ECOLOGY OF KING EDWARD COVE, SOUTH GEORGIA: MACRO-BENTHOS AND THE BENTHIC ENVIRONMENT

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ABSTRACT. The biomass of inshore Antarctic benthos from shallow soft-bottom areas in King Edward Cove, South Georgia, ranged from 34 to 279 g m^{-2} wet weight (4 to 38 g m^{-2} ash-free dry weight). These values were within the expected range reported from other comparable polar and temperate areas despite constant low temperatures and the reported impoverishment of inshore phytoplankton. A seasonal study of the major benthic environmental parameters describes the temporal stability characteristic of the habitat. The importance of these areas in terms of the general productivity around South Georgia is discussed.

WITH the current renewal of interest in the marine resources of the Southern Ocean, the British Antarctic Survey has initiated intensive ecological investigations into shallow near-shore environments at South Georgia. Coastal areas are of prime importance to the whole production cycle in these high-latitude waters; nowhere is this more so than around South Georgia (Holdgate, 1967; Everson, 1976). Aspects of growth (Ralph and Everson, 1972; Clarke and Lakhani, 1979), biochemistry (Clarke, 1977), respiration (Ralph and Maxwell, 1977), hydrocarbon distribution (Mackie and others, 1978) and secondary production (Everson, 1977) have recently been reported from the area. The present study is a contribution to this work and concerns the ecology of a sheltered semi-enclosed bay, King Edward Cove (lat. 54°17′S, long. 36°30′W).

A general description of King Edward Cove and its recent history in relation to past whaling activity has been given elsewhere (Platt, 1978).

This paper deals with the benthic macro-fauna and the nature of the sediment environment. Subsequent publications will deal with aspects of the distribution and cycling of organic material throughout the ecosystem. The overall aim of the investigation is to promote a better understanding of Antarctic marine systems in the light of increasing commercial interest and the environmental stress which might accompany it.

METHODS

Sampling

A main sampling site, station A (Fig. 1) was located in a shallow sandy area adjacent to a major kelp (*Macrocystis pyrifera*) bed. Six deeper sites were selected for less intensive study at various points along the length of King Edward Cove (stations B1–6). Eight replicate 0.1 m^2 macro-fauna samples were taken at station A in August 1973 using a diver-operated suction sampler, essentially similar to that of Barnett and Hardy (1967). Separate cores for sediment analysis were obtained by hand. Stations B1–6 were sampled with a 0.1 m^2 Smith-McIntyre grab between 30 October 1973 and 9 November 1973; three replicates were taken at each location and material for sediment analysis was obtained by coring the undisturbed grab contents.

Seasonal variations in the selected environmental parameter were observed at station A on nine occasions during the period 27 April 1975–19 March 1976. Twelve 2 cm^2 cores were taken per sample from within a 1 m^2 area according to a stratified random sampling regime. Each core was cut into 2 cm sections to a depth of 12 cm. Eight sectioned cores were preserved for meiofaunal analysis, two provided material for carbon analysis and two for pigment analysis. Additional cores were taken less frequently for sediment grain-size, porosity and oxygen-content determinations. Water for salinity and temperature measurements was taken from immediately above the sediment.

