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Macroinfauna and human disturbance in a sandy beach of south-central Chile

Macroinfauna y perturbación humana en una playa arenosa del centro-sur de Chile

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E. JARAMILLO[1], H. CONTRERAS and P. QUIJON

Instituto de Zoología, Universidad Austral de Chile, Casilla 567, Valdivia, Chile
[1]E - mail: ejaramil@valdivia.uca.uach.cl

ABSTRACT

The effect of recreational beach users on the abundance of the intertidal macroinfauna was studied on a sandy beach of south-central Chile (ca. 39° S) during the summer of 1992. A field experiment was conducted over a period of about two months. A fence was installed in the middle of the beach the early morning of January 22; thus, the beach was divided into a north side to which beach users were denied access and an accessible south side. The statistical analyses (BACI design with non-parametric Mann-Whitney U-test) was based upon the differences in macroinfaunal abundances on both sides of the fence, before and after it was installed. The results did not show any significant effect of human exclusion on the macroinfaunal abundances. In the majority of cases, no significant differences in physical characteristics of sands occupied by the species on either side of the fence were detected. We conclude that presence of recreational beach users did not produce significant effect on the macroinfauna during the summer of 1992. We argue that this kind of experimental approach is a useful tool in the design of management plans for sandy beaches affected by recreational pressures.

Key words: Sandy beach, macroinfauna, recreational beach users, human disturbance.

RESUMEN

Se estudió el efecto de los veraneantes sobre la abundancia de la macroinfauna intermareal en una playa arenosa del centro sur de Chile (ca. 39° S) durante el verano de 1992. Para ello se realizó un experimento de terreno de aproximadamente dos meses. Se instaló un cerco en la mitad de la playa durante la mañana del 22 de enero, es decir, la playa quedó dividida en un lado norte sin acceso a la gente y un lado sur con acceso a veraneantes. Los análisis estadísticos (diseño "BACI" con test no parámetrico de Mann-Whitney) se basaron en las diferencias entre abundancias poblacionales ocurrentes a ambos lados del cerco, antes y después de su instalación. Los resultados no mostraron efecto significativo de la presencia y actividades de los veraneantes sobre las abundancias de la macroinfauna. En la mayoría de los casos no se detectaron diferencias en las caracte-rísticas físicas de las arenas ocupadas por las especies a ambos lados del cerco. Se concluye que la presencia de veraneantes no produjo efecto significativo sobre la macroinfauna durante el verano de 1992. Se argumenta que este tipo de aproximación experimental es una herramienta útil para diseñar planes de manejo para playas arenosas afectadas por presiones recrea-cionales.

Palabras clave: Playas arenosas, macroinfauna, veraneantes, perturbación humana.

INTRODUCTION

Changes in population abundances and community structure of natural populations are usually related to disturbances; i.e., the remotion of numbers of organisms by physical or biological agents (see review by Sousa 1984). In some cases, physical disturbances kill appreciable number of organisms, as shown for stream fishes (Larimore et al., 1959), bird and mammals (Bendell 1974), soft bottom invertebrates (Dauer & Simon 1976), cobblestones invertebrates (Sousa 1979), and lake fishes (Tonn & Magnuson 1982), among others.

Physical disturbances may also produce changes in habitat which can result in indirect negative effects on species populations (Sousa 1984), as the following examples demonstrate. As a result of a heavy storm, large volumes of sands were eroded from an exposed sandy beach in south central Chile (ca. 39°S) during the early fall of 1978 (Jaramillo 1987 a). Due probably to loss of

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habitat, the density of the macroinfauna declined significantly during that period. Similarly, in Discovery Bay, Jamaica, Kaufman (1983) observed declines of fish populations after alterations in habitat (damage in coral reefs) due to storms.

