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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 m^2 for sediments and 0.0095 m^2 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 $-1.0\ \phi$ to separate the gravel and $4\ \phi$ 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') (Klemn *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 arcos $\sqrt{P}$. 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).

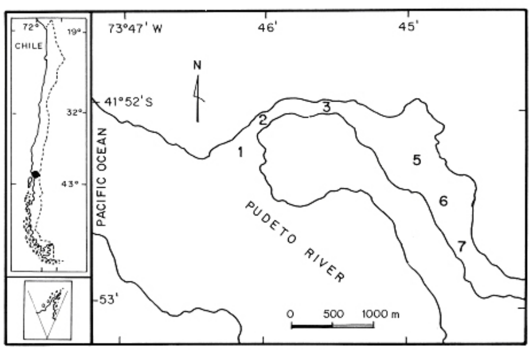

FIGURE 1: The Quempillén Estuary: Location of the study area and of the sampled subtidal stations. The numbers show the exactly position of the stations.

FIGURA 1: Estuario Quempillén: Ubicación del área de estudio y de las estaciones submareales muestreadas. Los números indican la ubicación exacta de las estaciones.

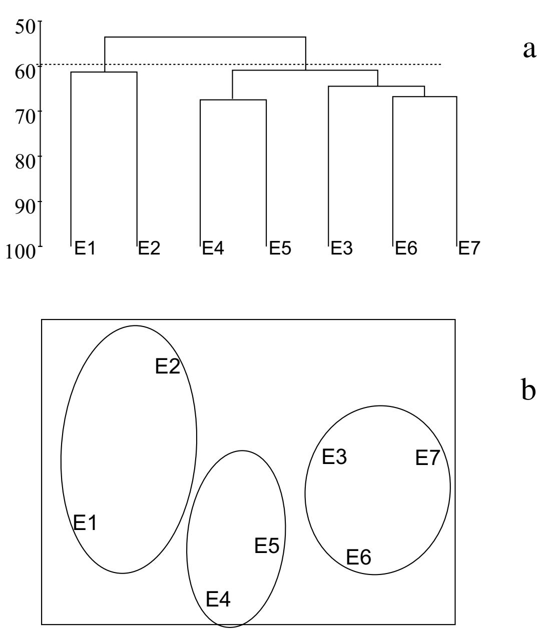

FIGURE 2: Cluster (a) and nonmetric MDS (b) analyses of sediments, per stations, in the Quempillén estuary. E = station.

FIGURA 2: Análisis de Cluster (a) y MDS (b) de sedimentos, de las estaciones, en el estuario Quempillén. E = estación.

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).

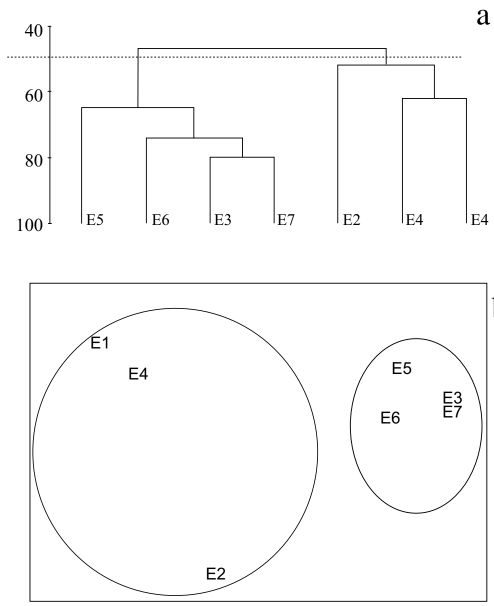

FIGURE 3: Cluster (a) and nonmetric MDS (b) analyses of macrofauna, per stations, in the Quempillén estuary. E = station.

FIGURA 3: Análisis de Cluster (a) y MDS (b) de fauna, de las estaciones, en el estuario Quempillén. E = estación.

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).

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).

Tabla 1: Variación de las fracciones del sedimento y contenido de materia orgánica, en cada estación del estuario Quempillén. Los datos representados son la media ± S.D. (n=5 por grupo de cada estación muestreada). Letras diferentes indican diferencias significativas entre estaciones (P<0.05, una-vía ANOVA, prueba de Tukey).