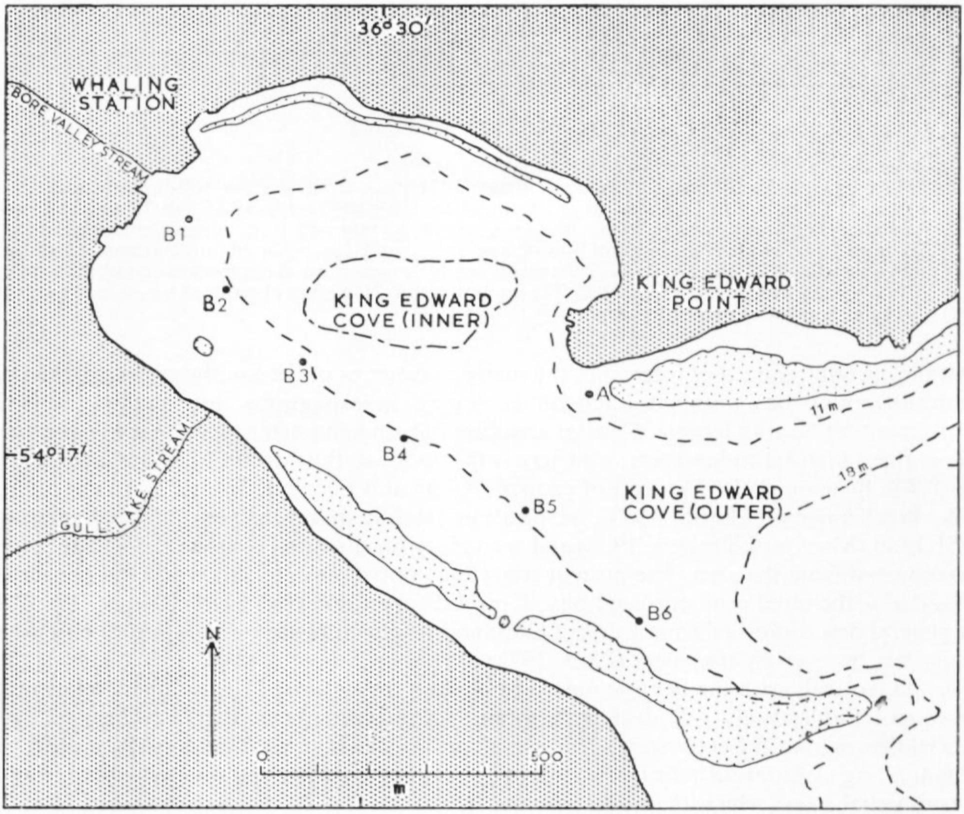

Fig. 1. King Edward Cove, South Georgia, showing the positions of sampling sites and general distribution of the kelp.

Analyses

The following methods of analysis were used: salinity by silver nitrate titration; organic carbon by chromic acid oxidation (Morgans, 1956); plant pigments by absorption spectrophotometry (Lorenzen, 1967); oxygen content by micro-Winkler titration (Fox and Wingfield, 1938); particle-size analysis by dry sieving (Morgans, 1956); porosity by simple gravimetric analysis using minimally disturbed cores; calcium carbonate content by weight loss on dilute acid digestion.

Macro-benthic organisms were separated from the sediment on a 1.0 mm sieve. For dry and ash weight determinations, temperatures of 60° and 550° C were used, respectively. Most specimens were analysed for biomass but numerical assessments of the very abundant species were made from randomly selected sub-samples and total biomass estimates made by using experimentally determined ash-free dry weight conversion factors.

Results

Environmental

Seasonal variation in most of the sediment parameters measured at station A was small. Temperature varied between −0.2° (August) and +3.8° C (March) with an annual mean of +2.2° C; this is similar to the range reported for the open water in King Edward Cove (Clarke and Lakhani, 1979). Salinity varied between 34.1‰ (July) and 31.4‰ (January), the latter being rather lower than normal summer values in the open water. Mean annual salinity was 33.2‰. The redox potential discontinuity (RPD) lay between 3.2 and 5.0 cm from the surface with a mean depth of 3.8 cm and no discernible seasonal fluctuation. Analysis of variance showed that there were no significant differences among the mean plant-pigment and organic carbon values for each of the nine samples taken during the year.

However, chlorophyll *a* and phaeopigment means for the four pooled summer samples (November–March) were significantly higher ($p < 0.01$) than the five pooled winter samples (April–October). For the 0–2 cm layer, mean chlorophyll *a* values were 15.5 μg/g in summer and 3.9 μg/g in winter, and the phaeopigment values 36.6 μg/g in summer and 17.3 μg/g in winter (dry weight values). Annual plant-pigment and organic carbon amounts also show significant reductions (at or above the 5% level of probability) with depth in the sediment (Table I), although the 2–8 cm layer appears more uniform apart from the 2–4 cm phaeopigment figure. The ratios of the unacidified to acidified extracts, indicating the proportion of degraded chlorophyll *a*, were low, in the range 1·1–1·2 in the 0–2 cm layer, with the higher values occurring in the summer. The average median grain-size of the top 6 cm of sand was 160 μm ($n = 24$) with a range of 123–205 μm. The median grain-size appears not to vary below the 2 cm depth (Table II) and porosity decreases only gradually beneath this level. The porosity

TABLE I. ANNUAL MEAN ($n = 9$) AND RANGE OF PLANT-PIGMENT AND ORGANIC CARBON DATA FROM VARIOUS DEPTHS IN THE SEDIMENT AT STATION A DURING THE PERIOD 22 APRIL 1975–19 MARCH 1976

