Artigo

DREDGING IN THE ITAQUI PORT AREA, MARANHÃO - BRASIL: EFFECTS ON THE COMPOSITION AND ABUNDANCE OF ICHTHYOPLANKTON

DRAGAGEM NA ÁREA DO PORTO DE ITAQUI, MARANHÃO - BRASIL: EFEITOS SOBRE A COMPOSIÇÃO E ABUNDÂNCIA DO ICTIOPLEÂNCTON

DRAGADO EN LA ZONA PORTUARIA DE ITAQUI, MARANHÃO - BRASIL: EFECTOS SOBRE LA COMPOSICIÓN Y ABUNDANCIA DEL ICTIOPLEÁNCTON

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ABSTRACT: Assessments of the effects of dredging on biological resources show decreases in density and abundance of species as a result of dredging activity in port areas. Ichthyoplankton samples were taken before, during and after dredging at the Itaqui port complex west of the Golfão Maranhense. The trawls were drawn horizontally on the surface with a duration of 5 minutes. A plankton net of cone-cylindrical type was used, equipped with a flow meter. 677 fish larvae were collected, obtaining a total of 17 species. Significant effects of dredging were observed on species richness during the three stages. The species Anchoviella lepidentostole was dominant before dredging and its abundance reduced during the dredging, which is causing as consequence behavioral disturbance of these organisms. The Engraulidae family was dominant in this study and this may be a consequence of the greater resistance of their representatives to the changes in the environment caused by dredging. However, the results showed us that dredging activity influences the composition, density and abundance of these organisms.

KEYWORDS: engraulidae, clupeidae, Golfão Maranhense, dredging.

RESUMO: Avaliações sobre os efeitos da dragagem nos recursos biológicos mostram diminuições na densidade e abundância das espécies como resultados da atividade de dragagem em áreas portuárias. Amostragens do ictioplâncton foram realizadas antes, durante e depois da dragagem no complexo portuário do Itaqui a oeste do Golfão Maranhense. Os arrastos foram horizontais na superfície com duração de 5 minutos. Foi utilizada rede de plâncton do tipo cônico-cilíndrica, equipada com fluxômetro. 677 larvas de peixes foram coletadas obtendo um total de 17 espécies. Efeitos significativos da dragagem foram observados sobre a riqueza de espécies durante as três etapas. A espécie Anchoviella lepidentostole foi dominante antes da dragagem e sua abundância reduziu durante a dragagem, em consequência desta atividade provocando perturbação comportamental destes organismos. A família Engraulidae foi dominante nesse estudo e isso pode ser consequência da maior resistência dos seus representantes às alterações ocasionadas no ambiente por essa atividade. No entanto, os resultados nos mostraram que a atividade de dragagem influencia na composição, densidade e abundância desses organismos.

PALAVRAS-CHAVE: engraulidae, clupeidae, Golfão Maranhense, dragagem.
RESUMEN: Las evaluaciones de los efectos del dragado en los recursos biológicos muestran disminuciones en la densidad y abundancia de especies como resultado de las actividades de dragado en zonas portuarias. Se tomaron muestras de ictioplancton antes, durante y después del dragado en el complejo portuario de Itaqui, al oeste del Golfão Maranhense. Las redes de arrastre eran horizontales en la superficie y duraban 5 minutos. Se utilizó una red de plancton cónico-cilíndrica equipada con un caudalímetro. Se recogieron 677 larvas de peces, con un total de 17 especies. Se observaron efectos significativos del dragado en la riqueza de especies durante las tres etapas. La especie Anchoviella lepidentostole era dominante antes del dragado y su abundancia disminuyó durante el mismo, como consecuencia de que esta actividad provocaba alteraciones en el comportamiento de estos organismos. La familia Engraulidae fue dominante en este estudio y esto puede deberse a la mayor resistencia de sus representantes a los cambios causados en el medio por esta actividad. Sin embargo, los resultados mostraron que la actividad de dragado influye en la composición, densidad y abundancia de estos organismos.

PALABRAS CLAVE: engraulidae, clupeidae, Golfão Maranhense, dragado.

