THE ANTARCTIC PREDATORY MITE *GAMASELLUS RACOVITZAI* (TROUESSART) (MESOSTIGMATA) : A MORPHOMETRIC STUDY OF TWO SUBSPECIES

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ANTARCTIC
MORPHOMETRIC
PREDATORY MITE
PRINCIPAL CO-ORDINATES
ANALYSIS
SUBSPECIATION

ABSTRACT : 57 morphological characters were scored on a sample of 46 male and 55 characters on a sample of 40 female *Gamasellus racovitzai*, which had been collected from 10 localities in the maritime Antarctic. A lectotype of *G. racovitzai*, selected from the collection studied by TROUESSART, is designated. The same morphological characters have been scored for the lectotype and for the holotype of *G. r. neo-orcadensis*. Principal co-ordinates analysis indicates that there is a morphological separation between specimens of *G. racovitzai* from the South Orkney Islands and from elsewhere in the maritime Antarctic. Since LISTER (1984a) also found esterase differences, it is concluded that two subspecies of *G. racovitzai* should be recognised. The nominate subspecies is distributed along the Antarctic Peninsula, its offshore islands, and the South Shetland Islands, whilst subspecies *neo-orcadensis* is restricted to the South Orkney Island. *G. r. neo-orcadensis* is redefined

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RÉSUMÉ : 57 caractères morphologiques d'un échantillon de 46 mâles et 55 caractères d'un échantillon de 40 femelles *Gamasellus racovitzai* prélevés parmi, dix localités de l'Antarctique maritime ont été quantifiés. Un lectotype de *G. racovitzai*, choisi parmi ceux de la collection étudiée par TROUESSART, est désigné. Les mêmes caractères morphologiques ont été relevés sur le lectotype et sur l'holotype de *G. r. neo-ordicadensis*. Une analyse des coordonnées principales indique qu'il existe une séparation morphologique entre les spécimens de *G. racovitzai* provenant des Iles des Orcades du Sud et ceux provenant d'autres localités de l'Antarctique maritime. Puisque l'on trouve également des différences entre les estérases, il en est conclu qu'il existe effectivement deux sous-espèces de *G. racovitzai*. La sous-espèce *G. racovitzai* est distribuée le long de la Péninsule Antarctique, dans les îles au large de ses côtes, ainsi que dans les Iles Shetland du Sud, alors que la sous-espèce *neo-orcadensis* est restreinte aux Iles des Orcades du Sud. La sous-espèce *G. r. neo-orcadensis* est redélimitée.

INTRODUCTION

During the early biological exploration of Antarctica, only one species of mesostigmatid mite was regularly collected. It was described by TROUESSART (1903) from specimens collected during the Belgian Antarctic Expedition, and named *Gamasus racovitzai*. The generic place-

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ment was questioned by TRÄGÅRDH (1907a), who redescribed the species in the genus *Gamasellus* using material collected during the Swedish South Polar Expedition. Subsequenly, using material collected by the first French Antarctic Expedition, TRÄGÅRDH (1907b) transferred the species to the genus *Digamasellus*. BERLESE (1917), describing the mites collected by the second French Antarctic Expedition, reverted to *Gamasellus*, but placed the species in the subgenus *Digamasellus*. RYKE (1962) synonymised *Gamasellus* with *Cyrtolaelaps*, hence relagating *Gamasellus* to the level of a subgenus. Modern usage, following LEE (1966) and HIRSCHMANN (1966), tends not to accept the sub-generic level for *Gamasellus*, and the use of *Gamasellus* as the generic name for this species has become standard (see, for example, HUNTER, 1970).

Although there have been these changes at the generic level, there has been general agreement at the specific level. There is only one synonym. TRÄGÅRDH (1907a) described a single nymph as *Zercon tuberculatus* : this was synonymised as the protonymph of *G. racovitzai* by HUNTER (1967). From material collected on the Scottish National Antarctic Expedition, TROUESSART (1912) described a subspecies, *neo-orcadensis*, of *G. racovitzai*. This name has not been used in the modern literature, except by RYKE (1962) who retained it as a subspecies of *racovitzai*, noting only one small difference between the subspecies and the nominate subspecies.

Since *G. racovitzai* is the only known predator in many terrestrial Antarctic communities, there has been a number of studies of its biology. Both GODDARD (1979) and USHER & BOOTH (1984) discussed aspects of its population dynamics, and BOOTH & USHER (1984) described the relationships between its population density and various environmental influences. GODDARD (1982) and LISTER (1984a) described the feeding biology, indicating that the main prey species is the collembolan, *Cryptopygus antarcticus*. The methods of catching this prey have been investigated by USHER and BOWRING (1984).

Whilst investigating the feeding preferences of *G. racovitzai*, LISTER (1984b) used polyacrylamide gel electrophoresis and staining techniques to characterise the esterases of both prey and predator species. He found a characteristic esterase band in the South Orkney Islands populations of *G. racovitzai*, whilst the populations from the Antarctic Peninsula and the South Shetlands Islands showed variability in relation to this band (LISTER, 1984a). These observations have led us to re-examine TROUESSART's (1912) subspecies *neo-orcadensis* : if there are clear esterase differences between *G. racovitzai* from the South Orkney Islands and from elsewhere in the maritime Antarctic, are there also morphological differences ? Subspecies *neo-orcadensis* was described on the basis of a single male and two nymphs, and it appears that there has been no subsequent investigation of its status. The aim of the present study is to compare the morphology of *G. racovitzai* from the South Orkney Islands and from elsewhere in the maritime Antarctic with a view to deciding whether sub-specific status is appropriate for the South Orkney Island populations.

