ECOLOGICAL AND PHYSIOLOGICAL STUDIES OF TERRESTRIAL ARTHROPODS IN THE ROSS DEPENDENCY 1984–85

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ABSTRACT. Aspects of the ecology and physiology of terrestrial arthropods were studied at nine locations on Ross Island and South Victoria Land during the 1984–85 summer. Four species (three mites and one springtail) were identified from a range of terrestrial habitats. Physiological work was concentrated on the cold resistance of two of these species (*Gomphiocephalus hodgsoni* (Collembola) and *Stereotydeus mollis* (Acarina). Supercooling of cold adapted individuals was extensive (range of −24 to −30°C) before freezing, which was lethal in both forms. Thus, freezing avoidance by supercooling is the strategy adopted by these invertebrates, which appear well able to resist the thermal minima experienced during summer. Experiments demonstrated that moisture, ingested or absorbed, caused nucleation at higher sub-zero temperatures, thereby reducing cold resistance. Levels of potential anti-freezes in sample extracts are being assayed by gas–liquid chromatography. The abundance and field movement of individuals in these arthropod populations was directly related not only to substrate moisture but also to the presence of vegetation (e.g. mosses, lichens, algae). A special study of the microclimates of terrestrial habitats was undertaken to define the environmental conditions experienced in summer by both arthropods and discrete plant patches. Temperature and relative humidity readings at 5-min intervals were logged for periods up to 25 days in soil, vegetation, under stones and rocks, and in air at the ground surface. Minimum temperatures reached −8 to −11°C in such micro-sites, and maxima of *c.* 26°C were recorded on vegetation surfaces. Atmospheric humidity at the surface of soil and vegetation patches was also variable (minima 8–11%; maxima 90–97%). An opportunity was taken to collect 40 small soil and plant samples from eight of the locations for protozoological and nematological studies.

INTRODUCTION

Research on the terrestrial arthropods (Acarina and Collembola) of South Victoria Land and Ross Island has been mainly confined to taxonomic studies (e.g. Wise, 1967; Strandtmann, 1982) and ecology (e.g. Janetschek, 1967*a*, *b*; Peterson, 1971). Much ecological work had been undertaken on the springtail *Gomphiocephalus hodgsoni* at Cape Bird, Ross Island (Smith, 1970; Duncan, 1979). No data exist on the physiological characteristics of such populations, nor on their field activity, and information on their field microclimates was limited. An attempt was made to fill this gap utilizing experience and techniques developed through field studies in the maritime Antarctic (the Antarctic Peninsula, and Signy Island, South Orkney Islands).

The specific aims of the project were:

(*a*) To investigate the ecophysiology of terrestrial arthropods at locations on Ross Island and the Dry Valley region of South Victoria Land.

(*b*) To examine experimentally the cold resistance of field populations of mites (Acarina) and springtails (Collembola) in order to evaluate their survival characteristics.

(*c*) To assess the field movement and activity of species representative of extreme fellfield communities.

(*d*) To provide environmental data for the above experiments, microclimate monitoring (temperature and relative humidity (RH)) was undertaken in a range of terrestrial habitats.

(*e*) To collect small soil and vegetation samples from a variety of terrestrial habitats for subsequent analyses of the nematode and protozoan fauna.

Methods

As far as possible, the methods for this project were simple, enabling them to be used under field (camp) conditions, and most had been tested previously.

(*1*) *Arthropod cold resistance*

Individual supercooling points (= whole body freezing points) of mites and springtails were measured using a Cu-con thermocouple and a battery-driven Grant recorder. Body temperatures were monitored in air with a cooling rate of *c*. 1 deg. min^{-1}. This was achieved by lowering the animal on the thermocouple inside an air-filled tube into a freezing mixture of granular snow and Ca $Cl_2 . 6H_2O$ (1.5:1 v/v) contained in a vacuum flask. Supercooling points were read as the point of origin of the small temperature rise that accompanied the emission of latent heat during freezing. Supercooling is the maintenance of the animal's body fluid in the liquid phase below its freezing point. Full experimental details are given in Block & Sømme (1982).

