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The terrestrial arthropod fauna and its habitats in northern Marguerite Bay and Alexander Island, maritime Antarctic

PETER CONVEY and RONALD I. LEWIS SMITH

British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge CB3 0ET, UK

Abstract: Field surveys of free-living terrestrial microarthropods were made during the 1994–95 summer at four sites in northern Marguerite Bay (Anchorage Island, Lagoon Island, Léonie Island, Rothera Point; *c.* 68°S, 68°W) and three on southern Alexander Island (Two Step Cliffs, Fossil Bluff, Ablation Valley; *c.* 71–72°S, 68°W). Detailed site descriptions are presented, as little previous information exists. Twenty species (four Collembola, 16 Acari) were recorded from the Marguerite Bay sites, with a maximum of 17 species at one site. A further four species (one Collembola, two Acari, one Diptera) have been recorded from the same area by other authors. Species diversity at these sites, in particular Léonie Island, is as great as at any known site elsewhere in the maritime Antarctic, although the total area of terrestrial habitat available is small. Individual species and total population densities are also similar to, if not greater than, published studies from the South Shetland and South Orkney Islands. None of the species is new to the maritime Antarctic, although the distributions of several are extended southwards. Only nine species (maximum seven at one site) were found on Alexander Island, concurrent with decreases in population densities to levels similar to those found in many continental Antarctic studies. This still represents a high species diversity for such a high latitude site. The richness of two sites, Ablation Valley and Mars Oasis (Two Step Cliffs), is unlikely to be repeated elsewhere on Alexander Island. The Alexander Island fauna is clearly related to that of the maritime Antarctic, as all except one species occur at more northerly sites elsewhere on the Antarctic Peninsula, and none in the continental Antarctic. One species, *Friesia topo* (Collembola), is known only from Alexander Island.

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Key words: Acari, Alexander Island, Collembola, diversity, Marguerite Bay, maritime Antarctic

Introduction

The terrestrial arthropod fauna of the maritime and continental Antarctic regions (*sensu* Smith 1984) is generally well-documented, in that few undescribed species are likely to be present. The fauna is dominated by mites (Acari) and springtails (Collembola) with, additionally, three species of midge (Diptera) being present in the maritime Antarctic. On a regional scale the distribution of Acari is summarized by Pugh (1993) and that of Collembola by Greenslade (1995). The limited distributions of Antarctic Diptera are described by Convey & Block (1996). Both Greenslade (1995) and Marshall & Pugh (1996) propose an important difference in the origin of the maritime and continental Antarctic faunas, based on levels of specific and generic endemism, in that the latter contains at least some Gondwanan relics whilst the former is much more recent and is likely to be of post-Pleistocene origin. There is little overlap at specific level between the two regions.

The mountains of south and east Alexander Island represent a dissected plateau, 250–800 m altitude, and provide the southernmost exposures of ice or snow-free ground in the maritime Antarctic. They are formed of sedimentary strata, particularly shales, arkosic sandstones, mudstones, conglomerates and volcanoclastic sandstones of Late Jurassic to Early Cretaceous origin (Horne 1969, Bell 1973, Crame & Howlett 1988, Moncrieff & Kelly 1993). The largest areas of ice- and snow-free ground occur on the east coast of Alexander Island, three of which (Two Step Cliffs, Fossil Bluff and Ablation Point; Fig. 1) were visited. They provide an environment intermediate between those of the maritime and continental Antarctic zones (Longton 1988, Smith 1988a). Sheltered from the maritime weather systems approaching from the west and often under the influence of stable continental high pressure systems to the east, they experience low precipitation, and provide the closest comparison with continental "Dry Valley" systems present in the Antarctic Peninsula region.

Knowledge of the biology of these isolated sites is extremely limited. The limnology of the permanently ice-covered Ablation Lake was described by Light & Heywood (1975) and Heywood (1977). Smith (1988a) described the vegetation of Ablation Valley using preserved material and associated field notes, and opportunistic collections of plant and animal material from various sites are preserved in the British Antarctic Survey's Terrestrial and Freshwater Life Sciences Data and Resources Centre. Information on the terrestrial zoology of the region is limited to collection records of a number of springtails (Collembola) and oribatid mites (Acari)

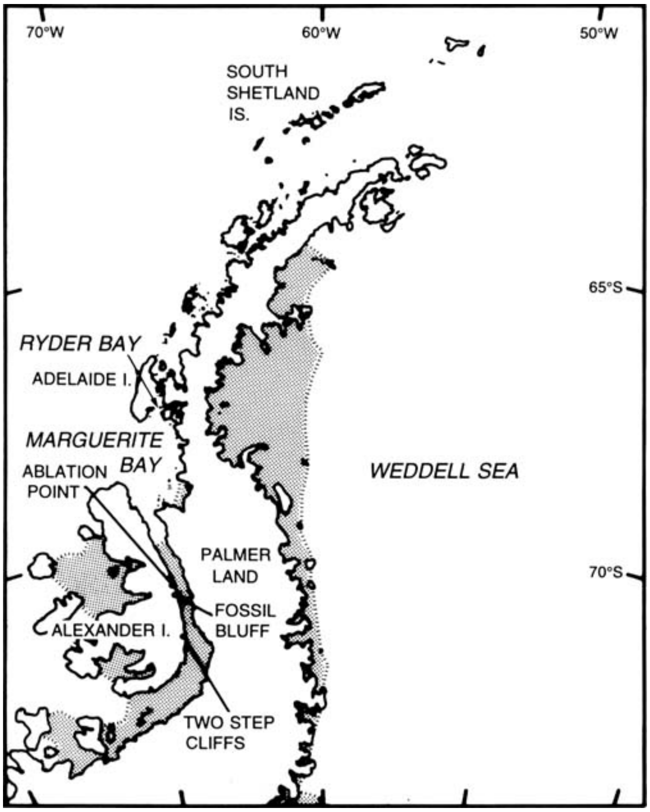

Fig. 1. General map of the Antarctic Peninsula indicating the position of the areas studied on the east coast of Alexander Island and identifying Ryder Bay in northern Marguerite Bay. Stippling indicates permanent ice shelves.

mentioned by Greenslade (1995) and Block & Stary (1996) respectively.

Rothera Research Station, on the south-east coast of Adelaide Island (northern Marguerite Bay; Fig. 1), provides access to a range of terrestrial habitats on nearby islands in Ryder Bay. Little terrestrial biological information has been published either from Rothera Point or the neighbouring islands, although a number of unpublished surveys have been made. Invertebrate and plant species known from Rothera Point are listed, without background information, by Bonner & Smith (1989). Freshwater invertebrates, algae and testate rhizopods were studied by Dartnall (1980), Priddle & Belcher (1981) and Smith (1986) respectively, whilst the terrestrial micro-arthropods of the Rothera Point Site of Special Scientific Interest were surveyed by Usher (1986). Additionally, records of oribatid mites and springtails from the neighbouring Lagoon and Léonie Islands are given by Block & Stary (1996) and Greenslade (1995). Records of terrestrial micro-arthropods and Diptera from other islands in Marguerite Bay are given by Usher & Edwards (1984a, 1986a).

These ice-free habitats of southern Alexander Island thus lie at the extreme south of the region conventionally included in the maritime Antarctic and are close to the coastal and slope provinces of the continental Antarctic. Lying at the junction of two climatically contrasting regions, the area is of considerable biogeographical interest. The current study, undertaken between December 1994 and February 1995, documented species richness and abundance at several sites on southern Alexander Island and compares this with similar studies of the fauna of several sites in northern Marguerite Bay and with other previously published studies of various sites on the western Antarctic Peninsula, South Shetland Islands and South Orkney Islands. Since these southern areas are to be the focus of considerable terrestrial research over the next decade the opportunity is also taken to provide habitat descriptions.

Site descriptions

Alexander Island

Two Step Cliffs (Fig. 2).
Sandstones and mudstones exposed in the Two Step Cliffs massif represent some of the youngest rocks in the Fossil Bluff Group, of late Albian age (Moncrieff & Kelly 1993). Four areas containing significant macro- or microbiological communities have been identified in the region of the spectacularly stratified Two Step Cliffs (71°54'S, 68°13'W), these being Mars Oasis, Two Step Moraine, Viking Valley and Ares Oasis. In addition, sporadic occurrences of sparse vegetation, particularly lichens, are found throughout the massif, usually associated with ridge crests and other areas prone to occult precipitation.

Mars Oasis (71°52.7'S, 68°15'W) consists of a lower and an upper site (Fig. 2b). The lower site lies on the older of two moraine ridges formed by the contact of the George VI Ice Shelf with the coast of Alexander Island, and consists of a fresh ice-cored moraine adjacent to the active ice margin and, on its landward side, an older and more stable subdued moraine ridge or bench (Sugden & Clapperton 1981). The ice-cored moraine is highly unstable and shows no evidence of macrobiological colonization. In comparison with Ares Oasis and Two Step Moraine, Mars Oasis soils have a much lower proportion of clay-sized particles (Sugden & Clapperton 1981), and therefore experience a lower incidence of blowing dust.