Oceanic sandy beaches are quite dynamic coastal habitats (Brown & McLachlan 1990). Waves and both, longshore and rip currents can mobilize large volumes of sand (e.g., Jaramillo 1987 a, McGwynne & McLachlan 1992, Swart 1983), resulting in the high dynamism of these habitats (Aubrey 1983, Chapman 1983, Wright & Short 1984). Despite this, it has been shown that sandy shores are quite diverse habitats (Brown & McLachlan 1990, Dexter 1992), supporting permanent macroinfaunal populations (e.g., Ansell et al. 1972, Leber 1982, McLachlan 1983, Jaramillo 1987a, Jaramillo et al. 1987).

Macroinfaunal communities inhabiting exposed sandy beaches are characterized by patchy distributions across and along shore (see review of McLachlan 1983). The across and along scape heterogeneity is evidentiated by faunal belts and mosaic of patches usually related to gradients in the physical environment (Bally 1983, McLachlan 1983). Such gradients have been found to be related to mechanical disturbance such as loss of habitat due to erosion of sand during sudden storms (Jaramillo 1987 a, Jaramillo et al., 1987, McLusky et al., 1975).

The intertidal macroinfauna of exposed sandy beaches of south - central Chile (ca. 39-40° S) is dominated by crustaceans (Jaramillo 1994, Jaramillo et al. 1993). Talitrid amphipods, cirolanid isopods and hippid crabs respectively characterize the upper, middle and low beach (swash zone) levels of these beaches. Even when this zonation scheme is quite conservative, seasonal shifting of macroinfaunal bands is a common feature observed throughout the years (Jaramillo, unpublished data); i.e., during the warmer months, most of these macroinfauna occupy lower beach levels than those occupied during the coldest and rainiest months of the year.

The most typical physical disturbance on these beaches is the variability in sand storage, with a typical recurrent seasonal cycle of erosion and acretion of sand (Jaramillo 1987 a). Even when it has been shown that extreme erosion conditions (i.e., habitat loss) seriously affect the population abundance of these macroinfauna (Jaramillo 1987 a), it has been impossible to link seasonal variability in population abundance or zonation of the macroinfauna to sediment variability such as grain size (Jaramillo 1987 a).

The apparent down shore migration of the macroinfauna during the warmest months, is coincident with the highest densities of recreational beach users. This result in an evident mechanical disturbance of sand fabric. There are several examples of studies dealing with this kind of physical disturbance on the sandy beach macroinfauna. Van der Merwe & Van der Merwe (1991) studied the effects of off-road vehicles on sandy beach macroinfauna of a sandy beach in South Africa and found differential species vulnerability. Negative effects of this type of disturbance has been shown for dune and grassland vegetation on a barrier sand beach of North Carolina (USA) (Hosier & Eaton 1980) and on the South African dune system of Algoa Bay (Rickard et al. 1994). It has also been shown that human activity has significant effects on the physical stability of sandy beaches (Artukhin 1990).

The objective of this study was to evaluate the eventual effect of recreational beach users on the abundance of the intertidal beach macroinfauna. Thus, it was hypothesized that human presence (through mechanical disturbance of substratum) might well affect the population abundances of burrowing crustaceans. To test this hypothesis field experiments (sensu Diamond & Case 1986) were carried out on the beach of Mehuín (ca. 39° S) during the summer of 1992.

METHODS

This study was carried out on the Playa Universitaria beach, located in Mehuín (39° 26' S, 73° 13' W), south central Chile (Fig. 1). The beach is approximately 300 m long and is fully exposed to the breaking waves of the Pacific Ocean. This beach is of the high-energy intermediate to dissipative type (sensu Short & Wright 1983). The tides are

