BENTHIC MACROINVERTEBRATES AS ECOLOGICAL INDICATORS OF WATER LEVEL CHANGES IN MARGINAL LAGOONS AT LOWER SÃO FRANCISCO FLOODPLAIN RIVER

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ABSTRACT

The diversity of benthic macroinvertebrates in marginal lagoons at the low São Francisco watershed is dependent on water flow of upstream reservoirs. These organisms inhabit the bottom of freshwater ecosystems and their presence/absence, abundance and species richness are ecological indicators of water level fluctuations and human impacts in the watershed. The objective of this study was to assess the taxonomic composition and community structure of benthic macroinvertebrates at four marginal lagoons at the low part of São Francisco watershed (Lagoa do Morro, Lagoa Pindoba, Várzea Matias de Souza, and Várzea Marituba do Peixe), comparing dry (October/2007) and rainy (June/2008) seasons. Sediment samples were collected using an Eckman-Birge dredge (0.0225m²) in seven replicates at each system in each seasonal period, and another sample was taken to evaluate the organic matter content and granulometric composition. Some physical-chemical parameters were measured in the water column to assess the water quality such as temperature, pH, dissolved oxygen, Total-P and Total-N, turbidity, electrical conductivity and total alkalinity. During the dry season the total richness was low (4-8 *taxa*) with the predominance of Ceratopogonidae, Chironomidae and Oligochaeta in all lagoons, the last two being the most abundant (64-90% of total invertebrates). At Lagoa do Morro we found higher taxonomic richness (8 *taxa*), density (882.54 ind.m²) and Shannon-Wiener diversity (1.13). The obtained results will support the calculation of the minimum discharge necessary to maintain the benthic diversity (called ecological discharge).

Keywords: benthic macroinvertebrates, bioindicators, environmental impact, marginal lagoons, ecological discharge.

INTRODUCTION

Aquatic ecosystems have been suffering significant changes due to anthropic activities like mining, artificial eutrophication, channeling and rectification of water courses, pollution, sediment deposition, overfishing and allien species introductions, all of which produce biodiversity losses as a direct consequence (Callisto *et al*, 2001; 2005; Agostinho *et al,* 2005).

Other important factors that negatively contribute to biodiversity losses are river damming and flow suppressing at hydroelectric power stations. These alter the downstream water flow and modify the natural hydrologic regime of water courses, reduce the mean annual flow volume and the seasonal variation of it, alter the occurrence of extreme outflows, reduce the magnitude of these outflows and/or impose unnatural discharges (Alves & Bernardo, 2000).

Floodplains are periodically submersed areas that can be flooded due to an increase in the water level of an adjacent river, by precipitation, or by soil saturation. This produces peculiar ecosystems with highly adapted biological communities (Junk *et al.*, 1989; Junk & Wantzen, 2004). The presence of *várzeas* and marginal lagoons formed by the filling up of terrain depressions during river outflows is frequent in these regions (Sperling, 1999). These environments are widely recognized for their importance for the maintenance and integrity of aquatic biodiversity (Agostinho *et al*., 1993; 2000), and for their high ecologic and economic values that are due to their role as nurseries for the initial developmental stages of *piracema* (seasonally reproductive) species (Pompeu & Godinho, 2003).

The benthic macroinvertebrate communities found in the marginal lagoons complex at the lower course of the São Francisco River are important environmental indicators. These organisms are easy to measure, sensitive to alterations in ecosystems that cause detectable and measurable responses in them; they predict changes that can be avoided by implementing management actions; they respond to natural disturbances and anthropic induced stresses and to temporal variations in water quality characteristics; and their responses to the environmental alterations present low variability (Dale & Beyeler, 2001). Their distribution and structure are directly influenced by the type of substrate, the ecosystem morphology, the amount and kind of organic detritus, the presence of aquatic vegetation and the size of the riparian forests. They are also indirectly affected by modifications in nutrient concentration and changes in primary productivity. Adverse outflow conditions are limiting factors for the success of these communities (Poff & Ward, 1989; Ward, 1992).

The benthic invertebrates have an important role in the conversion of vegetal material and detritus into animal tissue in the aquatic and riparian decomposition chains, being fundamental for the aquatic food webs. Disturbances in these webs can cause alterations in the energy supply for the entire ecosystem with potential effects at the hydrographic basin scale (Vannote *et al.,* 1980). The objective of this study was to evaluate the structure and composition of the bioindicator benthic communities at marginal lagoons located at the lower São Francisco River in order to contribute for the knowledge of the potential impact of the regularization of its course due to the construction of hydroelectric dams. This knowledge will provide baseline information for the establishment of a minimum outflow to be released in order to preserve the integrity and maintenance of the benthic communities.

