Status of the Barra das Jangadas estuary (North-eastern Brazil): an ecological approach

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Abstract

The basic hydrological and planktonic characteristics of the Barra das Jangadas estuary were monitored to assess the water quality and the abiotic factors influencing the plankton populations. An intensive seven day sampling program was conducted at a fixed station, during the dry (January/2001) and the rainy (July/2001) seasons. Phytoplankton, zooplankton and the water physicochemical parameters were sampled in different tides, totaling 56 sampling procedures during the 168-hours-program, in each season. The dissolved oxygen was under saturation at low tide in both seasons, indicating a polluted area; and saturated during high tide due to marine influence. High overall nutrient concentrations indicated an eutrophic environment. Chlorophyll-a was high (~25 mg.m⁻³). The marine eurihaline plankton dominated the area. Phytoplankton presented 266 species, however only six were abundant and frequent; density varied from 95.10³ cell.L⁻¹ to 7,830.10³ both in the rainy season, and cyanobacterial blooms usually occurred in the estuary unbalancing the system. The zooplankton presented 87 taxa and varied from 1,300 to 18,500 ind.m⁻³. The plankton diversity was low, mostly composed of r-strategists. The main pattern observed was marine eurihaline species in the dry season during high tide and limnetic species in the rainy season, low tide. During the neap tide in both seasons the water renovation was very poor, increasing the pollution load residence time.

Keywords: estuary, water quality, nutrients, phytoplankton, zooplankton.
1 Introduction

An estuary, due to its condition as boundary between marine and freshwater systems, is characterized by extreme environmental gradients. Thus, the estuarine communities present a variability pattern that is a function of its geographic distribution. Nevertheless, that natural variability is often hidden under other much more erratic variability associated with anthropogenic activity, both urban-industrial and agricultural [1, 2].

The widespread human population cause nutrient enrichment of estuarine ecosystem and this trend is predicted to increase further in the present decade [3]. High rates of nutrient loading to coastal environments frequently enhance phytoplankton growth and biomass, and increase the rate of organic matter loading, ultimately resulting in eutrophication [3, 4]. Change in nutrient loading, can alter the species composition of primary producers [5]. Such shifts in the primary producer community are likely to cascade through the food web, altering consumer food web dynamics, and thus the flow of carbon through a system. It is therefore critical to understand the ecosystem response to nutrient loading.

The Barra das Jangadas tropical estuary, formed by the confluence of the perennial Jaboatão and Pirapama rivers, is under intense anthropogenic impacts since the sixties. Earlier surveys in this estuary [6] showed already an impacted ecosystem, as the water quality was degraded by the discharge of domestic sewage and sugar cane residuals. At that time, Eskinazi [7] showed already, that the phytoplankton community indicated an eutrophic system with intense diatoms blooms. For nearly 4 decades very few studies on the water quality were conducted in the estuarine area, most of them carried out in the last four years as impacts reports, dissertations or thesis (see [8, 9]).

The purpose of this study was to assess the status of the Barra das Jangadas estuary through the structural and functional aspects of the plankton communities and their relationship with the organic enrichment and nutrient gradients.

2 Material and methods

2.1 Study area

The Barra das Jangadas estuarine system is located in Northeastern Brazil in Pernambuco State (8°12'30”- 8°15'20”S and 34°55'00”- 34°57'30”W), and is formed by the Pirapama and Jaboatão rivers and their tributaries. It has a long “S” shape with 200-250m wide and 1 Km long [10]. These rivers drain together a 1,002.3 Km² area into the Atlantic Ocean, fig. 1. Tides at Barra das Jangadas are semidiurnal with a mean range of 1.3 m at neap tide and 2.2 m at spring tide.

The annual mean temperature is approximately 26±2.8°C. The regional year can be divided in two different periods: the rainy season (March to August) with frequent rain (>400 mm) and the summer dry season (September to February), with lower amounts of rain (<100 mm) [10].

The Jaboatão is a shallow (1-4 m deep), 75 Km long tropical river. Its tributaries drain a basin of 413 Km² including small areas covered by the original Atlantic forest. It receives a high load of domestic and industrial wastes as well
as a seasonal input of high levels of organic matter from the sugar-cane industries in its middle course; its lower course is bordered by relatively well preserved mangrove swamps [10].

The Pirapama River is located in the southern part of the Atlantic forest. Its springs and tributaries are used as water supplies. There is an industrial zone on its banks comprising mostly rum distilleries and sugar factories [10].

Figure 1: Barra das Jangadas area and sampling station, Pernambuco, Brazil.