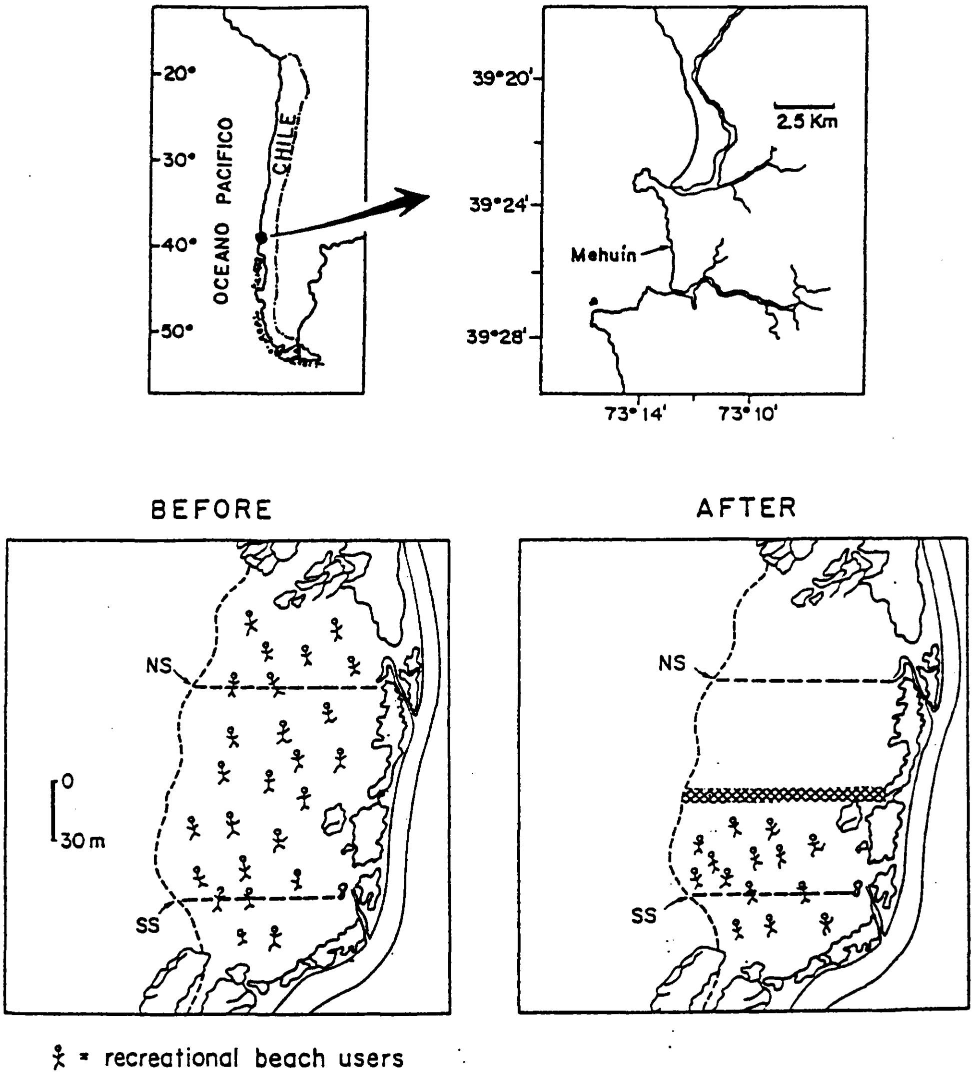

Fig. 1: Map of the Chilean coast (a) showing the location of Playa Universitaria at Mehuín (b). The lower insets (c) show the experimental design followed in this study. The "before" inset shows the situation before the fence was set up in January 1992 (i.e., people had access to the whole beach); the "after" inset shows the situation after the fence was set up (i.e., people had access just to one side of the beach).

Mapa de la costa chilena (a) mostrando la localización de la Playa Universitaria en Mehuín (b). Los cuadros inferiores (c) muestran el diseño experimental usado en este estudio. El cuadro "antes" muestra la situación antes de la instalación del cerco en enero de 1992 (i.e., la gente tenía acceso a toda la playa); el cuadro "después" muestra la situación después de la instalación del mismo (i.e., la gente tuvo acceso sólo a un lado de la playa).

semidiurnal with a maximum range of approximately 1.5 m.

