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The cryptostigmatid mite *Halozetes belgicae* (Michael) in the maritime Antarctic

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Abstract: *Halozetes belgicae* is distributed widely in the Subantarctic and maritime Antarctic, with subspecies described from Macquarie Island and the South Sandwich Islands. A morphometrical study, based largely on the development of the setae, indicates that the nominate subspecies is confined to the Antarctic Peninsula and its offshore islands (including the South Shetland Islands), whilst specimens from the South Orkney Islands are probably consubspecific with individuals on the South Sandwich Islands. In comparison with other studies of the Acari, the results strengthen the case for the recognition of a South Orkadian biogeographical zone.

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Introduction

The study of Antarctic orbatid mites (Acari: Cryptostigmata) originated with the collections made by the Belgian Antarctic Expedition, 1897–99. Michael (1903) recorded that these collections contained "very numerous specimens but only three species"; one of these species was described as *Notaspis belgicae*. Specimens seen by Michael were deposited in the collection of The Natural History Museum, London, in 1930 but are not labelled with any locality. Michael (1903) recorded only that the collections "were found in moss and lichen on the Antarctic lands, in the Gerlache Strait, between south latitudes 64° 23' and 67° 59' and west longitudes 62° 02' and 70° 39'". He did not designate type material.

The Antarctic Cryptostigmata were reviewed by Wallwork (1965), who also redescribed many of the species including *Halozetes belgicae*. Previously Wallwork (1963) had described ssp. *brevipilis* from Macquarie Island (*c.*55°S, 159°E) on the basis of its shorter interlamellar setae and weaker aggenital neotrichy in adult males. Subsequently, Wallwork (1967) described another subspecies, ssp. *longisetae*, from the South Sandwich Islands (*c.*57°S, 28°W) which differed from the nominate subspecies and from ssp. *brevipilis* by its strongly developed notogastral setae.

Whilst undertaking ecological studies of Antarctic mites and Collembola (Usher & Booth 1984) it was noticed that there was considerable variation in the length of setae on specimens of *H. belgicae*. The aim of this study is therefore to investigate the range of variation, especially in relation to setal length, in populations of *H. belgicae* throughout the maritime Antarctic. Specifically, one question to be answered is "Is the range of variation in the nominate subspecies encompassed within the morphological extremes described by Wallwork (1963, 1967) for the subspecies on Macquarie Island (short setae) and the South Sandwich Islands (long setae)?". Multivariate analyses, previously used to investigate subspecific status of the Antarctic mites *Oppia loxolineata* Wallwork (Buryn & Usher 1986) and *Gamasellus racovitzai* (Trouessart) (Jumeau & Usher 1987), have been used to answer this question.

Methods

Slides were prepared of male and female individuals of *H. belgicae* from material collected from the maritime Antarctic by British Antarctic Survey (Signy Island) and R.G. Booth & M.B. Usher (all areas). These represented 35 geographical areas (Appendix 1) between latitudes 60°39'S and 68°21'S. A total of 52 characters (Fig. 1 and Appendix 2) were measured on 53 males and 50 females, as well as on the male and female from Michael's collection; no material of ssp. *brevipilis* was available. There was a relatively high proportion of missing values for Michael's two specimens because they were not completely translucent and were consequently difficult to measure.

For all of the analyses, a reduced data set, which eliminated variables with more than 20% of their values missing, was used. Male and female data sets were analysed separately. In the principal component analysis (PCA), missing values were substituted by the mean of the corresponding variable, since eliminating all cases with missing values would have greatly reduced the data set. A correlation matrix was used in the PCA. For cluster analysis, all variables were standardised, and a matrix of average squared euclidean distances was used with various clustering techniques, including average linkage (UPGMA), complete linkage, single linkage, flexible

