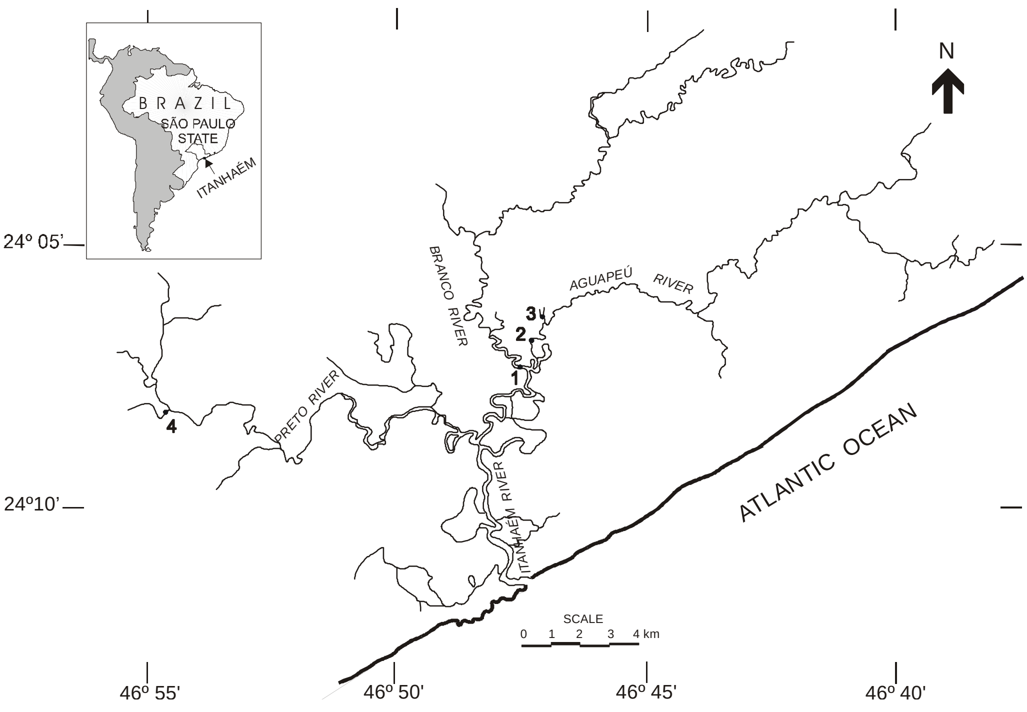

Figure 1: Map of the study area located in São Paulo State (Brazil, South America) showing sampling sites (1 - 4) in Itanhaém River basin.

(II) coastal plain region with marine terraces on Holocene, Pleistocene or Quaternary terrain, low drainage density with meandrous streams with low velocity, surrounded by Atlantic rain forest or "restinga" (coastal plain forest), all sampling sites were located in this region; (III) marine plain close to sea level on Holocene terrain, low drainage density and surrounded by "restinga" or mangrove vegetation. The mountainous area is placed at a distance from the coastline, allowing the development of an extensive coastal plain. The annual average precipitation ranges from 1500 mm to 2000 mm and the annual average temperatures are higher than 20°C. According to Köppen system, the climate is classified in the plain region as Af, tropical humid climate without dry season, and toward the mountainous region as Cfa, mild mid-latitude climate without dry season and with warm summers.

The distances between sampling sites 1, 2, 3, 4 and the mouth of estuary (Fig. 1) were 12, 14, 15 and 26 km, and the channel widths were 187, 26, 21 and 28 m, respectively. There were tidal variations in all sites. Site 1 had the highest salinity (0.417±0.228 PSU, mean±SD), but it was still classified as freshwater according to Esteves (1988); and in all other sites the salinity was extremely low (<0.030 PSU). Riparian forest covered the riverbanks and aquatic macrophytes colonized the littoral zone. The macrophyte stands were composed by a mixture of species, and the most abundant species were Eichhornia azurea in site 1, Egeria densa in site 2, Pistia stratiotes in site 3, and E. azurea in site 4. We decided to sample in aquatic macrophyte stands, because the dip net was effective in catching fishes in this environment.

