Sewage input effects on the macroinvertebrate community associated to *Typha domingensis* Pers in a coastal lagoon in southeastern Brazil

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(With 3 figures)

Abstract

This study was carried out at Imboassica Lagoon, located in an urban zone in the municipality of Macaé, Rio de Janeiro state, Brazil. This lagoon has been subject to anthropogenic impacts due to the increasing city population, such as the input of sewage. Areas of variable degree of anthropogenic influence in the lagoon were compared regarding the structure of the macroinvertebrate community associated to *Typha domingensis* leaves. For sampling, we used 35 x 20 cm net plastic bags, with 6.8 mm mesh containing *T. domingensis* leaves for colonization. Two different sampling stations were selected: station A, under direct input of sewage; and station B with lesser sewage influence. The bags were removed after 20, 40 and 75 days of colonization. For each sample the Shannon-Wiever Diversity, Pielou Evenness, Jaccard Similarity Indices, Correspondence Analysis and taxonomic richness were calculated. A total of 31,874 individuals were sampled, belonging to 34 taxa. The main taxonomical groups were: Oligochaeta (41%), Chironomidae (40%), Ancylidae (4.6%), Polymitarcyidae (4%) and Thiaridae (3%). At station A, the taxonomic richness, the Evenness and Diversity values were lower than in station B. On the other hand, the total density was three times higher in station A than in B. It was already possible to discriminate the community structure of each sampling station in the first sampling. Trichoptera and Ephemeroptera were the main exclusive groups of station B and are considered good water quality indicators due to their high sensibility to contamination. The major contribution to discriminate between the macroinvertebrate communities of the two sample stations came from Chironomidae, Oligochaeta and Ephemeroptera.

Keywords: macroinvertebrates, coastal lagoons, macrophytes colonization, *Typha domingensis*, eutrophication.

Efeitos do aporte de esgotos sobre a comunidade de macroinvertebrados associada à *Typha domingensis* Pers em uma lagoa costeira no Sudeste do Brasil

Resumo

O presente estudo foi realizado na Lagoa Imboassica, localizada no perímetro urbano da cidade de Macaé, RJ, Brasil. Esta lagoa vem sofrendo impactos antrópicos com o aumento da cidade, como o aporte de esgotos sem tratamento. Áreas com diferentes graus de influência antrópica na lagoa foram comparadas quanto à estrutura da fauna de macroinvertebrados associada a folhas de *Typha domingensis*. A amostragem da fauna foi realizada por meio de cestos de tela plástica de 35 x 20 cm e malha de 6,8 mm, com folhas de *T. domingensis* para colonização. Dois pontos amostrais foram selecionados: ponto A, sujeito a aporte direto de esgotos; e ponto B, sob menor influência de esgotos. Os cestos foram retirados após 20, 40 e 75 dias de colonização. Foram aplicados em cada amostra os índices de diversidade de Shannon-Wiever, equitabilidade de Pielou e similaridade de Jaccard, riqueza taxonômica e Análise de Correspondência. Foram encontrados 31.874 indivíduos, distribuídos em 34 táxons. Os principais grupos foram: Oligochaeta (41%); Chironomidae (40%); Ancylidae (4,6%); Polimitarcyidae (4%); e Thyaridae (3%). No ponto A, os valores de riqueza taxonômica, equitabilidade e diversidade foram inferiores aos do ponto B. Por outro lado, a densidade total foi três vezes maior no ponto A. A estrutura da comunidade foi diferente nos dois pontos amostrais para todos os testes utilizados, desde a primeira retirada. Trichoptera e Ephemeroptera foram os principais grupos exclusivos do ponto B, sendo considerados indicadores da qualidade da água devido à sua sensibilidade. Chironomidae, Oligochaeta e Ephemeroptera foram os principais grupos a contribuir com as diferenças nas comunidades de macroinvertebrados entre os pontos amostrais.

Palavras-chave: macroinvertebrados, lagoas costeiras, colonização de macrófitas, *Typha domingensis,* eutrofização.

