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# Semi-quantitative study of macrobenthic fauna in the region of the South Shetland Islands and the Antarctic Peninsula

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**Abstract** During the BENTART 95 Expedition, 24 Agassiz trawls for macrozoobenthos sampling were carried out at depths of 40–850 m, from north of Livingston Island to the Antarctic Peninsula. The samples were analysed using a semi-quantitative method, and with the resulting numerical data, transformed into a six-point scale, we constructed a Bray-Curtis similarity matrix. A total of 74,624 specimens, belonging to 38 taxonomic groups, were collected. The most abundant group was Polychaeta Sedentaria, with 36% of the total, whereas the highest relative masses were from Ascidiacea (23%), Echinoidea Regularia (18%) and Ophiuroidea (16%). The maximum number of specimens recorded was 15,600 ind./50 l. Cluster analysis separated stations located in Foster Bay (Deception Island), characterised by low taxonomic richness and high relative mass (average: 26.7 kg). A zonation of ascidians, regular sea urchins and ophiuroids was observed at Deception Island, clearly related to depth and substratum type. The remaining stations were separated into two groups. The first one comprised the shallowest stations (40–130 m), dominated by sessile active filter-feeders, belonging to Ascidiacea, Demospongia and Bryozoa, and probably related to high primary production zones. The second group comprised deeper stations and was dominated by classes exhibiting a diversity of trophic strategies: Ophiuroidea and Asteroidea, to 400 m, and Polychaeta Sedentaria at greater depths.

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## Introduction

Previous abundance and biomass assessments of Antarctic benthic fauna have been carried out either by scuba-diving, as far down as 50 m (Gruzov et al. 1967; Everson and White 1969; Propp 1970; Hardy 1972; White and Robins 1972; Dayton and Oliver 1977; Nakajima et al. 1982; Zamorano 1983; Jazdzewski et al. 1991; Barnes 1995a, b), or by different sampling devices, grabs and corers (e.g., Van Veen, Petersen, Smith Mclntyre, Boxcorer, Multiboxcorer) (Gallardo and Castillo 1969; Desbruyères and Guille 1973; Mills and Hessler 1974; Lowry 1975; Gallardo et al. 1977; Guille 1977; Richardson and Hedgpeth 1977; Retamal et al. 1982; Jazdzewski et al. 1986; Mühlenhardt-Siegel 1988, 1989; Gerdes et al. 1992; Saiz-Salinas et al. 1997).

Although trawling has been used frequently in Antarctica, the data obtained have been analysed only qualitatively (Bullivant 1959; Ushakov 1963; Retamal et al. 1982). Voß (1988), studying macrozoobenthic communities of the Weddell Sea, calculated fauna densities from 1000 $m^2$ of bottom surface, using samples obtained with an Agassiz trawl; however, Eleftheriou and Holme (1984) pointed out that this method is only semi-quantitative, due to the lack of accurate knowledge regarding the surface effectively sampled by the trawl. Recently, Arnaud et al. (1990) proposed a semi-quantitative method for studying macrozoobenthic communities by trawling. The aim of this method, which involves no specific identification of the material, is to give a preliminary insight into the distribution and trophic structure of communities in the study area. It was used during EPOS leg 3 Expedition in the Weddell Sea, and the results (Arnaud et al. 1990; Galeron et al. 1992) confirmed those obtained by Voß (1988). This method was also used by Arntz et al. (1996) for the study of benthic communities in the Magellan region.

During the BENTART 95 Expedition on board the R/V *Hesperides*, the macrozoobenthos was sampled from north of Livingston Island to the Antarctic Peninsula, as part of a project studying the benthic flora and fauna of the South Shetland Islands. This paper deals with the primarily epibenthic macrofaunal communities.

## Materials and methods

A total of 24 operations were carried out with an Agassiz trawl (2.01 m wide and 1.12 m high, having a mesh size of 10 mm) at depths of 40–850 m, ranging from north of Livingston Island to the Antarctic Peninsula (Fig. 1, Table 1). Before each operation, a bathymetric survey was conducted with echo-sounding. The actual working time on the bottom for each trawl was 5 min.

The large volume of benthic material brought in with the trawls made exhaustive sorting impossible. Therefore, a semi-quantitative method, developed during the EPOS programme on board the R/S *Polarstern* (Arnaud et al. 1990), was used. A subsample of 50 l was taken randomly from each catch, and immediately sieved using three mesh sizes: 10, 5 and 1 mm. The material retained on the largest mesh was then split into 38 taxonomic groups, which were