The older moraine provides areas of till, fluvial and lacustrine sediments, in addition to streams and shallow ponds (Fig. 2c), which are sufficiently stable to allow colonization by various algae, cyanobacteria, lichens, mosses and invertebrates. Moss communities are generally sparse and fragmentary, although small stands (15–20 m^2) dominated by *Bryum amblyodon, B. pseudotriquetrum* and *B. urbanskyii* occur near sources of water (Fig 2d). This moss, occasionally with other species, may form a subpsammic community, buried by sand but retaining its vitality. Other calcicolous species growing regularly in small turves associated with rock shelter include *Bryoerythro-phyllum recurvirostre, Bryum argenteum, Distichium capillaceum, Encalypta*

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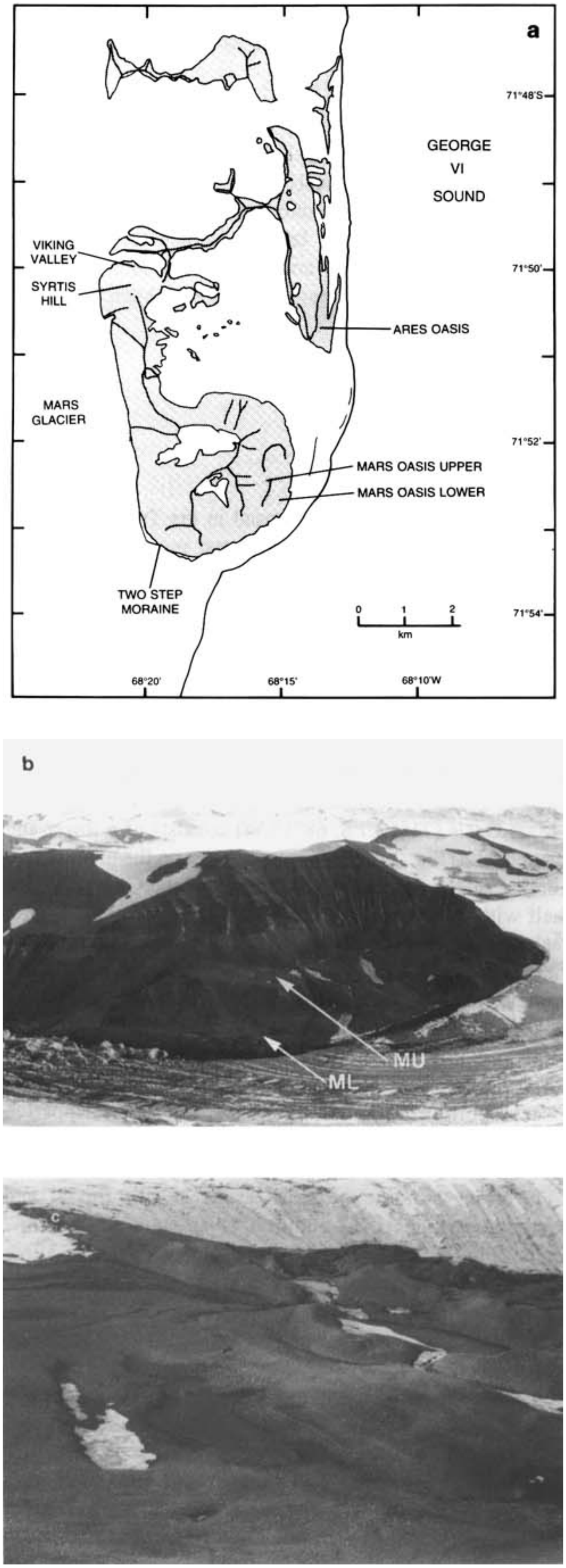

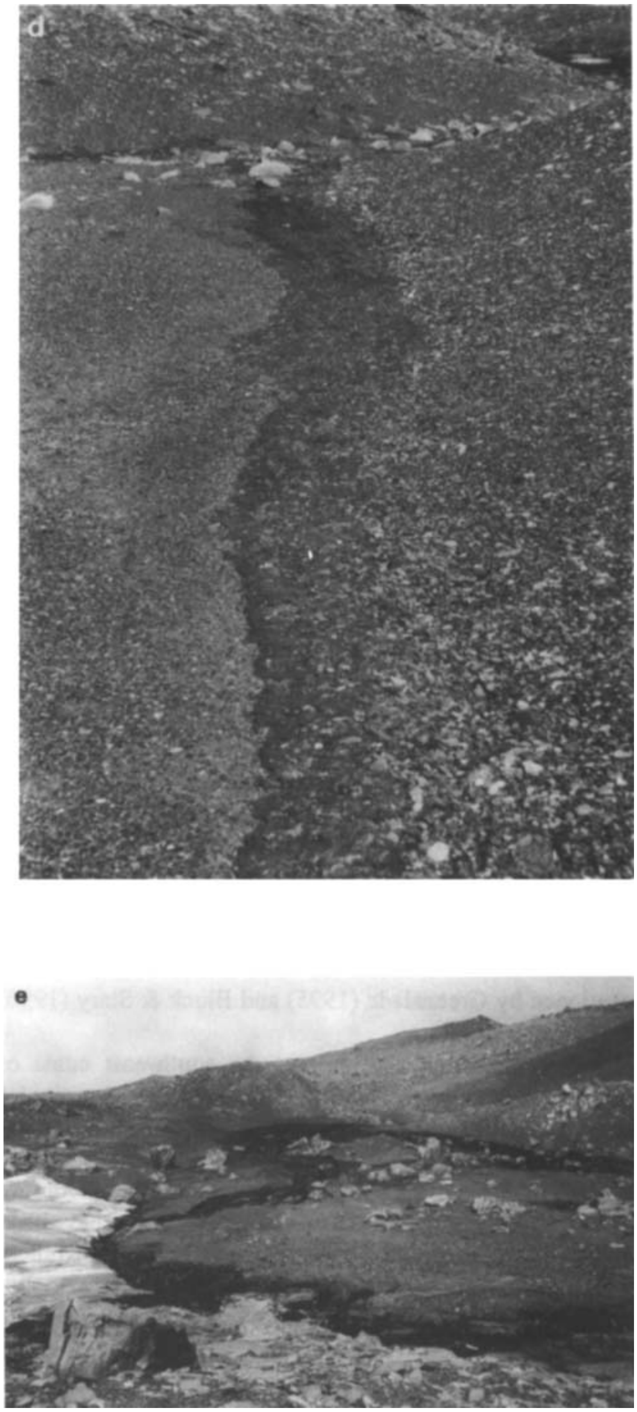

Fig. 2. a. Map of Two Step Cliffs indicating the four main study sites, Ares Oasis, Mars Oasis, Two Step Moraine and Viking Valley; ice-free ground and moraines are indicated by stippling, within which solid lines indicate ridge crests. **b.** Oblique aerial photograph of Mars Oasis, identifying the lower site on older ice-shelf moraine (ML) and the upper terrace site (MU). **c.** View of Mars Oasis lower site from the upper terrace. **d.** Band of moss growth (*c.* 50 cm across, predominantly *Bryum amblyodon*) at the edge of an alluvial fan, Mars Oasis lower site. **e.** Mars Oasis upper site from the head of the access gully.

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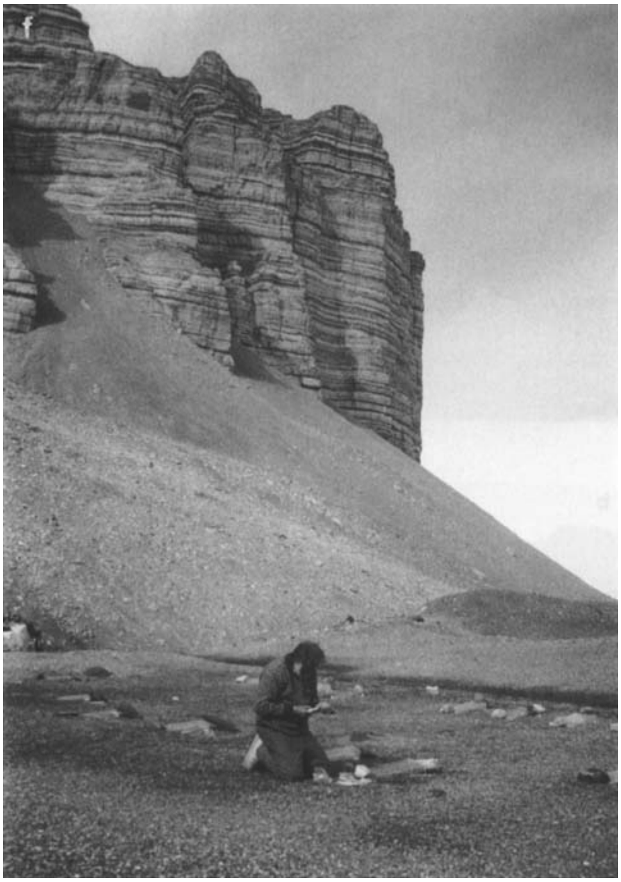

Fig. 2. (cont) **f.** The small study area at Two Step Moraine. **g.** Ares Oasis from the south, showing young ice-cored moraine (far right), older stable moraine (centre right) and alluvial flats (centre left, foreground).

patagonica, E. procera, Hennediella heimii, Hypnum cf. *revolutum,Pohlia cruda, Tortella* cf. *fragilis* and *Tortula princeps*. Lichens are generally very sparse and mostly chasmolithic forms, usually reduced to apothecia only, with no thallus but rhizomorphs penetrating into the rock. Dry stands of *Bryum* are sometimes extensively colonized by white encrustations of*Leproloma cacuminum*. The total area of this lower site is small, *c.* 400 x 50 m.

Barnacle shells found in the older subdued ridge at Two Step Cliffs have been ^{14}C dated to 6000–6500 yrBP, indicating that both moraines must be younger than this (Sugden & Clapperton 1981). No more precise dating of the moraines is available, although Clapperton & Sugden (1982) used evidence of Little Ice Age glacial advances in South Georgia, the South Orkney and South Shetland islands to suggest that the youngest ice-cored moraines may be as little as100–700 yr.

The upper site is a terrace *c.* 100 m above the lower site, on bedrock at the foot of screes draining permanent snow patches on Two Step Cliffs. Apart from the immediate vicinity of meltwater runnels and seepages, the terrace is barren and windswept. However, in very small areas, particularly damp depressions at the foot of large boulders and the fringes of melt stream channels, there are rich moss, with associated muscicolous lichens, and invertebrate communities. Some of the harder rocks house small stands of lichens, notably *Buellia frigida* and *Usnea sphacelata*. The terrace is *c.* 1 km x 200 m, but biological development is limited to a depressed area of *c.* 200 x 50 m either side of the head of the central drainage gully, which holds a late snow patch (Fig 2e).

Two Step Moraine (71°53'S, 68°20'W) lies *c.* 3 km south-west of Mars Oasis. The intervening ground along the foot of screes below Two Step Cliffs consists of barren ice-cored moraine. Two Step Moraine is formed by the same paired ice-shelf moraine as described above. However, the older moraine is in the form of steep, unstable hillocks. A number of small melt streams and temporary pools contain algal growth, but areas of visible terrestrial vegetation are limited to the edges of a single terrace *c.* 20 m x 20 m, and are mostly buried due to considerable movement of windborne silt (Fig. 2f). *Bryum amblyodon* is again dominant, with *B. argenteum, Hennediella heimii* and *Encalypta procera* also present in small turves.

Viking Valley (71°50'S, 68°21'W) lies *c.* 3 km north-west of Two Step Moraine, below the north-east shoulder of Syrtis Hill. The valley floor is *c.* 400 m long, containing a small lake (Secret Lake) in a glacially over-deepened basin dammed by a rock bar at the valley mouth (Meikljohn 1994). The head of the valley contains a small glacier which drains into Secret Lake via a braided channel system. With the exception of small quantities of stream algae, a lacustrine moss (*Campyliadelphus polygamus*) and very occasional lichens (mainly *Usnea sphacelata*), the valley is barren.

