BIOMASS ESTIMATES FOR SOME SHALLOW-WATER INFAUNAL COMMUNITIES AT SIGNY ISLAND, SOUTH ORKNEY ISLANDS

By P. HARDY

ABSTRACT. Aqualung divers working to a depth of 35 m. have begun studies of the infaunal communities of Borge Bay, Signy Island, South Orkney Islands. Six mobile substrates were sampled using small hand corers and 96 samples were collected. Mean wet-weight biomass densities for the five substrates ranged from 788·8 to 307·3 g./m.², decreasing at greater depths. The changes of the means reflect depth and substrate variation and also the interactions of the three major faunas; the decrease in the biomass of the dominant Pelecypoda, 636·2 to 180·8 g./m.², and annelid biomass increase with depth to 233·9 g./m.². The amphipod biomass was highest in the more sandy substrates with a maximum of 111·3 g./m.². Gastropoda, Priapulida, Ostracoda and Apoda (Echinodermata) were the other common groups present but they formed only 7 per cent of the total biomass. The biomass values obtained are higher than those previously recorded for other regions of Antarctica.

The effects of the substantial biomass of *Laternula elliptica* are discussed. Although precise values cannot be set out because of the limitations of the sampling technique, some estimates are proposed for the communities, namely up to 1·5 kg./m.² at 6–7 m. and up to 2·6 kg./m.² at 13–15 m.

THE mobile substrate faunas of the Antarctic continental shelf are among the more interesting benthic communities of Antarctic waters. Interest stems mainly from the diversity of the fauna, the high biomasses recorded in the sub-littoral zone and from the protection offered by the substrate.

All littoral and sub-littoral shores of the Antarctic regions are subject to considerable ice abrasion as a result of fast ice moving on the tide or brash ice grounding during the summer months. It is thus very difficult for permanent communities to become established unless they are well protected. At Signy Island, protection was present in the form of crevices in the boulder beaches which, when filled with mixed mobile substrate frequently supported the only permanent communities of the sub-littoral zone. In this zone the epiflora and epifauna may develop in more sheltered coves but even here the crevice communities are more diverse and have greater biomass. In deeper waters the rocky shores merge into extensive well-graded or mixed mobile substrates which suffer less ice abrasion but which support similar infaunas to the crevices.

Few researchers have been able to study these communities before so that it has not been possible to assess their importance in the epibenthic system as a whole. Even in the most intensively studied areas of Antarctica, such as the Haswell Islands, Molodezhnaya, McMurdo Sound and Arthur Harbour, biologists have concentrated on the epifauna and epiflora. This was also true of research work at Signy Island (Price and Redfearn, 1968) but here a wide selection of mobile substrates has now been found in the shallow waters of Borge Bay. Everson and White (1969) briefly mentioned one of these offshore sandy substrates, but not until recently have the communities been studied in any detail. Bregazzi (1972*a*, *b*, 1973), Hardy (1969, 1970, 1971) and Rabarts (1970, 1971) have begun the work on the amphipods, polychaetes and pelecypods present, but no overall picture of any community has been presented yet.

This paper, in part, attempts to give a general account of the composition of the infaunas of these habitats in terms of biomass.

METHODS

During a 27 month period, January 1968–March 1971, aqualung divers collected 96 samples from six different substrates at depths down to 35 m. (Fig. 1). The divers worked from 12 ft. [3·7 m.] and 16 ft. [4·9 m.] dinghies in the summer and continued sampling through holes cut in the sea ice during the winter.

Hand-operated corers, essentially the same as those described by Everson and White (1969), were chosen as the most suitable and convenient sampling method. The six substrate types sampled are here referred to as stations, although station III comprised five sampling sites, dispersed over a similar subtrate type, and station IV two sites.

The cores were generally taken in pairs but 19 cores, eight from station V and 11 from

