THE VEGETATION OF ELEPHANT ISLAND, SOUTH SHETLAND ISLANDS

By J. S. ALLISON *and* R. I. L. SMITH

ABSTRACT. An account is presented of a primary ecological survey of the vegetation of Elephant Island, made during the Joint Services Expedition, 1970–71. Previous visits of botanical importance are summarized and a complete list is given of all species of terrestrial plants which have been collected. The plant communities are classified according to the system used by Smith for Signy Island, and comparisons are made between their development, distribution and species composition and those on other members of the South Shetland and South Orkney Islands. Five new sociations are described briefly.

The development and distribution of plant communities is related to the principal environmental factors and availability of suitable habitats, the majority of communities occurring above 150 m. An exceptional depth of peat accumulation, for a site within the Antarctic botanical zone, was noted at *c.* 200 m. altitude near Walker Point.

THIS paper gives an account of the vegetation of Elephant Island, South Shetland Islands, which was surveyed botanically, between December 1970 and March 1971, whilst one of the authors (J. S. Allison) was participating in the Joint Services Expedition, 1970–71, to Elephant Island (Burley, 1971). No intensive botanical work had been carried out previously on this island and only the principal members of the group had been visited, i.e. Elephant, Clarence and Gibbs Islands. Nevertheless, a small number of specimens had been collected (Table I).

Early visitors to Elephant Island had stressed the harshness of its climate and the sparseness of its plant and animal life (Shackleton, 1919; Wild, 1923). However, according to Wild (1923, p. 162) "The reports of whalers speak of a large bay [Mensa Bay] . . . with safe anchorage, where the landing is good, where seals, sea-elephants, penguins and all sorts of seabirds abound, and where tussock grass grows luxuriantly". This interesting reference to tussock grass has been proved to be quite erroneous, although scattered tufts of *Deschampsia antarctica* were recorded during the 1970–71 expedition near Stinker Point, *c.* 10 km. south of Mensa Bay. Wild (1923, p. 166) also commented that the Seal Islands, lying *c.* 5–8 km. north-west of Cape Yelcho, "are covered on the north side with lichen, the only form of vegetable life which exists in these regions". However, Wilkins (1925) added that "The only vegetation observed on its [Elephant Island] shores and heights was various stunted lichens and mosses. Even these were comparatively few, and only one species of each was collected (*Hypnum uncinatum* Hedw. and *Usnea melaxantha* Ach.)". The plants referred to were *Drepanocladus uncinatus* and *Usnea antarctica* respectively (Table I). The collecting notes with these specimens state "The only vegetable matter noticed on the island". None of the early visitors, with the exception of members of the Imperial Trans-Antarctic Expedition, 1914–17 (Shackleton, 1919), stayed more than a day and none ventured inland, probably because of its inaccessibility.

A study of air photographs of the island group taken before the expedition had shown little ice-free terrain, and neither extensive stands of vegetation nor a large number of species were expected. However, as a range of habitats was probably available for plant colonization, the main objective of the botanical field work was a phytosociological survey of such terrestrial plant communities as occurred on Elephant Island. It was also intended to collect a representative series of all terrestrial plant species from as many islands as possible.

COMPOSITION OF FLORA

A total of 80 terrestrial plant species was collected on Elephant Island, neighbouring islands and Bridgeman Island. *Orthotrichum crassifolium*, collected on Eadie Island, was the only species not seen on Elephant Island. It should be noted, however, that the *Amblystegium subvarium*, *Bryum antarcticum* and *Verrucaria racovitzae*, collected during earlier expeditions (Table I), were not seen in the field.

TABLE I. HISTORY OF BOTANICAL COLLECTING ON CLARENCE, ELEPHANT AND GIBBS ISLANDS PRIOR TO 1970–71

Expedition and/or collector	*Date*	*Locality*	*Species collected*	*Reference and/or herbarium*
Clarence Island				
Discovery II expedition	13 Nov. 1936	*c.* 0·8 km. east of Cape Bowles	*Brachythecium austro-salebrosum* *Bryum algens* *Ceratodon* cf. *grossiretis* *Drepanocladus uncinatus* *Mastodia tesselata*	Lamb, 1948 Hydrographic Department, 1961 Herbarium British Museum (Nat. Hist.)
Elephant Island				
Imperial Trans-Antarctic Expedition R. S. Clark	Aug. 1916	Cape Valentine or Point Wild	*Amblystegium subvarium* *Bryum antarcticum* *Drepanocladus uncinatus* *Umbilicaria antarctica* *Verrucaria racovitzae*	Shackleton, 1919 Darbishire, 1923 Herbarium British Museum (Nat. Hist.)
Shackleton–Rowett Antarctic Expedition G. H. Wilkins	27 Feb. 1922	Cape Lookout, at 30 m. alt.	*Ceratodon* sp. *Drepanocladus uncinatus* *Usnea antarctica*	Wild, 1923 Wilkins, 1925 Lamb, 1964
British Antarctic Survey H. A. D. Cameron and P. Kennett	15 Dec. 1961	South coast at 10 m. alt.	*Mastodia tesselata*	Herbarium British Antarctic Survey
United States Antarctic Research Program G. A. Llano and J. L. Gressitt	17 Feb. 1966	Cape Belsham, at 10 m. alt.	*Amblystegium subvarium* *Brachythecium austro-salebrosum* *Bryum algens* *Drepanocladus uncinatus*	Herbarium New York Botanical Garden
Gibbs Island				
Discovery II expedition	2 Feb. 1937	On south coast *c.* 0·8 km. west of The Spit, at *c.* 100 m. alt.	*Brachythecium austro-salebrosum* *Tortula fuscoviridis*	Herbarium British Museum (Nat. Hist.) Hydrographic Department, 1961
British Antarctic Survey H. A. D. Cameron and P. Kennett	15 Dec. 1961	South-east extremity, at 10 m. alt.	*Ramalina terebrata* *Usnea antarctica* *Verrucaria* sp.	Lindsay, 1969 Herbarium British Antarctic Survey

The species list for Elephant Island is as follows:

Mosses

Amblystegium subvarium†
Andreaea depressinervis
Andreaea gainii
*Andreaea regularis**
*Bartramia patens**
Brachythecium cf. *antarcticum*
Brachythecium austro-salebrosum
Bryum antarcticum†
*Bryum algens**
Bryum sp.
Ceratodon cf. *grossiretis*
Chorisodontium aciphyllum
*Dicranoweisia grimmiacea**
Drepanocladus uncinatus
*Grimmia antarctici**
Pohlia cruda var. *imbricata*
Pohlia inflexa
Pohlia nutans
Polytrichum alpestre
Polytrichum alpinum
Tortula conferta
Tortula excelsa
Tortula fuscoviridis
Tortula cf. *grossiretis*

Liverworts

Anthelia juratzkana
Barbilophozia hatcheri
Cephalozia badia
Cephaloziella varians
Cephaloziella sp.
Lophozia sp.
Roivainenia jacquinotii

Lichens

Alectoria chalybeiformis
Alectoria nigricans var. *implexiformis*
Alectoria pubescens
Buellia anisomera
Buellia coniops
Buellia latemarginata
Buellia russa
Caloplaca regalis
Caloplaca sp.
Catillaria corymbosa

Lichens (continued)

Cladonia cf. *balfourii*
Cladonia furcata
Cladonia cf. *gonecha*
Cladonia metacorallifera
Cladonia rangiferina var. *vicaria*
Cladonia sp.
Cystocoleus niger
Haematomma erythromma
Himantormia lugubris
Lecanora aspidophora
Lecanora atra
Lecanora sp.
Lecania brialmontii
Lecidea sp.
Leptogium sp.
Mastodia tesselata
Ochrolechia antarctica
Ochrolechia frigida
Pannaria sp.
Parmelia saxatilis
Peltigera rufescens
Pertusaria sp.
Physcia sp.
Placopsis contortuplicata
Psoroma sp.
Ramalina terebrata
Rhizocarpon geographicum
Rinodina petermanii
Sphaerophorus globosus
Stereocaulon alpinum
Umbilicaria antarctica
Usnea antarctica
Usnea fasciata
Verrucaria cf. *maura*
Verrucaria racovitzae†
Xanthoria candelaria
Xanthoria elegans
Xanthoria sp.

Alga

Prasiola crispa

Flowering plants

Colobanthus quitensis
Deschampsia antarctica

Species marked with an asterisk (*) were found with fruit. Species marked with a dagger (†) were collected during earlier visits to Elephant Island.

While the majority of specimens were obtained on Elephant Island, collections were also made on Bridgeman, Clarence, Eadie and Gibbs Islands (Table II), and the presence of vegetation on Cornwallis and Rowett Islands was noted but none was seen on Aspland and O'Brien Islands. *Deschampsia antarctica* was observed on Rowett Island (personal communication from R. J. Campbell). Far fewer species were recorded on the smaller islands than on Elephant Island, but collecting was less thorough and was limited to the areas around the triangulation stations. The ultrabasic rocks of Gibbs Island apparently supported a similar group of species to those on Elephant Island, but no detailed investigation was made of the vegetation of this island.

A representative series of the 246 numbers of the J. S. Allison (1970–71) Collection has been deposited in the British Antarctic Survey herbarium, at present housed in the Department of Botany, University of Birmingham, and a full record of all the specimens has been lodged in the herbarium's data bank.

TABLE II. BOTANICAL COLLECTIONS MADE ON BRIDGEMAN, CLARENCE, EADIE AND GIBBS ISLANDS DURING 1970–71

Collector	*Date*	*Locality*	*Species collected*			
			Mosses	*Liverworts*	*Lichens*	*Alga*
Bridgeman Island R. J. Campbell	26 Dec. 1970	Triangulation station at 10 m. alt.	*Dicranoweisia* sp. *Drepanocladus uncinatus*	–	*Himantormia lugubris* *Lecanora* sp. *Usnea antarctica*	–
Clarence Island J. F. Hunt	8 Dec. 1970	Around Chinstrap Cove, at 152 m. alt.	*Andreaea depressinervis* *Chorisodontium aciphyllum* *Drepanocladus uncinatus* *Polytrichum alpestre* *Tortula fuscoviridis* *Tortula* cf. *grossiretis*	*Barbilophozia hatcheri*	*Buellia anisomera* *B. latemarginata* *Caloplaca* sp. *Lecidea* sp. *Ochrolechia frigida* *Pertusaria* sp. *Sphaerophorus globosus* *Umbilicaria antarctica* *Usnea antarctica* *Xanthoria elegans*	*Prasiola crispa*
R. Y. Roxburgh	8 Dec. 1970	Near Chinstrap Cove, at 135 m. alt.	*Dicranoweisia* sp.	–	*Caloplaca regalis* *Cladonia* sp. *Lecidea* sp. *Ramalina terebrata* *Umbilicaria antarctica*	*Prasiola crispa*
Eadie Island R. J. Campbell	20 Dec. 1970	Triangulation station at 10 m. alt.	*Orthotrichum crassifolium*	–	*Caloplaca* sp. *Catillaria corymbosa* *Usnea antarctica*	*Prasiola crispa*
Gibbs Island J. S. Allison	15 Dec. 1970	Eastern end at 259 m. and 298 m. alt.	*Drepanocladus uncinatus*	–	*Caloplaca* sp. *Catillaria corymbosa* *Lecania briallmontii* *Lecanora* sp. *Lecidea* sp. *Leptogium* sp. *Pertusaria* sp.	*Prasiola crispa*
J. S. Allison	16 Dec. 1970	Western end at 305 m. alt.	–	–	*Lecidea* sp.	–

Topography, Climate and Soils of Elephant Island

Elephant Island and its neighbouring islands (Fig. 1) are the northernmost and easternmost of the South Shetland Islands, lying between lat. 61°00′S. and 61°30′S., and long. 54°00′W. and 55°40′W., while Bridgeman Island is situated at lat. 62°04′S., long. 56°40′W. Thus they occupy a position on the Scotia Ridge, at the southern edge of Drake Passage, *c.* 800 km. south-east of Cape Horn, *c.* 480 km. west-south-west of the South Orkney Islands and *c.* 265 km. north-north-east of the northern extremity of the Antarctic Peninsula. All of the islands are mountainous with steep cliffs and narrow beaches, and they are extensively covered by permanent snow and ice.

Topography

Elephant Island (lat. 61°10′S., long. 55°14′W.) (Fig. 1) is the largest of the group, being *c.* 40 km. from east to west and *c.* 24 km. from north to south at its western end. The coastline is extremely broken with alternating glacier snouts and high steep cliffs. Nowhere does the island shelve gently into the sea and the few beaches are very narrow, the only exception being a long broad gently inclined beach on the south-west coast south-east of Stinker Point.

Geologically, the island is composed mainly of highly metamorphosed sedimentary rocks. To the south-west of Endurance Glacier garnetiferous mica-schists predominate, whilst to the north and east the predominant rocks are dark grey or green chloritic phyllites (personal communication from R. Y. Roxburgh).