1. Introduction

The Bay of São Marcos is considered one of the most important of the Golfão Maranhense. This importance is due to physiographic aspects: being the mouth of flowing rivers and presenting intense landscape dynamics, as well as the density of human and commercial activities (Teixeira; Souza-Filho, 2009). In this environment includes the Itaqui port complex, which represents one of the largest export sectors in the world, in terms of cargo handling (Amaral et al., 2010). The navigation of numerous large-scale vessels moving industrialized products, by-products of oil, gas and large quantities of iron ore is intense (Chagas, 2013).

The most frequent effects of dredging in aquatic ecosystems include alterations in suspended solids concentration, increase of turbidity, increase
of nutrients in the water column, changes in water depth and temperature (Brooker, 1985; Lewis et al., 2001). According to Torres (2000), the dredged sediments can release toxic substances which can dissolve or become suspended and contaminate the water, causing different impacts on the aquatic biota.

Among the impacts of dredging on the aquatic biota, studies have shown reductions in the density and total biomass of ichthyofauna, mortality of some species besides the changes in population structure (Brooker, 1985).

Studies relating the effects of dredging on the structure of ichthyoplankton communities are scarce (Jiang et al., 2008; Maltez et al., 2014), and for São Marcos Bay there are no records available in the literature on the effects of dredging on composition and diversity of eggs and larvae of ichthyoplankton. According to Cunningham et al. (2005), ichthyoplankton can be used as a bioindicator of environmental quality, considering that these organisms present low biological diversity and relative sensitivity to environmental variations.

In this way, the objective of this study was to evaluate the effects on the composition, density and abundance of the ichthioplankton assemblages before, during and after the dredging of the Itaqui port channel, and to correlate the community structure with the water quality.

2. Methodology

2.1 Study Area

The Itaqui port area is located in the eastern portion of the São Marcos Bay and west of the Maranhense Golfão, between the parallels 02º34'S and 02º36'S and the meridians 44º21'W. This region is part of a coastal zone, marked by the presence of estuaries and reentrances in the north of the Maranhão. In addition, São Marcos Bay has a tidal regime with semidiurnal
periodicity and amplitudes of high tide above four meters, with an average variation of four meters and maximum values over seven meters, influencing distant areas up to 150 km from the coast (Teixeira; Souza-Filho, 2009).

The access channel to the port of Itaqui has a natural depth of at least 27 m and a width of approximately 1.8 km. The river connections with the port occur through the main navigable rivers of the State of Maranhão: Grajaú, Pindaré, Mearim and Cachorros, limited by small depths of one meter to 2.5 m near the mouth. This area presents morphology and extension which allow the circulation of large amounts of water, capable of forming currents that contribute to the channel depth maintenance together with the dredging activities (Vaz et al., 2008).

2.2 Sampling

The sampling of ichthioplankton was carried out in eight collection points (Figure 1), distributed in the Itaqui port area. The samples were divided into three stages, the first one corresponding to pre-dredging (PD, December 2014); the second sampling during dredging (DD, February 2015) and the third sample representing post-dredging (PO, June 2015).
The trawls were drawn horizontally on the surface with a duration of five minutes. The plankton network used in the trawls was the cone-cylindrical type with 300μm mesh, 60 cm of diameter of mouth and was equipped with flowmeter to aid the calculations of the water volume to obtain the density. The collected samples were fixed in 4% formaldehyde solution, neutralized with borax for further analysis. In the laboratory the ichthyoplankton samples were separated from the other planktonic organisms. The larvae were identified to the smallest possible taxon with the help of the works of Okyama (1988), Olivar and Fortuño (1991) and Richards (2005). The environmental characteristics of the area were described by measurements of the following variables: temperature, (° C), salinity (ppt) determined by the HANNA HI-9828® multiparameter probe, and dissolved oxygen-OD (mg L⁻¹) determined by the use of the oximeter HANNA HI-9146®.
2.3 Statistical Analysis

For the ichthyoplankton fauna was calculate the Relative abundance (RA) and the density (D). The RA was calculated according to the formula:

\[ RA = \frac{NA \times 100}{N} \]

where:

- \( NA \) = total number of individuals of each taxon in the sample
- \( N \) = total number of organisms in the sample

