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Differentiation between two epilittoral species, *Scutovertex arenocolus* spec. nov. and *Scutovertex pilosetosus* Polderman (Acari: Oribatida) from different European coasts

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Abstract

Scutovertex arenocolus **spec. nov.** living in the sandy shore of the Baltic coast is described. Additionally, a closely related species, *S. pilosetosus*, occurring in marsh habitats of the North Sea coast, is redescribed in detail. Both species show a similar habitus. *Scutovertex arenocolus* differs from *S. pilosetosus* in the length of body, cusps and notogastral setae, in the ridge on mentum as well as in a different exochorion structure of the eggs. A morphometric analysis of 14 morphological characters confirmed distinctly shorter cusps and notogastral setae in *S. arenocolus*. Additionally, a principal component analysis performed with 17 morphological traits provided a clear separation of these two species and of *S. minutus*. The results of these analyses lead to the conclusion that earlier reports of *S. minutus* in the coastal zone of the Atlantic, the Baltic and the North Sea should be assigned to the one or the other of these two littoral species.

Key words: *Scutovertex minutus*, morphology, morphometry, PCA, exochorion

Introduction

The majority of oribatid mite species live in habitats of the inland and represent mainly soil inhabiting animals. Only about one percent of oribatid mites show a close ecological relation to the marine littoral environment, as for example members of the families Ameronothridae, Selenoribatidae, Fortuyniidae and Podacaridae (Schuster 1966). There are only a few single representatives of other families that are known to inhabit littoral ecosystems as well as terrestrial areas. Within the Scutoverticidae the typical inland moss-dwelling *Scutovertex minutus* (Koch, 1836) was reported to occur also at the North Sea and the Baltic coast (Weigmann 1973; 2008). Polderman (1977) discovered one epilittoral living species in the Netherlands, *Scutovertex pilosetosus* Poldermann, 1977, which was formerly mistaken for *S. minutus*. Weigmann (2006) lists *S. pilosetosus* as a “species inquirenda” and mentions a possible synonymy with *S. minutus*. Recently collected specimens of *Scutovertex* at the German Baltic coast which could be assigned neither to *S. minutus* nor to any other species necessitate a detailed morphological analysis of the unidentified (new) species and a comparison with *S. pilosetosus* as well as *S. minutus*.

Materials and methods

Specimens of *S. arenocolus* were sampled from upper regions of sandy beaches.

German Baltic coast: a) Darss-Zingst (Mecklenburg-Western Pomerania); 28/06/2007 (leg. C. Hellig). – b) Behrensdorf (Schleswig-Holstein), sand and root balls of grass (*Elymus arenarius*, *Ammophila arenaria*); 22/09/2007 (leg. T. Pfingstl).

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Atlantic coast: a) Great Britain, Talacre Dunes, 20 km W Liverpool (NW Wales), mosses; 18/03/1999 (leg. F. Monson). – b) Portugal, Aljezur, estuary of the Ribeiro de Aljezur, overgrown sand dunes; Oct. 2008 (leg. G. Weigmann; sample-no. Po139).

Specimens of *S. pilosetosus* from the North Sea coast: a) The Netherlands, Ameland, W.G.M. Wester Grie; Oct. 1975; paratypes, collection number 1224 of the „Naturalis" National Museum of Natural History Leiden (the former Rijksmuseum van Natuurlijke Historie). - b) Germany, Sylt, salt marshes near List; 1968 (leg. G. Weigmann; sample-no. 414). - c) Germany, Grüne Insel, estuary of the river Eider; 1968 (leg. G. Weigmann; sample-no. 437).

Individuals of *S. minutus* were obtained from mosses on roofs: a) Austria, Styria, Pogier near Kapfenberg; 12.10.2006 (leg. S. Schäffer). - b) Styria, Bachsdorf near Wildon; 08.05.2007 (leg. J. Jagersbacher-Baumann).

For breeding experiments at room temperature adults of *S. arenocolus* were put into polystyrol-boxes supplied with plaster of Paris and were fed with collected substrate and coccal green algae from the samples.

For permanent slides the specimens were embedded in BERLESE mountant and for temporary slides lactic acid was used. LM-micrographs were taken with an Olympus Camedia C4040 zoom digital camera. The measurements and drawings were performed with a differential interference contrast microscope (Olympus BH-2). For SEM-investigations the samples were dehydrated in ascending ethanol concentrations, dried on air and mounted on aluminium-stubs with double sided sticky tape. At last the specimens were sputter-coated with gold. The SEM-micrographs were made at the Research Institute for Electron Microscopy and Fine Structure Research, Graz, University of Technology, with a Zeiss Leo Gemini DSM 982.

Multivariate analysis of data was performed with PAST version 1.82b (Hammer *et al.* 2001). Logarithms of 14 measured continuous morphological characters of 13 individuals of *S. pilosetosus* and 27 specimens of *S. arenocolus* were taken and analysed with a Principal Component Analysis (PCA) using a covariance matrix (the number of specimens to investigate was restricted because only 8 intact individuals from *S. pilosetosus* loaned by the museum were available). Additionally the specimens of *S. arenocolus* and 61 individuals of *S. minutus* were also analysed with an extended set of 17 variables; two different numbers of variables (14, 17) were used as the second set was created after the return of *S. pilosetosus* to the museum in Leiden. Measured variables are shown and explained in Fig. 11.

Taxonomy

Scutovertex arenocolus Pfingstl & Schäffer spec. nov. [1]

Species diagnosis. Habitus corresponding to typical *Scutovertex*. Average length 574 µm, average body width 348 µm. Colour dark brown. Cuticle pusticulate. Notogaster with irregularly distributed foveae. Short cusps, narrow lamellae and median ridge between lamellae reaching translamella. Sensillus short, slightly capitate and spinose. Ten pairs of notogastral setae. Setae *lp*, *dm*, $h_{1\text{-}3}$ and ps_1 slightly broadened and spinose. Transverse ridge on mentum incomplete. Legs shaped slender, chaetome without solenidia: I (1-4-3-4-18), II (1-4-3-4-15), III (2-2-2-3-15), IV (1-2-2-3-12). Solenidia: I (1-2-2), II (1-1-2), III (1-1-0), IV (0-1-0).

Type series. Holotype (Colnr. ZMB 47959) and 5 paratypes (no. ZMB 47960) preserved in ethanol are deposited in the Museum of Natural History, Department of Arachnids, Myriapods and Stemgroup Arthropoda, Humboldt-University Berlin and, additionally, 5 paratypes in the collection of the "Naturalis" National Museum of Natural History Leiden (Colnr.D. 53108). The type material comes from the epilittoral of the sandy beach near Darss-Zingst (Mecklenburg-Western Pomerania; German Baltic coast).

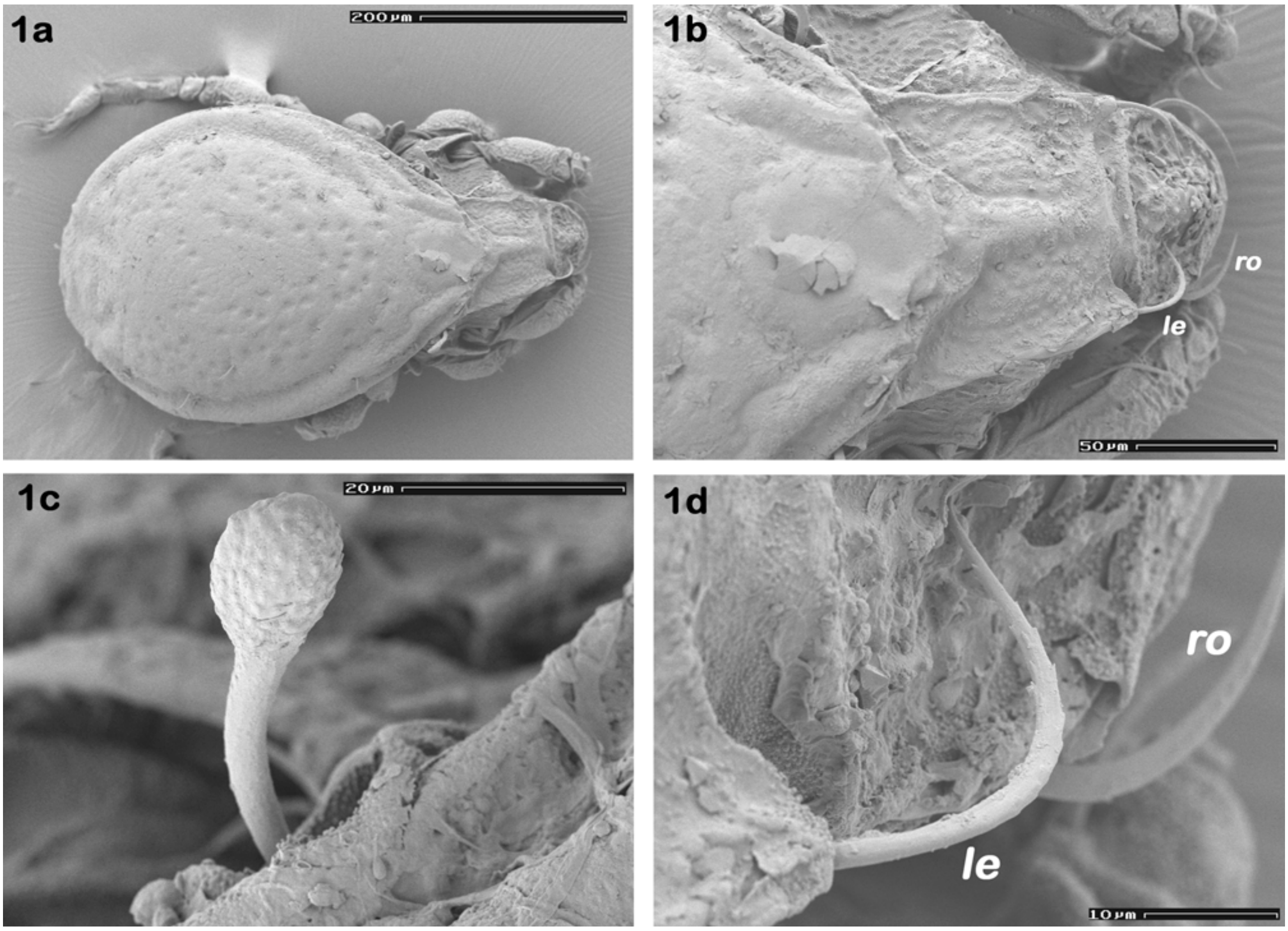
Etymology. The species name is derived from the latin noun *arena* which means sand and the latin verb *colere* meaning dwelling as this species lives in sandy habitats.

