THE SIGNY ISLAND TERRESTRIAL REFERENCE SITES: VIII. OXYGEN UPTAKE OF SOME ANTARCTIC PROSTIGMATID MITES (ACARI : PROSTIGMATA)

By D. G. GODDARD

ABSTRACT. Data are presented of individual oxygen-consumption rates for adults of six species of Antarctic Prostigmata (Acari) found on Signy Island, South Orkney Islands. Limited data for some juvenile stages are also presented. Measurements were made using a Cartesian diver micro-respirometer at 0°, +5° and +10° C. Mean individual oxygen-uptake rates for adults (expressed as $\times 10^{-3}$ μl. O_2 individual^{-1} hr.$^{-1}$) were: *Stereotydeus villosus* (Trouessart) 3·600 at 0° C to 9·162 at +10° C; *Tydeus tilbrooki* Strandtmann 0·656 at 0° C to 0·945 at +10° C; *Nanorchestes antarcticus* (Strandtmann) 2·586 at +5° C to 3·792 at +10° C; *Ereynetes macquariensis* Fain 1·904 at 0° C to 2·705 at +10° C; *Eupodes minutus* (Strandtmann) 1·972 at 0° C to 1·834 at +5° C; *Halotydeus signiensis* Strandtmann 3·567 at +5° C (for gravid females). Q_{10} values calculated for four species both on individual and weight-specific respiration rates were within the normal range recorded for terrestrial micro-arthropods. The weight exponent *b* of the linear regression of $\log_{10}$ respiration rate against $\log_{10}$ live weight is given for *S. villosus* and *N. antarcticus* at +5° and +10° C.

THIS paper presents information on the oxygen uptake of six species of terrestrial prostigmatid mites from Signy Island, South Orkney Islands. The field work and respirometry were undertaken in the period November 1971–April 1974. As with the respirometric study of the Antarctic mesostigmatid mite *Gamasellus racovitzai* (Trouessart) (Goddard, 1977), this research is part of a long-term ecosystem study of two contrasting bryophyte-dominated communities at Signy Island. These moss communities have been designated as Signy Island reference site (SIRS) 1 (relatively dry *Polytrichum alpestre–Chorisodontium aciphyllum* moss-turf banks) and 2 (permanently wet *Calliergon sarmentosum–Calliergidium austro-stramineum–Drepanocladus uncinatus* moss carpets), and a full description of them has been given by Tilbrook (1973).

The aims of this study were to measure the oxygen uptake of the most important species of prostigmatid mites occurring on SIRS 1 and 2, and to examine the effect of live weight and temperature on the respiration rate of both adults and juveniles. Extrapolation of these data to the field, using field temperatures and mite population counts will provide an estimate of population respiration in the two ecosystems. This will be reported in a later paper.

Most publications on the respiration of terrestrial Acari concern temperate species of Cryptostigmata, e.g. Engelmann (1961), Berthet (1964), Zinkler (1966), Webb (1969, 1970*a*, 1975), and Wood and Lawton (1973). Respiration data for temperate Mesostigmata have been reported by Webb (1970*b*) and Wood and Lawton (1973). The only available information on Prostigmata respiration are the sparse data of Wood and Lawton (1973), whose measurements were made at one temperature (+10° C) on 13 individuals belonging to five species. Information on the respiratory rates of Antarctic Acari consists of Block (in press) for the cryptostigmatid *Alaskozetes antarcticus* (Michael), and Goddard (1977) for the mesostigmatid *G. racovitzai*.

The Prostigmata comprises a large group of mites of diverse morphology and habit. Little is known of their biology. Many of the Antarctic species have been described taxonomically only in recent years from adult specimens, very little information being available for the immature stages. The majority of the species are very small, fragile and difficult to collect and manipulate without causing them injury.

The following is an annotated list of the species studied:

EUPODIDAE

Eupodes minutus (Strandtmann)

A small, green-brown pear-shaped mite often with a dorsal longitudinal red or white stripe, and with short, thick translucent reddish or whitish legs. Adults range in length from

260 to 360 μm. and are about 2 μg. live weight. The species is extremely active and very fragile. This was the most numerous mite in the moss banks of SIRS 1 during the study period. *E. minutus* has been recorded from the sub-Antarctic as well as from the Antarctic Peninsula (Strandtmann, 1967).

Halotydeus signiensis Strandtmann

A medium-sized (length 500 μm.) dark olive-green ovoid mite. A relatively inactive species preferring damper moss habitats, *H. signiensis* was rare at SIRS 2. The species has been recorded only from Signy Island (Strandtmann and Tilbrook, 1968).

Ereynetidae

Ereynetes macquariensis Fain

A small pear-shaped and extremely active mite of variable coloration. Macroscopically, it is essentially very similar to *Eupodes minutus*, although some specimens tend to be lighter in colour and slightly larger. The adults range from 250 to 380 μm. in length. This species was fairly common at SIRS 1 and it was impossible to separate it from *Eupodes minutus* without microscopic examination. *Ereynetes macquariensis* has been recorded from the sub-Antarctic (Fain, 1962; Strandtmann, 1970) and from the northern Antarctic Peninsula and the South Orkney Islands (Strandtmann and Tilbrook, 1968).

Tydeidae

Tydeus tilbrooki Strandtmann

A small, active pear-shaped mite, dark reddish green in colour with a red longitudinal dorsal stripe and bright scarlet legs and gnathosoma. Adults range from 250 to 320 μm. in length and are approximately 1·9 μg. live weight. The species is less fragile than either *Eupodes minutus* or *Ereynetes macquariensis* but it still requires careful handling. *T. tilbrooki* occurs in aggregations on lichen encrustations and algal mats. It was infrequent in the moss turf but common on lichen on SIRS 1. The species has been recorded from the Antarctic Peninsula and the South Orkney Islands (Strandtmann, 1967; Tilbrook, 1967), and from South Georgia (Strandtmann, 1970).

Penthalodidae

Stereotydeus villosus (Trouessart)

This species is the largest of the Prostigmata recorded from Signy Island. Ovoid in shape, the adults range from 500 to 750 μm. in length and are 20–34 μg. live weight. This moderately active species is dark olive-green in colour with a red fringe bordering the opisthosoma. The bright scarlet legs are long and slender, and the mite is common in aggregations under stones on moss banks, often in association with the mesostigmatid mite *G. racovitzai*. *S. villosus* has been recorded from the Antarctic Peninsula (Trouessart, 1902; Womersley and Strandtmann, 1963) and from the South Orkney and South Shetland Islands (Tilbrook, 1967).