Ares Oasis (71°50.7'S, 68°13.5'W) also includes the ice-shelf moraine associated with George VI Ice Shelf. This section of the moraine runs for *c.* 10 km north–south along the foot of Ares Ridge. However, for the majority of its length it is narrow and dominated by unstable ice-cored moraine, backed or overrun by screes extending from the ridge. At its southern end the moraine widens, and the older component is represented over *c.* 1 km by a series of low moraine ridges, associated with melt streams, decayed stream beds, ponds and alluvial flats (Fig 2g). At the south-east foot of Ares Ridge there is a large alluvial outwash fan and seasonally ice-covered lake. Soil particle size, particularly in the flats, is small with a high proportion of glacially derived "rock flour", and the oasis suffers a large amount of wind-blown debris. Vegetation development is very limited, with only six moss species recorded. Small open stands dominated by *Bryum* spp., maximum extent 10 m^2, are found around some pools and flood plain margins, but are largely buried by wind-blown sand and silt.

Fossil Bluff (71°20'S, 68°17'W).
The sedimentary rocks of this massif are closely related to those of Ablation Valley and Two Step Cliffs (Crame & Howlett 1988). There are no extensive areas of vegetation in the vicinity of Fossil Bluff, although a total of *c.* 14 mosses and numerous lichens occur sporadically. Mosses are limited to very small colonies on damp rock ledges and in crevices, and are best developed on the north-east slopes of Scarab Bluff and Khufu Peak, and the fringes of frost-sorted soil polygons found on the summit plateau of Scarab Bluff and an area of ridge crest to the north of "Elephant" (unofficial name). The most common mosses are *Bryum pseudotriquetrum*, *B. urbanskii*, *Encalypta procera*, *Tortella fragilis* and *Schistidium* spp. Dense stands of lichen occur on most ridge crests and mountain summits, in particular the black *Usnea sphacelata* and *Pseudephebe minuscula*, and several apotheciate crustose taxa.

Ablation Valley (70°48'S, 68°30'W) (Fig. 3)
The Ablation Point-Ganymede Heights massif and associated valleys, on the central east coast of Alexander Island, is the largest ablation feature in the Antarctic Peninsula sector of Antarctica. The stratigraphy, geomorphology and glacial history of the region have been described by Elliott (1974), Taylor *et al.* (1979), Clapperton & Sugden (1982, 1983) and Butterworth *et al.* (1988). Rock types are dominated by marine conglomerates, mudstones and sandstones. Valleys are likely initially to have become free of ice during the retreat of the Alexander Island ice cap after the Wisconsin glacial maximum. The floor of Ablation Valley west of Ablation Lake and south of the main alluvial fan is formed by glacial till from this period of retreat ("Valley Stage", Clapperton & Sugden 1983), and is the main area of invertebrate and cryptogamic interest. Subsequently the valleys have probably remained partially ice-free, although a number of glacial advances and retreats have occurred, the most recent over the last few hundred years. Precise descriptions and dating of glacial advances and retreats are not available. The penetration of the George VI ice shelf into the massif's eastern valleys has also varied, associated with changes in sea level, including a period *c.* 6500 yr BP in which the shelf disappeared altogether

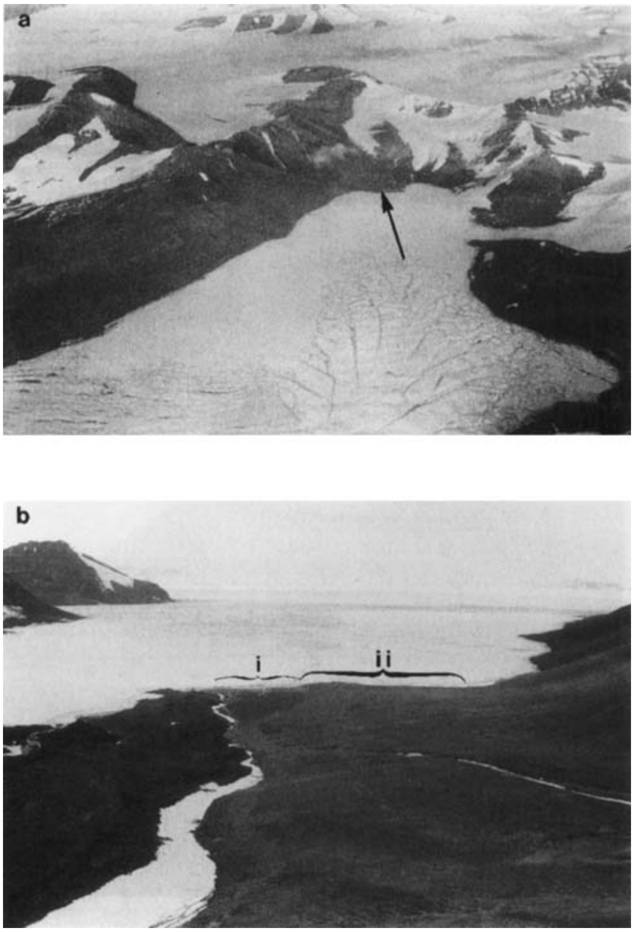

Fig. 3. **a.** Oblique aerial photograph of Ablation Valley viewed from the east, indicating the ice-covered Ablation Lake and the valley floor study area (arrowed). **b.** The floor of Ablation Valley viewed from the west, indicating the main alluvial fan (i) and area of lakeshore flats (ii).

(Clapperton & Sugden 1982).
Extensive unstable screes and fine glacial debris covering valley slopes and floors limit the area suitable for microbial, plant or invertebrate colonization. The massif includes four predominantly ice-free valleys (Ablation, Moutonnée, Flatiron and Striation), the first three containing a large ice-covered freshwater lake. Ablation and Moutonnée Lakes are unusual in that they are in direct contact with seawater under the shelf ice of George VI Sound, such that a stable layer of fresh water overlies seawater, and the lakes show tidal movements (Heywood 1977). Lake ice cover was described as permanent, with a thickness of 2.5–4.5 m, by Heywood (1977), but during the 1994/95 season Ablation Lake had a small ice-free "moat", whilst Moutonnée Lake had broken ice cover, with *c.* 25% of its surface ice-free, indicative of the influence of recent climate warming in the Antarctic Peninsula region (King 1994, Vaughan & Doake 1996). No macro or microclimatic data are available for sites within the massif,

although the large area of bare rock and scree would absorb more incoming radiation than is possible at Two Step Cliffs and Fossil Bluff, and would probably create slightly higher summer mean temperatures (Heywood 1977). Annual precipitation is less than 20 cm water equivalent, with little falling in summer (Smith 1988a).

Terrestrial plant communities, especially in Ablation Valley, are associated with summer melt streams and groundwater seepages. There are two main areas of interest – the flood bank margins of the central valley stream, extending *c.* 1 km west of its outflow into the lake, and an extensive area of lakeside flats extending *c.* 1 km south from the fluvial fan, and within 50–200 m of the lake shore (Fig. 3b). The bryophyte communities are the best-developed and most diverse in any area of Antarctica south of 70°S (Smith 1988a), with at least 21 species recorded, many of which fruit at their southern limit. At least 25 lichen taxa are also present. Streamside plant communities are dominated by *Bryum amblyodon* and *Hennediella heimii*, and individual stands on the lakeshore flats contain at least 13 bryophyte species. Virtually nothing is known of the associated terrestrial arthropod community. Heywood (1977) reported that short-lived moraine pools around Ablation Point and Moutonnée Valley contained a range of algae, aquatic mosses, microscopic animals and the copepod *Pseudoboeckella poppei*, but noted neither significant terrestrial vegetation nor fauna. The scientific value of the area has been recognized by its international description as a Site of Special Scientific Interest.

Vertebrate activity at all three sites visited on Alexander Island was very limited, with no evidence of breeding. Vagrant Antarctic skuas (*Catharacta lonnbergi*, maximum four individuals) were observed regularly at Fossil Bluff and Two Step Cliffs, whilst three other species were noted as single individuals (Dominican gull, *Larus dominicanus*; Wilson's storm petrel, *Oceanites oceanicus*; snow petrel, *Pagodroma nivea*).

Non-surveyed sites on south-eastern Alexander Island

The sites described above are likely to be the richest, but not the only, biological sites on south-eastern Alexander Island. Lichen development similar to that observed on ridge crests around Fossil Bluff and Two Step Cliffs is typical of both coastal and inland nunataks, as is sporadic moss growth on damp terraces and crevices similar to that noted at Fossil Bluff. Rocks of the Fossil Bluff Group are exposed in a belt *c.* 250 km by 30 km on the east coast of Alexander Island, between Tilt Rock and Stephenson Nunatak (Butterworth *et al.* 1988). The coastal ice-shelf moraine described by Sugden & Clapperton (1981) is known to exist within this range at several sites between Ablation Point and Two Step Cliffs. With the exception of the moraine pools in Ablation and Moutonnée Valleys mentioned above and the current study, none of these sites has been examined in detail for biological activity. Airborne observations indicate that sites similar to Ares Oasis or Two Step Moraine exist on moraines below Tombaugh Cliffs, Succession Cliffs, Georgian Cliff, Waitabit Cliffs and Cannonball Cliffs. These appear to be dominated by recent ice-cored moraine, with only limited areas of more stable ground. Ablation Valley is unique, and it is unlikely that a second site as rich even as Mars Oasis remains to be identified.

Northern Marguerite Bay (Fig. 4)

Four terrestrial sites in the vicinity of Rothera Point (67°34' S, 68°08' W) were examined. In addition to the Point itself, the three largest of the Léonie Islands were visited – Léonie Island (67°36'S, 68°21'W), Lagoon Island (67°35'S, 68°16'W) and Anchorage Island (67°36'S, 68°13'W). Other smaller, low-lying and more distant islands in the Léonie group (Limpet Island, Mikkelsen Island) were not visited, but seem unlikely to harbour different or more diverse invertebrate or plant communities than those examined.

The invertebrate fauna and bryophyte flora of northern Marguerite Bay are better-known than those of Alexander Island although, with the exception of bryophyte and lichen species lists for Rothera Point (Bonner & Smith 1989), no explicit studies of the flora have been published. It is not known how long any of these terrestrial sites in Ryder Bay have been ice-free, and no attempts have been made to date biological material such as peat. However, the generally limited development of moss communities suggests an age considerably less than the 5000 years proposed for moss banks at sites in the northern maritime Antarctic (Fenton & Smith 1982, Björck *et al.* 1991).

