

THE MAGELLAN-ANTARCTIC CONNECTION: LINKS AND FRONTIERS AT HIGH SOUTHERN LATITUDES.  
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## Soft-bottom macrobenthic faunal associations in the southern Chilean glacial fjord complex\*

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**SUMMARY:** Macrobenthic associations were investigated at 29 sampling stations with a semi-quantitative Agassiz trawl, ranging from the South Patagonian Icefield to the Straits of Magellan in the South Chilean fjord system. A total of 1,895 individuals belonging to 131 species were collected. 19 species belong to colonial organisms, mainly Bryozoa (17 species) and Octocorallia (2 species). The phylum Echinodermata was the most diverse in species number (47 species), with asteroids (25 species) and ophiuroids (13 species) being the best represented within this taxon. Polychaeta was the second dominant group in terms of species richness (46 species). Multidimensional scaling ordination (MDS) separated two station groups, one related to fjords and channels off the South Patagonian Icefield and the second one to stations surrounding the Straits of Magellan. 45 species account for 90% of the dissimilarity between these two groups. These differences can mainly be explained by the influence of local environmental conditions determined by processes closely related to the presence/absence of glaciers. Abiotic parameters such as water depth, type of sediment and chemical features of the superficial sediment were not correlated with the numbers of individuals caught by the Agassiz trawl in each group of sampling stations.

**Keywords:** Magellan region, South Patagonian Icefield, Straits of Magellan, community structure, biodiversity.

**RESUMEN:** ASOCIACIONES FAUNÍSTICAS MACROBENTÓNICAS DE FONDOS BLANDOS EN EL COMPLEJO DE FIORDOS GLACIARES DE CHILE AUSTRAL. – Mediante el uso de una rastra Agassiz modificada se investigaron las asociaciones macrobentónicas presentes en 29 estaciones de muestreo, localizadas entre el Campo Patagónico de Hielo Sur y el Estrecho de Magallanes en el sistema de fiordos de Chile austral. Se colectó un total de 1.895 individuos pertenecientes a 131 especies, además de 19 especies de organismos coloniales, especialmente Bryozoa (17 especies) y Octocorallia (2 especies). El phylum Echinodermata fue el más diverso en términos de número de especies (47 especies), con una mejor representación de asteroideos (25 especies) y ofiuroides (13 especies). El segundo grupo dominante en términos de riqueza de especies fue Polychaeta (46 especies). La técnica de “Escalamiento Multidimensional” (MDS) permitió separar dos grupos de estaciones: uno relacionado con los fiordos y canales del Campo Patagónico de Hielo Sur y el otro con las estaciones localizadas alrededor del Estrecho de Magallanes. Cuarenta y cinco especies explican el 90% de disimilitud entre estos dos grupos. Las diferencias se pueden explicar principalmente por la influencia de condiciones ambientales locales, determinadas por procesos estrechamente relacionados con la presencia/ausencia de glaciares. No hubo correlación entre parámetros abióticos tales como profundidad, tipo de sedimentos y características químicas del sedimento superficial y el número de individuos capturados por la rastra Agassiz en cada grupo de estaciones de muestreo.

**Palabras clave:** Región de Magallanes, Campo de Hielo Patagónico Sur, estrecho de Magallanes, estructura comunitaria, biodiversidad.

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## INTRODUCTION

Much of the Magellan region at the southern tip of South America is still under the influence of a massive, elongated, narrow ice sheet, which continues to be active but reached its largest extension during the Last Glacial Maximum period (around 19,000-23,000 yr ago; Hulton *et al.*, 2002). At present, there is evidence of a wide and intensive retreat of several of the conforming fjordic glaciers which began 12,000 years ago (Moreno *et al.*, 1999). The resulting geomorphologic area is a large complex of fjords and channels whose linear extension is estimated at about 30,000 km of linear shoreline.

In contrast to northern hemisphere fjord environments (e.g. Pearson, 1980; Gulliksen *et al.*, 1985; Holte and Gulliksen, 1998; Larsen, 1997; Kendall *et al.*, 2003; Wlodarska-Kowalczyk *et al.*, 1998; Wlodarska-Kowalczyk and Pearson, 2004) and even in comparison with the Antarctic ecosystem (Dawber and Powell, 1997; Arntz *et al.*, 1994; Jazdzewski *et al.*, 2001), there is a lack of biological information on the Magellan region. However, this region represents a corner-stone for elucidating several biogeographical and ecological questions related to latitudinal gradients in species diversity or biomass (Clarke, 1992; Gray, 2001a; b; Piepenburg *et al.*, 2002), origin and evolution of the (sub)Antarctic biota (Gallardo *et al.*, 1992; Arntz and Ríos, 1999) or the split of zoogeographical units along the western coast of South America (Brattström and Johanssen, 1983; Lancellotti and Vásquez, 2000; Camus, 2001; Montiel *et al.*, 2004).

The benthic sublittoral macrofauna inhabiting the Magellan region has been described mainly for the Straits of Magellan and related channels (e.g. Gutt *et al.*, 1999; Gerdes and Montiel, 1999; Thatje and Mutschke, 1999; Brey and Gerdes, 1999; Montiel *et al.*, 2001; Ríos *et al.*, 2003) and mostly after the 1994 "Victor Hensen" scientific cruise in the Magellan region (Arntz and Gorny, 1996). Nevertheless, there still is a lack of comparative studies for the Magellan region, including an update of the taxonomic knowledge of this Subantarctic area (Arntz, 1999). A study on the benthic macrofauna along the entire Magellan coastal zone by Gerdes *et al.* is still underway, focusing on the analysis of abundance and biomass of major taxa (e.g. Mollusca, Polychaeta, Crustacea and Echinodermata). The lowest values were obtained at the stations in the South Patagonian Icefield, with an increasing gradi-

ent of abundance and biomass towards the southernmost sampling areas.