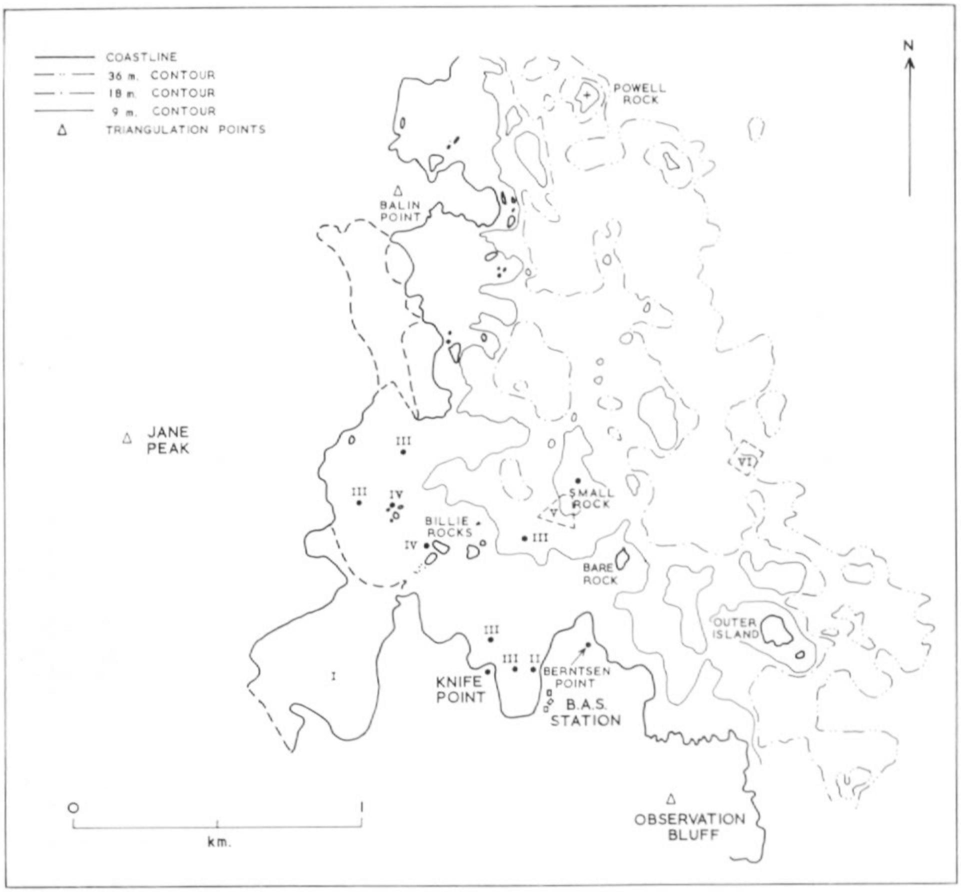

Fig. 1. Contour map of Borge Bay, Signy Island, showing the six sampling stations.

station II, were analysed for particle-size proportional composition as well as biomass so these were all treated individually. The corer surface area was 0·078 m.^{2} and each core was taken to a depth of 7 or 15 cm., being fixed for each substrate but varying between different substrates as compactness altered. Thus, only at stations I, III and VI were the deeper cores of 15 cm. possible. For efficient handling under water the cores were carried in crates of four or six units. In the laboratory these were stood in baths of shallow sea-water (7–10 cm.) at ambient temperatures until sorting took place. At most 48 hr. elapsed between collection and sorting. Pairs of cores were combined for sorting, the small weights of some faunas present making this a suitable method of reducing likely errors due to adsorbed sea-water and patchy distribution in the substrate.

A two-tier wet-sieving process proved the most suitable and effective method of sorting. Interlocking Endecot sieves were used, a "5" mesh being superimposed on a 30 mesh. Extracted macro-algae and fauna were then grouped and weighed to obtain wet-weight biomass. The collections were preserved in 4 per cent neutralized formol saline for further examination at a later date. A 30 mesh sieve was selected because it allowed the extraction of the major part of the fauna in a relatively short sorting time (Reisch, 1959).

Analysis

Five faunal groups were considered for analysis, the three predominant ones being the annelids, the amphipods and the pelecypods (excluding the single species *Laternula elliptica*).

Gastropoda and a mixed association of Apoda, Ostracoda and Priapulida were the two subordinate groups. The collected biomass data were converted into g./m.^{2} before means and variances were calculated.

Further statistical analysis was complicated by the frequency distribution of the biomass densities. Examination of the largest group of samples, from station V, showed a skewed distribution closely fitting a negative binomial curve (Fig. 2). A χ^2 test indicated insignificant variation from the theoretical curve at probability levels as high as $p = 0{\cdot}001$ ($\chi^2 = 3{\cdot}9935$), so the logarithmic transformation, $x = \log_{10}(u+1)$,* was invoked to normalize the raw data (Gérard and Berthet, 1966). Subsequent calculations were performed using the transformed data.