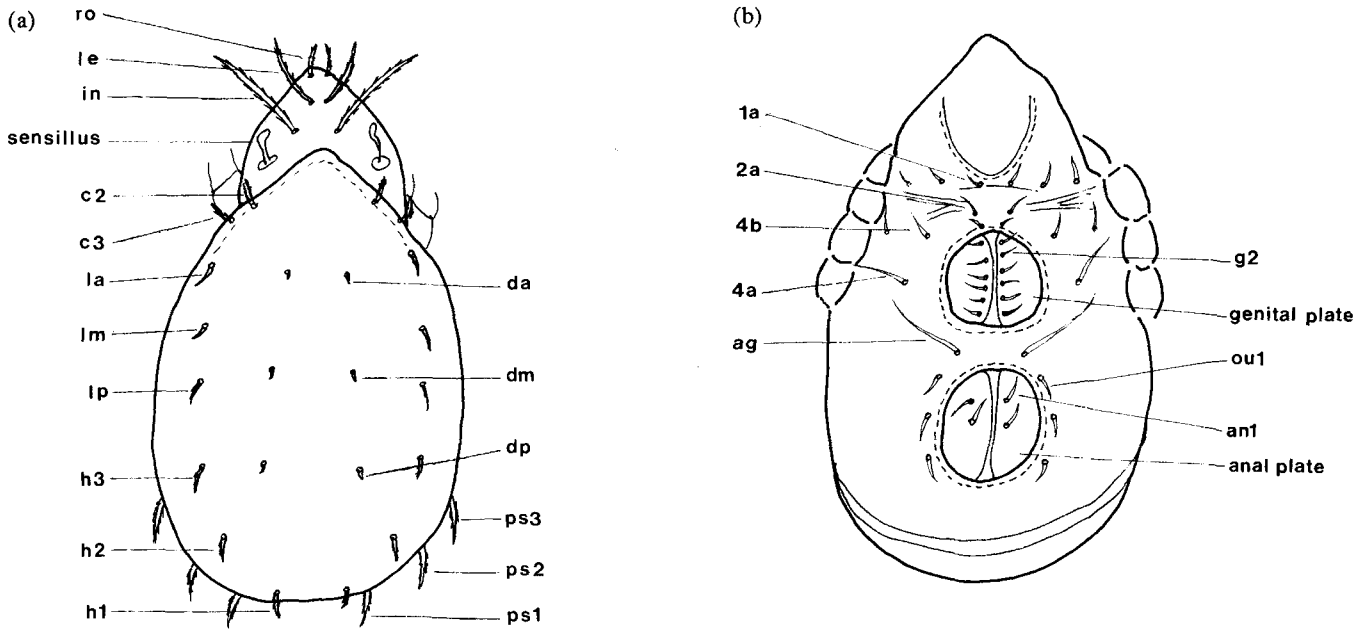

Fig. 1. Location of setae and other characters measured and listed in Appendix 2. (a) dorsal and (b) ventral views of the mite. The following abbreviations have been used: ro (rostral seta), le (lamella seta), in (interlamella seta) and ag (aggenital seta).

linkage and Ward's Method (minimum variance). These analyses were carried out using a package of programs ("FITOPAC") being developed by G.J.S. Discriminant function analysis was carried out using the "SYSTAT" package, once again substituting missing values by the mean of the appropriate variable.

Results

Cluster analysis using average linkage (Fig. 2) showed a clear separation of the material into two main groups, one containing the specimens from the South Orkney Islands and the other containing those from the South Shetland Islands, the Antarctic Peninsula and its offshore islands. This separation was evident both in the females, where there was no overlap between the two areas (Fig. 2a) and in the males, where the Michael material formed a third group by itself (Fig. 2b). This pattern was consistent, apart from minor changes in group membership, in all of the clustering methods used, with the exception of single linkage where extensive chaining occurred, although even here the South Orkney material formed a reasonably coherent group, especially for the females. The specimens from Michael's collections were less consistent in their position and either formed an isolated group or were attached to one or other of the two major groups, depending on the clustering technique used. This indicates a rather isolated and ambiguous position for this material (for which there were many missing characters). The subgroups formed within the two major clusters were not consistent in the dendrograms produced by the different clustering techniques, and could not be interpreted in an obvious way either in morphological or geographical terms.

The PCA confirmed the separation suggested by cluster analysis, with the first axis in both male and female data sets essentially contrasting the South Orkney material with the remaining specimens from the Antarctic Peninsula (Fig. 3). In the females, the first axis accounted for 21% of the total variance and show a complete separation between the two groups (Fig. 3a). The characters most heavily weighted on this axis were almost all setal lengths, with lengths of setae 1p, 1a, 1m, h1, h2 and h3 receiving the highest loadings, while lengths of setae c2 and ps2 and the distance between setae dm and dp were also quite highly weighted (Table I). The second axis accounted for 13% of the total variance and appeared to be almost entirely a size component, since only two characters received negative weights (both very small). On this axis, the highest loadings were on the general body size characters and particularly on the genital and anal plate measurements.