1. Introduction

Coastal lagoons are abundant on the Brazilian coast, especially in Rio de Janeiro and Rio Grande do Sul States (Esteves, 1998a). Such lagoons show primary productivity comparable to estuarine environments and have many important resources for human exploitation (e.g., fishing, production of macrophytes for feeding, fertilizers, handcrafts and tourism) (Esteves et al., 1984). Contrasting to temperate lakes, in tropical coastal lagoons the primary productivity of macrophytes and associated periphyton is relatively more important than the phytoplankton productivity. Aquatic and semi-aquatic macrophytes usually contain larger macroinvertebrate densities than other substrates (Minshall, 1984). Macrophytes are substratum for the main food sources exploited by macroinvertebrates: periphyton and particulate organic matter (Ward, 1992). Moreover, the macrophytes produce debris and increase the habitat heterogeneity leading to higher diversity of the macroinvertebrate fauna (Hynes, 1970; Minshall, 1984).

The coastal lagoons of northern Rio de Janeiro State, Brazil have undergone various anthropogenic impacts since the first half of the XX century (Soffiati, 1998). The sewage input may act as an energy source or a stress factor for an ecosystem, altering its productivity and community development. An effect associated to the stress hypothesis is the decrease of species diversity, as a result of the taxonomic richness decrease and the dominance increase of a few more resistant species (Odum, 1985, 1988). Freshwater macroinvertebrates have been frequently used in water quality studies. The main advantages regarding their use in these studies are the great number of species that may be sensitive to environmental stress, their wide distribution in various freshwater habitats and the relatively sedentary behavior and short life cycle in relation to fish, which facilitates the detection of temporal changes (Rosenberg and Resh, 1993).

In this study, a natural substrate, leaves from *Typha domingensis* Pers (Thyphaceae), was used for benthic macroinvertebrates colonization. *T. domingensis* is the dominant macrophyte surrounding the Imboassica Lagoon and represents the main vegetable substrate to periphyton and invertebrates. The sewage input causes eutrophication and increases suspension detritus that deposit on the macrophyte leaves. The Imboassica lagoon is a mosaic differing in the intensity of domestic sewage input that resumes differences on the limnological and biotic parameters (e.g., suspended detritus, ammonia concentration, fecal coliforms concentrations) (Henriques de Oliveira, 2002; Petrucio and Furtado, 1998). Responses of organisms according to their habits and characteristics deal with differences in community parameters such as dominance, richness, diversity and evenness (Resh and Rosenberg, 1984). The aim of this study is to assess if the variation in raw domestic sewage input influences the macroinvertebrate community structure associated to *T. domingensis* leaves.

2. Material and Methods

2.1. Study area

The Imboassica lagoon (22° 20' and 22° 25' S; 41° 45' and 41° 55' W) is located in the urban zone of the municipality of Macaé, Rio de Janeiro state, Brazil. It presents a total area of 3.26 km^2, maximum width of 1.3 km, length of 5.3 km, average depth of 1.09 m and average volume of 3.53 km^3 (Panosso et al., 1998). Due to the rapid growth of Macaé since the 1960's, the Imboassica Lagoon has been subjected to discharge of raw domestic sewage in different points and about 20% of its area was landfilled for real estate use (Esteves, 1998b). As a result of these anthropogenic factors, there is a continuous reduction in the lagoon depth leading to an increase in its water surface in relation to volume (Esteves et al., 1984). The reduction in the area/volume rate helps to establish macrophytes. *Typha domingensis*, the Cyperaceae *Eleocharis* cf. *fistulosa* (Mart.) Solms and various species of Poaceae occupy roughly 38% of the total area of the lagoon (Furtado, 1994).