Rothera Point is a low (maximum altitude 39 m) rocky promontory at the southern extremity of the Wormald Ice Piedmont. An area of *c.* 1000 x 250 m of ice-free ground is present, including a Site of Special Scientific Interest designated to monitor the environmental impact of the operation of Rothera Research Station. The rocks of the Point are predominantly heterogeneous intrusions (diorite, granodiorite) of mid-Cretaceous to early Tertiary age (Dewar 1970). A low raised beach extends around Rothera Point. Soil and vegetation development is sparse, the former limited to a small number of frost-sorted circles and the latter formed by an *Usnea sphacelata*-dominated lichen fellfield. Other than two small (< 20 m^2) patches of the moss *Drepanocladus uncinatus*, bryophyte development is fragmentary, with *c.* 17 species present, limited to very small quantities associated with sorted circles, melt water seepage, or damp crevices.

Anchorage and Lagoon Islands are also low-lying. The rocks of Anchorage Island are similar to those of Rothera Point. The larger size of the island, *c.* 3 km in length, allows the development of moss stands dominated by *Drepanocladus uncinatus*, *Andreaea* spp., *Brachythecium austro-salebrosum* and *Polytrichum alpinum* on moist east-facing slopes. Small quantities of both Antarctic flowering plants are also present. Lichen fellfield (*Pseudephebe minuscula,*

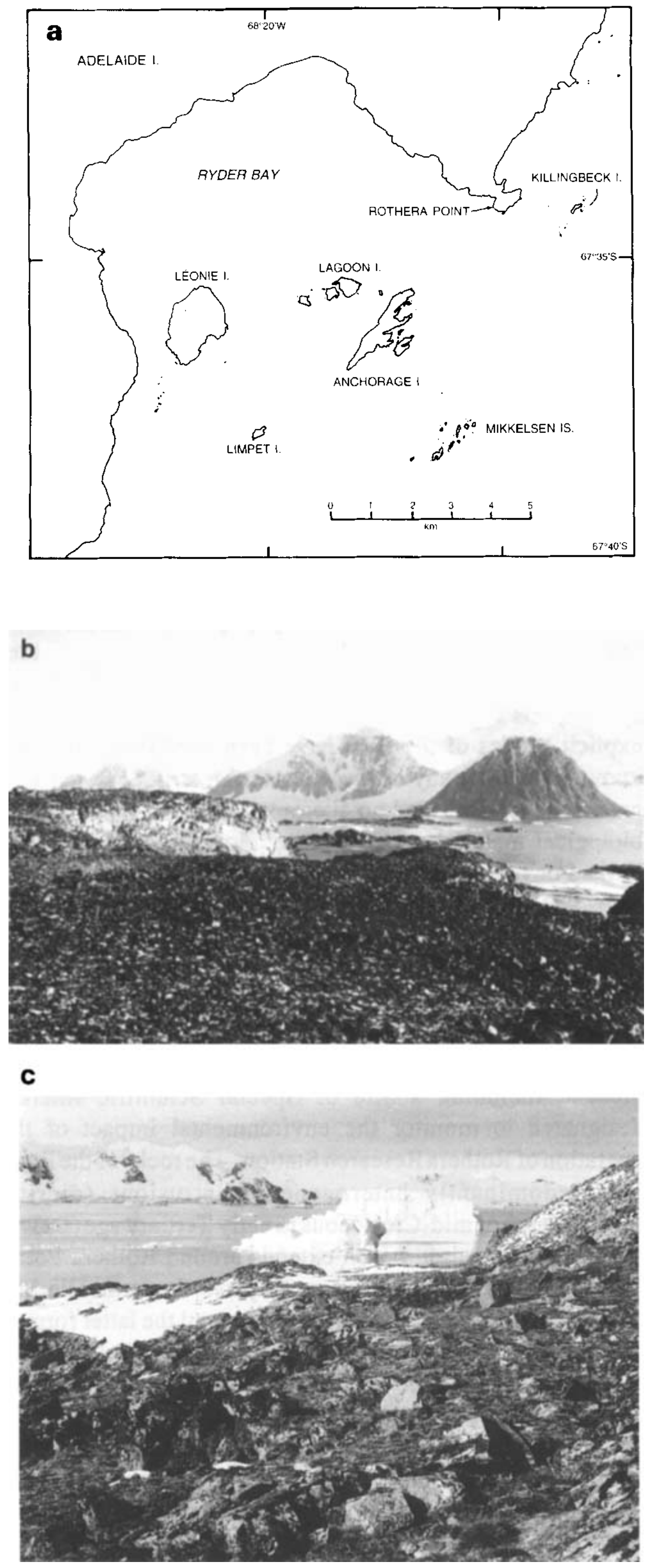

Fig. 4. **a.** Map of Ryder Bay (northern Marguerite Bay), showing Rothera Point and Léonie, Anchorage and Lagoon islands. **b.** Extensive lichen fellfield on Lagoon Island (Léonie Island is centre-right in the middle distance). **c.** Vegetation dominated by Antarctic hairgrass (*Deschampsia antarctica*) on terraces above the north coast of Léonie Island.

Umbilicaria decussata, Usnea spp. and many crustose species) is the dominant vegetation on rocks over much of the island although, with greater water availability and soil development, bryophyte communities are more in evidence than at Rothera Point. Lagoon Island consists of Upper Jurassic volcanic rocks (quench-brecciated lava; Dewar 1970). Much of the island, down to rocks just above high water, is covered by a dense, well-developed lichen fellfield of similar species composition to that found on Anchorage Island. However, raised beach terraces on the island's eastern slopes are locally dominated by the grass *Deschampsia antarctica* and the moss *Polytrichum alpinum*, whilst west-facing damp gullies and slopes are covered by a moss carpet dominated by *D. uncinatus, B. austro-salebrosum* and *Andreaea* spp. Moist rock faces are festooned with large thalli of macro-lichens (notably *Umbilicaria* spp. and *Usnea* spp.).

Léonie Island, by contrast, rises steeply to a height of *c.* 500 m and is predominantly composed of gabbro and heterogeneous intrusive rock types (Dewar 1970). More than half the island is covered by a permanent ice cap. The northern part of the island, including raised beaches, rock terraces and 100–200 m of scree below the summit cliffs, is snow-free in summer. This part of the island is sheltered and receives much reflected radiation from the nearby Hurley and Turner glaciers on Adelaide Island. Additionally, water is permanently available during the summer from late and permanent snow beds, including a number of small defined streams. Stable terraces, crags and gullies from sea level to *c.* 50 m support large and diverse vegetation stands, while more consolidated boulder screes at the same altitude harbour a typical lichen fellfield community. Vegetation is also well-developed on ledges and in crevices on the north-facing cliffs above 150 m a.s.l. Several coastal terraces support stands of vegetation of 400–500 m^2, including many closed stands of higher plants (*Deschampsia antarctica, Colobanthus quitensis*) of up to 10 m^2. Dominant bryophytes include *Andreaea* spp., *Barbilophozia hatcheri, Cephaloziella exiliflora, Brachythecium austro-salebrosum, Bryum amblyodon, Drepanocladus uncinatus, Pohlia nutans* and *Polytrichum alpinum*, with a total of *c.* 33 species recorded. There is also a very diverse lichen flora. The vegetation is exceptionally diverse and well-developed for such a high latitude.

Significant input of nutrients from vertebrate sources occurs on all three islands and at Rothera Point. The three islands support large (50–200 pairs) breeding populations of skuas (*Catharacta maccormicki, C. lonnbergi*) widely dispersed on all ice-free ground below *c.* 50 m a.s.l., in addition to large numbers of non-breeding individuals. A colony of *c.* 50 pairs of Dominican gulls (*Larus dominicanus*) is present on Léonie Island. Elephant, Weddell and fur seals haul out on the shores and raised beaches of all sites. The population of the latter, currently small, is rising and may ultimately cause a similar threat to the terrestrial environment as experienced at sites in the South Orkney Islands (cf. Smith

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1988b, in press). No penguin or giant petrel colonies are present at these sites, although all are visited regularly and used as moult sites by Adélie penguins. The sparse soils contain egg shell and bone fragments indicative of the earlier existence of penguin colonies (Bonner & Smith 1989, British Antarctic Survey 1995).

Materials and methods

Site visits

Invertebrate collections were made in Ryder Bay during two periods, 22–31 December 1994, and 8–27 February 1995. Due to constant accumulation of pack and brash ice, and exposure to prevailing winds, Léonie Island was visited only twice, on 16 and 23 February 1995, and Lagoon and Anchorage islands once each, on 17 and 18 February 1995, respectively. On each occasion invertebrates were collected by hand from a wide range of substrates, and material was collected for extraction at Rothera Research Station.

The four sites in the vicinity of Two Step Cliffs were visited between 2 and 19 January 1995, Fossil Bluff between between 20–29 January, and Ablation Valley on 31 January 1995. Substrates collected in Ablation Valley were kept at local ambient temperature (0 – 5°C) and subsequently extracted at Rothera. Ablation Point and Rothera Point Sites of Special Scientific Interest were visited under permit.

Collection details

Between two and 30 separate microarthropod collections were made at each study area. Three collection techniques were employed (see Southwood 1966):

1) Brushing (hand sampling). The under-surface and sides of stones were examined and individual microarthropods collected on the tip of a moistened artists' paintbrush (00/000 grade) and transferred immediately to a small vial containing 70% Industrial Methylated Spirits (IMS). This basic method is effective for sampling the micro-arthropod population associated with stones embedded in vegetation or soil, giving a qualitative description of species present, but under-recording smaller specimens or species.

2) Heat extraction. A simple field extractor was used consisting of three 10 cm diameter plastic funnels each containing an 8 cm wire gauze disk and placed *c.* 15 cm below a 60 W tungsten light bulb for *c.* 24h. A disk of substrate *c.* 8 cm diameter and 3–5 cm depth (*c.* 0.005 m^2 surface area, *c.* 0.2 l total volume) was placed in the funnel. Microarthropods extracted were preserved in IMS. This method provides a quantitative measure of population density but such data should be interpreted with caution as many characteristics of both the substrate structure and species extracted are known to affect extraction efficiencies. Although a long-recognized problem (*e.g.* Murphy 1962, Block 1966), such characteristics may be impossible to quantify, with the result that comparisons between studies, or even between substrates in a single study, can be justified only in more general terms. Density values for this study (m^{-2}) can be converted to l^{-1} by multiplying each value by 0.025, but as presented here are directly comparable with most published studies of Antarctic micro-arthropods.

