Changes to the benthic assemblage associated with mollusc and seaweed cultivation in the Quempillén estuary, north Patagonia, Chile.

Cambios bentónicos asociados a los cultivos de moluscos y de algas del estuario Quempillén en la patagonia norte de Chile.

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RESUMEN

Las principales actividades acuícolas en el estuario de Quempillén son la acuicultura de ostras, Ostrea chilensis, y del alga Gracilaria chilensis. La intervención antropogénica al interior del estuario genera cambios significativos a nivel del sedimento y de los contenidos de materia orgánica.

ABSTRACT

The main aquaculture activities in the Quempillén estuary involve cultures of oysters, Ostrea chilensis and algae Gracilaria chilensis. Anthropogenic intervention inside the estuary generates significant changes in sediments and organic matter content.

Estuaries are coastal habitats that show a great deal of heterogeneity in both the physical and chemical characteristics of the water column (e.g. current velocity and salinity gradient), which are generated mainly by the action of the tides (Bertrán et al. 2001, Jaramillo et al. 1984). The fauna inhabiting these estuaries are subjected to considerable variation in environmental factors that determine their distribution, these physical-chemical factors include temperature and salinity (Beukema 1990, Holland et al. 1987), gradients in the interstitial water (Meadows & Tait 1989) and the characteristics of the sediment, including texture and organic matter content (Nichols et al. 1986, Richter 1985). The aim of this study was to determine the composition and distribution patterns of subtidal macrobenthic communities inhabiting the sediment in the Quempillén estuary, and the effects of two anthropogenic sources of perturbation, mollusc and seaweed cultivation.

The Quempillén estuary is located on the Island of Chiloé (41º52' S; 73º46' W). It was divided into seven stations from the mouth, to the head of the estuary (Fig. 1). The estuary supports aquacultural activity, including the cultivation of oysters (Ostrea chilensis) (stations 3, 4 and 5) and further up the estuary (stations 6 and 7) the cultivation of the algae (Gracilaria chilensis). Sediment and macrofauna samples (n=5) were collected using a PVC corer, 0.0019 m² for sediments and 0.0095 m² for macrofauna, at all sampling stations. The sediment samples were frozen and the macrofaunal samples fixed with 10% formalin, the fauna was then extracted with a 0.5 mm sieve, and then preserved in 70% alcohol for later laboratory analysis. Sediment fractions and organic matter content were determined using the methodology of Folk (1980) and Mills (1978) respectively. The samples were sieved using mesh sizes of −1.0 φ to separate the gravel and 4 φ to separate the sand from the mud fraction. The fauna was removed from the sediment using a stereomicroscope, identified and then counted. Community parameters: Species Richness, Diversity (H'), Dominance (D) and Uniformity (J') (Klemm et al. 1990) were calculated from the obtained data. Analyses of the community structure and sediments were made using nonmetric-Multidimensional Scaling (MDS) with a Bray-Curtis similarity matrix calculated using data averaged for each station. A one-way ANOVA was made for sediments and the macrofauna. The sediment data were transformed using arcs √P. For those data that presented significant differences a posteriori Tuckey HSD (P<0.05) analysis was conducted.

Gravel, sand and mud fractions are all present in the sediments of the Quempillén estuary with varying percentages at each
of the stations. The biggest percentage of gravel occurred at station 1 (64.71%), the highest percentage of sand at station 3 (93.54%) and the mud fraction was highest at station 7 (48.75%). Across the whole estuary, the sand fraction was the most common type of sediment, whilst gravel was the least common (Table 1, P<0.05). The total organic matter content was highest at station 7 (19.88 %) (Table 2, P<0.05). Based on the results of the MDS and Cluster analyses the separation of several stations is determined by grain size. Throughout cluster and the MDS analyses on the x-axis, it is possible to observe the gradient of grain size, with coarser grains toward the left (1-2) and finer toward the right (Fig. 2 a and b).

Overall 36 species were identified, *Corophium insidiosum* (Arthropoda, Corophiidae) being the most abundant species (Table 3). Community parameters showed that Diversity values were highest at station 2 (value of 1.88). The values of Uniformity (J) were also high, which relates to the low Dominance of Simpson (D = 1-J') values and this was reflected by the high values of Diversity (see Table 4). The Diversity and Species Richness values exhibited significant differences (P<0.05), while Uniformity and Abundance did not exhibit significant differences (P>0.05) between stations. Both cluster and MDS analyses supported this finding, forming two large groups: a) stations 1, 2 and 4 and b) stations 3, 5, 6 and 7, separating the stations of both ends, and placing together the stations at the centre of the estuary (Figs. 3 a and b).