MATERIALS AND METHODS

The material used in this study was obtained from the collection of arthropods, presently in the Department of Biology, University of York, mainly collected between 1980 and 1982 by Drs. R. G. BOOTH and M. B. USHER. Up to 5 male and 5 female specimens were taken from each of ten maritime Antarctic localities (see Fig. 1), were mounted in PVA (polyvinyl alcohol), and were scored for 57 morphological characters in the male and for 55 characters in the female. These characters are listed in Appendix 1. Other than for two characters relating to setal arrangement and the degree of sclerotization, all characters consisted of simple length and width measurements, which are recorded in μm.

Two methods of mathematical analysis have been used. First, a principal co-ordinate analysis has been used to investigate the two data sets (males and females have been analysed separately). This form of analysis was found useful in the investigation of other Antarctic taxa, *Eupo-*

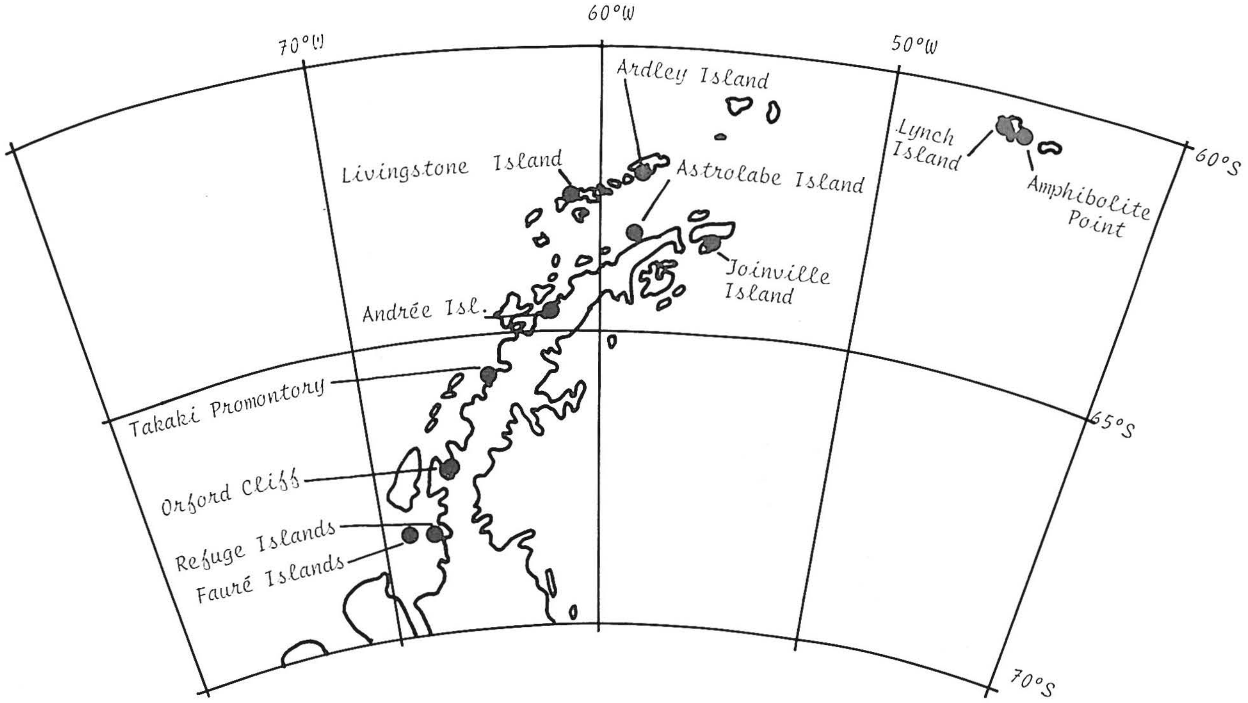

FIG. 1 : Sketch map of the maritime Antarctic indicating the localities where *G. racovitzai* was collected. In the analysis specimens from the Refuge Islands and Fauré Islands were combined into a single Marguerite Bay locality. In Figs. 3 and 4, and in Tables 1 and 2, four groups of collection localities are recognised. These are the South Orkney Islands (Lynch Island and Amphibolite Point), the South Shetland Islands (Ardley Island and Livingston Island), the northern section of the Peninsula (north of 65° S) and the southern section of the Peninsula (south of 65° S).

des (BOOTH *et al.*, 1985) and *Tydeus s. lat.* (USHER & EDWARDS, 1986). The analysis provides an ordination of the mites in a space of few dimensions (2 dimensional space was found to be satisfactory), thus allowing the similitary of the mites to each other to be assessed visually. Each of the characters was then correlated with the two principal co-ordinate axes so as to identify which characters, or groups of characters, were most important in determining the similarities and dissimilarities of the mites. In this way the male and female character sets were reduced to the 12 and 11 characters, respectively, that were contributing significantly to the ordination.

Second, each of these contributing characters was analysed by a one-way analysis of variance, comparing the variation of the character between collection localities with the variation within the localities. With ten collection localities (see Fig. 1) and 46 male specimens, the variance ratios are based on (9,36) degrees of freedom, the denominator degrees of freedom being reduced for specimens in which a character was indeterminate or missing. In the females, only one specimen from the Marguerite Bay islands was available, and hence the comparisons can only be made between 9 collection localities. The maximum number of degrees of freedom is (8,30) since there were only 39 female specimens, the one from the Refuge Islands being excluded from the analysis.