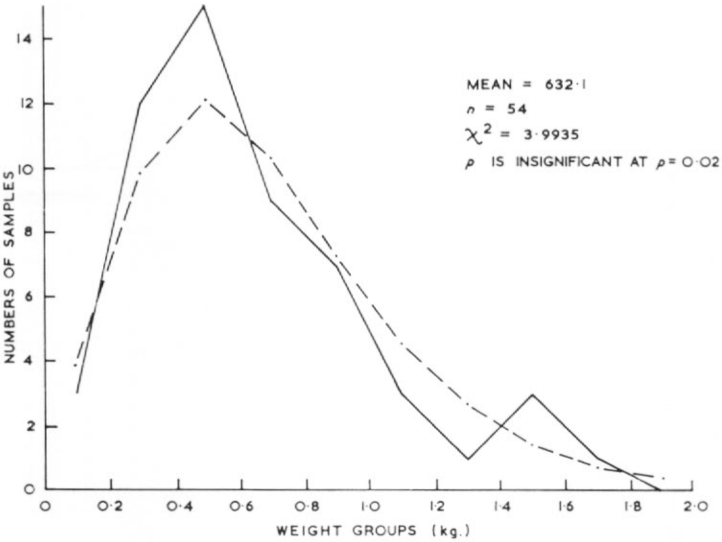

Fig. 2. The frequency distribution of the total infauna biomass figures for station V, matched with a calculated negative binomial curve. Solid line, observed data; dashed line, negative binomial curve. ($k = 4{\cdot}4019$ and $q = 0{\cdot}5895$.)

Total infauna biomasses from stations II and III also approximate very closely to a negative binomial distribution, but because of the small number of samples a test of goodness of fit was not practicable. For the purpose of analysis, it was not thought unreasonable to assume that the observed distribution was a negative binomial and would be demonstrably so with larger numbers of samples. Very small numbers at the other three stations made even the graphical representation of the distribution pointless, but a negative binomial distribution was again assumed.

Analysis of the figures for station V demonstrated that the negative binomial curve fitted the distribution of the data for each of the three principal component faunas as well as the Gastropoda (Fig. 3a–d). The figures for the other five stations were not plotted, but it can be assumed that these also approximate to the negative binomial distribution. All of the data were therefore normalized using the logarithmic transformation presented in the preceding paragraph. Student's "t" test and correlation analysis were applied to the data in this form, aiding the formulation of conclusions.

Results

The six sub-littoral substrates studied were spread widely over the shallow areas of Borge Bay (Fig. 1) and varied markedly in particle composition. Station I was an area of flocculant mud with the larger particle grades almost entirely absent. Stations II and V represented mixed

* u = the raw data item and x = the transformed data.