The field experiment consisted of the exclusion of beach users by dividing the beach in two areas of similar length (ca. 100 m). A wire fence was installed during the early morning of January 22, 1992. The human exclusion spanned about 9 weeks (January 22 - March 30, 1992); during this time, both sides (the impact site or south side of the beach and the human exclusion site or north side of the beach) were sampled to study the across beach variability in species abundances and distribution. Sampling dates were February 6, February 22, March 7 and April 4, 1992. Samples (0.03 m^2, 30 cm deep) were collected with plastic cores at ten equally spaced levels along three replicated transects (separated by 1 m) extending from above the drift line to the swash zone; i.e., the uppermost station was located above the drift line, the second on the drift line and the last at the lowest limit of the swash zone (indicated by bore collapse). The sediment was sieved through 1 mm mesh and the macroinfauna was stored in 5% formalin until sorting. Sediment samples were collected at each station for water content analyses. These samples were collected by inserting a 3.5 cm diameter plastic core to a depth approximately 3 cm. Samples were wrapped in aluminium foil and weighed immediately after collection. Water content of the sand was estimated by loss in weight of wet sediments after drying (120° C for 96 hours). The penetrability of the sediments was measured by dropping a 33.6 g metal rod down a 1 m tube. The depth to which the rod penetrated into the sediment was measured several times at each station.

The data was analyzed by following the BACI (Before/After and Control/Impact Sites) (Fig. 1) design of Stewart-Oaten et al. (1986). To apply this design, we used data from five sampling periods before the fence was installed: December 1990, January, February and March 1991 and January 1992. The four first samplings were carried out in the north and south side of the beach as part of routine sampling to study spatial variability of the intertidal macroinfauna inhabiting this beach. That sampling of January 1992 was carried out one day before the beach was fenced.

BACI design can be applied by two ways. One of them, is that suggested by Stewart-Oaten et al. (1986) in which the differences between treatment and control are independents. The other one is based upon a random selection of data gathered before and after an especial event (Underwood 1991) The field data gathered during this study are better suited for the design suggested by Stewart-Oaten et al. (1986); i.e., because the studied beach is a public recreational site, it is not possible to run long term experiments in which numerous field data from people - excluded areas could be collected.

The statistical analyses (non-parametric Mann-Whitney U-test, Sokal & Rohlf 1969) was based upon the differences in abundance at each side of the beach. Stewart-Oaten et al. (1992) mention that one of the assumptions of BACI analyses is additivity; i.e., time and location (site) effects are additive (in the absence of the disturbance, the expected control-impact differences is the same for all dates). To evaluate the additivity assumption we tested for zero slope in the regression of differences against average values for biological and physical variables (Stewart-Oaten et al. 1986). All, but one analysis (that of the water content of sediments occupied by *Orchestoidea tuberculata*), did not show any departure from additivity ($p > 0.01$). We also tested for independence (i.e., observed differences from independent dates are independent) as indicated by Stewart-Oaten et al. 1986). Thus, we carried out regression analyses between control-impact differences and time; since those analyses did not show any significant correlation ($p > 0.01$) the data were independent.

RESULTS

Figure 2 shows the temporal variability in macroinfaunal abundances on both sides of the beach, before and after the fence was

TABLE 1

Estimated U values for differences in abundances, water content and penetrability of sands occupied by the macroinfauna on each side of the beach before and after the fence was installed. The critical value for U at a probability level of 0.05 is 19 (Rohlf & Sokal 1981), thus most of the observed values indicate no significant differences between the comparisons carried out

Valores estimados de U para las diferencias en abundancias, contenido de agua y penetrabilidad de los sedimentos ocupados por la macroinfauna a cada lado de la playa antes y después que se instaló el cerco. El valor crítico a un nivel de probabilidad de 0.05 es 19 (Rohlf & Sokal 1981), por lo tanto la mayoría de los valores observados no indican diferencias significativas entre las comparaciones realizadas

	abundance	water content	penetrability
Orchestoidea tuberculata	16	14	11
Excirolana braziliensis	14	12	12
Excirolana hirsuticauda	11	19	13
Emerita analoga	17	12	14