Material from the Muséum National d'Histoire Naturelle was subsequently included in the ordinations. The material in TROUESSART's collection (see Fig. 2), which had dried, was remounted. Although TROUESSART (1912) had not formally designated a holotype, the only adult, a male, of subspecies *neo-orcadensis* has been selected as the holotype (the two nymphs were only

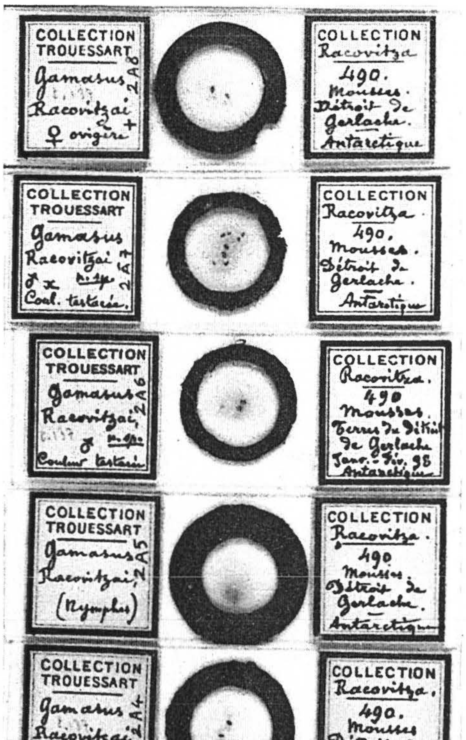

FIG. 2 : Trouessart's collection from the Muséum National d'Histoire Naturelle in Paris prior to remounting some of the mites. The bottom two slides relate to the subspecies *neo-orcadensis*.

briefly mentioned in the original description, which separated the subspecies *neo-orcadensis* from the nominate subspecies on the basis of the structure of the leg of the male). Similarly, there was no holotype of *racovitzai*, and hence one of the males has been selected and designated the lectotype (labelled " 490. Mousses. Terres du détroit de Gerlache. Janv. Fev. 98. Antarctique ", and numbered 2A6 in the MNHN collection) (see Fig. 2). The holotype of *neo-orcadensis* and the lectotype of *racovitzai* were scored for the 57 characters listed in Appendix 1, and the principal co-ordinate analysis was repeated. This allowed the type material to be placed in relation to the modern material.

RESULTS

Males

The results of a principal co-ordinate analysis of the male data, including the lectotype of *racovitzai* and the holotype of *neo-orcadensis*, are shown in Fig. 3. The first axis accounted for 13 percent of the variance and the second axis for 7 percent : no other axis accounted for more than 5 percent of the variance.

The first axis is mainly related to size, and the second to the position of the setae on the ventral surface. The nine specimens from the South Orkney Islands form a relatively distinct group in the lower part of the diagram, and the holotype of *neo-orcadensis* is located clearly within the polygon surrounding this group. Specimens from the Antarctic Peninsula and the South Shetland Islands occur in the upper part of Fig. 3. Three groups of collection localities have been recognised : the South Shetland Islands, the northern part of the Peninsula (Joinville Island, Astrolabe Island and Andrée Island) and the southern part of the Peninsula (Takaki Promontory, Orford Cliff and the Fauré and Refuge Islands). The polygons in Fig. 3 surrounding each of these three groups of localities overlap each other, but none of them overlap the polygon of the South Orkney Islands. The lectotype of *racovitzai* is located relatively centrally. Two of the specimens from the South Shetland Islands appear in an intermediate position, being plotted in Fig. 3 between the other seven South Shetland Island specimens and those of the South Orkney Islands. These two specimens were atypical since the ventral setae were assymetrical.

TABLE 1 : Analyses of variance of the male and female data. Characters are arranged in decreasing order of the value of *F* (♂ value being given before ♀ value μm if a character is significant for both sexes). All means are given to the nearest. Variance ratios (*F*) for males have 9,36 degrees of freedom (unless otherwise stated), and for females have 8,30 degrees of freedom.

Character	Sex	F	Locality group means: South Orkney Islands	North Antarctic Peninsula	South Shetland Islands	South Antarctic Peninsula
Position of ventral seta *Zv3*	♂	25.68	on	off	off*	off
Width of gnathosoma	♂	7.04	196	197	184	183
Length of tritosternum base	♀	6.47	48	42	42	42
Length of tarsus I	♀	5.91	247	230	221	222
Width of tristosternum base	♂	5.61	38	31	34	31
	♀	10.90	50	39	37	42
Length of ventro-anal shield	♂	5.05	412	391	394	375
	♀	11.08	398	374	360	346
Length of corniculus	♀	4.98	71	66	67	66
Length of idiosoma	♂	4.93	927	912	897	872
	♀	10.54	999	957	929	912
Length of coxa I	♂	4.70	141	139	135	133
	♀	5.00	137	134	130	131
Width of ventro-anal shield	♂	4.46	421	406	374	382
	♀	5.26	194	172	166	175
Length of gnathosoma	♂	4.15	301	303	292	290
	♀	4.91	306	300	299	285
Width of stigma	♀	3.96	26	23	22	24
Length of ventral seta *Zv2*	♂	3.95	74	81	75	73
Length of 1st hypostomal seta	♂	3.76[1]	54	51	50	48
Length of genu I	♀	2.95	127	123	113	119
Length of ventral seta *Jv4*	♂	2.74	68	67	65	63
Width of idiosoma	♂	2.15	564	562	528	537

* 2 sepcimens assymetrical with one seta on and one seta off.
1. d.f. 9,35.