**Anthropogenic activities at the inside the Quempillén estuary** (mollusc and algae cultivation) would depend upon the type and textural characteristics of the sediment and the composition and diversity of macrofauna associated. Summarizing our results, the sediment in the estuary (after analysis of ANOVA, Pos Hoc, MDS and Cluster Analyses) can be divided into 3 groups. The first group formed by the stations nearest to the mouth (1 and 2) was dominated by coarse sediments (< -1 Φ) (Folk 1980) with low organic content, the second group (stations 4 and 5) covered the middle reaches of the estuary and was dominated by sand (between -1 and 4 Φ), finally the third group (3, 6 and 7 stations) at the head of the estuary dominated by sand-muddy sediments (> 4 Φ).
Benthic assemblages in north Patagonia, Chile: Elizabeth Encalada et al.

The distribution of sediment type and organic matter within the estuary concur with that reported by Bertrán (1984, 1989), Jaramillo et al. (1985) and Richter (1985) for the Queule and Lingüe estuaries (Southern Chile). In those estuaries the sand fraction decreased while the mud fraction increases across the transition from marine waters to the limnetic waters. These results are also similar to those obtained for estuarine areas at other latitudes: Chester et al. (1983) in North Carolina (USA) and Peterson et al. (1984) in Washington and Oregon (USA). However, the values of total organic matter at all stations were very high supporting the observations of authors such as Alveal 1988, Berrios et al. 1991-1992; who indicated that cultivated algae such as Gracilaria chilensis serves as a trap for fine sediment.

Table 1: Variation in the sediment fractions and organic matter content, at each station of the Quempillén estuary. Data points represents mean ± S.D. (n=5 per group at each sampling station). Different letters indicate significant differences among stations (P<0.05, one-way ANOVA, Tukey test).

<table>
<thead>
<tr>
<th>Stations</th>
<th>Fraction (%)</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gravel</td>
<td>64.71 ± 15.6a</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td>33.67 ± 15.8a</td>
</tr>
<tr>
<td></td>
<td>mud</td>
<td>1.61 ± 0.4a</td>
</tr>
<tr>
<td>Station 1</td>
<td>gravel</td>
<td>35.90 ± 13.4b</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td>62.65 ± 13.7b</td>
</tr>
<tr>
<td></td>
<td>mud</td>
<td>1.45 ± 1.1a</td>
</tr>
<tr>
<td>Station 2</td>
<td>gravel</td>
<td>2.24 ± 1.7c</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td>93.54 ± 2.4c</td>
</tr>
<tr>
<td></td>
<td>mud</td>
<td>4.22 ± 2.3a</td>
</tr>
<tr>
<td>Station 3</td>
<td>gravel</td>
<td>20.71 ± 22.0bc</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td>77.05 ± 20.3bc</td>
</tr>
<tr>
<td></td>
<td>mud</td>
<td>2.24 ± 3.3a</td>
</tr>
<tr>
<td>Station 4</td>
<td>gravel</td>
<td>9.85 ± 16.4bc</td>
</tr>
<tr>
<td></td>
<td>sand</td>
<td>85.60 ± 15.8bc</td>
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<tr>
<td></td>
<td>mud</td>
<td>4.55 ± 3.5a</td>
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<tr>
<td>Station 5</td>
<td>gravel</td>
<td>4.20 ± 7.3 bc</td>
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<tr>
<td></td>
<td>sand</td>
<td>90.00 ± 8.3 bc</td>
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<tr>
<td></td>
<td>mud</td>
<td>5.81 ± 5.4a</td>
</tr>
<tr>
<td>Station 6</td>
<td>gravel</td>
<td>6.92 ± 9.9 bc</td>
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<tr>
<td></td>
<td>sand</td>
<td>44.34 ± 12.8ab</td>
</tr>
<tr>
<td></td>
<td>mud</td>
<td>48.75 ± 9.3b</td>
</tr>
</tbody>
</table>

Table 2: Average percentage of the Total Organic Matter in the sediments, of the Quempillén estuary. Further details as in legend of table 1.

<table>
<thead>
<tr>
<th>Stations</th>
<th>Total Organic Matter (%)</th>
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</thead>
<tbody>
<tr>
<td>Station 1</td>
<td>1.20 ± 0.4a</td>
</tr>
<tr>
<td>Station 2</td>
<td>1.43 ± 0.2a</td>
</tr>
<tr>
<td>Station 3</td>
<td>2.84 ±1.2a</td>
</tr>
<tr>
<td>Station 4</td>
<td>1.18 ± 0.6a</td>
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<tr>
<td>Station 5</td>
<td>1.63 ± 0.4a</td>
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<tr>
<td>Station 6</td>
<td>2.82 ± 1.1a</td>
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<tr>
<td>Station 7</td>
<td>19.88 ± 4.2b</td>
</tr>
</tbody>
</table>
**Table 3:** Average Abundance (Nº ind.m$^{-2}$) of macroinfauna collected at each station, in the Quempillén estuary.

