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TEMPERATURE AND THREE SPECIES OF ANTARCTIC ARTHROPODS[1]

By **J. M. Fitzsimons**[2]

Abstract: In temperature gradient tests the springtail *Gomphiocephalus hodgsoni* Carp. aggregated within a range of +8° to +11.5°C, whereas the mites *Nanorchestes antarcticus* Str. and *Stereotydeus mollis* Wom. & Str. did not aggregate in limited ranges. *N. antarcticus* has the greatest tolerance to temperature extremes and is active over the greatest temperature range.

Before the brief work of Janetschek (1963) there had been scarcely any research conducted on the physiological ecology of Antarctic arthropods. Although entomologists have amassed considerable microclimatological data at numerous places on the Antarctic continent, they had little opportunity to objectively relate these findings to faunal behavior. There is some evidence, too, that previous attempts to quantify elements of the microclimates may have changed them more than measured them. This paper presents a few simple albeit crude experiments in which controllable microclimates were produced in the laboratory and the subsequent activity of arthropods recorded. The test apparati were contrived from ordinary laboratory materials, and it is hoped that future studies with refined equipment will produce more definitive information. It is especially hoped that future field work in Antarctic entomology will develop new methods and instruments for measuring the standing state of abiotic factors where the animal lives—whether it be five centimeters deep in soil, under a flat rock, or in thick beds of moss. Only then will we begin to understand why arthropods are extremely abundant in certain areas and mysteriously lacking in other apparently suitable habitats. Undoubtedly such information will also aid in explaining why one of two mite species collected under the same stone is limited to a few areas along the Victoria Land coast while the other species occurs south to within a few hundred kilometers of the Pole, throughout Victoria Land, and in certain Subantarctic islands.

This paper deals with the influence of temperature on the activity and survival of three species of Antarctic arthropods from the southern Ross Sea coast. Data on these species and other variable environmental factors has also been accumulated.

Nanorchestes antarcticus Strandtmann, the most southerly occurring arthropod, has a broad distribution from northern Victoria Land to 85° 32′ S and certain Subantarctic islands (Gressitt & Shoup 1967). The mite *Stereotydeus mollis* Womersley & Strandtmann has been collected from Terra Nova Bay to Minna Bluff in Victoria Land. The springtail *Gomphiocephalus hodgsoni* Carpenter occurs from Mt. George Murray nunatak south to Minna Bluff. Specimens for this study were collected on three occasions at Marble Point across the Ross Sea from McMurdo Station.

Response to temperature gradients

Two rather crude apparati were assembled for studying the responses of mites and springtails to temperature gradients. Two thin (1.5 mm) sheets of copper, each with a median groove (Fig. 1), were covered with a light coat of fiberglass resin. Foam neoprene gaskets placed on the rims of the grooves assured a tight fit when small glass plates were laid over them. One gradient

1. Partial results of grant GA-131 from the National Science Foundation (Office of Antarctic Programs) to Bishop Museum.

2. Bishop Museum, Honolulu. Present address: Dept. Zoology & Physiology, Louisiana State University, Baton Rouge, Louisiana 70803.

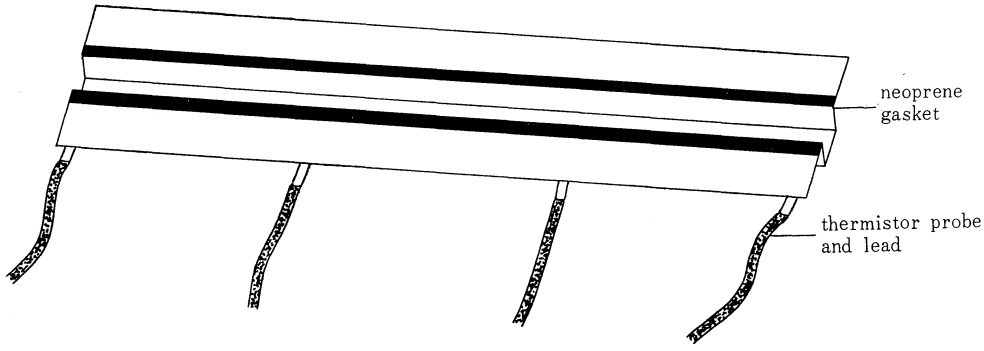

Fig. 1. Temperature Gradient Apparatus.