Two sampling stations subjected to different intensity of raw domestic sewage input were chosen, both in the coastal zone, close to the macrophytes stand (Figure 1). Station A, located close to the main sewage inflow, presented fecal coliform concentrations higher than 2,500 Most Probable Number (MPN)/100 mL, an average oxygen concentration of 8.1 $mg.L^{-1}$, an ammonia concentra-

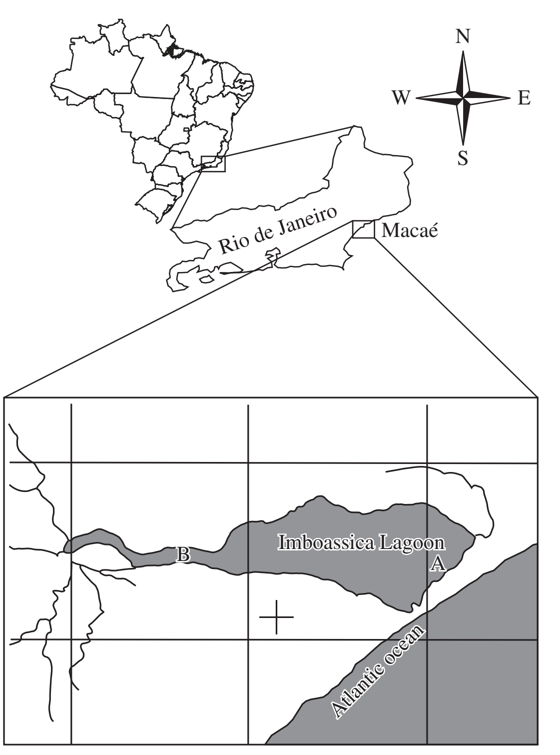

Figure 1. Imboassica Lagoon map, Macaé, RJ. A and B - sample stations.

tion between 11.90 and 26.19 mg.L^{-1}, a pH slightly acid (6.8) and a salinity around 1 S. Station B, representing the control station, is located near the Imboassica River at about 3.5 km from the station A (Figure 1). It presented fecal coliform concentrations around 500 MPN/100 mL, an average oxygen concentration of 5.0 mg.L^{-1}, an ammonia concentration between 0.31 and 2.38 mg.L^{-1}, a pH between 6.7 and 7.3 and salinity values not surpassing 0.9 S.

2.2. Sampling design

The benthic macroinvertebrate samples were obtained from colonizing green leaves of Southern Cat-tail, *T. domingensis*. Emerged parts of the *T. domingensis* leaves were cut and placed in net plastic bags, with a size of 35 x 20 cm and mesh 6.8 mm. Each bag contained 100 g of leaves. In each station, nine bags were installed, distributed in three sampling sets, with a total of 18 bags in the two stations. The sampling sets were removed after three different colonization periods (20, 40 and 75 days) between November 2000 and January 2001. These time intervals are based on other macroinvertebrate colonization studies and are related to minimum times necessary for establishment and stabilization of the community (Nessimian and De Lima, 1997; Walker, 1998; Gonçalves-Jr., 1999; Kuhlmann, 2000). The leaves were washed and the material retained in sieves of 187 µm mesh was sorted and identified under a stereomicroscope with 160x magnification. All specimens were deposited in the Coleção do Departamento de Zoologia da Universidade Federal do Rio de Janeiro.

2.3. Data analysis

The shannon index (H'), Evenness (J) (Magurran, 1988) and richness (number of taxa) were measured for each sample (up to the smaller possible taxonomic level). Hutcheson's method, described by Magurran (1988), calculates the *t*-value and degrees of freedom, testing the significance of differences in diversity between the sampling stations and colonization periods.

The Jaccard Similarity Index was used to evaluate the qualitative macroinvertebrate community similarity among samples. Correspondence Analysis (Ludwig and Reynolds, 1988) was performed on a data matrix of macroinvertebrate densities, with the help of the NTSYS program, version 1.70 (Rohlf, 1992).