Pachygnathidae

Nanorchestes antarcticus (Strandtmann)

A small, deep red, almost spherical mite with short, thick bright red legs. It is moderately active and for its size fairly robust but it is not very resistant to desiccation. Adults range from 240 to 320 μm. in length and approximately 8–12 μg. live weight. This species is common in the moss turf on SIRS 1 and also occurs in large aggregations under stones in damp barren ground, especially near ice fields. *N. antarcticus* is the southernmost occurring terrestrial arthropod in the world, having been recorded at lat. 85° S. in the Queen Maud Mountains and from many sites on the Antarctic continent (Strandtmann, 1967; Rounsevell, in press), Antarctic Peninsula, maritime Antarctic islands and sub-Antarctic islands (Tilbrook, 1967). There is a single record from sub-alpine habitats in Japan (Shiba, 1969).

METHODS

Measurements of oxygen uptake of individual mites were made using a Cartesian diver micro-respirometer (Zeuthen, 1950, 1964). The techniques were as described by Goddard (1977) except for differences in the collecting and handling of the mites.

The experimental animals were all hand collected in the field, normally just prior to the measurement of their respiration. *T. tilbrooki* was extracted from patches of the alga *Prasiola crispa* (Lightf.) Menegh. and the lichen *Xanthoria candelaria* (L.) Th. Fr. The mites were kept in small petri dishes containing their food material at ambient temperatures in summer and at *c.* +5° C, when ambient temperatures were constantly below 0° C in winter. *N. antarcticus* was obtained from the undersides of small stones at the edges of ice fields and melt rivulets. The stones were placed in black polythene bags which were sealed without handling the mites. The temperature of the micro-habitat was measured at the time of collection and the bags containing the mites were kept within ± 2° C of this temperature. All of the other species studied were collected immediately prior to respirometry.

S. villosus was collected by aspirator from under stones on moss banks. *Ereynetes macquariensis* and *Eupodes minutus* were very difficult to collect alive without using heat extraction methods, and individuals obtained by this method generally did not survive for long. They are extremely fragile and all attempts at culturing these two species failed. A few specimens were collected on dry days when field temperatures were above 0° C, by tapping small stones on to a white enamel tray. The mites, which could easily be seen against the white background, were transported to the laboratory and immediately loaded into the divers by means of a mounted hair. Manipulation of the more robust species was with a mounted bristle. The two specimens of *H. signiensis* were tapped out from a sample of wet moss, *Drepanocladus uncinatus* (Hedw.) Warnst.

The smallest divers (gas volume 4·0 μl.) available did not allow the measurements of individual respiratory rates of *N. antarcticus* and *T. tilbrooki* so groups of two to nine individuals were used. The oxygen uptake of the other four species was measured using individual specimens. After loading the divers into the respirometer, an equilibration period of 1 hr. was allowed before readings commenced. Hourly readings were taken and experiments were run for 5–7 hr. Observations made on the activity of the mites in the divers showed that after some initial activity during equilibration, single mites normally became quiescent and remained so thereafter. However, groups of mites tended to walk over each other and around the air bubble in the diver, but this activity was usually of a much lower level than that observed in laboratory cultures and in the field.

After the experiment, the mites were removed from the divers and mounted individually in Hoyer's medium on microscope slides. After the mites had cleared, verification of species, life stage and, where possible, sex was made under ×100 or ×400 phase-contrast magnification.

Measurements of respiration rates were made at three temperatures: 0°, +5° and +10° C, and at least ten measurements, either of single individuals or of groups, were made for most species at each temperature. A total of 205 measurements of oxygen uptake was made on six mite species (Table I). All respiration measurements were made on unweighed mites as it was not possible to weigh the mites at Signy Island. Cultures of each species were transported to England for determination of individual live weights, but few animals survived so the live-weight data are limited.

Fifty individuals of *S. villosus*, mostly adults, were weighed on a Cahn electromicrobalance. The mites were then mounted in Hoyer's medium on microscope slides, and the length and width of the idiosoma measured under the microscope. To minimize any error resulting from different degrees of distortion during mounting and measuring the mites, the techniques and materials used for the weighed mites were identical with those used for the mites in the respirometry experiments. A relationship of the area of the idiosoma (calculated from length and width) to live weight was derived by means of a linear regression (Fig. 1). The live weight of each of the unweighed mites used in respirometry was calculated from the idiosomal area using the regression equation:

$$y = 67053{\cdot}535 + 5081{\cdot}897x \quad (r = 0{\cdot}908 \text{ at } p < 0{\cdot}001,\ n = 50),$$

where y = area of idiosoma (μm.^{2}) and x = live weight (μg.).

TABLE I. DISTRIBUTION OF MEASUREMENTS OF RESPIRATION RATE FOR SIX SPECIES OF PROSTIGMATID MITES AT SIGNY ISLAND

Species	*Experimental temperature* (°C)		
	0	+5	+10
Stereotydeus villosus (Trouessart)			
♂	7	12	4
♀	5	7	7
Tritonymph	0	0	1
Deutonymph	0	3	2
Tydeus tilbrooki (Strandtmann)			
♂	0	7	4
♀	1	3	3
♂ and ♀ mixed in same diver	8	13	8
Adults and nymphs mixed in same diver	8	1	2
Tritonymph	3	0	0
Nanorchestes antarcticus Strandtmann			
♂	0	0	5
♀	0	0	0
Adults and nymphs mixed in same diver	0	1	4
Tritonymph	14	16	11
Deutonymph	0	1	0
Ereynetes macquariensis Fain			
♂	2	2	1
♀	8	8	4
♂ and ♀ mixed in same diver	0	1	3
Tritonymph	1	0	0
Eupodes minutus Strandtmann			
♂	0	7	0
♀	3	2	0
Halotydeus signiensis Strandtmann			
Gravid ♀	0	2	0