Sampling and measurements

We made a total of three field expeditions in June, July and August of 1997. Fishes were sampled with gill nets (10 m x 1.5 m, 15 mm mesh knot to knot) for large fish and with dip nets for small fish (0.20 m^2 circular mouth area, 5 mm mesh knot to knot). A previous study was carried out to determine the mesh size of gill nets. Nets with 15, 20, 25, 30 and 35 mm were tested and the 15 mm net was the only one effective. At each sampling site, we developed three gill nets near aquatic macrophyte stands in the late afternoon (16:00 h) and retrieved them in the following morning (7:00 h). Small fishes were sampled from a small boat by plunging a dip net into aquatic macrophyte stands close to the gill nets. It was done 180 times in the first day (16:30 h) and 180 times in the second day (7:30 h) at each site. We preserved the fishes in 10% formalin for subsequent identification. The total number of fish caught by site in each month was a sample unit. At each site, we measured the following environmental variables in triplicate and in three depths (surface, middle and bottom): temperature, pH, O_2, conductivity and salinity, using Horiba Water Quality Checker U10 and Corning TDS meter PS18.

Data Analysis

Fish assemblage structure was studied through qualitative and quantitative similarity, species richness, diversity, and evenness. Qualitative similarity between the sites was calculated using Jaccard index (Krebs, 1989), and quantitative similarity was calculated using Morisita-Horn index (Horn, 1966; Magurran, 1988). Dendrograms were constructed from the similarity matrixes using UPGMA algorithm (Unweighted Pair-Group Method using Arithmetic Average) (Johnson & Wichern, 1992). Species richness was calculated using Margalef index (Margalef, 1951). Diversity was calculated using Shannon index (Magurran, 1988) and evenness was calculated according to Magurran (1988). In order to quantify the effect of marine-estuarine species on the structure of fish assemblage, all analyses were performed twice, one with all species and another with freshwater species only.

Canonical correspondence analysis was used to associate the abundance of fishes with the environmental variables (Ter Braak, 1986; Ter Braak & Prentice, 1988).

This technique is suitable to determine the correlation structure of community data that can be naturally divided in fish abundance and environmental variables.

Results

A total of 570 specimens from 19 species within 12 families was collected (Tab. I); 14 were freshwater species and five were marine-estuarine. Characidae was the family with highest number of species (5 or 26%) and abundance (255 or 45%). Most abundant species were Hyphessobrycon reticulatus (31%), followed by Geophagus brasiliensis (22%), Characidium lanei (21%) and Phalloceros caudimaculatus (8%), and they were

Table I: Number of specimens collected listed by taxa and sampling site. Origin: F = freshwater, ME = marine-estuarine.

Family	**Origin**	**Site**			
Species		**1**	**2**	**3**	**4**
Characidae					
Deuterodon iguape Eigenmann, 1907	F	17	-	-	-
Hyphessobrycon griemi Hoedeman, 1957	F	19	4	8	-
Hyphessobrycon reticulatus Ellis, 1911	F	2	63	5	105
Oligosarcus hepsetus (Cuvier, 1829)	F	18	1	-	-
Mimagoniates microlepis (Steindachner, 1876)	F	-	-	-	13
Cichlidae					
Geophagus brasiliensis (Quoy & Gainard, 1824)	F	42	76	5	1
Crenicichla lacustris (Castelnau, 1855)	F	-	1	-	-
Crenuchidae					
Characidium lanei Travassos, 1967	F	37	3	7	71
Erythrinidae					
Hoplias malabaricus (Block, 1794)	F	2	1	1	-
Loricariidae					
Rineloricaria cf. kronei (Miranda-Ribeiro, 1911)	F	-	-	1	1
Pseudotothyris obtusa (Miranda-Ribeiro, 1911)	F	-	-	-	1
Poeciliidae					
Poecilia cf. vivipara Bloch & Schneider, 1801	F	6	-	-	-
Phalloceros caudimaculatus (Hensel, 1868)	F	6	3	6	32
Lebiasinidae					
Nannostomus sp.	F	1	-	-	-
Centropomidae					
Centropomus pectinatus Poey, 1860	ME	2	-	-	1
Eleotridae					
Dormitator maculatus (Bloch, 1792)	ME	1	-	-	-
Engraulidae					
Anchoa tricolor (Agassiz, 1829)	ME	1	-	-	-
Gobiidae					
Awaous tajasica (Lichtenstein, 1822)	ME	1	-	-	-
Syngnathidae					
Syngnathus folletti Herald, 1942	ME	3	2	-	-
Total		158	154	33	225