was 12 cm in length with thermistor probes attached to the underside of the groove at each end and at 4 cm intervals; the other apparatus was 35 cm long with probes attached at 5 cm intervals. The thermistor leads were inserted into the control box of a telethermometer so that the temperatures throughout the length of the copper sheets could be determined simultaneously. Since there was no device available for measuring the humidity within the sealed grooves, each test was conducted with both wet and dry cotton plugs inserted into the open ends of the grooves. When wet plugs were used, the apparatus was left sealed for several hours to allow for a more or less uniform distribution of moisture throughout the chamber before rapidly introducing animals. When dry cotton plugs were used, care was taken to be sure that the cotton, as well as the rest of the apparatus, was absolutely dry to prevent orientation to a moisture source by the animals. The entire setup, i.e., the copper plates, probes, and telethermometer, was placed inside a "walk-in" refrigerator maintained at approximately 1.6 °C. The copper plates were warmed on one end with a 100 watt light bulb wrapped in aluminum foil to produce the thermal gradient inside the test grooves. The tests were conducted in total darkness to eliminate photic responses by the animals. The number of animals between probes was recorded at the end of 12 hr for the 12 cm chamber and after 24 hr for the 35 cm apparatus.

The data are summarized in Fig. 2. The width of the blocks represents the temperature range between a given pair of thermistor probes; the numbers within the blocks indicate how many animals were found between adjacent probes at the end of the test periods. *S. mollis* and *N. antarcticus* did not orient to a given temperature range but were widely dispersed throughout the gradient. However, an average of 64% of the springtails (note stipled blocks in Fig. 2) aggregated within a temperature range from 8° C to 11.5 °C in both test apparati at high and low humidities. These temperatures, which are assumed to delimit the optimum range for *G. hodgsoni*, are favorably comparable with the results obtained by Janetschek (1963) who concluded that the "temperature preference" of these springtails is $+11.32 \pm 0.55$ °C.

Upper lethal temperatures

As shown above, *N. antarcticus*, *S. mollis*, and *G. hodgsoni* are able to withstand the highest temperatures under conditions of high humidity. Moreover, Edney (1957) writes that the "highest temperature an insect can withstand at 90% RH is close to its true thermal death point." High humidity apparently eliminates the possibility of the animal's body being cooled by the transpirational loss of water and subsequent evaporation or, if such water loss is detrimental, a low saturation deficit precludes premature death by desiccation.

In the following experiments humidity was maintained constantly near saturation.

