REPORT ON ANTARCTIC FIELDWORK

PLANT ECOLOGICAL STUDIES IN THE FELLFIELD ECOSYSTEM NEAR CASEY STATION, AUSTRALIAN ANTARCTIC TERRITORY, 1985–86

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ABSTRACT. An ecological and ecophysiological study of the fellfield vegetation near Casey Station, Australian Antarctic Territory, was undertaken in the 1985–86 summer. Much of the research was concentrated in the newly designated Bailey Peninsula SSSI close to the station where the vegetation is exceptionally well developed and comprises a relatively diverse cryptogamic flora (3 moss, 1 liverwort and at least 25 lichen taxa) in terms of the continental Antarctic terrestrial ecosystem. The study included both autecological investigations of the dominant species (especially growth and water relations), and synecological investigations of change in community structure along environmental gradients, and also a phytosociological assessment of the fellfield ecosystem as a whole. Various laboratory experiments were undertaken to test the viable buried propagule bank by culturing samples of unvegetated soil, while the success of bryophyte fragments as colonizing propagules was assessed on fellfield soil treated with various forms of nitrogen. These experiments are being continued in UK. The rate of water loss and volume of water uptake in the dominant macrolichens and mosses was determined in laboratory experiments under relatively controlled conditions to relate to their ecological distribution, niche preference and their photosynthetic and respiration activity as determined in a separate study. The change in floristic structure and composition in relation to moisture availability, wind exposure and substrate quality was assessed in contiguous quadrats along transects across sites exhibiting distinct environmental gradients. Samples of soil and vegetation were taken at intervals along the transects for physical and chemical analyses. Continuous monitoring of surface and sub-surface temperatures and, in some instances of atmospheric relative humidity and exposure (in terms of water loss) along these gradients indicated that vegetation in summer can be subjected to very large diel fluctuations, occasionally exceeding 50°C, thereby probably imposing severe physiological stress on the plants and invertebrates inhabiting such niches. The vegetation of the region comprises numerous closely related community types, many of which have virtually identical species composition but differ in the abundance of certain species. An approximate age for the dense lichen stands may be postulated from radiocarbon dates obtained for egg-shell fragments buried in accumulations of pebbles representing former penguin colonies.

INTRODUCTION

The Windmill Islands lie in the north of Vincennes Bay, Budd Coast, Wilkes Land. They comprise many low and largely ice-free islands, composed of migmatites, gneisses and granites (Robertson, 1959), close to the coast of continental Antarctica, several of which are joined to the mainland by thick permanent icesheets extending from the polar plateau, transforming them into 'peninsulas' (Hollin and Cameron, 1961). The Australian Casey Station (lat. 66° 17′ S, long. 100° 32′ E), established in 1969, is located on the north-west corner of Bailey Peninsula; the former Australian (originally American) Wilkes Station, established in 1957, is situated on the south-west corner of Clark Peninsula, 2.5 km to the north across Newcomb Bay.

Excluding the Antarctic Peninsula the terrestrial ecosystem on Bailey and Clark Peninsulas has, as far as is known, the most extensive and best developed plant communities on continental Antarctica. Here, many hectares of windswept ice-free terrain support a relatively diverse cryptogamic flora which forms dense stands of macrolichens, while in moister more sheltered situations bryophytes are abundant and locally form closed stands of 25–50 m^2 comprising a moss turf up to almost 30 cm depth. For this reason, large representative areas of the two peninsulas have been designated SSSIs (see Bonner and Smith, 1985, p. 297). That on Bailey Peninsula covers approximately 0.5 km^2 and lies about 0.5 km south of Casey Station; that on Clark Peninsula covers approximately 12 km^2 and lies about 0.7 km north-east of the now abandoned Wilkes Station.