<table>
<thead>
<tr>
<th>Species</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E1</td>
</tr>
<tr>
<td>Acmea sp</td>
<td>63</td>
</tr>
<tr>
<td>Phymactis clematis</td>
<td>21</td>
</tr>
<tr>
<td>Arenicolidae</td>
<td>0</td>
</tr>
<tr>
<td>Bathyporeiapus sp</td>
<td>0</td>
</tr>
<tr>
<td>Caecum chilense</td>
<td>0</td>
</tr>
<tr>
<td>Capiella sp</td>
<td>2190</td>
</tr>
<tr>
<td>Carazziella sp</td>
<td>653</td>
</tr>
<tr>
<td>Chaetone cirrautas</td>
<td>211</td>
</tr>
<tr>
<td>Corophium insidiosum</td>
<td>1158</td>
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<tr>
<td>Crepidula dilatata</td>
<td>63</td>
</tr>
<tr>
<td>Dipolydora socialis</td>
<td>42</td>
</tr>
<tr>
<td>Hemigrapsus crenulatus</td>
<td>42</td>
</tr>
<tr>
<td>Hyale sp</td>
<td>21</td>
</tr>
<tr>
<td>Linincta pisum</td>
<td>0</td>
</tr>
<tr>
<td>Lysianassidae</td>
<td>0</td>
</tr>
<tr>
<td>Maldanidae</td>
<td>0</td>
</tr>
<tr>
<td>Marphisa aenea</td>
<td>21</td>
</tr>
<tr>
<td>Melita sp</td>
<td>168</td>
</tr>
<tr>
<td>Munna chilensis</td>
<td>0</td>
</tr>
<tr>
<td>Nematoda</td>
<td>0</td>
</tr>
<tr>
<td>Nemertinea</td>
<td>0</td>
</tr>
<tr>
<td>Paracorophium hartmannorum</td>
<td>42</td>
</tr>
<tr>
<td>Perinereis guelpensis</td>
<td>758</td>
</tr>
<tr>
<td>Phoxorgia simuata</td>
<td>0</td>
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<tr>
<td>Polychaeta i.e.</td>
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<tr>
<td>Polygordius sp</td>
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<tr>
<td>Prionospio patagonica</td>
<td>105</td>
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<td>Rhynchospio glutaeae</td>
<td>274</td>
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<tr>
<td>Scololepis chilensis</td>
<td>84</td>
</tr>
<tr>
<td>Scoloplos sp</td>
<td>0</td>
</tr>
<tr>
<td>Spionidae</td>
<td>0</td>
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<tr>
<td>Syllis sp</td>
<td>0</td>
</tr>
<tr>
<td>Tanaidacea</td>
<td>0</td>
</tr>
<tr>
<td>Terebellidae</td>
<td>126</td>
</tr>
<tr>
<td>Tharyx sp</td>
<td>463</td>
</tr>
<tr>
<td>Venus antiqua</td>
<td>21</td>
</tr>
</tbody>
</table>

**Table 4:** Community parameters: Species Richness, Diversity (H’') and Uniformity (J’’) at all stations.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Stations</th>
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<tr>
<td></td>
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<tr>
<td>Species Richness</td>
<td>20</td>
</tr>
<tr>
<td>Diversity (H’’)</td>
<td>1.68</td>
</tr>
<tr>
<td>Uniformity (J’’)</td>
<td>0.79</td>
</tr>
</tbody>
</table>
The subtidal macrobenthic communities in the Quempillén estuary comprised of 36 species, which is similar to other estuaries studied in southern Chile, such as the Queule estuary where Bravo (1984) reported 35 species, the Lingüe where Richter (1985) reported 20 species, and the BioBio estuary where, depending on the seasons of the year, between 16 and 42 species were recorded (Bertrán et al. 2001). Diverse studies made in estuarine areas (Bertrán et al. 2001, Hughes & Gerdol 1997, Jaramillo et al. 1985, Richter 1985, Bravo 1984) have concluded that a decrease species diversity moving upstream correlates with an increase in the density of those species present. The results obtained in the present study concur with this hypothesis, there was a gradual decrease in the number of species moving from the most marine station upstream (from 20 to 12 different species). The Cluster and the MDS analyses indicate 2 groups, with stations 1, 2 and 4 in the first group and the remaining stations in the second group (3, 5, 6 and 7 stations), representing the change in the diversity in the middle zone of the estuary. The higher Diversities and Species Richness values were found in the first group (stations 1, 2 and 4), towards the mouth of the estuary, as has been found previously by Bertrán et al. 2001, Hughes & Gerdol 1997, Richter 1985, Jaramillo et al. 1985, Bravo 1984. The conclusion of this study is that different anthropogenic activities change the characteristics of the macrofaunal benthos, and particularly the sediment structure and organic matter content.

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