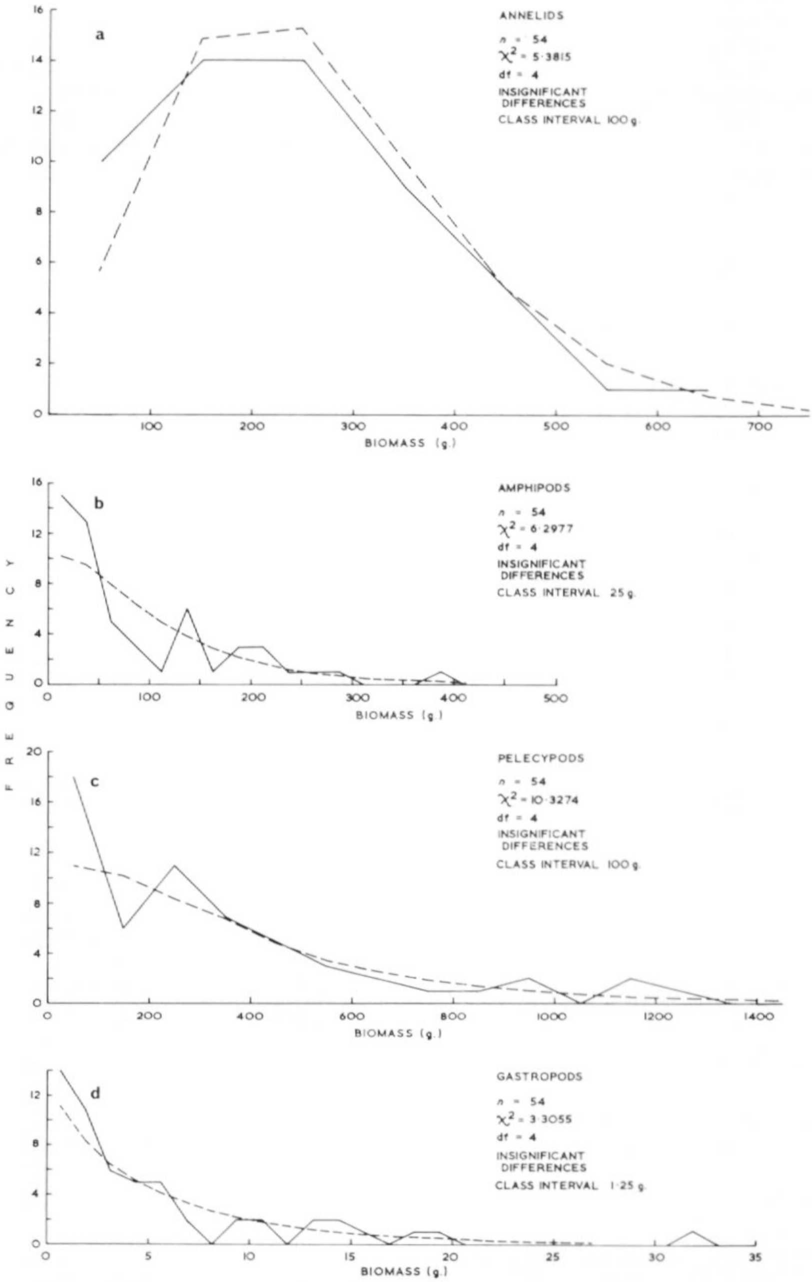

Fig. 3. Frequency distribution of component fauna sample weights at station V. Solid line, observed data; dashed line, negative binomial curve. (a. $k = 7{\cdot}0963$ and $q = 0{\cdot}3973$; b. $k = 1{\cdot}2725$ and $q = 0{\cdot}7307$; c. k = 1·3115 and $q = 0{\cdot}6998$; d. $k = 0{\cdot}8829$ and $q = 0{\cdot}8277$.)

substrates of glacial origin containing small and large pebbles as well as a significant proportion of very fine sand and silt. Station III represented a more evenly graded, sedimented substrate of sands and silt, with a patchy variation in compactness. The remaining two stations, IV and VI, abutted areas of mixed substrates and sedimented substrates, and reflect the mixing which occurs along the interfaces (Table I).

TABLE I. PARAMETERS FOR SIX MOBILE SUBSTRATES IN BORGE BAY, SIGNY ISLAND

Station	*Depth at mean tide level* (m.)	*Substrate parameters*
I	3–4	Very soft flocculant ooze
II	6–7	Sloping sea bed. Sand/silt and small pebbles filling crevices. A few large boulders
III	8–10	Flat bottom. Sand, silt, and degraded whalebone and bivalve shell
IV	6–8 and 9–10	Sand and silt with a proportion of gravel and pebble present
V	13–15	Small cobbles lying over sand/silt/gravel in a mixed substrate. Flat sea bed
VI	33–35	Mainly silt, with some fine sand and gravel

Total biomass figures for the infauna (Table II) show a considerable variation over the substrate and depth range sampled and also within the sampling of any of the separate substrate types. Thus the range is from 788·8 g./m.^{2} at 8–10 m. (station III) to 307·3 g./m.^{2} at 33–35 m. (station VI). The standard deviation of all the six station means is of the same magnitude as the mean in each case.

A similar pattern of variance emerges when the component fauna means are considered. The dominant fauna, except at station I, was the Pelecypoda, 636·2 g./m.^{2} at 6·7 m. (station II) down to 180·8 g./m.^{2} at 33–35 m. (station VI) (a decline in biomass which is reflected in the total biomass figures). Again the standard deviation is as large or larger than the mean and the same is true for the Annelida and the Amphipoda. The annelids show an increase in biomass with depth, 90 g./m.^{2} or more below 8 m., with a peak at 13–15 m. of 233·9 g./m.^{2}. The amphipoda are more prominent at the sandier stations III and IV (approximately 100 g./m.^{2}) but they are also well represented at 13–15 m. (station V), 86·3 g./m.^{2}. Although present in all the substrates, the Gastropoda are a relatively insignificant part of the total fauna (Fig. 4), maximum biomass being 38·4 g./m.^{2} at 6–7 m. (station II). The three principal faunas, Pelecypoda, Annelida and Amphipoda, account for 93–97 per cent of the total biomass. A break-down of the total biomass at each station is illustrated in Fig. 4.

Although 96 samples were taken, the sampling was not evenly distributed between the stations (Table II). 54 were taken from station V over the whole of the 27 month period, the remaining 42 coming from the other stations and all being collected in a much shorter period.

Station I was an anomalous situation from which only five samples were taken. The mean biomass was 499·9 g./m.^{2} but the proportions of the component faunas were quite distinct from the rest of Borge Bay.

TABLE II. MEAN WET WEIGHT OF THE INFAUNA AND THE CONSTITUENT FAUNAL GROUPS IN g./m.²

Station	*n*	*Mean biomass and standard deviation*					
		Total biomass	*Annelid*	*Amphipod*	*Pelecypod*	*Gastropod*	*Other groups*
I	5	499·9±218·4	269·7±202·5	38·1± 32·4	191·3±207·0	0·84± 1·33	0·0
II	13	763·9±630·9	21·2± 49·8	65·5±118·4	636·2±602·0	38·4 ±60·8	2·5 ±3·1
III	16	788·8±849·0	58·0± 99·6	106·6± 94·2	623·3±886·7	1·0 ± 1·3	0·0
IV	5	658·2±674·5	96·8±157·0	111·3±210·6	446·8±611·3	1·2 ± 1·5	0·0
V	54	632·1±392·4	233·9±139·3	86·3± 89·5	305·7±319·1	5·3 ± 6·2	1·12±1·7
VI	3	307·3±235·3	93·1± 67·9	12·0± 19·1	180·8±193·1	21·4 ±37·1	0·0

