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Antarctic terrestrial ecosystems: The Vestfold Hills in context

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Abstract

Antarctic terrestrial ecosystems are briefly described, with emphasis on Signy Island in the maritime antarctic region, and the McMurdo oasis, southern Victoria Land, and Vestfold Hills in the continental antarctic region.

As the largest and best known coastal ice-free oasis, the Vestfold Hills contain excellent examples of terrestrial sublithic, epilithic, chasmoendolithic, epiphytic and terricolous algal communities, as well as epilithic, endolithic, and epiphytic lichen communities, and moss communities. Many of the numerous lakes support dense communities of aquatic algae.

Introduction

Little more than 1% of the 14 million km^2 of the antarctic continent is ice-free. Terrestrial plant life is restricted to the ice-free areas of coastal outcrops and offshore islands, inland nunataks, mountain ranges and 'oases'. The flora is dominated by lichens, bryophytes and algae; only two species of vascular plants occur on the continent, both restricted to the north-west parts of the Antarctic Peninsula.

The distribution of antarctic terrestrial plant life is determined by three principal factors – climatic (temperature, incident radiation, availability of moisture, wind, exposure, etc.), edaphic (substrate characteristics) and biotic (animals and other plants).

Schemes of phytogeographic subdivision of Antarctica and adjacent ocean areas have been reviewed by Pickard & Seppelt (1984a) and Smith (1984a). The southern polar regions have been broadly subdivided into a subantarctic zone, generally between the Antarctic Convergence and Divergence, and two antarctic zones (maritime and continental) generally south of the Antarctic Divergence.

There appears to be general agreement that at least the north-west coast of the Antarctic Peninsula belongs to the maritime antarctic zone, which includes Bouvetøya, the South Sandwich, South Orkney and South Shetland Islands (Holdgate, 1964; Korotkevich, 1966; Longton, 1967; Markov *et al.*, 1970; Lindsay, 1977; Pickard & Seppelt, 1984a; Smith, 1984a) The two vascular plants occur throughout this region (except Bouvetøya) as far south as Marguerite Bay at the south of the Antarctic Peninsula. The eastern coast of the Antarctic Peninsula and the remainder of the Continent together with Peter I Øy and the Balleny Islands form the continental antarctic zone.

A biogeographic zoning of Greater or East Antarctica was proposed by Gollerbakh & Syroechkovskii (1958 – see Markov *et al.*, 1970: 322). They distinguished four major 'life arenas' the continental ice sheet, young antarctic oases, mature antarctic oases, and offshore islands and sea ice. Bugaev (1960 – see Markov *et al.*, 1970: 180) subdivided continental Antarctica into three climatic subregions: the central ice plateau above an altitude of about 2800 m, the ice slopes from this elevation to the sea, and the coastal subregion. Weyant (1966) independently proposed identical subregions which were later adopted by Holdgate (1970, 1977) and modified by Smith (1984a).

The continental ice sheet appears devoid of life. The ice slope subregion included isolated nunataks and mountain ranges. Scattered local populations of lichens, bryophytes and algae with associated invertebrates occur on these outcrops and snow algae may be found in surficial layers of ice and snow. The coastal subregion includes ice-free oases, coastal outcrops and islands, as well as ice shelves. The distribution of plant life in this subregion may be influenced significantly by wind-borne sea spray or the activities of birds and seals, in regions where no ice shelf or permanent dense pack-ice persists.

The climate of these subregions is described in detail by Markov *et al.* (1970: 180) and by Walton (1984). In the coastal subregion, summer air temperatures rarely rise above 0 °C or thereabouts. In the ice slope subregion, mean monthly air temperatures during summer (December to March) are generally less than about −5 °C, while the central ice plateau is substantially colder, less than −15 °C. In the maritime zone, during at least one month in summer, the mean air temperature rises above 0 °C at sea level while mean monthly winter temperatures rarely fall below −10 °C.

Discussion

Maritime Antarctic

Cryptogams dominate the vegetation of the maritime antarctic although there are small closed stands of the only two phanerogams, *Deschampsia antarctica* and *Colobanthus quitensis* (Fig. 1), present on the antarctic continent. Mosses form closed stands in wetter habitats with local accumulations of peat. Lichens predominate in exposed and higher sites. There are several species of macrofungi and snow algae which may be abundant in summer months.