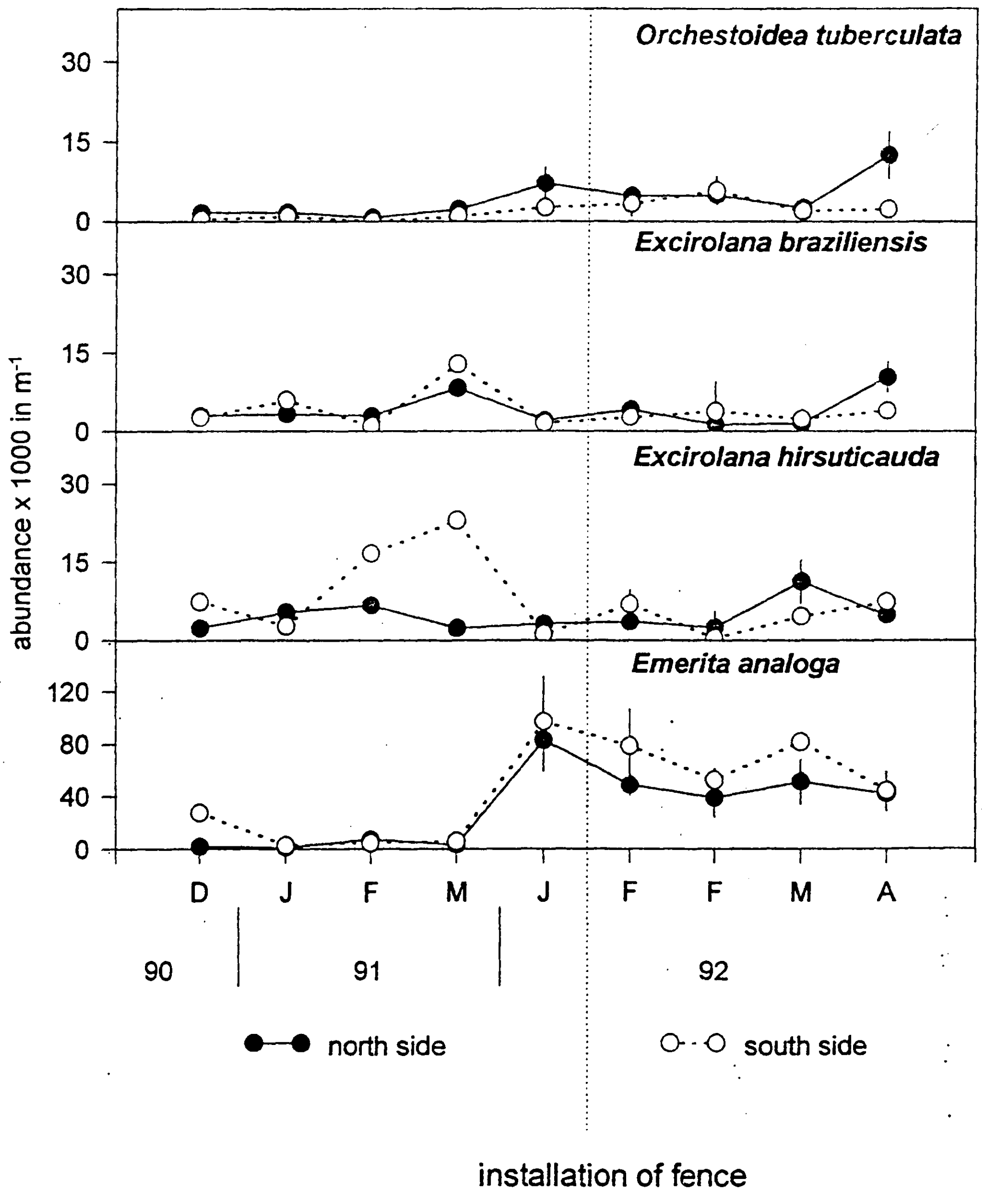

Fig. 2: Macroinfaunal abundances at Playa Universitaria before and after the fence was installed.

Abundancias de la macroinfauna en Playa Universitaria, antes y después de la instalación del cerco.

installed at both sides of the beach. The observed U-statistic values indicate that no significant differences were detected between treatments (Table 1); thus, human exclusion did not affect the macroinfaunal abundance of the amphipod *Orchestoidea tuberculata* (Nicolet), the isopods *Excirolana braziliensis* Richardson and *Excirolana hirsuticauda* Menzies and the anomuran crab *Emerita analoga* (Stimpson).