MATERIALS AND METHODS

Study area

With an extension of ca. 2800 km, the São Francisco River is born at the Serra da Canastra National Park, in the south east of the Brazilian state of Minas Gerais and discharges at the Atlantic Ocean, in the border between the states of Alagoas and Sergipe. Its course drains the states of Minas Gerais, Bahia, Pernambuco, Alagoas, Sergipe and the Federal District, running through three different Brazilian biomes: the Cerrado, the Caatinga and the Atlantic Forest.

Four marginal lagoons belonging to the lower São Francisco River floodplains were studied between October 2007 and June 2008:

- Lagoa do Morro (Sergipe) - 10º 13’ 34.6” S, 36º 49’ 23.8” W
- Lagora Pindoba (Sergipe) - 10º 16’ 22.0”S, 36º 42’ 50.5”W
- Várzea Matias de Souza (Sergipe) - 10º 15’ 59.3”S, 36º 37’ 27.5”W
- Várzea Marituba do Peixe (Alagoas) - 10º 19’ 29.7”S, 36º 29’ 06.5”W

Water and sediment abiotic parameters

The following measures were taken in each lake: water temperature, electrical conductivity, pH and turbidity were measured using a multi-probe HORIBA, model U10. Total alkalinity was measured and the dissolved oxygen was determined by the Winkler method using triltration with sodium thiosulfate. Water samples were taken to the laboratory at the Universidade Federal de Minas Gerais (UFMG) for the analysis of total-P (Strickland & Parsons, 1960) and total-N (Mackereth, 1978).

Sediment samples were collected in each lake for the determination of the granulometric composition following the methodology of Suguio (1973) modified by Callisto & Esteves (1996). In order to determine the organic matter content 0.3 g aliquots were calcinated at 550º C in a mufla oven (gravimetrics).

Benthic macroinvertebrate communities

Seven quantitative sediment samples were collected at each lake during wet and dry periods taking into account available habitats and geomorphologic characteristics that allowed the comparison of the benthic macroinvertebrate communities found in the lakes. An Eckman-Birge sampler with 0.0225 m² sampling area was used.

The sediment samples were taken to the Laboratório de Ecologia de Bentos at the UFMG, washed in a 0.5 mm mesh size sieve, stored in containers with 70% alcohol solution until specimen identification (to the lower taxonomic category possible) using a stereomicroscope (Zeiss, 20x) and with the aid of taxonomic keys (Pérez, 1988; Merritt & Cummins, 1998). The specimens collected were deposited at the Benthic Macroinvertebrate Reference Collection of the ICB/UFMG according to the methodology described in França & Callisto (2007).

To characterize the structure of the benthic macroinvertebrate communities the following indices were calculated: Shannon-Wiener diversity, Pielou equitability, organismal density (ind/m^2) and relative abundance (% ind/m²).

RESULTS AND DISCUSSION

Water and sediment abiotic parameters

The Lagoa do Morro presented the higher values for most of the abiotic parameters measured during the wet and the dry seasons. Dissolved oxygen values were reduced at the Pindoba, Várzea Matias de Souza and Várzea Marituba do Peixe from the dry period to the wet season. The highest dissolved oxygen value observed at the Lagoa do Morro during the wet season can be partly explained because the sample collection was made during rainfall when there is oxygen exchange in the water-air interphase that oxygenates the water column.

The organic matter contents of the sediments varied between 7.70 and 11.67% during the dry season and from 6.47 to 17.17% during the wet season. At the Pindoba lake this variation was considerable (10.12 – 17.17%) and was accompanied by an increase in turbidity, total-P and total-N and a dissolved oxygen reduction. The short term effects of river regularization can be noticed at this local since the outflow released by upstream reservoirs was not enough to flood the lake and, as a consequence, macrophytes occupied the entire surface of the lake altering the structure of this ecosystem.

The analysis of the granulometric composition of sediments revealed the dominance of fine sand fractions at the lakes during both sampling periods. This is a typical composition of lentic environments where particle sedimentation is intense. However, a slight seasonal variation could be observed with an increase of coarser particles and the reduction of the fine sand particles (Table 1).