Of the fifty seven characters initially chosen for the ordination, thirty two were shown by a one-way analysis of variance to have between-group differences that were significantly greater than within-group differences ($P < 0.05$). However, only those characters which were also correlated with the principal co-ordinate axes are listed in Table 1 (in decreasing order of their F-value from the analysis of variance). Partitioning the data into locality group means demonstrates that whilst specimens from the south of the Peninsula are markedly smaller in size than specimens from the South Orkney Islands, no such size difference is observed between the north of the Peninsula and the South Orkney Islands. On the whole it would appear that the South Shetland Island specimens occupy an intermediate position along this size gradient. The position of one of the pairs of ventral setae, *Zv3*, relative to the ventro-anal shield, was scored as either 'on' or 'off' the shield, and after the ordination had been carried out this character was consistently used to differentiate between South Orkney Island specimens and specimens from the Peninsula and the South Shetland Islands. The setae were on the shield in all individuals from the South Orkney Islands, but they were off the shield in all specimens from the South Shetland Islands and the Peninsula, except for two specimens in which the setal arrangement was assymetrical.

Females

The principal co-ordinate analysis of the female data (Fig. 4) is broadly similar to that of the male data, except that the two axes are rotated through about 135°. The first axis accounted for 16 percent of the variance, the second for 6 percent, and the remaining axes for 5 percent or less of the variance. The specimens, from the South Orkney Islands are separated from those from other localities : the polygon surrounding the individual mites in Fig. 4 does not overlap with any other polygon in that illustration. As with the males, the polygons surrounding the mites from the South Shetland Islands, from the northern part of the Peninsula (same three islands as the males) and from the southern part of the Peninsula (same localities, except there were no females from the Refuge or Fauré Islands) all overlap each other. The interesting similarity in Figs. 3 and 4 is that there is a minimum of overlap between the northern and southern portions of the Antarctic Peninsula (the mites tend to become smaller with increasing southerly latitude, as noted by ROUNSEVELL (1977) for *Tydeus erebus*), and that the greatest overlap is between the South Shetland Islands and the southern part of the Antarctic Peninsula.