Signy Island, South Orkney Islands (60°S, 45°W) falls within the maritime antarctic region (Holdgate, 1964). It lies 640 km from the Antarctic Peninsula, the nearest land mass, 900 km south-west of the island of South Georgia, and 1440 km south-east of Tierra del Fuego. The climate is cold oceanic. The topography is generally rugged. There are a number of freshwater lakes and a small ice cap (Holdgate, 1967; Heywood, 1970). The vegetation of the island is similar to that found elsewhere in the maritime antarctic (Longton, 1967; Gimingham & Smith, 1970; Lindsay, 1971; Smith, 1972; Alison & Smith, 1972; Smith & Corner, 1973; Longton & Holdgate,

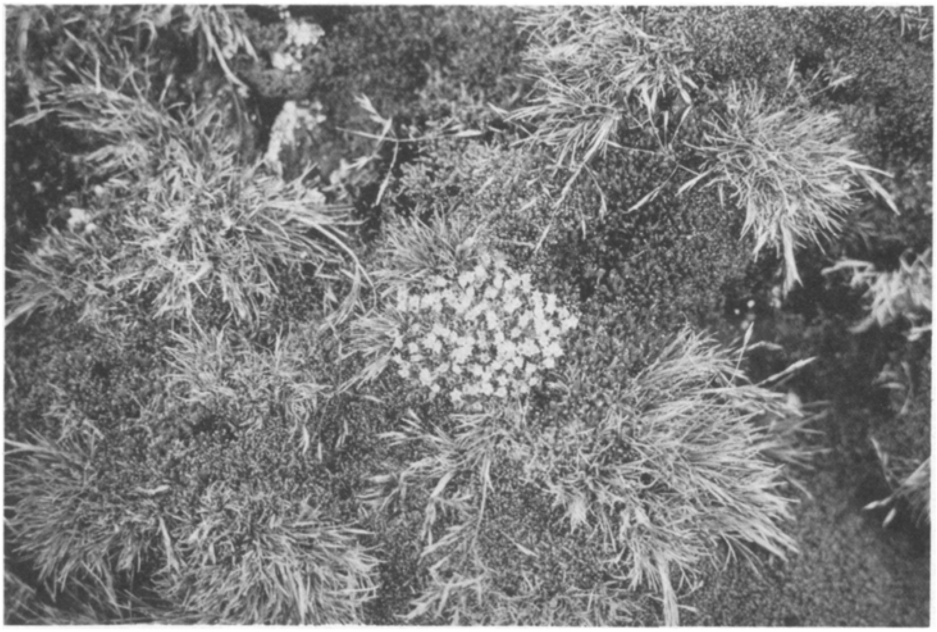

Fig. 1. Signy Island: *Deschampsia-Colobanthus* association. Typical maritime community in Maritime Antarctica.

1979). Intensive interrelated biological and microclimatic studies have been conducted at two reference sites in contrasting bryophyte systems (Tilbrook, 1973).

The macrovegetation of Signy Island is predominantly cryptogamic, with approximately 200 species of lichen, 75 mosses, 12 hepatics and only two vascular plants. Floristic studies of the algae are incomplete although Broady (1977a, 1977b, 1979a, 1979b) reported an algal flora of at least 162 species.

The most extensive closed stands of vegetation have developed in the more stable areas of scree slopes and valley floors, rocky ridges, plateaux and headlands. More open communities occur in areas subjected to cryoturbic disturbance. The more exposed rock surfaces are colonized almost solely by lichens. *Caloplaca, Verrucaria* and *Xanthoria* species are abundant on rocks directly influenced by sea spray. Nitrophilous species of *Biatorella, Buellia, Haematomma, Lecidea, Physcia, Rinodina* and *Xanthoria* are abundant near bird nesting sites on cliffs and rocky slopes. On inland rocks, stands of *Lecidea, Ochrolechia, Pertusaria, Placopsis* and *Rhizocarpon* species are abundant. On the more stable lithosols and rock surfaces, communities dominated by fruticose lichens, particularly *Usnea* and *Himmantornia,* and cushion-forming mosses such as species of *Andreaea, Grimmia* and *Dicranoweisia* are common. The mosses are usually dominant where there is a more stable substratum and abundant water supply. Only 17 of the moss species produce sporophytes (Webb, 1973). In the wetter depressions mosses such as *Calliergon, Calliergidium* and *Drepanocladus* species predominate and lichens are usually absent. Annual growth increments of species in these wetter depressions may be as much as 4 cm (Collins, 1973), contrasting with the lesser increments of only 3 – 5 mm for mosses in drier and unstable habitats (Webb, 1973).

The green alga *Prasiola crispa* (Lightf.) Menegh. is locally abundant in permanently wet areas and in pools or runnels enriched by seal excrement or near penguin colonies. The cyanophyte *Nostoc commune* Vaucher is also locally abundant on bare, wet solifluction slopes supplied with slightly alkaline meltwater (Horne, 1972).

Snow algae, chiefly *Chlamydomonas, Rhaphidonema* and *Ochromonas* species are commonly found on the surface of firm snow during summer (Fogg, 1977).

Data from the many studies that have been conducted in the dry moss turf community and wet moss carpet community that comprise the Signy Island Terrestrial Reference Sites have been synthesized by Davis (1981). Such intensive integrated studies have, as yet, no parallel in continental antarctic communities.