The antifreezes in the body fluid were examined by making extracts of polyhydric alcohols and sugars in 70% ethanol from samples of 25–100 individual micro-arthropods. About 40 such extracts are being analysed by gas–liquid chromatography at BAS, Cambridge (see Block & Sømme (1982) for further details). Further whole animal samples were preserved for osmometry.

(*2*) *Arthropod field activity*

A measure of ground surface movement of micro-arthropods was obtained from sticky traps placed among field transects in moss patches, algal felts and lichen communities. Traps were operated also in wet and dry soils at Cape Bird and Cape Crozier with up to 20 traps being used per transect. Each trap comprised a clear perspex sheet (5 × 8 cm), coated on one surface with Sticktite, and it was exposed in either a vertical or horizontal position on the substrate. After differing exposure periods, trapped animals were identified and counted using a binocular microscope.

(*3*) *Microclimates*

Soil, rock and vegetation temperatures, together with atmospheric RH, were monitored continuously in selected terrestrial habitats using two Grant Squirrel data loggers (Fig. 1). Mini-thermistors (range −35 to 35°C) and capacitative Vaisala probes (0 to 100%) were used for sensing temperature and RH respectively. Recording was at 5-min intervals for up to six days, the loggers were then interfaced with an Epson HX-20 micro-computer and the data down-loaded for subsequent analysis. Data analysis including the calculation of means (±SD), selection of maximum and minimum values with their times of occurrence, and plots of all the data points for selected periods or for complete runs were undertaken in the field. Further analyses will be done on the field data transferred to micro-cassette tapes.

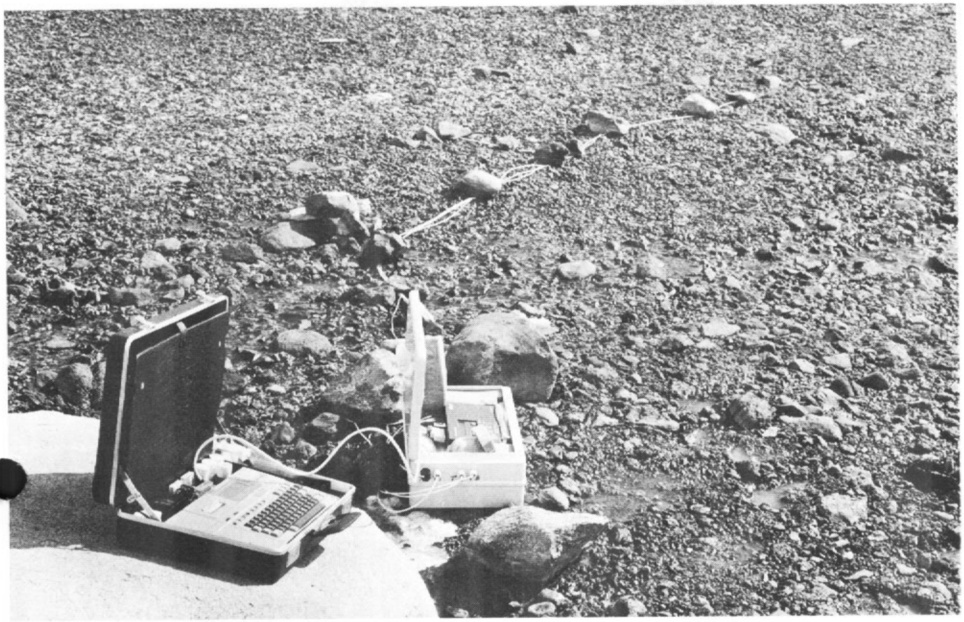

Fig. 1. Microclimate data logger (Grant Squirrel) located in a fellfield study area at Cape Bird, Ross Island. The Epson HX-20 microcomputer (in black case) is interfaced with the logger for data transmission.

Table I. Occurrence of arthropod species at locations visited in the 1984–85 field season.