The present study encompasses a geographically wide range of the Magellan region and is based on data from semi-quantitative benthic research in this heterogeneous marine ecosystem. The aim is to give a better insight into the structure of benthic macrofaunal communities for the area at species level. Additionally, we identify and compare benthic key species, which are representative of the fjord and channel ecosystem in this region. Finally, we evaluate the influence of some physical environmental variables on the obtained macrobenthic distribution patterns.

## MATERIAL AND METHODS

Samples were taken during the CIMAR-Fiordo III (October 1995) and CIMAR-Fiordo VII (November 1997) campaigns organised by the Chilean Comisión Oceanográfica Nacional (CONA) from on board the R/V "Vidal Gormaz". A total of 29 localities were sampled using a modified Agassiz trawl (AGT) (3.15 m wide and 1.1 m high, with a mesh size of 10 mm) at depths of 24-732 m, ranging from the northern limit of the South Patagonian Icefield (SPI) to the eastern entrance of the Straits of Magellan (SM) (Fig. 1). Working time on the bottom for each haul averaged 12 min. Detailed sampling station data are summarised in Table 1.

Catch volumes of the AGT were relatively small at each station, in terms of both sediment and epibenthic fauna. Therefore, all the collected material was considered as a sample for later analysis and the number of caught specimens was used as representative of abundance for similarity analysis. The samples were immediately sorted onboard by separating all the collected fauna from the sediment using sieves with 1 mm mesh size. The sorted animals were preserved in a 5% formaldehyde seawater solution buffered with hexamethylenetetramin.

The collected macrofauna was identified to the lowest possible taxonomic level, but for some taxa (e.g. Holothuroidea) identification was possible only to higher taxonomic levels. Organisms were identified based on standard publications (Retamal, 1974; Forcelli, 2000), experts who assisted in the identification of different taxa (see "Acknowledgement") and the identified benthic species at the "Edmundo Pisano Reference Collection" of the Instituto de la Patagonia, Universidad de Magallanes.

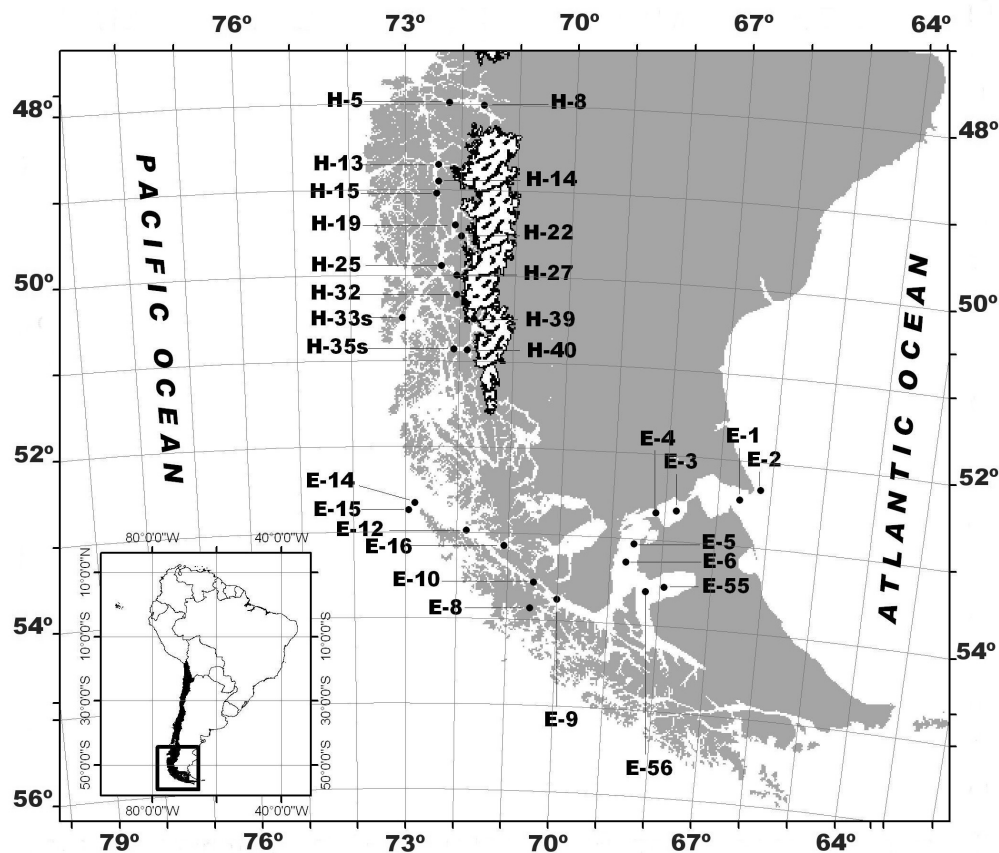


FIG. 1. – Map showing the Magellan region and the sampling sites in the South Patagonian Icefield (SPI) and Straits of Magellan (SM) areas.