\( D \) (larvae/100 m\(^3\)) calculation based on the volume of filtered water. The calculation of the network filtered water volume was performed using the following formula: \( V = a.n.c. \). \( D \) (larvae/100 m\(^3\)) was obtained from the following formula:

\[ N = \frac{V}{100} \]

where:

- \( N \) = total number of organisms obtained in each sample
- \( V \) = volume of filtered water

The analysis of variance (ANOVA) was used to evaluate the effects caused on the density, richness and abundance of some species before, during and after dredging. The Canonical Correspondence Analysis (CCA) on the biotic and abiotic matrices a was used to verify the influence of the water quality on the composition of the ichthyoplankton. Statistical analyzes were conducted on the Platform R, version 3.2.2 (R Core Team, 2015).
3. Results and Discussions

During the investigation an increase of the water surface temperature was observed, accompanying the progression of the stages. In pre-dredging the average temperature was 27.97°C, during the dredging operation a mean of 28.50°C was recorded, and the post-dredging average recorded was 29.55°C, (Figure 2 A). The salinity showed a variation in its values during the stages. In the pre-dredging the average salinity was 33.2 ppt, during the dredging the average of 34.7 ppt and the post-dredging stage registered a mean of 26.0 ppt (Figure 2 B). The dissolved oxygen presented a behavior similar to the temperature, obtaining an increase in the last stage of the dredging. 4.6 mg L\(^{-1}\) was recorded during the pre-dredging, while the average value during the dredging was 4.2 mg L\(^{-1}\) and the post-dredging value averaged 5.6 mg L\(^{-1}\) (Figure 2 C).

A total of 677 specimens of fish larvae were collected, obtaining a total of 17 species belonging to 10 families and 17 genera. The greatest species richness was found during the dredging, which decreased in the post-dredging stage (Table 1).
Table 1. Taxonomic list of ichthyoplankton fauna sampled in the Itaqui port area, São Luís municipality (MA), Brazil. A-PD abundance in the pre-dredging samples; A-DD abundance in the during dredging samples; A-PO abundance in the post-dredging dredging samples; TA total abundance; RA - relative abundance (%).

<table>
<thead>
<tr>
<th>Taxa</th>
<th>A-PD</th>
<th>A-DD</th>
<th>A-PO</th>
<th>TA</th>
<th>RA%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELOPIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elopidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Elops saurus</em> (Linnaeus, 1766)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>0.7</td>
</tr>
<tr>
<td>CLUPEIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clupeidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sardinella brasiliensis</em> (Steindachner, 1879)</td>
<td>24</td>
<td>26</td>
<td>5</td>
<td>55</td>
<td>8.1</td>
</tr>
<tr>
<td>Engraulidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Anchoviella lepidentostole</em> (Fowler, 1911)</td>
<td>129</td>
<td>15</td>
<td>29</td>
<td>173</td>
<td>25.5</td>
</tr>
<tr>
<td><em>Anchoa sp</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cetengraulis edentulus</em> (Cuvier, 1829)</td>
<td>35</td>
<td>258</td>
<td>74</td>
<td>367</td>
<td>54.2</td>
</tr>
<tr>
<td><em>Lycengraulis grossidens</em> (Spix &amp; Agassiz, 1829)</td>
<td>1</td>
<td>29</td>
<td>18</td>
<td>48</td>
<td>7.0</td>
</tr>
<tr>
<td><em>Anchovia clupeoides</em> (Swainson, 1839)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>PERCIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carangidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oligoplistes saurus</em> (Bloch &amp; Schneider, 1801)</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>Lutjanidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Lutjanus sp</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sciaenidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cynoscion acoupa</em> (Lacepéde, 1801)</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>1.0</td>
</tr>
<tr>
<td><em>Stellifer sp</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sciaenidae A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mugil curema</em> (Valenciennes, 1836)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Mugilidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Coryphopterus sp</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLEURONECTIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achiridae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Achirus achirus</em> (Linnaeus, 1758)</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>TETRAODONTIFORMES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetraodontidae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sphoeroides testudineus</em> (Linnaeus, 1758)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td><em>Colomesus psittacus</em> (Bloch &amp; Schneider, 1801)</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>Total larvae</td>
<td>200</td>
<td>345</td>
<td>132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of species</td>
<td>12</td>
<td>11</td>
<td>8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: The authors
Before dredging 200 specimens of fish larvae of 8 families were collected. The species *Anchoviella lepidentostolle* (Fowler, 1911) (65%), *Cetengraulis edentulus* (Cuvier, 1829) (17%) and *Sardinella brasiliensis* (Steindachner, 1879) with 12% presented the highest relative abundances and were predominant in this stage (Figure 3 A). During the dredging 345 larvae of fish belongs to six families and two eggs were sampled. *C. edentulus* with 74% of the total larvae showed the greatest abundance while *Lycengraulis grossidens* (Spix and Agassiz, 1829) (8%), *S. brasiliensis* (7%) and *A. lepidentostolle* (5%) were the least abundant species (Figure 3 B).

