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# Intertidal and subtidal macroinfauna in the Queule River Estuary, South of Chile

## Macroinfauna intermareal y submareal en el Estuario del Río Queule, Sur de Chile

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ABSTRACT

An intertidal and subtidal survey of the soft bottom macroinfauna was conducted in the Queule River Estuary (South of Chile) during January 1981. Samples of 0.0225 $m^2$ were taken from two transects, one located outside the mouth of the estuary (transect A), the other one in the upper part of the estuary (transect B). The sedimentological analyses showed sandy bottoms at both transects, with the content of organic matter being higher in transect B. One way analyses of variance showed that the values of most of the sedimentary parameters (sorting and sand, mud and organic matter percentages) were not significantly different between the intertidal and subtidal zones of transect A. At transect B, significant differences were shown for the values of all the parameters, except for the organic matter content. The ordination of stations by Principal Component Analysis showed results consistent with those obtained by one way analysis of variance.

A total of 23 and 21 taxa were obtained from transects A and B, respectively. In both, peracarid crustacea were the most diverse group. At transect A, density and diversity (Shannon-Weaver Index) increased significantly from intertidal to subtidal levels, but not at transect B. At transect A, low tide level separates an intertidal from a subtidal assemblage, while in B separate assemblages were not detected. These results are discussed in relation to feeding types and sedimentological conditions prevalent at both transects. The zonation schemes obtained in this study are compared with those mentioned for other estuarine or sheltered marine beaches adjacent to the Queule River Estuary.

Key words: transects, sediments, zonation, benthic fauna.

RESUMEN

En enero de 1981 se muestreó la macroinfauna intermareal y submareal del Estuario del Río Queule (Sur de Chile). Las muestras (0,0225 $m^2$) se obtuvieron en dos transecciones, una localizada al exterior de la boca del estuario (transección A), la otra en la parte superior del mismo (transección B). Los análisis granulométricos muestran que ambas áreas están constituidas por sedimentos arenosos, siendo mayor el contenido de materia orgánica en B. Los resultados de los análisis de varianza de una vía muestran que los valores de la mayoría de los parámetros sedimentológicos (sorteo y porcentajes de arena, fango y contenido de materia orgánica) no fueron significativamente diferentes entre la zona intermareal y submareal de la transección A. En B, tales análisis muestran diferencias significativas en los valores de todos los parámetros, con excepción del contenido de materia orgánica. La ordenación de las estaciones producida por el Análisis de Componentes Principales muestra resultados consistentes con los obtenidos en los análisis de varianza.

En total se colectaron 23 y 21 taxa respectivamente (transecciones A y B). En ambas transecciones, Peracarida (Crustácea) fue el grupo más diverso. En la transección A la densidad y diversidad (Indice de Shannon-Weaver) aumentan significativamente desde la zona intermareal a submareal, pero no en B. En la transección A el nivel de marea baja separa un conjunto faunístico intermareal de otro submareal, a la vez que en B no se detectaron conjuntos separados. Estos resultados se discuten en relación a modalidades alimentarias y condiciones sedimentológicas prevalentes en ambas transecciones. Los esquemas de zonación obtenidos en este estudio se comparan con aquellos mencionados para otras playas estuariales o marinas protegidas adyacentes al Estuario del Río Queule.

Palabras claves: transecciones, sedimentos, zonación, fauna bentónica.

## INTRODUCTION

Until recently, very little was known of the estuarine soft bottom environment, representing one of the most typical features of the central south area of the Chilean littoral (37-41°S). Studies on the estuarine geological setting and sedimentological facies were reported by Pino and Mulsow (1983). The intertidal estuarine macroinfauna was studied by Bertrán (1983) in the Lingue River Estuary and

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by Turner (1984) in the Queule River Estuary. More recently, the subtidal macroinfauna has been analyzed by Jaramillo *et al.* (1984, in press) and Bravo (1984). Bravo (1984) has also described the subtidal community from shallow waters of Queule Bay, close to the outlet of the Queule River Estuary. Until now however, there has been no attempt to describe coincidentally a broad or general scheme of community structure for both the intertidal and subtidal zones.

This study was planned for the Queule River Estuary to find answers to the following main questions: (1) Are there tidal patterns of density and diversity in different intertidal and subtidal areas of the estuary? (2) Can distinct intertidal and subtidal assemblages be detected? To answer these questions, the intertidal and subtidal zones were sampled in two transects located in areas sufficiently separated so as to cover the widest possible range of environmental conditions.

*The Study Area*

The Queule River Estuary is located in the south part of Queule Bay (39°24'S, 73°13'W) (Fig. 1). Transect areas chosen for this study were located on the south side of the estuary. One of them (A) was located outside the mouth of the estuary, the other (B) in the upper part of the estuary (Fig. 1). Unpublished data, indicate that the bottom water temperature ranged from 10° to 14.5°C in the area adjacent to transect A, while the values of salinity varied between 25.4 and 35.2‰ (October 1980 to April 1981). No significant differences were detected between high and low tides. In the upper part of the estuary, the bottom water temperature ranged from 10.0 to 16.8°C at high tide (mean = 12.5°C) and between 9.4 and 21.0°C at low tide (mean = 14.6°C). Bottom water salinity ranged from 0.1 to 31.6‰ at high tide (mean = 23.0‰) and between 0.1 to 18.0‰ at low tide (mean = 6.2‰) March 1980 to February 1982).