Depth in sediment (cm)	*Chlorophyll a* (μg/g dry weight) *Mean*	*Range*	*Phaeopigments* (μg/g dry weight) *Mean*	*Range*	*Organic carbon* (mg/g) *Mean*	*Range*
0–2	9.0	3.1–19.9	25.9	16.2–49.3	4.9	4.1–6.5
2–4	1.5	0.9– 3.1	7.6	4.1–12.3	2.8	2.2–3.9
4–6	1.0	0.6– 1.8	4.1	2.8– 6.5	2.6	2.1–3.4
6–8	1.4	0.8– 2.9	4.5	2.6– 6.9	2.5	1.9–3.4
8–10	0.6	0.4– 0.9	1.7	0.5– 3.4	1.8	1.7–2.1
10–12	0.4	0.1– 0.7	0.5	0.0– 1.2	1.7	1.4–1.8

TABLE II. GRANULOMETRIC PARAMETERS AND POROSITY FOR VARIOUS DEPTHS IN THE SEDIMENT AT STATION A

Depth in sediment (cm)	*Median grain-size* (μm)	*Phi quartile deviation*	*Phi skewness*	*Porosity* (%)
0–2	178	0.43	+0.1	61.6
2–4	200	0.39	+0.2	48.6
4–6	195	0.35	+0.1	47.2
6–8	195	0.35	+0.1	51.0*
8–10	212	0.25	0.0	47.6
10–12	195	0.30	0.0	46.0

* See text.

value for the 6–8 cm layer (Table II) is probably too high, due to faulty coring. The oxygen profile (Table III) which was only measured on one occasion indicated that, although the

TABLE III. OXYGEN CONTENT OF OVERLYING AND INTERSTITIAL WATER AT STATION A IN OCTOBER 1975

Depth in sediment (cm)	*Oxygen content* (ml/l)	*Percentage saturation*
0	8.5–10.8	111–138
0.5	3.7	48
1.0	0.3	4
2.0	0.2	2
3.0	0.0	0
4.0	0.0	0
5.0	0.0	0

overlying water may be supersaturated, the oxygen content is very rapidly reduced only a short distance beneath the surface. Carbonate content was $2.8 \pm 0.7\%$ of the dry sediment weight.

Some sediment data for the other stations, together with the specific values at the time of macro-fauna sampling at station A, are given in Table IV. Stations B1–4 were similar, being

TABLE IV. SEDIMENT CHARACTERISTICS OF SAMPLES TAKEN AUGUST–NOVEMBER 1973

Station	*Depth* (m)	*Carbon content** (mg/g)	*Chlorophyll a** (μg/cm²) (SD)	*Phaeopigments** (μg/cm²) (SD)	*Median grain-size*† (μm)	*Depth of RPD* (cm)	*Notes*
A	4–6	3.4	8.4 (1.2)	51.2 (22.1)	160	1.5–4.0	Fine sand, "clean"
B1	9	30.6	18.0	103.0	39	1.0–3.5	Mud with much detritus, including clinker, glass fibre, wood, aluminium foil, ball bearings, old cloth
B2	10	35.0	39.5 (23.9)	141.5 (36.3)	42	0.5–1.0	Similar to B1
B3	9	34.7	17.0	80.0	48	0.5–1.5	Mud with detritus, including remains of terrestrial plants
B4	10	23.4	73.0 (20.4)	70.0 (16.0)	52	1.0–1.5	Mud with detritus, including plants, coal and clinker
B5	12	9.7	10.0 (1.8)	35.0 (11.5)	1 000	–	Coarse sand, poorly sorted, with some detritus, including clinker, linoleum tile and whalebone
B6	11	1.9	21.0 (24.8)	17.0 (2.7)	130	2.0	Fine sand, "clean" with little detritus

* Data for upper 0–2 cm layer of sediment.
† Data for upper 0–6 cm layer of sediment.

highly anaerobic muds with a high organic content. Stations B5 and B6 are both sandy, although the sediment was much coarser and poorly sorted at station B5.