TABLE 1. – List of stations sampled in the Magellan region. n.i. = no information.

| Station N° | Locations                        | Depth (m) | Latitude S | Longitude W | Sampling date | Bottom type | C org (ug at/g) | N org (ug at/g) | P total (ug at/g) |
|------------|----------------------------------|-----------|------------|-------------|---------------|-------------|-----------------|-----------------|-------------------|
| H8         | Canal Baker                      | 723       | 47°58.6    | 74°13.2     | 22.08.95      | Mud         | 540.7           | 86.5            | 14.4              |
| H5         | Canal Baker                      | 382       | 48°00.3    | 73°36.7     | 22.08.95      | Mud         | 403.5           | 72.2            | 11.7              |
| H13        | Canal Hammick                    | 345       | 48°42.3    | 74°24.3     | 23.08.95      | Sand        | 387.4           | 36.8            | 11.1              |
| H14        | Angostura Inglesa                | 385       | 46°53.9    | 74°24.2     | 23.08.95      | Sand        | 540.7           | 89.3            | 12.3              |
| H15        | Paso del Indio                   | 166       | 49°02.4    | 74°26.1     | 23.08.95      | Sand        | 1024.9          | 187.8           | 16.2              |
| H19        | Fiordo Eyre                      | 349       | 49°24.5    | 74°05.9     | 24.08.95      | Mud         | 212.1           | 30.7            | 11.4              |
| H22        | Fiordo Falcon (sector Agüada)    | 122       | 49°32.1    | 73°59.1     | 24.08.95      | Mud         | 355.1           | 58.8            | 9.4               |
| H27        | Fiordo Penguin                   | 232       | 49°53.3    | 74°20.3     | 26.08.95      | Mud         | 581.1           | 80.5            | 8.5               |
| H25        | Fiordo Penguin                   | 298       | 49°59.6    | 74°03.7     | 26.08.95      | Mud         | 322.8           | 48.1            | 11.8              |
| H32        | Fiordo Europa                    | 66        | 50°13.5    | 74°03.1     | 27.08.95      | Mud         | 226.0           | 34.5            | 11.1              |
| H33S       | Canal Oeste                      | 75        | 50°29.6    | 75°02.5     | 28.08.95      | Sand        | n.i.            | n.i.            | n.i.              |
| H35S       | Fiordo Peel (Paso la Piedra)     | 117       | 50°51.7    | 74°05.9     | 29.08.95      | Mud         | 355.1           | 53.2            | 18.5              |
| H39        | Fiordo Peel (Bahía Chubretovich) | 110       | 50°30.3    | 73°44.3     | 29.08.95      | Mud         | 266.3           | 23.0            | 10.7              |
| H40        | Fiordo Amalia (Interior)         | 148       | 50°52.3    | 73°50.8     | 29.08.95      | Mud         | 500.4           | 71.5            | 13.5              |
| E1         | Boca Oriental E. de Magallanes   | 70        | 52°27.4    | 68°35.0     | 06.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E2         | Bahía Posesión                   | 40        | 52°19.4    | 69°12.2     | 06.10.97      | Mud         | n.i.            | n.i.            | n.i.              |
| E3         | 1° Angostura E. de Magallanes    | 24        | 52°38.6    | 69°46.48    | 07.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E4         | 2° Angostura E. de Magallanes    | 41        | 52°41.1    | 70°10.2     | 07.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E5         | Paso Ancho                       | 88        | 53°03.6    | 70°32.8     | 07.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E6         | Paso Ancho                       | 177       | 53°16.5    | 70°41.2     | 07.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E56        | Bahía Inutil                     | 270       | 53°32.6    | 69°54.7     | 08.10.97      | Mud         | n.i.            | n.i.            | n.i.              |
| E55        | Bahía Inutil                     | 50        | 53°36.3    | 70°16.0     | 07.10.97      | Mud         | n.i.            | n.i.            | n.i.              |
| E8         | Bahía Snug                       | 260       | 53°51.8    | 72°32.0     | 14.10.97      | Mud         | n.i.            | n.i.            | n.i.              |
| E9         | Isla Wood                        | 313       | 53°45.1    | 71°59.9     | 15.10.97      | Mud         | n.i.            | n.i.            | n.i.              |
| E10        | Paso Tortuoso                    | 404       | 53°33.7    | 72°28.6     | 15.10.97      | Sand        | n.i.            | n.i.            | n.i.              |
| E15        | Cabo Tamar                       | 604       | 52°58.6    | 73°48.6     | 16.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E14        | Boca Occidental E. de Magallanes | 66        | 52°39.5    | 74°48.5     | 16.10.97      | Sand gravel | n.i.            | n.i.            | n.i.              |
| E12        | Boca Occidental E. de Magallanes | 90        | 52°44.4    | 74°55.6     | 16.10.97      | Sand        | n.i.            | n.i.            | n.i.              |
| E16        | Golfo Xaltega                    | 411       | 53°8.65    | 73°4.70     | 16.10.97      | Mud         | n.i.            | n.i.            | n.i.              |

Data were analysed using the PRIMERv5 computer package (Clarke and Warwick, 1994). To analyse the spatial distribution of sampling sites over the study area, the MDS (“multidimensional scaling”) program based on presence-absence matrix data was employed. This procedure also made it possible to consider colonial organisms (e.g. Gorgonaria and Bryozoa), which were collected at several sampling stations. Routine SIMPER (“similarity percentage”) was used to discriminate species and their percentage of contribution to (dis) similarities within and between groups defined by the MDS. In this case, only solitary (counted) organisms were considered.