3) Flotation extraction. A quantity of substrate (*c.* 50 cm^3) was agitated in a saturated salt (NaCl) solution and allowed to settle. Microarthropods were collected from the surface. These data are only considered qualitatively.

Microarthropod identification

Specimens were examined initially using a binocular microscope. Any requiring critical examination were placed on temporary Barr (= cavity) mounts (Barr 1973), cleared with 50% lactic acid and examined under a compound microscope at ×40 or ×100. A number of mite species (the larger oribatids *Alaskozetes antarcticus*, *Magellozetes antarcticus* and *Halozetes belgicae*, and the predatory mesostigmatid *Gamasellus racovitzai*) cannot be confused with other species occurring in this region. Two species of the large predatory prostigmatid genus *Rhagidia* are known from the Antarctic Peninsula and offshore islands (Edwards & Usher 1987). Springtails (Collembola) were identified by reference to Greenslade (1995).

Most smaller prostigmatid mites required critical examination. Where necessary these were assigned to family using Krantz (1978), and specific identifications were then obtained using a variety of sources, including Eupodidae (Strandtmann 1971, Booth *et al.* 1985), Nanorchestidae (Booth 1984), Tydeidae (Usher & Edwards 1986b) (noting that adults of two species of the genus *Apotriophtydeus* may only be separated by use of multivariate analysis, and that juvenile tydeids and eupodids may not be separated reliably). Antarctic species of the genus *Stereotydeus* may be separated following Strandtmann (1967), although a single species only, *S. villosus*, is known from the Antarctic Peninsula. Finally, the smaller cryptostigmatid mites (*Globoppia* and related genera) were identified following Wallwork (1965, 1967) with nomenclature modified as presented by Block & Stary (1996). Most specimens are preserved in their original collections in the Terrestrial and Freshwater Data and Resources Centre of the British Antarctic Survey, Cambridge.

Comparisons of diversity

The data obtained in the current study are analysed below simply in terms of species richness and abundance. Although many more complex measures of diversity are available (*e.g.* Krebs 1972, pp 500–509), some of which have been used in a single previous study of Antarctic microarthropod diversity (Usher & Edwards 1986a), it is felt that the use of such measures would not contribute significantly to the interpretation of the current results. This is because

i) most measures do not take into account species identity when comparing different sites;

ii) the relatively small numbers of extractions obtained here from any site or substrate render the data vulnerable to the stochastic consequences of uneven population distribution ("clumping"), a phenomenon widely recognized in studies of soil microarthropods;

iii) the unquantified variation between substrates and species in the extraction efficiencies achieved may render detailed analyses meaningless.

Results

Alexander Island

Table I details the species recorded, each with their median and maximum density, and mean total population density (all species, individuals m^{-2}), at each of the sites studied on Alexander Island. Heat extractions gave a total of 725 specimens. Additionally, a similar number of microarthropods were preserved from hand collections and flotation extractions.

Population densities found in heat extractions were generally very low and represent 1–7 individual microarthropods of any species being obtained from a single extraction. *Cryptopygus badasa*, however, had higher population densities at both Mars Oasis sites and in Ablation Valley. These two sites have a greater number of species resident than other sites examined around Two Step Cliffs and Fossil Bluff (Table I).

The heat extraction data are unsuitable for statistical identification of patterns of species occurrence between different samples, due to the small number of samples overall, and the number of species recorded only in one or two samples. Qualitative observations indicated that the mites *Magellozetes antarcticus* and *Stereotydeus villosus* were more common in hand collections on or beneath stones embedded in vegetation at Mars Oasis and Ablation Valley than suggested by their density in heat extractions. *M. antarcticus* was similarly common on stones around frost-sorted circles at Fossil Bluff. The two springtails showed different habitat preferences. *Cryptopygus badasa* was particularly common in extractions of moss turf and on stones embedded in such turves or cushions, and less frequent in more open habitats such as stream edge moss clumps, whereas *Friesia topo* was found on stones at very low population densities, and was virtually absent from the moss habitat.

Northern Marguerite Bay

Species occurrence, median and maximum population density and mean total population density at the four sites examined around Ryder Bay, northern Marguerite Bay, are given in

Table I. Microarthropods collected from Alexander Island field sites during January 1995. For each species, data presented indicate presence (+) for species recorded only in hand collections or flotation extractions, or the mean and maximum density (n individuals m^{-2}) and number of samples from which the species was recorded in heat extractions (presented as mean/maximum/*n*). For each site the total numbers of extractions (b, brush; f, flotation; h, heat), heat-extracted specimens and mean total population density (all species, indivduals m^{-2}) are also given. Species not recorded at a given site are indicated by (-). New records for Alexander Island are indicated by *. Site abbreviations: AO, Ares Oasis; AV, Ablation Valley; FB, Fossil Bluff; ML, Mars Oasis, lower site; MU, Mars Oasis, upper site; TS, Two Step Moraine.

Site	AO	ML	MU	TS	FB	AV
Cryptostigmata						
Magellozetes antarcticus	-	+	300/400/2	-	+	-/400/1
Prostigmata						
*Eupodes parvus**	-	-	-	-	-	200/200/3
Eupodes sp.	-	-/400/1	-	-	+	+
Apotriophtydeus sp.*	-	+	-	-	-	-
*Pretriophtydeus tilbrooki**	-	400/600/2	-	-	-	-
*Nanorchestes gressitti**	-/600/1	-	+	-	-	400/600/2
Stereotydeus villosus	-/200/1	1200/2200/2	300/400/2	-	+	400/600/5
*Rhagidia gerlachei**	-	-	-	-	-	+
Collembola						
Cryptopygus badasa	-	1400/3400/4	3200/7000/3	-/600/1	-	19 800/38 800/6
Friesia topo	-/400/1	+	-/200/1	-/200/1	+	500/800/2
Number of samples	2b, 2f, 5h	4b, 4f, 4h	4b, 3h	1b, 1h	4b	4b, 6h
Total species	3	7	5	2	4	7
Total specimens obtained from heat extractions	6	46	55	4	n/a	615
Mean microarthropod population density	240	2500	3000	800	n/a	20500

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Table II. A total of *c.* 25 000 heat-extracted specimens were examined, with several hundred additional hand-collected specimens used for confirmation of species presence.

Comparison of Tables I and II reveals that population densities were considerably greater at Marguerite Bay sites than those sampled on Alexander Island (with the exception of Ablation Valley). Extractions from the four sites had generally very similar species composition. In keeping with the high plant diversity, those from Léonie Island gave the greatest species richness, but it should be noted that two are recorded as possibly present on the basis of single damaged specimens (*Austroppia crozetensis* and *Globoppia intermedia*) and a further species was represented by a single heat-extracted specimen only (*Eupodes parvus*).

The highest density of any species (*c.* 1.5 x 10^6 *Cryptopygus antarcticus* m^{-2}) was found in extractions of debris from an Adélie penguin moult area on Lagoon Island; this resulted in the highest mean total population density being recorded on that island (Table II). Considering data from Léonie Island (18 heat extractions), the most widely distributed species were *Globoppia loxolineata, Gamasellus racovitzai, Eupodes minutus, Nanorchestes berryi, Stereotydeus villosus, C. antarcticus, C. badasa* and *F. grisea*, all found in 10 or more extractions (Table II). Fewer samples were obtained from the other three sites, where the number of species found in 50% or more of the extractions was also lower. *G. racovitzai, C. antarcticus* and *F. grisea* were again widely distributed, with *Halozetes belgicae* being widespread on Lagoon Island and *Alaskozetes antarcticus* on Anchorage Island. The presence of the latter species indicate the coastal influence on these low-lying islands.

As with Alexander Island samples, certain species were poorly represented in heat extractions when compared to hand collections. In particular, cryptostigmatid mites (*Alaskozetes antarcticus, Halozetes belgicae, Magellozetes antarcticus*) tended to be restricted to the surfaces of stones in contact with moss or soil substrates, being found only infrequently amongst the substrate itself. Both *A. antarcticus*

Table II. Microarthropods collected from field sites in northern Marguerite Bay during December 1994 and February 1995. For each species, data presented indicate presence (+) for species recorded only in hand collections, or the mean and maximum density (n individuals m^{-2}) and number of samples from which the species was recorded in heat extractions (presented as mean/maximum/n). For each site the total numbers of extractions (b, brush; h, heat), heat-extracted specimens and mean total population density (all species, indivduals m^{-2}) are also given. Species not recorded at a given site are indicated by (-). New records for northern Marguerite Bay are indicated by *. Site abbreviations: AN, Anchorage Island; LA, Lagoon Island; LE, Léonie Island; R, Rothera Point.

Site	AN	LA	LE	R
Cryptostigmata				
Austroppia crozetensis	-	-	? +	-
Alaskozetes antarcticus	1400/2600/3	400/600/2	4400/9000/3	+
Halozetes belgicae	700/800/2	1200/2800/6	28600/91000/6	82000/128000/3
Globoppia loxolineata	-/400/1	-	3000/18400/10	-/200/1
*Globoppia intermedia**	-	-	? +	-
Magellozetes antarcticus	200/200/2	-/200/1	+	+
Mesostigmata				
Gamasellus racovitzai	1200/2200/3	700/800/2	900/2600/16	600/1200/6
Prostigmata				
*Eupodes exiguus**	-	-/c.4,000/1	-	-
Eupodes minutus	-	-	1500/5600/10	200/200/2
*Eupodes parvus**	-	-	-/200/1	-
Apotriophtydeus sp.	-/400/1	-	-	-
Pretriophtydeus tilbrooki	+	-/3000/1	-	+
*Nanorchestes berryi**	800/1000/2	1800/3600/3	4200/10000/12	400/1000/4
Nanorchestes gressitti	-/200/1	-	+	+
Nanorchestes sp.	1200/2600/3	1300/1800/2	-	-/200/1
Stereotydeus villosus	2400/3400/2	-/200/1	900/4200/15	300/400/2
*Rhagidia gerlachei**	+	200/200/2	400/1000/6	+
Collembola				
Cryptopygus antarcticus	139000/360000/5	510000/1560000/5	57200/374600/15	14200/25400/8
Cryptopygus badasa	-/800/1	-/200/1	4600/9800/10	+
Friesia grisea	1600/2000/3	4400/10400/4	7800/46000/16	2400/4400/9
*Isotoma (Folsomotoma) octooculata**	-	-	-/400/1	-
Total samples	4b, 6h	4b, 6h	12b, 18h	15b, 9h
Total species	14	12	17/15	14
Total specimens obtained from heat extractions	3613	12939	6699	1933
Mean microarthropod population density	120900	433000	74600	43000

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and *H. belgicae* are coastal species, and are often found in large aggregations, accounting for the high maximum density of the latter found in heat extractions of *Prasiola crispa*, and its lichenized form *Mastodia tesselata*, from Léonie Island and Rothera Point. The two predatory mites, *Gamasellus racovitzai* (Mesostigmata) and *Rhagidia gerlachei* (Prostigmata), and the herbivore/detritivore *Stereotydeus villosus* (Prostigmata) were also often found in greater numbers on the surface of a single stone than in extractions of the surrounding substrate.