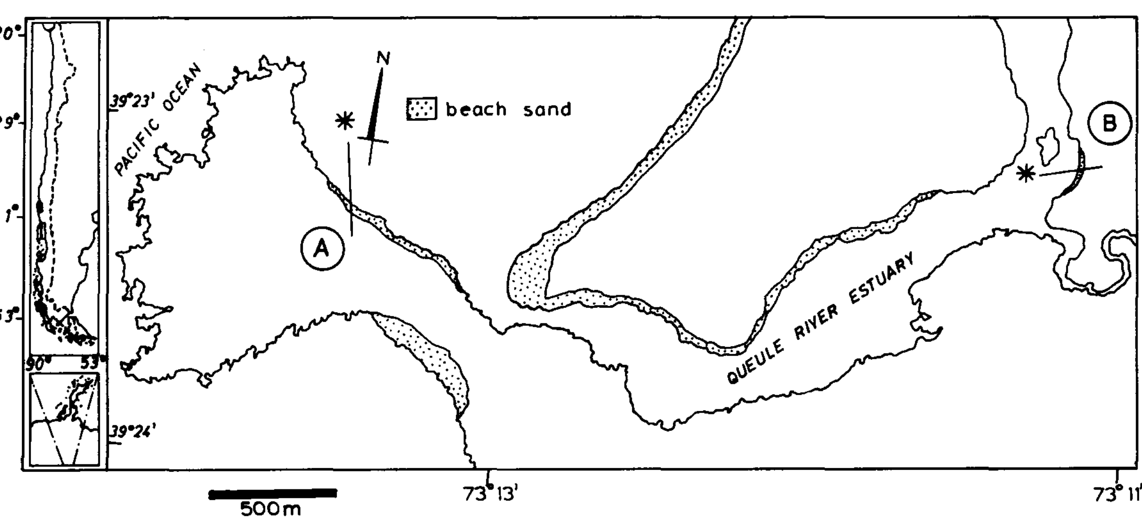


*Fig. 1:* Queule River Estuary. Location of transects A and B in the area of study.
Estuario del Río Queule. Ubicación de las transecciones A y B en el área de estudio.

## MATERIAL AND METHODS

The intertidal and subtidal macroinfauna was sampled during January 1981. Stations were ordered on a perpendicular transect in relation to low tide line, 5 meters apart in the intertidal and 1 meter depth apart in the subtidal zone.

Five replicates of 0.0225 m² area were obtained at each of the intertidal stations using a brass bucket buried to a depth of 5 cm. The same number of replicates was obtained in the subtidal zone by using an Emery grab. A sixth sample for sedimentological analyses (percentage of gravel, sand, mud, organic matter content, mean size and sorting) was obtained at each station. For mean size and sorting McBride's (1971) method of moments was used. The organic matter content was calculated as the loss in weight of dried sediment (60°C, 96h) after combustion (550°C, 6h). Comparison of sedimentological variables between intertidal (including low tide level) and subtidal zones at each transect was accomplished by using a one-way analysis of variance (Sokal & Rohlf 1979). The values of sedimentological variables from each station were used for Principal Component Analysis to group samples with similar bottom characteristics. For this purpose, the program 4M-BMDP-79 (University of California Press, Berkeley) was used.

Samples for macroinfauna were sieved (0.5 mm net), preserved with 10% buffered formalin, identified and counted. Comparisons of the total density per $m^2$ between the intertidal and subtidal zones of each transect were made by using a one-way analysis of variance. The mean data of specific abundance were used for calculations of indices of diversity and similarity. Diversity was analyzed by using the Shannon-Wearer Index according to Brower & Zar (1977). Comparisons of the mean diversity values between the intertidal and subtidal zone were carried out with the Wilcoxon Test (Wilcoxon U test, Sokal & Rohlf 1979). The biocenotic similarity between pairs of stations was calculated with Winer's Index (Saiz 1980). The similarity values were used for Cluster Analysis. A dendrogram was obtained after the Weighed Pair Group Method (Sokal & Sneath 1973). The program ACOM, elaborated in Basic Language by Navarro (1984), was used for the diversity and similarity indices. The former analyses, beside the Principal Component Analysis were perfomed on a DECSYSTEM-2020 computer at the Centro de Informática y Computación, Universidad Austral de Chile.

## RESULTS

### *The bottom*

The sedimentological analyses indicate that sand was the dominant fraction in both transects, intertidal and subtidal zones (Table 1). Mean size values were in the

TABLE 1

Queule River Estuary. Sedimentary parameters from the stations at transects A and B.
[1] For the intertidal zone the reference is according to methodology of Emery (1961). $^2\phi = -\log_2$ of particle diameter in mm. + low tide level.

Estuario del Río Queule. Parámetros sedimentológicos en las estaciones de las transecciones A y B.
[1] Para la zona intermareal la referencia es según metodología de Emery (1961).
$^2\phi = -\log_2$ del diámetro de la partícula en mm. + nivel de marea baja.