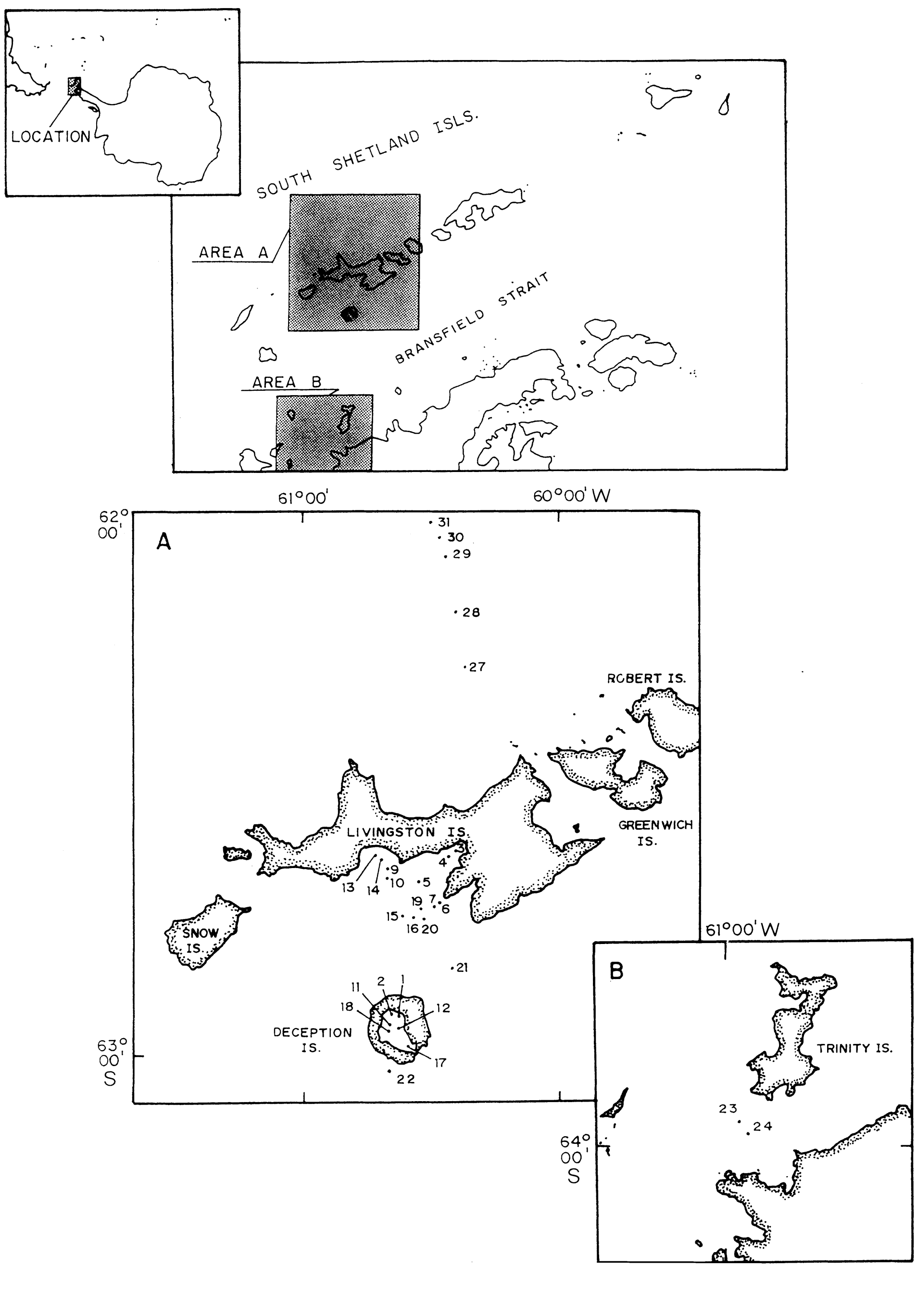


**Fig. 1** Position of Agassiz trawl stations during the BENTART-95 cruise

**Table 1** Station data for the Agassiz trawl stations

| Station | Date (1995) | Latitude S | Longitude W | Depth (m) | Bottom type |
|---|---|---|---|---|---|
| 1 | 23.01 | 62°55.01′ | 60°36.44′ | 40 | Gravel |
| 2 | 16.01 | 62°56.29′ | 60°38.71′ | 148 | Mud |
| 3 | 17.01 | 62°37.70′ | 60°22.81′ | 92 | Mud |
| 4 | 17.01 | 62°38.45′ | 60°24.18′ | 173 | Mud |
| 5 | 23.01 | 62°41.68′ | 60°31.81′ | 256 | Mud |
| 6 | 18.01 | 62°43.58′ | 60°26.96′ | 49 | Mud |
| 7 | 18.01 | 62°44.12′ | 60°27.70′ | 80 | Mud |
| 9 | 19.01 | 62°39.56′ | 60°38.62′ | 182 | Gravel and mud |
| 10 | 21.01 | 62°40.53′ | 60°38.95′ | 220 | Mud |
| 11 | 20.01 | 62°56.86′ | 60°39.34′ | 167 | Mud |
| 12 | 20.01 | 62°57.67′ | 60°38.00′ | 167 | Mud |
| 15 | 22.01 | 62°45.79′ | 60°35.70′ | 335 | Mud |
| 16 | 24.01 | 62°45.17′ | 60°33.10′ | 429 | Mud |
| 17 | 23.01 | 62°59.36′ | 60°33.85′ | 107 | Sand |
| 18 | 24.01 | 62°58.10′ | 60°40.24′ | 114 | Sand |
| 19 | 25.01 | 62°43.73′ | 60°31.46′ | 235 | Mud |
| 22 | 31.01 | 63°03.55′ | 60°39.54′ | 330 | Gravel |
| 23 | 29.01 | 63°57.14′ | 60°59.73′ | 141 | Gravel |
| 24 | 30.01 | 63°58.52′ | 60°52.60′ | 233 | Gravel |
| 27 | 02.02 | 62°20.41′ | 60°19.67′ | 70 | Mud and gravel |
| 28 | 02.02 | 62°12.12′ | 60°23.18′ | 126 | Mud |
| 29 | 03.02 | 62°05.16′ | 60°25.94′ | 237 | Mud |
| 30 | 03.02 | 62°01.41′ | 60°26.26′ | 710 | Mud and gravel |
| 31 | 04.02 | 62°01.40′ | 60°28.84′ | 1019 | Mud |

counted (or estimated on a six-point subjective scale, in the case of colonial organisms) and weighed. Finally, the fauna was preserved in 4% formaldehyde or 70° alcohol for later study.