G. hodgsoni were separated into groups of ten and placed into vials with moist cotton plugs.

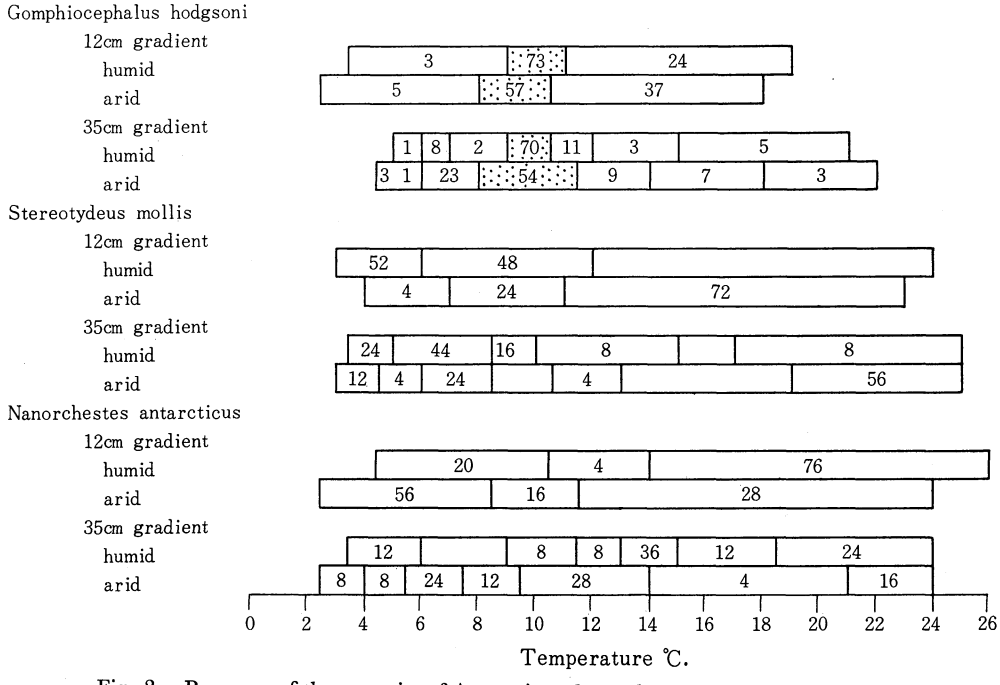

Fig. 2. Response of three species of Antarctic arthropods to a temperature gradient.

The animals were kept at 5 ± 0.2 °C for three to five hours before testing and were reexamined before each experiment to assure their being alive and in good condition. The temperature around the vials was raised each hour and the number of live animals recorded. The experiment was repeated twice with "fresh" animals.

Fig. 3 illustrates the results obtained for the springtails. Each point on the graph represents the number of live animals at a given temperature; the distance between consecutive points in each of the curves indicates the hourly temperature increment. A lethal temperature is deduced from these data on the basis of the average LD50, i.e., the average time and temperature required to kill one half a group of animals. These data suggest that the upper lethal temperature for *Gomphiocephalus hodgsoni* is +29.5 °C at a constant humidity of 90+% RH with a mean hourly increase of 2.6 °C over a period of approximately 8.5 hrs. Janetschek (1963) noted that the springtails were killed by heat at temperatures above +33 °C.

In the preceding experiments the springtails in a single vial were never recounted; thus, a total of 380 insects were used. Unfortunately, the mites could not be obtained in good condition in such large numbers. Live specimens of each of the two mite species were divided into three groups of 20 individuals each. The groups of 20 were separated into small petri dishes with net covers. These dishes were subsequently placed into larger dishes containing moist cotton. Edney paper hygrometers in control dishes without arthropods indicated that a constant humidity was maintained. A mirror was positioned beneath the culture dishes and a dissecting microscope was focused on the mirror for viewing the arthropods from below. With this arrangement it was possible to observe even the slightest movements of the mites without disturbing them or the temperature and humidity around them.

