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Effect of Temporary Closure of the Mouth of an Estuary on the Benthic Macroinfauna: Lenga-Chile, A Case Study

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Estuarine systems form wetlands of high productivity, low biological diversity, and high sedimentary organic content. These systems often have wide expanses of shallow water (< 2 m) (Fischer 1961), export nutrients and organic matter to the adjacent coastal zone (Cameron and Pritchard 1963; Dyer 1973), and provide habitat for reproduction and development of animal and plant species, many of which migrate to the estuary during their reproductive periods (Stuardo and Valdovinos 1989). Man's activities near the wetlands often lead to eutrophication (Heip 1995). The Lenga Estuary a small coastal basin of approximately 3.2 km^2 which has experienced man-induced organic enrichment. Its outflow is located SW of the head of the San Vicente Bay (36°44'48''S, 73°10'22''W), forming part of the Hualpén Natural Sanctuary. This area is near to one of the most highly active industrial areas in Chile, primarily the steel industry (Rudolph et al. 2002; Ahumada and Vargas 2004).

Valdovinos et al. (1993) reported on the muddy sediments in this wetland, where the most abundant organisms included the oligochaetes, polychaetes (Spionidae and Nereidae), and the gastropod *Littorina cumingi*. It also supports an artisanal culture of the marine alga *Gracilaria*. There was an accidental spill of 17,000 tons of crude oil in San Vicente Bay in 1978, part of which entered the main portion of its estuary (Ahumada et al. 2000). In order to promote elimination of spilled hydrocarbons, a decision was made to cut the natural vegetation of the area (i.e., *Spartina salicornia*) which subsequently affected the dynamics and stability of the sediments. This was unfortunate, as a considerable amount of work had to be done constructing barriers to stabilize erosion around the borders of the estuary.

During the summer of 1995-96, high swells caused sand transport that narrowed the entrance and closed the outflow, disconnecting the Lenga Estuary with San Vicente Bay for a period of five years (2001), interrupting the tidal flow in this estuary. This event that causes the prolonged closing of the mouth of the estuary has happened twice during the last 25 years.

The present study represents an analysis made on the sediments and associated benthic macroinfauna of the main body of the Lenga estuary, to determine if the

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isolation of the estuary from the adjacent coastal zone had produced changes in the community structure in comparison with a period in which the estuary mouth is open.

MATERIALS AND METHODS

In order to compare this study with the reported by Valdovinos et al. (1993), the samples were collected in the same portion of the main body of the Lenga Estuary. Here, two samples were obtained at nine stations using a 0.025 m^2 corer (Figure 1) during the austral autumn of 2001. One sample was used to determine organic matter content (Mook and Hoskin 1982) and for granulometric analyses (Folk and Ward 1957). Granulometry was evaluated using an electronic microparticulate analyzer (ELZONE model 282 PC) and characterization of the textural phases followed the protocol of Buchanan and Kain (1984). The second sample was used for obtaining the biological material.

Dissolved oxygen content, temperature, and salinity were measured in the water column (<2.0 m) at all stations (Strickland and Parsons 1972). These variables were used to determine the percentage saturation of dissolved oxygen in the water (Weiss 1970).

Macroinfauna was extracted from the sediments by screening on a 500 μm mesh sieve and fixed in 10% seawater-formalin. The organisms were separated with the aid of a stereoscopic microscope, and were counted and determined to the lowest possible taxonomic level. The specimens were preserved in 90% EtOH.

The number of species (S) and number of individuals (N) were determined by station. These parameters were then used to calculate the Shannon diversity (H'), and the evenness (J') (Pielou 1966). The dominance index (D') was calculated to complement the diversity information (Simpson 1949). In order to relate the biological variables with the environmental variables (%TOM, % sand, % silt-clay, and depth) we performed correlations among all variables. TOM, sand and silt-clay were arcsine transformed and depth was log (z+1) transformed.