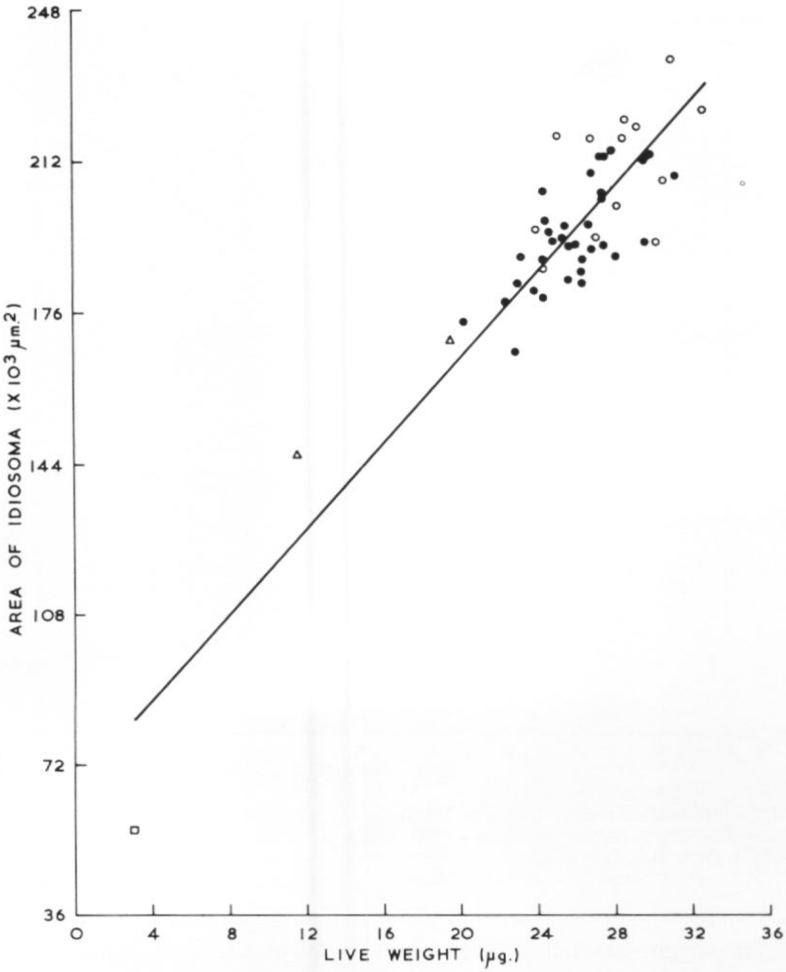

Fig. 1. Relationship between length × width (μm.²) of the idiosoma (y) and live weight (μg.) (x) for *Stereotydeus villosus*. The linear regression line $y = 67053 \cdot 535 + 5081 \cdot 897x$ has been fitted. ($r = 0 \cdot 908$; $p < 0 \cdot 001$; $n = 59$.)
● ♂; ○ ♀; △ Tritonymph; □ Protonymph.

For *N. antarcticus*, 55 individuals of several different life stages were weighed alive and then mounted in Hoyer's on slides. The diameter of the spherical idiosoma of each mite was measured under the microscope, and the relationship of idiosomal diameter to live weight was derived by means of a linear regression. Fig. 2 illustrates this relationship with the fitted line. The live weight of the unweighed animals used in respirometry was calculated from the idiosomal diameter using the regression equation:

$$y = 146 \cdot 27 + 13 \cdot 81x \; (r = 0 \cdot 767 \text{ at } p < 0 \cdot 001, \; n = 55),$$

where y = diameter of idiosoma (μm.) and x = live weight (μg.).

The electromicrobalance failed to register individuals of *T. tilbrooki* on its most sensitive range, so groups of five and ten individuals were weighed, the composition of each group being changed each time; a total of 16 group weighings was made and a mean individual weight for the species was calculated. Subsequent microscopic examination showed that all the mites weighed were adults. The overall mean adult live weight ($1 \cdot 90 \pm 0 \cdot 04$ μg.) was used

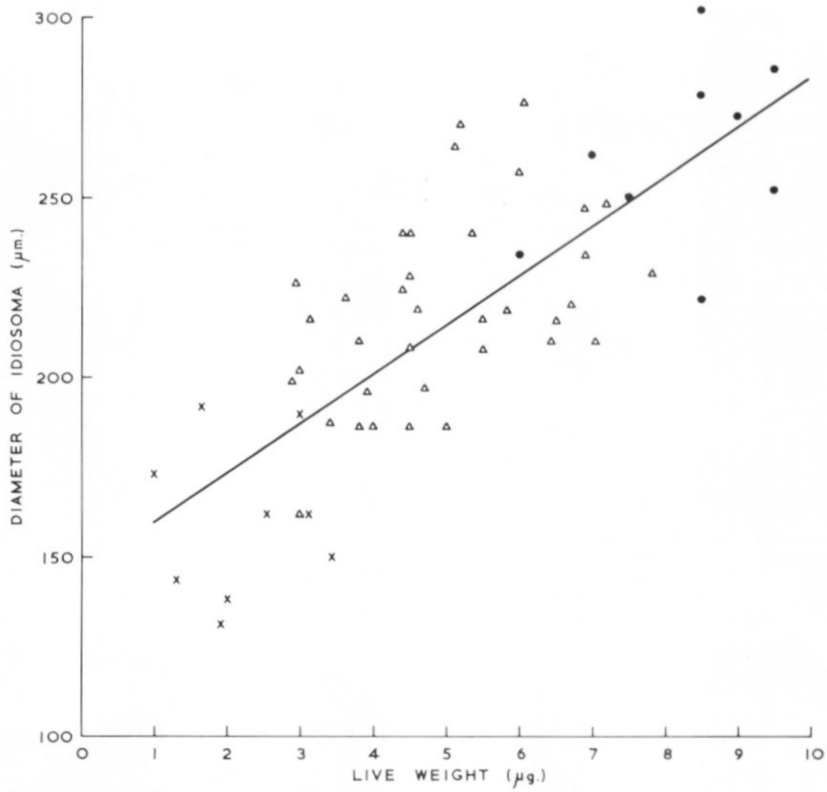

Fig. 2. Relationship between diameter (μm.) of the idiosoma (y) and live weight (μg.) (x) for *Nanorchestes antarcticus*. The linear regression line $y = 146 \cdot 272 + 13 \cdot 813x$ has been fitted. ($r = 0 \cdot 767$; $p < 0 \cdot 001$; $n = 55$.)
● Adult; △ Tritonymph; × Deutonymph.

to calculate the weight-specific oxygen-uptake rates of the individuals measured in the respirometry.

No *Eupodes minutus*, *Ereynetes macquariensis* or *H. signiensis* survived culture and transport to England. Both *Eupodes minutus* and *Ereynetes macquariensis* are similar in size and shape to *T. tilbrooki*. The idiosomal lengths of 50 *T. tilbrooki* were measured and a mean of 322 μm. was calculated. The idiosomal lengths of the *Eupodes minutus*, *Ereynetes macquariensis* and juvenile *T. tilbrooki* used in experiments were measured and an estimated mean live weight for each species was calculated using the weighed adult *T. tilbrooki* as standard. Using this method, the mean weight of adult *Eupodes minutus* and *Ereynetes macquariensis* was 2·0 μg. and the mean weight of tritonymphs of all three species was 1·5 μg.