Over 95 per cent of the island is permanently covered by snow and ice with the major ice cap towards the western end. The interior is mountainous rising to a maximum height of 973 m. in Mount Pendragon. Such ice- and snow-free ground as occurred was restricted mainly to headlands and raised marine platforms, intervening valleys and the narrow low-lying raised beaches around the coasts so that plant habitats were restricted mainly to rock and cliff faces and their associated rock crevices, scree slopes and moraines. Farther inland snow-free rock faces were generally devoid of vegetation. Melt streams and summer rain or snowfall provide the source of water for most habitats. Only two large areas of shallow standing water were seen, both in the vicinity of Stinker Point.

Climate

A meteorological station was set up at the Expedition's base camp, south-west of Endurance Glacier, at an altitude of 171 m., where routine observations were made from 10 December 1970 until 26 March 1971 inclusive. A detailed account of these observations will be provided by R. M. G. O'Brien to whom the authors are indebted for the following information.

During the 107 day period of the observations, the mean daily temperature was −0·5° C (Table III). Mean day-time temperatures seldom rose above 3·5° C while 5·0° C was exceeded on only 7 days. There were 10 days when the mean temperature dropped below −5·0° C, but sub-zero temperatures were recorded on 93 days, i.e. for 87 per cent of the period. The longest frost-free period lasted 4 days, from 1 to 4 March 1971. The mean maximum temperature was only 1·4° C with an absolute maximum of 15·0° C recorded on 4 March 1971. The mean minimum temperature was −2·3° C with −8·9° C on 16 March 1971 being the lowest temperature recorded.

Cloudy conditions prevailed most of the time, although there were some long periods of clear weather. Precipitation was frequent with snow falling on 69 days* and rain on many other days. Although a total of >415 mm. of water equivalent was recorded, this figure incorporates an unknown substantial error due to drifting snow. Relative humidity remained high throughout but the daily mean of 95 per cent was based on only a single reading per day. The mean daily wind speed during the same period was 7·2 m./sec. and, although wind speeds of over 30 m./sec. were occasionally recorded, there were only 3 days of gales. There were no calm days.

The data in Table IV provide a comparison between Elephant Island and four neighbouring

* Based on 111 days of observations.

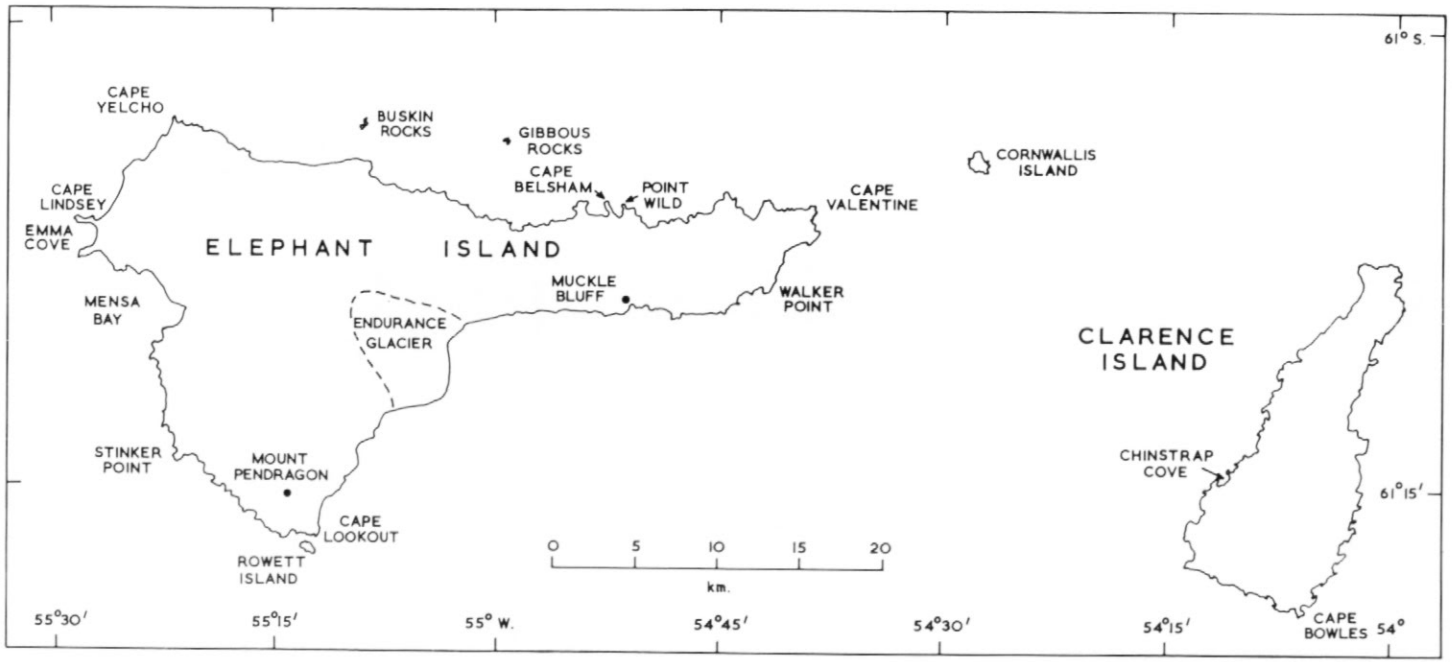

Fig. 1. Botanical collecting localities on Elephant and Clarence Islands. Map based on Directorate of Overseas Surveys sheet W6154 extn., 1 : 200,000.

TABLE III. CLIMATIC DATA FOR SUCCESSIVE 10 day PERIODS BETWEEN DECEMBER 1970 AND MARCH 1971 AT ELEPHANT ISLAND BASE CAMP

Dates	*Mean daily temperature* (° C)	*Mean daily maximum temperature* (° C)	*Highest maximum temperature* (° C)	*Mean daily minimum temperature* (° C)	*Lowest minimum temperature* (° C)	*Number of days with frost*	*Mean daily humidity* (per cent)	*Mean daily wind speed* (m./sec.)	*Total precipitation* (as mm. water equivalent)
10–19 December	−1·6	0·5	6·1	−3·2	−4·1	10	88·9 (9 days)	5·1	23
20–29 December	−1·1	0·4	4·7	−2·5	−4·1	10	95·5	6·8	44
30 December–8 January	−1·1	0·4	3·3	−2·4	−4·6	10	97·3 (7 days)	4·9	10
9–18 January	1·7	3·3	4·8	0	−2·4	6	94·7 (7 days)	7·5	27
19–28 January	−1·1	0·1	3·4	−2·3	−4·0	10	100·0 (5 days)	7·2	51
29 January–7 February	−2·2	−0·3	2·8	−4·1	−6·7	10	95·6 (7 days)	5·3	>14
8–17 February	0	2·1	4·5	−1·8	−5·2	8	not recorded	6·1	>12
18–27 February	0·4	2·0	6·8	−1·4	−4·1	9	96·7 (3 days)	11·9	>61
28 February–9 March	1·9	5·0	15·0	−1·0	−4·4	6	91·3	6·9	35
10–19 March	−1·2	1·3	4·2	−3·5	−8·9	8	94·3	7·6	88
20–26 March	−0·9	0·8	2·0	−3·3	−8·8	6	97·7 (7 days)	9·9	50
Means or totals for period 10 December–26 March	−0·5	1·4	–	−2·3	–	93	95·2	7·2	>415

Mean daily temperature derived from observations at 09.00 and 21.00 hr., the daily maximum and daily minimum. Mean daily humidity recorded at 09.00 hr. only. Mean daily wind speed derived from observations at 09.00 and 21.00 hr. and converted to standard velocity at 10 m. above ground level. Precipitation expressed as water equivalent. Base camp at 170 m. altitude.

TABLE IV. COMPARISON OF CLIMATIC DATA FOR ELEPHANT, KING GEORGE, DECEPTION, SIGNY AND LAURIE ISLANDS

Station	*Period of observation*	*Mean daily temperature* (° C)				*Mean daily humidity* (per cent)				*Mean daily wind speed* (m./sec.)				*Total precipitation* (mm.)			
		Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Feb.	Mar.
South Shetland Islands																	
Elephant Island	1970–71	−1·4	−0·2	−0·5	−0·1	96	95	–	93	5·6	6·8	7·9	7·9	79	96	*c.* 75	171
King George Island (Admiralty Bay)	1944–60	−0·5	1·2	1·1	0·1	89	83	85	85	5·1	5·3	6·1	6·7	–	–	–	–
Deception Island	1944–60	0·3	1·3	1·2	−0·1	83	83	85	87	5·9	5·8	6·6	7·1	50	55	68	57
South Orkney Islands																	
Signy Island	1948–67	−0·2	0·8	0·9	0·3	87	85	85	87	6·2	6·0	7·3	7·7	–	–	–	–
Laurie Island	1904–50	−0·8	0·1	0·2	−0·6	85	85	86	86	4·0	4·1	4·8	5·0	27	35	39	48

Source of data. Data for Elephant Island recorded at 171 m. altitude between 10 December 1970 and 26 March 1971 inclusive. Mean daily temperature derived from observations at 09.00 and 21.00 hr., the daily maximum and daily minimum. Mean daily humidity recorded at 09.00 hr. only. Mean daily wind speed derived from observations at 09.00 and 21.00 hr., and converted to standard velocity at 10 m. above ground level. Total precipitation was expressed as water equivalent.

Data for Admiralty Bay recorded at 18 m. altitude, and for Deception Island at 8 m. altitude, both from Pepper (1954) for the years 1944–50, from the *Falkland Islands Dependencies annual meteorological tables* for the years 1951–59 and from the *British Antarctic annual meteorological tables* for the year 1960.

Data for Signy Island recorded at 12 m. and Laurie Island at 4 m., from Smith (1972, table I).

stations, and suggest that the climate of Elephant Island is more severe than that recorded on other members of the South Shetland Islands or in the South Orkney Islands. But, because of the altitude at which the Elephant Island data were obtained, care must be exercised when comparing the figures. A greater climatic severity would not be unexpected, however, in view of the exposed situation of the station on Elephant Island at the southern edge of Drake Passage whereas the other meteorological stations, with the possible exception of that on Laurie Island, receive a considerable degree of shelter from local topographical features. On Signy Island, for example, some shelter is provided by the proximity of Coronation Island, while the station at Admiralty Bay was on the lee side of King George Island.

Temperatures measured in several species of moss at various times during the season showed that plant-level temperatures could be as much as 20° C or more above the ambient air temperature, particularly during periods of sunshine. The highest temperatures were recorded at the surface and amongst the shoot apices of the moss where the daily amplitude was also greatest.

Fig. 2 illustrates the temperatures in two colonies of *Polytrichum alpestre* at an altitude of *c.* 250 m. during $4\frac{1}{2}$ hr. of continuous sunshine. Site 1 was on a slope with an easterly aspect and was initially sheltered from the wind, while site 2 was on level ground, *c.* 0·5 m. above site 1, and was exposed to the wind. Initially the temperatures in the moss at the more sheltered position were higher than those at the more exposed site, but later in the day the wind veered to the east and the situation was reversed. In both cases temperatures between the shoot apices, at about 3–5 mm. below the surface of the colony, were higher than those at the surface of the moss and considerably higher than the air temperature recorded at 10 cm. above each

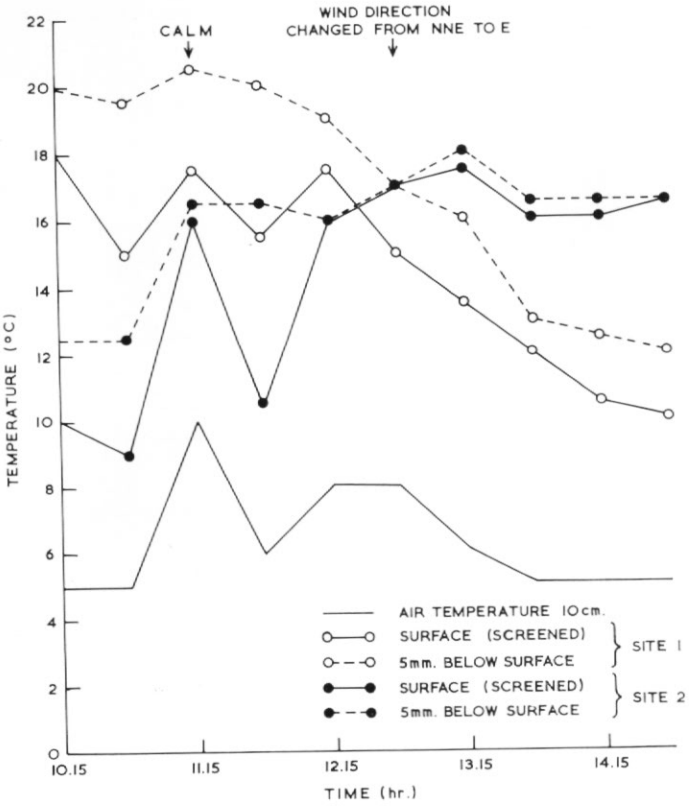

Fig. 2. Temperatures recorded at 30 min. intervals in a *Polytrichum alpestre* turf, at *c.* 250 m. altitude, south-west of Endurance Glacier on 28 December 1970.

colony. During the same period the maximum temperature recorded in the Stevenson screen at the neighbouring base camp was only 1·8° C.