To enable both the numerical data (derived from counting solitary organisms) and the estimates (concerning the colonial groups) to be used, a six-point scale of relative abundance was employed: absent, very rare, rare, rather common, common and very common. These data of transformed abundance were used to construct a Bray-Curtis similarity matrix. Classification was performed using the complete linkage clustering technique.

## Results

### Faunistic composition

A total of 74,624 specimens of macrobenthic invertebrates (size >10 mm) were collected, mainly from the epibenthos, but also from the endobenthos (Echiura, Priapulida, Sipuncula, Scaphopoda, Bivalvia), belonging to 38 high-range taxa (phylum, class, order).

The taxon having the highest number of individuals was Polychaeta Sedentaria (36%) (Fig. 2a). The highest relative masses were yielded by Ascidiacea (23%), Echinoidea Regularia (18%) and Ophiuroidea (16%) (Fig. 2b). Ophiuroidea were collected at every station sampled; Asteroidea and Ascidiacea were present at more than 90% of stations, and Hydroidea, Polychaeta Errantia and Sedentaria, and Amphipoda were collected at more than 75% of stations. Pterobranchia, Turbellaria and Polyplacophora were sampled at only one station.

The highest number of specimens were found at station 31, due to the number of Polychaeta Sedentaria, and the highest relative mass was collected at station 17, due to Echinoidea Regularia. Taxonomic richness reached a maximum of 28 taxa at stations 19 and 30, while station 17 yielded the minimum, 6 taxa (Fig. 3).

### Affinity between stations

The dendrogram of similarity derived from the Bray-Curtis index (Fig. 4), after the number of specimens was transformed into a scale from 1 to 6 (Table 2), distinguishes two groups of stations: a group comprising the

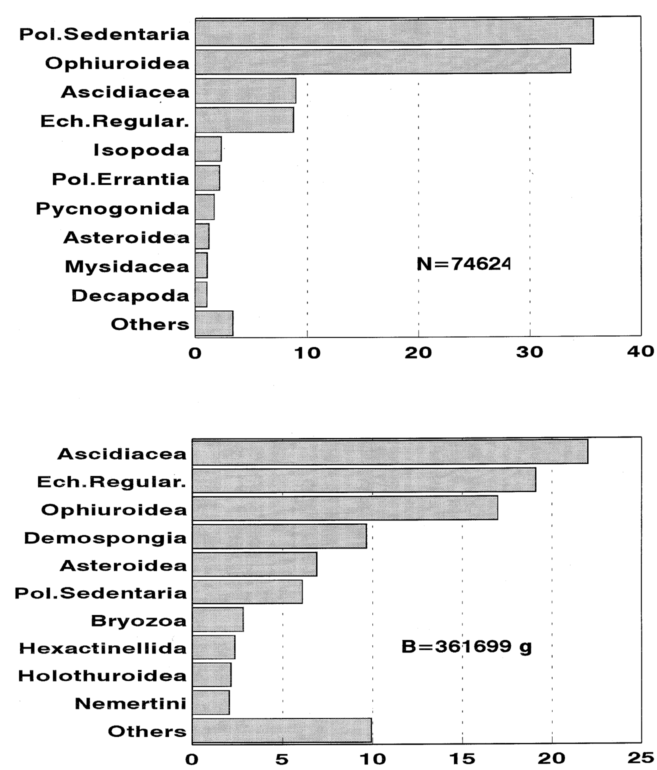


**Fig. 2** Abundance in terms of number (upper) and relative mass (lower) by group in total Agassiz trawls

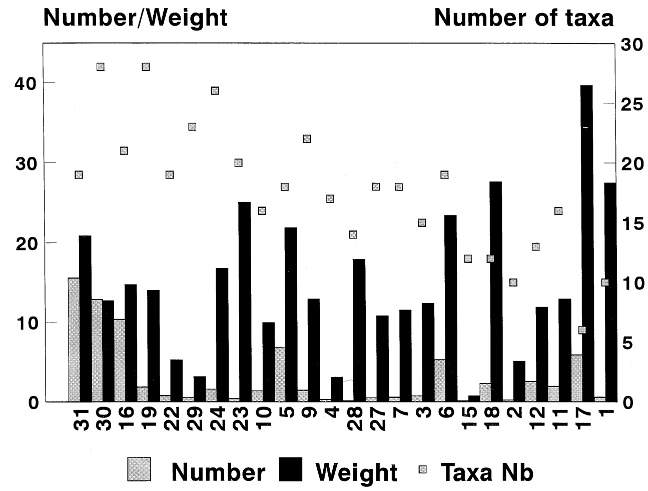


**Fig. 3** Relative mass (kg wet weight) and abundance (number of specimens) values, with superimposed major taxa richness, from the Agassiz trawls, in 50-l samples

stations of the inner bay (Foster Bay) of Deception Island (group I) and another comprising the remaining stations (group II), including four subgroups. The average relative mass of each group is represented in Fig. 5.