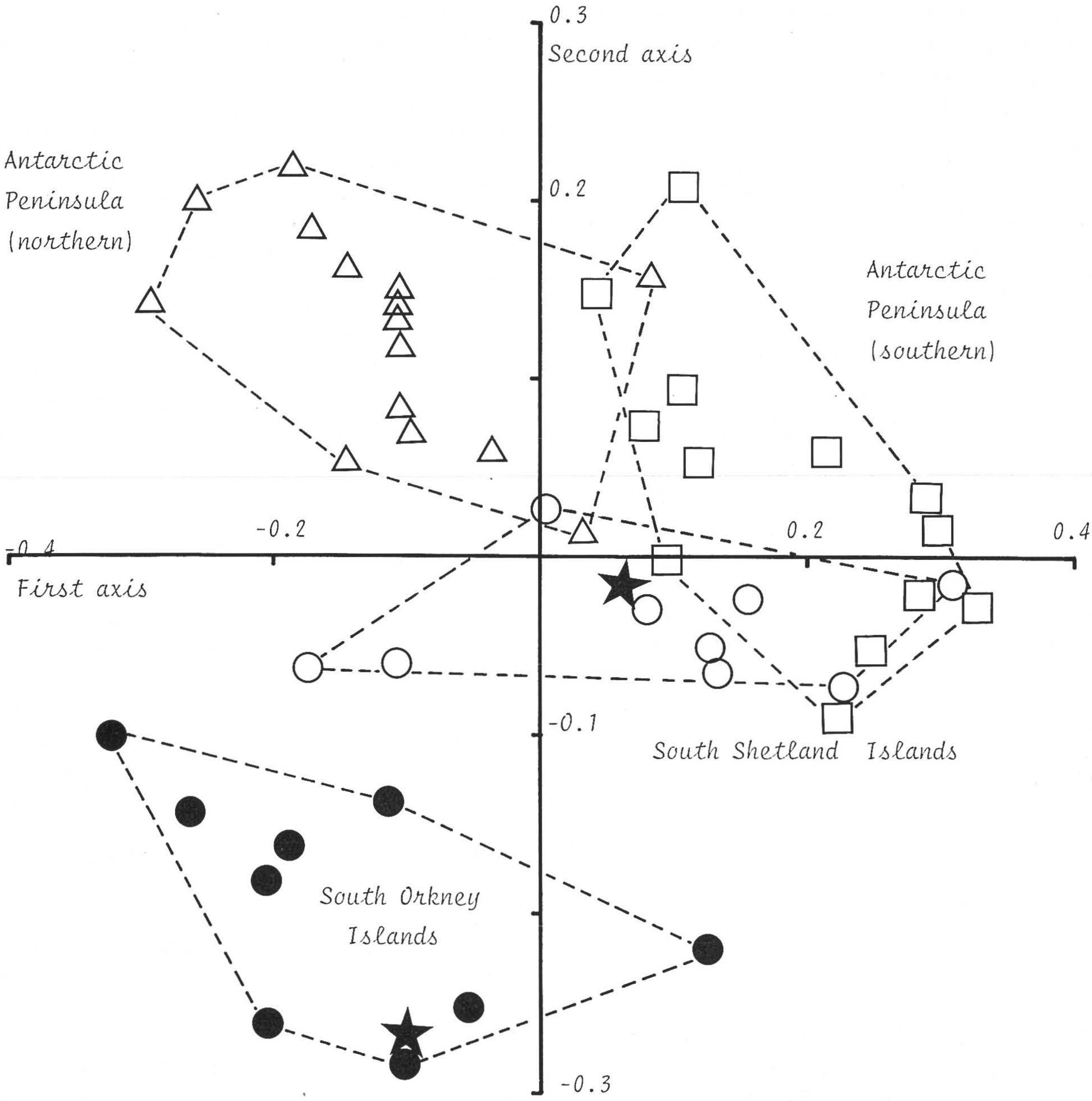

FIG. 3 : The first two axes of a principal co-ordinate analysis of the male data. The localities from which the specimens were collected are indicated thus : ●, South Orkney Islands ; ○, South Shetland Islands ; △, Antarctic Peninsula ; northern section (Joinville, Andrée and Astrolabe Islands) ; and □, Antarctic Peninsula, southern section (Takaki Promontory, Orford Cliff, and Marguerite Bay Islands). Points from any one of these four groups of localites are enclosed by a polygon (dashed lines). The holotype of *neo-orcadensis* and the lectotype of *racovitzai* are indicated thus : ★.

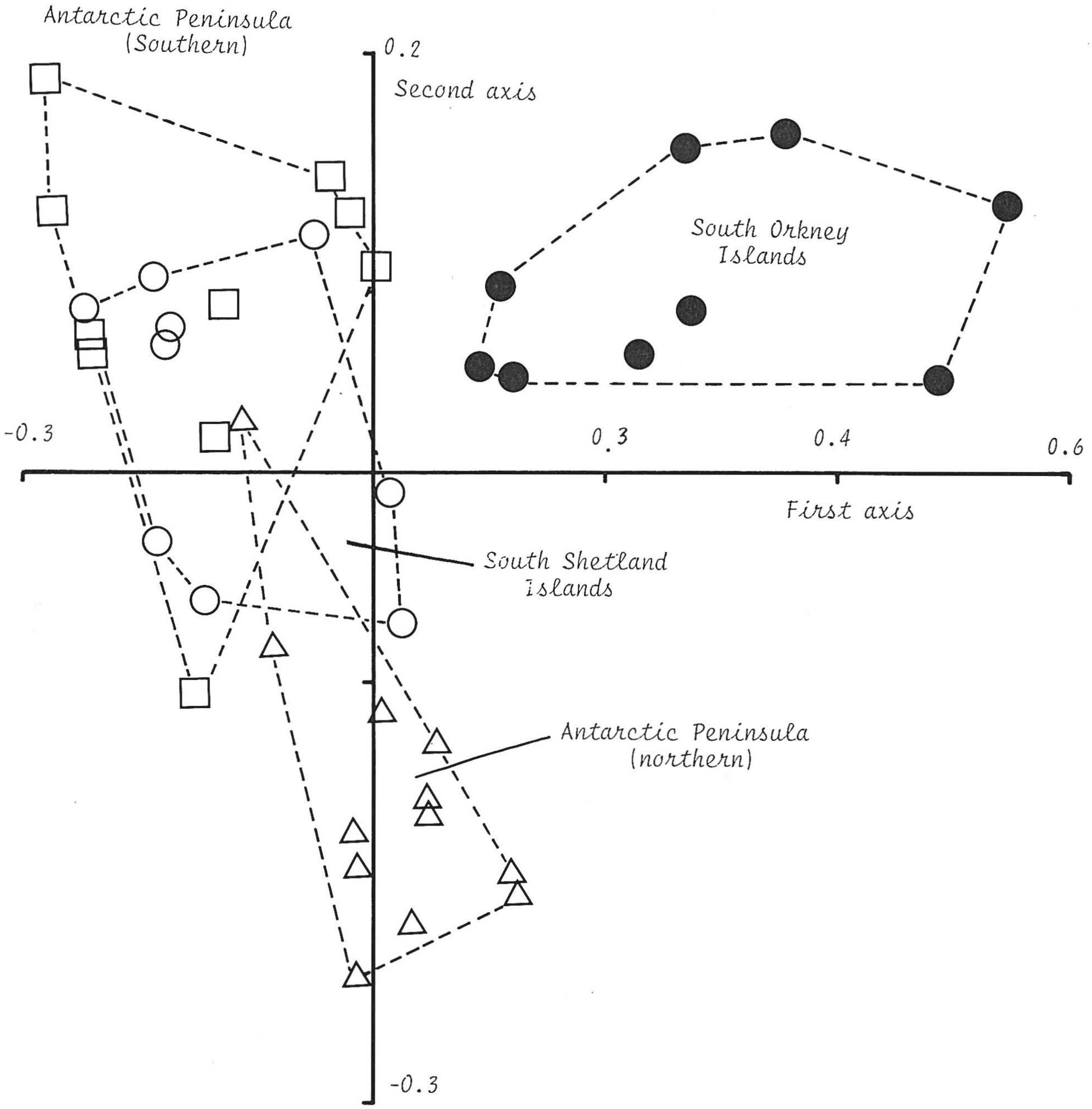

FIG. 4 : The first two axes of a principal co-ordinate analysis of the female data. The points are labelled as in Fig. 3.

As in the case of the male data, the one-way analysis of variance of the female data suggests that there are interlocality differences for 31 out of the 55 characters initially chosen for the ordination. Table 1 lists those 11 characters which were also correlated with the principal co-ordinate axes. Locality group means (Table 1) point to a gradient of decreasing size with increasing latitude. In contrast to the male data there is a marked size difference between the South Orkney

Island females and those from all the sampled localities along the north of the Peninsula and South Shetland Islands.