To determine whether the benthic distribution patterns showed relationships to environmental abiotic parameters, the BIO-ENV procedure from PRIMER was applied to data available for the study area. BIOENV (Clarke and Gorley, 2001) selects a combination of environmental factors best explaining a community pattern by maximising a Spearman rank correlation between the respective similarity matrices using all possible permutations of environmental factors. The similarity measure used was the Normalized Euclidean Distance. Environmental variables (water depth, substrate) and some sediment chemical features of the SPI (organic carbon and nitrogen, total phosphate) were obtained from Ahumada *et al.* (1996) and Silva and Prego (2002). Comparable information for the SM area is relatively scarce. The effects of water depth, bottom type, hydrodynamic regime and suspended particulate matter (Brambatti *et al.*, 1991; Fontolan and Panela, 1991) were also analysed.

## RESULTS

### Species composition and numerical dominance

The sampling stations showed relatively low numbers of specimens in the catches by the Agassiz trawl. A total of 1,895 individuals were caught belonging to 5 epi- and endobenthos major taxa, from which 131 species were identified (Table 2). Another 19 species belonged to colonial taxa, mainly Bryozoa (17 species) and Octocorallia (2 species).

The taxon Echinodermata was the most diverse in numbers of species (47 species), with 25 species belonging to asteroids, 13 species to ophiuroids, 6 species to holothuroids and 3 to echinoids. Polychaeta (46 species) were the second dominant taxon

in terms of species richness. Mollusca (25 species) were the third important taxon, encompassing Bivalvia (13 species), Gastropoda (8 species), Polyplacophora and Scaphopoda (2 species each).

Echinodermata were the taxon with the highest number of individuals, representing 51% of the total catch. Ophiuroidea were the most abundant class, representing 20% of the total collected organisms.

The frequency of occurrence of species at the sampling stations was low, in accordance with the number of macrofauna caught. The echinoid *Pseudechinus magellanicus* was caught at 35% of the sampling sites, whereas *Ctenodiscus procurator* (Asteroidea), *Ophiuroglypha lymani* (Ophiuroidea) and *Euripodius latreillei* (Crustacea) were collected at 24% of the stations.

### Comparison between sampling sites

Two major groups of stations can be discriminated in the two-dimensional MDS configuration of the 29 sampling sites, based on presence-absence data (Fig 2a). The stress value for the ordination ( $s = 0.13$ ) corresponds to a good representation (Clarke and Warwick, 1994). One group includes all the stations associated with the South Patagonian Icefield and the second one comprises stations mostly situated in the Straits of Magellan area. The average dissimilarity of all pairwise coefficients in the SPI and SM group was 97.4. Of these, 10.5 were contributed by *Ctenodiscus procurator*, 7.3 by *Ophiuroglypha lymani* and 6.5 by *Magellania venosa*, accounting for 24.9% of the overall value of 97.4 (Table 3). These three species are representative of the SM station group. A total of 45 species account for 90% of the dissimilarity between these two groups. The stations in the Straits of Magellan show consistently higher catch levels than the stations off the SPI.

The ordination of sampling stations for the Straits of Magellan suggests a subordinate segregation of sampling sites, which was analysed in more detail considering only sample sites of this area (Fig 2b). In this case, distinct clusters of sites emerge, showing a relation to geographical positions across the Straits of Magellan. One group is related to the eastern entrance of the Straits (Boca Oriental, Primera Angostura, Segunda Angostura and Bahía Posesión), whereas stations from the Pacific entrance (e.g. Boca Occidental) form another separate subgroup. From sampling stations between the two Strait entrances (Atlantic and Pacific) there emerge two other subgroups. The sampling sites





TABLE 2 (Cont.). – A list of marine invertebrate species found in the areas of study. Number of individuals caught with the Agassiz trawl at each station is included (H = South Patagonian Icefield stations; E = Straits of Magellan stations). Colonial organisms are indicated by p=presence.