Figures 3 and 4 show the variability in sand desiccation related factors (water content and penetrability of the sediments) in the substrate occupied by these species. *Orchestoidea tuberculata* and *Excirolana braziliensis* occupied the driest and softest sands, while *Excirolana hirsuticauda* and *Emerita analoga* were found in more compacted sediments with higher water contents. In the majority of cases no significant differences were found between the differences in water content and penetrability of sands between both sides (Table 1) indicating that human exclusion

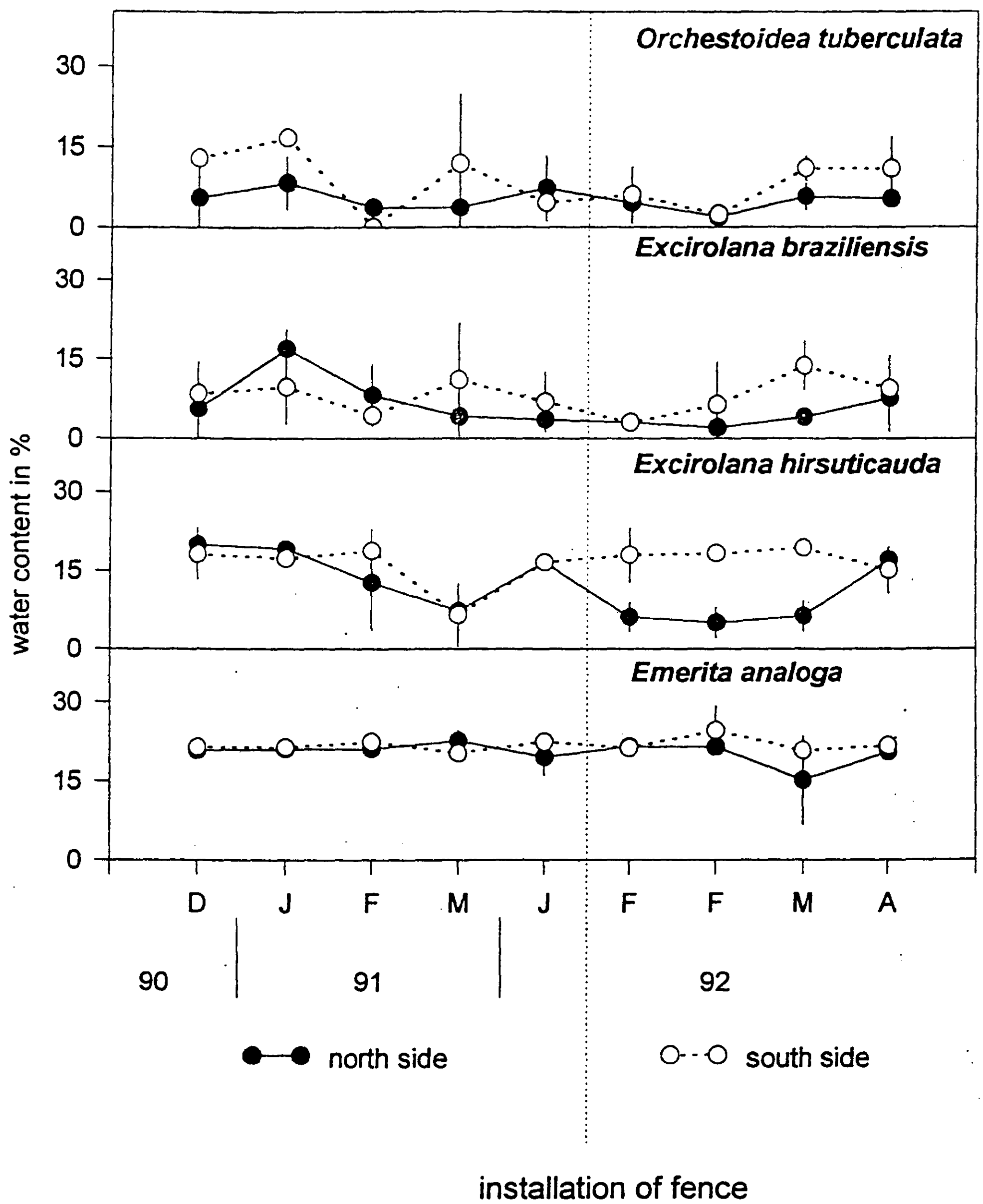

Fig. 3: Water contents of the sediments occupied by the macroinfauna at Playa Universitaria before and after the fence was installed.