Morphology of the adult (Figs. 1, 2) (N=20, 8 males and 12 females)

1. As describer of the new species only the first two authors of this paper are to be cited

Body length : 527–614 µm (mean 574 µm / m = 566 µm, f = 599 µm). Body width: 298–391 µm (mean 348 µm / m = 339 µm, f = 370 µm).

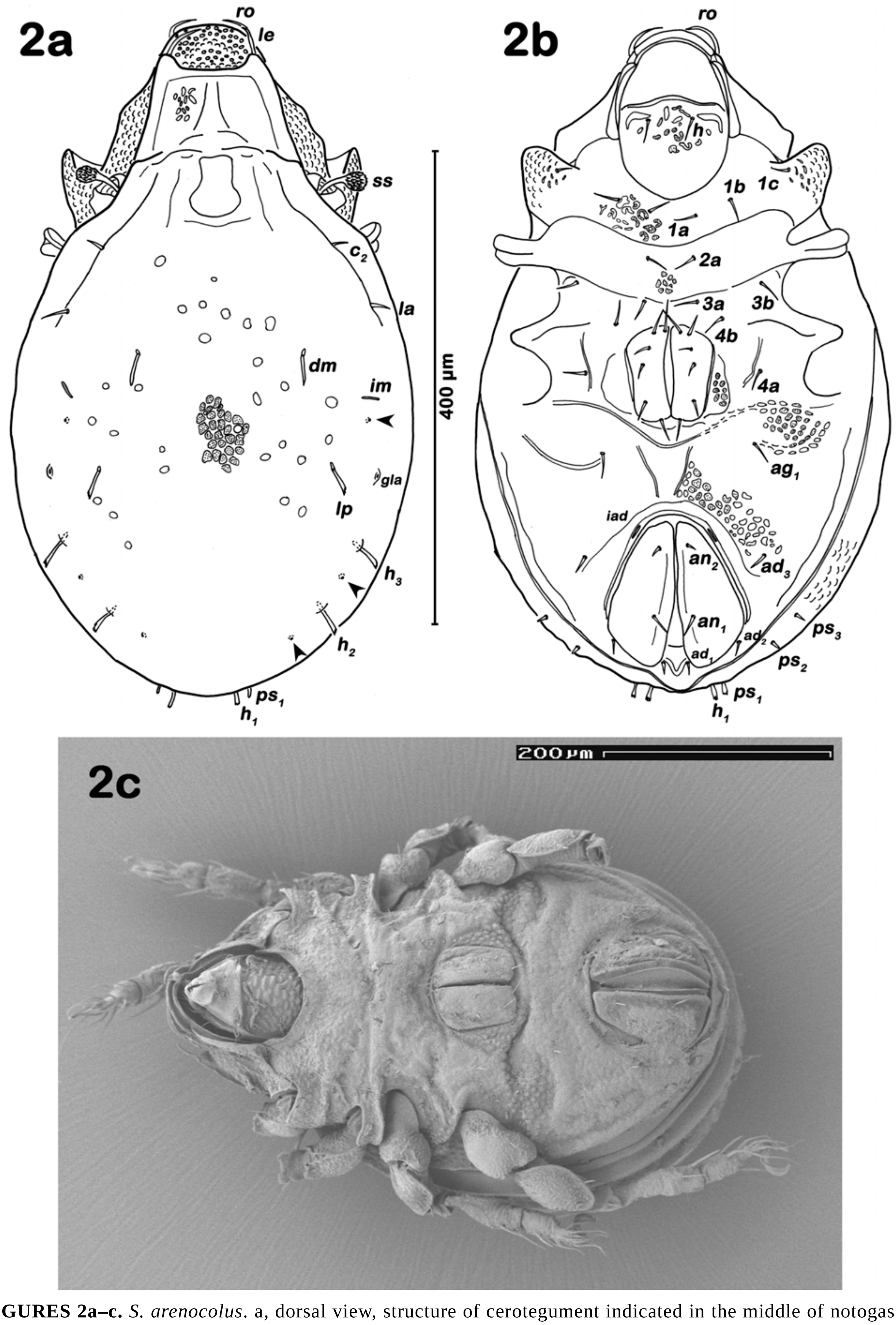
Prodorsum (Figs. 1b, 2a). Cuticle strongly pusticulate. Sensillus short, slightly capitate and serrate (Fig. 1c). Strongly projecting cup-like bothridia with a small apophysis on antiaxial side with a ridge running ventrally. Interlamellar and exobothridial setae absent. Lamellae narrow, slightly converging, connected by translamella. Cusps short, lamellar setae (*le*) spiniform and thin (Fig. 1d). Two ridges between lamellae converging to median axis from proximal end of lamellae to translamella, reaching it. Rostral setae (*ro*) completely smooth and of approximately the same length as *le*.



FIGURES 1a–d. *Scutovertex arenocolus* (SEM-micrographs). a, dorsal view; b, prodorsum; c, right sensillus ; d, cuspis and lamellar seta (*le*) in detail.

Gastronotic region (Fig. 2a) – Cerotegument forms polygonal spots consisting of densely packed granules. Cuticular foveae arranged irregularly over whole notogaster. Lenticulus with lateral concave margins, posterior part broadened. Ten pairs of notogastral setae present (Fig. 3a): c_2, *la*, *lp*, *dm*, h_1-h_3, ps_1-ps_3. Setae c_2 and *la* short approximately of the same length, setae *lp* and *dm* (Fig. 3b) slightly serrate and broadened distally, setae $h_{1\text{-}3}$ also serrate but broadened to a greater extend and blunt, seta ps_1 short, broadened, blunt and serrate (Fig. 3c), setae $ps_{2\text{-}3}$ very short with rounded tip. Humeral angle well developed (Fig. 4a). Five pairs of lyrifissures: *ia*, *im*, *ih*, *ips*, *ip*; *ia* situated laterally on a small cuticular nodule ventrally to humeral angle. Lyrifissure *im* slit-shaped, located laterally and posterior to seta *la*; *ih* and *ips* positioned next to each other anteriorly seta ps_3. Lyrifissure *ip* in posterior part of notogaster situated between setae h_1 and ps_2. Well discernable orifice of opisthonotal gland next to seta *lp*. Octotaxic system represented by three pairs of small sacculi. Two small median emarginations of cuticle on posterior part of notogaster.

Subcapitulum and camerostome (Figs. 4b, 5a–c). Cuticle strongly pusticulate. Rostrophragma forming inner margin of camerostome. Longish triangular lamellae flanking rostrophragma laterally and median

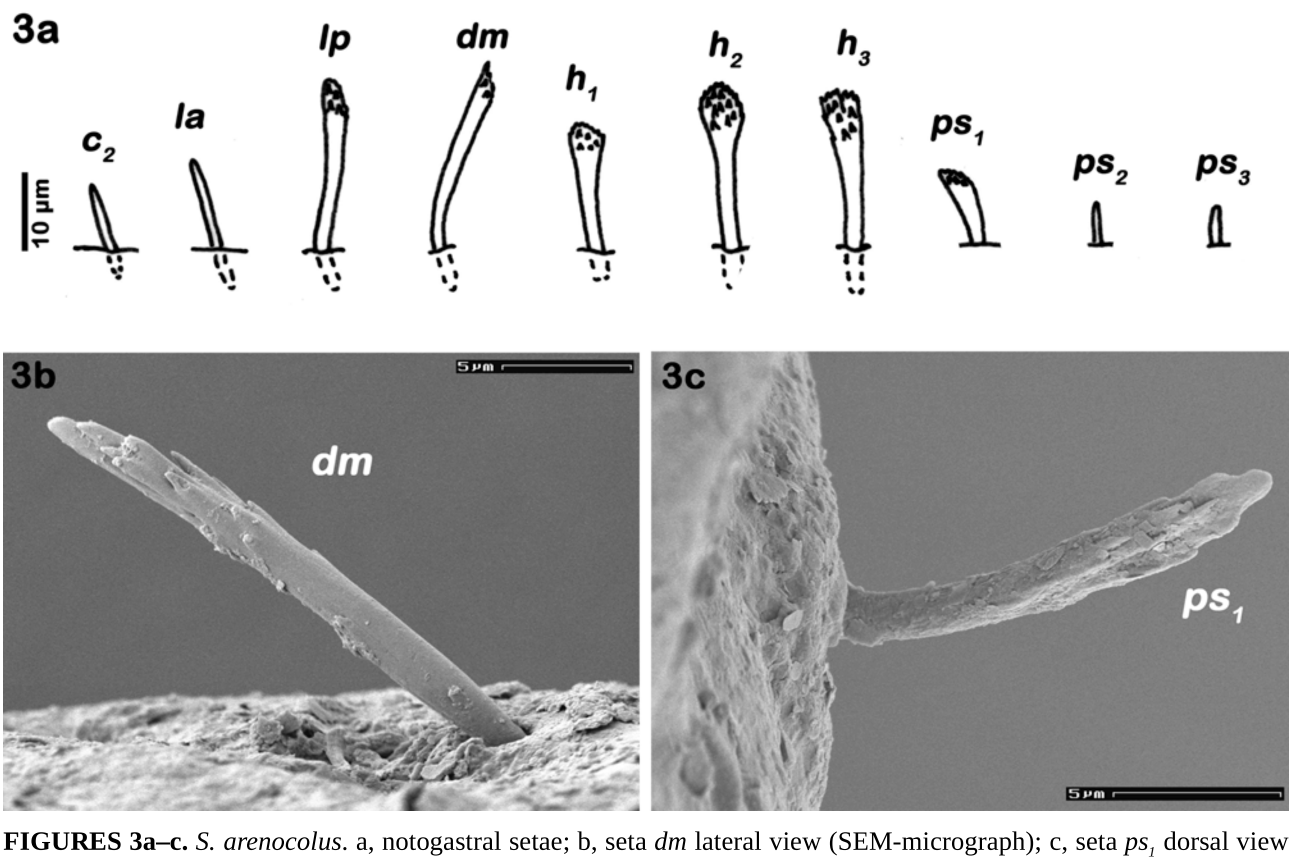


FIGURES 2a–c. *S. arenocolus*. a, dorsal view, structure of cerotegument indicated in the middle of notogaster, arrowheads pointing to sacculi; b, ventral view; c, ventral view (SEM-micrograph).