	Collembola	Acarina		
Location	*Gomphiocephalus hodgsoni*	*Stereotydeus mollis*	*Nanorchestes antarcticus*	*Nanorchestes* sp.*
Ross Island				
Cape Bird (Keble Valley)	+	+	+	+
Cape Royds (Collembola Heights)	+	+	+	–
Cape Crozier (nr Post Office Hill)	+	+	+	–
Scott Base, Hut Point	+	+	–	–
South Victoria Land				
Garwood Glacier, Garwood Valley	+	+	–	–
Lake Fryxell, Taylor Valley	–	+	–	–
Lake Bonney, Taylor Valley	–	–	–	–
Lake Vanda, Wright Valley	–	–	–	–
West Beacon Mountains, Taylor Glacier	–	–	–	–

* Probably *Nanorchestes bellus* or *Nanorchestes lalae*, but subject to confirmation.

Table II. Mean (±SD) supercooling points (SCP) of field samples of two species of arthropods from locations on Ross Island and South Victoria Land. (*n*): number of observations.

Location	Date	SCP (°C) High group	SCP (°C) Low group
Gomphiocephalus hodgsoni			
Cape Bird (Keble Valley)	27 Nov. 1984	−15.4±3.8 (3)	−30.4±1.9 (72)
(Keble Valley)	5 Dec. 1984	−11.2±3.2 (5)	−29.9±0.9 (53)
(Keble Valley)	14 Dec. 1984	−7.6±3.3 (10)	−30.6±1.8 (56)
Cape Royds (Collembola Heights)	24 Dec. 1984	−13.8±5.5 (6)	−29.5±1.7 (65)
Garwood Glacier	29 Dec. 1984	−13.6±5.3 (16)	−29.8±1.4 (54)
Cape Crozier (nr Post Office Hill)	12 Jan. 1985	−18.3±5.1 (18)	−30.4±1.5 (70)
Stereotydeus mollis			
Cape Bird (Keble Valley)	30 Nov. 1984	−18.3±2.6 (59)	−26.4±1.4 (27)
(Keble Valley)	7 Dec. 1984	−14.7±3.6 (52)	−25.0±1.8 (10)
(Keble Valley)	18 Dec. 1984	−15.4±4.1 (73)	−24.9±0.7 (8)
Cape Royds (Collembola Heights)	24 Dec. 1984	−17.9 (1)	−24.8±1.1 (8)
Garwood Glacier	30 Dec. 1984	−16.3±3.2 (40)	−25.3±1.6 (13)
Cape Crozier (nr. Post Office Hill)	16 Jan. 1985	−16.7±4.3 (59)	−27.7±1.1 (33)

(*4*) *Qualitative invertebrate samples*

A total of 40 small samples of soils and plants was collected by hand from eight locations on Ross Island and South Victoria Land for analysis of their protozoan and nematode fauna. Material was placed in small polythene bags, labelled and transported to the UK for specialist study.

RESULTS

(*1*) *Arthropod cold resistance*

Arthropods were found at six out of the nine locations visited (Table I). Four species (one collembolan and three mites) were found in Keble Valley, Cape Bird, the second species of *Nanorchestes* being a new record for that area. The commonest species was the collembolan *Gomphiocephalus hodgsoni*, which was particularly abundant in Keble Valley at Cape Bird (Fig. 2).

Cold resistance experiments were concentrated on *G. hodgsoni* and the prostigmatid mite *Stereotydeus mollis*. Both species were susceptible to freezing, i.e. ice formation in their bodies was lethal. Frequency distributions of the supercooling points (SCP) determined for each experiment often showed a separation into a high group (HG) (> −20°C) and a low group (LG) (< −20°C), but this was less clear for data from *S. mollis*. The HG is caused mainly by nucleation of food and water within the gut system during supercooling, whereas the LG probably represents the maximum potential cold resistance of the species under the experimental conditions. Table II shows the mean SCP for both groups for all the field samples. The HG values vary considerably, whereas the LG means do not, for both species. *C. hodgsoni* is more cold resistant than *S. mollis* under summer field conditions, with mean LG SCP around −30°C for the former and from −24 to −28°C for the latter species.