As *N. antarcticus* and *T. tilbrooki* were placed in groups in the divers, and as it was not possible to separate their life stages reliably, a number of the results obtained are for mixed groups of adults and nymphs. An attempt was made to determine the proportions of the results for these mixed groups which were accountable to separate adult and nymphal respiration. This was done by subtracting the mean respiration for adults from the result for the mixed group; the remaining value was assumed to be attributable to nymphal respiration. Conversely, the mean result for nymphs was subtracted from the group data, the remainder being assumed to be adult respiration. The values obtained by these two methods were within the standard-error range of the mean values. The former method was employed in all cases.

Results

Oxygen uptake and live weight

Table II gives the derived mean live weights of all the mite species in this study, with the exception of *H. signiensis*. The live-weight derivations of *S. villosus* are the most reliable, although data for its juvenile stages are sparse. Weights for the other species must be regarded with caution, as they are based on fewer data than for *S. villosus*; however, they are probably representative of the species. Little information is available on the range of weight over all life stages within these species.

Table II. Mean live weights (±S.E.) for five species of Prostigmata. All weights are derived from linear measurements (see text)

Species and life stage	*Mean (±S.E.) live weight* (μg).	*n*
Stereotydeus villosus		
♂	26·60±0·39	35
♀	30·18±0·44	12
Gravid ♀	37·10	1
Tritonymph	15·50±4·00	2
Deutonymph	6·00	1
Protonymph	2·80	1
Tydeus tilbrooki		
Adult	1·90±0·04	18
Tritonymph	1·50*	
Nanorchestes antarcticus		
Adult	8·50	8
Tritonymph	5·09	36
Deutonymph	2·61	9
Ereynetes macquariensis		
Adult	2·0*	
Tritonymph	1·5*	
Eupodes minutus		
Adult	2·0*	

* Mean estimated from mean weight of adult *T. tilbrooki*.

Table III shows the mean individual oxygen-uptake rates of each species measured at three temperatures, and the mean weight-specific oxygen-uptake rates. The respiration data for all temperatures can be divided into three groups with differing orders of magnitude.

TABLE III. MEAN OXYGEN-UPTAKE RATES OF SOME PROSTIGMATID MITES FROM SIGNY ISLAND. RATES PER INDIVIDUAL AND PER g. LIVE WEIGHT ARE GIVEN

Species	*Mean ± S.E. oxygen-uptake rate* ($\times 10^{-3}$ µl. O_2 ind.$^{-1}$ hr.$^{-1}$)			*Mean ± S.E. oxygen-uptake rate* (µl. O_2 g.$^{-1}$ hr.$^{-1}$)		
	0° C	+5° C	+10° C	0° C	+5° C	+10° C
Stereotydeus villosus						
♂	3·664±0·308	6·456±0·939	9·234±0·710	143·45±14·66	328·70±32·81	365·64±21·25
♀	3·530±0·599	6·684±1·326	9·091±0·739	110·91±14·14	228·85±52·18	295·19±20·46
Tritonymph	n.d.	n.d.	7·939	n.d.	n.d.	620·24
Deutonymph	n.d.	1·308±0·229	1·836±0·268	n.d.	252·97±28·08	285·38±24·05
Tydeus tilbrooki						
Adult	0·656±0·109	0·726±0·043	0·945±0·086	345·08±57·76	382·03±22·74	497·20±45·32
Tritonymph	0·242	n.d.	0·422±0·110	111·00	n.d.	281·07±73·01
Nanorchestes antarcticus						
Adult	n.d.	2·586	3·792±0·607	n.d.	222·88	363·18±47·05
Tritonymph	0·713±0·044	1·066±0·119	1·475±0·190	98·04	135·38±22·27	159·80±20·87
Deutonymph	n.d.	0·429	n.d.	n.d.	153·23	n.d.
Ereynetes macquariensis						
Adult	1·904±0·126	2·558±0·274	2·705±0·195	951·98±63·09	1,279·20±137·16	1,352·49±97·68
Tritonymph	1·629	n.d.	n.d.	1,086·00	n.d.	n.d.
Eupodes minutus						
Adult	1·972±0·184	1·834±0·205	n.d.	986·01±92·42	917·01±102·48	n.d.
Halotydeus signiensis						
Gravid ♀	n.d.	3·567±0·955	n.d.	n.d.	n.d.	n.d.

n.d. No determination.

S. villosus has the highest rates of oxygen uptake per individual; a second group comprises *Ereynetes macquariensis* and *Eupodes minutus*, while *N. antarcticus* and *T. tilbrooki* comprise a group with the lowest respiration rates. However, on a weight-specific basis, the respiration of *S. villosus* is of a similar order of magnitude to *N. antarcticus* and *T. tilbrooki*, and they have similar levels of locomotory activity in the field. *Ereynetes macquariensis* and *Eupodes minutus* have the highest weight-specific oxygen-uptake rates and they are much more active than the other species.

Fig. 3 illustrates the relationship between oxygen uptake and live weight of individuals of five species at each experimental temperature, plotted on a double-log scale. The slope (b) of the regression line changes with the temperature but the change is not significant. Therefore, only limited general conclusions can be drawn from these data. The exclusion of any one group of data, e.g. those for *Eupodes minutus* and *Ereynetes macquariensis*, alters the slope of the regression line considerably (from $b = 0 \cdot 652$ and $r = 0 \cdot 760$ to $b = 0 \cdot 966$ and $r = 0 \cdot 067$ at $+5°$ C), thus suggesting that a single regression line cannot adequately describe the relationship between $\log_{10}$ respiration rate and $\log_{10}$ live weight for all the studied species. Wood and Lawton (1973) reached a similar conclusion for their data on Prostigmata at $+10°$ C. However, Zinkler (1966) found that a single regression line could represent the data of $\log_{10}$ respiration rate to $\log_{10}$ live weight for seven species of Collembola at $+18°$ C. Zinkler suggested that an inter-specific comparison was valid when the individual species were systematically similar. The Prostigmata in the present study and those studied by Wood and Lawton are not systematically similar. In Zinkler's study the species which differed from the general regression-line trend was the relatively inactive *Neanura muscorum* (Temp.), which had a much lower respiration rate than related species of a similar size. This suggests that inter-specific comparisons may be valid only when activity levels are similar, whether or not the species are taxonomically related.

Stereotydeus villosus. This was the heaviest of the species studied. Most of the data are for adult mites, although there are a few for tritonymphs and deutonymphs. It was possible to fit linear regression lines to the oxygen-uptake data of individuals of this species at $+5°$ and $+10°$ C (the b values were $1 \cdot 010$ and $1 \cdot 035$, and the r values $0 \cdot 949$ and $0 \cdot 999$, respectively), suggesting that in this species respiration is directly proportional to weight. This is similar to the Antarctic oribatid mite *Alaskozetes antarcticus* in which, for all its life stages over the same temperature range, the b value was $0 \cdot 927$ (Block, in press). This contrasts with the Antarctic mesostigmatid mite *G. racovitzai* ($b = 0 \cdot 693$), in which respiration is proportional to surface area (Goddard, 1977). The mean live weight for female *S. villosus* was significantly higher than that for the male by $2 \cdot 35 \pm 0 \cdot 07$ μg. ($p < 0 \cdot 05$). However, there was no significant difference in respiration rate between the sexes, although there was an indication of a slightly higher rate in males at $+10°$ C (Table III).