| st. | tidal reference in cm[1] | mean phi $\phi^2$ | phi of sorting $\phi$ | gravel % | sand % | mud % | organic matter % |
|---|---|---|---|---|---|---|---|
| A 1 | 184 | 2.13 | 0.57 | -- | 99.99 | 0.01 | 1.48 |
| 2 | 146 | 2.13 | 0.41 | -- | 99.99 | 0.01 | 1.07 |
| 3 | 108 | 2.12 | 0.49 | -- | 99.99 | 0.01 | 0.97 |
| 4 | 70 | 1.95 | 0.37 | -- | 99.97 | 0.03 | 1.00 |
| 5 | 34 | 1.88 | 0.54 | -- | 99.98 | 0.02 | 0.63 |
| +6 | 0 | 1.73 | 0.48 | -- | 99.98 | 0.02 | 0.99 |
| 7 | −100 | 1.73 | 0.54 | -- | 99.99 | 0.01 | 0.90 |
| 8 | −200 | 1.53 | 0.73 | -- | 99.75 | 0.25 | 1.02 |
| 9 | −300 | 1.57 | 0.57 | -- | 99.93 | 0.07 | 1.05 |
| 10 | −400 | 1.83 | 0.72 | -- | 99.99 | 0.01 | 1.89 |
| 11 | −500 | 1.95 | 0.77 | -- | 99.78 | 0.22 | 1.20 |
| B 1 | 90 | 1.33 | 0.81 | -- | 99.99 | 0.01 | 3.62 |
| 2 | 62 | 1.70 | 0.86 | -- | 99.99 | 0.01 | 1.08 |
| 3 | 45 | 1.68 | 0.84 | -- | 99.97 | 0.03 | 4.71 |
| 4 | 25 | 1.77 | 0.80 | -- | 99.98 | 0.02 | 1.91 |
| +5 | 0 | 1.25 | 0.79 | -- | 99.96 | 0.04 | 1.64 |
| 6 | −100 | 1.98 | 1.29 | 0.04 | 85.52 | 14.44 | 3.10 |
| 7 | −200 | 1.77 | 1.52 | 0.54 | 91.35 | 8.11 | 2.55 |
| 8 | −300 | 2.10 | 0.64 | 0.14 | 94.29 | 5.57 | 7.71 |
| 9 | −400 | 1.73 | 1.25 | 0.82 | 92.69 | 6.49 | 2.29 |
| 10 | −500 | 1.75 | 1.31 | 4.54 | 89.98 | 5.48 | 1.48 |

range of medium sand (1-2 $\phi$ or 250-500 microns), except for some upper intertidal levels of transect A and one subtidal level from B, corresponding to fine sand (2-3 $\phi$ or 125-250 microns) (after Folk 1974). In general, stations of transect A were in the range of well sorted (0.35-0.50 $\phi$) or moderately well sorted sediments (0.50-0.70 $\phi$), while stations of B were moderately sorted (0.70-1.0 $\phi$) or poorly sorted (1.0-2.0 $\phi$) (after Folk, 1974). Only in subtidal levels of transect B (poorly sorted) were detected particles larger than 2,000 microns, which were representing broken shells of the barnacle *Elminius kingii*, an inhabitant of intertidal and subtidal hard bottoms (sandstone) of the upper part of the estuary.

One way analysis of variance test indicates that mean size was significantly different ($P < 0.05$) between intertidal and subtidal zones in transect A, but not sorting or percentages of sand, mud and organic matter content. In transect B, significant differences were detected in values of mean size, sorting and percentages of sand and mud, but not in the organic matter content.

In the Principal Component Analysis, the first two components accounted for 80.6% (I:60.3; II:20.3) of the total variance in the correlation matrix obtained for transect A. In component I, percentages of sand and mud have the major load, while in component II, the organic matter content has the major load. Ordination of stations as projections on the first two components (Fig. 2) shows no clear separation between intertidal and subtidal levels. In transect B, the first two components accounted for 81.5% (I: 53.2, II: 28.3) of the total variance. As in transect A, sand and mud percentages have the major load in component I and the organic matter content in component II. Ordination of stations over these two components (Fig. 3) show a clear gap between intertidal and subtidal levels.