Research on the terrestrial and freshwater biota of this biologically rich region has been confined mainly to the collection of various groups of plants and invertebrates and to taxonomic assessments of these. Little of this work has yet been published, e.g. Dodge (1965, 1968), Filson (1974) – lichens, Seppelt (1983) and Seppelt and others (in press) – bryophytes. A brief general account of the vegetation was provided by Llano (1959). The only ecological study is an analysis of change in plant distribution along a moisture gradient in the Bailey Peninsula SSSI (Seppelt and Selkirk, in press). No invertebrate, microclimate or edaphic data are available.

The biological importance of Bailey and Clark Peninsulas has only recently been recognized and it is the intention of Australia's Antarctic Division to develop a continuous research programme in the SSSI on Bailey Peninsula. This site had already undergone considerable disturbance and unintentional contamination before being designated an SSSI. Future research on various aspects of the terrestrial ecosystem will have the opportunity to compare the influence of the nearby Casey Station, and the new station currently being built 0.7 km to the south-east, with the virtually identical ecosystem on the unperturbed Clark Peninsula.

The work reported here was undertaken at Casey Station between 30 October 1985 and 16 January 1986 at the invitation of the Australian Antarctic Division. It was carried out as part of an international collaborative research programme by plant ecologists from Australia, West Germany and United Kingdom and established the basis of a long-term series of projects to be undertaken near Casey Station. Some of the work by the author was directly comparable to that carried out during the previous summer at Signy Island, South Orkney Islands, as part of the British Antarctic Survey Fellfield Ecology Research Programme (Smith, 1985). This account presents a summary of the research carried out and some provisional generalized results.

The primary aims of the project, most of which was carried out in the Bailey Peninsula SSSI, were:

(1) To examine the process of cryptogamic colonization by testing the soil for viable plant propagules and the ability of bryophyte fragments to establish new plants on fellfield soils.

(2) To investigate the growth rate of each moss species *in situ*.

(3) To study the water relations of the principal macrolichens and mosses to provide a possible physiological basis for their micro-distribution in the field.

(4) To examine the change in community structure along environmental gradients and provide continuous temperature data to demonstrate the fluctuating conditions under which plants in different niches are subjected.

(5) To carry out a phytosociological assessment of the fellfield ecosystem on the two peninsulas.

Because of the very basic laboratory facilities available at Casey Station, the short period (10 weeks) spent there and the early commencement of investigations, most experimental work was under-replicated.

METHODS

1. Bryophyte colonization

(*a*) *Soil propagule bank* in situ. For the purpose of assessing the potential propagule bank of fellfield soils, four sub-sites of fine soil devoid of macroscopic vegetation were chosen, on each of which four 20 × 20 cm quadrats were marked out within an area of about 2 m². Locating suitably large barren areas early in the season proved difficult, yet by mid-summer many extensive areas of unvegetated patterned ground were revealed by the melting snow. Two of the sub-sites represented unperturbed natural substrata, one an elongated frost-heave feature outside the SSSI and the other on a similar feature near the shore of a small melt lake within the SSSI. The other two sub-sites were in a large area of the SSSI which had had the surface material removed for road construction (Fig. 1). These were selected to provide an indication of the recovery potential of perturbed areas. One was in a relatively sheltered hollow and the other on the crest of an exposed slope. At each sub-site 400 cm² quadrats were marked with orange tipped pegs; two were covered by clear polystyrene cloches to maintain high humidity and increase air temperature during daytime and two left exposed as controls. One control and one cloche quadrat was treated twice weekly with a nutrient solution providing both nitrate and ammonium as well as Ca, Mg, K and P. The experiment is intended to continue for several years to follow the development of any buried cryptogamic propagules and to compare the effects of increasing the nutrient status and providing a more favourable microclimate.

(*b*) *Soil propagule bank in cultures*. Samples of the top 1 cm of the soils from each of the sub-sites were cultured in closed, deep, clear polystyrene boxes in the laboratory at Casey Station. Natural illumination from a window was provided, but did not exceed 150 μE m^{-2} s^{-1}, at a room temperature 2–5°C at night and 5–10°C during the day. For each soil one dish was treated with deionized water and a duplicate dish treated with the same nutrient solution as for the field experiment. After eight weeks the dishes were returned to BAS, Cambridge, to continue incubation.