After dredging 132 fish larvae and 3 eggs distributed in five families and nine species were recorded. *C. edentulus* had the highest relative abundance (49%). *L. grossidens* was the least abundant species with 12% of the total larvae collected in this sampling (Figure 3 C).

The Engraulidae and Clupeidae families were the most representative and contributed 96% of the total abundance of larvae captured in this study.

The density of fish larvae was 7.97 larvae / 100 m$^3$ before dredging, increased to 22.37 larvae / 100 m$^3$ during dredging and reduced to 4.94 larvae / 100 m$^3$ after dredging (Figure 4).
According to the results of the analysis of variance (ANOVA), dredging influenced only the species richness ($P < 0.05$) (Table 2).

Table 2 Results of the analysis of variance on the density, richness and abundance of the two most representative species during the dredging stages in the Itaqui port area, São Luís-MA.

<table>
<thead>
<tr>
<th>ANOVA Variables</th>
<th>F</th>
<th>Pr(&gt;F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1.986</td>
<td>0.133</td>
</tr>
<tr>
<td>Richness</td>
<td>2.943</td>
<td>0.046*</td>
</tr>
<tr>
<td>Centengraulis edentulus</td>
<td>2.229</td>
<td>0.102</td>
</tr>
<tr>
<td>Anchoviella lepidentostole</td>
<td>1.639</td>
<td>0.197</td>
</tr>
</tbody>
</table>

Signif. codes: 0 ‘***’, 0.001 ‘**’, 0.01 ‘*’, 0.05 Source: The authors

In the CCA between physical-chemical variables and the species composition the first axis explained 62% of the data variation and the second axis explained 27% (Figure 5). The main explicators factors were in order: temperature, salinity and dissolved oxygen.
Figure 5. Ordination diagram of the Canonical Correspondence Analysis (CCA) to evaluate the influence of water quality on the species distributed in the Itaqui port area, São Luís (MA), Brazil. The species, physical-chemical variables and the samples stages have their abbreviated names in the table 3.

Table 3 Abbreviated names of species, physical-chemical variables and the samples stages as used in the CCA graphics.

<table>
<thead>
<tr>
<th>Species</th>
<th>Abbreviated</th>
<th>physical-chemical variables</th>
<th>Abbreviated</th>
<th>samples stages</th>
<th>Abbreviated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligoplites saurus</td>
<td>opt</td>
<td>Temperature</td>
<td>temp</td>
<td>Pre-dredging</td>
<td>PRE</td>
</tr>
<tr>
<td>Anchoa sp</td>
<td>ans</td>
<td>Salinity</td>
<td>Sali</td>
<td>During dredging</td>
<td>1DRAGA</td>
</tr>
<tr>
<td>Achirus achirus</td>
<td>aca</td>
<td>Dissolved oxygen</td>
<td>oxig</td>
<td>Post-dredging</td>
<td>2DRAGA</td>
</tr>
<tr>
<td>Mugil curema</td>
<td>muc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anchoviella</td>
<td>anl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iepidentostole</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Elops saurus</td>
<td>els</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Coryphopterus sp</td>
<td>cos</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anchovia clupeoides</td>
<td>anc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lycengraulis edentulus</td>
<td>lyg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sardinella brasiliensis</td>
<td>sab</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lutjanus sp</td>
<td>lus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Cynoscion acoupa</td>
<td>cya</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cetengraulis edentulus</td>
<td>cee</td>
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</tr>
</tbody>
</table>
The average temperature values were high and above 27°C, presenting a small range of variation, showing the strong influence of the solar irradiation, favoring the evaporation processes in the estuary.