DISCUSSION

Morphometrical studies have indicated that there are distinctions between specimens of *G. racovitzai* from the South Orkney Islands and from the Antarctic Peninsula together with the South Shetland Islands. The group of 10 males collected from the South Orkney Islands were separated clearly on the ordination diagram (Fig. 3) from a collection of 36 males from elsewhere in the maritime Antarctic, although two of the South Shetland Island males, which were atypical, occupied an intermediate position. However, the amount of variance accounted for by the first and second axes, about 13 and 7 percent respectively, is small in comparison with studies on other taxa of Antarctic mites, for example 41 and 17 percent in a study of three species, one with two subspecies, of *Eupodes* (BOOTH *et al.*, 1985) and 25 and 19 percent in a study of three species of *Apotriophtydeus* (USHER & EDWARDS, 1986). The separation of the Shouth Orkney Island specimens from specimens collected in all of the other localities, the overlapping nature of the specimens from the other localities (although there is a tendency to a north-south cline along the Peninsula), and the relatively small amount of variance accounted

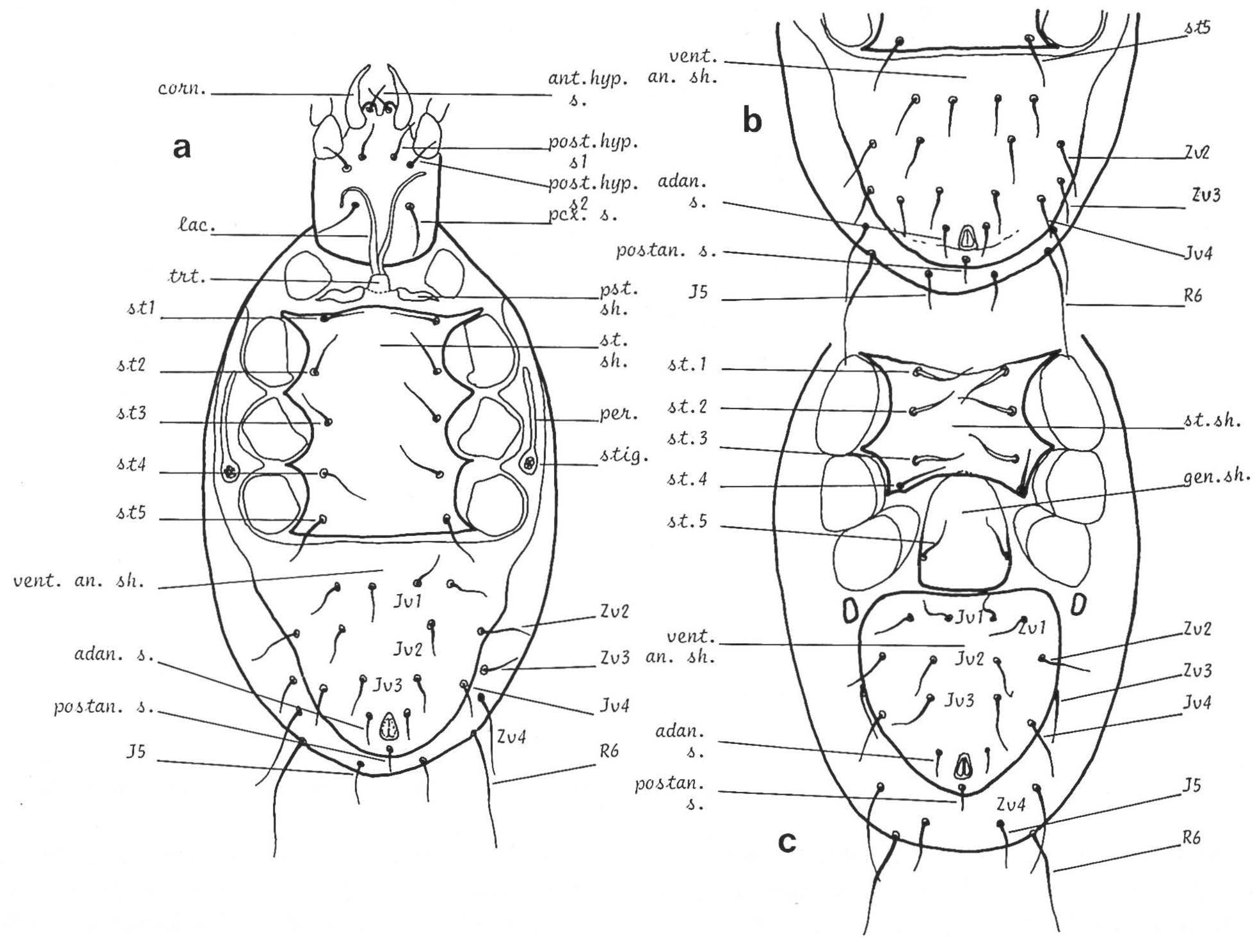

FIG. 5 : Schematic ventral view of : (a) *Gamasellus racovitzai racovitzai* ♂, (b) *Gamasellus racovitzai neo-orcadensis* ♂ and, (c) ♀ (of either sub-species). The abbreviations relate to those listed in Appendix 1.

for, are suggestive of the South Orkney Island material being a separate subspecies from that occurring along the Antarctic Peninsula and in the South Shetland Islands.