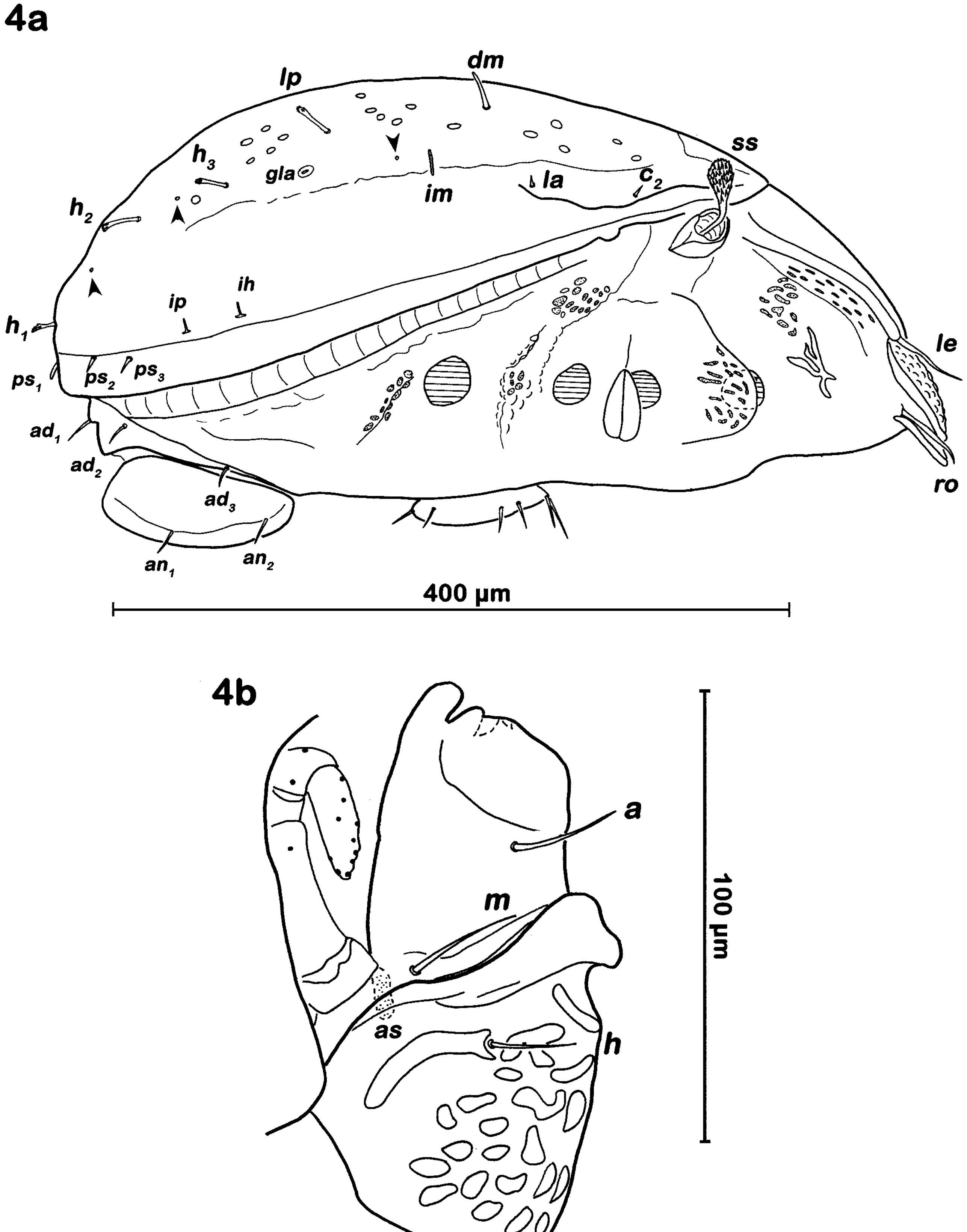
rostral lobe forming anterior border of camerostome. Mentum with cuticular ribs located laterally to long and spiniform seta *h* (Fig. 5a). Median part of transverse ridge on mentum consisting of dispersed pieces or lacking completely (Fig. 5b). Setae *a* and *m* long and acuminate. Three teeth present on rutellum, first one broadest but only slightly longer (Figs. 4b, 5c). Pedipalp pentamerous, chaetome: 0-2-1-3-9 (solenidion excluded), solenidion inclined touching eupathidium *acm*. Porous axillary sacculus *as* located at basis of pedipalp.

Ventral region of idiosoma (Figs. 2b, c). Cerotegument forms polygonal spots consisting of densely packed granules. Epimeral setation (I–IV): 3-1-2-2. Pedotectum I well developed, hiding acetabulum I completely. Pedotectum II Y-shaped in dorsal view. Epimeron I and II complete, epimeron III and IV divided medially. Apodemes I and III short, not reaching median axis. Apodemes II and sejugal continuous. Apodeme IV missing. Genital setation 6+6 (variations 5+6, 6+5). The first two genital setae standing side by side, the others arranged in a slightly laterally curved row. Genital valves anteriorly broadened and surrounded by a narrow cuticular groove. Posterior to genital opening whole ventral region crossed transversely by a broad and slightly caudad curved groove. One pair of spiniform aggenital setae ag_1. Two pairs of anal setae, an_2 only half the length of an_1. Anal valves posteriorly broadened. Three pairs of adanal setae $ad_{1\text{-}3}$. Lyrifissure *iad* flanking anterior border of anal opening. Preanal organ shaped cup-like.

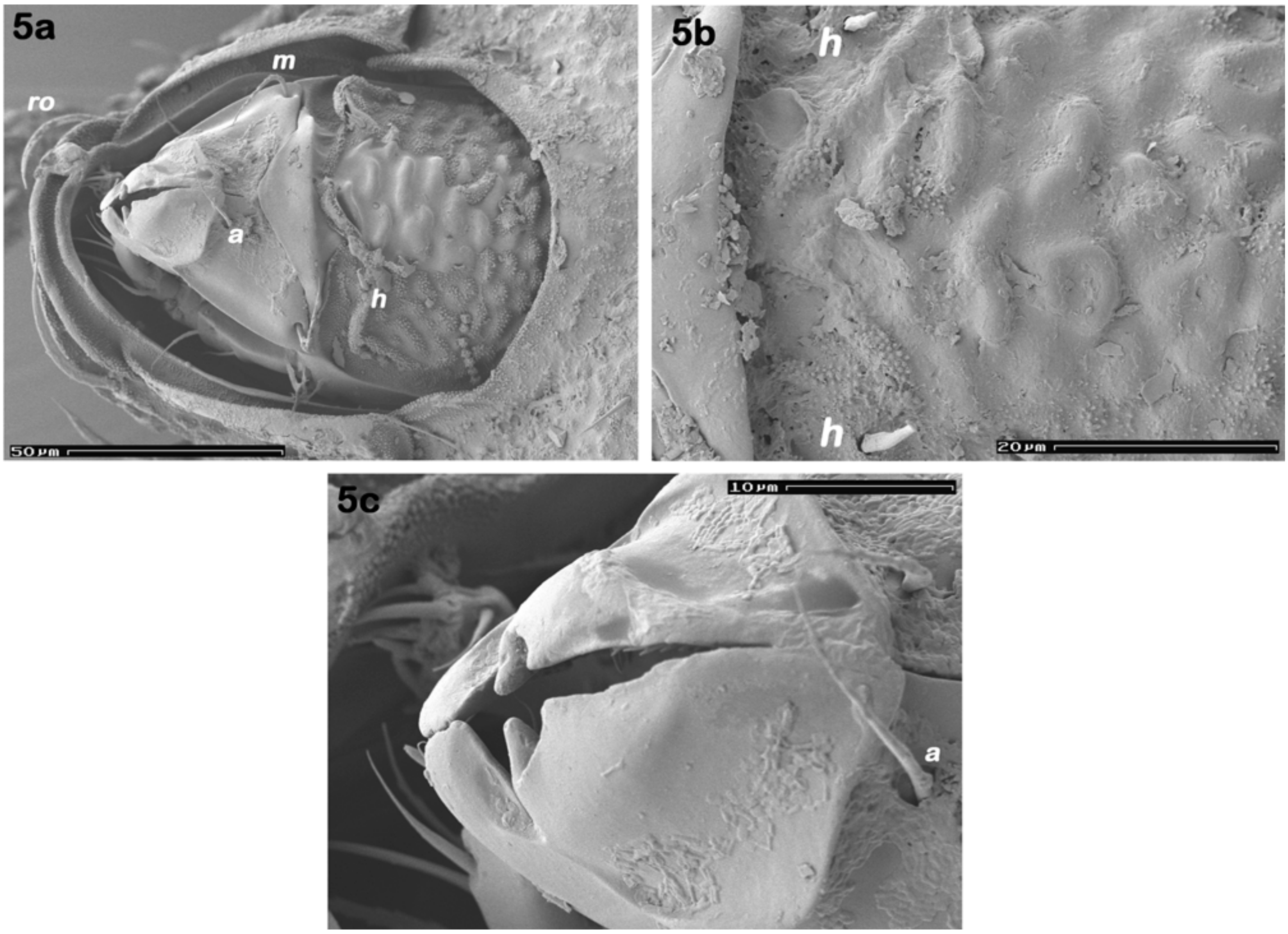
Legs (Figs. 6a–d). Legs slender. Tridactylous, heterodactylous; median claw largest, all claws dorsally slightly dentate. Cuticle from trochanter to tibia rugose, forming a few strong ribs. Tibial setae robust and serrate. Ventral and lateral setae of tarsus also serrate. Tibia I distally with large apophysis bearing solenidia $\varphi_{1\text{-}2}$. All legs showing tracheae originating on the axial dorsolateral side of femur. Tracheae on leg I and II divided into one branch reaching into proximal part of femur and one branch extending to distal part of tibia. Tracheae on leg III and IV shaped simple, reaching into proximal part of tarsus. Trochanter III and IV showing simple tracheae curving from proximal dorsolateral positioned stigma along the inner wall to the ventral side.