Nanorchestes antarcticus. Most of the measurements for this species are for tritonymphs, although some data for adults and deutonymphs were obtained. At $+5°$ and $+10°$ C a linear regression has been fitted to the data for $\log_{10}$ respiratory rate against $\log_{10}$ live weight for individuals. The slopes of the lines were respectively $1 \cdot 514$ and $1 \cdot 843$ ($r = 0 \cdot 998$ and $0 \cdot 900$, respectively). In general, *N. antarcticus* has a similar activity level and respiration rate to *T. tilbrooki* (Table III) and both species were measured in samples of similar number.

Ereynetes macquariensis and Eupodes minutus. The data for these two species are the most interesting as it was possible to measure the respiration of individual mites. They are of a similar size and weight to *T. tilbrooki* but they are both very much more active. The respiration rates were considerably higher than those of the other species and this is probably due to greater locomotory activity. Wood and Lawton (1973) suggested that activity had a significant effect on respiration rate, especially in the less sclerotized species, such as the Prostigmata. *Eupodes minutus* and *Ereynetes macquariensis* are the least sclerotized of the species studied. There was no detectable difference in the respiration rates of males and females of either species.

In general, these data suggest that the normal field level of locomotory activity in Antarctic species of Prostigmata affects their individual resting respiratory rates as measured by the Cartesian diver micro-respirometer.

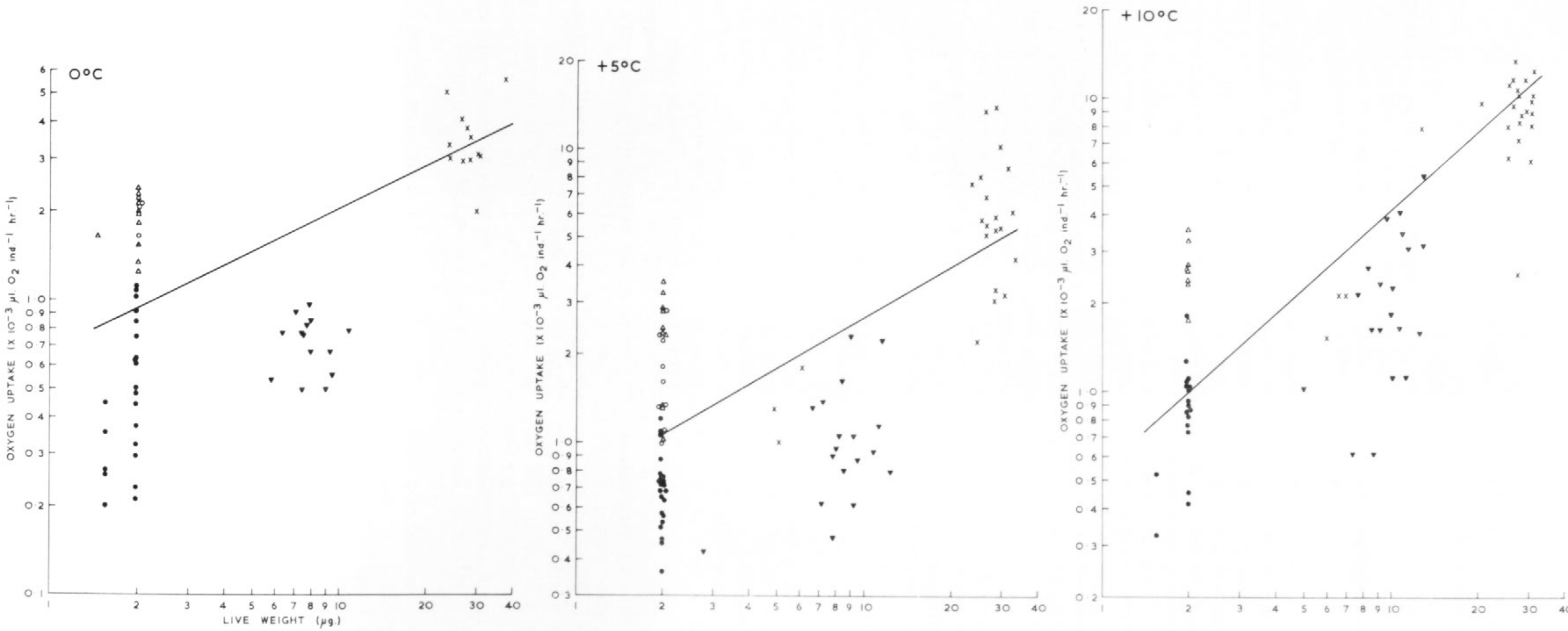

Fig. 3. Oxygen consumption ($\log_{10} \times 10^{-3}$ μl. O_2 ind.$^{-1}$ hr.$^{-1}$) as a function of live weight ($\log_{10}$ μg.) for five species of Antarctic Prostigmata at 0°, +5° and +10° C. Individual measurements are plotted for each species. Linear regressions are fitted for each temperature. The coefficients for these regressions (see text) are:

0° C	$a = -0{\cdot}164$;	$b = 0{\cdot}467$;	$r = 0{\cdot}631$;	$n = 60$
+5° C	$a = -0{\cdot}218$;	$b = 0{\cdot}652$;	$r = 0{\cdot}760$;	$n = 84$
+10° C	$a = -0{\cdot}260$;	$b = 0{\cdot}855$;	$r = 0{\cdot}900$;	$n = 59$

× *Stereotydeus villosus*; ▼ *Nanorchestes antarcticus*; △ *Ereynetes macquariensis*; ○ *Eupodes minutus*; ● *Tydeus tilbrooki*.

Oxygen uptake and temperature

The relationships between mean individual oxygen-uptake rate and temperature (Fig. 4) and between mean weight-specific respiration rate and temperature (Fig. 5) are shown for five of the six Prostigmata species studied. Mean oxygen-uptake rates of individual adult *S. villosus* and tritonymph *N. antarcticus* increased almost linearly over the temperature range 0° to +10° C, but *Ereynetes macquariensis* showed a slightly greater increase in mean respiration rate between 0° and +5° C than between +5° and +10° C.