Group I is clearly distinguishable from the remaining stations (similarity <50%). It is characterised by a lower taxonomic richness (less than 50% of the taxa collected), but a higher relative mass (average of 26.6 g ± 9.9) than group II (average of 13.9 g ± 6.3). A zonation of the dominant taxa is also noticeable: 40–50 m, Ascidiacea (st. 1); 100–150 m, Echinoidea Regularia (sts. 2, 17, 18); and 150–170 m, Ophiuroidea (sts. 11, 12).

In group II, station 15 is clearly differentiated (similarity <50%). It shows a comparatively lower richness (12 taxa) and number of specimens (116 individuals) than the remaining stations in the group, with a predominance of Ophiuroidea and Polychaeta Errantia (mainly Aphroditidae), and the lowest mass (750 g) in the group.

The remaining stations are divided into two subgroups, depending on depth. Subgroup IIa comprises the stations shallower than 130 m, either south (sts. 3, 6, 7) or north (sts. 27, 28) of Livingston Island, where a dominance of sessile active suspension-feeders (Ascidiacea, Demospongia and Bryozoa) was observed. Its stations south of Livingston Island show a great dominance of Ascidiacea, both in number of individuals and relative mass, while north of Livingston Island the dominance of filter-feeders is only in relative mass.

The second group (including subgroups Ib, Ic and Id) comprises the stations deeper than 140 m, characterised by a predominance of vagile fauna, mainly Echinodermata (140–419 m) and Polychaeta Sedentaria (710–850 m). It may be divided into three subgroups. Subgroup Ib includes stations south of Livingston Island, at South Bay and Walker Bay, between 150 and 260 m. These stations, showing a distinct dominance of Ophiuroidea, in terms of number and relative mass, and a scarcity of sessile epifauna, have muddy bottoms, probably as a consequence of a high sedimentation rate proceeding from the glaciers of the bays.

The more heterogeneous subgroup Ic comprises stations from the Orleans Strait (sts. 23, 24) and north of Livingston Island (st. 29) between 140 and 286 m. A predominance of Ophiuroidea and Asteroidea was observed, but with many suspension-feeders (Crinoidea, Ascidiacea, Demospongia, Hexactinellida, Bryozoa). This abundance of suspension-feeders, as well as the heterogeneous granulometry (with pebbles, gravel, sand and mud), suggest the existence of currents at the bottom.

Subgroup Id includes five stations from the Bransfield Strait (st. 22), south of Livingston Island (sts. 16, 19) and north of Livingston Island (sts. 30, 31). In the shallowest of these stations (sts. 16, 19, 22: 214–419 m), Echinodermata (Ophiuroidea, Asteroidea, Echinoidea) and Arthropoda (Pycnogonida, Isopoda) prevailed, while in the deepest ones (sts. 30, 31: 710–850 m) Polychaeta (Maldanidae) were dominant, in both number of individuals and weight. Within this subgroup, station 22 (Bransfield Strait) is noteworthy, because, together with the predominance of Echinodermata, it yielded abundant sessile fauna, mainly Brachiopoda and Pennatularia (the latter collected only at this station, which has a gravelly bottom).

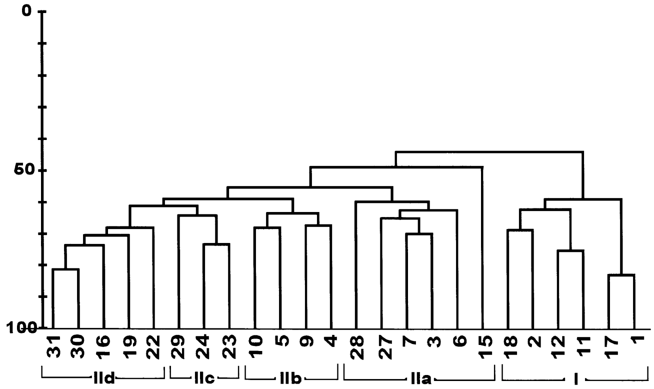


**Fig. 4** Dendrogram resulting from clustering of transformed abundance values

## Discussion

The most evident result was the difference between the stations at Deception Island and the stations located elsewhere, an already well-known consequence of the island's volcanic activity (Gallardo et al. 1977; Retamal 1981; Gallardo 1987, 1992). In addition, some new features were revealed, especially regarding depth zonation and the faunistic composition of the communities found in the area of South Shetlands. The scarcity of hexactinellid sponges, and the abundance of ascidians, found at most stations and previously noted at neighbouring