The result of analysing the male mites was confirmed by the analysis of female mites. The 9 South Orkney Island mites are separated in the ordination diagram (Fig. 4) from the 31 mites collected elsewhere, which, as with the males, show a tendency towards a north-south cline. The amount of variance accounted for by these first two axes is small, 16 and 6 percent respectively, when compared with analyses of female *Eupodes* (42 and 17 percent ; BOOTH *et al.*, 1985) and female *Apotriophtydeus* (30 and 11 percent ; USHER & EDWARDS, 1986). However, there are striking similarities between the female and male analyses, leading to a similar conclusion that there are two subspecies of *G. racovitzai* in the maritime Antarctic.

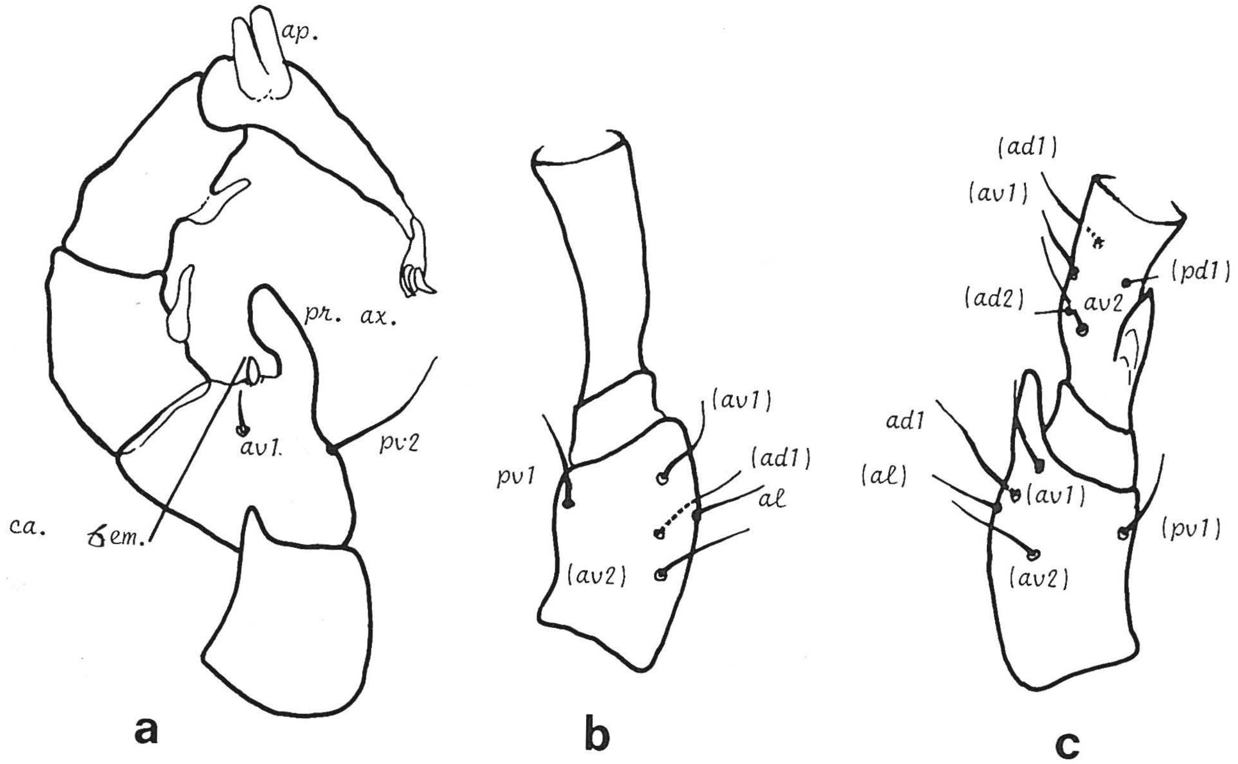

FIG. 6 : Leg II of ♂ (a) and trochanter and femur IV of ♂ (b) and ♀ (c). The abbreviations relate to those listed in Appendix 1. Setae have been named as in Evans & Till (1979), where the abbreviations denote anterior (*a*), posterior (*p*), dorsal (*d*), ventral (*v*) and lateral (*l*), and setae are numbered from the distal to the proximal end of each segment.

Further support for the recognition of the subspecies is found in the work of LISTER (1984a). He found that on electrophoresis there was a characteristic esterase band for *Gamasellus* in the South Orkney Islands. Subsequent work in the South Shetland Islands (2 localities) and Antarctic Peninsula (10 localities) indicated that there were two electromorphs, an isomorphic fast and an isomorphic slow, together with heteromorphs. All individuals in the South Orkney Islands, when compared to the other material, were isomorphic fast, the morph that was absent from several localities along the Antarctic Peninsula and scarce at many of the other localities.

Morphologically and biochemically there are relatively small differences between *G. racovitzai* from the South Orkney Islands and from other localities in the maritime Antarctic, including the

Antarctic Peninsula, its offshore islands, and the South Shetland Islands. The recognition of two subspecies would therefore seem appropriate. The nominate subspecies is the one from the Antarctic Peninsula, originally described by TROUESSART (1903) from material on the shores of the Gerlache Strait. The suspecies in the South Orkney Islands is *neo-orcadensis*, originally described by TROUESSART (1912) from a single male and two juveniles collected on Laurie Island.