Including subjective information from hand collections, a number of species showed evidence of habitat preference. *A. antarcticus* and *H. belgicae* were always found close to the coast, often associated with visibly damp rocks and wet substrates. *M. antarcticus,* however, was usually found in drier fellfield habitats (but still associated with damper areas therein, such as the edge of frost-sorted soil polygons) away from the coast, and was rarely found in collections with the previous two species. *Nanorchestes berryi* was widely distributed in vegetation extractions but rare in collections from solid surfaces, whereas the slightly larger *N. gressitti* showed the reverse pattern. It was particularly abundant on water-splashed rocks in a melt stream on Léonie Island, and amongst rafts of *C. antarcticus* on the surface of a melt pool at Rothera Point, but virtually absent from extractions of vegetation. On Alexander Island, *N. gressitti* was similarly found in collections from damp rocks and was rarely encountered in extractions. The springtails *C. antarcticus* and *C. badasa* showed little overlap at Ryder Bay sites, the latter being more abundant in material taken from small growths of moss found on ledges and crevices at higher altitude (on Léonie Island in particular) and the former dominating more extensive coastal (consistently damper?) habitats. Within extractions from these coastal habitats, *F. grisea* was generally encountered infrequently, with the exception of drier *Polytrichum alpinum* turfs where it was dominant. As with the cryptostigmatid mites, this species was better-represented in hand-collections from stone surfaces. The two predatory mites, *Gamasellus racovitzai* and *Rhagidia gerlachei*, were found in most substrates sampled, occasionally being the dominant microarthropod present in hand-collections.

Comparisons of diversity

The data from Alexander Island show that species richness was similar at both Mars Oasis sites and in Ablation Valley, although microarthropod abundance was considerably greater at the latter (Table I). These represent the richest biological sites known on Alexander Island. The microarthropod communities of Mars Oasis were not numerically dominated by a single species to the same extent as those from Ablation Valley. However, in both cases *Cryptopygus badasa* was most frequently encountered (Table III). Most extractions from Ablation Valley were obtained from the lakeshore moss carpet, which is a continuous habitat over a relatively large area and is not present at Mars Oasis, possibly accounting for the different patterns of diversity observed.

Table III. Percentage contribution (of the total extracted) of each microarthropod species present in heat extractions at each of the major study sites examined on Alexander Island. Site codes as in Table I. (+, recorded at site, but not in heat extractions; -, not recorded at site).

Site	AO	ML	MU	TS	FB	AV
Cryptostigmata						
Magellozetes antarcticus	-	+	5.5	-	+	0.3
Prostigmata						
Eupodes parvus	-	-	-	-	-	0.5
Eupodes sp.	-	4.3	-	-	+	+
Apotriophtydeus sp.	-	+	-	-	-	-
Pretriophtydeus tilbrooki	-	8.7	-	-	-	-
Nanorchestes gressitti	50	-	+	-	-	0.7
Stereotydeus villosus	16.7	26.1	5.5	-	+	1.6
Rhagidia gerlachei	-	-	-	-	-	+
Collembola						
Cryptopygus badasa	-	60.9	87.3	75	-	96.6
Friesia topo	33.3	+	1.8	25	+	0.8

In Ryder Bay differences in species richness between sites were found, being greatest on Léonie Island, intermediate on Anchorage Island and Rothera Point, and most limited on Lagoon Island (Table II). However, these differences were not great and may simply reflect differences in sampling intensity.

Cryptopygus antarcticus was the species most frequently obtained in heat extractions of substrates from Anchorage and Lagoon Islands and, to a lesser extent, Léonie Island, whereas *Halozetes belgicae* was numerically dominant at Rothera Point (Table IV). However these results may demonstrate the influence of aggregated distributions: a single species occurring in very large numbers in a small number of extractions may cause different dominance patterns in other samples to remain unnoticed. For instance, of the 18 heat extractions obtained from Léonie Island, only two were dominated by *C. antarcticus* (> 95% of individuals), with two by *Friesia grisea* (> 62%) and two approximately equally between *C. antarcticus* and *H. belgicae* (> 91% in total). The remainder showed a more even distribution between species. Two of the six Lagoon Island samples were dominated by *C. antarcticus* (> 99%), as were two of the six from Anchorage Island (> 96%). *C. antarcticus* dominated the majority (6/9) of Rothera Point samples (56–90%), with one being dominated by *F. grisea* (69%) and two by *H. belgicae* (> 98%).

A wider comparison between the four Ryder Bay and three Alexander Island sites using pooled data revealed that diversity measured simply by number of species obtained per heat-extracted sample was significantly greater in the former sites [Ryder Bay, 5.5±0.4 (s e), Alexander Island, 3.2±0.4, two-sample *t*-test, $t_{29} = 3.99$, $P < 0.001$].

Table IV. Percentage contribution (of the total extracted) of each microarthropod species present in heat extractions at each of the major study sites examined in Ryder Bay. Site codes as in Table II. (+, recorded at site, but not in heat extractions; -, not recorded at site).

Site	AN	LA	LE	R
Cryptostigmata				
Austroppia crozetensis	-	-	? +	-
Alaskozetes antarcticus	0.6	0.03	1.0	+
Halozetes belgicae	0.2	0.3	12.8	63.6
Globoppia loxolineata	0.06	-	2.2	0.05
Globoppia intermedia	-	-	? +	-
Magellozetes antarcticus	0.06	0.01	+	+
Mesostigmata				
Gamasellus racovitzai	0.5	0.05	1.1	0.9
Prostigmata				
Eupodes exiguus	-	0.2	-	-
Eupodes minutus	-	-	1.1	0.1
Eupodes parvus	-	-	0.01	-
Apotriophtydeus sp.	0.06	-	-	-
Pretriophtydeus tilbrooki	+	0.1	-	+
Nanorchestes berryi	0.2	0.2	3.8	0.4
Nanorchestes gressitti	0.03	-	+	+
Nanorchestes sp.	0.5	0.1	-	0.05
Stereotydeus villosus	0.7	0.01	1.0	0.2
Rhagidia gerlachei	+	0.02	0.2	+
Collembola				
Cryptopygus antarcticus	96.2	98.5	64.0	29.4
Cryptopygus badasa	0.1	0.01	3.4	+
Friesia grisea	0.7	0.7	9.3	5.6
Isotoma (Folsomotoma) octooculata	-	-	0.03	-

Discussion

Knowledge of the detailed distribution of Antarctic terrestrial arthropods is limited by at least three major factors. First, many sites have either not been visited by specialists or, at best, very limited collections have been made during a small number of brief opportunistic visits. Second, many of the collections that have been made concentrate on larger more visible species and fail to search adequately for or differentiate smaller groups, particularly the prostigmatid mites. Third, some habitats, even in otherwise well-known sites, have been inadequately sampled (e.g. the intertidal and supralittoral zones). Fourth, the specific habitat requirements of most species are unknown. The current study does not fully escape these shortcomings, but still provides quantitative data on species richness and abundance from previously little-studied areas of Alexander Island and northern Marguerite Bay. Other studies with which these data may be compared have been carried out on the South Orkney Islands (Goddard 1979a, b, Block 1982, Usher & Booth 1984, Usher & Edwards 1984b), South Shetland Islands (Richard *et al.* 1994, Convey *et al.* 1996) and at sites on the west coast of the Antarctic Peninsula including Marguerite Bay (Gressitt 1967, Usher 1986, Usher & Edwards, 1986a). Although all these sites are within the maritime Antarctic, those in the South Shetland and South Orkney islands are separated from the current study by 1000–1500 km and 10–12 degrees of latitude, thereby highlighting the paucity of data available.

A total of nine microarthropod species was recorded in the current study from sites on Alexander Island (Table I), with two sites containing seven species (Mars Oasis and Ablation Valley). This represents a considerably greater diversity than has previously been recognized at such a high latitude. A maximum of six mite species has been recorded from mountain ranges at a similar latitude in continental Dronning Maud Land (*c.* 71°S) (Marshall & Pugh 1996), although single nunataks only harbour up to three species of mite and a single springtail (Sømme 1986, Ryan & Watkins 1989). Four mite species are reported in the region of the coastal Syowa Station (69°14'S) (Sugawara *et al.* 1995) and three from the Vestfold Hills (68–69°S) (Rounsevell & Horne 1986). Up to three springtail and three mite species are known from specific sites in southern Victoria Land (75–78°S) (Gressitt *et al.* 1963), although a total of ten Acari and seven Collembola are recorded from Victoria Land as a whole (71–78°S) (Gressitt & Shoup 1967).

It is clear from the current data that the terrestrial microarthropod fauna of Alexander Island has close affinities with that of the maritime Antarctic in general, with most species in common, and none with the continental Antarctic. *Magellozetes antarcticus* and *Stereotydeus villosus* are widely distributed in the maritime Antarctic and have been recorded previously from southern Alexander Island (Block & Stary 1996, W. Block unpublished data). The smaller prostigmatid mites (Eupodidae, Tydeidae) are likely to have been overlooked. The records of these families presented here do not include species new to the region as a whole, but represent significant southward extensions to their known range. The occurrence of the predatory *Rhagidia gerlachei*, a large, active and visually obvious species, in Ablation Valley is significant in that it is the first record of a predatory microarthropod in a terrestrial community on Alexander Island. This species is unlikely to have been overlooked in the detailed examinations made of Mars Oasis and other Two Step Cliffs habitats, and its distribution on Alexander Island is likely to be very limited. Block & Stary (1996) also refer to specimens of the oribatid mites *Alaskozetes antarcticus* and *Halozetes* sp. collected on southern Alexander Island, but neither of these normally obvious species was located during the current study.