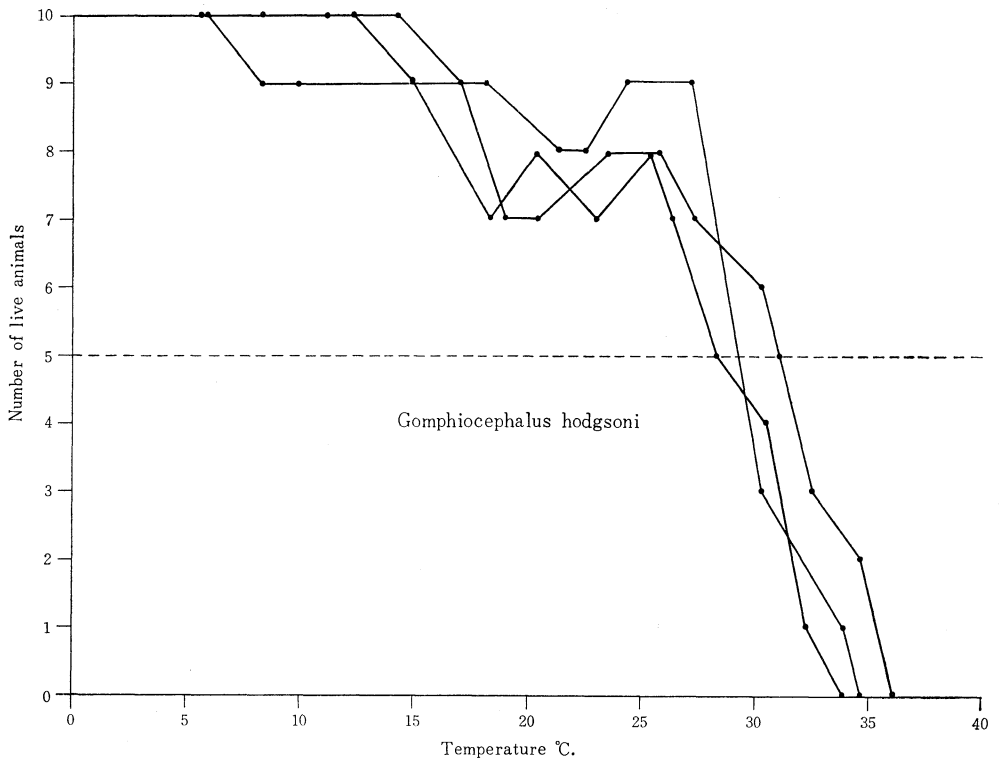

Fig. 3. Upper lethal temperatures for *Gomphiocephalus hodgsoni*.

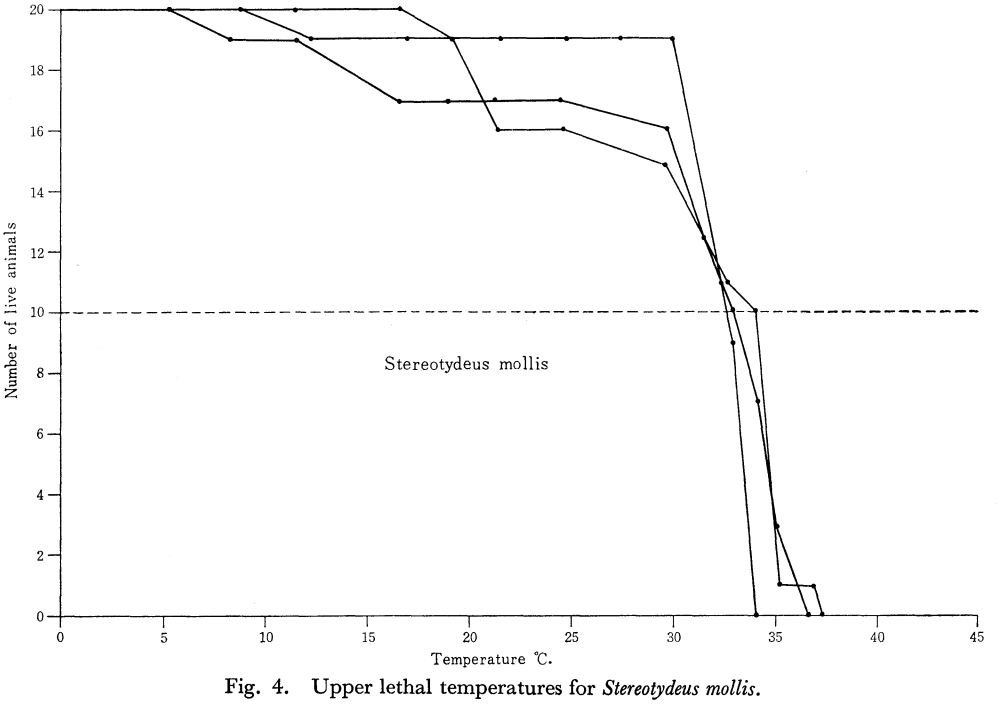

Fig. 4. Upper lethal temperatures for *Stereotydeus mollis*.

Fig. 4 demonstrates that the upper lethal temperature for *Stereotydeus mollis* is approximately +33.2 °C at 90+% RH with a mean hourly increase in temperature of 2.9 °C over a 12.5 hr period. The upper lethal temperature for *Nanorchestes antarcticus* (Fig. 5) is +37.2 °C at high humidity with a temperature increase of 2.1 °C every hour for 19.5 hrs.

Next mites and springtails were placed in culture dishes at approximately 0 °C, 10 °C, and 20 °C. After three to five hours 20 animals of each species were removed from the various temperatures and placed immediately into a humid chamber at 38 °C. The number of live arthropods was recorded hourly.

The results (Fig. 6, 7, 8) indicate that animals previously maintained at 20 °C survived 38 °C longer than animals held at 10 °C or 0 °C. Similarly, animals kept at 10 °C lived longer at the lethal temperature of 38 °C than did those from dishes at 0 °C. Previous temperature experience is apparently important in the survival of these arthropods at upper lethal temperatures since animals from contiguously warmer microclimates withstood supramaximum temperatures for the greatest length of time.