Contenidos de agua de los sedimentos ocupados por la macroinfauna en Playa Universitaria, antes y después de la instalación del cerco.

did not result in habitat differences; i.e., the species occurred in sands which had similar physical characteristics on both sides of the fence.

DISCUSSION

Because most of the intertidal organisms examined in this study occur primarily in shallow sediments (no more than 10 cm below the sand surface) (Jaramillo 1987 a), it was thought that human disturbance during the summer periods might well affect the abundance and distribution of this macroinfauna. The results presented here do not provide any evidence of disturbance by beach users on the macroinfauna of Playa Universitaria during the summer studied. Thus, destruction of substrate fabrique and mound and through formation by beach gamers, walkers and sun bathers did not affect the abundance of these organisms.

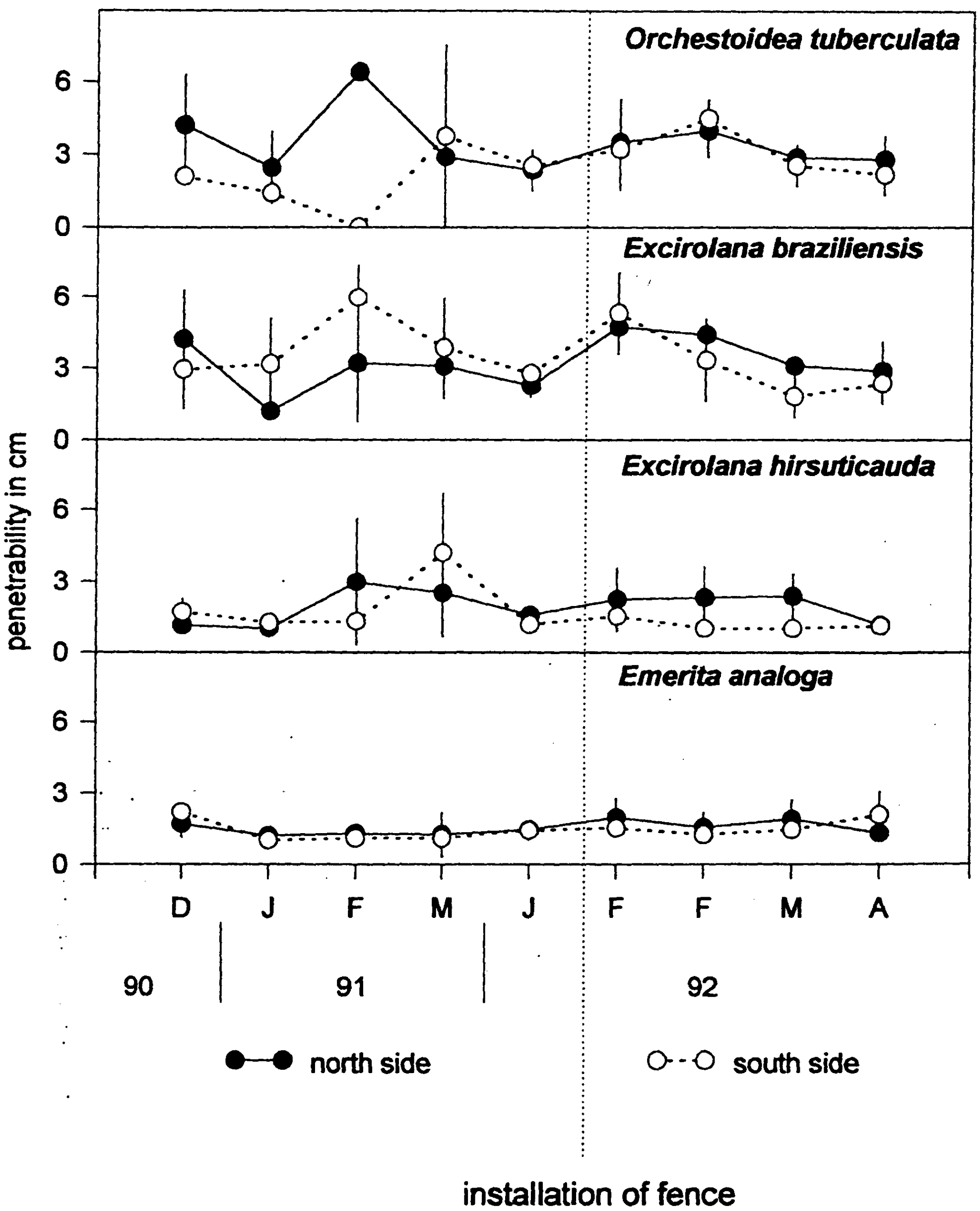

Fig. 4: Penetrability of the sediments occupied by the macroinfauna at Playa Universitaria before and after the fence was installed.

Penetrabilidad de los sedimentos ocupados por la macroinfauna en Playa Universitaria, antes y después de la instalación del cerco.

Two of the species collected, *Orchestoidea tuberculata* and *Excirolana braziliensis*, occur in the soft, poorly compacted sand of the upper beach levels. There, mound and through formation by people sunbathing and playing result in the destruction of sand fabric. However, this process did not appears to affect the abundance of these organisms. Perhaps amphipods with their capacity to burrow deep into the sands during the summer (down to about 1 meter; personal observations) are able to withstand these disturbances.

Some of the animals studied (*Emerita analoga*) are found at beach levels where the sand is relatively hard and most resistant to mechanical pressure (favourable for walking, running and gaming). However, they seem to be unaffected by this mechanical disturbance since we did not find any evidence of physical damage such as crushed caparaces. Similarly to our results, Wolcott & Wolcott (1984) did not find any effects of mechanical disturbance (off-road vehicles) on anomuran crabs (*Emerita talpoida*) and bivalves (*Donax variabilis*) in a Atlantic beach of the USA.