FIGURES 3a–c. *S. arenocolus*. a, notogastral setae; b, seta *dm* lateral view (SEM-micrograph); c, seta ps_1 dorsal view (SEM-micrograph).



FIGURES 4a–b. *S. arenocolus*. a, lateral view; b, right half of subcapitulum, only insertions of pedipalp setae depicted.



FIGURES 5a–c. *S. arenocolus* (SEM-micrographs). a, subcapitulum ventral view; b, mentum detailed view on cuticular structures; c, rutella in detail.

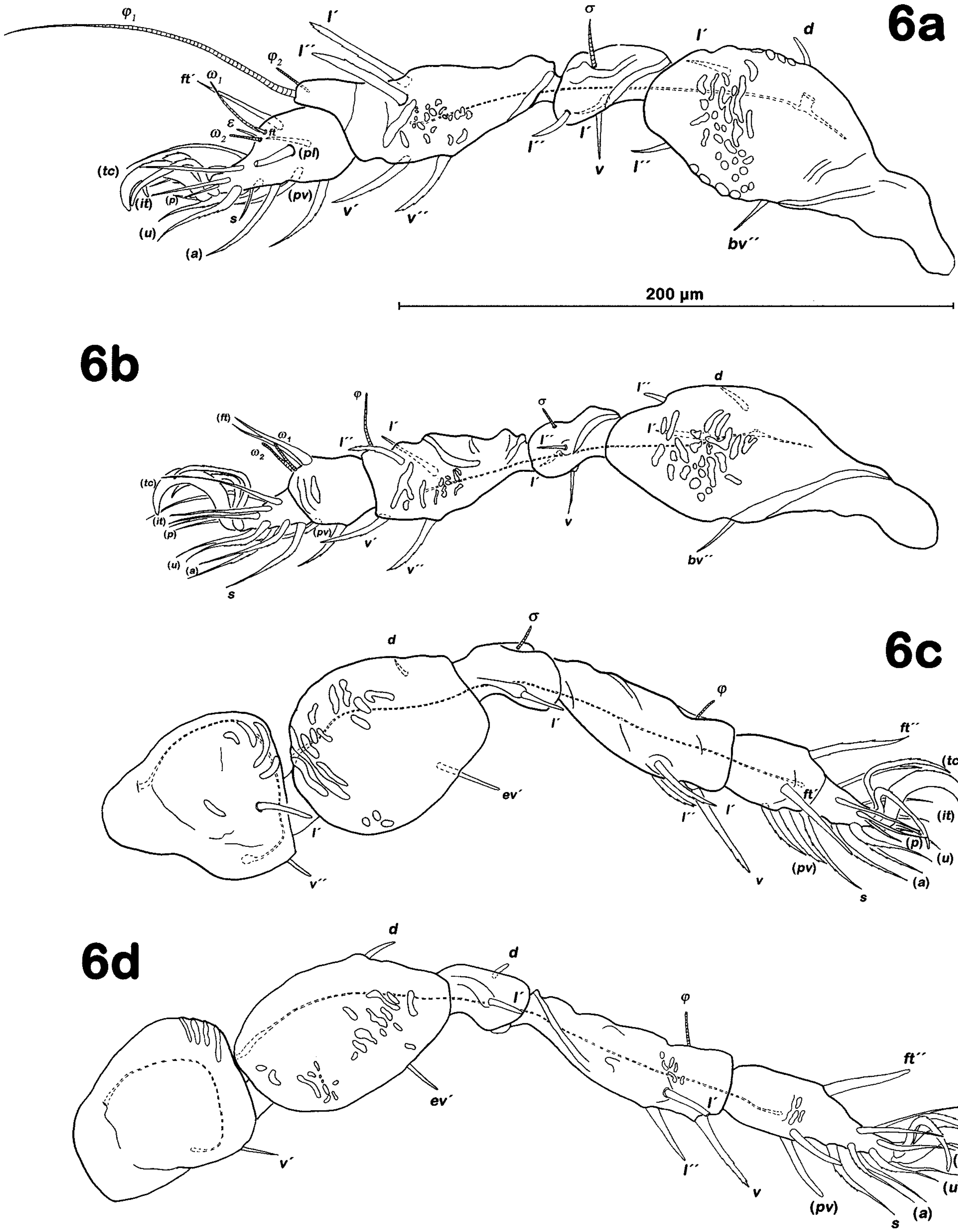
Ecology and reproduction. *Scutovertex arenocolus* represents a halophilous species that can be found in the epilittoral zone of Baltic and European Atlantic coasts. The typical habitat is the rhizosphere of plant communities growing on secondary sand dunes (e.g. *Elymus arenarius, Ammophila arenaria*).

In the course of breeding-experiments observations on the reproductive behaviour were done.

Scutovertex arenocolus represents a bisexual species (sex-ratio of sampled specimens: 28 males – 30 females), the mode of reproduction is a dissociated indirect sperm transfer. Males deposit simple, stalked spermatophores; the head of the spermatophore is incorporated by the female and the bare stalk is left. Eggs are laid into small cavities or crevices of the substrate. The exochorion of the eggs (Figs. 7a, b) shows granules and mushroom like structures covered by an additional external layer that is supposed to protect the embryo from osmotic effects (see Krisper *et al.* 2008, *Scutovertex* sp.). Time from egg-laying to eclosion of larva is 6–7 days at room temperature.

Redescription of *Scutovertex pilosetosus* Poldermann, 1977

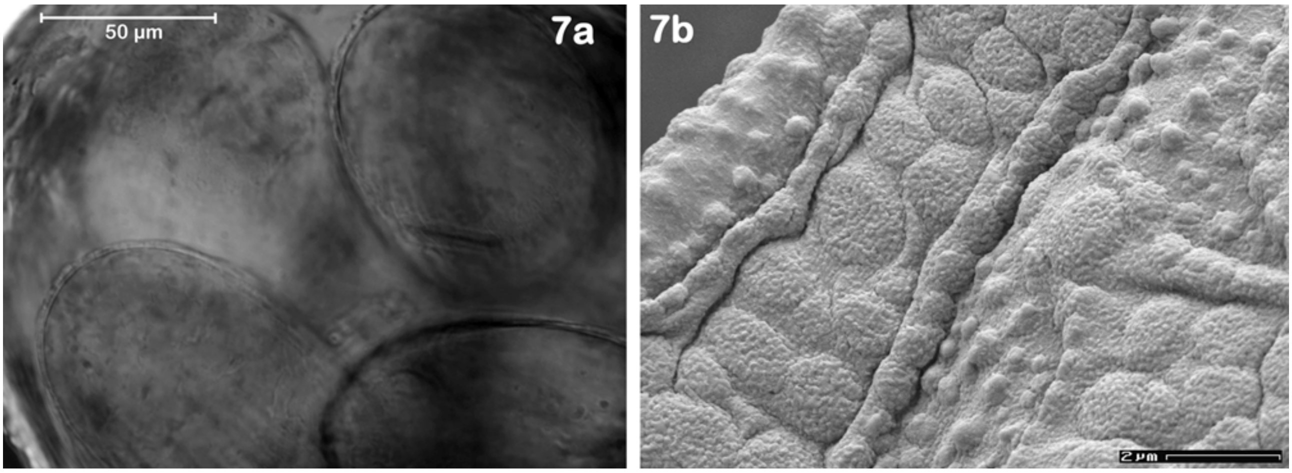
Diagnosis. Mean body length 675 µm, mean body width 429 µm. Dark brown cuticle. Pusticulate cuticle over the whole body with irregularly distributed foveae on notogaster. Long cusps, weakly developed median ridge between lamellae. Sensillus, short, slightly capitate, spinose. 10 pairs of spiniform and slightly serrate notogastral setae. Seta *la* twice as long as seta c_2. Transverse ridge on mentum lacking. Legs slender. Chaetome: I (1-4-3-4-18), II (1-4-3-4-15), III (2-2-2-3-15), IV (1-2-2-3-12). Solenidia: I (1-2-2), II (1-1-2), III (1-1-0), IV (0-1-0).



FIGURES 6a–d. *S. arenocolus*, left legs antiaxial view (leg I and II depicted without trochanter, dashed lines represent tracheae). a, leg I; b, leg II; c, leg III; d, leg IV.

Morphology of the adult (N=8, 4 males and 4 females)

Body length : 655–718 µm (mean 675 µm / m = 659 µm, f = 690 µm). Body width: 403–477 µm (mean 429 µm / m = 414 µm, f = 443 µm). Colour brown to dark brown. Outline of body oval.