Continental Antarctic

A much less diverse flora with a narrow range of cryptogamic communities is found in the extreme cold and arid environment of continental antarctic localities than in the maritime antarctic. Bare ground predominates. Under such conditions water availability assumes great importance in determining plant distribution (Llano, 1965; Rudolph, 1971).

1. Southern Victoria Land.
Longton (1973, 1979) reported few plant associations from Ross Island. The most widespread vegetation consisted of sparsely developed communities of turf- and cushion-forming mosses in habitats ranging from dry cinder slopes to sand and gravel in seepage areas and at the side of and in meltwater streams. The bryophyte colonies seldom exceeded 4 cm in depth and total plant cover was frequently under 5%. *Sarconeurum* was generally found in drier habitats than *Bryum* species. Exposed rock habitats usually supported only small scattered thalli of crustaceous lichens such as *Xanthoria elegans* (Link) Th. Fr., *Candelaria concolor* var. *antarctica* Murray, *Caloplaca darbishieri* Dodge & Baker and *Lecanora melanophthalma* (Ram.) Ram. These communities were similar to those described for the Syowa Station area, Prince Olav Coast (Nakanishi, 1977) and the Mawson Station area, Mac. Robertson Coast (Seppelt & Ashton, 1978) although species dominance differed. Although no attempt was made to classify the vegetation the communities at Cape Hallett, nothern Victoria Land, also appear to be similar (Rudolph, 1963).

Detailed studies of the terrestrial algae of continental antarctic localities have been attempted only in recent years. Broady (1981d, 1981e, 1983) has studied the ecology and taxonomy of the terrestrial algae of southern Victoria Land. Other studies on soil, epilithic and chasmolithic algae (Broady, 1981a, 1981b) and on chasmolithic algae (Broady, 1981c) for other coastal localities have also been made. The role of endolithic cyanobacteria in the dry valley desert environment of southern Victoria Land has been discussed by Friedmann & Ocampo (1976) and Friedmann (1977, 1980, 1982).

The dry valleys of southern Victoria Land (Fig. 2) have been studied as examples of extremely arid, cold environments where the importance of the endolithic habitat occupancy as a niche for microbial life could be investigated (Friedmann, 1977, 1980, 1982; Friedmann & Ocampo, 1976).

Fumarole vegetation has been studied on Mt Erebus by Broady (1982, 1983, 1984). Heated soils around fumaroles (Fig. 3) provide considerable zonation of algal growth and, in addition, unidentified moss protonema have been recovered. A well-developed fumarole vegetation has also been reported for the South Sandwich Islands (Longton & Holdgate, 1979; Smith, 1984a, 1984b) and, following recent eruptions, on Deception Island (Collins, 1969) where areas of fumarole activity and their associated vegetation are ephemeral (Smith, 1984b). Other geothermically heated areas on the island currently support a community of short turf-forming mosses (Smith, 1984b, 1984c).

2. Vestfold Hills, Ingrid Christensen Coast

The Vestfold Hills 'oasis' is a 400 km^2 area of ice-free rock mainly of low relief. Much of the landscape is covered by moraines and tills (Fig. 4). The physiography and biology of the region have been generally described by Johnstone *et al.* (1973) while Burton & Campbell (1980) have discussed the climate. A detailed discussion of the geology, geomorphology, Cainozoic history, climate, vegetation, terrestrial invertebrates and significance of the Vestfold Hills is given in a recent book (Pickard, 1986a).

Davis Station (68°35′S, 77°58′E) is situated approximately 25 km from the continental ice plateau. Consequently, katabatic winds, which play a significant role in determining local plant distribution at Mawson Station (Seppelt & Ashton, 1978), dissipate before reaching the coastal perimeter near the Station, and therefore have an effect only close to the ice plateau.

Fig. 2. Taylor Valley: looking towards McMurdo Sound, with Lake Fryxell and Canada Glacier. Valley is approximately 5 km wide.

Fig. 3. Mt Erebus: steaming ground near the summit.

Fig. 4. Vestfold Hills: typical coastal desert habitat with glacial till.

The flora of the Vestfold Hills comprises at least 82 species of terrestrial algae (Broady, 1986), six moss species (Seppelt, 1986a) and at least 23 lichen species (Seppelt, 1986b). The lichens and mosses are distributed chiefly in the eastern or inland sector and their distribution patterns reflect the availability of drift snow, time since exposure of the substrate from the ice plateau and time since the last glaciation, elevation, and proximity to saline waters (Seppelt *et al.*, this volume). Very few occurrences of lichens or mosses have been noted towards the coastal margin where the low terrain is densely clothed with moraine and till. Mobile sands in these areas may actively inhibit colonization by the extremely slow growing lichens and mosses. In contrast, sublithic algae are widespread in these till-covered areas (Broady, 1981a; Seppelt *et al.*, this volume).