3. Results

A total of 31,874 macroinvertebrate specimens were collected, distributed through 34 taxa, including 14,779 Insecta and 12,946 Oligochaeta. Regarding the sampling station, 24,739 were found in station A and 7,135 in station B (Table 1). Station A presented smaller taxonomic richness and diversity (Table 2). Oligochaeta was the most representative taxon in this station (49%), followed by Chironomidae (44%). Dominant genera of Chironomidae were *Goeldichironomus* and *Chironomus*. Ancylidae and Thiaridae (both Gastropoda) completed the group of taxa which presented a relative abundance higher than 1%. In station B 31 taxa were found, amongst which the most abundant were Chironomidae (33%), Polymitarcyidae (Ephemeroptera) (19%), Ancylidae (11%) and Oligochaeta (9%). *Polypedilum* (*Asheum*) was the main Chironomidae taxon. Station B presented higher evenness values than station A (Table 2). Trichoptera and Ephemeroptera were found only in station B, representing roughly 23% of the total sampled specimens in that station. Other macroinvertebrates found only in station B were *Quadrivisio lutzi* (Shoemaker, 1933) (Gammaridae; Amphipoda), *Micrathyria* and *Miathyria* (both Odonata; Libellulidae), Ceratopogonidae (Diptera) and *Helisoma duryi* (Wetherby, 1879), *Physa marmorata* (Guilding, 1828), *Pomacea* and *Melanoides tuberculata* (Müller, 1774) (all Gastropoda). Considered together, the latter cited taxa represented roughly 3% of the total specimens sampled from station B (Table 1). The Jaccard Index distinguished two clusters separating samples of stations A and B (Figure 2).

In the Correspondence Analysis, the first two axes explained together 80% of the total variation. Axis I (60% of the variation) might be interpreted as the varia-

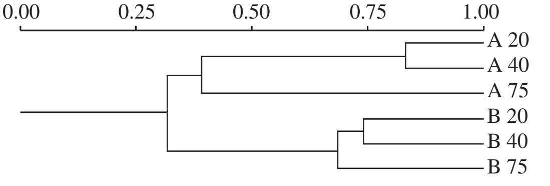

Figure 2. Cluster analysis (UPGMA) from values of Jaccard similarity index of the benthic macroinvertebrates colonizing *Typha domingensis* leaves during different colonization periods in stations of the Imboassica Lagoon, Macaé, RJ, November, 2000 through January, 2001. Sample stations: A and B; colonization periods: 20, 40 and 75 days.

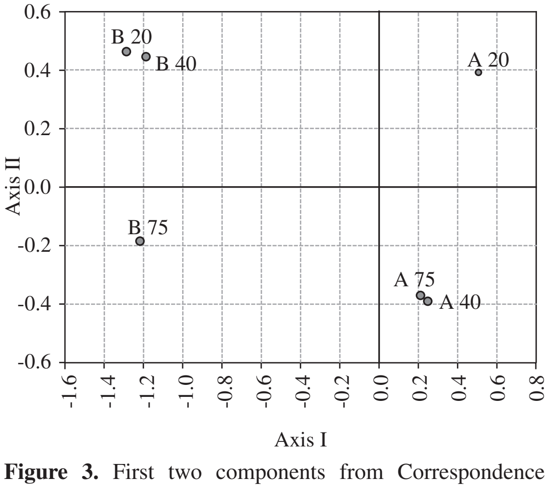

Figure 3. First two components from Correspondence Analysis among colonization periods of *Typha domingensis* leaves by benthic macroinvertebrates in sample stations of the Imboassica Lagoon, Macaé, RJ, November, 2000 through January, 2001. Sample stations: A and B; colonization periods: 20, 40, and 75 days.

Table 1. Total abundance of benthic macroinvertebrates colonizing *Typha domingensis* leaves during different colonization periods in stations A and B of the Imboassica Lagoon, Macaé, RJ, November 2000 through January 2001.

	Colonization period (days)					
	Station A			Station B		
	20	40	75	20	40	75
ARTHROPODA						
INSECTA						
COLLEMBOLA			4		3	
EPHEMEROPTERA						
Baetidae						
Callibaetis spp.				15	1	
Caenidae						
Caenis spp.				8	13	25
Polymitarcyidae						
Campsurus melanocephalus				350	186	839
ODONATA						
Coenagrionidae	2	4		81	23	43
Libellulidae						
Micrathyria spp.				8	2	4
Miathyria sp.				1		0
Perithemis sp.	0	0	3	4		1
Brachymesia sp.	1	1		1		5
HETEROPTERA						
Pleidae		1				
TRICHOPTERA						
Polycentropodidae						
Cyrnellus sp.				133	39	29
Leptoceridae						
Oecetis spp.				11	5	11
Hydroptilidae						
Neotrichia sp.						1
COLEOPTERA						
Hydrophilidae						
Berosus sp.			1		1	
Elateridae						
Pachyderini sp.			1			
DIPTERA						
Chironomidae	2405	6683	1455	667	254	1447
Ceratopogonidae				3		2
CRUSTACEA						
CLADOCERA	1	5		65	21	208
COPEPODA	12	1	11	162	15	69
ISOPODA						
Sphaeromatidae						
Exosphaeroma sp.	5	5		23	24	44
OSTRACODA	5	31	27	93	47	95
ARACHNIDA						
ACARINA			1	3	1	10
ARANEAE					2	5

Table 1. Continued...