present in all four sites. We captured Nannostomus sp. in site 1; it is a native species in rivers of the Amazon River basin (Géry, 1977), and could have escaped from an ornamental fish farm. There is not any information about previous occurrence of this species or about its natural reproduction in Itanhaém River basin. The contribution of marine-estuarine species to the freshwater fish assemblage was high in terms of richness and accounted for 26% of the total number of species. Nevertheless, in terms of abundance the marine-estuarine contribution was very low and corresponded to only 1.9% of the total number of fish. Dormitator maculatus, Anchoa tricolor, and Awaous tajasica were found only in site 1 next to the estuary. However, other species, besides being found in the lower reaches, had gone to a long distance as Syngnathus folletti and Centropomus pectinatus that were sampled in sites 2 and 4, respectively.

The analyses of qualitative similarity resulted in two different dendrograms (Fig. 2A). If marine-estuarine species were included in the analysis, the similarity between sites decreases (long branches in the diagram) and as consequence, three groups are created. If marine-estuarine species were not included, the similarity between sites increases and only two groups are created. Therefore, marine-estuarine species make the sites more dissimilar, especially site 1. The difference between these dendrograms is an estimation of qualitative effect of marine-estuarine species on fish assemblage. On other hand, the similarity analyses using Morisita-Horn index resulted in virtually the same dendrograms regardless the presence of marine-estuarine fishes (Fig. 2B). This result shows that marine-estuarine fishes do not play an important role in quantitative terms.