2.2 Sampling and sample processing

Intensive seven days sampling was conducted at one fixed station located at the Barra das Jangadas estuary, fig. 1, from a spring to a neap tide, in different tide
levels (high, low, ebb, flood) nearly 3 hours intervals, during the dry (January/2001) and the rainy (July/2001) seasons, totaling 168 hours sampling program in each season. Since the aim of this study was directed towards impacts of the Barra das Jangadas loading on plankton abundances, sampling was restricted to the surface layer. Water for abiotic factors data were collected at surface with a Nansen bottle. The following variables were measured: temperature – digital thermometer; salinity (Mohr-Knudsen method); dissolved oxygen according to modified Winkler method [11]; pH - Hanna Instrument 8417 pHmeter; nutrients [12, 13], and chlorophyll a concentrations were determined using the spectrophotometric technique [14].

Water samples for phytoplankton were collected with a Van Dorn bottle and samples preserved with 1% Lugol’s iodine solution. In laboratory qualitative-analysis were carried out using the Ütermol method under an inverted microscope. Zooplankton was sampled with a plankton net 65µm mesh size, hauled horizontally for 3 minutes at sub-surface. A flowmeter (Hydrobios, Kiel) was fitted on the opening of the net used. Samples were preserved in a 4% buffered formaldehyde/seawater solution. Zooplankton species were identified until the lowest taxonomic unit possible and taxon abundance (per cubic meter) counted under a compound microscope (1ml subsample). These samples were taken with a Stempel-pipette of each the entire sample (250 ml).

The Shannon diversity index (H’) [15] was applied for the estimation of plankton community diversity based on log₂, and the evenness according to Pielou [16].

3 Results

3.1 Abiotic parameters

The most characteristic physical feature of Barra das Jangadas estuary is the shallow water column, often well mixed. The circulation pattern is mainly dominated by tidal currents. The current velocity varied from 0 to 1.10 m.s⁻¹. Water transparence, varied from 0.4 m (rainy season) to 1.41 m (dry season), and higher values were registered during the dry season spring high tide. The studied estuary presents a warm temperature with slight daily variation with a minimum of 25.2°C in the rainy season and a maximum of 29.7°C in the dry season. Average temperature was 26.61±0.75°C (rainy season) and 28.11±0.77°C (dry season). The minimum (6.12) and maximum (8.76) pH values were registered in the rainy season. General average for both seasons was 7.47±0.61.

Salinity varied largely between tides and with season, fig. 2. The smallest salinity values (PSU) were 0.27 (rainy season, flood, neap tide) and the highest was 34.76 (dry season, high tide, spring tide) with an average value of 9.43±11.61 (rainy season) and 19.16±11.91 (dry season), table 1. These results show that the salinity regime in the area varies from oligohaline to euhaline in the dry summer season, and from limnetic to euhaline during the rainy season.

Dissolved oxygen also varied significantly (p<0.05) from 0.13 ml.L⁻¹ (2.34% saturation) in the rainy season to 7.96 ml.L⁻¹ (160.37% saturation), fig. 2, with
averages values of 2.66±1.61 ml.L⁻¹ (51.92±34.73%) in the rainy season and 4.02±1.08 ml.L⁻¹ (82.81±24.88%) in the dry season, table 1. The occurrence of very low dissolved oxygen, even with anoxic periods is explained by the increased production of organic matter within the ecosystem.

Nutrients (ammonium, nitrite, nitrate, phosphate and silicate) data can be seen in table 1. They were variable, but in general were higher in the rainy season and low tides. Nutrients levels generally were indicative of eutrophication. Nitrate the most variable can be seen in figure 2. It was also observed a trend to increase from spring to neap tide, due higher residence time of the organic pollution.

Table 1: Abiotic parameters at Barra das Jangadas estuary.