It has been shown that recreational pressures on sandy beaches increase the mobility of sand rendering the coasts more liable to storm erosion (Carter 1975). Artukhin (1990) found that on a sand beach of the Azov sea, the activity of the recreational beach users resulted in mound and through formation to appear, which eventually leads to sand movement (and hence erosion) towards the water line. The difference in magnitude of sand volumes removed by the effects of mechanical disturbances produced by recreational beach users versus that produced by waves or currents has not been thoroughly documented. However it can reasonably guessed that naturally occurrring disturbances is a far more important disruptive event than mechanical disturbance by human activity.

Even though the design of our experiment did not include the analysis of short-term effects (e.g. from tides to tides) which might show the effects of human activity, our results so far show that mechanical disturbance produced by recreational beach users is not expected to have a significant effect on the macroinfauna. Most probably, in highly dynamic beaches such as Playa Universitaria (Jaramillo 1987 a), local effects such as those listed earlier are overrun by massive movements of sands due to the effect of a changing wave climate.

Demands for recreational facilities and property development along the Chilean sandy beaches have increased over the last few decades. Even when this study did not show any effect of mechanical disturbance by beach users, caution shoud be advised since high energy dissipative Chilean sandy beaches support quite diverse faunas (Sánchez et al 1982, Jaramillo 1987 a, b, Clarke & Peña 1988). Rather than restricting use of these areas, management plans should be developed to minimise any eventual impact. In this sense, this study constitutes the first to manipulate human recreational pressures on a Chilean sandy beach or elsewhere; thus it provides an example of how ecological and recreational capacity of sandy beaches can be studied in order to quantify human impact on the whole sandy beach community.

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