Lower lethal temperatures

Animals of each species were subjected to temperatures of −11 ± 0.8°C., −23 ± 0.4°C., and −41 ± 0.1 °C. After two weeks 39 of 50 *G. hodgsoni*, 15 of 20 *S. mollis*, and 18 of 20 *N. antarcticus* survived temperatures near −11 °C. After 24 hrs −23 °C was lethal to *G. hodgsoni* and *S. mollis* although *N. antarcticus* were kept alive at this temperature until removed from the freezing unit 13 days later. Janetschek (1963) found the frost resistance for *G. hodgsoni* to be −20 ± 2 °C and that lower temperatures, as −28 °C, are lethal. *N. antarcticus* became immobile at −41 °C, and after nine days 8 of 20 animals remained alive.

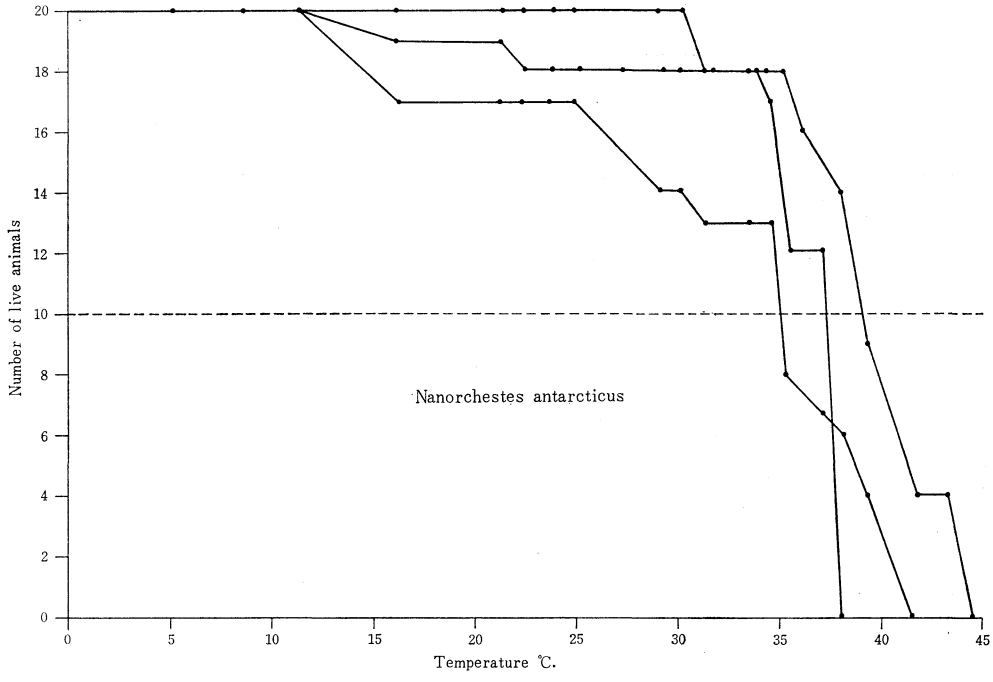

Fig. 5. Upper lethal temperatures for *Nanorchestes antarcticus*.