**Table 2** Relative abundance of macrozoobenthic taxa according to a six-point classification (no sign absent, – very rare, + rare, ○ rather common, • common, ● very common)

| Station no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 10 | 11 | 12 | 15 | 16 | 17 | 18 | 19 | 22 | 23 | 24 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hexactinellida | | | | | | | – | | | | | | | | | – | | ● | ● | | | | | |
| Demospongia | | • | – | – | | ○ | + | | | – | ○ | | + | | • | • | | ● | – | + | ● | – | + | |
| Actiniaria | | | | | | | | – | – | | | | + | | – | ○ | – | + | | | | | ○ | • |
| Scleractinia | | | | – | • | | | | | | | | | | | – | | | + | | | | • | • |
| Hydroidea | | | + | – | | – | + | – | – | – | – | | – | | – | • | – | – | – | • | • | ○ | – | – |
| Alcyonaria | | | | | | | | | | | | | | | | | | – | – | | | – | ○ | ○ |
| Pennatularia | | | | | | | | | | | | | | | | | + | | + | | | | | |
| Gorgonaria | | | + | – | | – | + | | – | – | | | – | | | • | – | – | – | • | | – | | |
| Bryozoa | | | | • | – | • | + | ○ | – | • | – | | ○ | | – | | – | ● | • | ● | – | + | – | – |
| Brachiopoda | | | | | | | – | + | | | | | | | | + | • | | | ○ | | | | |
| Turbellaria | | | | | | | | | | | | | | | | | | | | | | | – | |
| Nemertini | + | – | | + | | + | | ○ | | • | • | | ● | ○ | ○ | + | | | | | | – | ○ | + |
| Echiurida | | | | | | | | | | | | | | | | | | + | | | | – | – | |
| Priapulida | – | | | | | | | – | | | | | | | | | | | | | | | – | |
| Sipunculida | | | | – | – | | | | | | | | | | | | | | | | | | | |
| Pol. Errantia | ○ | + | – | – | ● | • | | + | + | + | | ○ | • | – | | • | • | ○ | • | + | – | + | • | • |
| Pol. Sedentaria | | + | ● | + | ○ | • | | – | | • | – | + | • | | | ● | • | ○ | + | ○ | + | ○ | ● | ● |
| Aplacophora | | | | | | – | | | | | | | | | | – | | | | | | | | |
| Polyplacophora | | | | | | | | | | | | | | | | ○ | | | | | | | | |
| Prosobranchia | | | – | – | • | ○ | + | ○ | • | + | | + | • | | | • | | + | ○ | – | – | | • | • |
| Opistobranchia | – | | | | | ○ | – | | | | | | | | | | | | + | – | | | | |
| Scaphopoda | | | | | | | | – | | | | | | | | | | | | | – | | + | |
| Bivalvia | – | + | + | | + | • | + | ○ | + | ○ | • | | | | + | • | | | – | ○ | + | + | ○ | |
| Cephalopoda | | | – | | + | + | + | + | – | | | – | ○ | | | + | ○ | | | + | | – | ○ | ○ |
| Pycnogonida | | | ○ | • | ● | | – | • | | + | – | | ● | | | ● | ● | | ○ | + | | + | • | ● |
| Decapoda | | | | + | ● | | | ○ | ○ | ● | • | + | | | | ● | | | • | | | | + | |
| Mysidacea | | + | | | ○ | | | + | | ● | ● | – | ● | | • | • | | | + | | | + | • | + |
| Isopoda | – | | + | ○ | ○ | | | • | • | – | | + | ● | | | + | • | + | ○ | ● | | + | • | ● |
| Amphipoda | | – | + | | + | + | + | + | – | | | – | ○ | | + | • | ○ | + | + | • | + | + | • | ○ |
| Cirripedia | | | | | ○ | | | | | | | | + | | | – | | | | | | + | | |
| Crinoidea | | | | | | | | | | | | + | | | | ● | + | • | ● | | | • | • | ○ |
| Asteroidea | – | | ○ | ○ | ○ | ● | • | • | ○ | | – | + | ○ | + | ○ | • | ● | ○ | • | • | • | • | • | • |
| Ophiuroidea | ● | • | ● | ● | ● | + | • | ● | ● | ● | ● | • | ● | ● | ● | ● | • | ● | ● | + | • | ● | • | • |
| Ech Regular. | ● | ● | | | | ○ | – | | | ● | • | | ○ | ● | ● | + | • | • | ○ | | | – | ○ | |
| Ech Irregul. | | | | | | ○ | + | ○ | + | | | | • | | | • | • | + | ○ | | – | + | + | + |
| Holothuroidea | | | ○ | + | + | ● | ○ | ○ | + | | | – | + | | | ○ | ○ | • | • | – | + | – | • | + |
| Pterobranchia | | | | | | | | | | | | | | | | | | | + | | | | | |
| Ascidiacea | ● | + | ● | ○ | – | ● | ● | ● | – | • | – | | • | • | • | • | + | • | • | ● | + | + | + | |