Table V. Mean abundance (ind./0.1 m²) and percentage ash-free dry weight (AFDW) biomass of main invertebrate taxa and total mean abundance and biomass data per 0.1 m²

	Station													
	A		B1		B2		B3		B4		B5		B6	
	n	%AFDW	*n*	%AFDW	*n*	%AFDW	*n*	%AFDW	*n*	%AFDW	*n*	%AFDW	*n*	%AFDW
Anthozoa	–	–	103	23.0	–	–	–	–	–	–	21	3.0	–	–
Agloaphamus ornatus	4	14.8	12	48.1	17	22.7	8	31.7	7	37.3	8	41.4	7	57.5
Scoloplos sp.	517	16.3	69	7.8	12	1.9	3	1.8	6	0.3	3	0.4	20	7.4
Polydora sp.	990	5.5	9	0.2	–	–	–	–	–	–	–	–	–	–
Cirratulus sp.	189	11.5	1	0.2	–	–	–	–	4	0.4	60	1.7	48	5.8
Amphitrite sp.	6	10.8	–	–	–	–	–	–	–	–	1	7.3	–	–
Other Polychaeta	4	0.6	P	–	–	–	–	–	P	–	26	5.7	32	4.2
Chlanidota densisculpta	2	9.8	1	6.3	<1	14.0	<1	17.9	<1	2.6	–	–	<1	20.4
Philine gibba	2	3.0	<1	3.6	2	13.4	3	14.6	1	0.8	–	–	–	–
Yoldia eightsii	1	6.4	<1	6.3	3	45.8	1	14.4	3	58.4	4	36.5	–	–
Mysella charcoti	607	6.1	1	0.1	–	–	–	–	–	–	9	0.3	47	2.9
Other Mollusca	15	0.9	3	2.3	–	–	P	–	P	–	42	0.9	P	–
Ostracoda	42	0.6	–	–	–	–	–	–	–	–	34	0.8	–	–
Cumacea	453	3.6	47	2.0	11	0.2	30	8.4	16	0.2	5	0.1	2	0.2
Amphipoda	283	6.8	2	0.1	–	–	P	–	–	–	18	0.4	8	1.0
Other groups	<1	3.3	–	–	1	2.0	1	11.2	–	–	1	1.5	<1	0.6
Total abundance (SD)	3 115 (1 450)		249 (120)		46 (4)		326 (135)		39 (51)		232 (170)		166 (112)	
Biomass, wet weight g 0.1 m⁻² (SD)	27.9 (10.03)		9.91 (6.57)		11.86 (10.66)		10.20 (10.23)		22.58 (23.51)		18.28 (14.54)		3.42 (0.53)	
Biomass, AFDW g 0.1 m⁻² (SD)	3.76 (1.12)		0.99 (0.41)		1.05 (0.91)		1.16 (1.11)		1.98 (2.32)		1.62 (1.44)		0.40 (0.14)	

P Present in small numbers (mean $n < 1$) and their low biomass not determined.

The presence of refuse material at all but stations A and B6 is a result of the use of the inner part of King Edward Cove as a general dumping ground.

Mean abundance and biomass data for the macro-benthos are presented in Table V. The figures are very variable, both within and between stations, and only station A was significantly different (at the 0.1% level of probability) in both abundance and biomass. There was no significant difference in total ash-free dry weight (AFDW) among stations B1–6, but some degree of significance can be attached to the low number of individuals at stations B2 and B4. The relatively higher figure for station B3 was due almost entirely to Cumacea and, if this group is not included, stations B2–4 were much more alike. The conversion factors (*a*) used for estimating ash-free weight of commoner species are given in Table VI.

TABLE VI. MEAN WET WEIGHT (WW) OR LENGTH (L) TO ASH-FREE DRY WEIGHT CONVERSION VALUES (*a*) FOR SELECTED COMMON SPECIES

Species	*WW or L*	*a (SD)*	*n*
Parborlasia corrugatus	WW	0.148 (0.025)	33
Amphitrite sp.	WW	0.143 (0.075)	95
Scoloplos sp.	WW	0.186 (0.034)	19
Cirratulus sp.	WW	0.186 (0.021)	10
Polydora sp.	WW	0.198 (0.027)	21
Agloaphamus ornatus	WW	0.142 (0.030)	42
Philine gibba	WW	0.078 (0.018)	43
*Chlanidota densisculpta**	L	0.035 (0.008)	21
Mysella charcoti†	L	0.028 (0.007)	10
Yoldia eightsii†	L	0.012 (0.003)	29

* Length measured is maximum height.
† Length measured from anterior to posterior of valve.

DISCUSSION

Antarctic benthic ecosystems are characterized by relatively constant levels of physical and chemical conditions. Temperature and salinity vary little and nutrient levels are almost never limiting (Clowes, 1938). Organic carbon and plant-pigment levels were of a similar order of magnitude to those reported from shallow sheltered areas in temperate latitudes (Steele and Baird, 1968; Tietjen, 1968; Leach, 1970). The effect of shelter and a sill between the inner and outer King Edward Cove areas was reflected in the relative sediment carbon and total pigment values, which were markedly higher in the inner part of the cove.

