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Effects of Artificial Canal Openings on Fish Community Structure of Imboassica Coastal Lagoon, Rio deJaneiro, Brazil

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ABSTRACT

The embankment of the Imboassica River formed the Imboassica Lagoon located to north of the State of Rio de Janeiro by the coastal sandbank, which separates it permanently from the sea. Formerly, the lagoon used to be connected to the sea naturally when waves broke the sandbar. Presently, connection is established artificially to prevent roads and houses from flooding. Such action increases the diversity of fish species living in the lagoon and therefore expands the fishing activity. This study investigated the effects of such openings on the structure of local fish community. Among the 26 species collected by gillnets, *Hoplias malabaricus, Paralichythys brasiliensis, Gerres aprion, Genidens genidens, Strongylura timucu, Mugil curema*, and *Geophagus brasiliensis* were the most abundant during the study. *Lycengraulis grossidens, Archosargos probatocephalus, Tilapia rendalli*, and *Micropogonias furnieri* were dominant before the canal was opened, whereas Anchovia clupeoides and *Trachinotus carolinus* were dominant in the period after the canal opening. Species diversity and evenness were practically constant during the months before the canal opening. Although both indices decreased substantially while the sea connection remained open, they returned to the same level as before when the canal was closed again. Cluster and detrended correspondence analyses showed similar patterns of two distinct groups of months before and after the canal opening supporting the idea that distinct fish assemblages occupied that environment before and after the event. Our results show that artificial canal opening is a factor that affects the structure and species composition of the fish community in the Imboassica Lagoon.

ADDITIONALINDEXWORDS: *disturbance, diversity, fishery management, South Atlantic.*

INTRODUCTION

Coastal lagoons are defined as enclosed bodies of water, separated from the sea by a sand bar and linked to the ocean by one or more canals which may be closed from time to time by sediment deposits resulting from the action of littoral waves and winds. The number of canals and the size of such connections with the sea, as well as environmental conditions such as winds, tidal streams, rivers and precipitation account for variation in salinity gradients and water circulation, both of which have a direct influence on the hydro-salt balance, water quality and eutrophication levels (KJERFVE, 1994). Such ecosystems are shallow, subject to the deposition of sediments. They have short life spans in the geological scale, due to silting processes, which have accelerated due to recent inputs of household and industrial effluents. Other factors such as the excessive exploitation of fish and minerals, disordered occupation of the margins, as well as the lowering of water levels because of landfills, have also been compromising the geomorphological, physical-chemical and bio-ecological structures of these systems (COUTINHO, 1986; ESTEVES, 1998). The preservation and effective management of these coastal systems will be aided by a sound knowledge of the geomorphology, chemical and physical processes, as well as the structure and the dynamics of the communities living in such systems (YANEZ-ARANCIBIA, 1986).

The State of Rio de Janeiro is rich in lagoon systems, which individually differ in size, salinity gradient, shape, origin, number of canals, sea-connection types and other particular features. Lately, these systems have been subject of anthropogenic impacts and the greatest challenge is to preserve the diversity of species living in them. Major disturbances in lagoons are the high volumes of organic and inorganic effluents running into the lagoons, as well as landfills, which gradually block connections with the sea and accelerate eutrophication. Therefore, governmental agencies are now looking for ways to minimize these problems by opening several lagoons artificially to provide them with occasional connection with the sea. Imboassica is a coastal lagoon that has a sea connection completely blocked by sedimentation. Presently, Imboassica Lagoon is disturbed due to the dumping of domestic effluents, facing critical sanitary conditions that may seriously compromise this ecosystem (ESTEVES, 1998). At least once a year, this canal is artificially opened increasing fish diversity and abundance, and therefore expanding fishing activity. This study investigates the effects of such openings on the structure of local fish community.