| Species/stations number          | H5 | H8 | H13H14 | H15 | H19 | H22 | H25 | H27 | H32H33s | H35s | H39 | H40 | E1 | E2 | E3 | E4 | E5 | E6 | E55E56 | E8 | E9 | E10 | E12 | E14 | E15E16 |   |
|----------------------------------|----|----|--------|-----|-----|-----|-----|-----|---------|------|-----|-----|----|----|----|----|----|----|--------|----|----|-----|-----|-----|--------|---|
| <b>Asteroidea</b>                |    |    |        |     |     |     |     |     |         |      |     |     |    |    |    |    |    |    |        |    |    |     |     |     |        |   |
| <i>Ganeria falklandica</i>       | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 4  | 0  | 0  | 1  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Bathybiaster loripes</i>      | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 3  | 0      | 2  | 0  | 0   | 1   | 0   | 0      | 4 |
| <i>Poraniopsis echinaster</i>    | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 2    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Cycethra verrucosa</i>        | 0  | 0  | 0      | 0   | 18  | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 2  | 0  | 1  | 10 | 0  | 0  | 0      | 0  | 0  | 4   | 0   | 0   | 0      | 0 |
| <i>Austrocidaris lorioli</i>     | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 2  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 2  | 0   | 0   | 0   | 0      | 0 |
| <i>Brisaster moseleyi</i>        | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 1  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <b>Echinoidea</b>                |    |    |        |     |     |     |     |     |         |      |     |     |    |    |    |    |    |    |        |    |    |     |     |     |        |   |
| <i>Tripylaster philippii</i>     | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 14     | 0  | 0  | 0   | 0   | 0   | 0      | 2 |
| <i>Arbacia dufresnei</i>         | 0  | 0  | 1      | 0   | 0   | 0   | 0   | 0   | 0       | 20   | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 1   | 0   | 0   | 0      | 0 |
| <i>Pseudechinus magellanicus</i> | 0  | 0  | 0      | 0   | 0   | 2   | 0   | 0   | 0       | 8    | 4   | 24  | 0  | 0  | 6  | 1  | 0  | 11 | 20     | 0  | 0  | 5   | 9   | 0   | 0      | 0 |
| <b>Ophiuroidea</b>               |    |    |        |     |     |     |     |     |         |      |     |     |    |    |    |    |    |    |        |    |    |     |     |     |        |   |
| <i>Ophiura INDET</i>             | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 1  | 1  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiacantha cf. pentactis</i> | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 9   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiactis</i> sp.             | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 111  | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiacten amitinum</i>        | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 13  | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiacantha vivipara</i>      | 0  | 0  | 0      | 0   | 0   | 2   | 0   | 0   | 0       | 16   | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiuroglypha lymani</i>      | 13 | 0  | 7      | 0   | 0   | 0   | 3   | 0   | 0       | 0    | 8   | 0   | 0  | 0  | 0  | 0  | 0  | 55 | 0      | 0  | 4  | 65  | 0   | 0   | 0      | 0 |
| <i>Gorgonocephalus chilensis</i> | 0  | 0  | 0      | 0   | 0   | 3   | 0   | 0   | 0       | 27   | 0   | 0   | 1  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiomyxa vivipara</i>        | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 4    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophiactis asperula</i>        | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 5  | 5  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 1      | 1 |
| <i>Astrotoma agassizii</i>       | 0  | 0  | 0      | 0   | 0   | 0   | 3   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Homalophiura inornata</i>     | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 9  | 0   | 0   | 0   | 0      | 0 |
| <i>Ophioscolex nutrix</i>        | 0  | 0  | 0      | 0   | 0   | 2   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Homalophiura</i> sp.          | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <b>Holothuroidea</b>             |    |    |        |     |     |     |     |     |         |      |     |     |    |    |    |    |    |    |        |    |    |     |     |     |        |   |
| <i>Hemiodema spectabilis</i>     | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 1  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| <i>Psolus patagonicus</i>        | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 1  | 1  | 0      | 0  | 79 | 0   | 0   | 0   | 0      | 0 |
| <i>Pseudocnus leoninus</i>       |    |    |        |     |     |     |     |     |         |      |     |     |    |    |    |    |    |    |        |    |    |     |     |     |        |   |
| <i>dubiosus</i>                  | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 1  | 0  | 0  | 0  | 0  | 0      | 0  | 0  | 0   | 0   | 0   | 0      | 0 |
| Holothuroidea sp 1               | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 0      | 0  | 1  | 0   | 0   | 0   | 0      | 0 |
| Holothuroidea sp 2               | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 0  | 0  | 34     | 0  | 12 | 0   | 2   | 0   | 0      | 0 |
| Holothuroidea sp 3               | 0  | 0  | 0      | 0   | 0   | 0   | 0   | 0   | 0       | 0    | 0   | 0   | 0  | 0  | 0  | 0  | 4  | 0  | 0      | 0  | 7  | 0   | 0   | 0   | 0      | 0 |

with the biggest catches were the two stations in Paso Ancho (stations C5 and C6; see Fig. 1), Isla Wood (C9), and Paso Tortuoso (C10). The most frequently occurring group of specimens in the entire SM area was Brachiopoda, with the articulate brachiopod *Magellania venosa* as the most prominent species. Another dominant group was the Asteroidea, mainly *Ctenodiscus procurator* and *Cycethra verrucosa*. The ophiuroids *Ophiuroglypha lymani* and *Ophiactis asperula*, and the holothurian *Psolus patagonicus* were also relatively abundant at some sampling stations.

Differences between the subgroups determined on the basis of samples from the Atlantic (eastern) and Pacific (western) entrance of the Strait of Magellan appear to be defined mainly by the occurrence of echinoderms and brachiopods. In the western area, the asteroids *Ctenodiscus procurator* and *Bathybiaster loripes* and the isopod *Acanthoserolis schythei* dominated the samples, whereas at the eastern entrance *Magellania venosa* and *Terebratella dorsata* (brachiopods), *Ophiactis asperula* (ophiuroid) and *Cycethra verrucosa* (asteroid) were the dominant species.

A similar analysis with the SPI sampling sites showed no clear-cut relation to geographical positions (Fig 2c). Agassiz trawl catches were larger at sampling sites situated in channels (e.g. Canal Oeste and Paso del Indio) and also at the entrance of the Penguin Fjord. The remaining stations, mainly those in the fjords, showed smaller catches as compared with the relatively big ones obtained at sites less influenced by glaciers. The bivalve *Camptonectus (P.) subhyalinus* was the most abundant species off the SPI, followed by the ophiuroids *Ophiactis* sp., *Ophiuroglypha lymani* and *Gorgonocephalus chilensis*. Other dominant species in this area were the polychaetes *Polyeunoa laevis* and *Harmothoe campoglacialis*, and the asteroids *Ctenodiscus procurator* and *Luidiaster planatus*.

According to the results from the BIOENV analysis, no relationship was found between the benthic distribution patterns observed and the abiotic parameters in the SPI area. A similar result was obtained for the SM area; however, a low level of correlation was obtained between the faunal composition, the hydrodynamic regime and suspended particulate matter ( $R = 0.040$ ;  $p = 0.24$ ).