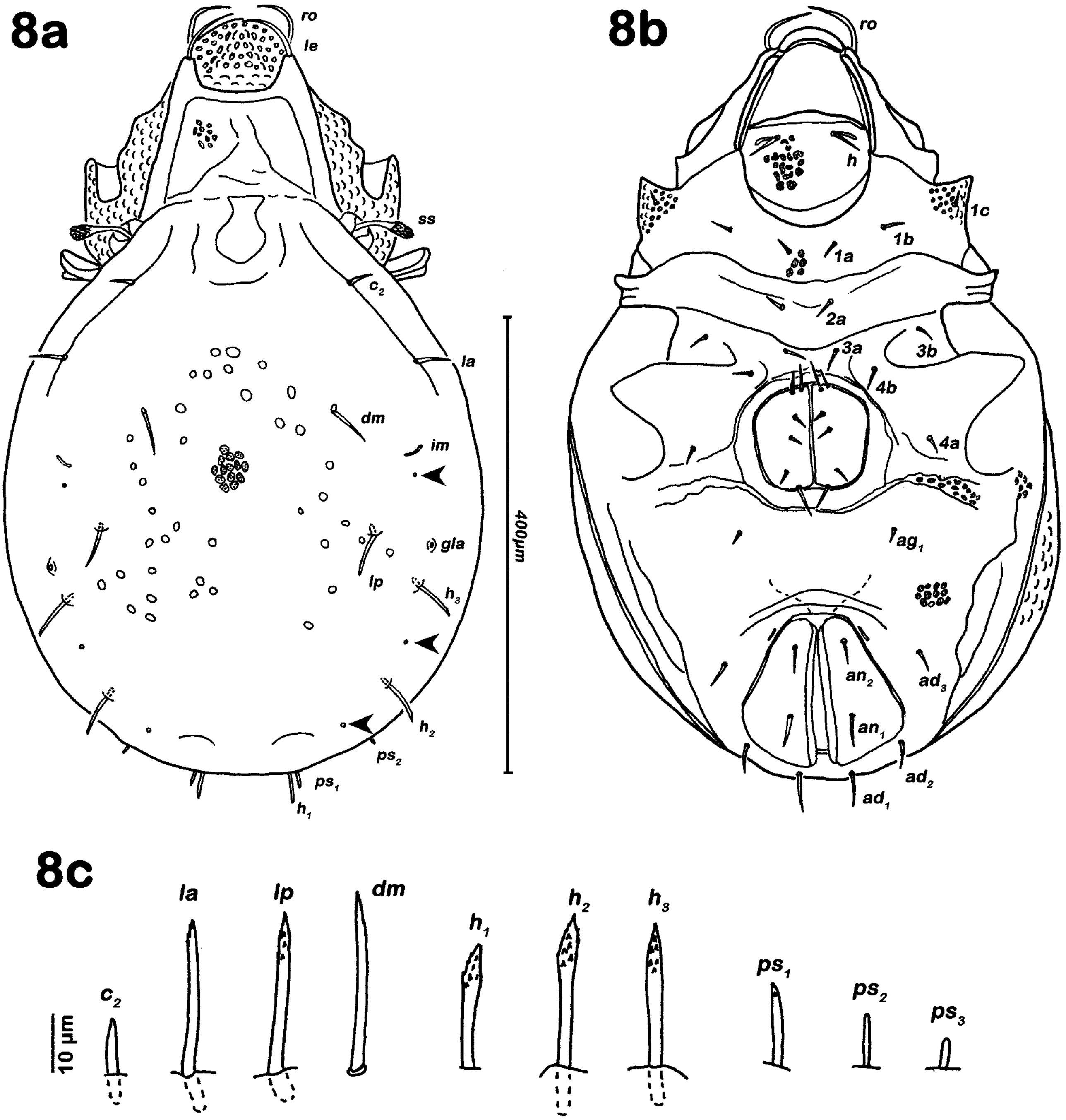
FIGURES 7a–b. *S. arenocolus*. a, eggs photographed through body wall; b, SEM-micrograph of exochorion structure.

Prodorsum (Fig. 8a). Cuticle strongly pusticulate. Sensillus short, slightly capitate and serrate. Bothridia strong cup-like projections, showing a small apophysis on antiaxial side of margin with a ridge running ventrally. Interlamellar or exobothridial setae absent. Lamellae well developed, slightly converging, connected by small translamella. Between bothridia two strongly convergent ridges, fused in the middle of interlamellar field. Fused ridge weakly developed running towards translamella not reaching it. Cusps long, bearing thin and spiniform lamellar setae (*le*), bent to median axis. Rostral setae (*ro*) completely smooth, of approximately the same length as *le*.

Gastronotic region (Fig. 8a). Cerotegument forms polygonal spots consisting of densely packed granules. Cuticular foveae with indistinct margin distributed irregularly over notogaster. Lenticulus with concave lateral borders, posterior part broader than anterior part. Ten pairs of notogastral setae present (Fig. 8c): c_2, *la*, *lp*, *dm*, $h_{1\text{-}3}$, $ps_{1\text{-}3}$. Setae c_2 short, acute. Seta *la* spiniform, twice as long as c_2. Setae *lp*, *dm* slightly serrate and spine shaped. Setae $h_{1\text{-}3}$ slightly broadened distally and serrate. Setae $ps_{1\text{-}3}$ short with rounded tip, seta ps_1 the longest and seta ps_3 the shortest. Humeral angle conspicuously developed. Five pairs of lyrifissures present: *ia*, *im*, *ih*, *ips* and *ip*; *ia* located on a small cuticular nodule under humeral angle. Lyrifissure *im* broad, situated laterally between setae *la* and *lp*, *ih* and *ips* positioned laterally on a level near posterior lateral border of notogaster anteriorly seta ps_3. Lyrifissure *ip* in posterior part of notogaster situated between setae h_1 and ps_2. Orifice of opisthonotal gland situated laterally to seta *lp*, well discernable. Three pairs of exiguous sacculi represent elements of the octotaxic system. Two small median emarginations of cuticle on posterior part of notogaster.

Subcapitulum and camerostome. Cuticle strongly pusticulate. Border of rostrum showing an apical lobe-like projection and lateral triangular longish lamellae originating from the posterolateral corner of camerostome. Consistent rostrophragma around camerostome reaching articulation of subcapitulum. No transverse ridge on mentum. Seta *h* long and acuminate. Genae with solid and slightly pectinate setae *a* and *m*. Rutellum with three teeth, first one largest. Pedipalp pentamerous; chaetome: 0-2-1-3-9 (solenidion excluded).

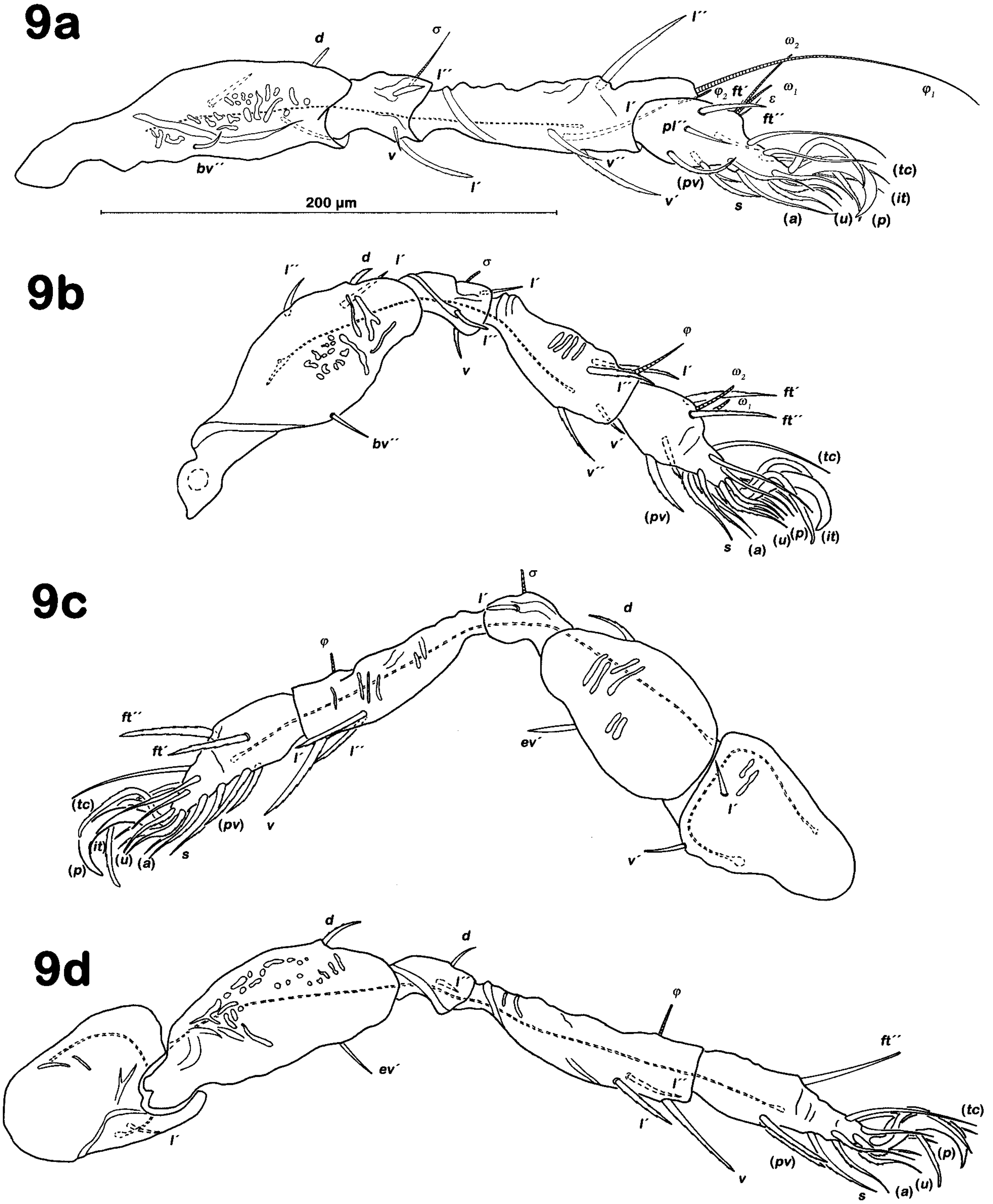
Ventral region of idiosoma (Fig. 8b). Cerotegument forms polygonal spots consisting of densely packed granules; weaker developed in the epimeral region. Epimeral setation (I-IV): 3-1-2-2. Pedotectum I well developed, hiding completely acetabulum I, pedotectum II large, Y-shaped in dorsal view. Apodemes I and II reaching median axis, apodeme III small and apodeme IV absent. Genital setation 6+6 (variations 5+6 or 6+5). Genital valves anteriorly broadened and surrounded by cuticular grooves. The anterior one arcuated rostrad, the posterior one slightly curved caudad crossing transversely whole ventral region. Posterior half of ventral region strongly pusticulate. One pair of short spiniform aggenital setae ag_1. Anal valves posteriorly broadened. Two pairs of anal setae, an_2 situated on the anterior third and an_1 on the posterior half of anal plates. Three pairs of long acuminate adanal setae $ad_{1\text{-}3}$. Lyrifissure *iad* flanking anterior end of anal orifice. Preanal organ broad, shaped cup-like.