METHODS

The Imboassica Lagoon (Figure 1) is located next to the city of Macaé (110.000 inhabitants; 200 km north of the city of Rio de Janeiro). It is formed from the closure of the Imboassica River by the coastal sandbank, which separates it permanently from the sea. Formerly, the sea connection occurred naturally when waves broke the sandbar. Presently, connection is established artificially by actions of the Macaé City Administration, in order to prevent roads and houses from flooding. This process allows a great amount of water to flow out to the sea, almost emptying the lagoon. The water flows back inside slowly with the tides, and sand deposits enable the canal to close again after a few days. The Imboassica Lagoon has an area of c. 320 hectares, nearly 1.3 km wide and 5.3 km long. The average depth is about 1.0 m, reaching a maximum of 2.20 m; water transparency ranges from 0.30 to 1.10 m. Dissolved oxygen varies between 20.7% and 87.6% of the saturation level and pH ranges from 6 to 8. The local climate is considered sub-humid with temperature ranging from 25 to 30°C. Average annual precipitation varies from 800 to 1200 mm (PETRUCIO and FURTADO, 1998).

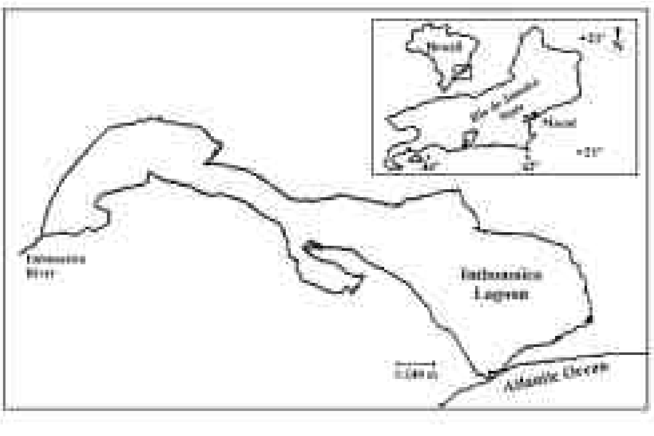

Figure 1. Study Area.

Fish were collected monthly from October 1993 to September 1994. During this period, the canal was artificially opened twice, in March and April 1994. A set of gillnets with mesh varying from 15 to 45 mm (c. 550 m^2 of total area) were deployed randomly throughout the lagoon and kept assembled for a 12-hour period (between dusk and dawn), with one inspection in the middle of the night. Also, a seine net (8.0 m long, 1.2 m high, 10 mm mesh) was used in 3-minute shoreline drags once at dusk and again at dawn next to the sand bar in order to improve the fish fauna inventory. Although fish collected by both kinds of gear were included in the fish inventory, only the fish collected by gillnets were used in quantitative analyses. .

In order to investigate the structure of fish communities before and after the canal opening, we analyzed species composition and relative abundance for each monthly sample, as well as species richness, diversity (Shannon-Weiner) and evenness. Also, temporal fluctuations in fish community structure were investigated using cluster and detrended correspondence analyses (DCA) for the 20 most abundant species. Absolute abundance and biomass data were transformed by Log_{10} (x+1). The Bray-Curtis similarity index was used in a UPGMA cluster analysis (BEAUMORD, 1991; LEGENDRE and LEGENDRE, 1998).

RESULTS

A total of 2,467 specimens of 35 species were captured in the Imboassica Lagoon, 75% of which were predominantly marine fish (Table 1), 22 species were captured before the canal opening, and 18 species after the opening. *Lycengraulis grossidens*, *Archosargos probatocephalus* and *Elops saurus* were exclusive to the period before the canal opening, whereas *Trachinotus carolinus*, *Centropomus mexicanus* and *Caranx hippos* were exclusive to the period after the canal opening. *Hoplias malabaricus*, *Paralichythys brasiliensis*, *Gerres aprion*, *Genidens genidens*, *Strongylura timucu*, *Mugil liza*, *Mugil curema*, *Micropogonias furnieri*, *Anchovia clupeoides*, *Tilapia rendalli* and *Geophagus brasiliensis* were captured all over the sampling period. Among the 26 species collected by gillnets, 7 were abundant during the whole year; *H. malabaricus*, *P. brasiliensis*, *G. aprion*, *G. genidens*, *S.timucu*, *M.curema*, *and G. brasiliensis*. Still, *L. grossidens*, *A. probatocephalus*, *T. rendalli* and *M. furnieri* were abundant before the canal opening and A. clupeoides and T. carolinus were abundant in the period after the canal opening (Table 1).