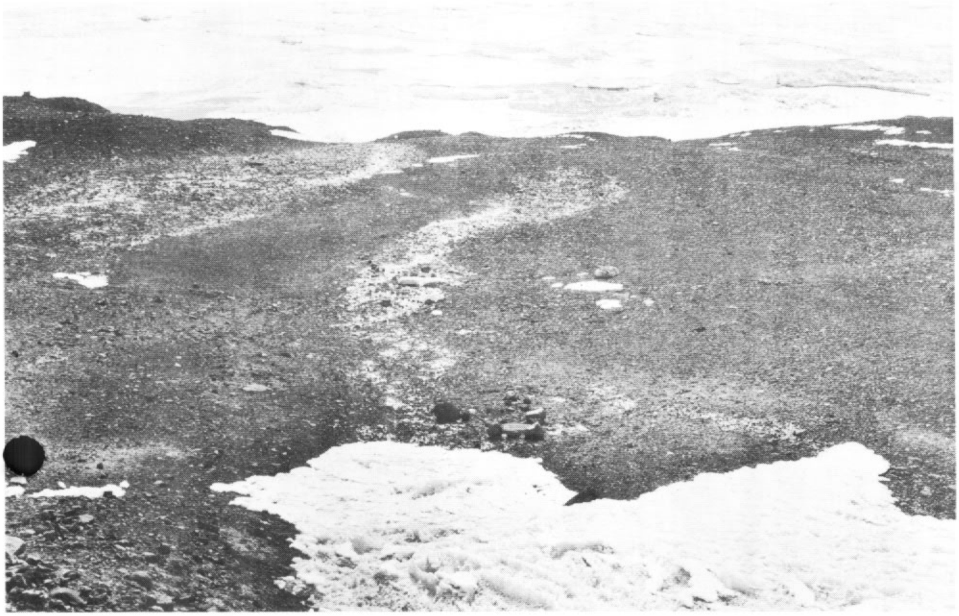

Fig. 2. Continental Antarctic fellfield on Ross Island (Cape Bird). The photograph shows one of the meltstreams in Keble Valley and the area where arthropod field studies were made in December 1984.

Fig. 3. A clump of the moss *Bryum antarcticum* with associated algae (*Phormidium* spp.) forming a typical streamside community on Ross Island, Antarctica. The scale is in centimetres.

Experiments were conducted at Cape Bird and Cape Crozier to determine if exposure to moisture altered the extent of supercooling in the collembolan. Although the mean LG SCP changed little, the proportions of animals in the groups altered with the majority (68–100%) being in the HG. Thus ingestion and inhibition of moisture for growth, etc. appears to reduce the cold resistance in this species.

The levels of antifreezes and their role in the cold resistance of these micro-arthropods will be discussed later.

(2) Arthropod field activity

Using the total number of trapped individuals per unit time for comparison, it is clear that arthropod activity was highest at microsites where both vegetative growth (mosses, algal or lichens) and moisture were present (Fig. 3). Fewer animals were trapped in the drier microsites along the transects, and none were found in the extremely dry areas. No significant differences were found between the catches of vertical or horizontal traps in similar microsites.

(3) Microclimates

Table III presents a summary of the mean values (and their ranges) for temperature and atmospheric RH in the twelve terrestrial habitats in which recording was undertaken. Minimum microsite temperatures (−8 to −11°C) occurred early in the summer (Nov.–Dec.) and at the mountain location (West Beacon) in January. Maximum temperature records were for surfaces of mosses and lichens (26°C) at Cape Bird and Cape Crozier respectively. Lowest RH measurements were at West Beacon (8%) during a cold period, and in the Garwood Valley (11%) with a high air temperature (*c.* 17°C). RHs up to 97% were measured at moss surfaces. For the locations where micro-arthropods occurred in sufficient numbers for cold resistance experiments to be undertaken (Table II), it is clear that both species were well able to avoid lethal freezing by supercooling. Summer conditions in microsites occupied by both arthropods did not appear to be thermally stressful, but alternatively atmospheric water vapour may be limiting at certain times.

Further analyses will help to define more precisely the environmental conditions which are experienced by such arthropods. In addition, it is hoped that the particular characteristics of favoured microsites in such continental Antarctic habitats will be elaborated.