In the males, the PCA produced very similar results (Fig. 3b), with the first axis, representing 20% of the total variance, again separating the two groups completely. The character weightings were quite similar to those obtained for the females, except that lengths of setae ps1 and ps2 received larger loadings and the distance between setae dm and dp was not highly weighted (Table I). The second axis (12% of the total variance) once again appeared to be essentially a size component, although in this case the number of characters

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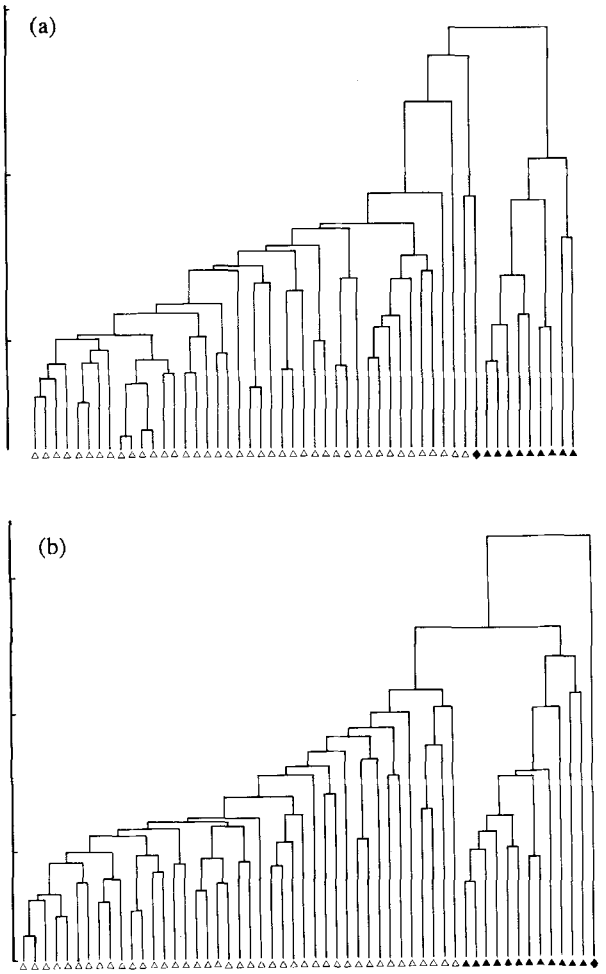

Fig. 2. Dendrograms for (a) females and (b) males, produced by the average linkage (UPGMA) method on a matrix of mean Euclidian distances between individuals. The symbols have the following meaning: ▲ South Orkney Islands, △ Antarctic Peninsula and South Shetland Islands and ◆ Michael's material.

with negative weights was rather larger, but all of these weights were small. The weighting given to general body measurements was somewhat larger, and that of anal and genital plate measurements a little smaller. The remaining axes of the male and female PCAs could not be interpreted in any obvious way, and there was no evidence for any geographical differentiation along the Antarctic Peninsula.

In both males and females, Michael's material was similar to the Antarctic Peninsula specimens on the first axis, but occupied a rather isolated position on the second axis, being generally smaller than the majority of the Peninsula samples. Given the relatively high proportion of missing characters in the material form Michael's collection and its somewhat anomalous position in the cluster analyses, it was decided to carry out a discriminant function analysis, using the South Orkney material and the Antarctic Peninsula material as the groups to be discriminated, leaving Michael's specimens to be classified by the discriminant function. This analysis was carried out using a much reduced data set; all of the setal length characters had been eliminated as were all characters with four or more missing values. In all, only 14 characters were used for this analysis (indicated in Appendix 2). Although the separation between the two groups was shown to be mainly based on setal length characters in the PCA, it was still possible to differentiate the two groups almost completely when using non-setal length characters. The discriminant function produced a very good classification, with 4 individuals misclassified in the females and only 1 misclassified in the males. In both cases, Michael's specimens were placed in the South Orkney Islands group by the discriminant function. A PCA on this highly reduced data set also showed a position closer to the South Orkney material. Addition of the two most reliable setal length characters (which did not include those most heavily weighted in the first PCA) completely reversed this allocation of Michael's specimens, classifying them as part of the Antarctic Peninsula group.

Discussion

The analyses in Figs. 2 and 3 indicate that specimens of *Halozetes belgicae*, collected within the geographical range of the nominate subspecies, can be divided into two groups. One group is found within the maritime Antarctic zone of the Antarctic Peninsula, and its immediate offshore islands, whilst the other group is confined to the South Orkney Islands. The question arises as to whether the two groups encompass a continuous range of variation in the species, or whether there is a discontinuity so that the two groups should be recognised as separate taxa.