(*c*) *Growth and development of bryophyte shoot fragments*. To test the capability of bryophyte fragments to serve as viable propagules which can disseminate species and establish new colonies, the apical 1–2 mm of healthy bryophyte shoots were cut off and sown on a sterilized fellfield soil which had been passed through a 2 mm sieve. The fragments had been treated with Actidione to suppress fungal contamination; the soil was contained in small deep Petri dishes. For each of the four species (the mosses *Bryum algens*, *Ceratodon purpureus* and *Schistidium antarctici* and the liverwort *Cephaloziella varians*) duplicate sets of dishes were treated weekly with deionized water, melt water from a lake, and nutrient solutions containing nitrate or ammonium as the nitrogen source, and both nitrogen salts. The dishes were provided with the same light and temperature conditions as (*b*) above. These cultures were returned to England to continue the experiment.

Fig. 1. One of four sites where colonization of bare soil is being studied over several years. All former vegetation at this site had been removed by quarrying and its recovery will be assessed. The cloches provide an enhanced microclimate for the development of plant propagules buried in the soil. Bailey Peninsula SSSI.

2. In-situ moss growth

Growth *in situ* of the three moss species was assessed using a modification of the 'growth bag' technique used by Smith (1982). Because of the fragile nature of the moss shoots, their short stature, small annual increments and extremely dense packing (up to 1850 cm^{-2} in *Schistidium*), it was very difficult to separate individual shoots longer than about 1 cm and pack them in nylon mesh bags in the density encountered in the field. Consequently, series of 25 shoots cut to a precise length were placed along a strip of moist filter paper which was then carefully folded several times to create a flat roll with the apices just free of the top. Rolls were held together using fuse wire. They were then inserted into colonies of the corresponding species in the field with the apices level with those of the natural turf. The experimental shoots maintained close contact with the colony shoots and immediately responded to any fluctuations in the moisture regime of the colony turf since the filter paper reacted exactly as the fine moss shoots. Ten replicate sets of shoots for each species were placed in the field before the spring melt commenced and were removed in late summer for measurement and dry weight production of any new growth.

3. Lichen and moss water relations

The rate of moisture loss and volume of water uptake by individual fruticose lichens (*Alectoria minuscula*, *Usnea antarctica*, *U. sphacelata*) and foliose lichens (*Umbilicaria decussata*, *U. propagulifera*) thalli, and individual shoots and small colony samples of mosses (*Bryum*, *Ceratodon*, *Schistidium*) was investigated in the laboratory.

(*a*) *Water loss*. Samples of moss and lichen were kept on moist tissue paper in a sealed container for two days to ensure that plants were turgid, before being suspended by fine wires in the laboratory in which room conditions were maintained at a fairly constant 10°C and 40% relative humidity. 10–15 replicates per species were studied in each experiment. The initial fresh weight of the samples was determined and subsequent weighings were taken quickly at 10-minute intervals over the first hour, at half-hourly intervals over the next two hours, at hourly intervals for a further six hours, and at 12-hourly intervals over the next one to two days. Loss in sample weight caused by transpiration was calculated as a percentage of the final oven-dry weight.

(*b*) *Water uptake*. Samples were air dried for two days in the laboratory (*c*. 2–10°C, 40–45% RH), then attached by fine wires and suspended in a sealed 2 l conical flask containing 250 ml water. This maintained a saturated atmosphere, which was monitored twice a day with a relative humidity sensor. Ten samples per species were studied in each experiment. The initial dry weight of the samples was determined and subsequent weighings were quickly taken 12, 24, and occasionally 36 and 48 hours after the commencement of the experiment. Each increase in sample weight caused by absorbed moisture was calculated as a percentage of the final oven-dry weight.