	Colonization period (days)					
	Station A			Station B		
	20	**40**	**75**	**20**	**40**	**75**
MOLLUSCA						
GASTROPODA						
Ancylidae	293	287	84	7	196	598
Hidrobiidae	1		3	20	64	11
Thiaridae						
Hemisinus sp.	510	222	150			29
Melanoides tuberculata				3	4	13
Physidae						
Physa marmorata				37	13	2
Planorbidae						
Helisoma duryi				2	5	15
Ampullariidae						
Pomacea sp.				1	3	1
ANNELIDA						
OLIGOCHAETA	7686	3928	709	284	229	110
HIRUDINEA		2	3	121	87	98
Total	**10920**	**11370**	**2449**	**2111**	**1244**	**3780**

Table 2. Richness (S), Shannon index (H') and evenness (J) of the benthic macroinvertebates colonizing *Typha domingensis* leaves during different periods in stations A and B of the Imboassica Lagoon, Macaé, RJ, November 2000 through January 2001.

	Colonization periods (days)					
	Station A			Station B		
	20	**40**	**75**	**20**	**40**	**75**
S	10	12	12	28	26	27
H'	0.84	0.88	1.06	2.21	2.31	1.93
J	0.36	0.35	0.43	0.67	0.71	0.58

tion in water quality (Figure 3). The samples of station A were positively correlated to Axis I, whereas samples of station B were negatively correlated (Figure 3). The structure of the fauna varied more between stations than among periods of colonization. In station A, the abundance of Oligochaeta was about 20 times higher than in station B, contributing with 21% to the formation of Axis I. An exclusive taxon for station B, *Campsurus melanocephalus* Pereira and Da-Silva, 1991 (Ephemeroptera; Polymitarcyidae), showed a negative correlation with Axis I and contributed with 31% to its formation. Other organisms negatively correlated to Axis I were Coenagrionidae (3%), Cladocera (6%), Copepoda (5%), Hirudinea (7%), Ostracoda (4%) and *Cyrnellus* (5%) (Trichoptera: Polycentropodidae).

Axis II (20% of the variation) might be interpreted as the quality of the substrate available for colonization. Chironomidae (50%) and Oligochaeta (31%) presented the highest contribution for this axis, both representing some of the most abundant macroinvertebrate organisms found in the two sampling stations. They also presented the highest variation among different colonization periods. Chironomidae was more abundant in the sample set removed after 75 days of colonization at station B, in comparison to the shorter periods (20 and 40 days). Otherwise, the highest abundance at station A was found in the sample set removed after 40 days and the lowest abundance at the 75 day sample set. Oligochaeta also presented decreased abundance in the 75 day sample set at both studied stations. Other organisms showing decreasing abundance in the longest colonization period (75 days) were Hirudinea, Hydrobiidae (Gastropoda), Copepoda and *Cyrnellus*, contributing with 3, 2, 3 and 4%, respectively, to Axis II. Such results were more significant for station A, where the individual abundance for several taxa showed a higher decrease over time. The observed reduction in abundance throughout the colonization period in station A may be a result of the advanced degradation of the leaves (they seemed softer and thinner when observed visually and when touched) in that station, as compared to those at station B.