Table IV gives the temperature coefficients (Q_{10}) derived from the mean individual and

TABLE IV. TEMPERATURE COEFFICIENTS (Q_{10}) OF FOUR SPECIES OF PROSTIGMATA CALCULATED ON THE BASIS OF (a) INDIVIDUAL AND (b) $g.^{-1}$ RESPIRATION RATES

Species	*Temperature* (°C)		
	0 to +5	+5 to +10	0 to +10
	a. $\times 10^{-3}$ μl. O_2 ind.$^{-1}$ hr.$^{-1}$		
Stereotydeus villosus			
Adult ♂	3·09	2·05	2·52
Adult ♀	3·58	1·85	2·58
Deutonymph	–	1·97	–
Ereynetes macquariensis			
Adult	1·81	1·12	1·42
Tydeus tilbrooki			
Adult	1·23	1·70	1·44
Tritonymph	–	–	1·75
Nanorchestes antarcticus			
Adult	–	1·91	–
Tritonymph	2·24	2·15	2·07
	b. μl. O_2 g.$^{-1}$ hr.$^{-1}$		
Stereotydeus villosus			
Adult ♂	2·77	2·35	2·55
Adult ♀	4·26	1·66	2·66
Deutonymph	–	1·27	–
Nanorchestes antarcticus			
Adult	–	2·65	–
Tritonymph	1·91	1·39	1·63

As a single mean weight was used for *E. macquariensis* and *T. tilbrooki*, individual and weight-specific temperature coefficients are identical (see text).

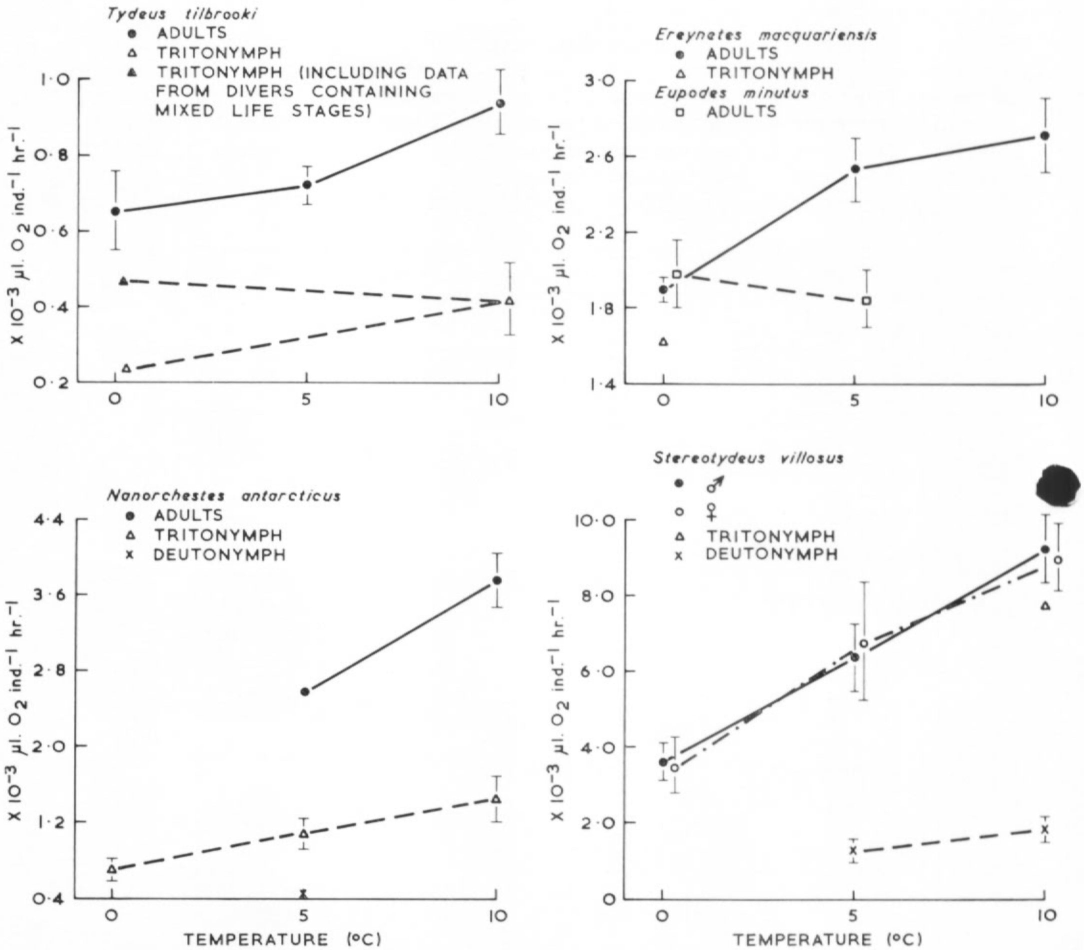

Fig. 4. Effect of temperature on the mean rate of oxygen uptake per individual ($\times 10^{-3}$ μl. O_2 ind.$^{-1}$ hr.$^{-1}$) for five species of Antarctic Prostigmata.

mean weight-specific oxygen-uptake rates (Table III) for four species of Antarctic Prostigmata. For the species for which individual weights are available, there is often a considerable variation between the two Q_{10} derivations for the same life stage over the same temperature range. A similar observation was made for *G. racovitzai* (Goddard, 1977). For the species for which no individual weights are available, a mean weight was applied to the individual data to calculate the weight-specific respiration rates, thus individual and weight-specific Q_{10} values are identical. It is better to consider the temperature coefficient of a species in terms of the individual as a whole rather than a unit weight of that species, so the individual Q_{10} value is probably the most meaningful. Few workers indicate whether Q_{10} determinations have been calculated from individual or weight-specific respiration data, and no comparisons have been reported. The Q_{10} values given in Table IV are within the normal range recorded for micro-arthropods, and are similar to those obtained for *Nothrus silvestris* Nicolet (Q_{10} 2·56) (Webb, 1969), *Steganacarus magnus* Nicolet (Q_{10} 2·03) (Webb, 1975), *A. antarcticus* (Q_{10} 3·13) (Block, in press) and *G. racovitzai* (Q_{10} 2·25) (Goddard, 1977).