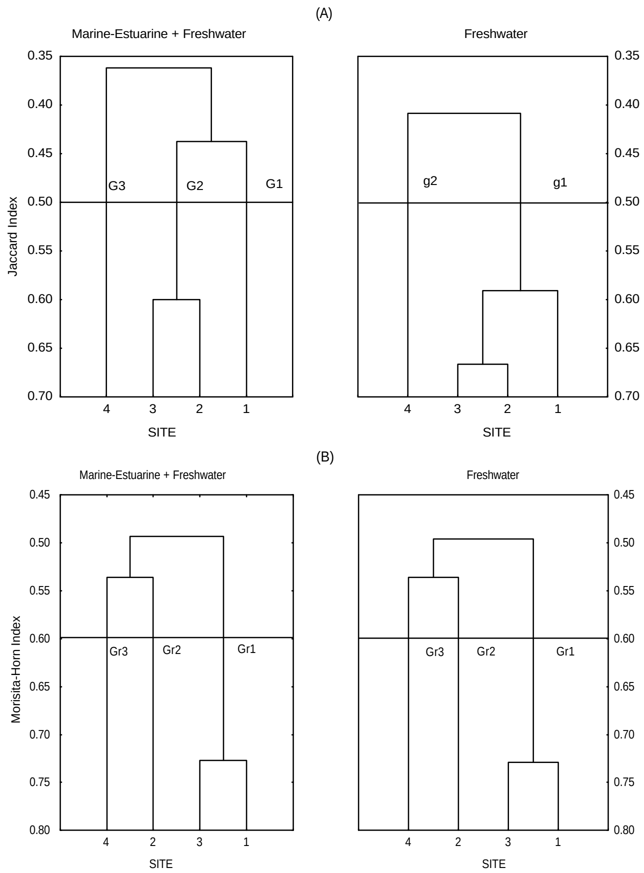

Figure 2: Dendrogram of qualitative and quantitative similarity among fish assemblages from sampling sites 1 - 4 using Jaccard index (A) and Morisita-Horn index (B). Analyses were performed taking into account all species (marine-estuarine + freshwater), and only freshwater species.

Site 1 had the highest richness measured directly by the number of species (Tab. II) and received the largest contribution of marine-estuarine species. In all other sites 2, 3 and 4, the number of species was very close, and the contribution of marine-estuarine species was very low or absent (Tab. II). Using indexes to analyze richness and diversity, site 1 still had the highest richness and diversity (Tab. II). However, if the contribution of marine-estuarine fishes were not taken into account, the indexes of richness and diversity would drop sharply. Removal of five marine-estuarine species from the riverine fauna would change the Margalef richness index from 2.77 to 1.80 and the Shannon's diversity index from 2.05 to 1.87. This results show markedly the importance of the marine-estuarine species to site 1. Site 3 had the second highest richness and diversity, followed by site 2 and site 4. Evenness measures the homogeneity of the proportional abundances of species. In this study, site 3 had the highest evenness index, and site 2 the lowest (Tab. II). The interpretation of these results means that in site 3 the dominance of some species was weak (H. griemi with 24% and C. lanei with 21%), however in site 2 there was a high dominance of G. brasiliensis with 49% and H. reticulatus with 41% making up 90% of total sampled

Table II: Number of species (S), number of marine-estuarine species (ME), number of fish (N), and the indexes of richness, diversity and evenness. The values in parenthesis were counted or calculated for freshwater species only, removing the marine-estuarine fishes.

Site	Number			Index		
	S	ME Species	N	Margalef's Richness	Shannon's Diversity	Evenness
1	15 (10)	5	158 (150)	2.77 (1.80)	2.05 (1.87)	0.78 (0.85)
2	9 (8)	1	154 (152)	1.59 (1.39)	1.12 (1.06)	0.51 (0.51)
3	7 (7)	0	33 (33)	1.72 (1.72)	1.77 (1.77)	0.91 (0.91)
4	8 (7)	1	225 (224)	1.29 (1.11)	1.26 (1.24)	0.60 (0.63)

fish. The diversity index is a combination of richness and evenness and its value increases with the increase of richness and/or evenness. For this reason, the low diversity indexes in sites 2 and 4 were due to low richness and evenness, and for the same reason the high diversity in sites 1 and 3 was due to high richness and evenness.

Canonical correspondence analysis was used to associate the abundance of fishes with the environmental variables. Salinity, pH, oxygen and distance to the estuary were correlated with the most abundant species, Hyphessobrycon griemi, H. reticulatus, G. brasiliensis, C. lanei, P. caudimaculatus, and marine-estuarine fishes. Marine-estuarine fishes were pooled into one category because of their low abundance. Correlations between fish abundance and environmental variables were R=0.979 (Monte Carlo test, p=0.01) for the first axes, and R=0.790 for the second axes. The correlation significance between the second axes was not tested using a simple randomization test, because it could bias the p-value (P. Legendre, personal communication). The first axis explained 48% (eigenvalue = 0.344) of total variance, and the second axis 14% (eigenvalue = 0.102). The resulting plot with the species, sampling sites and environmental variables is in Fig. 3. The dissolved oxygen was eliminated from the plot because it was a weak variable to explain the patterns ($R^2<0.20$). The sampling sites were divided in two region, left side (site 4, farthest from estuary), and right side (sites 1, 2 and 3 close to the estuary) (Fig. 3). Characidium lanei, H. reticulatus, and P. caudimaculatus were more abundant in site 4 (low salinity and pH, Fig. 3 and Tab. III). On the other hand, G. brasiliensis, H. griemi and marine-estuarine species were more abundant in sites close to the estuary. Geophagus brasiliensis was more abundant in sites 1 and 2 with higher pH (Fig. 3 and Tab. III), and H. griemi and marine-estuarine species were more abundant in site 1 with higher salinity and pH.