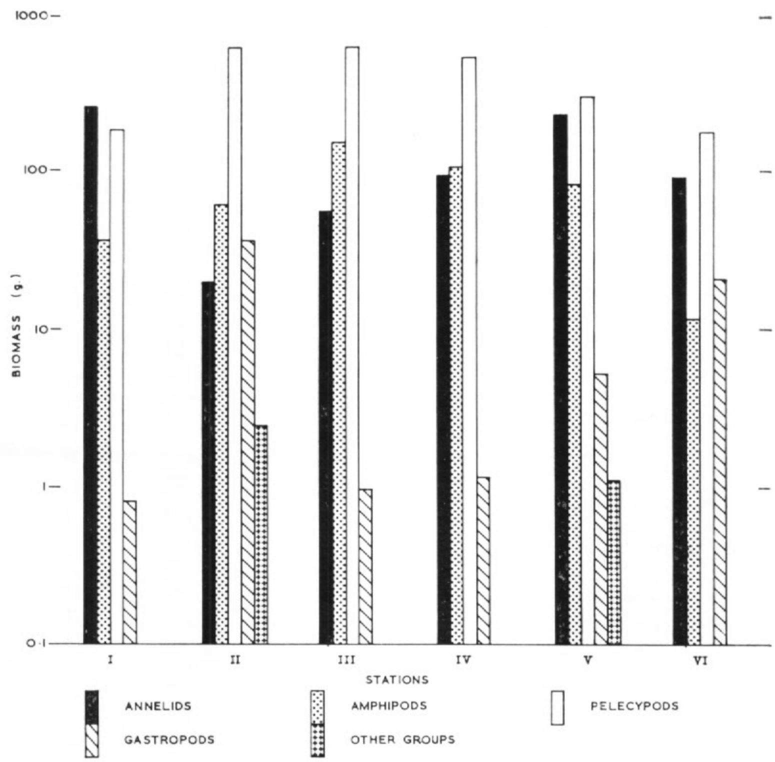

Fig. 4. Wet-weight biomass (g.) for the six stations, plotted on a logarithmic scale.

Discussion

Sampling technique

Two imperfections of the sampling technique exist and must be discussed here as they affect the subsequent biomass calculations.

First, it should be noted that the division between epifauna and infauna in the Antarctic benthos has yet to be clearly outlined. A number of species have not been examined in sufficient detail for them to be assigned to one fauna or the other, so a definition of the two faunas is essential before biomass estimates can be made. For the purposes of this paper these faunas are defined in Table III. Of necessity it must be arbitrary in some respects, but it does provide a framework on which biomasses can be calculated. The imperfection of the sampling technique was that some of the species defined as epifauna are slow-moving or semi-burrowing in their habits and were inevitably captured by the corers. Species most commonly captured were *Serolis* spp., *Neanthes kerguelensis* (a polychaete) and some polynoiid species. Cumacea and Asteroidea also figured in the capture records, though more rarely.

The second point which must be considered is that the relative sizes of *Laternula elliptica* and the corers made effective sampling of this species very difficult. The corers were designed to deal with relatively small, high-density species and *L. elliptica* is an example of a morphologically large species found at comparatively low densities in the substrates studied. Realistic sampling of the species is thus impossible by this method so that, although specimens were occasionally found in cores, their biomass was not included in the core data. Some distortion of the pelecypod and total biomass figures therefore occurs and this must be borne in mind. It was possible to make estimates of the biomass of *L. elliptica* present at some of the stations worked and this is considered below.

TABLE III. INFAUNA AND EPIFAUNA OF MOBILE SUBSTRATES IN BORGE BAY, SIGNY ISLAND

Infauna	*Epifauna*
Amphipoda	Cumacea
Apoda (Echinodermata)	Echinodermata—excluding
Echinoidean sp.	those groups and species
Gastropoda—excluding	of the infauna
Patinigera polaris	Isopoda
Nematoda	*Patinigera polaris* (Gastropoda)
Pelecypoda*	Polychaeta species:
Polychaeta—excluding	*Lumbrineris kerguelensis*
three errant species	*Neanthes kerguelensis*
of the epifauna	Polynoidae spp.
Priapulida	

* The group "Pelecypoda" does not include the species *Laternula elliptica* which was not sampled at all.