<table>
<thead>
<tr>
<th>ENVIRONMENTAL PARAMETERS</th>
<th>DRY SEASON</th>
<th></th>
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<th></th>
<th>RAINY SEASON</th>
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<tbody>
<tr>
<td></td>
<td>MINIMUM</td>
<td>MAXIMUM</td>
<td>MEAN</td>
<td>SD*</td>
<td>MINIMUM</td>
<td>MAXIMUM</td>
<td>MEAN</td>
<td>SD</td>
<td></td>
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</tr>
<tr>
<td>Temperature (°C)</td>
<td>26.40</td>
<td>29.70</td>
<td>28.11</td>
<td>0.77</td>
<td>25.20</td>
<td>28.00</td>
<td>26.61</td>
<td>0.75</td>
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<tr>
<td>Salinity (PSU)</td>
<td>1.72</td>
<td>34.76</td>
<td>19.16</td>
<td>11.91</td>
<td>0.27</td>
<td>33.73</td>
<td>9.43</td>
<td>11.61</td>
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</tr>
<tr>
<td>Dissolved Oxygen (ml.L⁻¹)</td>
<td>1.81</td>
<td>7.96</td>
<td>4.02</td>
<td>1.08</td>
<td>0.13</td>
<td>6.79</td>
<td>2.66</td>
<td>1.61</td>
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<tr>
<td>DO%</td>
<td>40.04</td>
<td>160.37</td>
<td>82.81</td>
<td>24.88</td>
<td>2.34</td>
<td>144.49</td>
<td>51.92</td>
<td>34.73</td>
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<tr>
<td>pH</td>
<td>6.75</td>
<td>8.30</td>
<td>7.61</td>
<td>0.57</td>
<td>6.12</td>
<td>8.76</td>
<td>7.32</td>
<td>0.66</td>
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<tr>
<td>Amonium-N (µmol.L⁻¹)</td>
<td>&lt;0.02</td>
<td>3.02</td>
<td>0.68</td>
<td>0.96</td>
<td>0.30</td>
<td>8.75</td>
<td>3.60</td>
<td>2.96</td>
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<td>Nitrite-N (µmol.L⁻¹)</td>
<td>0.05</td>
<td>0.99</td>
<td>0.40</td>
<td>0.27</td>
<td>0.13</td>
<td>1.41</td>
<td>0.75</td>
<td>0.36</td>
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<tr>
<td>Nitrate-N (µmol.L⁻¹)</td>
<td>0.76</td>
<td>9.10</td>
<td>3.63</td>
<td>2.69</td>
<td>0.33</td>
<td>12.55</td>
<td>5.07</td>
<td>3.05</td>
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<tr>
<td>Phosphate-P (mmol.L⁻¹)</td>
<td>&lt;0.02</td>
<td>0.69</td>
<td>0.25</td>
<td>0.15</td>
<td>0.35</td>
<td>2.94</td>
<td>1.38</td>
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<tr>
<td>Silicate-Si (µmol.L⁻¹)</td>
<td>12.15</td>
<td>245.24</td>
<td>75.63</td>
<td>65.87</td>
<td>20.78</td>
<td>476.04</td>
<td>155.88</td>
<td>148.30</td>
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</table>

*SD= Standard Deviation

3.2 Chlorophyll-a

During this study, chlorophyll-a concentrations ranged from 5.91 mg.m⁻³ (rainy season) to 158.60 mg.m⁻³ (dry season), averaging 33.07±32.53 mg.m⁻³ (dry season) and 20.32±13.2 mg.m⁻³ (rainy season), fig. 3. Peak concentrations occurred during the dry season, mainly at spring tide.

3.3 Phytoplankton

A total of 125 phytoplankton infrageneric taxa were identified to the Barra das Jangadas estuary. Bacillariophyta was the most abundant taxa (44.0%) followed by Chlorophyta (33.6%), Cyanophyta (13.6%), Euglenophyta (4.8%), Dinophyta (3.2%) and Chromophyta (0.8%).

Few species dominated in the estuary outranking Cyclotella meneghiniana, Microcystis flos-aquae, Oscillatoria sp. and Sphaerocystis sp. The blue-green Microcystis flos-aquae is potentially toxic and decreases the water quality when occurring in dense blooms as it was observed in the present study.
Figure 2: Main abiotic parameters in the Barra das Jangadas estuary. LT=low tide, HT=high tide, D=day, N=night.
Species diversity index were under 2 bits. ind$^{-1}$ and the evenness under 0.5 indicating an unbalanced system. This very low index is due the dominance of Cyclotella meneghiniana in the dry season and Cyclotella meneghiniana, Microcystis flos-aquae, and Oscillatoria in the rainy season.

During the dry season, the total abundance varied from $95.10^3$ Cel.L$^{-1}$ (high tide) to $7,830.10^3$ Cel.L$^{-1}$ (low tide), fig. 3, and this high density was due a bloom of Cyclotella meneghiniana. Higher abundances occurred during flood and low tide. No pattern was observed in the temporal series, with irregular blooms of diatoms and phytoflagellates. During the rainy season, the abundance varied from $35.10^3$ Cel.L$^{-1}$ (low-tide) to $8,200.10^3$ Cel.L$^{-1}$ (high tide), fig. 3. During this season a pattern was observed with blooms of the diatom Cyclotella meneghiniana from the first to the third day, followed by a Sphaerocystis sp.
(Chlorophycea) bloom (third to fifth day) and *Microcystis flos-aque* and *Oscillatoria* sp. (blue-greens) blooms from the fourth to the seventh day.

In general phytoplankton followed a pattern of decreases in biomass coupled with increases in diversity from low salinity waters (low tide) to high salinity (high tide).