In general, the temperature values observed in the water reflect the characteristic temperatures of the northeastern region of Brazil, the coastal zone of Maranhão has a humid tropical climate, registering monthly averages above 26°C and small seasonal variation (Teixeira; Souza-Filho 2009), with high temperatures throughout the year. The temperature presents a great seasonal stability in tropical regions, since it depends on the period and degree of insolation, besides little meteorological variations conditioned by periods of greater or less nebulosity, except for the small differences between the periods with or without rainfall (Eschrique 2011).

The salinity gradient between the dredging events in the estuary indicated the presence of two types of waters in the São Marcos Bay, according to the classification given by CONAMA Resolution No. 357/05, with the registration of salt water for the periods of pre-dredging and dredging, and a differentiation in the post-dredging period, with the presence of brackish water, highlighting the influence of the continental waters in this estuarine system during this period, considering that the collection was carried out at the end of the rainy period of the region with a higher water supply.

The local salinity varies, according to the inflow and outflow of fresh water in the estuary, and the main processes that govern its distribution in the São Marcos Bay are the tide and the seasonal periods of the region. The influence of the tide is relevant due to the large amplitudes of high tide, especially in this region, where the variation of the high tide is more

Source: The authors
significant, compared to the values of the southeast of Brazil. The drought and rainfall seasons contribute to a greater or lesser inflow of freshwater in this estuarine system, either by direct precipitation in the estuary, by increased river and urban drainage or by the high evaporation rates observed during the local drought.

This distribution of salinity controlled by tidal action and seasonality has also been described by several authors of estuarine studies, especially the authors Figueiredo et al. (2006) in the estuary of Rio Jaguaribe (CE) and Corrêa (2016) in the estuary of Rio Mearim (MA).

The concentration of dissolved oxygen in the estuarine environment is expected to have a minimum concentration of 4.0 mg L\(^{-1}\) in aquatic environments, in this range most fish species survive (Calazans, 2011). The estuarine waters of São Marcos Bay, at least during the dredging events, present oxygen values above the values of hypoxia (> 2.0 mg L\(^{-1}\)), ensuring the oxygenation of this estuarine environment to aquatic organisms.

The good availability of dissolved oxygen in the estuary is related to the gas exchange at the air-water interface, beyond the strong contribution of the tides and marine waters in the estuary. The lowest observed values of dissolved oxygen occurred during the dredging event, which should be associated to a greater use of this gas by the resuspension of organic material, due to the greater disturbance of the environment.

The level of dissolved oxygen in natural waters is often a direct indication of water quality, as this gas is essential for the subsistence of fish and other heterotrophic aquatic organisms and assists in the natural decomposition of organic matter. According to Fiorucci and Benedetti-Filho (2005), oxygen losses are caused by the consumption, by the decomposition of organic matter (oxidation), by losses to the atmosphere, respiration of aquatic organisms, nitrification and abiotic chemical oxidation of substances such as metallic ions - iron (II) and manganese (II).
Other studies carried out in this estuarine region recorded the contribution of tides and marine waters to the highest values of dissolved oxygen, corroborating with the results of this study, such as Lima (2016) in his studies conducted at Golfão Maranhense, Bahia do Arraial with, 6.2 mg L\(^{-1}\) of dissolved oxygen and Machado (2017) in the Anil River estuary with 4.67 mg L\(^{-1}\).

The ichthyoplanktonic community found in the eastern portion of São Marcos Bay, Itaqui port area, is composed of very abundant species and several rare species, according to the classification criteria of Omori and Ikeda (1984). This composition is a common feature of estuarine regions (Ramos et al., 2006). The number of 10 families, identified here, is lower than those recorded in other port areas. Maltez et al (2014) in the Baia de Aratu recorded 17 families; in the Bay of Guanabara and in the Todos os Santos Bay, 17 families were identified (Castro 2005). These are environments with similar characteristics and, like the São Marcos Bay, suffer from strong environmental pressures of port activities.