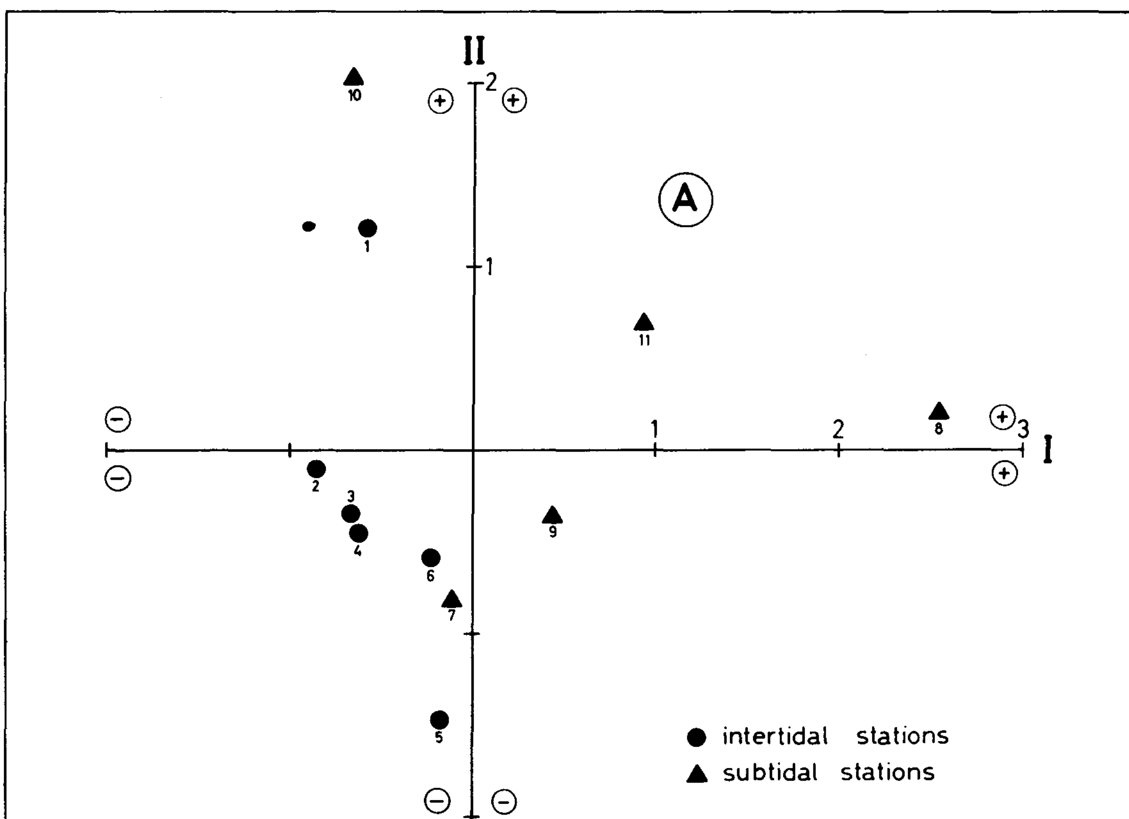


*Fig. 2:* Queule River Estuary. Principal component ordination of sedimentological samples from transect A. I. first Principal Component. II. second Principal Component.

Estuario del Río Queule. Ordenación de las muestras sedimentológicas de la transección A, según el análisis de Componentes Principales. I: primer Componente Principal, II: segundo Componente Principal.

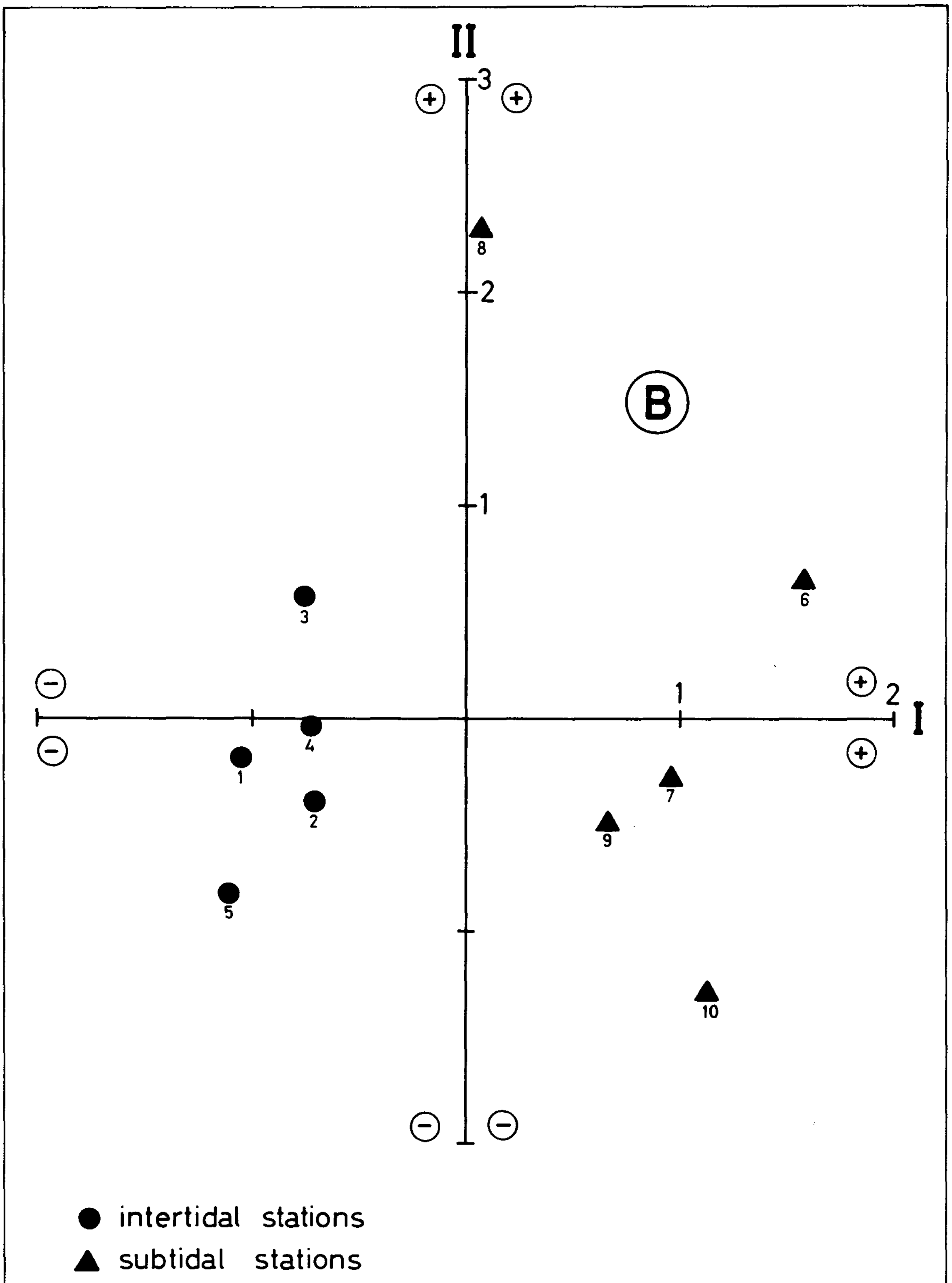


*Fig. 3:* Queule River Estuary. Principal Component ordination of sedimentological samples from transect B. I: first Principal Component. II: second Principal Component.

Estuario del Río Queule. Ordenación de las muestras sedimentológicas de la transección B, según el análisis de Componentes Principales. I: primer Componente Principal, II: segundo Componente Principal.