Fig. 3 illustrates the rapid changes in temperature which took place in a colony of *Chorisodontium aciphyllum* at an altitude of *c.* 175 m. over a 6½ hr. period of variable weather, a close correlation being noted between the temperature in the moss and that of the ambient air. Temperatures were again greater among the growing apices than on the colony surface, but heat also appeared to accumulate in the lower layers of the moss at 25 and 40 mm. The highest temperature recorded in the *Chorisodontium* was 32·5° C at a time when the air temperature at 10 cm. was 8° C.

Similar rapid temperature changes were also noted in species with different growth forms, Fig. 4 presenting data obtained from a shallow mat of *Drepanocladus uncinatus* overlying moist gravelly ground at an altitude of *c.* 110 m. Once again the changes in temperature of the moss closely followed those of the air but, unlike the two turf-forming species, the temperature in the lower peaty layer was higher than at 5 mm. below the surface, suggesting an accumulation of heat in the peat lying just above the mineral soil.

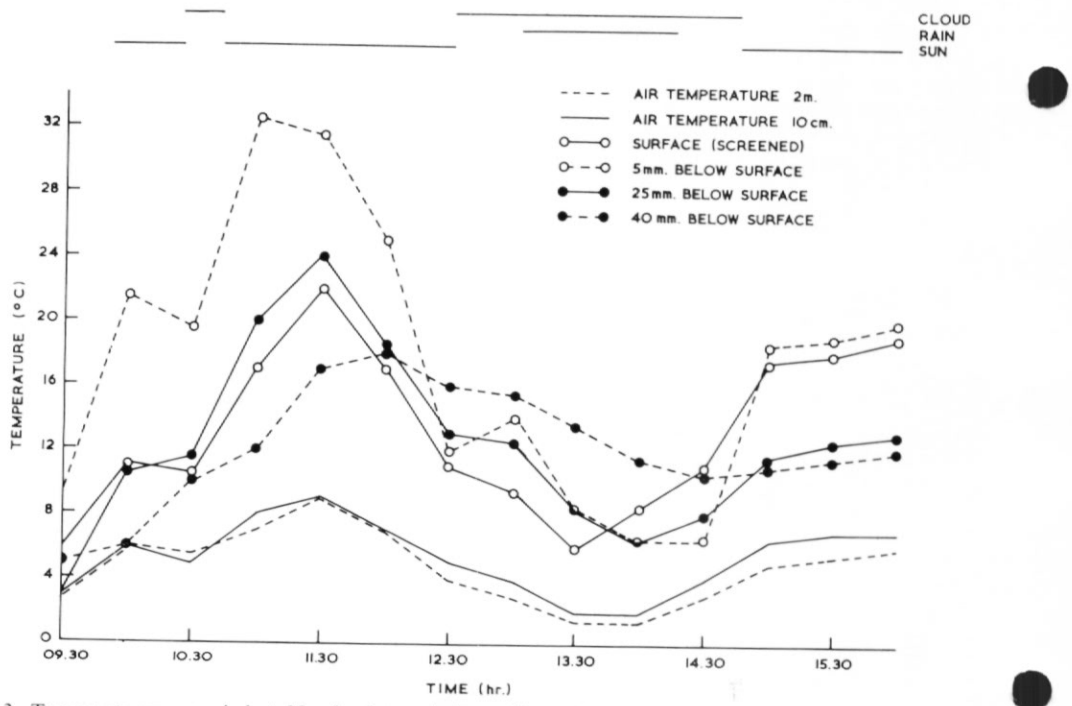

Fig. 3. Temperatures recorded at 30 min. intervals in a *Chorisodontium aciphyllum* turf, at *c.* 175 m. altitude, 3·5 km. south-west of Walker Point on 11 February 1971.

The above temperature data and trends in relation to the general weather pattern are very similar to those recorded by Holdgate (1964) in a *Polytrichum alpestre–Chorisodontium aciphyllum* bank on Signy Island and by Longton and Holdgate (1967) also in *Polytrichum alpestre* on the same island. However, it is of particular interest that these latter sites were at a relatively low altitude, whilst those on Elephant Island were between 110 and 250 m. a.s.l., yet the fluctuations in temperature within the mosses were of the same magnitude as those measured near sea-level on the more northerly island.

Soils

From a number of sites stone-free samples of soil were collected from the upper 5 cm. of soil. An E.I.L. portable pH meter with glass electrode was used to determine pH on part of

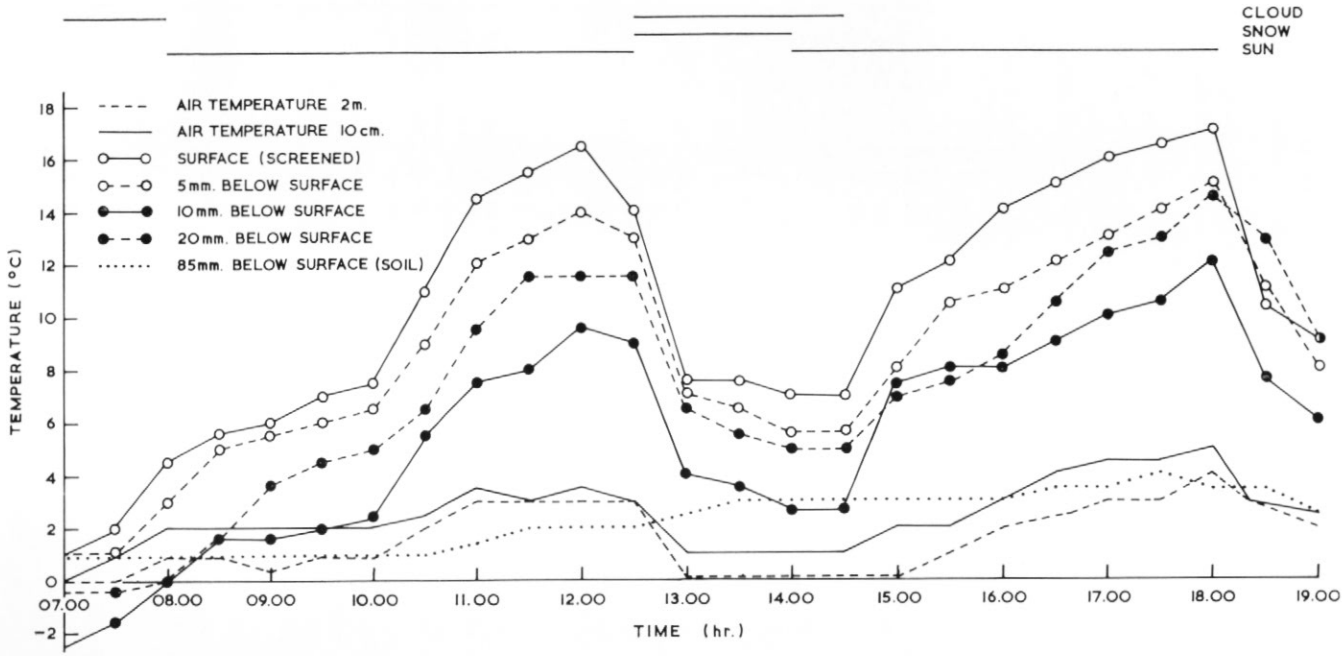

Fig. 4. Temperatures recorded at 30 min. intervals in a *Drepanocladus uncinatus* mat, at *c.* 110 m. altitude, near Stinker Point on 7 January 1971.

some of the fresh samples, the remainder being dried, sieved and the fine fraction (<2 mm.) retained for chemical analysis.

The 26 soil samples were separable into two groups, namely soils with a high organic content, and consequently a high level of nitrogen, and mineral soils with a low nitrogen content. There are no calcareous rocks or lavas and tuffs on Elephant Island, and consequently no base-rich soils.

The results of the chemical analyses are provided in Table V. Some of the soils had been enriched by bird excrement and so had exceptionally high contents of all the elements analysed, particularly phosphorus. For example, samples 1–6 were collected along a transect from within a penguin colony to vegetated ground nearby, and it can be seen that there was a progressive decrease in all the elements analysed as the influence of the penguins decreased. This point is further borne out by sample 21 which, although containing negligible organic matter, had a high concentration of calcium and phosphorus due to guano enrichment from giant petrels (*Macronectes giganteus*) nesting in the area.

Fairly organic soils below closed communities of turf- and carpet-forming mosses had a higher concentration of elements than more mineral soils of the open lichen and moss cushion communities. This is due principally to the accumulation and retention of nutrients in the peaty soils. Table VI provides a comparison with some soils on Signy Island and shows that soils of a similar origin or soils developed beneath similar vegetation are comparable in chemical composition on the two islands. Holdgate and others (1967) have shown that plant-nutrient levels in the soils of Signy Island do not appear to be a limiting factor for plant growth and, from the figures given in Table V, a similar conclusion can be reached for the soils of Elephant Island.

The Plant Communities of Elephant Island

Methods of study

Each area visited is described in the Appendix. Most of these sites were not extensive and some stands were analysed by means of 20 randomly placed 20 cm. by 20 cm. quadrats sub-divided into 5 cm. by 5 cm. units to facilitate estimation of the percentage cover of each species. From these data, the mean percentage cover and mean percentage frequency of each species was determined for each community examined.

Classification of communities

The vegetation of Elephant Island was found to form fairly distinct units the majority of which were similar in species composition to those reported by Gimingham and Smith (1970) from many parts of the maritime Antarctic, by Lindsay (1971) from elsewhere in the South Shetland Islands and by Smith (1972) from Signy Island. Because of the close resemblance of the Elephant Island communities to those in other regions of the maritime Antarctic, it was possible to identify and classify the various assemblages according to the system used by Smith (1972) for Signy Island. As more intergradation of assemblages was noted within associations than appears to exist on Signy Island, sociations have been excluded from the following list, although they are considered in the text.

ANTARCTIC NON-VASCULAR CRYPTOGAM TUNDRA FORMATION

i. Fruticose lichen and moss cushion sub-formation.
   a. *Andreaea–Usnea* association.
   b. Bryophyte and lichen assemblages of rock micro-habitats.
   c. *Tortula–Grimmia antarctici* association.

ii. Crustose lichen sub-formation.
   a. *Caloplaca–Xanthoria* association.
   b. *Placopsis contortuplicata* association.
   c. *Buellia–Lecanora–Lecidea* association.

iii. Moss turf sub-formation.
   a. *Polytrichum alpestre–Chorisodontium aciphyllum* association.
   b. *Polytrichum alpinum* association.