4. Discussion

The rapid establishment of the macroinvertebrates community in station A demonstrates the role of sewage as an energy source for some groups. Oligochaeta and Chironomidae were the main organisms found in this samping station. Chironomidae is one of the most abundant groups of the benthic fauna in freshwater environments (Coffman and Ferrington, 1996) and may be found in several different habitats (Pinder, 1986). The occurrence of Chironomidae as a dominant group has been observed in many studies on macroinvertebrate communities of natural and degraded environments (e.g., Nessimian and De Lima, 1997; Correia, 1999; Gonçalves-Jr, 1999; Araújo, 2000; Silveira, 2001). *Chironomus* and *Goeldichironomus*, the dominant genera of Chironomidae in station A, are considered as organisms with a high tolerance to habitats presenting high contents of organic matter and low oxygen levels (Ruse and Wilson, 1995). The abundance of these genera can be related to their collector-gatherer and, possibly, scraper feeding habits, as both kinds of organisms use debris as the main food item (Henriques-Oliveira et al., 2003). The increased abundance of Oligochaeta is correlated with environments subjected to a high input of domestic sewage, as pointed out by Navas-Pereira and Henrique (1996). Thus, organisms with a positive feedback response to sewage input, such as Oligochaeta, *Chironomus* and *Goeldichironomus* represent most of the disparity in the abundance of benthic organisms between the stations.

Despite the highest abundance of organisms in station A, the greatest richness was found in station B. The absence of some taxa in station A could be related to their low tolerance to organic pollution. According to Grosse et al. (1986), some Amphipoda families can be sensitive to high amounts of suspended organic material. Ephemeroptera and Trichoptera are often related to high or intermediate environmental integrity, as they are used as bioindicators in biological monitoring studies in freshwater environments. These taxa are, for example, very dependent on oxygen availability (Rosenberg and Resh, 1993; Lemly, 1982; Barbour et al., 1996; Silveira, 2001). The presence of Trichoptera and Ephemeroptera exclusively in station B indicates that these taxa present a high enough sensibility to react to the different amount of degradation found in the sampled stations.

Enrich-Prast and Fernandes (1998) found smaller rates of biological fixation of nitrogen by the periphyton associated to *T. domingensis* in station A of the Imboassica Lagoon. Such results were related to the formation of toxic compounds and to the inhibition of nitrogen fixation due to the presence of high nitrite and ammonia concentrations in polluted environments. The increase in the concentration of nitrogen and proteins from activities of bacteria, fungi, and epiphytic algae, may increase the attractiveness of the periphyton to macroinvertebrates (Suren and Lake, 1989). Thus, low values of nitrogen fixation could reduce the attractiveness of the periphyton, decreasing the diversity of invertebrates that feed upon these organisms. Fernandes (1998) observed smaller taxonomic richness of the periphytic community associated to leaves of *T. domingensis* in station A. The periphytic cover is considered an important factor influencing the structure of the macroinvertebrate community (Van Den Berg et al., 1997; Albertoni et al., 2001; Nessimian and De Lima, 1997; Correia, 1999). *Caenis cuniana* Froehlich, 1969 (Ephemeroptera: Caenidae) feeds mainly on algae, vegetable fibers, and organic debris (Francischetti et al., 2001). Amphipoda species associated to the aquatic vegetation can feed on epiphytic algae, small animals and organic debris (Pennak, 1978; Grosse et al., 1986). Most Gastropoda are herbivores, including vegetable tissue (live or dead) and periphytic algae in their diet (Pennak, 1978), as exemplified by Physidae and Hidrobiidae (Suren and Lake, 1989; Cardoso et al., 1993). The pollution influence on the distribution of the benthic macroinvertebrate species can be attributed to change in food availability or to toxins associated to food (Thorne and Willians, 1997). The greatest herbivore richness found at station B can corroborate the results pointed out by Enrich-Prast and Fernandes (1998) and Fernandes (1998) on periphyton richness in stations A and B.

The higher availability of organic matter close to the sewage discharge points may lead to the increase of abundance and biomass in the macroinvertebrates, as also observed in the same lagoon by Gonçalves Jr et al. (1998) and Albertoni et al. (2001). However, in the present study, the observed diversity values were smaller, in response to the richness decrease and the largest dominance of the more tolerant groups in station A. In studies of environmental biological integrity, higher values of evenness and richness may represent better environmental integrity. The increase in abundance and biomass of a few taxa may represent a negative effect of pollution, as only the more tolerant organisms are able to use the input of organic material as an energy subsidy.

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