*The macroinfauna*
Twenty-three and 21 taxa were counted from transects A and B, respectively. In both transects, Peracarid crustaceans (isopods, amphipods, cumaceans) were the most diverse group with 13 and 11 species respectively. Macroinfauna density increased in transect A from intertidal to subtidal stations, with the highest value found at low tide level (Table 2). In transect B, high values of density were found in both zones, with the low tide level station showing the highest value (Table 2). One-way analysis of variance indicates significant differences ($P < 0.05$) between the intertidal and subtidal zones of A (excluding low tide level from the analysis because of its high density), but not in B.

TABLE 2

Queule River Estuary. Macroinfaunal density, number of species and diversity per station at transects A and B. +low tide level.

Estuario del Río Queule. Densidad de la macroinfauna, número de especies y diversidad en cada estación de las transecciones A y B. +nivel de marea baja.

| transect A | 1 | 2 | 3 | 4 | 5 | +6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| density per m² | 32 | 96 | 16 | 128 | 296 | 6,368 | 424 | 944 | 952 | 752 | 528 |
| number of species | 2 | 1 | 1 | 1 | 3 | 8 | 9 | 13 | 14 | 10 | 11 |
| diversity index | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.2 | 2.4 | 2.8 | 3.2 | 2.4 | 2.3 |

| transect B | 1 | 2 | 3 | 4 | +5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| density per m² | 16 | 288 | 6,096 | 30,104 | 37,472 | 11,584 | 10,656 | 6,096 | 5,240 | 19,208 |
| number of species | 1 | 7 | 9 | 8 | 8 | 9 | 9 | 7 | 7 | 9 |
| diversity index | 0.0 | 2.6 | 1.6 | 1.1 | 1.5 | 1.8 | 1.8 | 1.9 | 1.7 | 0.6 |

In transect A, there was a tendency of increasing number of species and diversity from low intertidal to subtidal levels, while in transect B the number of species and values of diversity were similar in both levels (Table 2). Significant differences of diversity on both levels ($P < 0.05$, Wilcoxon U test) were found only in transect A. In this transect, intertidal stations 2, 3 and 4 have a 0 diversity value, due to the presence of only one species, the isopod *Excirolana hirsuticauda* (Fig. 4). A similar situation was detected in the high intertidal of transect B (station 1) where a single species was collected, the dipterous *Limonia* sp.

In transect A, the low tide level clearly separated an intertidal faunal assemblage from a subtidal one (Fig. 4). Cirolanid isopods (*Excirolana hirsuticauda* and *Excirolana monodi*) were the most characteristic taxa of upper and middle intertidal, while the polychaete *Euzonus* sp. (Opheliidae) was the most abundant species at the lower intertidal. Peracarids were the organisms with the highest number of species (12 out of 21 taxa), while polychaetes (*Hemipodus* sp., Glyceridae) were the most abundant organisms in the subtidal faunal assemblage. This distinct break between intertidal and subtidal assemblages is also shown by the dendrogram produced with Winer's Index (Fig. 6). Intertidal and subtidal stations are arranged in two distinct groups linked at a very low value of similarity (0.08). Station 6 (the low tide level) is not included in any of the two groups because of its high abundance (given by *Euzonus* sp. and the bivalve *Mesodesma donacium*) in relation to the other intertidal or subtidal stations.

In transect B (Fig. 5), on the other hand, there is no marked faunal break between the intertidal and subtidal zones. Three of the most abundant species (*Minuspio chilensis,* Spionidae; *Perinereis gualpensis,* Nereidae (Polychaeta) and *Paracorophium chilensis* Corophiidae (Amphipoda)) inhabited both zones and showed their highest abundance in the upper levels of their distribution (Fig. 5). Other taxa,