The statistically significant reduction in phaeopigment values (at the 1% level of probability) from stations B1 and B2 to station B6 indicates the large amount of dead plant material deposited in the more sheltered locations. However, the percentage of degraded pigments was high at all stations in the cove, comprising 78–85% of the total in all but the sediments at stations B4 and B6. It is probable that material of a land-plant origin plays a significant role in contributing to these high values, a conclusion supported by the distribution of *n*-alkane hydrocarbons in these sediments (Mackie and others, 1978).

Despite the suggestion of phytoplankton impoverishment in these coastal waters (Hart, 1942), primarily due to turbulence and large amounts of terrigenous detritus during the summer months, there appears to be no evidence for an unusually low benthic standing crop. The mean standing crop for the King Edward Cove stations of 173.8 ± 131.2 g m^{-2} wet weight and 19.9 ± 16.3 g m^{-2} AFDW is well within the range of values reported from other comparable parts of the world (Thorson, 1936; Zenkevich, 1963; Warwick and Price, 1975; Christie and Moldan, 1977). The cove levels, especially for the inner cove, may be somewhat underestimated, since a sample area of 0.1 m^2 may not have adequately sampled certain larger organisms, such as *Philine gibba*, *Yoldia eightsii* and *Chlanidota densisculpta*. When present, they contribute a large proportion of the biomass (Table V). For example, the population density reported here for the common mud-dwelling cephalaspid mollusc *Philine gibba*, known to be contagiously distributed, appears to be low when compared with intensive sampling of 1.0 m^2 areas one year later in the same localities (personal communication from J. R. Seager).

Nevertheless, even if underestimated by as much as a half, the biomass would not be particularly high. Earlier work suggested that Antarctic benthos was characterized by a high standing crop of slow-growing organisms (Holdgate, 1967). These data related primarily to epifaunal communities and subsequent work on infauna-dominated communities suggests that this generalization may be invalid. From 35–100 m depths at the South Shetland Islands, a mean wet-weight biomass of 164 g m^{-2} in fine sand, silt and clay was suggested by Gallardo and Castillo (1969). At the South Orkney Islands (Hardy, 1972), somewhat higher wet-weight values of 307.3 g m^{-2} at 33–35 m to 788.8 g m^{-2} at 8–10 m were recorded. Further data are required to ascertain whether a gradient of increasing infaunal biomass exists among comparable habitats from the lower to higher latitudes within the Antarctic region.

Although not primarily designed as a detailed study of species distribution, certain features are worthy of being highlighted. Polychaetes generally dominated the assemblages in both abundance and biomass, especially at the sandy stations. *Polydora* sp., the characteristic animal at station A, was only found elsewhere at the innermost station (B1). In terms of biomass, however, the large eurytopic nephthiid *Agloaphamus ornatus* was the most important polychaete. Other eurytopic taxa included the Cumacea, *Scoloplos* sp. and *Yoldia eightsii*.

Large numbers of a small burrowing anemone (unidentified) occurred at station B1, making a significant contribution to the total AFDW biomass. Elsewhere, it was only found at lower densities at the coarse sand station.

The small bivalve *Mysella charcoti*, the several species of amphipods and a species of *Cirratulus* were largely confined to the sandy localities.

Although the sediment parameters describe the general nature of each station, they provide no clear explanation for these observed features of distribution. This would require a more detailed survey than was possible here and ideally should include the kelp-associated community. Several important and characteristic species, such as the prawn *Chorismus antarcticus*, the shrimp *Notocrangon antarcticus* and young stages of commercially important nototheniid fish are associated with macro-algae. Since polychaetes and amphipods are known to form an important part of the diet of young *Notothenia* sp., these shallow sandy areas off the kelp beds are undoubtedly of importance to the life cycle of these fish and in transferring organic matter to higher trophic levels in the food web.

To conclude, the work reported in this paper had two main objectives: a detailed seasonal assessment of an Antarctic sea-bed environment and a quantification of general biomass levels of shallow infaunal macro-benthic communities. The environmental data illustrate the general temporal stability of the habitat. Despite the reputedly low level of primary production in waters near the coast of South Georgia, there appears to be no corresponding impoverishment in terms of macro-benthos standing crop. Unless phytoplankton production is greater than present knowledge suggests, an additional source of energy (such as from the land) or some means of conserving that which is available must prevail. Clearly, further data concerning primary and secondary production in these important inshore waters are required.

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