4. Environmental gradient transects and microclimates

The change in plant community composition in relation to changes in microrelief, substrate quality, exposure and water availability was investigated in detail at three sites. Contiguous quadrats ranging from 100 cm² (over a lichen dominated erratic) to 625 cm² (on bryophyte-dominated stony ground) were analysed along transects (6–16 m long) and the percentage cover afforded by all species was recorded. Soil and vegetation samples for moisture determinations and chemical analyses were taken at intervals along the transects. To relate the pattern of distribution of the dominant species to microclimatic factors soil, rock and vegetation temperature and atmospheric humidity were recorded using two Grant Squirrel data loggers (one with two temperature and two humidity channels, the other with 16 temperature channels). Temperatures were recorded by small metal and fine flexible mini thermistors (range −50° to 50°C), and humidity by capacitative Vaisala probes (range 0–100%). Recordings were made on micro-cassette tapes at 10-minute intervals for up to three weeks at a site; the loggers interfaced with an Epson HX-20 microcomputer in the field and the data down-loaded every three to five days for subsequent analyses. Because much of the SSSI is situated within the extensive array of radio transmitter aerials much static electricity is generated throughout the site. This caused considerable problems with the electronic components of the data loggers and many days of operation were lost while repairs where carried out on the equipment. This reduced the number and length of recording periods intended and also restricted the use of the RH sensors. Relative exposure along the transects was measured for periods of 8–10 hours using small evaporimeter tubes filled with distilled water and with wicks exposed 1 cm above the rock or vegetation surface. Loss in weight of the water was directly related to the degree of exposure to wind.

Several other short transects were analysed without monitoring microclimate, while some, using 10 cm by 2 cm quadrats, were placed across periglacial features to assess the micro-distribution of species in relation to substrate texture and stability.

Table I. Provisional list of bryophytes and lichens recorded from Bailey Peninsula SSSI.

Mosses	
Brum algens Card. (= *B. pseudotriquetrum* (Hedw.) Schwaegr.)	f–a
Ceratodon purpureus (Hedw.) Brid.	a
Schistidium antarctici (Card.) Sav.-Lyub. et Z. Smirn. (= *Grimmia antarctici* Card.)	a
Liverworts	
Cephaloziella varians (Gotts.) Steph. (= *C. exiliflora* (Tayl.) Steph.)	f
Lichens	
Alectoria minuscula (Nyl. ex Arnold) Degel (= *Pseudephebe minuscula* (Nyl. ex Arnold) Brodo & Hawksw.)	a
Acarospora gwynni Dodge & Rudolph	vr
Biatorella antarctica Murray (= *B. cerebriformis* Filson)	vr
Buellia frigida (Darb.) Dodge	a
Buellia grimmiae Filson	f
Buellia cf. *lignoides* Filson	o–f
Buellia soredians Filson	a
Caloplaca athallina Darb.	f
Caloplaca citrina (Hoffm.) Th. Fr. (= *Pyrenodesmia mawsonii* Dodge)	o
Candelariella antarctica Filson (= *Protoblastenia citrina* Dodge)	f
Lecanora expectans Darb.	o
Lecanora melanophthalma (Ram.) (= *Rhizoplaca melanophthalma* (Ram.) Leuck & Poelt; = *Lecanora rubina* var. *melanophthalma* (Ram.) Zahlbr.)	o
Lecidea phillipsiana Filson (= *L. andersonii* Filson)	o–f
Lecidea sp. (grey)	o
Physcia caesia (Hoffm.) Hampe (= *Parmelia coreyi* Dodge & Baker)	vr
Rhizocarpon flavum Dodge & Baker	vr
Rinodina olivaceobrunnea Dodge & Baker (= *R. archaeoides* H. Magn.)	f–a
Rinodina turfacea (Wahlenb.) Korb.	o–f
Umbilicaria decussata (Vill.) Zahlbr.	a
Umbilicaria cf. *propagulifera* (Vainio) Llano	o
Usnea antarctica Du Rietz	f–a
Usnea sphacelata R. Br. (= *U. sulphurea* (Koenig) Th. Fr.)	va
Xanthoria candelaria (L.) Th. Fr. (= *X. mawsonii* Dodge)	o
Several unidentified crustose taxa	
Additional lichens on Bailey Peninsula	
Buellia cf. *cladocarpiza* Lamb	f
Xanthoria elegans (Link) Th. Fr. (= *Caloplaca elegans* (Link) Th. Fr.)	vr