### 3.4 Zooplankton

The zooplankton presented 87 taxa outranking Copepoda during the dry season and Rotifera during the rainy season. A common trend was the Copepoda dominance during high tide and rotifers at low tide. Copepoda outranked with 21 species, followed by Rotatoria (18 species) and Protozoa (10 species). The meroplankton was represented by Polychaeta larvae (dominated by spionids), Gastropoda and Bivalvia larvae and nauplius of Cirripedia, sometimes dominating the community. Zooplankton density varied from 1,300 to 18,500 ind.m\(^{-3}\), both in the dry season, however average density was higher in the rainy season (4014.15 ± 3104.74 ind.m\(^{-3}\)). Species diversity and evenness were low (<2.3 bits.ind\(^{-1}\) and < 0.5, respectively).

The zooplankton was essentially composed of typical marine euryhaline species. The most common Copepoda were *Parvocalanus crassirostris*, *Acartia lilljeborgi*, *Oithona hebes* and *Euterpina acutifrons*, in all life cycle stages. The rotifers were mainly represented by *Brachionus plicatilis*, *Brachionus angularis*, *Rotaria* spp., *Filinia longiseta*, *Lecane bulla*, among others. Many taxa were marine and occurred only once during high tide.

### 4 Discussion

The environmental forcings that control plankton dynamics in tropical estuaries in Brazil are little studied compared with temperate Atlantic estuaries. Tropical waters have a warmer temperature regime, including periods of warm temperature (>28°C), and are more frequently impacted by large rainfall events.

Besides the rain, the open marine area imposes large physical and chemical forcing on the estuarine ecosystem, due to tide and wind generated water exchange. This pulse created by the boundary also insures a large transport of organic material and nutrients subsidizing primary and secondary production in the estuarine area.

In the last decades, many coastal areas in Brazil have undergone increased eutrophication, mainly due to nitrate runoff from agriculture and sewage. The insidious nature of the eutrophication process means that in its early stages, the ecological effects are often difficult to distinguish against the normally high variation and dynamic nature of most estuaries. As a consequence, eutrophication is usually clearly recognized only towards the end-point of the process when ecological effects become obvious and dramatic.

The high amount of nutrients, mainly nitrate in the Barra das Jangadas estuary has stimulated phytoplankton growth and increased light attenuation. This eventually result in a decrease in oxygen concentration, and has a trend of
anoxic system collapse, with the development of hydrogen-sulphide conditions, lethal to the benthic community. The Barra das Jangadas ecosystem showed low oxygen concentrations being the area classified as semi-polluted to polluted zone according to the classification of Macedo and Costa [17], only during high tide is the oxygen supersaturated. Studies carried out by Souza and Tundisi [18] along the Jaboatão watershed showed a condition of environmental degradation, and in the urbanized areas worst water quality conditions were found, especially in the summer period, resulting from industrial and domestic effluents. The critical variables in their study were dissolved oxygen, fecal coliformes, and total phosphorus.

The changes in nutrients and dissolved oxygen concentrations caused an increase in numerical abundance of some phytoplankton species altering the ecosystem structure contributing to a decrease in the biodiversity of the area. The low estuarine diversity of phytoplankton, compared with that of coastal marine or oceanic waters, has been attributed to extreme dominance by a few forms able to prosper in an osmotically adverse environment with otherwise favorable growth conditions [20]. However, the frequent phytoplankton blooms and concomitant decrease in oxygen indicate that the Barra das Jangadas brackish water system has been considerably eutrophicated. Like phytoplankton, estuarine zooplankton communities have long been described as very abundant, but composed of few species [1, 20]. The large salinity variations within the estuary imply that most of the species occurring should be euryhaline. These species may be endemic to the estuary or may be carried out from the outside by tides, thus occurring only temporarily [21]. Copepod assemblages then typically decrease in biomass and increase in diversity with salinity [22]. When the salinity decreases Rotifera dominate the zooplankton community, many of which are organic pollution indicators. In general, zooplankton was dominated by Copepoda, which made up nearly 30% of the total number of taxa registered and 62% of total abundance. The dominance of Copepoda in Brazilian tropical estuaries has already been described by Tundisi [23]. The most abundant species found in the present research are typical of estuarine waters [24]. It must be observed in the Barra das Jangadas estuary that the enhanced productivity caused by wastewater input is not passed on to higher trophic levels as was demonstrated by Schwamborn et al. [25] to Guanabara Bay, where extreme eutrophication reduced the zooplankton productivity by causing recurring breakdowns of phyto- and zooplankton communities, probably related to occasional anoxia and peak ammonium concentrations.

References