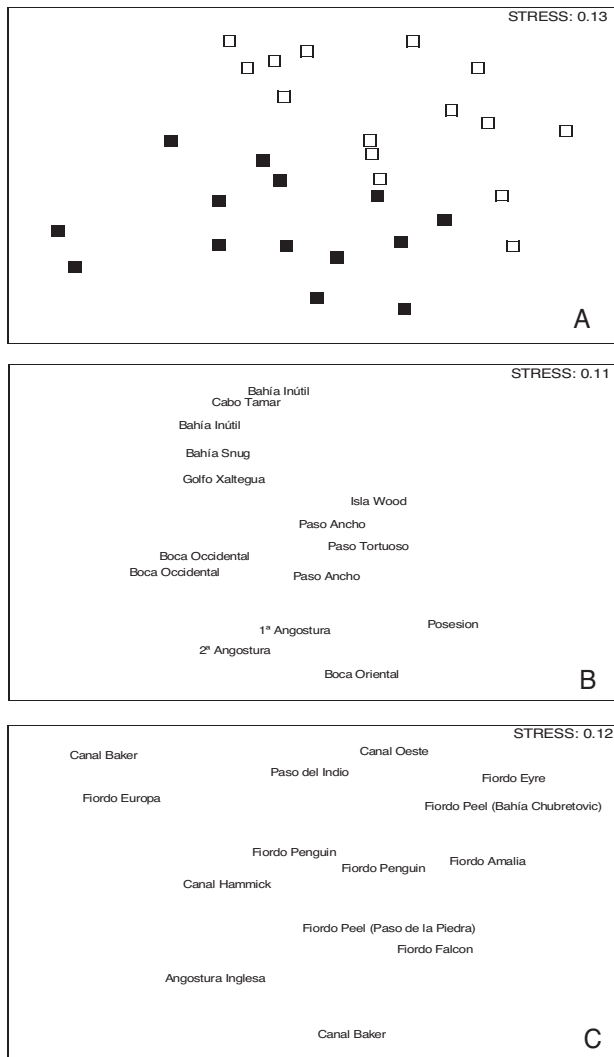


FIG. 2. – MDS plots of macrobenthic assemblages in the Magellan region (A; □ = SPI stations, ■ = EM stations), the Straits of Magellan (B) and the South Patagonian Icefield (C), based on the Bray-Curtis similarity index with presence/absence data.

## DISCUSSION

This study is the first attempt to describe and compare macrobenthic associations on a species level in the south Chilean glacial fjords and channels. However, due to the sampling gear used (Agassiz trawl), some caution is needed for the interpretation of the resulting ecological patterns. The study of macrozoobenthic communities by trawls can be considered to give only a first insight into the distribution of epibenthic communities, as mentioned by Arnaud *et al.* (1998), but it represents a fairly good picture of the variety of benthic species living in an ecosystem. Further quantitative research on species composition, biotic and abiotic variables and their temporal and spatial variability

is necessary for a more global understanding of community patterns and processes occurring in these fjords and channels.

A low number of specimens was an outstanding feature at all the sampling stations, especially at those stations located in the SPI area. Distribution patterns in the SM area were found to be more homogenous, as is obvious also from extensive quantitative analyses on a major taxon level. The lowest average abundance (625 ind/m<sup>2</sup>) was observed at sampling stations in the South Patagonian Icefield, increasing significantly southwards to a maximum (3,972 ind/m<sup>2</sup>) on the continental shelf off the eastern entrance of the Beagle Channel. The Straits of Magellan showed intermediate values (1,591 ind/m<sup>2</sup>). These differences are attributed to certain environmental properties of the areas, mainly those related to the stability of the bottom sediments. Silva and Prego (2002) indicated that glaciers provide cold oligotrophic waters rich in silt to the inlets, features which may explain the scarcity of benthic abundance and biomass production, as was suggested for the phytoplankton scarcity found in several of the fjords considered in our study (Vera *et al.*, 1996).

However, lack of repeated study in this ecosystem, including seasonal and long-term fluctuations of abundance and environmental abiotic parameters, make a more comprehensive analysis and explanation of the observed trends rather difficult, especially for the SPI. For instance, melting of glaciers during the austral spring (September-early December) and summer (December-March) might cause a strong sedimentary input of inorganic matter to the bottom, producing additional disturbance in the benthic regime, and consequently a decrease in animal abundance. Sedimentation has been suggested as one of the important factors determining epifaunal distribution at Antarctic coastal glaciers (e.g. Dawber and Powell, 1997), and more specifically in Potter Cove (King George Island), where benthic colonisation (ascidians instead of sponges) is strongly influenced by inorganic siltation from the glacier (Klöser *et al.*, 1994; Kowalke and Abele 1998; Sahade *et al.* 1998; Tatián *et al.* 1998). Similar results have also been obtained in the Canadian Arctic and Alaskan fjords, where epifauna is restricted to areas with low sedimentation rates (Evans *et al.*, 1980; Carney *et al.*, 1999).