With the exception of *Acarospora gwynni* and *Rhizocarpon flavum* all the above taxa were recorded in the Clark Peninsula SSSI, together with *Buellia* cf. *subpedicellata* (Hue) Darb. and *Rinodina* cf. *petermannii* (Hue) Darb.

a, abundant; f, frequent; o, occasional; r, rare; prefix v, very.

Species names in parentheses are frequently-used synonyms.

5. *Plant community analysis*

An analysis of the vegetation throughout Bailey Peninsula, but mainly within the SSSI, and also within the SSSI on Clark Peninsula was carried out to assess the floristic composition and environmental relationships of the various communities. At each of 60 sites relatively uniform stands were subjectively selected and twenty 625 cm^2 quadrats placed at random points on a grid within the site, which ranged from 25 to 100 m^2. Visual estimates of percentage cover afforded by all species present in each quadrat was recorded so that mean cover and frequency of occurrence data could be determined for each site. The data will be analysed by computer using classification and ordination programs. During the course of this study, collections of plants were made, under permit within the SSSIs, throughout the region to provide a general indication of the composition, distribution and ecology of the flora. A provisional list of the species recorded is given in Table I.

Results

1. *Bryophyte colonization*

(*a*) *Soil propagule bank* in situ. After ten weeks no visible colonization had occurred either in the control plots or within the cloches, but development will be followed over the next few years if possible.

(*b*) *Soil propagule bank cultures.* Within about three weeks several of the soil cultures treated with nutrients developed extensive micro-algal growth, while the corresponding soils treated only with water did not yield visible algae until two to three weeks later. After about five to six weeks a few shoots of *Bryum* appeared on the nutrient treated soils, but the experiments will continue for at least three months at BAS to assess any further bryophyte growth. Although far fewer viable bryophyte propagules appear to be buried in these soils, the results are very similar to those obtained on Signy Island (Smith, in press).

(*c*) *Growth and development of bryophyte shoot fragments.* After seven weeks' culturing on all the soil treatments, a large proportion of the *Bryum*, *Ceratodon* and *Cephaloziella* fragments had become established and were producing growth by shoot extension or new shoots from the original pieces. *Bryum* and *Ceratodon* quickly developed rhizoids and new growth within two to three weeks, while *Cephaloziella* took about five weeks before any significant growth was apparent. Although the experiment will continue for several months to assess the long term response to the different nitrogen treatments, there appeared to be no significant difference in the proportion of shoots which became established or the amount of growth between the different treatments, suggesting that these plants are adapted to growing well on the typically nitrogen-deficient fellfield soils. No growth was recorded on any treatment for *Schistidium*; it is possible that the initial treatment with Actidione may have killed the fragments, although it did not affect the other species.

2. *In-situ moss growth*

No data are yet available for this experiment.

3. *Lichen and moss water relations*

No data are yet available but it is hoped they will reveal differences in the water relations between species which will relate to their physiological performance (as determined by Professor L. Kappen in his detailed study of photosynthesis and respiration in these plants during the same period), and also to their ecological preferences and tolerances.