The occurrence of one species suggests a distinct Alexander Island element superimposed on the more general maritime Antarctic fauna. The springtail *Friesia topo* has been found only at sites on Alexander Island, and has not been found in detailed examination of an increasing amount of material from sites in Marguerite Bay and elsewhere in the maritime Antarctic (Greenslade 1995, P. Convey unpublished data).

The data on microarthropod occurrence on islands in northern Marguerite Bay may be compared directly with those of Usher (1986) for the Rothera Point SSSI and Usher

& Edwards (1986a) for the Dion and Fauré islands (islands off the south coast of Adelaide Island). Usher (1986) recorded 12 species from Rothera Point, including two Prostigmata (*Apotriophtydeus* sp., *Paratydaeolus* sp.), one unknown Astigmata and the dipteran *Belgica antarctica*, which were not recorded in the current study. Of these, two of the Acari were recorded as single specimens, and are thus likely to be overlooked as "rare", whilst *B. antarctica* may have been recorded in error, as there is no appropriate habitat for the species on Rothera Point, and no other records exist. *B. antarctica* is known to be present in Marguerite Bay on the Refuge and Fauré Islands (Usher & Edwards 1984a, 1986a). More recent studies (Greenslade 1995, Block & Stary 1996) have added further species recorded in the area, the former describing *C. badasa*, and recording the cosmopolitan *Hypogastrura viatica* from a single supralittoral collection site on Léonie Island, and the latter recording *Austroppia crozetensis* and an undescribed species of *Halozetes*.

The results of the current study therefore increase the microarthropod diversity of sites in northern Marguerite Bay by a total of six species (Table II). The record of *Globoppia intermedia* is doubtful, being based on a single damaged specimen. The species otherwise is found in southern Chile, has a wide distribution in the Subantarctic, and has been recorded from the maritime Antarctic only in the South Sandwich Islands (Wallwork 1970). *Eupodes parvus*, *E. exiguus* and *Nanorchestes berryi* are smaller prostigmatid mites likely either to have been overlooked or simply not collected in earlier studies. *E. parvus* has previously been recorded as far south as the Argentine Islands (65°31'S, Booth *et al.* 1985, Usher & Edwards 1986a), *E. exiguus* only from the South Orkney Islands (Booth *et al.* 1985) and *N. berryi* from Anvers Island (64°47'S) and more northerly sites in the maritime Antarctic (Strandtmann 1982).

The failure of earlier studies in Marguerite Bay to record the predatory *Rhagidia gerlachei* is surprising given its size, activity and the wide distribution found here, although the species is poorly represented in heat extractions and therefore may be overlooked. The collection of *Isotoma (Folsomotoma) octooculata* on Léonie Island represents a southwards extension of the species' range from *c.* 65°S. It may be suggestive that the specimens found were obtained in extractions of debris from within gull and skua colonies, as these birds represent a likely but unproven mode of transport between terrestrial habitats for Antarctic microarthropods.

Usher & Edwards (1986a) suggested that microarthropod diversity decreases at progressively more southerly latitudes on the Antarctic Peninsula from a maximum of 17 species (including two Diptera) then known on the Byers Peninsula (Livingston Island, South Shetland Islands) to seven species on the Dion Islands (northern Marguerite Bay). However, the current study found a total of 20 species, but no Diptera, at the four Marguerite Bay sites examined and a maximum of seven species at one site on Alexander Island. Including previously recorded species, a total of 24 microarthropod species are now known from northern Marguerite Bay. The diversity of these southern faunas is, therefore, greater than previously recognized. For instance, the latest information on the terrestrial fauna of the Byers Peninsula SSSI (South Shetland Islands, north of the Antarctic Peninsula) identifies a total of 23 microarthropod species (Convey *et al.* 1996), very similar to the figure obtained here, and suggestive that diversity may not decrease with progression southwards along the Antarctic Peninsula as previously thought. There is, however, a clear decrease in faunal diversity between essentially coastal sites, represented by virtually the entire west coast of the Antarctic Peninsula and associated islands, and the sites studied on southern Alexander Island, which are effectively inland although at low altitude, separated from the true coast by *c.* 150 km of permanent ice shelf.

Comparison of the results of the current study with those of Usher & Edwards (1986a) and Convey *et al.* (1996) reveals that islands in Marguerite Bay have among the most diverse Antarctic terrestrial faunas known. Similarly, Léonie Island has one of the most diverse floras of any site south of 62°S, and many species occur here at the southern limit of their known distribution. It is, however, important to highlight that the total area of ice-free ground on these islands is small when compared with more northerly sites in the maritime Antarctic, and that the complexity of invertebrate and vegetation community development observed is unlikely to be repeated at other accessible sites within Marguerite Bay. Biological studies of these islands must, therefore, be planned with great care and large scale sampling is clearly very unwise.

The springtail *Cryptopygus antarcticus* has often been recognized as the numerically dominant terrestrial microarthropod at sites in the maritime Antarctic (*e.g.* Block 1982, Usher & Booth 1984a, Usher & Edwards 1986a). However, this dominance is likely to be a consequence of the species' favoured moss turf or carpet habitat being most amenable to heat extraction techniques. Other studies of more fragmentary habitats (*e.g.* Usher 1986, Richard *et al.* 1994) have found *C. antarcticus* to be relatively rare with individual samples dominated by *Friesia grisea* in particular, but also by *Stereotydeus villosus* or smaller tydeid species. Similarly, in communities on Alexander Island, *C. badasa* is more restricted to extensive areas of moss carpet than *F. topo*. The occurrence of large aggregations of oribatid mites such as *Alaskozetes antarcticus* and *Halozetes belgicae* is well-known in field observations (Block & Convey 1995) but, as a result, controlled extractions often give contradictory results, either with very low or extremely high population densities. This pattern is shown in the current data, in addition to that reported by Usher (1986), Usher & Edwards (1986a) and Richard *et al.* (1994).

Total population densities varied widely between extractions, but were between one and two orders of magnitude greater at Marguerite Bay sites than at most on Alexander Island (Tables I, II). The high densities obtained in Ablation

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Valley are exceptional for such a high latitude site. In comparison with data from other maritime Antarctic sites, the mean Marguerite Bay values are virtually identical to those obtained in heat extractions of moss cores made on Livingston Island in the South Shetland Islands (Richard *et al.* 1994) and overlap with the upper end of the range found in studies on Signy Island, South Orkney Islands (Block 1982, Usher & Booth 1984), where Goddard (1979a) also reported similar densities of prostigmatid mites (*Eupodes* sp., *Nanorchestes* sp.) to those found here. Maximum densities, both of individual species and in total, also fall in very similar ranges to those found by Richard *et al.* (1994). In contrast, microarthropod population densities at continental Antarctic sites are often much lower (100–3000 m^{-2}) (*e.g.* Wise & Spain 1967, Petersen 1971, Ryan *et al.* 1989, Sugawara *et al.* 1995) although some species may have local population densities comparable with those found in the maritime Antarctic (*e.g.* Rounsevell 1977, Ryan *et al.* 1989). The current data from most Alexander Island sites are similar to the low population densities typical of the continental Antarctic.

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References

Barr, D. 1973. *Methods for the collection, preservation and study of water mites (Acari: Parasitengona).* Toronto: Royal Ontario Museum, 28 pp.

Bell, C.M. 1973. The geology of southern Alexander Island. *British Antarctic Survey Bulletin*, Nos 33 & 34, 1-16.

Björk, S., Malmer, N., Hjort, C., Sandgren, P., Ingólfsson, O., Wallén, B., Smith, R.I.L. & Jónsson, B.L. 1991. Stratigraphic and paleoclimatic studies of a 5500-year-old moss bank on Elephant Island, Antarctica. *Arctic and Alpine Research*, **23**, 361-374.

Block, W. 1966. Some characteristics of the Macfadyen high gradient extractor for soil micro-arthropods. *Oikos*, **17**, 1-9.

Block, W. 1982. The Signy Island terrestrial reference sites XIV. Population studies on the Collembola. *British Antarctic Survey Bulletin*, No. 55, 33-49.

Block, W. & Convey, P. 1995. The biology, life cycle and ecophysiology of the Antarctic mite *Alaskozetes antarcticus*. *Journal of Zoology, London*, **236**, 431-449.

Block, W. & Stary, J. 1996. Oribatid mites (Acari: Oribatida) of the maritime Antarctic and Antarctic Peninsula. *Journal of Natural History*, **30**, 1059-1067.

Bonner, W.N. & Smith, R.I.L. 1989. *Comprehensive environmental evaluation: proposed construction of a hard airstrip at Rothera Point, Adelaide Island, Antarctica.* Swindon: NERC, 56 pp.

Booth, R.G. 1984. A new species of mite in the genus *Nanorchestes* (Acari, Prostigmata) from Signy Island, South Orkney Islands. *British Antarctic Survey Bulletin*, No. 63, 111-116.

Booth, R.G., Edwards, M. & Usher, M.B. 1985. Mites of the genus *Eupodes* (Acari, Prostigmata) from maritime Antarctica: a biometrical and taxonomic study. *Journal of Zoology, London*, **207**, 381-406.

British Antarctic Survey. 1995. *Initial Environmental Evaluation. Expansion of Rothera research station, Rothera Point, Adelaide Island, Antarctica.* Cambridge: British Antarctic Survey, 37 pp.

Butterworth, P.J., Crame, J.A., Howlett, P.J. & Macdonald, D.I.M. 1988. Lithostratigraphy of Upper Jurassic-Lower Cretaceous strata of eastern Alexander Island, Antarctica. *Cretaceous Research*, **9**, 249-264.

Clapperton, C.M. & Sugden, D.E. 1982. Late Quaternary glacial history of George VI Sound area, West Antarctica. *Quaternary Research*, **18**, 243-267.

Clapperton, C.M. & Sugden, D.E. 1983. Geomorphology of the Ablation Point massif, Alexander Island, Antarctica. *Boreas*, **12**, 125-135.

Convey, P. & Block, W. 1996. Antarctic dipterans: ecology, physiology and distribution. *European Journal of Entomology*, **92**, 1-13.

Convey. P., Greenslade, P., Richard, K.J. & Block, W. 1996. The terrestrial arthropod fauna of the Byers Peninsula, Livingston Island, South Shetland Islands – Collembola. *Polar Biology*, **16**, 257-259.

Crame, J.A. & Howlett, P.J. 1988. Late Jurassic and early Cretaceous biostratigraphy of the Fossil Bluff Formation, Alexander Island. *British Antarctic Survey Bulletin*, No. 78, 1-35.

Dartnall, H.J.G. 1980. Freshwater biology at Rothera Point, Adelaide Island: I. General description of the pools and the fauna. *British Antarctic Survey Bulletin*, No. 50, 51-54.