FIGURES 8a–c. *S. pilosetosus*. a, dorsal view; b, ventral view; c, notogastral setae.

Legs (Figs. 9a–d). Tridactylous, heterodactylous. Lateral claws thinner, all three claws dorsally slightly dentate. Cuticle slightly rugose, with a few strong ribs on trochanter to tibia. All limbs shaped noticeable slender. Ventral and lateral setae on tibia and tarsus slightly serrate. Solenidia φ_1 and φ_2 located on large apophysis of tibia I. Femora I and II provided with bifurcated trachea, one long branch reaching into tibia and a short branch ending within the femur, spiracles opening dorsally on axial side of femur. Leg III–IV show simple trachea from femur to tarsus; stigma located proximally dorsally in a paraxial crevice of femur. Trochanter III–IV also equipped with trachea, curving along the inner wall. Chaetome: I (1-4-3-4-18), II (1-4-3-4-15), III (2-2-2-3-15), IV (1-2-2-3-12). Solenidia: I (1-2-2), II (1-1-2), III (1-1-0), IV (0-1-0).

The eggs of *S. pilosetosus* were only investigated by means of light microscopy (Fig. 10). The egg shell seems to consist of irregularly shaped mushroom like structures which are densely distributed over the whole surface.



FIGURES 9a–d. *S. pilosetosus*, right legs (leg I and II depicted without trochanter, dashed lines represent tracheae). a, leg I antiaxial view; b, leg II antiaxial view; c, leg III antiaxial view; d, leg IV axial view.

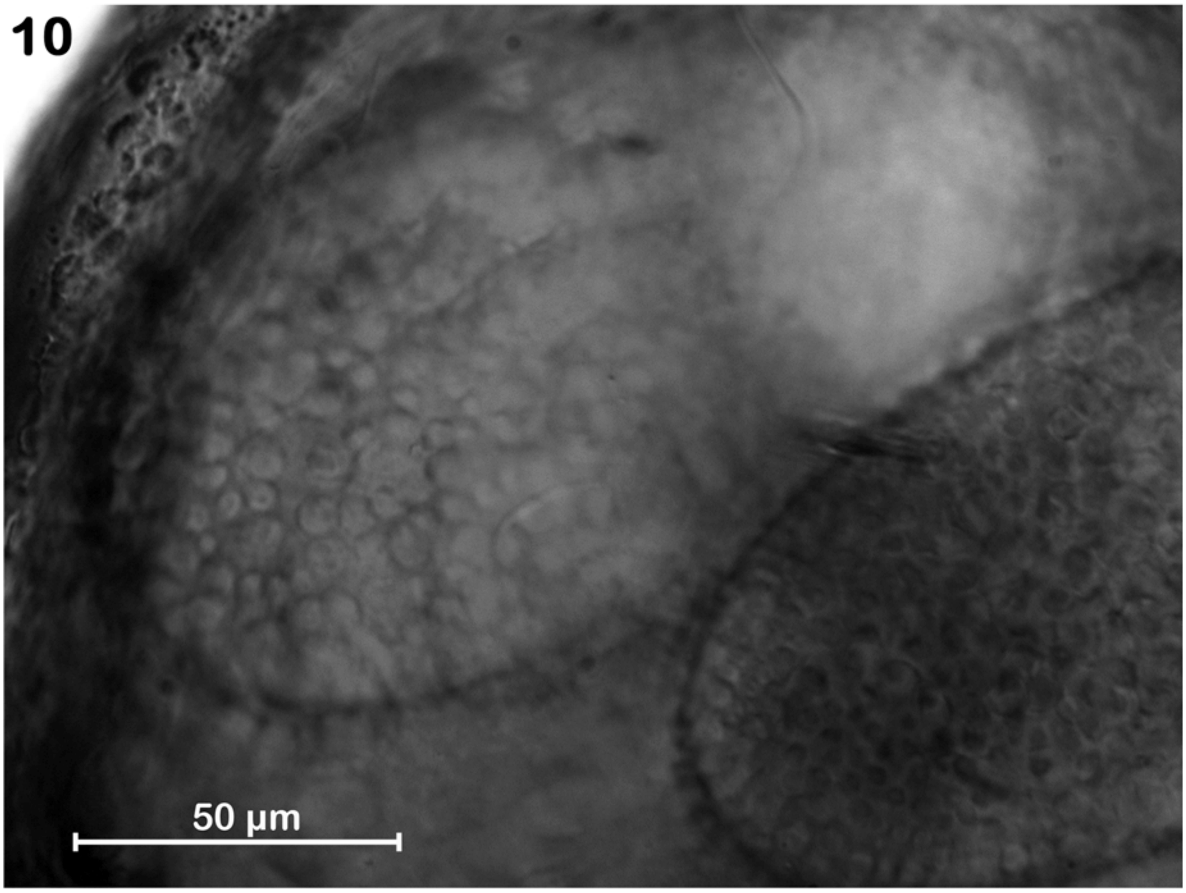


FIGURE 10. *S. pilosetosus*, eggs photographed through body wall.

Biometric analyses

Morphometric comparison of *S. pilosetosus* and *S. arenocolus*: The measured distances for *S. pilosetosus* given in Polderman´s description (1977) were compared to the measurements for *S. arenocolus* (N=20) except “width cuspis base” and “distance bothridia” because a clear definition of these distances was not given by Polderman. To relate the data to the different body size of these two species, the average value of each distance was divided by the “bodyindex” (average body length/average body width). There is no significant difference between the two species in the length of the translamella and seta c_2. All other data display higher values in *S. pilosetosus*. Especially the cuspis length, the length of seta *la* but also the length of setae $ps_{1\text{-}3}$ show noticeable differences. *Scutovertex pilosetosus* possesses, except for c_2, conspicuous longer notogastral setae (Table 1).

Principal Component Analysis: The measured continuous morphological variables of the PCA are shown in Table 2. The first analysis with a set of 14 variables of *S. arenocolus* and *S. pilosetosus* produced three components accounting for 89.8% of total variation. The first principal component (78.7% of total variance) shows moderately high negative loadings for most of the variables (Table 3a), indicating a strong correlation to body size. The second component (6.7% of total variation) has only high negative loadings for the variables *pl* and *ga* and the third component (4.4% of total variance) exhibits high positive loadings for *dc* and *dcg*. Projections of the principal component scores on the first-second as well as the first-third axes (Figs. 12a, b) present a clear separation of both species without overlapping. These results indicate that mainly size differences cause this division and that shape disparity plays a minor role.

PCA of *S. arenocolus* and *S. minutus*: The second analysis with a set of 17 variables of *S. arenocolus* and *S. minutus* shows three components accounting for 87.7% of total variance. The first component (58.7% of total variation) exhibits consistently low values for all variables except for the cuspis length with a loading of 0.9633 (Table 3b). The second principle component (25%) shows overall moderate negative loadings and the third component (4%) has only a high loading for the variable “distance between genital and anal opening”. PC1 separates both species very well and the projections of PC1 and PC2 as well as PC1 and PC3 show two distinct clusters without any overlap (Figs. 12c, d).

PCA of *S. pilosetosus* and *S. minutus*: A third analysis comprising 13 variables of *S. pilosetosus* and *S. minutus* shows three components accounting for 89% of total variance. The first principal component (75.9% of total variation) shows relatively low values (Table 3c). The second component (9.1%) displays a high value for *pl.* The third component (4%) exhibit low values in general, the highest concern the variables *dc*, *dga*, and *dcg*. Principle Component 1 separates both species clearly (Figs. 12e, f).

The morphometric comparison of all three species resulted in PC1 accounting for 69 %, PC2 for 10 % and PC3 for 7% of total variance and shows a small area of overlap between *S. arenocolus* and *S. minutus* due to the smaller (13) variables set used (Figs. 13a, b). There was no indication of morphometric differences between different European populations of *S. arenocolus* and of *S. pilosetosus* as well.