Station I

The biomass figures for station I stand out as being rather different from the other stations in Borge Bay. *L. elliptica* is absent and the station is anomalous in several other important respects. It is a shallow, virtually land-locked bay, which is subject to rapidly fluctuating environmental conditions caused by melt-water inflow from surrounding icefields and restrictive tide movements. The latter leave the whole expanse of the bay isolated for long periods between tides. During these periods brackish conditions develop. The bay is subject to an extended ice-cover period and during the summer it accumulates terrestrial detritus from the melt streams. Such an environment and substrate are not readily comparable with the rest of Borge Bay. Thus the biomass data for this station have been included as a record of the situation, but they have not been considered in the analyses.

Biomass

The pattern of biomass variation observed between stations II and VI was both interesting and informative. Even within the limitations imposed by the sampling technique, it was possible to detect two important constraints operating. These were depth and the particle structure of the substrate both of which can be seen to affect the biomass of the component faunas and hence the total biomass itself. It was unfortunate that substrate analyses were only possible at three stations (II, III and V), because this has limited the scope of the conclusions that can be drawn from the data. The uneven numbers of samples taken at the five stations has also hampered analysis.

A previous estimate for the infaunal biomass of sand at Signy Island was made by Everson and White (1969) but in the absence of further information this estimate has stood as an indication of the possible biomass levels for soft substrates throughout Borge Bay. Analysis of variance tests on the total biomass figures for the 91 samples from stations II–VI give an F value of $0{\cdot}734$, $p > 0{\cdot}05$ ($n_1 = 4$ and $n_2 = 85$). This ratio is of very low significance implying homogeneity between the stations. However, a closer look at the variance ratio shows that the low significance level is caused by a high intra-station variance. Here, this is a reflection of the patchy distribution of the fauna within the individual stations and it masks the inter-station variances which, if large, would indicate distinct communities. In this situation more emphasis must be placed on consideration of the stations as separate units with regard for their depth and structure.

Evidence of all the differences between the stations sampled is not yet complete but there is sufficient to support this viewpoint if the substrate descriptions (Table I), substrate analyses (Fig. 5) and the community descriptions are considered (Hardy, 1971; Rabarts, 1971; Bregazzi, 1972*a*, *b*). Further differences show up in the polychaete infauna of the communities (Table IV), where stations II and V stand out as being relatively rich in species.

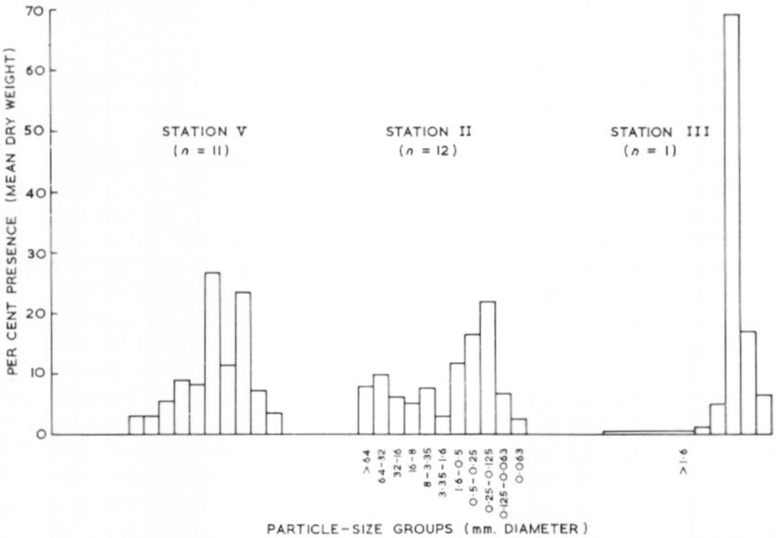

Fig. 5. Particle-size analysis of three shallow-water soft substrates at Signy Island.

TABLE IV. POLYCHAETE INFAUNA IN FIVE DIFFERENT MOBILE SUBSTRATES OF BORGE BAY, SIGNY ISLAND

Species present	Stations				
	II	III	IV	V	VI
Aglaophamus virginis	*	*	*	*	*
Cirratulis cirratus	*			*	*
Haploscoloplos kerguelensis	*		†	*	*
Rhodine loveni	*		†	*	*
Capitella capitata	*			*	
Notoproctus oculatus antarcticus				*	*
Scoloplos marginatus mcleani	*	†		*	*
Mesospio moorei		*	*		
Tharyx epiocta				*	
Pionosyllis comosa	*			*	
Terebellida sp.	*			*	

* Presence usual.
† Recorded present in small proportion of samples.

The mean biomass figures for the stations also support this idea, there being considerable differences between the actual biomasses of component faunas at different stations (Table II). However, not many of these are significant to the level $p = 0 \cdot 05\text{–}0 \cdot 001$ (Table V). Small sample numbers inevitably restrict the usefulness of any significance testing and here there are three stations with very low numbers. Several of the "*t*" tests show probability levels of $p = 0 \cdot 4\text{–}0 \cdot 1$ which cannot be considered as significant in any sense, but which may reflect the low sample numbers and may be masking important variations of the biomass. Further sampling would clarify this but in the present situation it is not reasonable to imply more than possible importance.