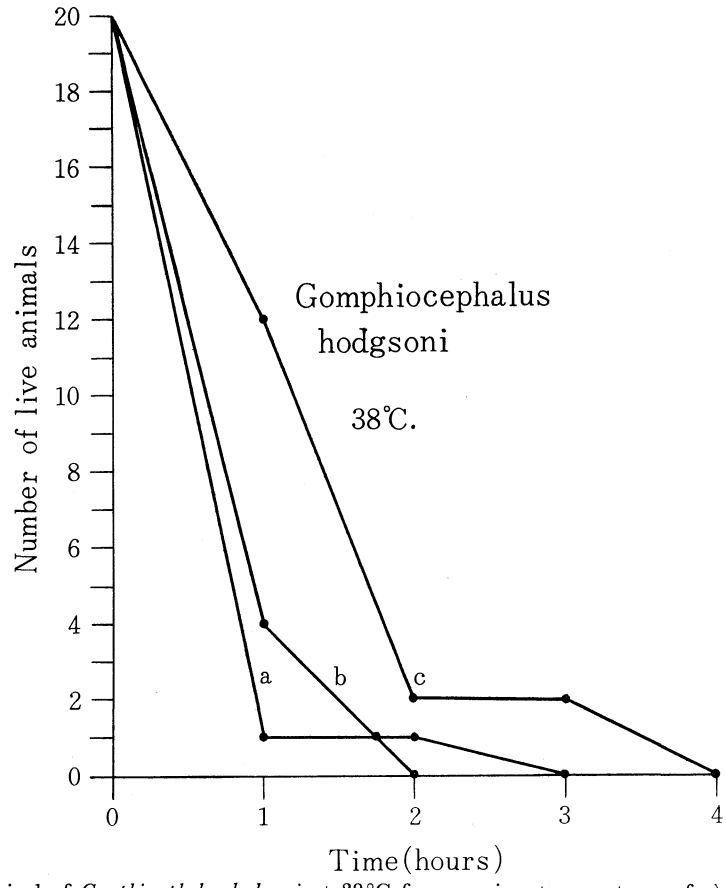

Fig. 6. Survival of *Gomphiocephalus hodgsoni* at 38°C from previous temperatures of a) 0°C, b) 10°C, and c) 20°C.

In a discussion of the resistance of arthropods to low temperatures, Edney (1957) cites examples in which the cold hardiness of animals was increased by the loss of body water. Specimens of *G. hodgsoni* and *S. mollis* were kept for several (3 to 6) hours at four humidities ranging from 90+% RH to below 20% RH. Water loss was indicated at low humidities by the shriveled appearance of the animals (especially the softer bodied springtails). These animals were subsequently placed in a freezing unit at −23°C. A comparision of survival rates of the arthropods from the various humidities does not imply significant differences in time to death.

Salt (in Edney 1957) indicates that certain arthropod larvae become less cold tolerant when food is in the gut. Salt contends that food in supercooled animals may act as a substratum for the formation of ice crystals within their bodies. Starved specimens of *G. hodgsoni*, and *S. mollis* however, were less hardy than animals to which food had been available.

When live specimens of *G. hodgsoni* were moved from a petri dish at −11°C to a dish with a layer of ice at the same temperature, the animals froze and died within a few hours. Apparently the animals are supercooled at this temperature and contact with ice causes the formation of ice