TABLE V. ANALYSES OF ELEPHANT ISLAND SOILS

Sample number	*Locality*	*Characteristics of soil*	*pH*	*Loss on ignition at 550° C (per cent)*	*Total N (per cent)*	*Extractable cations (mg./100 g. dry)*				
						Na	K	Ca	Mg	P
1*	3·5 km. south-west of Walker Point at *c.* 120 m.	Heavily trampled organic mud from chinstrap penguin rookery	–	32·0	2·25	218·0	266·0	628·0	486·0	814·0
2*		Heavily trampled organic soil from rocky area at margin of penguin rookery	–	36·0	2·94	112·0	182·0	673·0	386·0	530·0
3*		Organic soil beneath *Prasiola crispa* and dead moss 3 m. from margin of penguin rookery	–	61·0	2·46	62·0	105·0	279·0	124·0	59·0
4*		Organic soil beneath biotically eroded turves of *Polytrichum alpestre* and *Chorisodontium aciphyllum* used as resting place by penguins 5 m. from margin of penguin rookery	–	41·0	1·92	20·0	58·0	324·0	60·0	40·0
5*		Peat beneath live *Polytrichum alpestre* and *Chorisodontium aciphyllum* 11 m. from margin of penguin rookery	–	80·0	1·89	31·0	58·0	164·0	104·0	32·0
6*		Peat beneath unaffected *Polytrichum alpestre* and *Chorisodontium aciphyllum* 16 m. from margin of penguin rookery	–	81·0	1·65	38·0	46·0	156·0	179·0	11·0
7	As samples 1–6 at *c.* 150 m.	Peaty soil beneath *Drepanocladus uncinatus* mat	–	64·0	2·04	6·5	3·0	40·0	19·0	6·6
8		Peaty soil beneath *Polytrichum alpestre* turf	–	50·0	1·71	5·0	5·3	31·0	13·0	6·7
9		Peat beneath *Polytrichum alpestre* and *Chorisodontium aciphyllum* near penguin rookery	–	88·0	3·15	62·0	251·0	138·0	143·0	29·0
10		Peaty soil beneath *Polytrichum alpestre* and *Chorisodontium aciphyllum* near penguin rookery	–	60·0	2·13	8·3	5·9	130·0	52·0	2·3
11	As samples 1–6 at *c.* 120 m.	Mineral soil beneath scattered turves of *Polytrichum alpestre* and *Chorisodontium aciphyllum* near penguin rookery	–	21·0	0·87	10·0	3·4	73·0	17·0	9·5
12	3·5 km. east of Muckle Bluff at *c.* 155 m.	Peat beneath *Chorisodontium aciphyllum* turf	–	87·0	2·52	26·0	35·0	164·0	151·0	13·0
13		Peat beneath mixed stands of *Polytrichum alpinum*, *Chorisodontium aciphyllum*, *Alectoria pubescens*, *Stereocaulon alpinum*, *Cladonia* spp. and other lichens	–	87·0	3·42	36·0	48·0	128·0	126·0	5·1
14	0·5 km. south-west of Endurance Glacier at *c.* 200 m.	Organic soil beneath *Drepanocladus uncinatus* mat	6·0	50·0	2·43	18·0	16·0	106·0	79·0	2·7
15	As sample 14 at *c.* 305 m.	Mineral soil beneath open moss and lichen community, mainly *Himantormia lugubris* and *Usnea* spp.	5·3	27·0	1·14	17·0	8·0	64·0	59·0	0·5
16	As sample 14 at *c.* 290 m.	Mineral soil beneath *Andreaea regularis* and *Polytrichum alpestre*	5·2	8·9	0·38	3·0	3·4	15·0	11·0	1·3
17		Mineral soil beneath *Andreaea regularis*, *Polytrichum alpestre* and *Chorisodontium aciphyllum*	5·0	11·0	0·33	4·6	2·8	18·0	13·0	1·7
18	As sample 14 at *c.* 215 m.	Mineral soil from solifluction stripe	6·6	15·0	0·69	5·7	9·5	46·0	20·0	5·9
19	2 km. south-west of Endurance Glacier at *c.* 200 m.	Mineral soil beneath *Bartramia patens*	–	15·0	0·63	4·6	6·1	29·0	22·0	0·9
20		Peaty soil beneath shallow *Polytrichum alpestre–Chorisodontium aciphyllum* bank	6·7	32·0	1·35	17·0	15·0	72·0	66·0	1·5
21	0·5 km. south-east of Stinker Point at *c.* 90 m.	Mineral soil near giant petrel colony on sparsely vegetated moraine with *Drepanocladus uncinatus*, *Chorisodontium aciphyllum* and *Polytrichum alpestre*	–	1·5	0·09	6·5	1·2	419·0	8·8	214·0
22		Peaty soil beneath *Brachythecium* cf. *antarcticum* at edge of melt pool	–	31·0	0·81	11·0	8·1	176·0	33·0	31·0
23	Cape on south side of Emma Cove at *c.* 140 m.	Mineral soil beneath *Andreaea* sp. encrusted with *Ochrolechia antarctica*	5·5	6·5	0·40	3·7	2·8	20·0	11·0	2·8
24		Mineral soil beneath *Andreaea* sp. encrusted with *Ochrolechia antarctica*	6·1	8·5	0·36	12·0	5·5	41·0	25·0	3·3
25	As samples 23–24 at *c.* 120 m.	Mineral soil from sorted polygon	7·0	1·6	0·03	8·3	3·3	116·0	11·0	40·0
26	Near triangulation station, east end of Gibbs Island at *c.* 240 m.	Mineral soil beneath *Drepanocladus uncinatus* mat	–	12·0	0·44	7·4	5·0	41·0	117·0	0·8

* Samples 1–6 are from a transect extending from within a penguin colony (sample 1) into the nearby vegetation (sample 6).
Chemical analyses by the Chemical Section, The Nature Conservancy, Merlewood Research Station (July 1971).

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TABLE VI. COMPARISON OF SOME SOILS FROM ELEPHANT AND SIGNY ISLANDS

Type of soil	*Sample number*		*pH*		*Loss on ignition at 550° C* (per cent)		*Total* N (per cent)		*Extractable cations* (mg./100 g. dry)									
									Na		K		Ca		Mg		P	
	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island	Elephant Island	Signy Island
Barren mineral soil from sorted polygons	25	79	7·0	5·6	1·6	4·0	0·03	0·11	8·3	6	3·3	7	116	12	11	4	40·0	4
Barren mineral soil from solifluction stripe	18	156	6·6	6·0	15·0	4·0	0·69	0·08	5·7	20	9·5	6	46	88	20	55	5·9	5
Barren organic mud from penguin rookery	1	58	–	8·2	32·0	30·9	2·25	2·63	218·0	170	266·0	157	628	341	486	108	814·0	1,110
Mineral soil from sparsely vegetated moraine	21	2	–	5·8	1·5	1·9	0·09	0·16	6·5	9	1·2	7	419	32	9	11	214·0	6
Mineral soil beneath open moss and lichen community (mainly *Himantormia lugubris* and *Usnea* spp.)	15	155	5·3	5·5	27·0	6·9	1·14	0·31	17·0	6	8·0	6	64	29	59	13	0·5	2
Peaty soil beneath *Drepanocladus uncinatus* mat	7	47	–	4·8	64·0	71·9	2·04	2·98	6·5	40	3·0	19	40	70	19	44	7·0	9
Peaty soil beneath *Brachythecium* cf. *antarcticum* carpet	22	72	–	4·7	31·0	49·5	0·81	1·82	11·0	36	8·1	12	176	58	33	24	31·0	27
Peaty soil beneath shallow *Polytrichum alpestre* and *Chorisodontium aciphyllum* turf	20	19	6·7	5·3	32·0	27·6	1·35	0·99	17·0	18	15·0	13	72	122	66	55	1·5	13
Peat beneath *Chorisodontium aciphyllum* turf	12	20	–	4·7	87·0	85·4	2·52	1·87	26·0	146	35·0	22	164	246	151	221	13·0	2

Signy Island data from Holdgate and others (1967).

TABLE VII. PERCENTAGE COVER AND PERCENTAGE FREQUENCY OF OCCURRENCE OF SPECIES IN SOCIATIONS OF THREE SUB-FORMATIONS ON ELEPHANT ISLAND

Species	*Fruticose lichen and moss cushion sub-formation*	*Moss turf sub-formation*		*Grass and cushion chamaephyte sub-formation*
	Andreaea–lichen sociation (20 quadrats)	*Polytrichum alpestre–Chorisodontium aciphyllum–lichen sociation* (100 quadrats*)	*Polytrichum alpinum–lichen sociation* (60 quadrats†)	*Deschampsia antarctica–Colobanthus quitensis sociation* (20 quadrats)
Mosses				
Andreaea depressinervis	–	+; 2	–	–
Andreaea regularis	17; 65	–	<1; 3	–
Brachythecium austro-salebrosum	–	–	–	5; 30
Chorisodontium aciphyllum	1; 15	29; 81	4; 25	6; 25
Dicranoweisia grimmiacea	1; 20	–	–	–
Drepanocladus uncinatus	–	<1; 3	+; 7	8; 35
Polytrichum alpestre	–	38; 96	–	–
Polytrichum alpinum	4; 60	<1; 3	29; 88	8; 50
Tortula cf. *grossiretis*	–	–	–	9; 45
Liverworts				
Barbilophozia hatcheri	–	<1; 50	+; 3	–
Cephaloziella varians	–	<1; 95	<1; 15	<1; 20
Lichens				
Alectoria chalybeiformis	–	3; 23	2; 17	<1; 10
Alectoria pubescens	6; 55	12; 44	2; 22	<1; 10
Caloplaca sp.	–	–	–	<1; 10
Cladonia furcata	1; 45	2; 25	3; 30	9; 80
Cladonia metacorallifera	<1; 20	2; 29	2; 22	5; 55
Cladonia rangiferina var. *vicaria*	2; 20	<1; 16	1; 17	1; 10
Himantormia lugubris	–	–	+; 3	–
Ochrolechia frigida	3; 55	6; 52	11; 67	3; 40
Peltigera rufescens	–	–	–	3; 25
Placopsis contortuplicata	<1; 10	–	–	–
Psoroma sp.	–	<1; 2	<1; 8	–
Rhizocarpon geographicum	–	+; 4	–	+; 20
Sphaerophorus globosus	5; 55	3; 29	7; 50	1; 20
Stereocaulon alpinum	2; 35	<1; 4	<1; 8	5; 35
Umbilicaria antarctica	–	–	–	2; 15
Usnea antarctica	37;100	1; 13	22; 85	2; 30
Unidentified crustose species	5; 35	1; 10	15; 80	1; 35
Phanerogams				
Colobanthus quitensis	–	–	–	6; 45
Deschampsia antarctica	–	–	–	18; 90

The figure before the semi-colon is for percentage cover, that following it being for percentage frequency.
\+ Indicates the presence of a species outside, but close to, a quadrat.
* Data are mean of five sites each with 20 quadrats.
† Data are mean of three sites each with 20 quadrats.

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iv. Moss carpet sub-formation.
  a. *Brachythecium* cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus* association.
v. Moss hummock sub-formation.
  a. *Bryum–Drepanocladus uncinatus* association.
vi. Alga sub-formation.
  a. *Prasiola crispa* association.
vii. Snow alga sub-formation.

ANTARCTIC HERB TUNDRA FORMATION

i. Grass and cushion chamaephyte sub-formation.
  a. *Deschampsia antarctica–Colobanthus quitensis* association.

Antarctic non-vascular cryptogam tundra formation

Fruticose lichen and moss cushion sub-formation

This sub-formation was composed of a number of communities of physiognomically similar assemblages in which the dominant plants were fruticose lichens and cushion-forming mosses. Since these communities occupied the drier wind-swept hillsides, ridges and headlands on the island, the predominance of bryophytes or lichens was determined by the moisture status, degree of exposure to wind and stability of the substratum, lichens tending to increase in abundance in the more exposed situations and bryophytes in the sheltered moister areas. Several species of crustose lichen and occasionally scattered stems of turf-forming mosses were also found in these assemblages.

Andreaea–Usnea association. This was the largest and commonest association and was composed of seven intergrading sociations each of which had several species in common. These sociations included an *Andreaea*–lichen sociation, an *Andreaea–Himantormia lugubris* sociation, an *Usnea–Himantormia lugubris* sociation, an *Usnea–Himantormia lugubris–Andreaea* sociation, an *Usnea–Umbilicaria–Himantormia lugubris* sociation, an *Usnea antarctica* sociation and an *Usnea fasciata* sociation.

The *Usnea antarctica* sociation was the most extensive single sociation on Elephant Island, and was observed in all localities visited, occurring on dry wind-swept scree slopes and hill crests up to 390 m., with the cover of *Usnea antarctica* often exceeding 90 per cent. Because of exposure to wind and lack of moisture, bryophytes were rare although small cushions of *Andreaea* spp. often occurred in sheltered moist depressions where there was some accumulation of soil.

An *Andreaea*–lichen sociation was also a common community type which occurred on dry, fairly exposed, level to gently sloping stony ground, scree slopes and rock surfaces up to an altitude of 270 m. Data from one of these stands, south-west of Endurance Glacier, are given in Table VII. *Andreaea depressinervis* was usually the dominant species providing 40–50 per cent cover, although other species of *Andreaea* and *Polytrichum alpinum* were often associated. *Usnea antarctica* was the predominant lichen, although *Alectoria pubescens*, several species of *Cladonia* and *Sphaerophorus globosus* were also locally abundant. Cushions of *Andreaea* spp. were frequently encrusted by epiphytic lichens, in particular by *Ochrolechia frigida*, while rock surfaces had a variable cover of other crustose species. Where the substratum was affected by soil movement, cushions of *Andreaea* spp. and thalli of *Usnea* spp. were restricted to the more stable margins of the disturbed ground. Where this sociation intergraded with rock-crevice communities, the number of species increased.

Stands of the remaining five sociations were generally small in area and of limited distribution with the exception of an *Usnea–Umbilicaria–Himantormia lugubris* sociation. This was frequent on dry exposed rock faces usually at higher altitudes around the island. However, *Umbilicaria antarctica* was noted also on moist sheltered rock surfaces as low as *c.* 75 m. The only bryophytes recorded in this sociation were small cushions of *Andreaea regularis*. An *Usnea–Himantormia lugubris–Andreaea* sociation was one of these less extensive com-

munities which has not previously been recognized. It was recorded on several dry, wind-swept scree slopes and was similar to the *Andreaea–Himantormia lugubris* sociation except that *Usnea antarctica* was an important associate providing up to 20 per cent cover.

Bryophyte and lichen assemblages of rock micro-habitats. Various bryophyte and lichen assemblages occurred between the boulders of screes, in crevices and on ledges of rock faces where soil and moisture accumulated and some protection was afforded from wind. Because of the diversity of species composition between sites, no attempt was made to classify these assemblages.