From the confused pattern of significance which does emerge from the "*t*" tests it is possible to draw some conclusions. The annelid and amphipod faunas show the most convincingly significant variations and a high proportion of possibly important variations as well. In contrast, the dominant pelecypod fauna shows little difference between stations. This may well be a result of the distribution of *Yoldia eightsi*, the species which forms the greatest proportion of the pelecypod biomass at all stations when *L. elliptica* is not considered. It is distributed at very similar densities throughout stations II, V and VI, and in greater numbers at station III (Rabarts, 1971). Total biomass figures reflect the insignificant differences noted in the pelecypods, to some extent, but they are obviously modified by the other component faunas which do not necessarily respond to environmental factors in the same way.

In part, the significance pattern can be attributed to some of the physical factors of the environment. Two of these, depth and substrate structure, have been isolated here and their effect partially demonstrated. From analyses of the particle sizes at stations II, III and V, coarseness and the heterogeneity of the substrate can be quantified.* The relationship between these, and depth as well, is shown in Fig. 6. The trends, though, do suggest certain conditions. Thus, the amphipod biomass is greatest in the better graded substrates and tends to low biomass in the more heterogenous ones. At the same time, it also responds to the degree of coarseness of the substrate, the biomass being greatest in the coarser substrate. Annelid biomass shows no clear response to either of these aspects of substrate structure but it has a linear relationship with depth, increasing at greater depth. It may be suggested that this increase, and the corresponding decrease in the pelecypod biomass, reflects the state of competition between the two faunas, the annelids being the more successful at the deeper stations. However, such changes as were observed in the pelecypod biomass were very slight if considered as a proportion of the actual biomass, and no correlation between the two faunas could be established, Similarly, there is no linear correlation between the pelecypod biomass and the total biomass even though the two appear related in Fig. 6.

Total biomass was correlated with depth, decreasing at greater depth. This trend only becomes clear when the data from stations IV and VI are included and the significance level is not very convincing ($r = -0 \cdot 7896$, $n = 3$, therefore $p = 0 \cdot 2\text{–}0 \cdot 1$). However, bearing in mind the station substrate differences which are having an effect on the biomass at the same time, this correlation is quite meaningful. Without more data from a wider range of substrates at the same depth it is not possible to clarify the situation appreciably.

Antarctic infauna biomass

The data presented above would have more meaning in a biogeographic context if some estimate of the biomass of *L. elliptica* could be added. Such an estimate was possible for stations II and V so that the biomass at these stations can be compared with data from other parts of Antarctica.

Based on densities of 9/m.^{2} and 26/m.^{2} for stations II and V respectively, the approximate biomass of *L. elliptica* present was estimated as 550–750 g./m.^{2} and 1,750–2,000 g./m.^{2}. Everson and White (1969) proposed densities of up to 50/m.^{2} for the sandy or muddy substrates of Borge Bay (these substrates can be equated with the present stations III, IV and VI), but they quoted no biomass for the species. Instead they proposed a total infauna biomass of 1–4 kg., which includes the biomass of *L. elliptica* (Table VI). Gruzov and others (1967), working at the Haswell

* Morgans (1956) suggested two quantities calculable from his ϕ curve of particle-size analysis, median ($M_{D\phi}$) or grade of coarseness, and the slope ($Q_{D\phi}$), a measure of the heterogeneity of particle grades present.

Table V. Student's "t" values for between station tests, with their significance levels

Fauna		*Test pairs*									
		II–III	II–IV	II–V	II–VI	III–IV	III–V	III–VI	IV–V	IV–VI	V–VI
Total biomass	t		0·778		1·3021			0·8291	1·0072		1·6135
	p	ns	(0·4) ns	ns	(0·2) ns	ns	ns	(0·4) ns	(0·3) ns	ns	(0·1) ns
Annelid	t	1·2943	2·079	10·118	2·510	0·946	7·346	1·379	3·873		1·716
	p	(0·02)	(0·05)	(0·001)	(0·02)	(0·3) ns	(0·001)	(0·2) ns	(0·001)	ns	(0·1) ns
Amphipod	t	3·154	0·831	3·652	0·693	1·574	1·437	4·007		1·355	2·454
	p	(0·001)	(0·4) ns	(0·001)	(0·5) ns	(0·1) ns	(0·2) ns	(0·001)	ns	(0·2) ns	(0·02)
Pelecypod	t		1·794		1·164	0·92					
	p	ns	(0·1) ns	ns	(0·3) ns	(0·4) ns	ns	ns	ns	ns	ns
Gastropod	t	1·202	1·794	1·874	1·064	0·919			1·202		
	p	(0·2) ns	(0·1) ns	(0·05)	(0·3) ns	(0·4) ns	ns	ns	(0·2) ns	ns	ns

ns Not significant.