The affinity among stations (normal mode) and among species (inverse mode) was determined using non-metric multidimensional scaling (Clarke and Warwick 1994), where the values of stress of less than 0.1 indicate a good relation among elements (Clarke 1993). For this we used abundance of species per station after transformation to $y=\sqrt{\sqrt{x}}$, in order to generate a similarity matrix using the Bray-Curtis coefficient (Bray and Curtis 1957; Sneath and Sokal 1973; Pielou 1984).

The eventual differences among community attributes of communities in the present study and those reported in 1991 for the same area (Valdovinos et al. 1993) were evaluated by applying a one-way multivariate analysis of variance; one was applied to the measured values (N and S) and the other to calculated values (H', J', D'). Homogeneity of the variance was tested with a Cochran test (Zar, 1999).

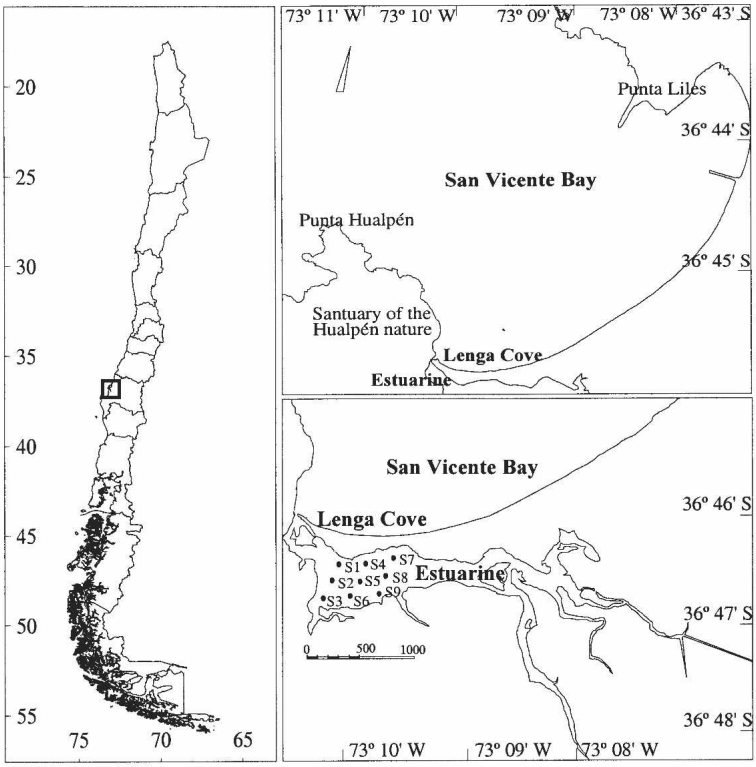

Figure 1. Geographic location of the nine benthic stations located in the main portion of the Lenga Estuary, San Vicente Bay, Chile.

RESULTS AND DISCUSION

The range of temperature and salinity in the Lenga Estuary during the study period sampling there was stable, low salinity (between 9.2 and 12.8 PSU) with oxygen saturation ranges in surface water between 32.9% and 122.4% and little temperature variation (between 12.8 and 13.5°C).

Sediment TOM was variable, eight stations ranged between 1.9 and 6.8 %, and one (S5) located in the center of the estuary registered 15.9%. In general, the values were lower than previously reported for the same area *i.e.*, > 17% (Valdovinos et al. 1993).

The granulometric analysis of the sediments showed sand to be the main constituent at all stations, at > 76 %. Stations S2 and S9 contained about 20% silt-clay, with mean grain size of moderately sorted fine sand. Station S7 had well-sorted fine sand. Information presented on sediment grain size in the same area by Valdovinos et al. (1993) did not differ from the present results, where two areas

Table 1. Numerical abundance (N) of the total species present in the Lenga Estuary, during the austral autumn of 2001. An analysis for species collected at each station and its diversity indexes is included.