The normal field temperatures experienced by the mites varied considerably. The lichen habitat of *T. tilbrooki* frequently reached +20° C when exposed to direct solar radiation,

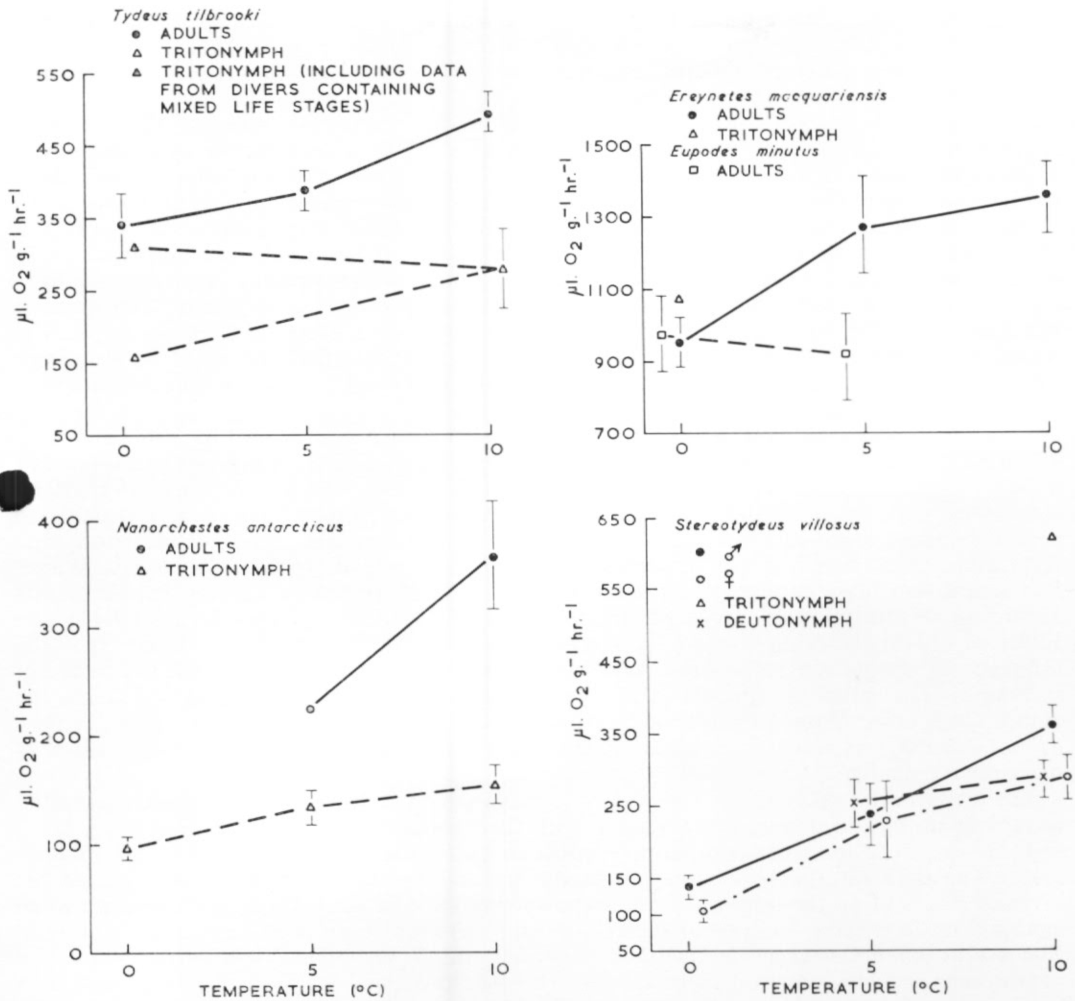

Fig. 5. Effect of temperature on the mean rate of oxygen uptake per g. live weight (μl. O_2 g.$^{-1}$ hr.$^{-1}$) for five species of Antarctic Prostigmata.

whereas the other species living mainly under stones or below the moss-turf surface only occasionally experienced temperatures above +5° C. There was a greater variation in oxygen uptake by individuals at +10° C than at 0° C for all species except *T. tilbrooki*, in which the greatest variability was at 0° C. As *T. tilbrooki* normally experienced higher field temperatures than the other species, this may explain the differences in respiration rates. Again, Block and Tilbrook (1975) found a greater variation in mean individual oxygen-uptake rates for *C. antarcticus* at +10° than at 0° C. This species rarely experienced field temperatures above +10° C on Signy Island.

Discussion

This paper presents the first information on the respiratory physiology of Antarctic Prostigmata. There is no published information on the respiration rates of juvenile prostigmatid mites or of their temperature coefficients. The five species studied by Wood and Lawton (1973) comprised 13 adult individuals with only one species identified below generic level. Two of the genera which they studied, *Bdella* sp. and *Rhagidia* sp. have Antarctic representatives, although they have not been recorded from the South Orkney Islands. Data comparisons are therefore difficult, especially in view of the wide morphological variation within the Prostigmata.

In general, the mean individual and weight-specific respiration rates of the Antarctic species are lower than those of temperate species at +10° C, except for the extremely active *Eupodes minutus* and *Ereynetes macquariensis*. The lower respiration rates may be indicative of adaptation to lower field temperatures. The weight-specific respiration rates of the Antarctic Prostigmata are similar to the rates measured for the Antarctic mite *G. racovitzai* (Goddard, 1977) and to data on the Antarctic collembolan *C. antarcticus* (Block and Tilbrook, 1975). *Eupodes minutus* and *Erynetes macquariensis* have similar weight-specific respiration rates to the larva of *G. racovitzai*, which is comparable to these species in its degree of sclerotization but it is less active. A higher level of normal summer field activity in a species appears to produce a higher resting metabolism. Respiration in the Prostigmata seems to be influenced as much by activity and degree of sclerotization as by live weight. This is a different situation to other micro-arthropods which have been studied.

It is not possible to represent the relationship between $\log_{10}$ respiratory rate and $\log_{10}$ live weight by a single regression line for the five species studied. It is difficult to explain the high *b* values for *N. antarcticus* (1·514 at +5° C and 1·843 at +10° C). Zeuthen (1947, 1953) established experimentally for a range of invertebrates that *b* may vary from 1·0 down to negative values. However, the values for *N. antarcticus* are mainly derived from tritonymph respiration results and may not be representative of the whole life span of the species. Wieser and Kanwisher (1960) found that the weight exponent of marine nematodes varied greatly according to the animals' stage of development, whilst Edwards and Irving (1943) and Edwards (1946), working on two crustaceans and an insect respectively, found that the influence of weight on respiration increased at higher temperatures (i.e. the *b* coefficient increased). This situation appears to be true for the Antarctic Prostigmata in this study, the composite *b* value ranging from 0·467 at 0° to 0·855 at +10° C; however, as these *b* values do not differ significantly and considering the above comments on Fig. 3, this observation may be purely coincidental.

The temperature response of the Antarctic Prostigmata follows a similar pattern to other groups of mites and it may be correlated with the field temperature.