4. *Environmental gradient transects and microclimates*

The principal factors responsible for the distribution of vegetation on Bailey and Clark Peninsulas are exposure to wind and availability of water. Bryophytes are widespread with scattered colonies growing on soil amongst stones. However, closed stands of moss turf are restricted to sheltered depressions and melt runnel margins which are deeply covered by snow in winter and well irrigated during the short summer by melting snow. On dry well drained surfaces the mosses assume a cushion growth form, with *Schistidium* developing almost spherical colonies around a core of soil detached from the substratum, on dry rock ledges. Besides growing in fissures in rocks, mosses do not grow as lithophytes. On all rock surfaces lichens are usually abundant, but only on the leeward faces, the windward sides being totally unvegetated except in crevices, as a result of abrasion by ice and soil particles. The prevailing winds are from the east and the appearance of a boulder-field looking west often reveals no vegetation, yet looking in the opposite direction the rock surfaces are densely covered by black *Usnea sphacelata* up to the crest of each boulder. This lichen, together with *Alectoria minuscula* and *Umbilicaria decussata* and crustose taxa, also forms dense stands on glacial deposits of smaller stones and pebbles. The change in distribution and abundance of the principal bryophyte and lichen species along these environmental gradients reflects their ecological requirements and tolerances.

Temperatures recorded in and below the surface of moss turf and lichen (*Usnea sphacelata*) thalli at points along three of the transects suggest that the plants are subjected to very large diel fluctuations which must cause severe physiological stress. Professor Kappen's study of photosynthesis in six lichen and one moss species revealed no metabolic activity above 25°C, so that when plant temperatures exceed this they become totally inactive, although they remained active at temperatures down to around −5°C. Block (1985), working at sites in Ross Dependency 10–12° latitude farther south than Casey Station, reported that such microsites, as habitats for arthropods, did not appear to be thermally stressful but that atmospheric water vapour may be limiting. From the present study it is suggested that moss and lichen niches very likely are both thermally and hydrologically stressful to both plants and invertebrates. For example, during periods of sunshine surface temperatures not infrequently exceed 35°C and can rise or fall 20 deg. within a few minutes. On several days temperatures in the surface of *Schistidium* and *Usnea sphacelata* exceeded 40°C, and on 3 January 1986 rose to 42.8° and 43.6°C, respectively, from −9.2°C ten hours earlier. The corresponding ranges 1 cm below the surface were −4.0 to 26.8°C in the moss and −7.6 to 32.8°C in the lichen. The air temperature range on this day was only −5° to 1°C, but there was a light breeze and continuous sunshine during the day which reduced the moisture content of these plants to less than 10% dry weight. Temperatures fluctuated irregularly at the lichen surface but followed a smooth unimodal curve both on and below the moss surface but to a lesser extent below the *Usnea*. Continuous recording of temperatures on the surface and at different depths within miniature ridge and hollow systems typical of *Ceratodon* stands should provide an insight into how diurnal freeze–thaw cycles during summer may create this morphological pattern. While temperatures at the surface and at depths down to *c*. 10 cm in the turf normally follow a diurnal trend with maximum temperatures around 1200–1500 hours and minimum temperatures around midnight to 0300 hours, below 10 cm there is an increasing lag in thermal conductance with maximum temperatures being reached in the evening and minimum temperatures attained in mid-morning. The microclimate data will be analysed in detail to provide a better understanding of the thermal conditions experienced by the vegetation and their influence on moisture availability.

5. *Plant community analysis*

The wide ecological amplitude of the principal species and the small range of distinct habitat types has resulted in numerous closely related fellfield communities comprising almost identical associations of species. Many of these differ only in the percentage cover of the dominant species. However, there are major physiognomic