Notwithstanding sampling deficiencies in the south-eastern and margins of the oasis, epilithic algae (Broady, 1981b; Seppelt *et al.*, this volume) appear to reflect closely the generalized patterns of lichen and moss distribution. The epilithic algae are chiefly encrusting growths of cyanobacteria on rocks which receive fresh meltwater percolations. The community does not appear to be salt tolerant.

Chasmoendolithic algae, growing in capillary-sized cracks in boulders and *in situ* country rock outcrops, are no doubt far more widespread than preliminary searches indicate (Broady, 1981c; Seppelt *et al.*, this volume). There are indications that such algae are more abundant in coastal locations than further inland. At least in coastal regions these chasmoendoliths appear not to be associated with chasmoendolithic lichens, such as *Lecidea phillipsiana* Filson, *Biatorella cerebriformis* (Dodge) Filson and *Acarospora gwynnii* Dodge & Baker, which have so far been reported only from inland localities and not the coastal margin.

Schofield & Ahmadjian (1972) have implicated the absence of a freely available nitrogen source, together with other environmental factors, in accounting for the paucity of vegetation in the ice-free areas of Antarctica. *Nostoc* may be an important source of nitrogen fixation in the poorly developed antarctic cold desert soils.

Although there are many communities of bryophytes in the Vestfold Hills which have no obvious algal associations, Davey (1982) reported *Nostoc* was always associated with bryophytes. *Nostoc* may contribute significant amounts of nitrogenous compounds for bryophyte growth.

Communities of *Nostoc commune* are found in association with bryophyte stands in areas of meltwater runoff. Davey (1982) discussed *in situ* nitrogen fixation by *Nostoc commune* in a stand of moss and algae at a site near Crooked Lake. Submerged colonies of *Nostoc* had the highest fixation rates with decreasing rates of fixation as dryness of the substrate or habitat increased. Fixation of nitrogen by cyanobacteria is maximal during periods of optimal microclimatic conditions. Davey (1983) reported diurnal fluctuations of nitrogenase activity and increasing rates of fixation with increased temperature. Moisture levels also affect fixation rates (Davey, 1982). *In situ* determination of nitrogenase activity showed that summer activity ceased when vegetation surface temperatures fell below $-7\,°C$ (Davey & Marchant, 1983).

While there are no large colonies of snow petrels, nesting sites are widely scattered in many parts of the Vestfold Hills (Brown, 1966). Rich lichen growths, particularly *Xanthoria mawsonii* Dodge, *X. elegans*, *Physcia caesia* (Hoffm.) Hampe and *Candelariella antarctica* Filson occur where meltwater runoff is enriched by nutrients derived from such nesting sites.

There are few localities with extensive moss beds and these are generally restricted to inland areas (Seppelt *et al.*, this volume). As in many other continental localities, *Bryum* species predominate. The taxonomy of this genus in Antarctica is confused but recent studies (Seppelt & Kanda, 1986) have shown that only two species – *B. argenteum* Hedw., and *B. pseudotriquetrum* (Hedw.) Meyer, Scherb., & Gaertn., – are represented in continental localities, the latter species including all material formerly identified as *B. algens* Card. (Seppelt, 1984). *Bryum* species exhibit a wide range of morphological variation in response to environmental factors. When inundated by meltwater, shoots of *Bryum* may etiolate conisderably (Seppelt, 1983). The aquatic *B. korotkevicziae* Savich-Lyubitskaya & Smirnova, which has been found in a number of water bodies in the Vestfold Hills, has been shown to be an aquatic habitat-induced variant of the terrestrial *B. algens* (Seppelt, 1983), although this species should now be considered as *B. pseudotriquetrum* (Seppelt & Kanda, 1986). Etiolated shoots of this species have been recovered from Holocene deposits near several water bodies (Pickard & Seppelt, 1984b).

The terrestrial flora of the Vestfold Hills is representative of most of continental Antarctica.

Thus, the oasis is not unique floristically. However, the presence on intertidal rocks near Davis Station of the lichen *Verrucaria* (Seppelt, 1986), the only record of this genus on the antarctic continent beyond the Antarctic Peninsula, and the deposits of subfossil moss (see above) are of particular interest.

The Vestfold Hills, because of the area of ice-free rock, geomorphic history and range of habitats, provide an excellent opportunity for the study of terrestrial life in continental Antarctica. Much remains to be studied of the taxonomy, ecology and physiology of the biota. Soils and soil-forming processes have not been addressed.

A complex relationship exists between plant distribution patterns and topography, proximity to the continental ice cap, and past geomorphic history (Seppelt *et al.*, this volume). Intensive field studies will need to be undertaken in order to understand these relationships. It is time to develop a fully integrated approach to the study of the terrestrial biology of the region.

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