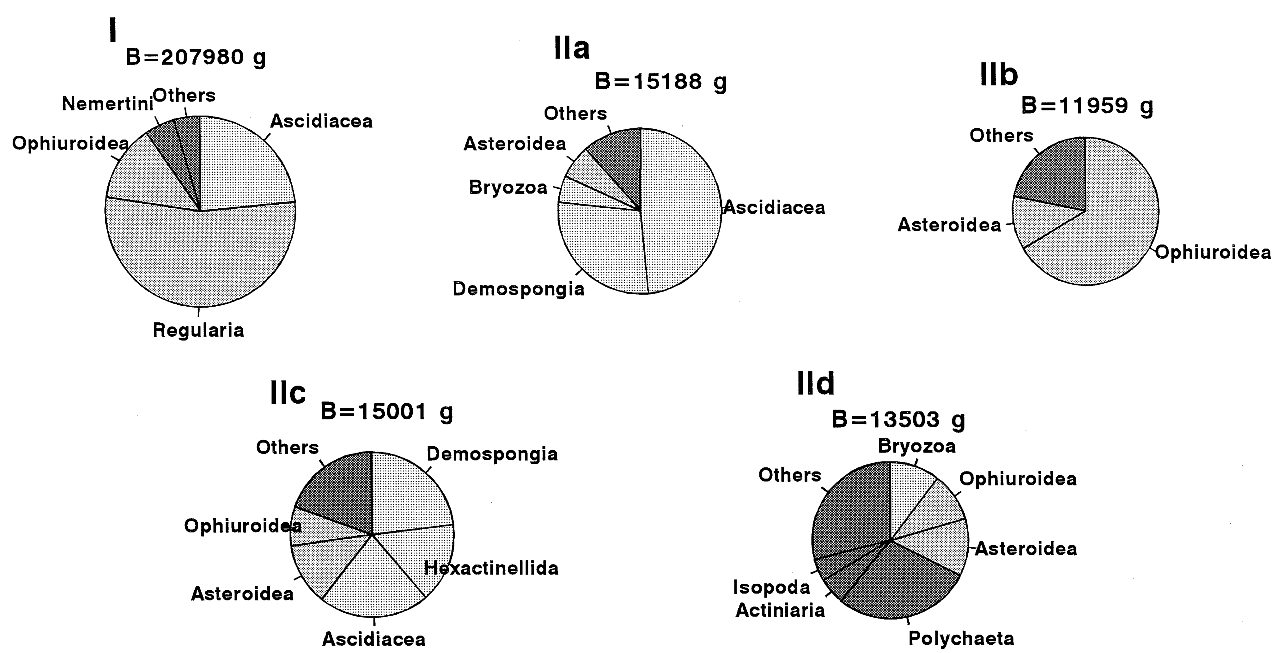


**Fig. 5** Major benthic fauna components, using relative mass (g wet weight) values in the separated clusters

King George Island (Jazdzewski et al. 1986; Rauschert 1991; Jazdzewski and Sicinski 1993), are an indication that the benthic communities of the South Shetland Islands have distinctive features, compared with those of continental Antarctica. The main differences regarding other Antarctic bottoms may be found in the composition of the shallow communities.

The Deception Island stations confirm a high general dominance of echinoderms in Foster Bay as a whole, particularly *Ophionotus victoriae* and *Sterechinus neumayeri*, which were also dominant in the samples of the Expédition Antarctique Française 1908–1910 (Koehler 1912). This suggests, in keeping with Gallardo et al. (1977), that this benthic community has reached the highest level of organisation that the island's volcanic activity allows. Nevertheless, a previously unreported relative dominance of suspension-feeders (mainly ascidians) was observed in the shallowest areas, although Retamal et al. (1982) had noted the presence of ascidians at depths shallower than 100 m.

The depth zonation at Deception Island seems to depend on the type of substratum. Whereas most Antarctic bottoms are characterised by the heterogeneity of the substratum (due to material falling from icebergs) (Knox 1994) the distribution of sediments in Foster Bay shows the features of a closed bay (A. Ramos and J. Rey, unpublished data), with the grain size decreasing with depth. The shallowest station (1) has a gravelly bottom; those placed at moderate depths (2, 17, 18) have sandy bottoms, and the deepest ones (11, 12) are muddy. Each zone has a characteristic fauna, dominated respectively by ascidians, regular sea urchins and ophiurans.

The abundance of suspension-feeders in shallow waters of Foster Bay could be related to currents of some intensity. Ushakov (1963) and Voß (1988) pointed out that currents at the bottom level result in both coarse granulometry, due to the removal of small particles, and resuspension of nutrients that are an appropriate food source for suspension-feeders, thus enhancing the presence of this type of organisms.

The fauna of moderate and deep waters of Foster Bay is dominated by echinoderms, with mainly necrophagous habits (Arnaud 1970, 1977, 1992; Presler 1986) and independent of the seasonality of primary production (Arntz et al. 1994). For instance, *O. victoriae*, which feeds commonly on benthic microflora (Kellog et al. 1982), may have a rather catholic diet, including krill, but is never a suspension-feeder (Dearborn 1977; Fratt and Dearborn 1984).

The remaining stations, except station 15, form a homogeneous group. However, two subgroups may be distinguished: shallow stations (less than 130 m) with a predominance of active suspension-feeders, and deep stations (more than 140 m) showing a variety of trophic strategies (carnivores, detritivores, necrophages, suspension-feeders). The existence of a community of sessile filter-feeders (mainly ascidians, demosponges and – less abundant – bryozoans) at the shallowest stations on muddy bottoms contrasts with the situation that has been described at other sites in the Antarctic Ocean. There, ascidians and bryozoans are predominant on hard bottoms, while the soft ones are dominated by detritivores or suspension-feeders, mainly polychaetes, molluscs and crustaceans (Jazdzewski et al. 1986).

Studies in the Weddell Sea revealed two different types of communities dominated by filter-feeders, both on hard substrata: one in stable areas and the other on unstable bottoms (Voß 1988; Galeron et al. 1992). These were associated, as noted above, with the existence of currents of a certain intensity at the bottom level, which remove small particles and resuspend organic substances (Voß 1988). In this study, the community is similar to that of unstable areas in the Weddell Sea (Galeron et al. 1992), but the muddy nature of the bottom indicates that currents are not strong, and the unusual dominance of sessile filter-feeders on this type of seabed could be related to a high but seasonal primary production that enhances the development of species with short life-cycles and high growth rates, such as ascidians and bryozoans.