The list of characters in Appendix 2 indicates how the two groups differ; the difference is essentially in the length of the setae (note, however, that a discriminant function analysis on non-setal characters was also able to discriminate the two groups with only a small proportion of misclassifications). In terms of size, the mites from the two areas are almost identical. Variation in size of mite, as demonstrated in the second axes of the PCAs in Fig. 3, is therefore continuous; however, in terms of setal lengths, the variation is discontinuous with one group having short setae and the other having long setae.

The group with short setae are distinct from Wallwork's (1963) spp. *brevipilis*, which has shorter lamellar and interlameller setae. However, the group with long setae encompass the description of Wallwork's (1967) ssp. *longisetae*. Unfortunately no specimens of *longisetae* could be located, and hence these could not be included in the cluster and ordination analyses. However, it appears that the South Orkney Islands specimens of *H. belgicae* are conspecific with *H. b. longisetae* from the South Sandwich Islands.

This conclusion has interesting biogeographical implications.

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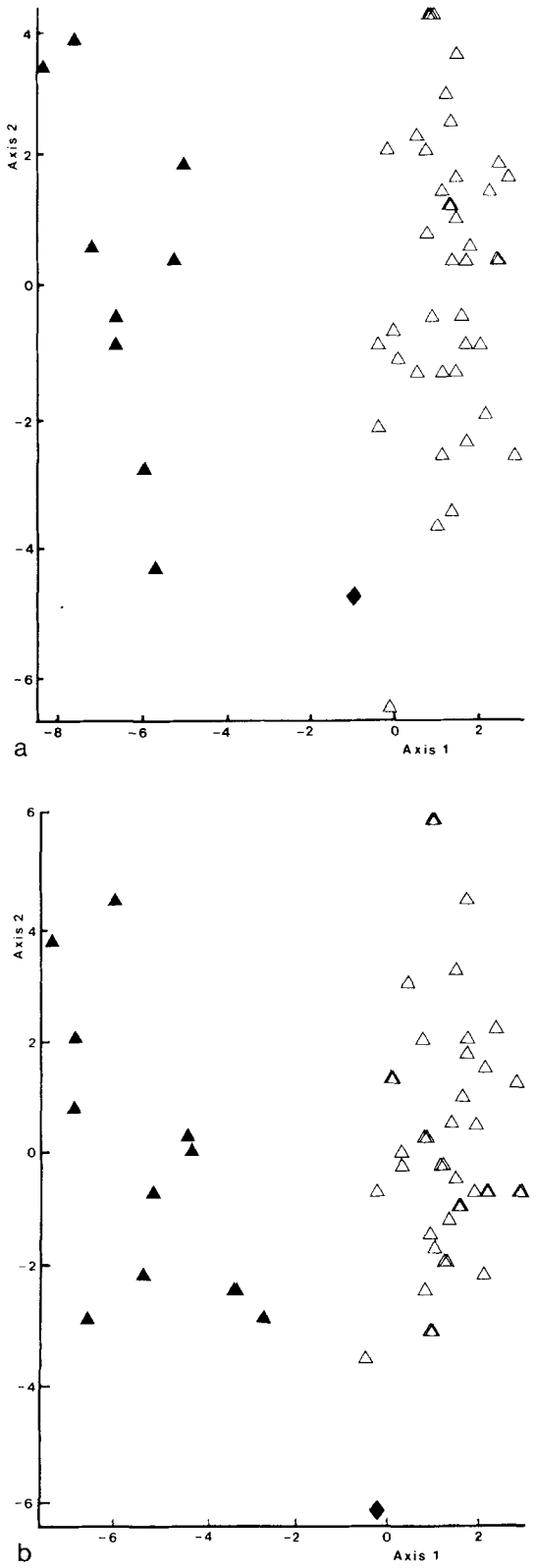

Fig. 3. Axis 1 (correlated with setal length) and Axis 2 (correlated with body size) of principal component analyses for (a) females and (b) males. The symbols have the same meaning as in Fig. 2.