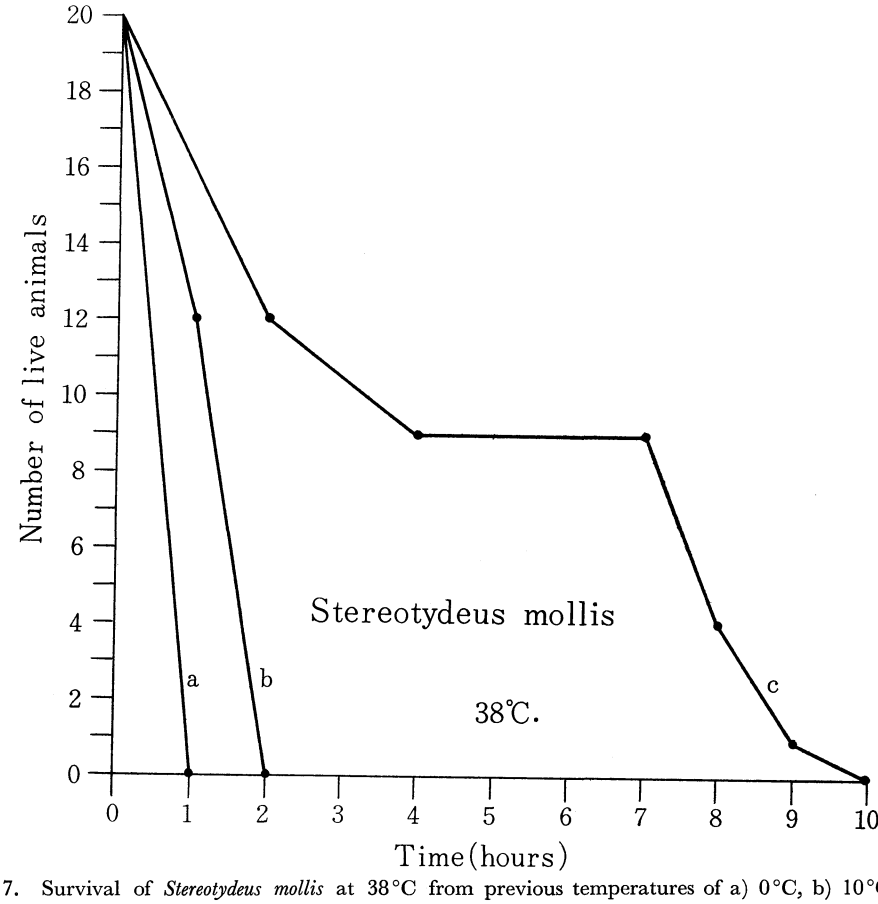

Fig. 7. Survival of *Stereotydeus mollis* at 38°C from previous temperatures of a) 0°C, b) 10°C, and c) 20°C.

crystals just as supercooled fishes of the genus *Fundulus* were "seeded" and frozen when touched with a piece of ice (Scholander in Smith 1961).

Although previous temperature experience is important in the survival time of arthropods at high temperatures, there is no evidence that gradually cooled animals survived longer at cold temperatures than did ones introduced directly from room temperature (about 20°C). On the contrary, springtails which were gradually cooled to −23°C over a 3.5–5 hr period survived an average of 2 hr 50 min less than animals which were not "precooled." This time difference is an average based on three tests with 20 animals each; the total survival time includes the time spent both at −23°C and above. Specimens of *G. hodgsoni* and *S. mollis* which were kept at −11°C for 74 hrs before being placed in a freezing unit at −23°C did not survive significantly longer than animals previously held at +5°C.

Temperature and optimum activity

Gomphiocephalus hodgsoni were most active at temperatures from +7°C to +15°C. At temperatures above +15°C the animals were extremely active but movements were erratic and

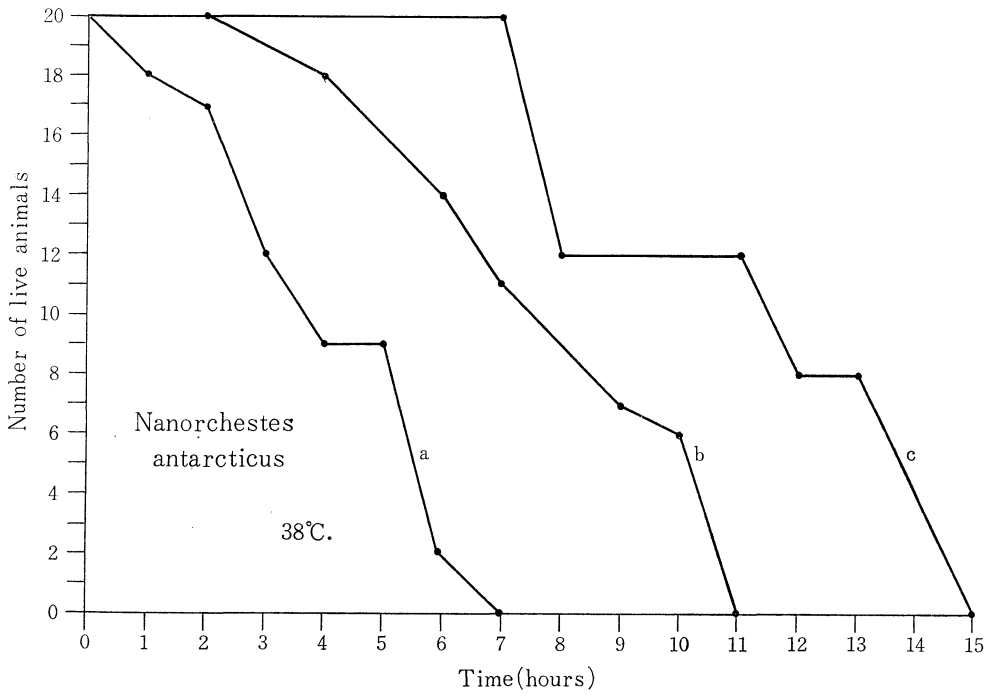

Fig. 8. Survival of *Nanorchestes antarcticus* at 38°C from previous temperatures of a) 0°C, b) 10°C, and c) 20°C.

limbs uncoordinated. Springtails were sluggish at +3°C. At 0°C and below the animals moved little if at all.