Species of *Andreaea*, *Bartramia*, *Bryum*, *Dicranoweisia*, *Pohlia*, *Tortula*, *Ceratodon* cf. *grossiretis*, *Drepanocladus uncinatus* and *Grimmia antarctici* were frequent in these crevice communities while some, e.g. the *Ceratodon* and the species of *Pohlia*, were virtually confined to this habitat. Species of both these genera were prominent associates in many terricolous communities. With the exception of *D. uncinatus*, which formed mats, these mosses grew as small cushions or short turves. *Barbilophozia hatcheri* and *Cephaloziella varians* were common associates. Where there was an accumulation of organic debris, as on ledges, diminutive turves of *Chorisodontium aciphyllum* and *Polytrichum alpinum* also occurred. The predominant lichen associates included *Cladonia furcata*, *C. metacorallifera*, *Ochrolechia frigida* and a species of *Psoroma*. In contrast to Signy Island, crustose lichens were infrequent within the crevices (Smith, 1972), although species of *Buellia*, *Lecidea* and *Rhizocarpon* grew on the surrounding rock surfaces. A further difference to Signy Island was the absence of calcareous crevice communities, due to the non-existence of this rock type on Elephant Island.

Tortula–Grimmia antarctici association. Small stands on the slopes of moist hollows on some moraines were dominated by species of *Tortula* and *Grimmia antarctici*, which often developed adjacent to communities of the *Polytrichum alpestre–Chorisodontium aciphyllum* and *Brachythecium* cf. *antarcticum–Calliergon–Drepanocladus uncinatus* associations or intergraded with crevice communities.

Two sociations were recognized both occupying similar habitats. A *Tortula* sociation was formed chiefly by *Bryum algens*, *Tortula fuscoviridis* and *T.* cf. *grossiretis*, although the latter moss seldom provided more than 20 per cent of the cover. *Cladonia metacorallifera* was usually present as scattered podetia amongst the moss stems. A *Tortula–Grimmia antarctici* sociation had *Tortula fuscoviridis* and *Grimmia antarctici* as co-dominants. *Bryum algens* was often present as scattered cushions, while the principal lichen was again *Cladonia metacorallifera*; occasional encrustations of *Ochrolechia frigida* grew on the compact cushions of *Grimmia antarctici*.

Crustose lichen sub-formation

Several communities of crustose lichens which contained no bryophyte associates were characteristic of coastal rocks, cliffs and headlands, where their distribution was influenced by such environmental factors as salt deposition, exposure to wind and the presence of cliff-breeding birds. The occurrence of lichens on offshore rocks was first noted by Wild (1923, p. 166) on the Seal Islands, *c.* 5 km. north-west of Cape Yelcho. He commented that "They are covered on the north side with lichen, the only form of vegetable life which exists in these regions". Farther inland crustose species occurred on dry rock faces usually as an understorey beneath fruticose lichens or in areas of frost-disturbed ground.

Caloplaca–Xanthoria association. This association was composed largely of species of *Caloplaca*, *Haematomma*, *Verrucaria* and *Xanthoria*, and several sociations of similar species composition formed an intergrading series from near the shore to the higher cliff tops, particularly where there were increased levels of nitrogen or of marine salts.

A *Verrucaria* sociation occurred as a zone extending from sea-level to about 1·5 m. above high-water mark on coastal rocks within the spray zone of storm beaches and low-lying offshore islands, particularly Buskin and Gibbous Rocks off the north coast. This sociation was not widely distributed on Elephant Island probably because of the regular scouring of rocks at sea-level by brash ice.

A *Caloplaca* sociation commenced at about 10 m. where *Caloplaca regalis* and another species of *Caloplaca* formed small closed aggregates of 60–70 cm.^{2}, particularly below cape pigeon (*Daption capensis*) nests. Where there was no biotic influence, the frequency and cover of the *Caloplaca* decreased and pure stands became rarer. On cliff faces *Ramalina terebrata*, *Mastodia tesselata* and species of *Buellia* and *Lecanora* were usually associated with the *Caloplaca*. On exposed headlands, particularly on boulders used as bird perches, the *Caloplaca* sociation integrated with a *Caloplaca regalis–Haematomma erythromma–Xanthoria elegans* sociation, a sociation not previously recognized, although small stands have been observed on Signy Island, while Lindsay (1971) has reported sociations of a similar nature from other members of the South Shetland Islands. For no apparent reason, dominance varied in different stands between the principal lichens. Individual stands were seldom extensive but one boulder, measuring *c.* 1 m. by 1·5 m., was entirely covered by thalli of *Caloplaca regalis* and *Haematomma erythromma*.

Placopsis contortuplicata association. This was a common association on Elephant Island being characteristic of ground disturbed by solifluction, e.g. soil stripes and sorted polygons. This association was not found on coastal cliffs, although large almost circular thalli of *P. contortuplicata* were found growing on boulders and dry rock faces up to 475 m. farther inland. Three sociations were recognized.

A *Placopsis contortuplicata* sociation was formed solely by this lichen and extensive stands developed on stable stones at the margins of soil stripes and sorted polygons, often in such abundance that the pink outlines of the stripes were visible from some distance. The thalli were often broken and irregular in shape due to the down-hill movement of the substratum. No other species were recorded in this sociation but intergradation with other assemblages within this association was observed.

The remaining two sociations were not described by Smith (1972) from Signy Island and are recognized for the first time, although strictly they do not belong to the crustose lichen sub-formation on account of the frequent occurrence of certain bryophytes.

A *Placopsis contortuplicata–Drepanocladus uncinatus* sociation was found in areas of frost-disturbed ground on the more stable coarser material around soil stripes and sorted polygons to an altitude of 260 m., *Drepanocladus uncinatus* forming a narrow zone over the least disturbed stones with the lichen growing at its edges. Since some polygons were surrounded solely by *D. uncinatus*, particularly where they occurred close to an extensive mat of that species, this sociation may be considered as a transitional assemblage between the *Placopsis contortuplicata* sociation and the *Drepanocladus uncinatus* sociation of the moss carpet sub-formation.

A *Placopsis contortuplicata–Drepanocladus uncinatus–Andreaea* sociation was also recognized. It was composed of *Andreaea depressinervis*, *A. regularis*, *Drepanocladus uncinatus* and *Placopsis contortuplicata*, and was developed at the margins of stone stripes on gentle slopes. The *Andreaea* cushions were generally small and measured only 2–3 cm. in diameter; *D. uncinatus* was occasionally absent. Small melt streams often followed the line of the stripes and the growth of the mosses in these situations was much more luxuriant than elsewhere.

Buellia–Lecanora–Lecidea association. Since the species of this association tended to be in fragmentary assemblages within the crustose lichen sub-formation, and because of diversity of species representation between sites, definable sociations were not recognized. These assemblages were widespread on the more exposed headlands and rock faces, often adjacent to sociations of the *Caloplaca–Xanthoria* association. The present association was frequently found as an understorey beneath fruticose lichens, and was particularly prominent on screes amongst a very open cover of *Usnea* spp. In such situations the principal species were considered as components of certain sociations of the *Andreaea–Usnea* association.

The principal genera of this association were *Buellia*, *Lecanora*, *Lecidea*, *Ochrolechia*, *Pannaria*, *Pertusaria*, *Physcia* and *Rhizocarpon*. Stands of many of these lichens often covered 90 per cent of the rock surface. Where the habitat was more sheltered, larger foliose species such as *Parmelia saxatilis* and *Umbilicaria antarctica* were also present.

Moss turf sub-formation

The species comprising this sub-formation had erect dense growth forms giving rise to tall turves. In the case of *Chorisodontium aciphyllum* and *Polytrichum alpestre* the mosses had built up a peat of variable depth, but this did not happen beneath the shorter and less dense *Polytrichum alpinum*. Stands of both groups of turf-forming mosses were best developed over well-drained level to gently sloping stony ground, although they were not restricted to such habitats. Two associations were represented on Elephant Island.

Polytrichum alpestre–Chorisodontium aciphyllum association. The two species, which were frequently co-dominant, usually formed large areas of shallow turf about 20–25 cm. deep on well-drained level to sloping ground to an altitude of 250 m. Pure stands of one or other of these mosses were rare and almost all banks of *P. alpestre* and *C. aciphyllum* were colonized by a number of epiphytic crustose and fruticose lichens.

Differences in species composition and dominance were mainly related to the water regime of the habitat. *C. aciphyllum* became dominant in wetter situations and usually adjoined stands of *D. uncinatus*, while *P. alpestre* assumed dominance on drier slopes. Growth of epiphytic lichens was greatest on the highest parts of the peat banks where the mosses tended to become moribund, probably as a result of frost action or wind erosion. Seven sociations were recognized but there was considerable intergradation between them.

The two commonest assemblages of the moss turf sub-formation on Elephant Island were a *Polytrichum alpestre–Chorisodontium aciphyllum* sociation and a *Polytrichum alpestre–Chorisodontium aciphyllum*–lichen sociation, each composed of the two dominant turf-forming mosses. The principal lichen associates included *Alectoria chalybeiformis*, *A. pubescens*, *Cladonia furcata*, *C. metacorallifera*, *Ochrolechia frigida*, *Sphaerophorus globosus* and occasionally *Usnea antarctica*, while *Cephaloziella varians* was always present in very small quantities amongst the shoots of *Chorisodontium aciphyllum*. The species composition of several *P. alpestre–C. aciphyllum*–lichen stands is given in Table VII. On well-drained slopes these two sociations formed extensive stands up to 400 m.^{2} but they tended to merge with a third sociation of *Polytrichum alpestre–Chorisodontium aciphyllum* heavily encrusted by *Ochrolechia frigida* and a species of *Buellia*. *Sphaerophorus globosus* often contributed 40–50 per cent cover, while most of the other fruticose species noted above were also present.

The remaining four sociations formed small stands and had only a local distribution. Both a *Polytrichum alpestre* and a *Polytrichum alpestre*–lichen sociation occurred as shallow banks, usually about 1 m. in diameter, on fairly dry gently sloping ground and always intergrading with stands of the *Chorisodontium aciphyllum–Polytrichum alpestre* sociation. The centres of these *Polytrichum* turves were often colonized by epiphytic lichens, particularly *Cladonia furcata*, *C. metacorallifera*, *Ochrolechia frigida*, *Sphaerophorus globosus* and *Stereocaulon alpinum*.

A *Chorisodontium aciphyllum* sociation and a *Chorisodontium aciphyllum*–lichen sociation occurred on level or sloping moist ground and in hollows often formed stands adjacent to mats of *Drepanocladus uncinatus*. *Cephaloziella varians* was usually associated, growing between the stems of the *Chorisodontium*. Species of *Cladonia* and *Sphaerophorus globosus* grew on the drier parts of the turf, with *Usnea antarctica* as an occasional associate.

Polytrichum alpinum association. Pure stands of *Polytrichum alpinum* were rare and seldom more than 1 m. in diameter, while the sociation which it formed occurred on moist level ground usually adjacent to shallow *Polytrichum alpestre–Chorisodontium aciphyllum* banks. Where the habitat became moister a *Polytrichum alpinum–Drepanocladus uncinatus* sociation developed, occasionally with species of *Andreaea* associated. A similar sociation has been reported from the South Orkney Islands often from the vicinity of penguin rookeries or other bird colonies and seal wallows (Smith, 1972). On drier stony ground, a previously undescribed *Polytrichum alpinum*–lichen sociation was locally frequent. *P. alpinum* and *Usnea antarctica* were predominant with *Chorisodontium aciphyllum*, *Ochrolechia frigida*, *Sphaerophorus globosus* and species of *Cladonia* all common associates. The species composition of this sociation is given in Table VII. *P. alpinum* was also frequent in rock crevices and on ledges or as an associate in certain *Polytrichum alpestre–Chorisodontium aciphyllum* sociations

on moist level ground where *P. alpestre* and *C. aciphyllum* formed about 80 per cent of the cover and *P. alpinum* was present as scattered shoots comprising the remaining 20 per cent.

Moss carpet sub-formation

The communities of this sub-formation were dominated by *Brachythecium* cf. *antarcticum* and *Drepanocladus uncinatus*, and formed extensive stands on moist shallow soil; in the permanently wet areas the *Brachythecium* developed a shallow peat about 5 cm. in depth. There were no associated lichens due to the wetness of the habitat. Elsewhere in the South Shetland Islands, as in the South Orkney Islands, *Calliergon sarmentosum* was often abundant in stands of this association, although this species was not seen on Elephant Island.

Brachythecium cf. *antarcticum–Calliergon sarmentosum–Drepanocladus uncinatus association.* This association formed the largest stands of closed moss vegetation on Elephant Island, although it was not extensively developed above 120 m.

A *Drepanocladus uncinatus* sociation was the most extensive community and closed stands measuring about 30 m. by 40 m. occurred in suitable areas. Where stands of *Drepanocladus uncinatus* dominated level or gently rising, moist stony ground the moss was noticed to vary in colour according to the wetness of the substratum, being bright to dark green where the ground was wet but yellow-green where the substratum was drier.