Discussion

Marine-estuarine fishes did contribute to structure the fish assemblages in

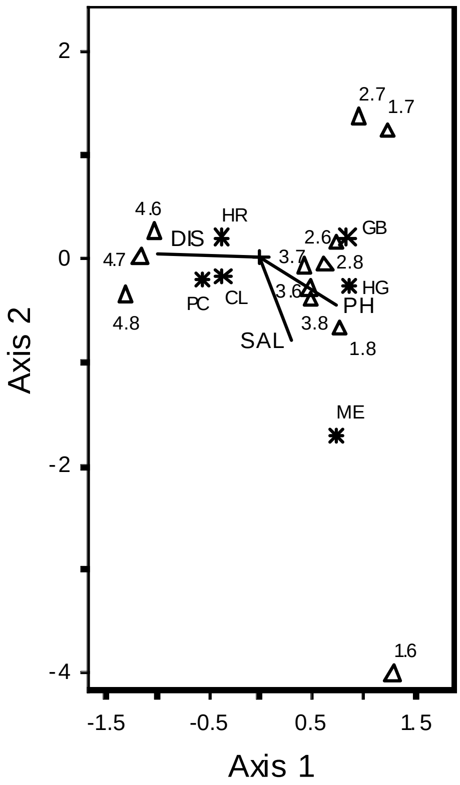

Figure 3: Canonical correspondence analysis ordination plot for sites and species, illustrating distribution patterns based upon environmental conditions (SAL: salinity, PH: pH) and distance of sites to estuary (DIS). Species are denoted by (*), and corresponded to HG: Hyphessobrycon griemi, HR: Hyphessobrycon reticulatus, GB: Geophagus brasiliensis, CL: Crenicichla lacustris, PC: Phalloceros caudimaculatus and ME: marine-estuarine species. Sites from different months are denoted by (D), and labeled by site number (1 - 4) and by month (6 - 8).

Table. III: Mean and standard deviation of environmental variables measured at the sampling sites.

Site	Month	Temperature (°C)	pH	Conductivity (µS/cm)	Salinity (PSU)	O_2 (mg/L)
1	6	18.5±0.34	5.81±0.23	1177±789	0.417±0.228	7.01±0.56
1	7	19.5±0.21	4.98±0.44	67±31	0.033±0.013	6.52±0.56
1	8	19.8±0.46	5.94±0.17	78±22	0.036±0.005	7.31±0.04
2	6	18.5±0.00	5.47±0.44	63±47	0.030±0	6.87±0.26
2	7	19.7±0.14	4.74±0.36	32±0	0.020±0	5.17±0.45
2	8	19.5±0.19	5.61±0.11	49±6	0.014±0.005	6.43±0.19
3	6	18.4±0.10	5.66±0.41	47±1	0.030±0	6.48±1.02
3	7	20.0±0.05	5.07±0.16	59±1	0.030±0	1.70±0.20
3	8	19.8±0.04	5.67±0.06	45±0	0.017±0.005	6.49±0.14
4	6	17.3±0.00	4.59±0.27	28±2	0.020±0	7.17±0.13
4	7	19.3±0.07	4.50±0.25	33±1	0.020±0	4.67±0.31
4	8	17.5±0.17	4.55±0.07	43±1	0.020±0	3.14±0.32