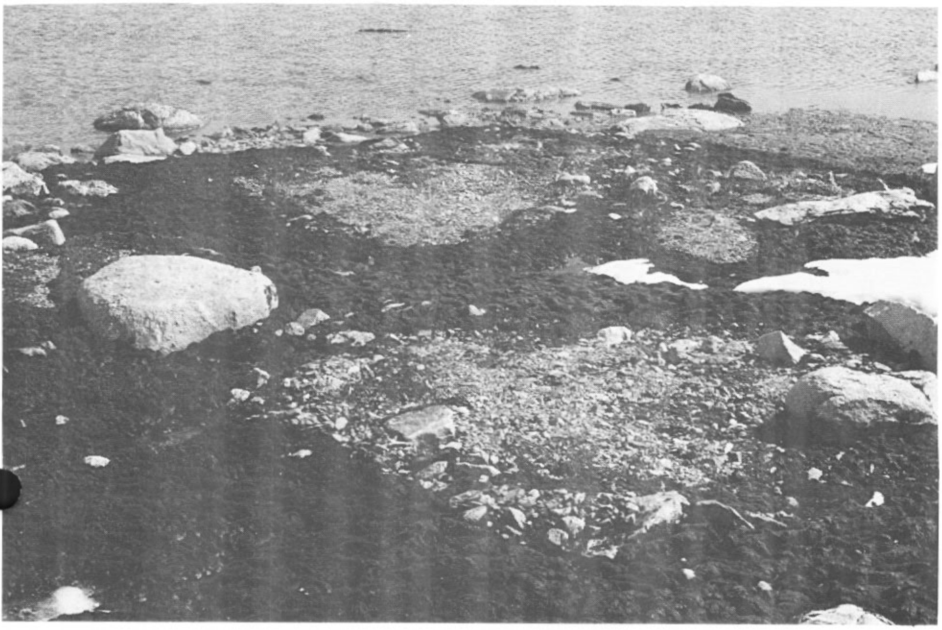

Fig. 2. Large stand of *Ceratodon purpureus* at a moist melt lake margin disrupted by partially sorted stone circles. The moss turf is 15–20 cm deep and the surface convoluted as a result of diurnal freeze–thaw cycles. Bailey Peninsula SSSI.

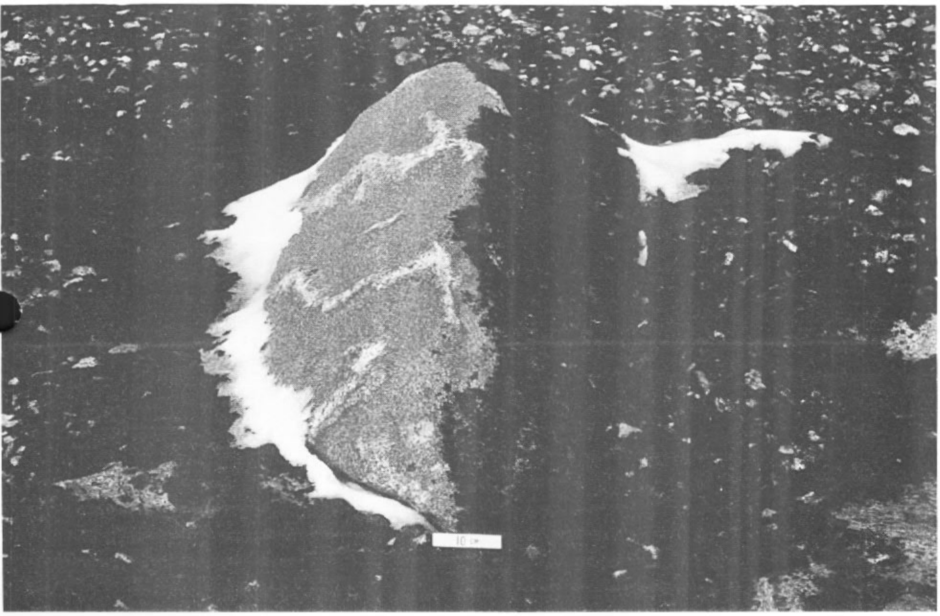

Fig. 3. Dense stand of black *Usnea sphacelata* on pebbles of a former penguin colony abandoned possibly several thousand years ago. The exposed windward side of the boulder is devoid of vegetation. The scale is 10 cm long. Bailey Peninsula SSSI.

differences, e.g. between moss-dominated (Fig. 2) and lichen-dominated (Fig. 3) communities, although the species composition may be remarkably similar. Communities not conforming to this pattern include pure moss stands in wet habitats (especially *Schistidium antarctici*), communities dominated by nitrophilous lichens (e.g. *Physcia caesia*, *Xanthoria candelaria*, *X. elegans*) associated with bird colonies or bird perches, and stands of *Prasiola crispa* around penguin colonies.