Dewar, G.J. 1970. The geology of Adelaide Island. *British Antarctic Survey Scientific Reports*, No. 57, 66 pp.

Edwards, M. & Usher, M.B. 1987. The adult and juvenile stages of two predatory mites, *Rhagidia gerlachei* and *Tuberostoma leechi*, in the maritime Antarctic. *British Antarctic Survey Bulletin*, No. 74, 37-48.

Elliott, M.H. 1974. Stratigraphy and sedimentary petrology of the Ablation Point area, Alexander Island. *British Antarctic Survey Bulletin*, No. 39, 87-113.

Fenton, J.H.C. 1982. The formation of vertical edges on Antarctic moss-peat banks. *Arctic and Alpine Research*, **14**, 21-26.

Fenton, J.H.C. & Smith, R.I.L. 1982. Distribution, composition and general characteristics of the moss banks of the maritime Antarctic. *British Antarctic Survey Bulletin*, No. 51, 215-236.

Goddard, D.G. 1979a. The Signy Island terrestrial reference sites XI. Population studies on the Acari. *British Antarctic Survey Bulletin*, No. 48, 71-92.

Goddard, D.G. 1979b. Biological observations on the free-living mites of Signy Island in the maritime Antarctic. *British Antarctic Survey Bulletin*, No. 49, 181-205.

Greenslade, P. 1995. Collembola from the Scotia Arc and Antarctic Peninsula including descriptions of two new species and notes on biogeography. *Polskie Pismo Entomologiczne*, **64**, 305-319.

Gressitt, J.L. (ed.) 1967. Entomology of Antarctica. *Antarctic Research Series*, **10**, 1-395.

Gressitt, J.L., Leech, R.E. & Wise, K.A.J. 1963. Entomological investigations in Antarctica. *Pacific Insects*, **5**, 287-304.

Gressitt, J.L. & Shoup, J. 1967. Ecological notes on free-living mites in north Victoria Land. *Antarctic Research Series*, **10**, 307-320.

HEYWOOD, R.B. 1977. A limnological survey of the Ablation Point area, Alexander Island, Antarctica. *Philosophical Transactions of the Royal Society of London,* **B279**, 39-54.

HORNE, R.R. 1969. Sedimentology and palaeogeography of the Lower Cretaceous depositional trough of south-eastern Alexander Island. *British Antarctic Survey Bulletin*, No. 22, 61-76.

KING, J.C. 1994. Recent climate variability in the vicinity of the Antarctic Peninsula. *International Journal of Climatology*, **14**, 357-369.

KRANTZ, G.W. 1978. *A manual of acarology* (second edition). Corvallis: Oregon State University Book Stores, 509 pp.

KREBS, C.J. 1972. *Ecology, the experimental analysis of distribution and abundance*. New York: Harper & Row, 694 pp.

LIGHT, J.J. & HEYWOOD, R.B. 1975. Is the vegetation of continental Antarctica predominantly aquatic? *Nature*, **256**, 199-200.

LONGTON, R.E. 1988. *Biology of polar bryophytes and lichens*. Cambridge: Cambridge University Press, 391 pp.

MARSHALL, D.J. & PUGH, P.J.A. 1996. Origin of the inland Acari of continental Antarctica, with particular reference to Dronning Maud Land. *Zoological Journal of the Linnean Society*, **118**, 101-118.

MEIKLJOHN, K.I. 1994. Valley asymmetry on south-eastern Alexander Island, Antarctica, and valley forms in the High Drakensberg, southern Africa. *South African Geographical Journal*, **76**, 68-72.

MONCRIEFF, A.C.M. & KELLY, S.R.A. 1993. Lithostratigraphy of the uppermost Fossil Bluff Group (early Cretaceous) of Alexander Island, Antarctica: history of an Albian regression. *Cretaceous Research*, **14**, 1-15.

MURPHY, P.W. (ed.) 1962. *Progress in soil zoology*. London: Butterworths, 398 pp.

PETERSON, A.J. 1971. Population studies on the Antarctic collembolan *Gomphiocephalus hodgsoni* Carpenter. *Pacific Insects Monograph*, **25**, 75-98.

PRIDDLE, J. & BELCHER, J.H. 1981. Freshwater biology at Rothera Point, Adelaide Island: II. Algae. *British Antarctic Survey Bulletin*, No. 53, 1-9.

PUGH, P.J.A. 1993. A synonymic catalogue of the Acari from Antarctica, the sub-Antarctic islands and the southern ocean. *Journal of Natural History*, **27**, 323-421.

RICHARD, K.J., CONVEY, P. & BLOCK, W. 1994. The terrestrial arthropod fauna of the Byers Peninsula, Livingston Island, South Shetland Islands. *Polar Biology*, **14**, 371-379.

ROUNSEVELL, D.E. 1977. The ecology of the pan-Antarctic mite *Nanorchestes antarcticus*. *In* LLANO, G.A., *ed*., *Adaptation within Antarctic ecosystems*. Houston: Gulf Publishing Co., 1023-1033.

ROUNSEVELL, D.E. & HORNE, P.A. 1986. Terrestrial, parasitic and introduced invertebrates of the Vestfold Hills. *In* PICKARD, J., *ed*., *Antarctic oasis, terrestrial environments and history of the Vestfold Hills*. Sydney: Academic Press, 309-331.

RYAN, P.G. & WATKINS, B.P. 1989. The influence of physical factors and ornithogenic products on plant and arthropod abundance at an inland nunatak group in Antarctica. *Polar Biology*, **10**, 151-160.

RYAN, P.G., WATKINS, B.P., SMITH, R.I.L, DASTYCH, H., EICKER, A., FOISSNER, W., HEATWOLE, H., MILLER, W.R. & THOMPSON, G. 1989. Biological survey of Robertskollen, western Dronning Maud Land: area description and preliminary species list. *South African Journal of Antarctic Research*, **19**, 10-20.

SMITH, H.G. 1986. The testate Rhizopod fauna of *Drepanocladus* moss carpet near Rothera Station, Adelaide Island. *British Antarctic Survey Bulletin*, No. 72, 77-79.

SMITH, R.I.L. 1984. Terrestrial plant biology of the sub-Antarctic and Antarctic. *In* LAWS, R.M., *ed*., *Antarctic Ecology*. London: Academic Press, 61-162.

SMITH, R.I.L. 1988a. Bryophyte oases in ablation valleys on Alexander Island, Antarctica. *Bryologist*, **91**, 45-50.

SMITH, R.I.L. 1988b. Destruction of Antarctic terrestrial ecosystems by a rapidly increasing fur seal population. *Biological Conservation*, **45**, 55-72.

SMITH, R.I.L. In press. Impact of an increasing fur seal population on Antarctic plant communities: resilience and recovery. *In* BATTAGLIA, B., VALENCIA, J. & WALTON, D.W.H., *eds*., *Antarctic commumities: species, structure and survival*. Cambridge: Cambridge University Press.

SØMME, L. 1986. New records of terrestrial arthropods from Dronning Maud Land, Antarctica. *Polar Research* (new series), **4**, 225-229.

SOUTHWOOD, T.R.E. 1966. *Ecological methods, with particular reference to the study of insect populations*. London: Methuen, 391 pp.

STRANDTMANN, R.W. 1967. Terrestrial Prostigmata (trombidiform mites). *Antarctic Research Series*, **10**, 51-80.

STRANDTMANN, R.W. 1971. The eupodoid mites of Alaska. *Pacific Insects*, **13**, 75-118.

STRANDTMANN, R.W. 1982. Notes on *Nanorchestes* V. Two new species of *Nanorchestes* (Acari: Nanorchestidae) from the Antarctic Peninsula and South Atlantic islands. *Pacific Insects*, **24**, 252-258.

SUGAWARA, H., OHYAMA, Y & HIGASHI, S. 1995. Distribution and temperature tolerance of the Antarctic free-living mite *Antarcticola meyeri* (Acari, Cryptostigmata). *Polar Biology*, **15**, 1-8.

SUGDEN, D.E. & CLAPPERTON, C.M. 1981. An ice-shelf moraine, George VI Sound, Antarctica. *Annals of Glaciology*, **2**, 135-141.

TAYLOR, B.J., THOMSON, M.R.A. & WILLEY, L.E. 1979. The geology of the Ablation Point - Keystone Cliffs area, Alexander Island. *British Antarctic Survey Scientific Reports*, No. 79, 65 pp.

USHER, M.B. 1986. Further conserved areas in the maritime Antarctic. *Environmental Conservation*, **13**, 265-266.

USHER, M.B. & BOOTH, R.G. 1984. Arthropod communities in a maritime Antarctic moss-turf habitat: three-dimensional distribution of mites and Collembola. *Journal of Animal Ecology*, **53**, 427-441.

USHER, M.B. & EDWARDS, M. 1984a. A dipteran from south of the Antarctic Circle: *Belgica antarctica* (Chironomidae), with a description of its larva. *Biological Journal of the Linnean Society*, **23**, 19-31.

USHER, M.B. & EDWARDS, M. 1984b. The terrestrial arthropods of the grass sward of Lynch Island, a specially protected area in Antarctica. *Oecologia*, **63**, 143-144.

USHER, M.B. & EDWARDS, M. 1986a. The selection of conservation areas in Antarctica: an example using the arthropod fauna of Antarctic islands. *Environmental Conservation*, **13**, 115-122.

USHER, M.B. & EDWARDS, M. 1986b. A biometrical study of the family Tydeidae (Acari, Prostigmata) in the maritime Antarctic, with descriptions of three new taxa. *Journal of Zoology, London*, **209**, 355-383.

VAUGHAN, D.G. & DOAKE, C.S.M. 1996. Recent atmospheric warming and retreat of ice shelves on the Antarctic Peninsula. *Nature*, **379**, 328-331.

WALLWORK, J.A. 1965. The Cryptostigmata (Acari) of Antarctica with special reference to the Antarctic Peninsula and South Shetland Islands. *Pacific Insects*, **7**, 453-468.

WALLWORK, J.A. 1967. Cryptostigmata (oribatid mites). *Antarctic Research Series*, **10**, 105-122.

WALLWORK, J.A. 1970. Acarina: Cryptostigmata of Heard and Kerguelen. *Pacific Insects Monograph*, **23**, 179-182.

WISE, K.A.J. & SPAIN, A.V. 1967. Entomological investigations in Antarctica, 1963-64 season. *Pacific Insects*, **9**, 271-293.