Table I. Eigenvectors 1 and 2 obtained from PCAs of the data for female and male *Halozetes belgicae*

Character	Females		Males	
	Vector1	Vector2	Vector1	Vector2
Length propodosoma	0.109	0.156	-0.034	0.208
Width propodosoma	-0.012	0.188	-0.004	0.259
Length hysterosoma	0.098	0.190	0.027	0.229
Width hysterosoma	0.040	0.217	-0.062	0.192
Length ro	-0.108	0.170	-0.220	0.081
Length le	0.033	0.179	0.064	0.157
Length in	-0.143	0.171	-0.147	0.076
Dist. ro-ro	-0.002	0.008	-0.117	0.145
Dist le-le	-0.025	0.026	-0.049	0.169
Dist. in-in	0.149	0.074	0.137	0.054
Dist. ro-le	0.096	0.186	-0.024	0.268
Dist. le-in	0.015	0.243	0.044	0.081
Length sensillum	-0.006	0.126	-0.022	0.183
Length c2	-0.274	0.070	-0.249	-0.044
Length c3	-0.082	0.057	-0.085	-0.044
Length la	-0.295	0.075	-0.313	-0.008
Length lm	-0.299	0.036	-0.309	-0.029
Length lp	-0.302	0.048	-0.310	-0.032
Length h1	-0.292	0.061	-0.289	-0.027
Length h2	-0.290	0.073	-0.291	0.004
Length h3	-0.298	0.091	-0.298	-0.045
Length ps1	-0.174	0.100	-0.216	0.053
Length ps2	-0.251	0.063	-0.234	-0.029
Length ps3	-0.197	0.108	-0.202	0.023
Length genital plate	0.110	0.244	-0.080	0.121
Width genital plate	0.009	0.277	-0.049	0.112
No. aggenital setae	-0.061	0.011	-0.108	0.093
Length aggenital seta	-0.028	0.149	0.037	0.140
Length anal plate	0.069	0.296	-0.025	0.244
Width anal plate	0.047	0.219	0.050	0.166
Dist. c2-c2	0.044	0.090	-0.007	0.244
Dist. da-da	0.042	0.135	-0.055	0.156
Dist. dm-dm	-0.039	0.093	-0.172	0.096
Dist. dp-dp	-0.118	-0.033	-0.111	0.056
Dist. c2-da	-0.042	0.015	-0.046	0.122
Dist. da-dm	0.003	0.122	0.045	0.074
Dist. dm-dp	0.214	0.080	0.085	0.124
Length tarsus I	0.024	-0.062	-0.014	0.185
Length tibia IV	0.078	0.220	0.047	0.314
Length femur IV	0.177	0.141	0.151	0.210
Length 1a	0.087	0.061	0.006	0.120
Length 4a	-0.079	0.158	0.012	0.145
Dist. 4a-4a	0.051	0.203	-0.001	0.091
Length g2	-0.042	0.174	-0.049	0.255
Length anl	0.047	0.175	0.057	0.106
Length oul	0.153	0.191	0.109	0.120

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The mesostigmatid mite *Gamasellus racovitzai* (Trouessart) is subspeciated, with the nominate subspecies on the Antarctic Peninsula, its offshore islands and the South Shetland Islands and subspecies *neo-orcadensis* in the South Orkney Islands (Jumeau & Usher 1987). The prostigmatid mite *Eupodes parvulus* Booth *et al.* is similarly subspeciated, with the nominate subspecies in the South Orkney Islands and subspecies *grahamensis* on the Peninsula and the South Shetland Islands (Booth *et al.* 1985). Other species of mites (e.g. *Rhagidia gerlachei* (Trouessart) and *Tuberostoma leechi* (Strandtmann)) and insects (e.g. *Belgica antarctica* Jacobs) are confined to the Antarctic Peninsula and neighbouring areas. The South Orkney Islands, although often included with the Antarctic Peninsula and the South Shetland Islands as the maritime Antarctic, are clearly biogeographically distinct in terms of their mite subspecies. With the identification of separate subspecies of *H. belgicae* in the two areas, subspeciation has been found in all three major groups of mites inhabiting Antarctica- Cryptostigmata, Mesostigmata and Prostigmata. The greater species richness of the Antarctic Peninsula and the South Shetland Islands, compared with the South Orkney Islands, is another indication of the biological isolation of the latter islands, even though they are located further north. In terms of the terrestrial Acari, this study strengthens the case for the recognition of a South Orkadian biogeographical zone.

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Appendix 1. Geographical locations and the numbers of specimens studied.