In many places on the two peninsulas and offshore islands large accumulations of pebbles represent former penguin colonies. These occur particularly around the 30-m contour and were probably abandoned when coastal ice fields increased in extent and cut off overland access from the sea. During a subsequent post-glacial epoch there may have been an isostatic rise of the land since it is probable that the colonies were closer to sea level when they were occupied. Many of these are now densely colonized by *Usnea sphacelata* (up to 900 g dry wt m^{-2}) and other lichens and these communities appear identical in their stage of development, and therefore age, to those elsewhere in the region (see Fig. 3). It is hoped to obtain radiocarbon ages for egg shell buried in these deposits to gain an insight into when the colonies were abandoned and, allowing for an unknown time factor required for the substrate to be leached of the thick guano accumulations and the sites rendered favourable for colonization by these nitrophobous lichens, the approximate age of the vegetation on these peninsulas may be suggested. Many of the *Usnea* thalli are very large with thick branches and it may be possible to postulate the maximum age for these plants.

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References

Block, W. 1985. Ecological and physiological studies of terrestrial arthropods in the Ross Dependency 1984–85. *British Antarctic Survey Bulletin*, No. 68, 115–22.

Bonner, W. N. *and* Smith, R. I. Lewis. 1985. *Conservation areas in the Antarctic*. Scientific Committee on Antarctic Research, Cambridge.

Dodge, C. W. 1965. Lichenological notes on the flora of the Antarctic continent and the sub-Antarctic islands. VI. New taxa from the Antarctic continent and adjacent islands. *Transactions of the American Microbiological Society*, **84**, No. 4, 507–29.

Dodge, C. W. 1968. Lichenological notes on the flora of the Antarctic continent and the sub-Antarctic islands. VIII. New taxa from the Antarctic continent and adjacent islands. *Nova Hedwigia*, **15**, 297–332.

Filson, R. B. 1974. Studies in Antarctic lichens II: Lichens from the Windmill Islands, Wilkes Land. *Muelleria*, **3**, Pt. 1, 9–36.

Hollin, J. T. *and* Cameron, R. L. 1961. I.G.Y. glaciological work at Wilkes Station, Antarctica. *Journal of Glaciology*, **3**, No. 29, 833–42.

Llano, G. A. 1959. Antarctic plant life. *Transactions of the American Geophysical Union*, **40**, No. 2, 200–3.

Robertson, R. 1959. *Preliminary report on the bedrock geology of the Windmill Islands*. The Ohio State University Research Foundation. Report 825–2, Pt. 6, 25 pp.

Seppelt, R. D. 1983. *Cephaloziella exiliflora* (Tayl.) Steph. from the Windmill Islands, continental Antarctica. *Lindbergia*, **9**, 27–8.

Seppelt, R. D. *and* Selkirk, P. M. In press. Species distribution within a moss bed in east Antarctica. *Acta Botanica Hungarica*.

Seppelt, R. D., Selkirk, P. M. *and* Ramsay, H. P. In press. Variation in *Bryum algens* and *Bryum argenteum* in east Antarctica. *Acta Botanica Hungarica*.

Smith, R. I. Lewis. 1982. Growth and production in South Georgia bryophytes. *Comité National Français des Recherches Antarctique*, No. 51, 229–39.

Smith, R. I. Lewis. 1985. Studies on plant colonization and community development in Antarctic fellfields. *British Antarctic Survey Bulletin*, No. 68, 109–13.

Smith, R. I. Lewis. In press. The bryophyte propagule bank of Antarctic fellfield soils. *Acta Botanica Hungarica*.