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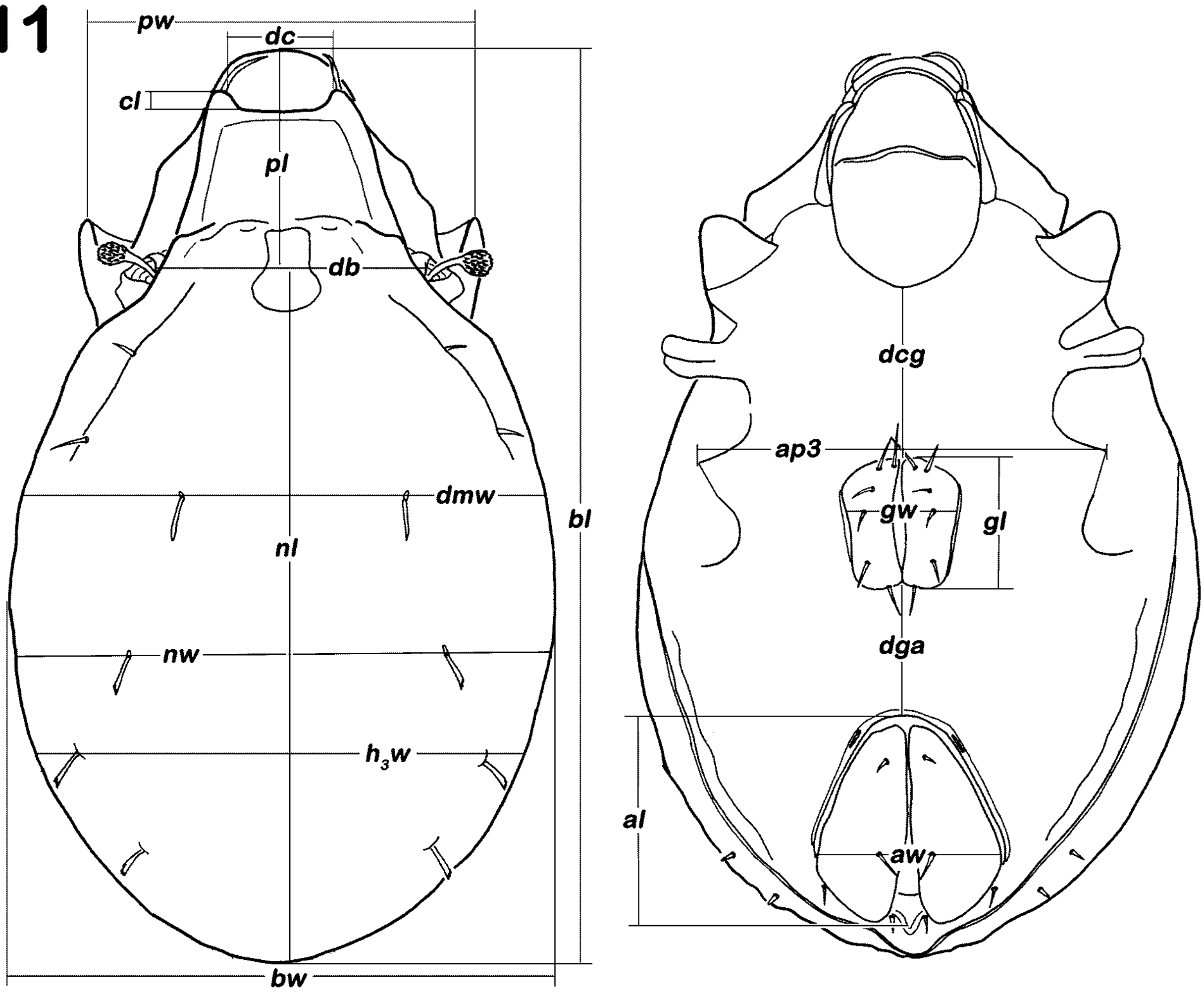

FIGURE 11. Graphic illustration of measured distances. Dorsal side: ***db*** – distance between bothridia, ***bl***—body length; ***bw***—body width, ***cl***—cuspis length, ***dc***—distance between cusps, ***dmw***—notogastral width on level of seta *dm*, ***h_3w***—notogastral width on level of seta h_3, ***nl***—notogaster length, ***nw***—notogaster width, ***pl***—prodorsum length, ***pw***—prodorsum width. Ventral side: ***al***—anal opening length, ***ap3***—distance between outer borders of apodeme 3, ***aw***— anal opening width, ***dcg***—distance between camerostome and genital opening, ***dga***—distance between genital and anal opening, ***gl***— genital opening length and ***gw***—genital opening width.

TABLE 1. Data of *Scutovertex pilosetosus* (ex Polderman 1977) compared to measurements of *S. arenocolus* (N=20). To relate data to different body sizes the average values are divided by the bodyindex (average body length / average body width). High differences in the values are marked bold. According to Polderman the “length connecting bar” is used for the length of translamella.

character	min-max (µm)	average (µm)	average / bodyindex
***Scutovertex pilosetosus* (ex Polderman 1977)**			
body length	630–760	695	-
body width	390–530	460	bodyindex = 1.51
cuspis length	18–36	30	**19.86**
length connecting bar	42–66	56	37.06
c_2	7–10	9	5.96
la	20–30	25	**16.55**
dm	30–42	36	**23.83**
lp	27–39	34	22.50
h_3	28–36	33	21.84
h_2	27–37	32	21.18
h_1	21–33	27	17.87
ps_1	18–29	26	**17.21**
ps_2	13–21	16	10.59
ps_3	13–21	16	10.59
Scutovertex arenocolus			
body length	527–614	574	-
body width	298–391	348	bodyindex = 1.65
cuspis length	8–17	12	**7.28**
length connecting bar	58–68	65	39.42
c_2	7–10	8	4.85
la	8–15	12	**7.28**
dm	8–27	18	**10.92**
lp	17–28	24	14.56
h_3	17–27	23	13.95
h_2	20–27	23	13.95
h_1	15–18	16	9.70
ps_1	10–13	12	**7.28**
ps_2	5–10	8	4.85
ps_3	5–10	8	4.85

Discussion

Scutovertex arenocolus and *S. pilosetosus* are two morphologically and ecologically very similar species. The idea that both species represent only two morphotypes of one single species which is geographically widespread is rejected by our results. The new species shows a conspicuously smaller body size, shorter cusps, notogastral setae and adanal setae. The shape of notogastral setae and interlamellar area also differs between both species. All these results are strongly supported by morphometric and PCA data. Finally, strong evidence for discrete species is given by the structure of egg shells as it is highly unlikely that one and the same species produces eggs with different exochorion structures.

TABLE 2. Measurements of 18 morphological characters of three *Scutovertex* species used for principle component analysis. *Variables only used in the 17—variables analysis. **Variables only used in the 14—variables analysis. Abbreviations of variables are explained in figure caption of figure 11.

Variable	***S. pilosetosus***	***S. arenocolus***	***S. minutus***
bl	655–718 (675± 27.34, N = 13)	539–624 (579±24.45, N = 27)	546–640 (594±24.79, N = 61)
bw	403–477 (429±31.25, N = 13)	316–384 (351±21.46, N=27)	310–403 (354±22.66, N = 61)
db	175–209 (195±11.86, N =13)	163–194 (178±8.21, N = 27)	148–182 (164±7.66, N = 61)
dc	74–88 (80±6.41, N = 13)	70–92 (80±5.45, N =27)	67–85 (75±3.96, N = 61)
*cl**		8–15 (12±1.74, N = 27)	15–25 (20±2.33, N = 61)
pl	180–215 (204±11.13, N = 13)	129–161 (148±7.38, N = 27)	117–160 (145±8.83, N = 61)
pw	262–286 (272±7.73, N = 13)	231–255 (244±7.68, N = 27)	222–252 (238±7.22, N = 61)
nl	440–521 (474±29.26, N = 13)	397–490 (431±22.84, N = 27)	409–508 (452±23.66, N = 61)
*nw***	397–477 (429±31.52, N = 13)	329–384 (356±21.48, N = 8)	
*dmw**		304–378 (336±19.97, N =27)	298–366 (336±18.11, N = 61)
h_3w*		291–366 (321±18.90, N = 27)	291–360 (324±19.39, N = 61)
gl	97–118 (103±7.24, N = 13)	80–108 (90±8.49, N = 27)	83–103 (94±5.52, N = 61)
gw	97–118 (104±6.61, N = 13)	73–93 (84±6.73, N = 27)	78–100 (89±5.11, N = 61)
dga	95–122 (108±8.96, N = 13)	77–105 (92±7.52, N = 27)	77–107 (91±7.49, N = 61)
al	137–167 (151±10.76, N = 13)	110–137 (124±7.75, N = 27)	108–148 (127±7.11, N = 61)
aw	128–157 (143±10.94, N = 13)	110–137 (123±6.17, N = 27)	100–133 (117±6.86, N = 61)
dcg	108–130 (124±7.54, N = 13)	122–143 (132±4.29, N = 27)	117–137 (127±4.30, N = 61)
*ap3**		252–299 (276±12.05, N = 27)	255–305 (285±11.56, N = 61)

TABLE 3a. Loadings of the 14 variables set on the first three principle components.
S. arenocolus and *S. pilosetosus*

variable	PC1	PC2	PC3
bl	-0.257	0.037	-0.036
bw	-0.374	-0.013	0.190
db	-0.178	0.130	0.038
dc	-0.015	-0.226	0.507
pl	-0.178	-0.501	0.131
pw	-0.186	-0.141	-0.041
nl	-0.285	0.253	-0.029
nw	-0.355	-0.089	0.214
gl	-0.274	0.371	-0.271
gw	-0.373	0.145	-0.167
dga	-0.322	-0.485	-0.047
al	-0.245	0.284	0.260
aw	-0.331	-0.084	-0.268
dcg	-0.027	0.326	0.629

TABLE 3b. Loadings of the 17 variables set on the first three principle components.
S. arenocolus and *S. minutus*.

variable	PC1	PC2	PC3
bl	0.056	-0.218	0.019
bw	0.034	-0.335	-0.030
db	-0.115	-0.225	0.244
dc	-0.098	-0.155	-0.190
cl	0.963	0.098	0.084
pl	0.001	-0.060	0.432
pw	-0.040	-0.149	0.054
nl	0.083	-0.259	-0.120
dmw	0.012	-0.294	0.011
h3w	0.046	-0.300	-0.051
gl	0.094	-0.336	-0.217
gw	0.121	-0.295	-0.243
dga	0.019	-0.332	0.687
al	0.046	-0.248	-0.293
aw	-0.052	-0.266	-0.046
dcg	-0.054	-0.057	0.148
ap3	0.053	-0.204	-0.045

TABLE 3c. Loadings of the 13 variables set on the first three components.
S. pilosetosus and *S. minutus*.

variable	PC1	PC2	PC3
bl	0.242	-0.088	0.007
bw	0.357	-0.153	-0.040
db	0.303	0.006	0.201
dc	0.133	-0.034	0.407
pl	0.401	0.819	0.013
pw	0.224	0.038	0.120
nl	0.179	-0.382	0.016
gl	0.207	-0.282	-0.313
gw	0.286	-0.105	-0.375
dga	0.374	-0.229	0.482
al	0.296	-0.041	-0.266
aw	0.329	-0.004	-0.252
dcg	0.038	-0.075	0.415

Comparing these two epilittoral species to recently redescribed moss-dwelling congeneric species, *S. minutus* (Schäffer & Krisper 2007) and *S. sculptus* Michael, 1879 (Pfingstl *et al*. 2008), two general morphological differences become apparent: the sensilla of *S. arenocolus* and *S. pilosetosus* are noticeably shorter and distally more rounded and their legs are peculiarly slender. These morphological features seem to be an adaptation to the littoral environment. Weigmann (2006) stated that the sensillus of semi-aquatic and aquatic oribatid mites is generally shortened or completely reduced. The slender shape of the legs could facilitate the locomotion between the grains of sand. Concerning the leg tracheae no special modifications could be observed. The extraordinary structure of the exochorion of *S. arenocolus* could also constitute an adaptation to the saline habitat (Krisper *et al.* 2008).