Stereotydeus mollis were normally active from 0°C to +23°C. At temperatures above +23°C the animals readily autotomized their appendages. No movement was seen at −11°C.

Nanorchestes antarcticus were observed crawling about slowly at −23°C and seemed to be equally active at +31°C. At higher temperatures distress was evident. These mites were immobile at −41°C.

Table 1 summarizes the temperature data for the three species. Considered alone, the numbers in the table have little significance since the quantification of other factors such as time or humidity is not provided.

It is noteworthy that *N. antarcticus*, the most widely distributed of Antarctic arthropods, not only survived the lowest and highest temperatures, but was active throughout the greatest temperature range.

Table 1. The temperature range of three Antarctic arthropod species

Temperature °C:	*N. antarcticus*	*S. mollis*	*G. hodgsoni*
Upper lethal	+37.2	+33.2	+29.5
Sublethal maximum	+31 to +37.2	+23 to +33.2	+15 to +29.5
Optimum	−23(?) to +31	0 to +23	+7 to +15
Lower lethal	−23 to −41	−11 to −23	−11 to −23

SUMMARY AND CONCLUSIONS

1. During the 1965–66 summer season studies were begun on the influence of temperature on three species of Antarctic arthropods, *Stereotydeus mollis* Womersley & Strandtmann, *Nanorchestes antarcticus* Strandtmann, and *Gomphiocephalus hodgsoni* Carpenter.

2. In a temperature gradient apparatus the springtail *Gomphiocephalus hodgsoni* aggregated within a temperature range of +8°C to +11.5°C.

3. The mites *Nanorchestes antarcticus* and *Stereotydeus mollis* did not aggregate within certain temperature ranges when placed in thermal gradients.

4. The upper lethal temperature for *Gomphiocephalus hodgsoni* is 29.5°C at a constant humidity of 90+% RH with a mean hourly temperature increase of 2.6°C over an 8.5 hr period.

5. The upper lethal temperature for *Stereotydeus mollis* is 33.2°C at a constant humidity of 90+% RH with a mean hourly temperature rise of 2.9°C over a 12.5 hr period.

6. The upper lethal temperature for *Nanorchestes antarcticus* is 37.2°C at a constant humidity of 90+% RH with a temperature increase of approximately 2.1°C every hour for 19.5 hrs.

7. Animals of each species survived upper lethal temperatures for a greater length of time when they were previously held at high sublethal temperatures.

8. The lower lethal temperatures for *Gomphiocephalus hodgsoni* are between −11°C and −23°C.

9. The lower lethal temperatures for *Stereotydeus mollis* are between −11°C and −23°C.

10. The lower lethal temperatures for *Nanorchestes antarcticus* are between −23°C and −41°C.

11. *G. hodgsoni* and *S. mollis* did not survive longer at lower lethal temperatures when their body water was decreased.

12. There was no evidence in *G. hodgsoni* or *S. mollis* that the presence of food in the gut inhibits cold hardiness; conversely, starved specimens succumbed to the cold more quickly than well-fed animals.

13. Supercooled *G. hodgsoni* at −11°C became frozen when touched with ice while animals in ice-free containers survived several days at this temperature.

14. Previous temperature experience had no detectable effect on the survival of *G. hodgsoni* or *S. mollis* at lower lethal temperatures.

15. *Gomphiocephalus hodgsoni* was most active from +7°C to +15°C.

16. The range of normal activity for *S. mollis* is approximately 0°C to +23°C.

17. Seemingly normal motor activity was observed in *Nanorchestes antarcticus* from −23°C to +31°C.

18. Having the broadest distribution of Antarctic arthropods, *Nanorchestes antarcticus* was the most tolerant to temperature extremes and was active over the greatest temperature range.

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