downstream reaches close to the estuary. The contribution takes place essentially by increase in number of species, whereas the abundances of the contributing fishes remain low. In site 1, the closest point to Itanhaém Estuary, 33% of fish species were marine-estuarine, but they corresponded to only 5% of the total sampled fish. This site already has a rich and diverse riverine fish assemblage resulting probably from the larger habitat size of a fifth order stream. In most streams, there is a continuous increase in species richness downstream (Horowitz, 1978). The stream channel tends to be wider and deeper increasing its habitat heterogeneity and supporting a higher number of species (Sheldon, 1968; Evans & Noble, 1978; Gelwick, 1990; Matthews, 1998). Most riverine teleosts cannot go into water with high salinity because of the limited capacity of osmotic adaptation (Lagler et al., 1977; Whitfield, 1999); therefore, they are excluded from the estuary. However, some marine-estuarine fishes can penetrate into streams as verified in this study for C. pectinatus, D. maculatus, A. tricolor, A. tajasica, and S. folletti. Their presence was more conspicuous in the sampling site close to the estuary, but it was also detected in upstream reaches. The analyses of similarity, richness, and diversity showed that the contribution of marine-estuarine species to freshwater fish assemblage was qualitative. The species could be considered rare in freshwater ecosystem because of their low abundance and/or small ranges (Gaston, 1994), but in some cases they could be important for the ecosystem as will be discussed afterward. From another aspect, catadromous species like A. tajasica may have an important function in restoration projects of coastal streams. The recurring migrations of juveniles from the ocean into coastal streams continuously renovate the stocks of adults living in freshwater, and it provides a source of new recruits for restocking restored streams (Swenson, 1999; Fitzsimons et al., 2002).

Canonical correspondence analysis showed that the presence of marine-estuarine fishes among sampling sites correlated positively with salinity and pH, and negatively with distance to estuary. Lonerangan et al. (1986), Mouny et al. (1998) and Whitfield & Harrison (2003) reported similar findings in relation to salinity gradient. The contrast between the mentioned works and our results is that their studies were carried out in estuaries or marine waters with higher salinities (0.5 - 38.2 PSU) and our study was carried out in freshwater, thus some different interpretations should be considered.

The relation between salinity and osmotic adaptation capacity would explain in part the distribution of the sampled marine-estuarine species. We could figure out three situations: (1) species with low tolerance to salinity changes are confined in the estuaries within brackish waters; (2) some salt-change tolerant species can enter freshwater stream, but stay at the lower reaches; (3) and others can go to a greater distance. In all these situations, a positive correlation could arise, but the interpretations for each situation would be different. The estuary mouth is the entrance of the system for marine fishes then it is natural that the abundance and the number of species are higher close to this point and they decrease as long as you move upstream (Gunter, 1961; Lonerangan et al., 1986; Mouny et al., 1998; Whitfield & Harrison, 2003). The fishes that enter the estuary will be progressively retained as they move upward according to their ability to tolerate salinity changes and their habit preferences (Day et al., 1989). This process will result in a positive correlation between fish abundance or number of species and salinity. Note that in the estuary, the salinity gradient is high and osmotic adaptation capacity is very important. The only marine species that would probably be limited by low salinity in the present study is A. tricolor. This fish is a schooling species found in coastal waters, but also enters brackish water (Whitehead et al., 1988). Positive correlations between abundance of A. tricolor and salinity were found by Silva & Araújo (2003) (18 - 30 PSU) and by Vendel et al. (2003) (21 - 33 PSU), showing that A. tricolor prefers waters with higher salinities. In our work, A. tricolor was found in freshwater next to the estuary with very low salinity, and it was probably at the upper limit of its distributional range.

Euryhaline species do not find difficulties to overcome low salinity barriers, but some of them stay at the lower reaches as consequence of their life history.