The comparison with other *Scutovertex* species shows also that *S. arenocolus* and *S. pilosetosus* share some characters with *S. sculptus*. All three species show cuticular foveae with indistinct margins on their gastronotic region and the same notogastral setae are spinose and broadened to certain extent but not as strong as in *S. sculptus*. To clarify the relationship it would be necessary to investigate the juvenile stages and molecular genetic data of both epilittoral species.

Weigmann (2006) mentions variability in species specific characters of *Scutovertex* species making the determination of *S. minutus* or *S. sculptus* specimens difficult. The two species described in this paper might have induced some confusion earlier in the attempt to determine collected material from coastal zones. Already Polderman (1977) demonstrated that some Dutch fauna reports of *S. minutus* were caused by a wrong assignment of *S. pilosetosus* specimens. The material, kindly provided by Gerd Weigmann, from areas of the German North Sea Coast could be clearly determined as *S. pilosetosus*, too. This species seems to be distributed in the epilittoral regions of the Dutch and German North Sea Coast. For the present *S. arenocolus* shows a scattered but a farther distribution from Atlantic to Baltic coasts. The recently described species *Scutovertex mikoi* Weigmann, 2009 from Portugal occurs in the same habitat as *S. arenocolus*. Weigmann (2009) hypothesised, that former findings of “small” *S. minutus* (Gil & Subias 1990, Minguez & Subias 1986) could refer to *S. mikoi*. Probably, other formerly published records of *S. minutus* and *S. sculptus* in European coastal areas of the Atlantic Ocean, the North and the Baltic Sea (e.g. Dalenius 1950; Gjelstrup & Søchting 1979; Karppinen 1971; Luxton 1966; Monson 1998; Niemi 1995) might be assigned to *S. arenocolus*, *S. mikoi* or *S. pilosetosus* after a re-examination.

TABLE 4. Comparison of selected morphological features of three different *Scutovertex* species.

character	***S. arenocolus***	***S. pilosetosus***	***S. minutus***
body length	527–614 µm	655–718 µm	590–660 µm
cusps	short	long	long
prodorsal ridges	convergent reaching translamella	convergent not reaching translamella	convergent not reaching translamella
sensillus shape	slightly capitate, spinose	slightly capitate, spinose	clavate, spinose
sensillus length	medium	medium	long
tutorium	V-shaped, small additional ridges	V-shaped	V-shaped
notogastral cuticular structure	polygonal spots, indistinct foveae	polygonal spots, indistinct foveae	nodules
number of notogastral setae	10	10	10–12
shape of notogastral setae *h*	slightly broadened, blunt, spinose	spiniform, spinose	spiniform, spinose
ridge on mentum	dispersed pieces or missing	missing	dispersed pieces
adanal setae length	short	medium	short
shape of legs	slender	slender	normal
setation leg III	(2-2-2-3-15) (1-1-0)	(2-2-2-3-15) (1-1-0)	(2-2-1-3-15) (1-1-0)

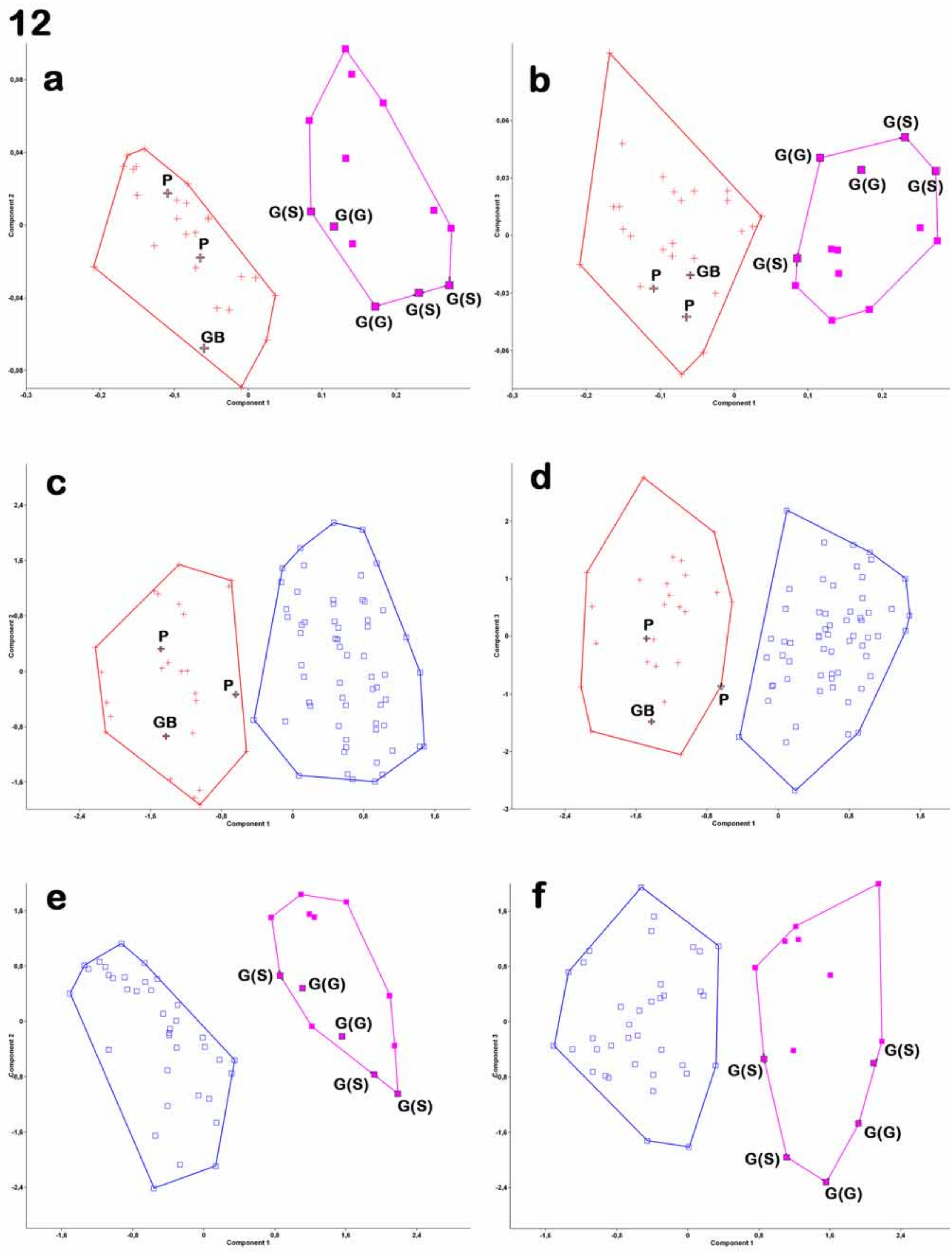

FIGURE 12. Projections of the principal component scores. a–b, *S. arenocolus* (cross) versus *S. pilosetosus* (filled square); c–d, *S. arenocolus* versus *S. minutus* (square); e–f, *S. minutus* versus *S. pilosetosus*. P = individuals from Portugal, GB = Great Britain, G(G) = Germany (Grüne Insel) and G(S) = Germany (Sylt).

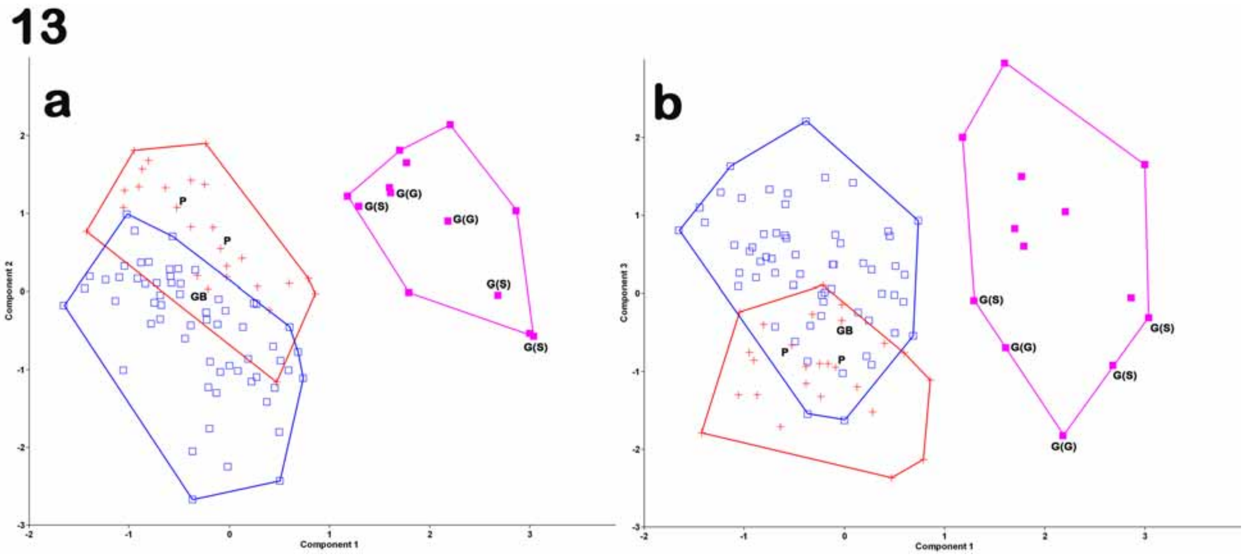

FIGURE 13. Projections of the principal component scores. a–b, *S. arenocolus* (cross) versus *S. pilosetosus* (filled square) versus *S. minutus* (square). P = individuals from Portugal, GB = Great Britain, G(G) = Germany (Grüne Insel) and G(S) = Germany (Sylt).

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