On saturated ground a *Brachythecium* cf. *antarcticum* sociation occurred as pure stands or with occasional *Drepanocladus uncinatus*, the largest stand observed measuring about 100 m. long by 3·5–4 m. wide.

Moss hummock sub-formation

Stands of this sub-formation were characteristic of some of the hollows in moraine-ridge systems particularly where organic debris and soil collected and where there was a plentiful supply of water. However, their distribution on Elephant Island was limited.

Bryum–Drepanocladus uncinatus association. This association was represented by small stands of a *Bryum–Drepanocladus uncinatus–Tortula excelsa* sociation, in which an unidentified species of *Bryum*, *Bryum algens* and *Drepanocladus uncinatus* were the predominant species. Where the habitat became wetter, towards the floors of depressions in moraines, *Tortula excelsa* and occasionally *T. conferta* became important associates but they seldom contributed more than 25 per cent cover. Two hepatics, *Barbilophozia hatcheri* and *Cephaloziella varians*, were also usually present but no lichens were recorded.

Alga sub-formation

This sub-formation was represented on Elephant Island by a single sociation, composed of the green alga *Prasiola crispa*, confined to wet biotically disturbed habitats. The blue-green alga *Nostoc* was not seen on the island, although it is known to form extensive stands elsewhere in the South Shetland Islands (Gimingham and Smith, 1970; Lindsay, 1971).

Prasiola crispa association. Prasiola crispa was widespread in wet habitats, particularly near the breeding colonies of penguins, cape pigeons and giant petrels, where it formed locally extensive stands sometimes in association with *Mastodia tesselata* and occasionally with species of *Caloplaca* and *Lecidea*. The alga was also frequent along the margins of melt streams, especially those running through penguin rookeries.

Snow alga sub-formation

Large areas of melting snow on many of the island's snowfields, at times close to penguin rookeries, were often coloured red by agglomerations of a unicellular alga or algae. These associations were not examined.

Antarctic herb tundra formation

Grass and cushion chamaephyte sub-formation

Both *Deschampsia antarctica* and *Colobanthus quitensis* were found on moist, sheltered, north-facing level to steeply sloping ground above the south coast of Elephant Island. Neither species was found below 60 m. but both occurred as high as *c.* 200 m. *Deschampsia antarctica* formed small closed swards at only three sites but it was also recorded as scattered plants at a further four localities. *Colobanthus quitensis*, on the other hand, was seen in only two situations in each of which it was associated with the grass. Inflorescences were frequent on *D. antarctica* but only closed buds were seen on *C. quitensis*.

Deschampsia antarctica–Colobanthus quitensis association. Two sociations were recognized in which *Drepanocladus uncinatus*, *Polytrichum alpinum*, *Tortula* cf. *grossiretis* and species of *Cladonia* were occasional associates. In a *Deschampsia antarctica* sociation the grass was nowhere extensive and formed only small swards of coalesced plants, the largest of which measured about 2 m.^{2}, and it was surrounded by scattered individual tufts and by *Drepanocladus uncinatus*. Elsewhere on the island the grass occurred as isolated plants or occasionally in small groups, usually amongst *D. uncinatus* but sometimes also on *Polytrichum alpestre–Chorisodontium aciphyllum* banks, particularly around the nests of skuas (*Catharacta skua*). It was considered that these birds were responsible for the dispersal of grass seeds in the vicinity of their nests.

A *Deschampsia antarctica–Colobanthus quitensis* sociation was seen at only one site where both species were relatively abundant, the species composition being given in Table VII. At the other locality where *C. quitensis* was recorded the plants were few and scattered amongst sparse *D. antarctica*.

Distribution and Development of Vegetation

Despite the comparatively small area of summer snow- and ice-free ground on Elephant Island, a wide range of habitats was available for plant colonization, particularly in coastal areas. Pattern within the vegetation appeared to be related mainly to environmental factors of which water availability, exposure to wind and stability of the substratum were considered the most important. Biotic influences were of only local significance, but where there were colonies of birds their effect on the vegetation was considerable. Only *Prasiola crispa* tolerated the excessive mineral concentration in penguin rookeries, while nitrogen-enriched rock faces below cliff-breeding petrels were brightly coloured by stands of the *Caloplaca–Xanthoria* association. The greatest expanses of snow-free ground occurred on the raised platforms, headlands and north-facing hillsides along the southern and western coasts. Wherever there was a regular source of water, some degree of shelter or stability, stands representative of the fruticose lichen and moss cushion sub-formation, the moss turf sub-formation and the moss carpet sub-formation were locally extensive, while more exposed but stable rocky habitats were colonized by dense stands of the *Andreaea–Usnea* association and the crustose lichen sub-formation.

Exposed rock faces and cliff tops

Coastal rocks. The sea cliffs around Elephant Island are steep, generally unstable and subjected to frequent rock falls (Fig. 5). Vegetation on the lower part of the exposed faces was almost restricted to crustose lichens, especially sociations dominated by species of *Caloplaca* and *Xanthoria*, particularly in the proximity of cliff-breeding birds, although species of *Buellia* were also generally present. Small thalli of *Usnea antarctica* usually colonized the wind-swept cliff tops. Rocks at or near sea-level supported very little plant life due to frequent scouring by brash ice. Thus the development of the typically halophilous *Verrucaria* sociations was noted in only a few places, the sociation being best developed on the low-lying offshore islands, Buskin and Gibbous Rocks, to the north of Elephant Island.

No plant life was observed on any of the beaches where instability and abrasion of the rocks was greatest due to wave action and passaging of elephant seals.

Fig. 5. Steep coastal cliffs and narrow beaches below a level marine platform, at *c.* 130 m. altitude, on the cape south of Emma Cove.

Inland rocks. Up to 90 per cent of rock surfaces in certain inland areas were colonized by species of the *Buellia–Lecanora–Lecidea* association. Elsewhere on dry exposed rocks the *Usnea–Himantormia lugubris–Andreaea* sociation was well represented (Fig. 6). Large circular thalli of *Placopsis contortuplicata* were not uncommon and this lichen, together with small plants of *Usnea antarctica* and scattered stems of *Chorisodontium aciphyllum*, was seen at 465 m. *c.* 3 km. north-east of Endurance Glacier, the highest point at which vegetation was observed on Elephant Island.

Crevices and rock ledges

This habitat differed from the last in that there was inevitably some degree of shading, a higher degree of relative humidity and usually some soil accumulation, so that plants experienced less extreme conditions than on exposed rock surfaces. The plants most frequently observed were species of *Andreaea*, *Bartramia*, *Bryum*, *Dicranoweisia*, *Pohlia* and *Tortula*, together with *Ceratodon* cf. *grossiretis*, *Drepanocladus uncinatus* and *Grimmia antarctici*. On a series of broad damp ledges some distance east of Muckle Bluff *Deschampsia antarctica* and *Colobanthus quitensis* were associated with a number of these mosses.

Headlands, raised marine platforms and raised beaches

Vegetation was only locally well developed on headlands, presumably due to exposure to wind, a shortage of moisture and the likelihood of no protective winter snow cover (Fig. 7). The main communities of this habitat were an open nitrophobous *Usnea antarctica* sociation and a *Caloplaca regalis–Haematomma erythromma–Xanthoria elegans* sociation mainly on boulders used as perches by sea birds. Farther inland *Usnea antarctica* increased in cover (Fig. 8) and small stands of an *Andreaea*–lichen sociation predominated in occasional shallow depressions. Wherever there was an increase in shelter and moisture availability, shallow carpets of *Drepanocladus uncinatus* replaced the lichen- and *Andreaea*-dominated sociations,

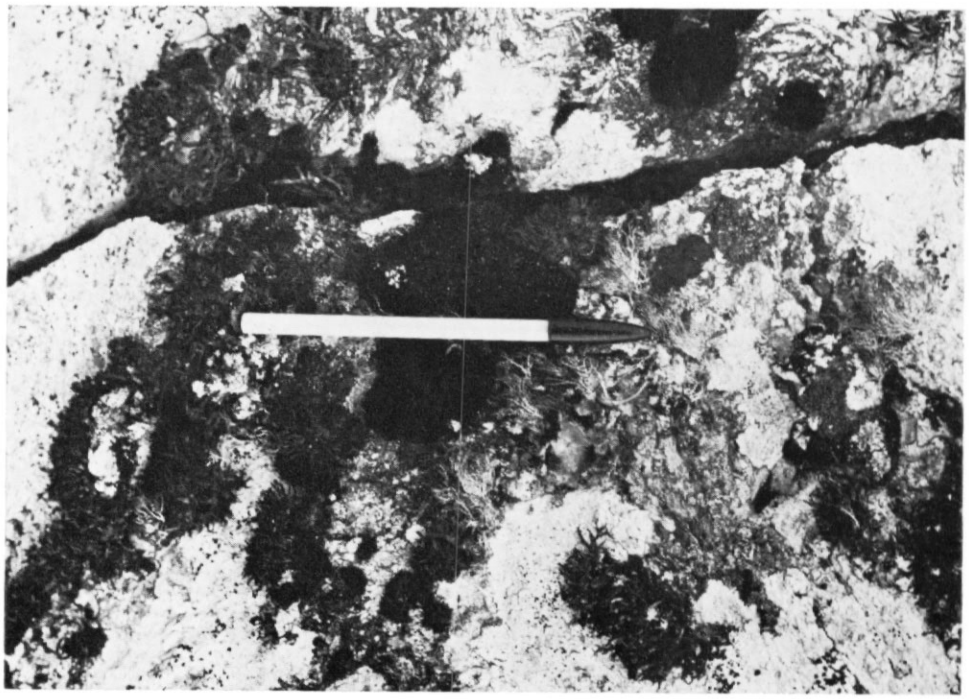

Fig. 6. *Himantormia lugubris* (black fruticose), *Usnea antarctica* (grey fruticose), *Umbilicaria antarctica* (grey foliose), species of *Andreaea* (black cushions) and various grey and white crustose lichens of the *Usnea–Himantormia lugubris–Andreaea* sociation on a sheltered rock face, at *c.* 200 m. altitude, about 3·5 km. south-west of Walker Point. The scale object is 15 cm. in length.

the *D. uncinatus* sociation being best developed a little to the south of Stinker Point where extensive closed stands covered wide areas of moist gravelly ground. Wherever the ground was uneven, as in areas of low knolls, the *Drepanocladus* mats tended to merge with shallow turves of *Chorisodontium aciphyllum*, *Polytrichum alpestre* and occasionally *P. alpinum* which were characteristic of the drier slopes.

Banks of turf-forming mosses sometimes occurred on level platforms running across scree slopes but they attained maximum development over well-drained stony level to sloping ground. The banks were generally shallow, usually about 20 cm. deep, and only seldom exceeding 40 cm. (Fig. 9). A noteworthy exception was at *c.* 200 m. above Walker Point where an extremely large and deep peat bank, formed by *Polytrichum alpestre* and *Chorisodontium aciphyllum*, measured *c.* 3 m. deep and *c.* 30 m. across on its down-hill side, by *c.* 50 m. in length, although it was only *c.* 30 cm. deep in its upper part (Fig. 10).

Moraines

Moraines were present at many localities but nowhere were they well vegetated. A series of lateral moraines below a large ice fall *c.* 2 km. south-west of Endurance Glacier was sparsely colonized by *Placopsis contortuplicata*, *Rhizocarpon geographicum* and some scattered thalli of *Usnea antarctica*. The upper area was prone to avalanches and this must have had a disruptive effect on the vegetation. By contrast, an *Usnea antarctica* sociation predominated on rock surfaces of an old stable lateral moraine composed of broken rocks ranging in size from small pebbles to large boulders *c.* 0·5 km. south-west of Endurance Glacier. Various bryophyte and lichen assemblages were also noted in crevices amongst the rocks.

A more complex system of moraines occurred above Stinker Point. Here a number of parallel moraines ran more or less from north-west to south-east producing a ridge and trough

Fig. 7. Plant communities on the marine platform, at *c.* 130 m. altitude, on the cape south of Emma Cove. The carpet of vegetation in the foreground is composed of *Drepanocladus uncinatus* with scattered darker cushions of *Andreaea regularis*, while the rock outcrops support species of *Usnea* and various crustose lichens. The plateau in the background is only sparsely vegetated, due to extensive disturbance by various forms of frost action.