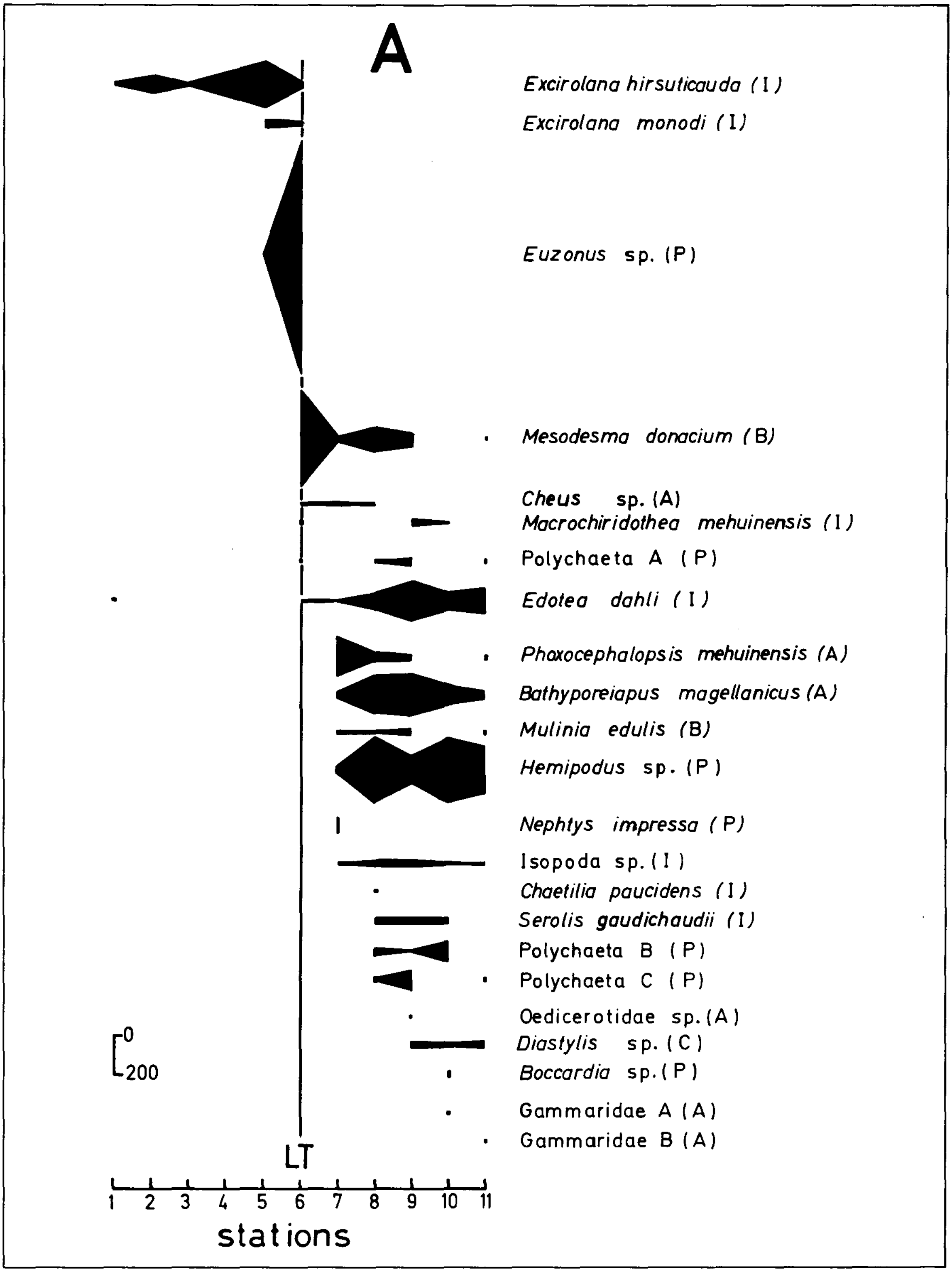


*Fig. 4:* Queule River Estuary. Transversal distribution of the macroinfauna at transect A: (I) Isopoda, (A) Amphipoda, (C) Cumacea, (B) Bivalvia and (P) Polychaeta. LT: low tide level. Scale: number of animals per $m^2$.

Estuario del Río Queule. Distribución transversal de la macroinfauna en la transección A: (I) Isopoda, (A) Anfipoda, (C) Cumacea, (B) Bivalvia y (P) Polichaeta. LT: nivel de marea baja. Escala: número de animales por $m^2$.