An important additional difference to sites located in the SPI area is the higher amount of inorganic carbon in surface sediments of the Straits of Magellan-



TABLE 3. – Average dissimilarity (AvDiss) and ratio between AvDiss and its corresponding standard deviation (Diss/SD) between SPI (South Patagonian Icefield) and SM (Straits of Magellan) groups. Species are ranked in decreasing contribution (%) to dissimilarity values. Cum=cumulative percentage. Average dissimilarity = 97.35

| Species                                    | Group SPI<br>AvAbund | Group SSM<br>AvAbund | AvDiss | Diss/SD | Contrib% | Cum   |
|--|----------------------|----------------------|--------|---------|----------|-------|
| <i>Ctenodiscus procurator</i>              | 3.64                 | 5.40                 | 10.45  | 0.65    | 10.71    | 10.71 |
| <i>Ophiuroglypha lymani</i>                | 2.21                 | 8.27                 | 7.33   | 0.57    | 7.52     | 18.23 |
| <i>Magellania venosa</i>                   | 0.07                 | 11.87                | 6.51   | 0.39    | 6.68     | 24.91 |
| <i>Pseudechinus magellanicus</i>           | 2.71                 | 3.47                 | 5.02   | 0.52    | 5.15     | 30.05 |
| <i>Acanthoserolis schythei</i>             | 0.00                 | 3.93                 | 4.94   | 0.36    | 5.07     | 35.12 |
| <i>Camptonectus(Pallioleum)subhyalinus</i> | 13.64                | 0.00                 | 4.54   | 0.27    | 4.65     | 39.77 |
| <i>Dentalium majorinum</i>                 | 0.43                 | 1.53                 | 3.40   | 0.42    | 3.49     | 43.26 |
| <i>Limopsis marionensis</i>                | 0.21                 | 5.13                 | 3.19   | 0.36    | 3.27     | 46.53 |
| <i>Psolus patagonicus</i>                  | 0.00                 | 5.40                 | 3.16   | 0.26    | 3.24     | 49.77 |
| <i>Holothuroidea sp 2</i>                  | 0.00                 | 3.20                 | 3.05   | 0.36    | 3.13     | 52.90 |
| <i>Cyathra verrucosa</i>                   | 1.29                 | 1.13                 | 2.91   | 0.36    | 2.99     | 55.88 |
| <i>Ophiactis sp.</i>                       | 7.93                 | 0.00                 | 2.36   | 0.27    | 2.42     | 58.30 |
| <i>Terebratella dorsata</i>                | 0.00                 | 2.60                 | 2.35   | 0.28    | 2.41     | 60.71 |
| <i>Cheiraster (Luidiaster) planeta</i>     | 2.14                 | 0.07                 | 2.31   | 0.26    | 2.37     | 63.07 |
| <i>Ophiactis asperula</i>                  | 0.00                 | 0.80                 | 1.73   | 0.37    | 1.77     | 64.85 |
| <i>Cosmasterias lurida</i>                 | 1.14                 | 0.67                 | 1.65   | 0.31    | 1.70     | 66.54 |
| <i>Leanira quatrefagesi</i>                | 1.36                 | 0.00                 | 1.61   | 0.59    | 1.65     | 68.19 |
| <i>Bathyiaster loripes</i>                 | 0.00                 | 0.67                 | 1.36   | 0.49    | 1.40     | 69.59 |
| <i>Ennucula grayi</i>                      | 0.64                 | 0.40                 | 1.29   | 0.28    | 1.32     | 70.91 |
| <i>Eurypodius latreillei</i>               | 0.64                 | 0.73                 | 1.19   | 0.42    | 1.22     | 72.13 |
| <i>Trypilaster philippi</i>                | 0.00                 | 1.07                 | 1.10   | 0.31    | 1.13     | 73.26 |
| <i>Ophiocten namitinum</i>                 | 0.93                 | 0.00                 | 1.08   | 0.25    | 1.11     | 74.37 |
| <i>Gorgonocephalus chilensis</i>           | 2.14                 | 0.07                 | 1.04   | 0.39    | 1.06     | 75.43 |
| <i>Polyeunoa laevis</i>                    | 2.57                 | 0.00                 | 1.03   | 0.35    | 1.06     | 76.49 |
| <i>Pista cristata</i>                      | 0.57                 | 0.00                 | 0.86   | 0.25    | 0.88     | 77.37 |
| <i>Maldane sarsi</i>                       | 0.43                 | 0.00                 | 0.85   | 0.42    | 0.88     | 78.25 |
| <i>Libidoclaea smithi</i>                  | 0.36                 | 0.13                 | 0.79   | 0.29    | 0.81     | 79.06 |
| <i>Crepidula dilatata</i>                  | 0.00                 | 0.40                 | 0.76   | 0.24    | 0.78     | 79.84 |
| <i>Ophiacantha cf. pentactis</i>           | 0.64                 | 0.00                 | 0.75   | 0.25    | 0.77     | 80.61 |
| <i>Cyclocardia velutinus</i>               | 0.14                 | 1.20                 | 0.75   | 0.35    | 0.77     | 81.37 |
| <i>Abyssoninoe abyssorum</i>               | 0.43                 | 0.00                 | 0.73   | 0.31    | 0.75     | 82.12 |
| <i>Sternaspis scutata</i>                  | 1.00                 | 0.00                 | 0.71   | 0.33    | 0.73     | 82.85 |
| <i>Porania antarctica magellanica</i>      | 0.00                 | 10.67                | 10.66  | 0.45    | 0.67     | 83.53 |
| <i>Laneria falklandica</i>                 | 0.00                 | 0.33                 | 0.64   | 0.24    | 0.66     | 84.18 |
| <i>Ophiacantha vivipara</i>                | 1.29                 | 0.00                 | 0.62   | 0.37    | 0.63     | 84.81 |
| <i>Berthella platei</i>                    | 0.07                 | 0.53                 | 0.61   | 0.31    | 0.63     | 85.44 |
| <i>Aulacomya ater</i>                      | 0.00                 | 0.40                 | 0.60   | 0.34    | 0.61     | 86.06 |
| <i>Arbacia dufresnei</i>                   | 1.50                 | 0.07                 | 0.58   | 0.36    | 0.60     | 86.65 |
| <i>Munida subrugosa</i>                    | 0.21                 | 0.13                 | 0.55   | 0.41    | 0.57     | 87.22 |
| <i>Campylonotus semistriatus</i>           | 0.00                 | 0.87                 | 0.52   | 0.34    | 0.54     | 87.75 |
| <i>Calyptaster tenuissimus</i>             | 0.00                 | 0.47                 | 0.51   | 0.25    | 0.52     | 88.28 |
| <i>Halicarcinus planatus</i>               | 0.00                 | 0.27                 | 0.51   | 0.24    | 0.52     | 88.80 |
| <i>Harmothoe campoglacialis</i>            | 1.64                 | 0.00                 | 0.49   | 0.27    | 0.50     | 89.30 |
| <i>Chlamys patagonicus</i>                 | 1.21                 | 0.27                 | 0.46   | 0.34    | 0.48     | 89.77 |
| <i>Homalophiura inornata</i>               | 0.00                 | 0.60                 | 0.41   | 0.25    | 0.42     | 90.20 |