During the months before the canal opening, monthly diversity (H') and evenness (J') were practically constant. Although both indices decreased substantially while the connection remained open, they returned to the same levels as before, when the canal was closed again (Table 2). The results of cluster analyses using both matrices, species abundance and biomass showed two distinct groups of

Table 1. Table 1. Absolute abundance of fish species captured by gillnets and seine net before and after episodes of canal openings of Imboassica Lagoon in 1994. Marine (M) or Freshwater (F) fishes.

		Gillnets		Seine net	
Species	Env	Before	After	Before	After
Anchovia clupeoides	**M**	10	20		
Archosargus probatocephalus	**M**	27			
Awaous tajasica	**M**	3	3		
Bathygobius soporator	**M**			2	
Caranx hippos	**M**		5		4
Centropomus mexicanus	**M**		4		
Citharichthys spilopterus	**M**	2			
Diapterus rhombeus	**M**	3	6		
Eleotris pisonis	**M**				1
Elops saurus	**M**	12			
Gerres aprion	**M**	132	99	171	27
Geophagus brasiliensis	**F**	22	44	71	13
Genidens genidens	**M**	59	36	101	7
Hoplosternum littorale	**F**	1			
Hoplias malabaricus	**F**	65	66		
Hoplerythrinus unitaeniatus	**F**	7	1		
Hyphessobrycon bifasciatus	**F**			1	
Hyporhamphus unifasciatus	**M**			7	
Jenynsia lineata	**F**			2	3
Lutjanus jocu	**M**	1			
Lycengraulis grossidens	**M**	127		8	
Micropogonias furnieri	**M**	98	17		
Mugil curema	**M**	38	37	1	1
Mugil liza	**M**	5	6		
Myrophis punctatus	**F**				1
Paralichthys brasiliensis	**M**	48	43	2	1
Platanichthys platana	**M**			96	75
Pomatomus saltatrix	**M**	1			
Poecilia vivipara	**F**				5
Sphaeroides testudineus	**M**			1	2
Strongylura timucu	**M**	32	26	13	1
Tilapia rendalli	**F**	21	9	16	31
Trachinotus carolinus	**M**		299		8
Trinectes paulistanus	**M**	2			
Xenomelaniris brasiliensis	**M**			111	247
Total		716	721	603	427

months before and after the canal opening (Figure 2) with cophenetic coefficients of 0.85 and 0.75 respectively. Results of the detrended correspondence analyses revealed the same patterns observed in the cluster analyses corroborating the fact that fish community changes after the events of canal openings (Figure 3). Cluster and detrended correspondence analyses revealed distinct groups, regarding species composition and abundance, before and after canal opening.

Table 3 summarizes the data for salinity and water temperature during the period of study. When the canal remained closed, salinity oscillated between 0 and 5 ‰. During the connection period, salinity varied between 18 and 35 %, depending on tidal flows. After the canal was completely blocked again, salinity returned to the previous levels due to water coming from the river and rains. The temperature of the water surface showed little seasonal variation with values reaching 21°C during winter and 26°C during summer.