Stations		Fraction (%)	Organic Matter (%)
Station 1	gravel	64.71 ± 15.6a	1.23 ± 0.9
	sand	33.67 ± 15.8a	1.02 ± 0.6a
	mud	1.61 ± 0.4a	13.10 ± 4.7
Station 2	gravel	35.90 ± 13.4b	1.27 ± 0.3
	sand	62.65 ± 13.7b	1.22 ± 0.2a
	mud	1.45 ± 1.1a	15.18 ± 3.8
Station 3	gravel	2.24 ± 1.7c	27.70 ± 29.4
	sand	93.54 ± 2.4c	1.89 ± 0.8a
	mud	4.22 ± 2.3a	16.53 ± 1.5
Station 4	gravel	20.71 ± 22.0bc	3.18 ± 5.4
	sand	77.05 ± 20.3bc	1.01 ± 0.4a
	mud	2.24 ± 3.3a	14.94 ± 2.1
Station 5	gravel	9.85 ± 16.4bc	2.51 ± 2.2
	sand	85.60 ± 15.8bc	1.24 ± 0.3a
	mud	4.55 ± 3.5a	11.92 ± 5.4
Station 6	gravel	4.20 ± 7.3 bc	30.13 ± 29.1
	sand	90.00 ± 8.3 bc	2.21 ± 0.8a
	mud	5.81 ± 5.4a	11.70 ± 3.1
Station 7	gravel	6.92 ± 9.9 bc	5.02 ± 8.1
	sand	44.34 ± 12.8ab	25.73 ± 4.7b
	mud	48.75 ± 9.3b	17.53 ± 3.0

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

Tabla 2: Promedio en el porcentaje del Total de Materia Orgánica de los sedimentos en el estuario Quempillén. Más detalles como en la leyenda de la tabla 1.

Stations	Total Organic Matter (%)
Station 1	1.20 ± 0.4a
Station 2	1.43 ± 0.2a
Station 3	2.84 ±1.2a
Station 4	1.18 ± 0.6a
Station 5	1.63 ± 0.4a
Station 6	2.82 ± 1.1a
Station 7	19.88 ± 4.2b

TABLE 3: Average Abundance (Nº ind.m^{-2}) of macroinfauna collected at each station, in the Quempillén estuary.

TABLA 3: Abundancia promedio (N° ind.m^{-2}) de la macroinfauna colectada en cada estación en el estuario Quempillén.

Species	Stations						
	E1	E2	E3	E4	E5	E6	E7
Acmea sp	63	0	0	0	0	0	0
Phymactis clematis	21	0	0	0	42	316	0
Arenicolidae	0	0	0	0	21	0	0
Bathyporeiapus sp	0	21	0	0	0	0	0
Caecum chilense	0	0	0	0	0	0	105
Capitella sp	2190	518	184	1453	2665	383	122
Carazziella sp	653	21	105	156	211	0	21
Chaetozone cirratus	211	21	0	0	177	0	76
Corophium insidiosum	1158	1688	4035	2295	4821	3752	4779
Crepidula dilatata	63	21	0	0	0	0	0
Dipolydora socialis	42	0	0	0	0	0	0
Hemigrapsus crenulatus	42	0	0	0	21	0	0
Hyale sp	21	531	0	0	0	0	0
Linucula pisum	0	21	0	0	0	0	21
Lysianassidae	0	21	0	0	0	0	0
Maldanidae	0	0	0	0	0	21	0
Marphisa aenea	21	51	0	0	0	0	0
Melita sp	168	1255	21	253	84	84	400
Munna chilensis	0	0	0	0	21	0	21
Nematoda	0	0	21	0	0	0	0
Nemertinea	0	21	21	21	21	0	0
Paracorophium hartmannorum	42	0	0	21	63	0	0
Perinereis gualpensis	758	1545	168	463	564	762	289
Phoxorgia sinuata	0	21	147	0	0	0	0
Polychaeta i.e.	0	0	0	63	21	0	0
Polygordius sp	0	0	42	21	0	0	0
Prionospio patagonica	105	21	0	42	0	0	0
Rhynchospio glutaea	274	463	367	487	632	152	42
Scolelepis chilensis	84	105	150	192	236	211	0
Scoloplos sp	0	522	79	126	63	0	42
Spionidae	0	0	0	0	105	158	147
Syllis sp	0	51	0	21	42	21	0
Tanaidacea	0	0	0	21	0	0	0
Terebellidae	126	333	21	21	0	0	0
Tharyx sp	463	21	21	0	0	0	0
Venus antiqua	21	21	0	0	0	0	0
Abundance	6526	7293	5382	5656	9810	5860	6065

TABLE 4: Community parameters: Species Richness, Diversity (H’) and Uniformity (J’) at all stations.
TABLA 4: Parámetros comunitarios: Riqueza de Especies, Diversidad (H’) y Uniformidad (J’) en todas las estaciones.

	Stations						
Parameters	1	2	3	4	5	6	7
Species Richness	20	22	14	17	18	10	12
Diversity (H’)	1.68	1.88	1.16	1.54	1.39	1.06	0.84
Uniformity (J’)	0.79	0.79	0.68	0.80	0.66	0.68	0.65

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 BioBío 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 hypotheses, 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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