The data in Table 1 can be used as a basis for the identification of the two subspecies. Individuals of ssp. *neo-orcadensis* are frequently larger than individuals of ssp. *racovitzai*, although, particulary in relation to the gnathosoma, they can resemble the larger individuals from the northern end of the Peninsula. TROUESSART (1912) distinguished ssp. *neo-orcadensis* on the basis of small differences in the spurs on the leg II : these differences, in the extensive material now available as opposed to the single specimen seen by TROUESSART, seem to be variable both from individual to individual and depending upon the angle of observation. A definitive character for use with the males is the position of the ventral setae *Zv3*. In males of ssp. *neo-orcadensis* this seta is always situated on the ventro-anal shield (Fig. 5b), and very close to it in the females. In ssp. *racovitzai* the seta is situated off the shield (Fig. 5a), except for individuals (only 2 seen), collected on the South Shetland Islands, which were assymetrical, with the seta on the shield on one side and off the shield on the other side. There is also another character that is virtually always consistent. In ssp. *neo-orcadensis* there is a very small ventral seta, *A1*, situated just posterior to the insertion of coxa IV (Fig. 5b). This seta is virtually always absent in ssp. *racovitzai*.

Besides the morphological and biochemical differences, it would be interesting to know if there are any ecological differences between the two subspecies. LISTER (1984a) has demonstrated that, in the South Orkney Islands, *G. racovitzai* consumed proportionally more *Parisotoma octo-oculata* than in the population of Collembola from the same habitat (*Cryptopygus antarcticus* was the most abundant Collembola, and *Friesa woyciechowskii* also occured). However, in his Antarctic Peninsula studies, there was not such a noticeable selection for *Parisotoma*, and *Cryptopygus* was frequently the predominant prey consumed. Whether there is a slight difference in prey selection between the two subspecies, or whether the difference is due to the presence of a second genus of predators, *Rhagidia s. lat.*, which do not occur on the South Orkney Islands, remains a subject for conjecture.

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APPENDIX 1

List of male and female characters used in the analysis. A " + " indicates that the character was used, a " — " that it was not used. Many of the characters used are illustrated in Figs. 5 and 6 : references are made to these illustrations where appropriate. Nomenclature for setae, etc., generally follows EVANS & TILL (1979).

character	Use in ♂	Use in ♀	Symbol	Figure
Lengths				
Idiosoma	+	+	—	—
Gnathosoma	+	+	—	—
Ventro-anal shield	+	+	vent. an. sh.	5a, b, c
Sternal shield	+	+	st. sh.	5a
Genital shield	—	+	gen. sh.	5c
Coxa I	+	+	—	—
Trochanter I	+	+	—	—
Femur I	+	+	—	—
Genu I	+	+	—	—
Tibia I	+	+	—	—
Tarsus I	+	+	—	—
Ambulacrum I	+	+	—	—
Trochanter IV	+	+	—	—
Femur IV	+	+	—	—

character	Use in ♂	Use in ♀	Symbol	Figure
Genu IV	+	+	—	—
Tibia IV	+	+	—	—
Tarsus IV	+	+	—	—
Ambulacrum IV	+	+	—	—
Palpal femur	+	—	—	—
Palpal genu	—	+	—	—
Palpal tibia	+	+	—	—
Palpal tarsus	+	+	—	—
Basal segment of tritosternum	+	+	trt.	5a
Lacinia	+	+	lac.	5a
Presternal shield	+	+	pst. sh.	5a, c
Corniculus	+	+	corn.	5a
Peritreme	+	+	per.	5a
1st hypostomal seta	+	+	ant. hyp. s.	5a
2nd hypostomal seta	+	+	post. hyp. s1	5a
3rd hypostomal seta	+	+	post. hyp. s2	5a
Palpcoxal seta	+	+	pcx. s.	5a
Calcar femoralis	+	—	ca. fem.	6a
Processus axillaris	+	—	pr. ax.	6a
Seta *pv2* on femur II	+	—	pv2	6a
Seta *av1* on femur II	+	—	av1	6a
Apophysis on tarsus II	+	—	ap.	6a
Spur on trochanter IV	—	+	troc. sp.	6c
Seta *ad1* trochanter IV	—	+	ad1	6c
Spur on femur IV	—	+	fem. sp.	6c
Seta *av2* on femur IV	—	+	av2	6c
Chelicerae	+	+	—	—
Sternal seta 1	+	+	st1	5a, c
Sternal seta 2	+	+	st2	5a, c
Sternal seta 3	+	+	st3	5a, c
Sternal seta 4	+	+	st4	5a, c
Sternal seta 5	+	—	st5	5a, b, c
Seta *Zv2*	+	+	Zv2	5a, b, c
Seta *Jv4*	+	+	Jv4	5a, b, c
Seta J5	—	+	J5	5a, b, c
Seta *al* on trochanter IV	+	—	al	6b
Seta *pv1* on trochanteur IV	+	+	pv1	6b
Seta *R6*	+	+	R6	5a, b, c
Adanal seta	+	+	Adan. s.	5a, b, c
Postanal seta	+	+	Postan. s.	5a, b, c
Plumed seta (*al1*) on palpal tibia	+	+	—	—
Widths				
Idiosoma	+	+	—	—
Gnathosoma	+	+	—	—
Ventro-anal shield	+	+	vent. an. sh.	5a, b, c
Sternal shield	+	+	st. sh.	5a, c
Genital shield	—	+	gen. sh.	5c
Basal segment of tritosternum	+	+	trt	5a
Presternal shield	+	+	pst. sh.	5a, c
Stigma	+	+	stig.	5a
Position of seta *Zv3*	+	—	Zv3	5a, b, c
Degree of sternal sclerotization	+	—	—	—

Paru en mars 1987.