(4) Qualitative invertebrate samples

Analyses of the micro-fauna (Protozoa and Nematoda) are in progress, and the results will add to the scant knowledge of these groups in the continental Antarctic.

Future Research

Work that could develop from these studies includes:

(*a*) a year-round seasonal examination of the cold resistance of *G. hodgsoni* and possibly *S. mollis* at Cape Bird;

(*b*) seasonal changes in terrestrial microclimates at selected sites (e.g. moss patches, algal felts) by means of automatic recording or integration systems or remote sensing techniques;

(*c*) an in-depth examination of the life cycle of the dominant arthropod, *G. hodgsoni.*

Table III. Summary of microclimate data from terrestrial habitats at six locations during the 1984–85 season. *n*: number of readings.

Location	*Habitat*	*Microsite**	*Record dates*	*Temp. & Rel. Humidity* *Mean*	*Range*	*n*
Cape Bird	Algal felt	1	26 Nov.–	2.2°C	−7.6–19.6	3728
		2	9 Dec. 1984	2.0°C	−7.3–14.0	
		3		2.5°C	−2.8–12.3	
		4		68.0%	29.5–87.0	
	Moss patch (lower)	1	26 Nov.–	1.7°C	−8.4–18.8	5721
		2	20 Dec. 1984	1.4°C	−6.2–12.6	
		3		2.2°C	−5.9–12.9	
		4		73.0%	54.5–85.5	
	Moss patch (upper)	1	10–20 Dec.	6.4°C	−4.5–26.6	2965
		2	1984	5.6°C	−2.5–19.3	
		3		2.8°C	0.3–13.4	
		4		81.0%	49.0–97.0	
Cape Royds	Unvegetated dry volcanic debris	1	23–26 Dec.	11.8°C	1.7–23.0	860
		2	1984	11.5°C	3.1–18.8	
		4		39.0%	15.5–74.0	
	Moss patch	1	23–26 Dec.	6.7°C	−1.1–22.7	927
		2	1984	5.6°C	−0.3–17.4	
		3		5.3°C	−2.2–24.9	
		4		56.0%	23.0–93.0	
Garwood Valley	Unvegetated dry stone 'pavement'	1	27 Dec. 1984	6.4°C	−0.6–16.8	1482
		2	–2 Jan. 1985	7.0°C	−0.6–17.6	
		3		6.2°C	1.1–12.9	
		4		29.0%	11.5–54.0	
	Moss patch	1	27 Dec. 1984	5.6°C	−0.6–22.1	1471
		2	–2 Jan. 1985	5.9°C	0.6–15.1	
		4		63.0%	27.5–84.5	
Lake Vanda	Unvegetated dry ridge	1	2–4 Jan. 1985	6.2°C	0.6–17.6	466
		2		7.0°C	1.4–12.6	
		3		5.9°C	1.4–10.6	
		4		29.5%	10.5–53.5	
West Beacon Mountain	Valley floor	1	4–8 Jan. 1985	−4.8°C	−11.8– 5.3	987
		2		−4.5°C	−10.9– 7.6	
		3		−4.2°C	−9.5– 6.2	
		4		46.5%	8.0–91.0	
	Exposed ridge	1	5–8 Jan. 1985	−2.5°C	−9.5–10.1	809
		2		−0.3°C	−6.7–10.1	
		4		41.0%	9.0–86.5	
Cape Crozier	Lichen patch	1	10–18 Jan.	5.0°C	−3.6–26.3	2421
		2	1985	6.2°C	−1.1–21.8	
		3		5.0°C	−1.4–19.3	
		4		43.5%	14.5–84.5	
	Exposed hill	1	10–18 Jan.	4.5°C	−1.1–14.6	876
		2	1985	4.5°C	−5.3–25.5	
		4		47.0%	21.5–82.5	

* The microsites were not always comparable but in general the sensors were located as follows:

Temperature

(1) Surface of vegetation, stone, rock or soil (unshielded).

(2) Beneath stone or rock or 3 cm inside vegetation.

(3) At 3 cm depth in mineral soil.

Relative Humidity

(4) Air at ground surface.

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