At moderate depth on soft bottoms, ophiurids and asteroids, both mobile and with a variety of trophic strategies, are dominant, while the deepest stations are characterised by detritivores, mainly maldanid polychaetes.

Group Ic comprises deep stations on bottoms of hard gravel, pebbles and stones produced by deposits from icebergs, in which ophiurids and asteroids are abundant, although a rich variety of suspension-feeders are also present (crinoids, ascidians, demosponges, hexactinellid sponges and bryozoans). The type of bottom and the existence of currents transporting nutritive particles may result in stable environmental conditions, enabling the development of long-lived suspension–feeders (Dayton et al. 1974). It is remarkable that hexactinellid sponges, characteristic of epibenthic communities off continental Antarctica (Galeron et al. 1992), occurred only in the Orleans Strait, at stations 23 and 24, the nearest to the Antarctic Peninsula.

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## References

Arnaud PM (1970) Frequency and ecological significance of necrophagy among the benthic species of Antarctic coastal waters. In: Holdgate M (ed) Antarctic ecology. Academic Press, London, pp 259–267

Arnaud PM (1977) Adaptations within the Antarctic marine benthic ecosystem. In: Llano GA (ed) Adaptations within Antarctic ecosystems. Gulf, Houston, pp 135–157

Arnaud PM (1992) The state of the art in Antarctic benthic research. In: Gallardo VA, Ferretti O, Moyano HI (eds) Ocean-