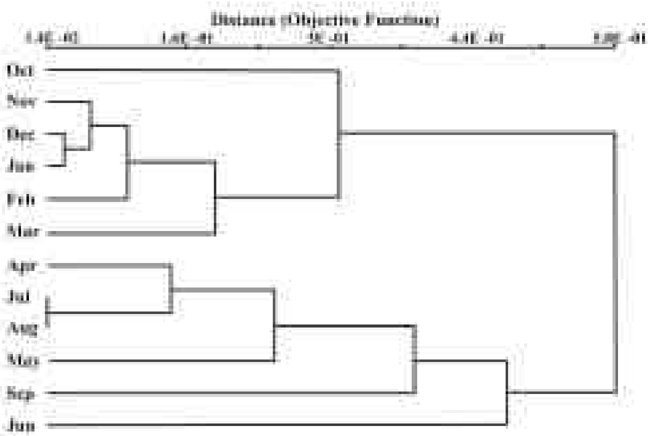

Figure 2. Dendrogram from the UPGMA cluster analyses based on abundance of the 20 most abundant species in 12 monthly samples (from October 1993 to September 1994). Artificial canal opening occurred in late March and early April.

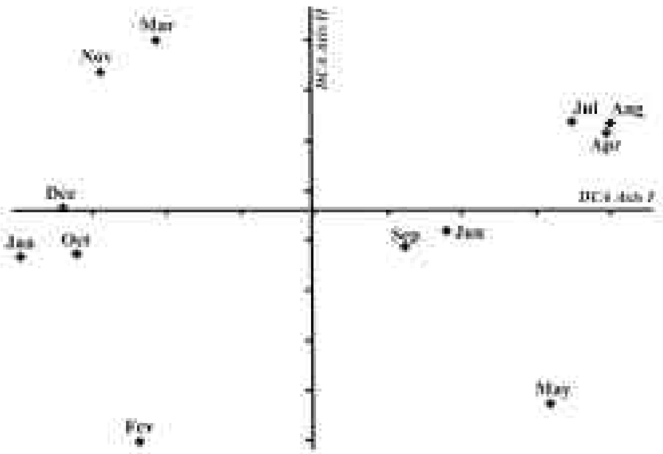

Figure 3. Plots of the first and second axis scores from a detrended correspondence analysis (DCA) based on abundance (eigenvalues 0.234 and 0.067) of the 20 most abundant species in 12 monthly samples (from October 1993 to September 1994). Artificial canal opening occurred in late March and early April.

Table 2. Monthly species richness, diversity (Shannon-Weiner) and evenness.

Month	Richness *(S)*	Diversity *(H')*	Evenness *(J')*
Oct	13	3.070	0.830
Nov	12	3.204	0.894
Dec	15	3.312	0.848
Jan	15	2.993	0.766
Feb	14	3.022	0.794
Mar	16	3.470	0.869
Apr	16	1.912	0.478
May	15	2.312	0.592
Jun	9	2.603	0.821
Jul	13	3.011	0.814
Aug	9	2.390	0.754
Sep	11	2.998	0.867

Table 3. Monthly salinity (‰) and watertemperature (°C) in Imboassica Lagoon from October 1993 to September 1994.

Month	Salinity (‰)	Temperature (C°)
Oct	0.5	25.0
Nov	2.3	26.0
Dec	1.7	26.0
Jan	1.8	27.0
Feb	2.6	27.0
Mar	25.0	25.0
Apr	23.0	25.0
May	10.5	24.0
Jun	9.4	24.0
Jul	2.5	20.0
Aug	2.1	21.0
Sep	1.2	22.0