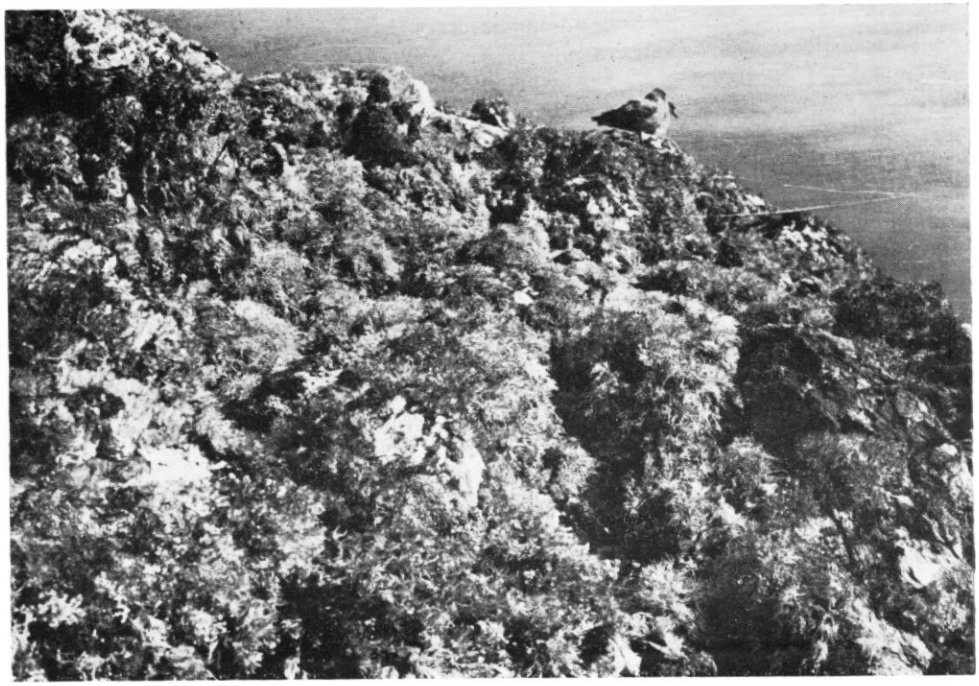

Fig. 8. A well-developed *Usnea antarctica* sociation on a wind-swept rocky ridge, at *c.* 130 m. altitude, about 3·5 km. east of Muckle Bluff.

Fig. 9. Shallow bank of *Chorisodontium aciphyllum* with some *Polytrichum alpestre* on gently sloping rocky ground, at *c.* 120 m. altitude, about 3·5 km. south-west of Walker Point.

Fig. 10. Deep eroded peat bank composed of *Chorisodontium aciphyllum* and some *Polytrichum alpestre* on a moderately steep rocky slope, at *c.* 200–220 m. altitude, above Walker Point. The down-hill face of the bank is 3 m. high.

system. Melt water from the surrounding snow fields percolated into the depressions so that the moist areas of the floors supported mats of *Drepanocladus uncinatus*. On the drier slopes of the ridges the *Drepanocladus* mats were replaced by hummocky turves of *Chorisodontium aciphyllum*, *Polytrichum alpestre* and less frequently *P. alpinum*, while cushions of *Tortula* spp. were also present. Several species of *Cladonia* grew amongst the mosses but no lichens were present amongst the wetter mats of *D. uncinatus*. On the drier and more exposed crests of the moraines communities of the *Andreaea–Usnea* association were usually present.

Screes

Screes, which varied greatly in the size and compactness of their component rock fragments, occurred on most hillsides on Elephant Island. These areas were usually dry, except below late-lying snow patches, and wind-swept so that vegetation was limited mainly to communities of the *Andreaea–Usnea* association. The most prominent of these were the *Usnea antarctica* sociation, the *Andreaea*–lichen sociation, the *Usnea–Himantormia lugubris* sociation and the *Usnea–Himantormia lugubris–Andreaea* sociation. Locally, where the snow patches provided an increase in moisture, bryophyte cover increased and occasionally small cushions of *Grimmia antarctici* occurred in association with species of *Andreaea*.

Shallow turves of *Chorisodontium aciphyllum* and *Polytrichum alpestre*, with several associated epiphytic lichens, sometimes developed on the terraces which occasionally traversed the scree slopes.

Gullies

Several sheltered steep gullies occurred above the shore on the south side of Elephant Island. The flanks of a long gully *c.* 3·5 km. south-west of Walker Point, which led from the beach to a raised platform, supported the best development of vegetation in this type of habitat. On the sheltered sides and ledges least affected by rock falls, species of *Bryum*, *Ceratodon* cf. *grossiretis*, *Drepanocladus uncinatus*, *Grimmia antarctici*, *Tortula conferta*, *T. fuscoviridis*, together with the lichens *Caloplaca regalis*, *Ramalina terebrata* and *Umbilicaria antarctica*, formed mixed communities. A number of gullies *c.* 0·5 km. south-west of Endurance Glacier supported similar mixed stands on their flanks where these were irrigated by drainage water from the higher ground. At the side of one of these ravines the two phanerogams *Deschampsia antarctica* and *Colobanthus quitensis* were noteworthy associates amongst the cryptogams.

Frost-disturbed areas

Frost-disturbed ground occurred on most of the snow- and ice-free areas of the island where there were accumulations of fine glacial detritus. This group of habitats, which is particularly conspicuous in some areas, includes solifluction lobes, stripes, polygons and any ground sorted by frost action.

A number of stone stripes to the south-west of Endurance Glacier had thalli of *Placopsis contortuplicata* growing on the larger rocks, while other stone stripes, which appeared to be more stable, were colonized by cushions of *Andreaea* spp. and large thalli of *Usnea antarctica*.

Large areas of sorted polygons and stone stripes were particularly evident on the two exposed headlands comprising Cape Lindsey and the cape on the south side of Emma Cove (Figs. 11 and 12). *Drepanocladus uncinatus*, *Placopsis contortuplicata* and less frequently *Andreaea depressinervis* and *A. regularis* were the only species recorded on these high wind-swept headlands which receive little protection from snow cover.

Stream and pool margins

Wherever there was a regular source of moisture, extensive bryophyte-dominated stands developed. Although such communities occurred in damp depressions and on wet cliff faces, the best-developed stands comprised carpet-forming mosses occupying the margins of melt streams and pools. For example, the *Brachythecium* cf. *antarcticum* sociation was restricted to this type of habitat. But as the substratum became drier there was usually a sharp transition from pure closed stands of the *Brachythecium* to pure closed stands of *Drepanocladus uncinatus*. The largest melt-water pool on Elephant Island measured *c.* 100 m. in length and *c.* 15 m.

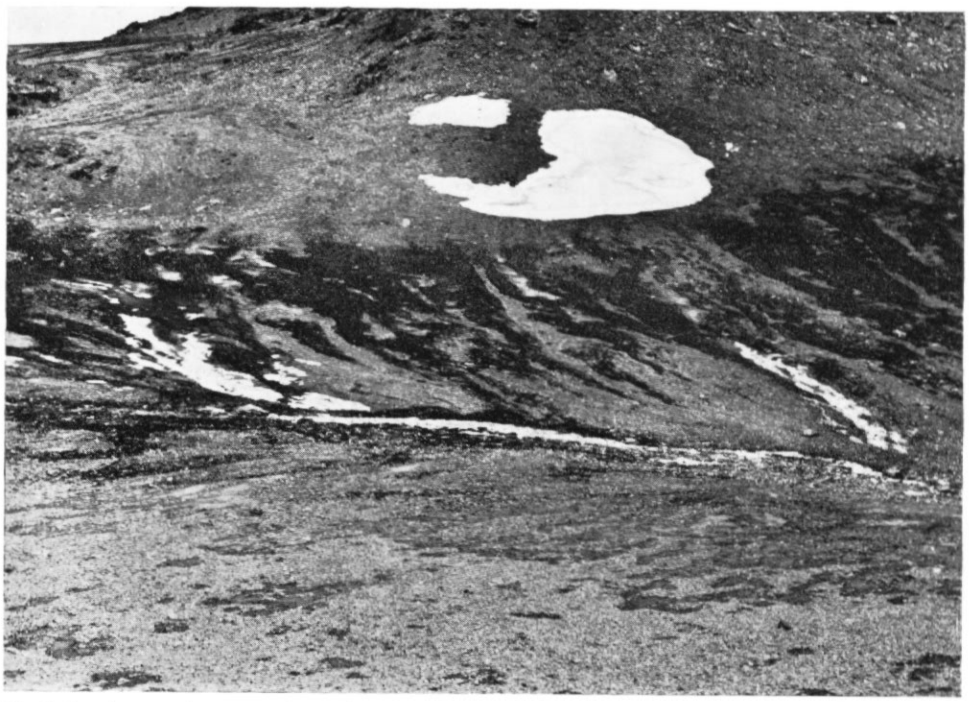

Fig. 11. Soil stripes, polygons and a melt stream in a broad valley, at *c.* 120 m. altitude, on the cape south of Emma Cove. The light grey patches in the foreground are clay fines in the centres of sorted polygons, while the dark areas on the hillside beyond are stands of the *Drepanocladus uncinatus* sociation.

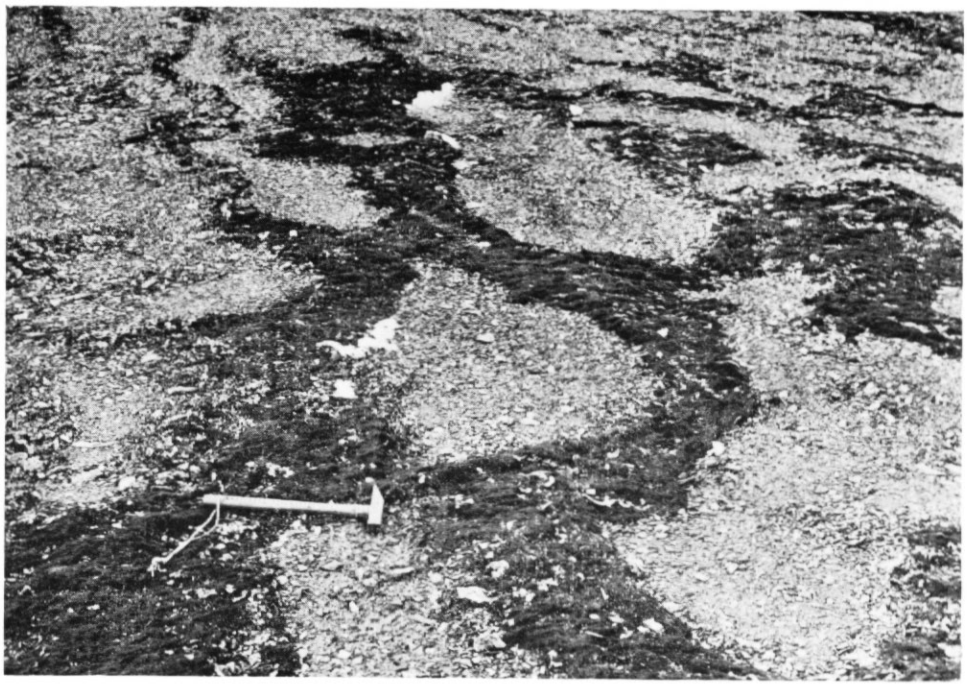

Fig. 12. Sorted solifluction lobe surrounded by *Drepanocladus uncinatus*, at *c.* 130 m. altitude, on the cape south of Emma Cove. The geological hammer is 30 cm. in length.

wide, and was situated near Stinker Point at the foot of a permanent snow slope. The entire margin of one side of this pool was surrounded by a zone of *Brachythecium* cf. *antarcticum* 3·5–4 m. wide. *Prasiola crispa* was a common constituent of the melt channels.

Areas influenced by biotic agents

Biotic influence was normally localized and entirely due to sea birds with the best example being a large area of degraded vegetation around a penguin rookery south-west of Walker Point (see below). Boulders used as bird perches were covered by lichens of the *Caloplaca regalis–Haematomma erythromma–Xanthoria elegans* sociation, while coalesced thalli of species of *Caloplaca* occurred below ledges and crevices used as nesting sites by cape pigeons and snow petrels (*Pagodroma nivea*). The nests of giant petrels consisted of pebbles and *Prasiola crispa* was the only species observed in heavily trampled areas around the nest sites. In contrast, there was very little degradation of vegetation around the nests of skuas, birds which create bowl-shaped depressions in *Polytrichum–Chorisodontium* turves by pulling out the upper parts of stems which are left scattered around the nest site. Although Dominican gulls (*Larus dominicanus*) accumulate limpet shells around their nests, no calcicole plants were recorded in these situations as has been reported from sites on the Antarctic Peninsula and Signy Island by Gimingham and Smith (1970).

It appeared that the size of the chinstrap penguin rookery (*Pygoscelis antarctica*) *c.* 3·5 km. south-west of Walker Point had recently increased, since banks of *Chorisodontium aciphyllum* and *Polytrichum alpestre* close to its edge showed successive stages of degeneration from healthy, virtually unaffected banks to areas of severely eroded moss peat. Within this rookery, apart from scattered colonies of *Prasiola crispa* in wet muddy areas and occasional thalli of *Mastodia tesselata* on wet rocks, the most heavily populated areas were devoid of plant life due to the constant trampling by the penguins and the thick layer of mud and guano covering the ground. Occasional small patches of dead moss were observed still attached to the substratum but they were steadily being covered by guano and regurgitated food. The rocky area immediately outside the rookery was also barren due to trampling. Beyond this, a zone of *Prasiola crispa* had developed on, or around, small moribund turves of *Chorisodontium aciphyllum* and *Polytrichum alpestre*, but this gave way to a zone of eroded hummocky turf, so severely streaked with droppings that only a few live green stems were visible. However, outside this zone the vegetation was entirely green and healthy, and appeared to be unaffected by the penguins except where they approached the rookery by well-defined paths. Elsewhere the moss banks were used as resting places by penguins and in these situations the turves became broken by trampling and showed signs of degenerating. An analysis of soil samples collected at intervals along a transect from within the rookery to the unaffected vegetation has already been given in Table V.