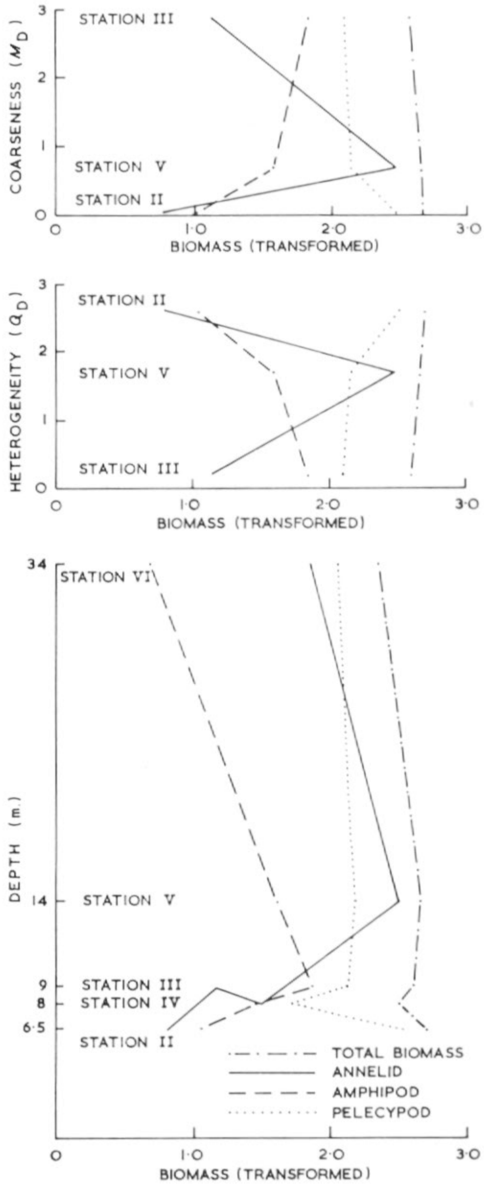

Fig. 6. The changes in fauna biomass related to depth and substrate coarseness and heterogeneity.

Islands (lat. 66°23′S., long. 93°00′E.), recorded 5 kg./m.^{2} as the maximum *L. elliptica* biomass, with a mean of 200–300 g./m.^{2}. This was for sandy and sandy-silt substrates. The infauna they recorded as having 500–600 g./m.^{2} total biomass, considerably lower than the figures calculated for Signy Island presented in Table VI. The same sort of differential is reflected in figures proposed by Gallardo and Castillo (1968, 1969). For Discovery Bay (lat. 62°29′S., long. 59°43′W.), in fine sand, silt and clay down to 100 m., they suggested 180 g./m.^{2} and for Port Foster (lat. 62°57′S., long. 60°39′W.), in sand at 37 m., they suggested 230 g./m.^{2}.

These are the only figures available for the Antarctic continental shelf, and on the basis of

TABLE VI. INFAUNA BIOMASS ESTIMATES FOR BORGE BAY INCLUDING THE SUGGESTED BIOMASS OF *Laternula elliptica*

Station	*Total biomass excluding L. elliptica biomass* (g./m.²)	*L. elliptica* (density/m.²)	*Estimated total biomass* (kg./m.²)
II	763·8	9±11 (n = 12)	1·314–1·514
III	788·8	Up to 50*	1–4·0*
IV	658·2		
V	631·1	26±17 (n = 23)	2·382–2·632
VI	307·3	Up to 50*	1–4·0*

* Figures quoted from Everson and White (1969).

this it would appear that Signy Island has a far higher infauna biomass. 1·3–1·5 kg./m.² at a depth of 6–7 m. and 2·3–2·6 kg./m.² at 13–15 m. reflect a far higher standing crop than might be expected from the earlier Antarctic reports. A parallel situation is found in the epifauna of rock and boulder shores at Signy Island, though the differences are not so marked and the epiflora forms the major proportion of the epibenthic biomass. White and Robins (1972) recorded 168 g./m.² as the epifauna at depths of 2–10 m. which is only one-tenth of the infauna found at these levels. It would thus appear that the protection against ice scour which crevices offer to the infauna of soft substrates makes this fauna a significant one in the benthic system, and one which deserves considerable attention.

ACKNOWLEDGEMENTS

Diving at Signy Island was not always a pleasure and I am very grateful for the assistance given by many co-divers, divers' attendants and boatmen, particularly A. Losh and O. H. S. Darling. My thanks are also due to Dr. I. Everson and M. G. White who patiently discussed the analysis with me.

MS. received 16 May 1972

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