TAXA	S1	S2	S3	S4	S5	S6	S7	S8	S9	N	N%
POLYCHAETA											
Nereis sp.	27	12		20	1	5	1	2	1	69	31.94
Lumbrineris bifilaris[1]	2		13			2				17	7.87
Aricidea pigmentata[2]	14	5	1	7	2	6		9		44	20.37
Protoariciella uncinata[3]	2					1				3	1.39
Cirratulus sp.	2					2				4	1.85
Polychaeta gen. sp.							2		1	3	1.39
MOLLUSCA											
Nassarius gayi[4]	2	3		17		13				35	16.20
CRUSTACEA											
Hyale maroubrae[5]				2						2	0.93
Hemigrapsus crenulatus[6]						1				1	0.46
Crustacea gen. sp.	14	3				21				38	17.59
Species number	7	4	2	4	2	8	2	2	2	10	
Individuals number	63	23	14	46	3	51	3	11	2	216	
Minimum	2	3	1	2	1	1	1	2	1	1	
Maximum	27	12	13	20	2	21	2	9	1	69	
Shannon diversity index	1.47	1.20	0.26	1.15	0.64	1.60	0.64	0.47	0.69		
Evenness index	0.76	0.87	0.37	0.83	0.92	0.77	0.92	0.68	1.00		
Simpson dominance index	0.29	0.35	0.87	0.35	0.56	0.26	0.56	0.70	0.50		

[1] (Ehlers 1901) [3] (Hartmann-Schröder 1962) [5] (Stebbing 1899)
[2] (Carrasco 1976) [4] (Kiener 1835) [6] (Milne-Edwards 1937)

defined included the estuarine boundary with its coarse to fine sands, and the interior zone made up of fine sand and muddy-clays.

In this study, the macroinfaunal analysis showed the presence of 10 taxa in the Lenga Estuary, with six Polychaeta, one Mollusca and three Crustacea (Table 1). The polychaetes *Nereis* sp. (31.9%) and *Aricidea pigmentata* (20.4%) were the most abundant. The same species showed the highest frequencies of occurrence (88.9% and 77.8% respectively).

Stations S6 and S1 (H'_{S6}=1.6, H'_{S1}=1.5) had the highest diversity values, which was in agreement with the higher richness and abundance values for these stations. The relation between the dominance and the diversity was inverse (r=-0.95), and the highest ecological dominance values were obtained at stations S3 and S8, stations in which were found the lowest values of evenness (Table 1).

Sediment grain size probably had a greater effect on the organisms than TOM content since the former parameter affected the amount of water retained in interstitial spaces (Mendez-Ubach et al. 1986). The sediments with a high percentage of silt-clay had lower abundance, which supposes a low degree of

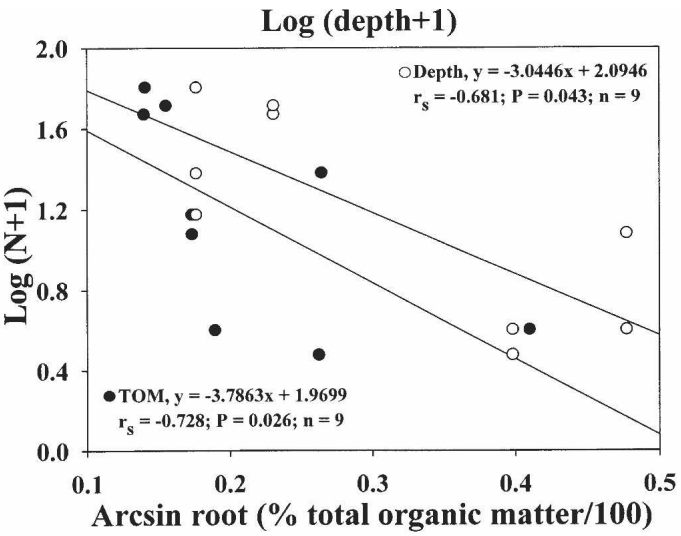

Figure 2. Relation between the number of individuals (N), total sediment organic matter, and depth at the stations showed in figure 1.

water circulation and low oxygen tension. In contrast, sectors of the estuary with medium and fine sands contained a high abundance of organisms.