Locality	Latitude	Longitude	Male	Female
Coronation Island	60°39'S	45°39'W	3	2
Signy Island	60°43'S	45°36'W	9	7
Livingston Island	62°39'S	61°03'W	1	2
Deception Island	62°58'S	60°42'W	2	2
Astrolabe Island	63°17'S	58°42'W	1	2
Cape Roquemaurel	63°33'S	58°57'W	1	0
Young Point	63°36'S	58°57'W	1	1
James Ross Island	63°48'S	57°54'W	1	0
Brabant Island	64°02'S	62°35'W	5	3
Spring Point	64°18'S	61°03'W	1	1
Andrée Island	64°31'S	61°31'W	2	1
Boxing Island	64°35'S	61°42'W	0	1
Cuverville Island	64°41'S	62°37'W	0	1
Brewster Island	64°43'S	62°34'W	1	1
Palmer Station	64°47'S	64°05'W	1	0
Uruguay Island	65°14'S	64°14'W	1	1
Leopard Island	65°15'S	64°18'W	1	1
Galindez Island	65°15'S	64°15'W	0	1
Black Island	65°16'S	64°17'W	1	0
Cape Tuxen	65°16'S	64°08'W	0	1
Green Island	65°19'S	64°10'W	1	0
Darboux Island	65°24'S	64°13'W	0	1
Takaki Promontary	65°31'S	64°12'W	1	1
Lahille Island	65°32'S	64°20'W	2	3
Pinero Island	67°34'S	67°50'W	1	0
Rothera Point	67°34'S	68°09'W	1	1
Jenny Island	67°44'S	68°24'W	4	3
Dion Island	67°52'S	68°43'W	2	6
Line Islands	67°55'S	67°12'W	1	0
Square Bay	67°56'S	67°08'W	0	2
Camp Point	67°58'S	67°16'W	1	0
Fauré Islands	68°06'S	68°51'W	3	3
Roman Four Promontary	68°13'S	66°58'W	1	1
Red Rock Ridge	68°17'S	67°11'W	1	1
Refuge Islands	68°21'S	67°08'W	2	0

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Appendix 2. The characters measured on *Halozetes belgicae* and their mean values for males and females from the South Orkney Islands and Antarctic Peninsula areas (all lengths μm). Setae are indicated on Fig. 1.

	South Orkney Islands		Antarctic Peninsula	
Character	Male	Female	Male	Female
*Length of prodosoma	189	181	188	197
*Width of prodosoma	271	292	277	290
*Length of hysterosoma	446	460	455	479
*Width of hysterosoma	389	404	377	413
Length of rostral seta (ro)	45	37	38	34
Length of lamella seta (le)	56	53	65	58
Length of interlamella set (in)	123	123	113	113
*Distance between ro-ro	28	24	24	24
Distance between le-le	21	21	19	19
*Distance between in-in	67	64	75	76
Distance between ro-le	159	156	158	165
Distance between le-in	84	88	86	90
Length of sensillum	44	45	44	44
Length of seta c2	38	40	20	18
Length of seta c3	7	8	1	2
+Length of seta da	14	15	7	6
+Length of seta dm	13	13	6	6
+Length of seta dp	17	16	7	7
Length of seta la	36	32	12	11
Length of seta lm	34	33	11	11
Length of seta lp	35	32	12	12
Length of seta h1	32	28	15	13
Length of seta h2	34	31	15	14
Length of seta h3	34	29	14	14
Length of seta ps1	40	33	31	25
Length of seta ps2	41	41	31	28
Length of seta ps3	39	38	32	29
*Length of genital plate	96	113	93	120
*Width of genital plate	106	139	103	140
*No. of aggenital setae	16	3	14	2
Length of aggenital seta	80	74	85	72
Length of anal plate	145	148	142	155
Width of anal plate	101	108	104	113
Distance between c2-c2	173	179	172	182
*Distance between da-da	77	73	71	76
*Distance between dm-dm	88	83	76	78
*Distance between dp-dp	84	82	72	72
Distance between c2-da	73	76	70	73
Distance between da-dm	116	121	117	123
Distance between dm-dp	95	92	105	113
Length of tarsus I	45	46	46	46
*Length of tibia IV	81	80	83	82
*Length of femur IV	91	91	98	102
Length of seta 1a	16	14	16	17
+Length of seta 2a	14	14	16	16
Length of seta 4a	61	63	63	55
+Distance between 2a-2a	44	42	51	53
+Distance between 2a-4b	52	58	50	56
Distance between 4a-4a	148	175	147	179
Length of seta g2 on genital plate	25	26	23	25
Length of seta anl on anal plate	30	33	33	35
Length of seta oul	29	28	33	36

* used in the discriminant analysis

+ excluded because of the large number of missing values

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