DISCUSSION

In coastal lagoon systems, variation in physical factors such as salinity, precipitation, evaporation, winds, streams and sea connections, determine the structure of local fish communities by either limiting or favoring specific groups. Nevertheless, there are families that are typical of coastal systems and utilize these systems as complementary areas for their life cycles, bearing broad variations of environmental factors (YANEZ-ARANCIBIA, 1986). Species belonging to freshwater families, such as the Characidae and the Erythrinidae, were associated with the coastal lagoons Imboassica, Cabiúnas and Comprida (AGUIARO and CARAMASCHI, 1995), in the State of Rio de Janeiro. The present study adds the occurrence of a species that represents the Callichthyidae family. Results found in this study corroborate with those found in other coastal lagoons in the State of Rio de Janeiro (ANDREATA *et al*., 1989; ANDREATA *et al*. 1992; AGUIARO and CARAMASCHI, 1995; SAAD, 1997), suggesting that these systems shelter a particular group of euryhaline species, predominantly marine, despite the variations of species composition among coastal lagoons. Artificial canal openings create an intense flow out to the sea dragging out fish and other organisms. Ocean tides invade the lagoon bringing new marine fish populations present on the surroundings of the coast when the canal is opened (SAAD, 1997). These populations come inside the lagoon and stay confined after the canal is naturally closed afterwards. Freshwater species, such as *T. rendalli* and *G. brasiliensis* are dragged out to the sea and die during the event; some individuals manage to hide upriver and return after salinity stabilizes. The fluctuation of species abundance in this lagoon is primarily associated with human activities such as fishing, pollution and artificial canal openings. Following the definitions provided by CONNEL and SOUZA (1983) regarding persistence, stability and constancy, we observed that nearly 30% of the species sampled ascribed persistence to this community, however with low stability. In this system, a different community was established when the canal was opened, suggesting a situation of a community with Multiple Stable Points (sense SUTHERLAND, 1974).

We analyzed both monthly diversity and evenness to investigate whether episodes of artificial canal openings might cause changes in the community structure. We verified a sharp decrease in diversity during the months the canal remained open due to changes in evenness instead of to abundance. However, in the following months, there was a tendency for these community parameters to return to the levels reported before the canal was opened, even after a new community had been established. According to CONNEL (1978), intermediate disturbance levels may promote the increase of diversity by limiting dominant competitive species, which are capable of excluding others. However, in Imboassica Lagoon, the high level of disturbance caused by the opening has caused a decrease in diversity, even if temporary, due to the noticeable dominance of some species upon others. Hence, if opening the canal artificially aims to promote renovation of marine stocks and increase fishing activities, it is essential to define how frequent the canal should be opened. According to SOUZA (1979), the frequency of disturbances in natural systems affects community structure altering species composition and diversity. Opening the canal too often may not only damage the structure of communities, but also may result in losses for the fishing activity, since the stocks of young fishes available in the lagoon will not have enough time to grow.

SKUD (1982) has demonstrated that not only the dynamics of a population, but also the composition of communities in each ecosystem depend on the variation of abiotic factors such as temperature and salinity, as well as other intra and inter-specific interactions with natural resources. He also observed that other factors associated with human activities, such as fishery and pollution might also reduce the abundance of dominant species, which in turn would favor the growth of the remaining populations. Our results showed that episodes of opening the canal artificially and consequently increasing the salinity gradient, affect both species composition and diversity of fish communities in the Imboassica Lagoon.

The results presented here confirm that the Imboassica Lagoon exhibits a mixed fish fauna, which is rich and abundant, mostly with marine species. Many of young individuals of different species go in the lagoon, and as they grow, populations decrease due to local fishing and predation. Also, domestic effluents or a failure to open the canal would reduce diversity and species abundance over time. This would occur due to the increasing dominance of few freshwater species over marine species, because most of the marine species cannot reproduce in this system (SAAD, 1997). On the other hand, opening the canal is beneficial to the fish community. Each time the canal is opened different populations enter and/or leave the lagoon, depending on the stocks available on the surrounding coast at the time (SAAD, 1997). Despite changes in species evenness, there is a strong tendency for community parameters to return to the previous level after the new community has been established. Opening the canal represents a short-term disturbance because of the sudden changes caused by physical factors mainly salinity. Consequently, it affects the structure of the fish community regarding the species composition, as well as their abundance and diversity. In order to establish an environmental policy to manage this system, further studies should address how often such openings should occur to assure a small scale fishing activity and a healthy environment.

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