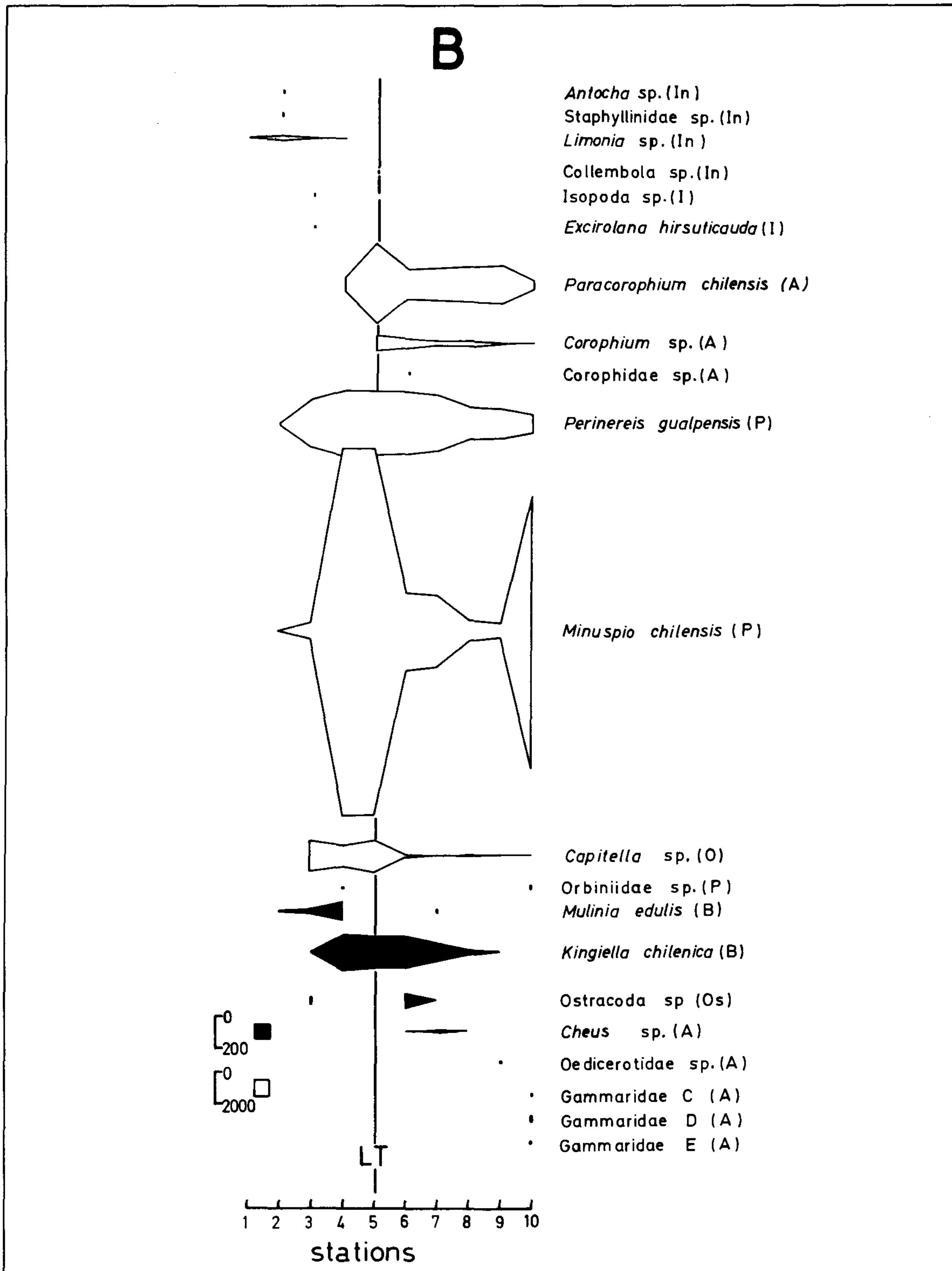


*FIG. 5:* Queule River Estuary. Transversal distribution of the macroinfauna at transect B: (I) Isopoda, (A) Amphipoda, (C) Cumacea, (B) Bivalvia and (P) Polychaeta. LT: low tide level. Scale: number of animals per m$^2$.

Estuario del Río Queule. Distribución transversal de la macroinfauna en la transección B: (I) Isopoda, (A) Anfípoda, (C) Cumacea, (B) Bivalvia y (P) Polichaeta. LT: nivel de marea baja. Escala: número de animales por m$^2$.

such as the bivalve *Kingiella chilenica,* and one species of *Capitellidae* (Polychaeta), also occupied intertidal and subtidal levels (Fig. 5). The dendrogram for this transect (Fig. 6) shows two groups of stations, including both intertidal and subtidal levels and linked at a value of 0.51. Station 1, with only one species (*Limonia* sp.) is separated from the rest of the stations.

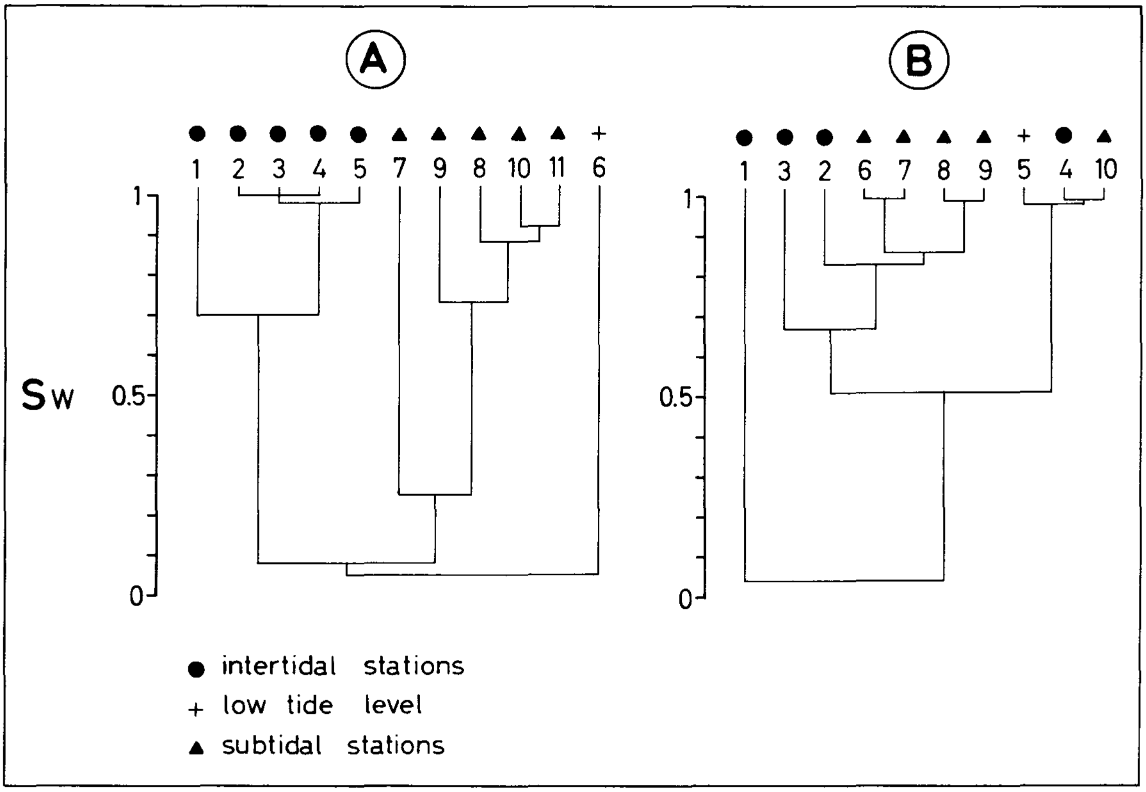


*Fig. 6:* Queule River Estuary. Dendrograms of transects A and B and produced by weighed pair group method with Winer's Similarity Index.

Estuario del Río Queule. Dendrograma de las transecciones A y B producidos por el "weighed pair group method" y basado en el Indice de Similitud de Winer.

## DISCUSSION

Results show a distinct difference in community structure of intertidal and subtidal zones near the mouth of the Queule River Estuary, while in the upper estuary, many of the numerically dominant species (*Minuspio chilensis, Perinereis gualpensis* and *Paracorophium chilensis*) were found in both zones. Persistent abundances of those species, together with similar diversity values through transect B, show that intertidal and subtidal zones of the upper part of the estuary have similar species composition, as has been shown in certain sandy bottoms of the northern hemisphere (Croker 1977, Croker *et al.* 1975, Fincham 1971, Knott *et al.* 1983 and McIntyre & Eleftheriou 1968).