Discussion and Summary

As a result of the botanical work undertaken during 1970–71, the number of mosses and lichens known from the Elephant and Clarence Islands group has risen from seven mosses and six lichens to 25 mosses and 48 lichens. In addition, seven species of liverwort, two species of angiosperm and one alga are now also known from the group of islands. Only one species, the moss *Orthotrichum crassifolium*, was found on a neighbouring island but not on Elephant Island, although a number of species on that island are known from only single localities. The discovery of *Alectoria nigricans* var. *implexiformis* on Elephant Island is noteworthy since it was previously not known farther south than Signy Island. Most species had a wide distribution and it is of interest to note that *Chorisodontium aciphyllum*, *Placopsis contortuplicata* and *Usnea antarctica* occurred as high as 465 m., *c.* 3 km. north-east of Endurance Glacier, while 12 species of moss and lichen were recorded at about 400 m. near Walker Point. Both flowering plants, *Colobanthus quitensis* and *Deschampsia antarctica*, were seen at about 200 m.

Although the flora was richer than anticipated, there are several notable omissions when comparison is made with that of other islands in the South Shetland and South Orkney Islands. Thus species of *Calliergon*, *Cornicularia*, *Marchantia*, *Nostoc*, *Pottia* and *Racomitrium* appeared to be absent as were *Polytrichum juniperinum*, *P. piliferum* and *Umbilicaria decussata*,

all of which are relatively common in one or both of these island groups. However, it is possible that some species were overlooked in areas which received inadequate survey.

The discovery of quite extensive areas of snow-free ground in several localities, notably at Cape Lindsey, at Stinker and Walker Points and on coastal areas on either side of Endurance Glacier, provided an unexpectedly wide range of habitats in which locally extensive plant communities had developed. But due to instability of the substratum in many areas, vegetation was sparse and consisted of open stands of bryophytes and lichens, although wherever there was a continual source of moisture or some degree of shelter from wind, coalescence occurred to give a closed cover of vegetation. Such vegetation occurred mainly on headlands, raised marine beaches and platforms, screes and rock faces on the south coast of the island and it is thought to be the absence of suitable habitats on the precipitous and more exposed north coast which has prevented the development of extensive stands of vegetation in that area. A similar restriction of vegetation to the southern side of certain other of the South Shetland Islands has been noted by Lindsay (1971) and to the southern side of Coronation Island (South Orkney Islands) by Smith (1972).

The most critical environmental factor affecting the distribution and development of vegetation on Elephant Island appeared to be water availability, a situation similar to that which has been emphasized by workers in other regions of the maritime Antarctic, for example, Lindsay (1971) and Smith (1972). Melt pools and streams were few on Elephant Island but where they occurred there existed some of the most extensive closed stands of vegetation of the carpet-forming mosses *Brachythecium* cf. *antarcticum* and *Drepanocladus uncinatus*. In less wet habitats, usually where there was some shelter and often a northerly aspect, the turf-forming species *Chorisodontium aciphyllum* and *Polytrichum alpestre* had built up shallow banks of fibrous peat, the most notable being at Walker Point where the depth of peat exceeds anything so far observed within the Antarctic botanical zone. However, the most frequent assemblages occurred on dry, exposed stony ground and formed extensive open or, less commonly, closed communities in which species of *Andreaea*, *Usnea* and various other lichens predominated. Areas where the freeze-thaw action of frost subjected the ground to continual disturbance were generally devoid of vegetation, but in the more stable marginal zone of coarser material *Placopsis contortuplicata* was frequently abundant. Coastal rocks and cliffs were often encrusted with lichens particularly where there was some degree of nitrogen enrichment from colonies of sea birds. Elsewhere large rookeries of chinstrap penguins occupied flat or sloping ground to a maximum altitude of 210 m. and *Prasiola crispa* was the only plant species able to tolerate the excessive trampling and high concentration of mineral ions in these areas.

The composition and development of the plant assemblages on Elephant Island, and its neighbouring islands, are closely comparable with the communities described from elsewhere in the South Shetland and South Orkney Islands, and at a number of localities along the west coast of the Antarctic Peninsula (Gimingham and Smith, 1970; Lindsay, 1971; Smith, 1972). While many communities had clearly defined boundaries, generally related to changes in particular environmental factors, others tended to show little consistency in composition from one site to another and seemed to represent assemblages comprising two or more over-lapping communities. Although many different community types were recognized, it appeared that the vegetational units intergraded to form a continuum similar to that suggested by Smith (1972) for the vegetation of Signy Island.

An attempt to place the Elephant Island community types into the classification system developed by Smith (1972) for Signy Island was achieved with some success and led to the recognition of five previously undescribed sociations. Of these, one belonged to the *Andreaea–Usnea* association and one to the *Polytrichum alpinum* association, while the other three may be incorporated in associations of the crustose lichen sub-formation. All bore a distinct resemblance to sociations already described from Signy Island. Thus the *Usnea–Himantormia lugubris–Andreaea* sociation, which occurred locally on scree slopes, was very similar to the *Usnea–Himantormia lugubris* sociation which on Signy Island has low *Andreaea* cover, but on Elephant Island the *Andreaea* cover was considerably greater and may contribute as much as 20 per cent. The *Caloplaca regalis–Haematomma erythromma–Xanthoria elegans* sociation of rock outcrops and boulders used as perches by sea birds is known from Signy Island as

diminutive stands and, because of its poor representation, was not described as a distinct sociation by Smith.

Elsewhere from the South Shetland Islands, Lindsay (1971) has described three ornithocoprophilous lichen sociations, while from the South Orkney Islands Smith (1972) has described a further three sociations, in all of which species of *Caloplaca*, *Haematomma erythromma*, *Xanthoria elegans* and other nitrophilous lichens were prominent. However, in the absence of quantitative species lists for most of these assemblages, detailed re-investigation of this series of lichen communities is essential before the phytosociological nomenclature can be revised.

The *Polytrichum alpinum*–lichen sociation of dry stony terrain appeared to represent a transitional community between open *P. alpinum* stands and lichen-dominated sociations of the *Andreaea–Usnea* association.

The remaining two sociations were dominated by *Placopsis contortuplicata* and were widespread on the stable margins of sorted stone stripes and polygons. Both the *Placopsis contortuplicata–Drepanocladus uncinatus* sociation and the *Placopsis contortuplicata–Drepanocladus uncinatus–Andreaea* sociation represented an intergradation between two sociations but, since both appeared to be relatively consistent in their composition over the island, these transitional communities have been given sociation status although, as noted earlier, they do not strictly belong to the crustose lichen sub-formation.

Because of the absence on Elephant Island of base-rich rocks or soils, such as the tuffs and lavas of other members of the South Shetland Islands or the marble outcrops of Signy Island, no communities comprising calcicolous species were seen. However, the typical *Tortula–Grimmia antarctici* association of base-rich areas on Signy Island was represented by very small open stands on some moraines where the glacial detritus was locally enriched. It was especially noteworthy that no calcicolous communities were seen on the ultrabasic rocks of Gibbs Island or the volcanic rocks of Bridgeman Island.

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APPENDIX

BOTANICAL LOCALITIES ON ELEPHANT ISLAND AND NEIGHBOURING ISLANDS WITH THE NUMBERS OF SPECIMENS COLLECTED

Locality	*Approximate altitude* (m.)	*Description of site*	*Extent of vegetation*	*Specimen numbers of collections* (1–246*)
Elephant Island				
2 km. south-west of Endurance Glacier	120–155	Gentle slope with stable rocks leading up-hill to a steep loose scree with large boulders	Foliose and crustose lichens only. Small stands of turf- and hummock-forming mosses	18–37, 44–55
0·5 km. south-west of Endurance Glacier	305	Large hill running north–south with scree and occasional solifluction stripes on slopes	Most of the area was vegetated, the slopes supporting open stands of the *Andreaea–Usnea* association	38–43, 56–60, 63, 64, 163, 164, 224, 241
	60	Several narrow gullies in the steep eastern face of the previous locality	Central mobile areas were barren but more stable flanks supported a variety of lichens, cushion mosses and scattered *Colobanthus quitensis* and *Deschampsia antarctica*	66–73
	245	North–south-running flat-topped elongated hill. Extensive areas of solifluction, soil stripes and frost-shattered rock	Only in the crevices and on the surface of large stable rocks	61, 62, 165–180
	180	Stable lateral moraine with fine loose mineral soil and rock fragments	Rocks covered by species of *Usnea* but otherwise vegetation mainly in the crevices	142–162
Cape Lookout area	80	Small area of sheltered snow-free ground	Extensive moss cover although only *Drepanocladus uncinatus* identified (personal communication from G. Bruce)	–
0·5 km. south-east of Stinker Point	120	Extensive sheltered, level area with a large melt pool. Numerous morainic ridges higher and farther inland	Extensive areas of carpet mosses, with several lichen and moss communities on the headlands and moraines	74–102, 113–118
	80	Small cove immediately to the west of previous locality. Steep cliffs supplied with water from snowfields above	North and north-west slopes below snowfield well vegetated by lichens and moss cushions	103–112
Cape Lindsey and cape on south side of Emma Cove	130	Two promontories to north and south of Emma Cove. Southern cape is a flat-topped platform with extensive areas of frost-sorted ground, while Cape Lindsey is smaller and narrower, both having steep unstable cliffs	Devoid of vegetation except for *Placopsis contortuplicata* association on surface of stable stones and bryophytes and lichens on the knolls at both ends of the southern cape	119–141
Cape Yelcho area	80	Snow-free ground confined to cliffs and cliff tops	Barren except for scattered thalli of a species of *Usnea* (personal communication from R. Y. Roxburgh)	–
1 km. west of Cape Belsham	185	Snow-free rocky headland	Vegetation sparse; four species of lichen and two species of moss observed (personal communication from E. C. Walshaw)	246
Cape Belsham	240	Narrow headland with steep rocky slopes	No vegetation (personal communication from E. C. Walshaw)	–
Point Wild	5	Low-lying promontory	A few scattered stems of a species of *Polytrichum* (personal communication from E. C. Walshaw)	–
Cape Valentine	sea-level–240	Narrow storm beach backed by steep cliffs	Some crustose lichens on cliffs	–
Walker Point	200–230	Two snow-free hills with extensive scree and some level areas. A ridge from one hill runs inland with a series of wind-swept snow-free crests	Large stands of turf-forming mosses with one extensive peat bank reaching 3 m. in depth. Lichen and moss communities also well developed	201–204
3·5 km. south-west of Walker Point	120–220	Raised platform partly surrounded by cliffs. A slope rises inland to a snow-free ridge	Platform supported large areas of turf-forming mosses. A variety of species were found on the cliffs and slope. Some of the area disturbed by penguins	181–194, 205–207, 213–223, 232, 242, 243
3·5 km. east of Muckle Bluff	275	A large hill running north–south with scree on the slopes. Below these the area is level and well irrigated	Hill sparsely vegetated except for one area of mixed moss and lichen communities with some *Deschampsia antarctica*. *Polytrichum–Chorisodontium* banks and *Deschampsia antarctica* on lower ground	195–200, 208–212, 244, 245
6·5 km. west of Muckle Bluff	250	Small snow- and ice-free hill with a level summit and a scree with scattered large boulders on the slopes	Isolated communities in crevices on slopes but extensive cover by *Andreaea–Usnea* and *Polytrichum–Chorisodontium* associations on the summit	–
Other islands				
Bridgeman Island	10	Open ground around triangulation station	Open communities of mosses and lichens (personal communication from R. J. Campbell)	236–240
Clarence Island	150	Gentle scree slopes around Chinstrap Cove	Mixed communities, *Andreaea–Usnea*, crustose lichen and crevice assemblages (personal communication from J. F. Hunt)	1a–l 2a–j
	135	Large area of snow-free ground near Chinstrap Cove	Mainly lichens with extensive cover of *Umbilicaria antarctica* (personal communication from R. Y. Roxburgh)	225–230
Eadie Island	10	Loose gravelly soil around triangulation station	Sparse plant cover; mainly lichens and *Prasiola crispa* (personal communication from R. J. Campbell)	231, 233–235
Gibbs Island	260–300	Large area of sheltered snow- and ice-free ground near triangulation station at eastern end of island	Some *Drepanocladus uncinatus* mats but mainly crustose lichens on the rock surfaces	3–16
	300	Open ground confined to boulders and ridge crest protruding above snowfield at western end of island	Only vegetation was formed by a species of *Lecidea*	17

* Specimen number 65 absent.

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