Table 1. Physical and chemical characterization of the sampling points in Lagoa do Morro, Lagoa Pindoba, Varzea Matias de Souza and Varzea Marituba do Peixe during dry and rainy seasons.

	L. do Morro		L. Pindoba		V. Matias de Souza		V. Marituba do Peixe	
	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy
Water column								
Temperature (ºC)	29.3	28.0	28.0	25.2	31.0	27.8	31.0	27.9
Dissolved oxygen (mg/L)	3.6	8.4	4.2	1.5	4.4	1.9	3.5	3.8
pH	7.19	7.23	6.49	5.89	6.24	6.05	6.66	5.45
Conductivity (µS/cm)	1061	919	83.8	89	586	475	227	157
Total Alcalinity (µEq/L CO_2)	957.5	1387.0	320.0	637.0	321.9	609.9	126.3	109.1
Turbidity (UTN)	524.0	439.0	5.8	304.0	109.0	10.4	255.0	3.5
Total Phosphorus (mg/L)	0.178	0.130	0.032	0.063	0.032	0.012	0.032	0.069
Total Nitrogen (mg/L)	0.392	0.294	0.077	0.217	0.084	0.154	0.119	0.203
Sediment								
Organic Matter content (%)	11.67	9.88	10.12	17.17	7.70	6.47	7.77	10.45
Granulometric Composition (%)								
Pebbles	11.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gravel	6.7	4.6	0.2	0.0	0.0	4.8	1.8	0.6
Very coarse sand	4.9	17.3	2.5	3.3	5.3	7.6	5.8	3.8
Coarse sand	9.7	21.7	8.4	15.3	13.4	15.7	12.3	11.9
Median sand	20	19.7	18.4	23.6	20.5	14.4	17.1	24.6
Fine sand	12.3	10.4	11.1	10.8	12.3	8.0	17.1	21.8
Very fine sand	21.2	17.0	26.4	21.2	20.3	37.0	27.6	24.8
Silt+Clay	14.0	10.3	32.3	25.6	27.7	12.7	18.3	12.4

Benthic macroinvertebrate communities

The benthic macroinvertebrate communities at the four marginal lagoons sampled during both seasons were composed by eleven taxa distributed in three Phyla (Mollusca, Annelida and Arthropoda), three Classes (Gastropoda, Oligochaeta and Insecta), five Orders (Odonata, Ephemeroptera, Coleoptera, Heteroptera and Diptera) and nine Families (Polymitarcyidae, Gomphidae, Libellulidae, Pleidae, Hydrophilidae, Ceratopogonidae, Chironomidae, Chaoboridae and Simuliidae).

During the dry season, of the nine taxa found in the four lakes, eight were found at the Lagoa do Morro. Oligochaeta, Chironomidae and Ceratopogonidae larvae were present in all the lakes. At the Lagoa do Morro, Lagoa Pindoba and at the Várzea Marituba do Peixe, Chironomidae and Oligochaeta were dominant (representing together 88 to 90% of the community) while at the Várzea Matias de Souza the family Chironomidae represented 88% of the community. The lagoa do Morro presented higher richness (eight taxa), higher total density (882.54 ind/m²) and higher Shannon diversity (H'=1.13) (Table 2).

Table 2. Taxonomic composition, densities (ind.m-^{2}), total richness, total densities, equitability and Shannon-Wiener diversity indices during the dry season in the four lakes sampled.

	Lagoa do Morro	Lagoa Pindoba	V. Matias de Souza	V. Marituba do Peixe
Gastropoda	1.14±1.35	0.29±0.49		
Annelida				
Oligochaeta	10.14±8.43	2.14±4.81	0.43±1.13	10.71±12.13
Arthropoda				
Insecta				
Ephemeroptera				
Polymitarcyidae	0.29±0.49			
Odonata				
Gomphidae			0.14±0.38	
Libellulidae	0.14±0.38			
Heteroptera				
Pleidae	0.14±0.38			
Coleoptera				
Hydrophilidae	0.14±0.38			0.14±0.38
Díptera				
Ceratopogonidae	0.43±1.13	0.29±0.49	1.14±1.21	1.86±1.86
Chironomidae	7.43±10.72	3.29±2.56	12±10.13	4±3.56
Total Richness	8	4	4	4
Total Density	882.54	266.67	609.52	742.86
Pielou Eveness	0.54	0.71	0.35	0.66
Shannon-Wiener Diversity	1.13	0.99	0.48	0.91

During the wet season, the Oligochaeta and Chironomidae were again dominant, representing together the 78 to 99% of the total community in each lake. The Lagoa do Morro had the higher richness values (seven taxa), equitability (0.647), Shannon diversity (H'=1.26) and total density (1561.9 ind/m²) (Table 3).