There is a need for more comparative information on the respiratory rates of the Prostigmata. The data for the species in this study are incomplete. More data are required for juvenile stages of all the important Antarctic species and the adult stage of *N. antarcticus* to enable a more reliable analysis of the relationship between respiration rate and live weight. The use of small Cartesian divers for *T. tilbrooki* and *N. antarcticus* will permit individual measurements to be made on these species. Thus the problems involved in interpreting data from divers containing several life stages will be overcome. Reliable and more comprehensive weight data are necessary for the Prostigmata to allow biomass estimates to be made. Direct weighing at Signy Island would be preferable. In particular, further respiration data are required for the extremely active *Eupodes minutus* and *Ereynetes macquariensis* in view of their relatively high oxygen-uptake rates and their numerical importance in the arthropod community of SIRS 1, a typical dry moss habitat in the maritime Antarctic.

Acknowledgements

I should like to thank my fellow base members at Signy Island for help and support during this research. My thanks are also due to Drs. W. Block and P. J. Tilbrook (Nature Conservancy Council, Inverness) for advice and encouragement during this study, and to these and Dr. N. R. Webb (Institute of Terrestrial Ecology, Furzebrook) and Dr. R. I. L. Smith for helpful criticism during the preparation of this paper. Finally, I wish to thank Mrs. S. Goddard for typing the drafts and translating some of the references.

MS. received 28 January 1976

REFERENCES

BERTHET, P. 1964. L'activité des Oribatides (Acari : Oribatei) d'une chênaie. *Mém. Inst. r. Sci. nat. Belg.*, **152**, 1–152.

BLOCK, W. In press. Oxygen consumption of the terrestrial mite *Alaskozetes antarcticus* (Acari : Cryptostigmata). *J. exp. Biol.*

———. *and* P. J. TILBROOK. 1975. Respiration studies on the Antarctic collembolan *Cryptopygus antarcticus*. *Oikos*, **26**, No. 1, 15–25.

EDWARDS, G. A. 1946. The influence of temperature upon the oxygen consumption of several arthropods. *J. cell. comp. Physiol.*, **27**, No. 1, 53–64.

———. *and* L. IRVING. 1943. The influence of temperature and season upon the oxygen consumption of the sand crab *Emerita talpoida* Say. *J. cell. comp. Physiol.*, **21**, No. 1, 169–82.

ENGELMANN, M. D. 1961. The role of soil arthropods in the energetics of an old field community. *Ecol. Monogr.*, **31**, 221–38.

FAIN, A. 1962. Insects of Macquarie Island. Acarina : Trombidiformes : Ereynetidae. *Pacif. Insects*, **4**, No. 4, 921–28.

GODDARD, D. G. 1977. The Signy Island terrestrial reference sites: VI. Oxygen uptake of *Gamasellus racovitzai* (Trouessart) (Acari : Mesostigmata). *British Antarctic Survey Bulletin*, No. 45, 1–11.

ROUNSEVELL, D. E. In Press. Ecological adaptation in the pan-Antarctic mite *Nanorchestes antarcticus* (Strandtmann). (*In* LLANO, G. A., *ed. Adaptations within Antarctic ecosystems.* Houston, Texas, Gulf Publishing Co.)

SHIBA, M. 1969. Taxonomic investigations on free living mites in the sub-alpine forest on Shiba Heights IBP area. II. Prostigmata. *Bull. natn. Sci. Mus., Tokyo*, **12**, No. 1, 65–115.

STRANDTMANN, R. W. 1967. Terrestrial Prostigmata (trombidiform mites). (*In* GRESSITT, J. L., *ed. Entomology of Antarctica.* Washington, D.C., American Geophysical Union, 51–80.) [Antarctic Research Series, Vol. 10.]

———. 1970. Acarina: eupodiform Prostigmata of South Georgia. *Pac. Insects Monogr.*, No. 23, 89–106.

———. *and* P. J. TILBROOK. 1968. Some Prostigmata (Acari) from Signy Island, South Orkney Islands, and Deception Island, South Shetland Islands. *British Antarctic Survey Bulletin*, No. 17, 51–57.

TILBROOK, P. J. 1967. The terrestrial invertebrate fauna of the maritime Antarctic. (*In* SMITH, J. E., *organizer.* A discussion on the terrestrial Antarctic ecosystem. *Phil. Trans. R. Soc.*, Ser. B, **252**, No. 777, 261–78.)

———. 1973. The Signy Island terrestrial reference sites: I. An introduction. *British Antarctic Survey Bulletin*, Nos. 33 and 34, 65–76.

TROUESSART, E. L. 1902. Acarina. (*In Report on the collections of natural history made in the Antarctic regions during the voyage of the "Southern Cross"*. London, Trustees of the British Museum (Natural History), 225–27.)

WEBB, N. R. 1969. The respiratory metabolism of *Nothrus silvestris* Nicolet (Acari). *Oikos*, **20**, No. 2, 294–99.

———. 1970*a*. Population metabolism of *Nothrus silvestris* Nicolet (Acari). *Oikos*, **21**, No. 2, 155–59.

———. 1970*b*. Oxygen consumption and population metabolism of some mesostigmatid mites (Acari : Mesostigmata). *Pedobiologia*, **10**, No. 6, 447–56.

———. 1975. Respiratory metabolism of *Steganacarus magnus* (Acari). *Oikos*, **26**, No. 1, 43–46.

WIESER, W. *and* J. KANWISHER. 1960. Growth and metabolism in a marine nematode, *Enoplus communis* (Bastian). *Z. vergl. Physiol.*, **43**, No. 1, 29–36.

WOMERSLEY, H. *and* R. W. STRANDTMANN. 1963. On some free-living prostigmatic mites of Antarctica. *Pacif. Insects*, **5**, No. 2, 451–72.

WOOD, T. G. *and* J. H. LAWTON. 1973. Experimental studies on the respiratory rates of mites (Acari) from beech-woodland leaf litter. *Oecologia*, **12**, No. 2, 169–91.

ZEUTHEN, E. 1947. Body size and metabolic rate in the animal kingdom. *C. r. Trav. Lab. Carlsberg*, Sér. chim., **26**, No. 1, 17–161.

———. 1950. Cartesian diver respirometer. *Biol. Bull.*, **98**, No. 2, 139–43.

———. 1955. Comparative physiology (respiration). *A. Rev. Physiol.*, **17**, No. 3, 459–83.

———. 1964. Microgasometric methods: Cartesian divers. (*In* SCHIEBLER, T. H., PEARSE, A. G. E. *and* H. H. WOLFF, *ed. 2nd International Congress on histo- and cyto-chemistry.* New York, Wiley, 70–80.)

ZINKLER, D. 1966. Vergleichende Untersuchungen zur Atmungsphysiologie von Collembolen (Apterygota) und anderen BodenKleinArthropoden. *Z. vergl. Physiol.*, **52**, No. 1, 99–144.