Considering the complexity of the port areas due to the hydrodynamic processes (e.g. tidal currents, sand waves, residual currents and others) and the constant morphological changes (Amaral 2010), dredging activity becomes a great importance for the development. This activity may increase the greater estuarine circulation, allowing the recolonization of new species (Branco, 2007), like the increase of the relative abundance of *C. edentulus* during dredging observed in this study.

The species regeneration capacity may be the explanation for this increase of abundance of fish larvae during the dredging activity. According to Frid and Clark (1999), marine environments can be reestablished in short or long term, depending on the species regeneration capacity. On the other hand, some species, more sensitive to this dredging condition, tend to decrease abundance. This suggests that *C. edentulus* has a resistance in relation to this changing environment, as well as it is using strategies, which
allow to survive in this place. Sergipense and Sazima (1995) reported that *C. edentulus* uses phytoplankton in its diet. This explains the dominance of this species as a reflection of a food strategy, taking advantage of the higher productivity of the phytoplankton, which in turn is favored by the increase of the nutrient load in the water column during and after dredging (Silva *et al.* 2003; Licursi; Gómez, 2009).

It is noteworthy that the Engraulidae were dominant during all phases of the study, representing 89% of the collected specimens, which suggests a behavioral disturbance, as well as a high resistance of these organisms to the changes caused in the environment through the dredging activity. The representatives of this family show another important factor to be highlighted: pelagic species are less affected than demersal species. Increasing the depth of the dredged channel poses risks to larvae and eggs of demersal species and benthic fauna. It is accepted that the removal of the bottom material promotes the removal of shelters of these species in larval stages (Branco, 2007; Cabrita, 2014).

The Canonical Correspondence Analysis (CCA) showed a separation between the three campaigns, highlighting the influence of salinity, temperature and dissolved oxygen on the composition of the species. Flores-Coto *et al.* (1988) comment that physical and chemical changes in habitat produce structural changes in the ichthyoplankton community. These changes reflect the quality of the environment (Araújo and Rocha 2012). In this sense it was observed, that *A. lepidentostole* was the most representative species before dredging and its abundance decreased drastically in the following stages of the study. According to Bendazoli and Rossi-Wongtschowski (1990), this species is highly dependent on the abiotic temperature and salinity parameters. Another factor responding to the decrease in larval abundance is the concentration of suspended sediment in the water column during the dredging, which interferes with the development of larval stage fish (Maltez *et al.* 2014). In this way, dredging activities can
enhance the sensitivity of this environment and especially the sensivity of the ichthyoplankton community.

According to the CCA, salinity is the parameter of greatest relation with *A. lepidentostole*. Therefore, it should be noted, that this species is eurihaline (Paiva Filho 1990), with physiological adaptations to support the variation of salinity presented in the different scenarios of dredging activity. These results indicate a greater sensitivity of this species to the dredging activity, causing a behavioral disturbance of these organisms, which influences the difference of abundance in this scenario of dredging activity.

The larval density had a high decrease after dredging. This decrease is a reflection of the low number of individuals, mainly *C. edentulus*. This suggests a migration of these organisms after dredging. The dredging activity showed changes in the composition, abundance and density of ichthyoplankton. Such changes have also been recorded in other studies (Whitfield and Paterson, 2003; Maltez *et al.* 2014; Forte *et al.* 2014). According to Elliot *et al.* (2007), the estuarine ichthyofauna is composed of opportunistic species, a reason to recolonize the disturbed areas more quickly. On the other hand, fish species that do not tolerate adverse conditions tend to avoid these sites (Pérez-ruzafa *et al.* 2006). In view of this, it is possible to infer, that disturbed ecosystems seek the stability of their functions.

The responses observed during the post-dredging period, especially he dominance of *A. lepidentostole*, coincide with those occurring during the first successional stages, which are characterized by the existence of empty niches (Begon *et al.* 1990).
4. Conclusion

The species *Anchoviella lepidentostole* was dominant before dredging and its abundance reduced during the dredging, which is causing as consequence behavioral disturbance of these organisms. The Engraulidae family was dominant in this study and this may be a consequence of the greater resistance of their representatives to the changes in the environment caused by dredging. However, the results showed us that dredging activity influences the composition, density and abundance of these organisms.

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