Table 3. Taxonomic composition, densities (ind.m-[2]), total richness, total densities, equitability and Shannon-Wiener diversity indices during the wet season in the four lakes sampled.

	Lagoa do Morro	Lagoa Pindoba	V. Matias de Souza	V. Marituba do Peixe
Gastropoda	1.14±1.86	0.43±0.79		
Annelida				
Oligochaeta	14.86±12.35	6.86±8.90	9.57±8.72	20.71±39.98
Arthropoda				
Insecta				
Ephemeroptera				
Polymitarcyidae	5.14±5.87			
Odonata				
Libellulidae		0.14±0.38		
Coleoptera				
Hydrophilidae	0.14±0.38			0.14±0.38
Díptera				
Ceratopogonidae	0.86±1.21		0.43±0.79	
Chironomidae	12.86±20.10	6.57±4.31	2.14±1.86	0.86±1.14
Chaoboridae	0.14±0.38			
Simuliidae			0.14±0.38	
Total Richness	7	4	4	3
Total Density	1561.90	622.22	546.03	965.08
Pielou Eveness	0.65	0.62	0.48	0.19
Shannon-Wiener Diversity	1.26	0.46	0.67	0.21

There was almost no richness variation between seasons. However, there was a relative increase in densities in three of the four studied lakes. In a review by Dewson *et al.* (2007), it was observed in rivers and streams that have low outflow or it is reduced artificially that the macroinvertebrate communities tend to respond to this situation with the reduction of their population density. The probable cause for this would be the changes in trophic relationships among individuals due to the alteration available resources quality and quantities (Cowx *et al*. 1984; Wood *et al*. 2000). On the other side, there can be a density increase when there is a low outflow episode (Dewson *et al*., 2007), since flow reduction decreases the total wet area and causes the concentration of the community in a smaller ecosystem area (Gore 1977; Wright & Berrie 1987). This could be applicable to the marginal lagoons that depend on the river overflow for the maintenance of the aquatic biodiversity. An outflow reduction would also result in a reduction of the wetted area and a concentration of the macroinvertebrates in a smaller area. This scenery can be observed at the lower course of the São Francisco River where the outflows are regulated by a sequence of upstream hydroelectric reservoirs (Callisto *et al.* 2001) located in the middle course of the river, that alter the natural pulse of floods and compromise the natural flooding of its floodplain.

The outflow reduction can lead to habitat loss (Dewson *et al.* 2007) affecting specific groups of organisms (Cazaubon & Giudicelli 1999) and reducing taxonomic richness (McIntosh *et al.* 2002). However, the richness reduction can be less if habitat diversity is maintained even if there is an outflow reduction (Wood & Petts 1999). In the case of marginal lagoons, typically lentic environments, there might not be great habitat alterations, maintaining the same conditions needed for the permanence of invertebrate communities when the outflow is near the natural or when there are low outflow episodes.

CONCLUSIONS

Human activities in a hydrographic basin can create and/or increase a period of low outflow in the river, altering natural episodes of high outflow and its natural cycle. The consequences of this are observed in the aquatic ecosystems through bioindicator communities that respond to these alterations. As can be seen at the marginal lagoons of the lower course of the São Francisco River, benthic macroinvertebrate communities are sensitive to these changes and respond through alterations in their composition, distribution, richness and abundance. Although there are some studies published regarding the ecological consequences of the outflow reduction, few of them were developed at marginal lagoons in the neotropical region. The benthic communities that live in these lakes reflect the magnitude of the impacts suffered by the main river channel and its basin. In addition, there is the importance of these lakes as an economic and subsistence resource for the riverine communities that live in their surroundings.

The study of the benthic macroinvertebrate communities at marginal lagoons provides base line information to evaluate the magnitude of the impact that the regularization of the lower course of the São Francisco River will have over the marginal lagoon system, aiding in the estimation of the outflow needed to be released in order to preserve the integrity and maintenance of the biological communities. This information will also aid for the establishment of management programs and policies that intend to preserve and rationally use these ecosystems.

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