ografía en Antártica. Centro Eula, University of Concepción, pp 341–345
Arnaud PM, Galeron J, Arntz W, Petersen GH (1990) Semi-quantitative study of macrobenthic assemblages on the Weddell Sea shelf and slope using trawl catch subsamples. In: Arntz W, Ernst W, Hempel I (eds) The Expedition ANTARKTIS VII/4 (EPOS leg 3) and VII/5 of RV *Polarstern* in 1989. Ber Polarforsch 68:98–104
Arntz WE, Gorny M, Lardies M, Mutschke E, Rios C (1996) Benthic macrofauna sampled with the Agassiz trawl. In: Arntz WE, Gorny M (eds) Cruise report of the Joint Chilean-German-Italian Magellan "Victor Hensen" Campaign in 1994. Ber Polarforsch 190:43–45
Arntz WE, Brey T, Gallardo VA (1994) Antarctic zoobenthos. In: Ansell AD, Gibson RN, Barnes M (eds) Oceanography and marine biology: an annual review, 32. UCL Press, London, pp 241–304
Barnes DKA (1995a) Sublittoral epifaunal communities at Signy Island, Antarctica. I. The ice-foot zone. Mar Biol 121:555–563
Barnes DKA (1995b) Sublittoral epifaunal communities at Signy Island, Antarctica. II. Below the ice-foot zone. Mar Biol 121:565–572
Bullivant JS (1959) An oceanographic survey of the Ross Sea. Nature 184:422–423
Dayton PK, Oliver JS (1977) Antarctic soft-bottom benthos in oligotrophic and eutrophic environments. Science 197:55–58
Dayton PK, Robilliard GA, Paine RT, Dayton LB (1974) Biological accommodation in the benthic community at McMurdo Sound, Antarctica. Ecol Monogr 44:105–128
Dearborn JH (1977) Food and feeding characteristics of Antarctic asteroids and ophiuroids. In: Llano GA (ed) Adaptations within Antarctic ecosystems. Gulf, Houston, pp 293–326
Desbruyères D, Guille A (1973) La Faune benthique de l'Archipel de Kerguelen. Premières données quantitatives. C R Acad Sci Paris 276:633–636
Eleftheriou A, Holme NA (1984) Macrofauna techniques. In: Holme NA, Mclntyre AD (eds) Methods for the study of the marine benthos, IBP Hand Book 16, Blackwell, Oxford, pp 140–216
Everson I, White MG (1969) Antarctic marine biological research methods involving diving. Rep Underwater Assoc 4:91–95
Fratt DB, Dearborn JH (1984) Feeding biology of the Antarctic brittle star *Ophionotus victoriae* (Echinodermata: Ophiuroidea). Polar Biol 3:127–139
Galeron JO, Herman RL, Arnaud PM, Arntz WE, Hain S, Klages M (1992) Macrofaunal communities on the continental shelf and slope of the southeastern Weddell Sea, Antarctica. Polar Biol 12:283–290
Gallardo VA (1987) Benthic macroinfauna of Antarctic sub-littoral soft bottoms. BIOMASS Antarct Aquat Biol 7:73–86
Gallardo VA (1992) Estudios bentónicos en bahías someras Antárticas de Archipiélago de las Islas Shetland del Sur. In: Gallardo VA, Ferretti O, Moyano HI (eds) Oceanografía en Antártica, Centro Eula University of Concepción, pp 383–393
Gallardo VA, Castillo JC (1969) Quantitative benthic survey of the infauna of Chile Bay (Greenwich Island, South Shetland Islands). Gayana Zool 16:3–17
Gallardo VA, Castillo JG, Retarnal MA, Yañez A, Moyano HI, Hermosilla JG (1977) Quantitative studies on the soft-bottom macrobenthic animal communities of shallow Antarctic Bays. In: Llano GA (ed) Adaptations within Antarctic ecosystems. Gulf, Houston, pp 361–387
Gerdes D, Klages M, Arntz WE, Herman RL, Galéron J, Hain S (1992) Quantitative investigations on macrobenthos communities of the southeastern Weddell Sea shelf based on multibox corer samples. Polar Biol 12:291–301
Gruzov EN, Propp MV, Pushkin AF (1967) Biological association of coastal areas of the Davis Sea, based on the observations of divers (in Russian). Sov Antarct Exped Inf Bull 65:124–141
Guille (1977) Benthic bionomy of the continental shelf of the Kerguelen Islands: quantitative data on the echinoderms of the Morbihan Gulf. In: Llano GA (ed) Adaptations within Antarctic ecosystems. Gulf, Houston, pp 253–262
Hardy P (1972) Biomass estimates for some shallow-water infaunal communities at Signy Island, South Orkney Island. Br Antarct Surv Bull 31:93–106
Jazdzewski K, Sicinski J (1993) Zoobenthos. 12.1. General remarks. In: Rakusa-Suszczewski S (ed) The maritime Antarctic coastal ecosystem of Admiralty Bay. Dept Antarct Biol, Polish Academy of Science Warsaw, pp 83–95
Jazdzewski K, Jurasz W, Kittel W, Presler P, Sicinski J (1986) Abundance and biomass estimates of the benthic fauna in Admiralty Bay, King George Island. Polar Biol 6:5–16
Jazdzewski K, Teodorczyk W, Sicinski J, Kontek B (1991) Amphipod crustaceans as an important component of zoobenthos of the shallow Antarctic sublittoral. Hydrobiologia 223:105–117
Kellog DE, Kellog TB, Dearborn JH, Edwards KC, Fratt DB (1982) Diatoms from brittle star stomach contents: implications for sediment reworking. Antarct J 17:167–169
Knox GA (1994) Benthic communities. In: Knox GA (ed) The biology of the Southern Ocean. Cambridge University Press, Cambridge, pp 193–220
Koehler R (1912) Echinodermes (Astèries, Ophiures et echinides). Deux Exp Antarct Franç (1908–1910). Doc. Sci. Nzt:1–272
Lowry JK (1975) Soft-bottom macrobenthic community of Arthur Harbor, Antarctica. Antarct Res 23:1–19
Mills EL, Hessler RR (1974) Antarctic benthic communities: Hudson"70 expedition. Antarct J 9:312–316
Mühlenhardt-Siegel U (1988) Some results of quantitative investigations of macrozoobenthos in the Scotia Arc (Antarctica). Polar Biol 8:241–248
Mühlenhardt-Siegel U (1989) Quantitative investigations of Antarctic zoobenthos communities in winter (May/June) 1986 with special reference to the sediment structure. Arch Fischereiweiss 39:123–141
Nakajima Y, Watanabe K, Naito Y (1982) Diving observations of the marine benthos at Syowa Station Antarctica. In: Hoshiai T, Naito Y (eds) Proceedings of the 5th Symposium on Antarctic Biology, Mem Nat Inst Polar Res, Spec Issue 23:44–54
Presler P (1986) Necrophagus invertebrates of the Admiralty Bay of King George Island (South Shetland Islands, Antarctica). Polar Res 7, 1–2:25–61
Propp MV (1970) The study of the bottom fauna at Haswell Island by scuba diving. In: Holdgate MV (ed) Antarctic ecology, vol I. Academy Press, London, pp 239–241
Rauschert M (1991) Faunistic investigations in the benthal of King George Island. Ber Polarforsch 76:1–75
Retamal MA (1981) Consecuencia en la biota bentónica de las erupciones volcánicas en la Isla Decepción y su comparación con Bahía Chile, Antártica. Bol Inst Antárt Chil 1, 2:15–17
Retamal MA, Quintana R, Neira F (1982) Análisis cuali y cuantitativo de las comunidades bentónicas en Bahía Foster (Isla Decepción) (XXXV Expedición Antártica Chilena, Jan 1981). Publ Inst Antárt Chil Ser Cient 29:5–15
Richardson MD, Hedgpeth JW (1977) Antarctic soft-bottom macrobenthic community adaptations to a cold, stable, highly productive, glacially affected environment. In: Llano GA (ed) Adaptations within Antarctic ecosystems. Gulf, Houston, pp 181–196
Sáiz-Salinas JI, Ramos A, García FJ, Troncoso JS, San Martin G, Sanz C, Palacin C (1997) Quantitative analysis of macrobenthic soft-bottom assemblages in South Shetland waters (Antarctica). Polar Biol 17:393–400
Ushakov PV (1963) Quelques particularites de la bionomie benthique de l'Antarctique de l'Est. Cah Biol Mar 4:81–89
Voß J (1988) Zoogeography and community analysis of macro zoobenthos of the Weddell Sea (Antarctica). Ber Polarforsch 45:1–145
White MG, Robins MW (1972) Biomass estimates from Borge Bay, South Orkney Islands. Br Antarct Surv Bull 31:45–50
Zamorano JH (1983) Zonación y biomasa de la macrofauna bentónica en Bahía South, Archipielago de Palmer, Antártida. INACH Ser Cient 30:27–38