Dormitator maculatus and A. tajasica were included in this category. Dormitator maculatus is amphidromous and migrate between freshwater and estuary (Riede, 2004). There is an evidence of differential use of the habitat by fish of different sizes. Almost all specimens captured by Nordlie (1981) in an estuary were small juveniles, while Winemiller & Ponwith (1998) captured a wide range of sizes in freshwater streams, showing that adult fish may prefer freshwater while juveniles may prefer brackish water. Awaous tajasica is catadromous and spend part of their lives in freshwater and migrate to the sea for breeding (Sabino & Castro, 1990; Riede, 2004). Uieda & Uieda (2001) verified that A. tajasica was more abundant in lower reaches of a small coastal stream (lowland section with freshwater, and mangrove section with oligohaline water) than upper reaches. The life histories of these two species have a strong link to the estuary, so it is natural that they would be found close to it. Syngnathus folletti is found in coastal and brackish waters (Teixeira & Vieira, 1995), but at the current work, it was sampled in freshwater, 14 km from the sea, indicating that this species is capable of moving into freshwater environment.

Some euryhaline fishes that penetrate rivers and streams have large autonomy for long journeys. Whitfield (1999) caught Mugil cephalus and Acanthopagrus berda 100 km from the sea in rivers of South Africa. In the present study, C. pectinatus was found close to estuary and far from the sea (26 km upstream), demonstrating that it can make long trips into riverine environment. According to Fraser (1978), C. pectinatus is found in coastal, brackish and fresh waters, but usually prefers very low brackish or fresh water. In this condition, a positive correlation between abundance and salinity can also arise, however its interpretation may not be related to the fish ability to tolerate salinity changes. In freshwater, the small variation of salinity would not threat the osmotic regulation system of a euryhaline fish (Lagler et al., 1977). The positive correlation may be in part explained as a dispersal phenomenon (Porter & Dooley, 1993), where the center of dispersion is the estuary with a higher abundance of fish. As the fish spread upstream from this center into freshwater, their abundance drops inversely to the distance to the estuary. In a similar way, the salinity also drops inversely to the distance to estuary. Therefore, the fish abundance and the salinity will be negatively correlated with the distance to estuary, and consequently, fish abundance and salinity will be positively correlated with each other. In this situation, the small variation in salinity would not be a challenge for euryhaline fish.

Marine-estuarine fishes may have an important influence on freshwater food web, notwithstanding their low abundance in the riverine environment. Recent studies in ecology suggest that the food web is under simultaneous control of bottom-up and top-down processes (Carpenter, 1988; Hunter & Price, 1992; Power, 1992). In the classical concept of bottom-up control, nutrient availability limits the producers that in turn limit the herbivores, which limit the predators. In the new concept of top-down control, predators regulate the population of herbivores and herbivores regulate the population of producers. This regulation of food web that is processed through multiple trophic levels is conceptualized as a trophic cascade (Carpenter & Kitchell, 1993). For example, C. pectinatus, which is widely distributed in Itanhaém River basin, feeds on fish and invertebrates (Bussing, 1998), and functions as a predator in the food web and can play an important role in regulating the lower trophic levels (Carpenter & Kitchell, 1993; Rosemond et al., 1993; Forrester et al., 1999). An increase of C. pectinatus could reduce the biomass of herbivores and increase the biomass of producers. On other hand, a decrease of C. pectinatus could have an inverse effect; it could lead to an increase of herbivores and a decline of producers (Forrester et al., 1999). Itanhaém River basin is an open system to migration of organisms, Centropomus pectinatus can move from the sea and estuary to the streams and vice versa, altering their density. The effect of this change may cascade throughout the food web in the freshwater ecosystem. Unfortunately, few studies in the tropics estimate the extent to which the effect of trophic interactions at the top of the food web is felt in other trophic levels (Lévêque, 1997).

Our findings indicate that marine-estuarine fishes play an important role in structuring the fish assemblages by increasing the species richness and the qualitative dissimilarity among sites. In addition, marine-estuarine fishes could regulate the food web through trophic cascade and top-down control exerted by predator fishes; and they should be considered in any project of restoration in coastal streams.

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