The distribution and abundance of the soft bottom macroinfauna has been related to the quality of the substrate (see reviews from Gray 1974, 1981). In this study, the species discontinuity between the intertidal and subtidal zones of transect A, was not correlated to sedimentary parameters whose values did not show significant differences between both zones. The latter situation was also reflected in the results of the Principal Component Analysis, which did not show a clear separation between stations of the intertidal and subtidal zone. An alternative explanation for that discontinuity is submergence and its control over the length of time available for feeding (Newell 1979). For example, the upper limit of distribution of suspension feeders on transect

A may be determined by that tide level at which sufficient food can be obtained for growth and reproduction (Newell 1979). On the other hand, variations of physical factors in the intertidal zone (e.g. temperature and water content of the sediment) may also be important for determining the upper limit at which subtidal species can survive. A search for the causative mechanisms explaining the restriction of cirolanid isopods (and also talitrid amphipods) to the intertidal zone of transect A (as is typical of Chilean sandy beaches where they occur, E. Jaramillo, personal observation) is more difficult. Biological interactions of intertidal species with animals living near the low tide level and/or shallow subtidal depths may be involved.

At transect B, significant differences were detected and supported by Principal Component Analysis for most of the sedimentary parameters (except organic matter) between intertidal and subtidal zones. Yet the species composition was similar. For this area of the estuary, two hypotheses are suggested to explain the macroinfaunal continuity between these zones. The first is related to the amount of food available for these (primarily) deposit feeders. The similar amount of organic matter along the transect would provide enough food to support high populations of such deposit feeders at both zones. Therefore, the limit between the intertidal and subtidal zone would not present a food barrier in the distribution of the species as suggested for the subtidal animals living outside the mouth of the estuary. The second hypothesis is related to the physical characteristic of the intertidal zone. The distribution of the macroinfauna would not be affected by the harshness of the intertidal zone, due to the fact that in this area of the estuary the water-table is at the surface of the beach. This fact is due to the flat profile of the intertidal zone and the amount of organic detritus which tend to clog the interstices and slow down drainage, a situation which is different in the intertidal of transect A where the water table is deeper. In this way, wide variations in the physical conditions of the sediment (e.g. temperature and water content) can be avoided.

The intertidal macroinfauna of exposed and semiexposed sandy beaches of the south Chilean coast has been characterized as dominated by peracarid crustaceans: cirolanid isopods and talitrid amphipods (Bertrán 1983, Jaramillo 1978, 1982). In this study, cirolanids were found in the upper, middle and lower levels of transect A (Fig. 4) as mentioned by Bertrán (1983) and by Jaramillo (1978), for the sandy habitats located in the outlet of the Lingue River Estuary (6 km south of Queule River Estuary). The talitrid amphipod *Orchestoidea tuberculata,* inhabitant of the upper levels of sandy areas adjacent to transect A was not detected in this study. Similarly to what was found by Bertrán (1983) at the outlet of the Lingue River Estuary, in the lower levels of transect A the decapod *Emerita analoga* characteristic of such levels in exposed and semiexposed sandy beaches (Jaramillo 1978, 1982) was lacking. Concerning the inhabitants of the low tide and subtidal levels, a general coincidence of some amphipods present (*Cheus* sp., *Phoxocephalopsis mehuinensis* and *Bathyporeiapus magellanicus*), was found with the schemes of Bertrán (1983) and Jaramillo (1978, 1982).

The intertidal of the upper part of the estuary (transect B) resembles the protected beaches studied by Bertrán (1983) in the middle and upper part of the Lingue River Estuary. *Perinereis gualpensis* and *Paracorophium chilensis* stand out among the most abundant and characteristic taxa of the intertidal in Bertrán' as well as in this study. However, Bertrán (1983) did not report the presence of *Minuspio chilensis,* the most abundant species in the transect B and also present as an abundant taxon in other intertidal areas of the middle part of the Queule River Estuary (Turner 1984).

The intertidal zonation schemes discussed here could undergo temporal modifications related to physical or biological disturbances. Jaramillo (1982) has found evidences of variations to the scheme proposed in 1978 for exposed sandy beaches of southern Chile. Variations were contemporaneous with changes in the topography of the beach and seasonal fluctuations of physical factors, e.g. temperature and water content of the substrate. Even though the topographic dynamics in the intertidal of transect A is not as strong as that observed in the exposed beaches studied by Jaramillo (1982), sediment erosion and deposition and contemporaneous macroinfaunal changes are observable. For example, we can mention the effect of the sand movement during deposition months (January to April) on the population of the bivalve, *Mesodesma donacium,* an inhabitant of the low tide and shallow subtidal levels of this area (Fig. 4). During these months, significant numbers of the bivalve are stranded and reburied in the middle and lower levels of the intertidal zone yielding a zonation scheme different from the one mentioned before. Similar topographic changes (erosion-deposition) have not been observed in the intertidal of the transect B. In this area of the estuary, biological disturbances may be more important as causes of temporal variations in the zonation schemes and community structure. Tidal flats of the middle and upper part of the estuary represent important feeding and resting areas for wading birds such as plovers (*Charadriidae*) and sandpipers (*Scolopacidae*), species that prey over the whole intertidal zone (unpublished data). Also, predation by demersal fishes and crabs appears to be important in determining the pattern of abundance of some of the macroinfaunal species living in this area of the estuary (unpublished data).

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