lan (Silva and Prego, 2002), which according to Brambati *et al.* (1991) can be attributed to the presence of calcite in the remains of bivalves, gastropods, crustaceans and foraminiferans. Unfortunately, information on chemical and physical processes of pelagobenthic coupling (Cattaneo-Vietti *et al.*, 1999) and in the bottom sediments is scarce for the area of study, and this represents a limiting factor to explain the (dis)similarities we found between the study areas. More focused research on inter-annual variability of biotic parameters and their relationship with variability in sediments features are clearly needed for the Magellan region. Recently, Ríos *et al.* (2003) reported for the Straits of Magellan a significant seasonal abundance pat-

tern, with variations in species richness and diversity in areas at the eastern SM entrance, and with maximum values observed in the austral summer period. Presently, this area is not affected by the direct influence of glacial processes. All these features suggest very intricate ecological dynamics in the benthic communities associated with the Chilean channel and fjord complex.

The most interesting result was the clear difference in species composition found between the South Patagonian Icefield and the Straits of Magellan. Recently, both areas have been separated into two different sectors according to carbon and nitrogen concentrations and distributions in the superficial sediment layers of the bottom (Silva and Prego,

2002). In addition, an east (glacially affected zone) and west (oceanically influenced zone) segregation in the SPI was identified. However, our biotic data do not indicate any clear relationship with the abiotic parameters determined by Silva and Prego (2002): the differences could be primarily explained by the occurrence of markedly different habitat conditions and gradients caused by the glaciers.

The discriminant invertebrate species determined for the SPI area are typical of the prevailing substrate (mud in the fjords and sand in the channels), but also for the presumably considerable disturbance produced by high sedimentation towards the bottom. These facts may explain the larger catches both in channels (e.g. Canal Oeste) and at the entrance of the fjords (e.g. Seno Pingüino). One of the discriminant genera in the SPI area, the ophiuroid *Ophiactis* sp. was collected at Canal Oeste sampling station, and has been frequently mentioned as being common in communities characterised by oligospecificity with dominance of suspension feeders, in which hydrodynamics represent both the most important limiting factor and the main carrier of organic matter (Giacobbe and Rinelli, 1991). Other species characterising this area were the carnivorous polynoids *Polyeunoa laevis* (dominant at the entrance of Seno Pingüino) and *Harmothoe campoglacialis* (Canal Oeste), and the ophiourid *Gorgonocephalus chilensis* (Canal Oeste). *P. laevis* has a circumpolar distribution, and is a dominant species in assemblages defined for deep water and hard bottoms off Subantarctic islands (Guillet, 1989). *H. campoglacialis* is a new, recently-identified species (Hilbig and Montiel, 2000) with a wide distribution range in the southern part of Chile, inhabiting mud and fine sand of fjords, channels and even microhabitats such as holdfasts of the kelp *Macrocystis pyrifera* (Montiel *et al.*, 2004). Species of the genus *Gorgonocephalus* are considered as “fortuitous predatory suspension feeders” adapted to life in strong currents (Emson *et al.*, 1991).

The SM represent a more diverse and probably less disturbed habitat for diverse benthic communities with higher organism densities. Furthermore, our data suggest the occurrence of separate subgroups of stations along the Straits with differences in community composition, e.g. at both entrances of SM. Such variability did not become evident in the comparison of mega-epibenthos distribution across the Straits by Gutt *et al.* (1999). In the SM area the most significant species regarding the discrimination from the SPI area (*Ctenodiscus procurator*, *Ophiuroglypha lymani*

and *Magellania venosa*) have been previously reported as characteristic species of benthic communities in the Straits of Magellan (Dahm, 1999; Larrain *et al.*, 1999; Gutt *et al.*, 1999). The genus *Ctenodiscus* is considered to be a non-selective deposit feeder (Shick *et al.*, 1981), whereas *O. lymani* is an omnivorous species and feeds mainly on crustaceans, the organic content of sediment and phytodetritus (Dahm, 1999). The brachiopod genus *Magellania* has been described as a dominant and characteristic filter feeder on deep soft substrates in the Subantarctic Prince Edward Islands (Branch *et al.*, 1993) and on the continental shelf of the high Antarctic Lazarev Sea (Brey *et al.*, 1995).

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