The presence of *H. maroubrae* on the edge of the estuary may be explained by its habit of burying itself to avoid desiccation (Mendez-Ubach et al. 1986).

Although the abundance by station did not show dependence on environmental variables, negative correlations were observed between the number of individuals and the TOM content, with a progressive increase in abundance with decreasing TOM content. It is postulated that the species present in the Lenga Estuary have a low tolerance for low oxygen conditions, as oxygen content of the sediment decreases with increase in TOM content (Diaz and Rosenberg 1995). This situation is in contrast with that proposed by Bravo (1984) who suggested that sediment-feeders (i.e., polychaetes) were dominant in muddy substrates having comparatively high contents of TOM.

Significant negative correlations were obtained between N and the TOM (r_s=-0.728, P=0.03, n=9) and between N and the depth (r_s= -0.681, P=0.04, n=9 (Figure 2). The inverse relation observed between the number of individuals and depth of water may signify that the fauna of the estuary is adapted to shallow tidal systems (Fischer 1961), and thus physiologically less well adapted for inhabiting the deeper zones.

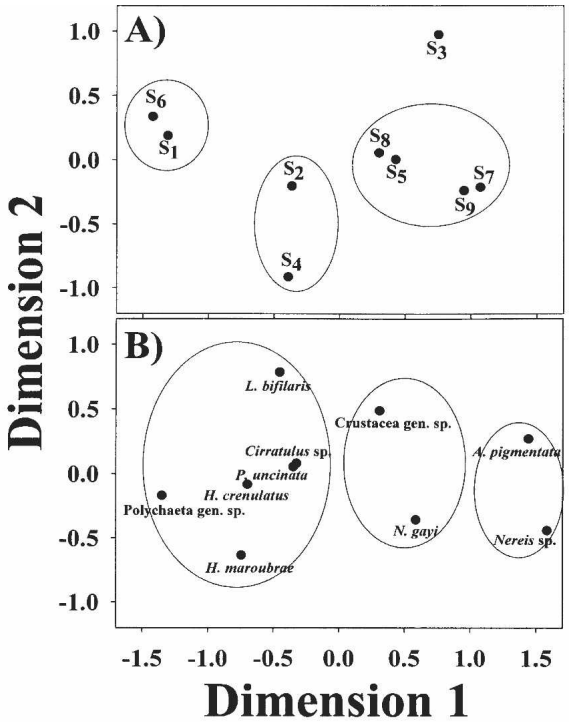

Figure 3. Ordination analysis (nMDS) based on the Bray-Curtis similarity for A) stations, B) species, present in the Lenga Estuary, Chile, during the austral autumn of 2001.

Four groups were recognized in the nMDS analysis in the normal mode (Stress < 0.01) i) with the greatest abundances (S1, S6), ii) with moderate abundances (S2, S4), iii) with low abundances, divided into two subgroups, the first (S5, S8) with low abundances of *Nereis* sp. and *A. pigmentata*, and the second subgroup (S7, S9) with low abundance of *Nereis* sp. and Polychaeta gen.sp. The fourth "group" consisted of station S3, marked by the presence of the polychaete *L. bifilaris* (Figure 3A).

Ordination in the inverse mode showed three groups of taxa (Stress=0.04). The first was formed by two taxa with relative abundances in the estuary of greater than 20%; the second group was formed by two taxa with moderate abundances between 16% and 18%, and the third group by six taxa with relatively minor abundances of less than 8% (Figure 3B).

Comparisons of present observations (2001) on the macroinfauna with data obtained 10 years prior (1991; Valdovinos et al. 1993) showed significant

differences regarding the numbers of individuals (MANOVA, λ=0.60; $F_{(2,14)}$=4.59; P=0.03); and evenness (MANOVA, λ=0.51; $F_{(3,13)}$=4.11; P=0.03).
It can be concluded from the study that the extended narrowing and closing-off of the Lenga Estuary from the adjacent coastal zone has generated changes in the community structure with a specific increase in polychaete taxa and decrease in the mollusk groups since it was last studied in 1991.

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