REVISTA IBÉRICA de Aracnología

ARTÍCULO:

Metasoma of *Orthochirus* (Scorpiones: Buthidae): are scorpions evolving a new sensory organ?

Elizabeth V. Fet
Department of Biological Sciences, Marshall University, Huntington, West Virginia 25755, USA
David P. A. Neff
Department of Chemistry, Marshall University, Huntington, West Virginia 25755, USA
Matthew R. Graham
Department of Biological Sciences, Marshall University, Huntington, West Virginia 25755, USA
Victor Fet
Department of Biological Sciences, Marshall University, Huntington, West Virginia 25755, USA. fet@marshall.edu
Corresponding Author

Revista Ibérica de Aracnología
ISSN: 1576 - 9518.
Dep. Legal: Z-2656-2000.
Vol. **8**, 31-XII-2003
Sección: Artículos y Notas.
Pp: 69 – 72

Edita: **Grupo Ibérico de Aracnología (GIA)**
Grupo de trabajo en Aracnología de la Sociedad Entomológica Aragonesa (SEA)
Avda. Radio Juventud, 37
50012 Zaragoza (ESPAÑA)
Tef. 976 324415
Fax. 976 535697
C-elect.: amelic@telefonica.net
Director: A. Melic

Indice, resúmenes, abstracts vols. publicados:
http://entomologia.rediris.es/sea/publicaciones/ria/index.htm

Página web GIA:
http://entomologia.rediris.es/gia

Página web SEA:
http://entomologia.rediris.es/sea

METASOMA OF *ORTHOCHIRUS* (SCORPIONES: BUTHIDAE): ARE SCORPIONS EVOLVING A NEW SENSORY ORGAN?

Elizabeth V. Fet, David Neff, Matthew R. Graham & Victor Fet

Abstract:
A peculiar array of over 1000 cuticular pits is found ventrally and laterally on the posterior segments of metasoma and telson of a few taxa of Buthidae (Scorpiones), including all species of the widespread Old World desert genus *Orthochirus* Karsch. SEM investigation shows those pits adorned with variable size setae, which exhibit microanatomical features characteristic for chemoreceptors (curved shape, end pore). Observations in nature (Central Asia) show an unusual in scorpions rest/defense posture in *Orthochirus*, with metasoma pressed flat to the mesosoma, its small telson folded dorsally in a groove, and the ventral surface of the metasomal segment V forming a "face shield". We suggest that the up-and-forward facing ventral/lateral surfaces of the posterior metasomal segments in *Orthochirus* and related genera could be used as a chemo-sensory array, analogous to insect antennae.
Key words: Scorpiones, Buthidae, *Orthochirus*, metasoma, sensory setae.

El metasoma de *Orthochirus* (Scorpiones: Buthidae): ¿está creando la evolución un nuevo órgano sensorial en los escorpiones?

Resumen:
Hay una peculiar serie de más de 1000 fosetas cuticulares, en posición ventral y lateral, en los segmentos posteriores del metasoma y el telson de unos cuantos taxones de Buthidae (Scorpiones), incluídas todas las especies del género *Orthochirus* Karsch, bien distribuído por los desiertos del Viejo Mundo. El examen con microscopio electrónico de barrido permite ver que dichas fosetas portan setas de tamaños variables que presentan caracteres microanatómicos característicos de los quimiorreceptores (forma curva, poro terminal). Observaciones hechas en la naturaleza (Asia Central) han permitido constatar en *Orthochirus* una postura de reposo/defensa inusual para los escorpiones, con el metasoma plano contra el mesosoma, el pequeño telson plegado dorsalmente en un surco y la superficie ventral del V segmento metasomal formando un "escudo facial". Sugerimos que las superficies de los segmentos metasomales posteriores orientadas hacia arriba y hacia adelante en *Orthochirus* y géneros relacionados podrían servir de dispositivo quimiosensor, análogo a las antenas de los insectos.
Palabras clave: Scorpiones, Buthidae, *Orthochirus*, metasoma, sensory setae.

Introduction

As soon as the first species of the genus *Orthochirus* Karsch, 1880 (Scorpiones: Buthidae) have been described, the unusual among scorpions structure of their metasoma ("tail") has been noticed: pitted ventral and lateral surfaces of metasomal posterior segments, especially IV and V, and the telson. The name *scrobiculosus* given by Grube (1873) to the most widespread species of *Orthochirus*, means "pitted" (from Latin *scrobiculus*, "a little trench"); the word "scrobiculated" in fact exists in English.

These metasomal pits have been used as a taxonomic character in Buthidae (Levy & Amitai, 1980), but were never analyzed at the microscopic level. Several small (below 50 mm), dark-colored species of *Orthochirus* are common in the Palearctic deserts from North Africa to Central Asia (Levy & Amitai, 1980; Fet & Lowe, 2000). Levy & Amitai (1980: 101) observed that its "metasoma is held curled, pressed to the back with the stinger completely hidden", which is not a common feature in scorpions. Also, a peculiar side-to-side motion of metasoma in "pitted" species of buthids during prey search was reported (Shulov & Amitai, 1960; Lourenço, 2001)

Pitted metasomal surface has been found in several scorpion genera, all from the Old World deserts, and presumably of African origin (Fet *et al*., 2003). Birula (1917) even established a special subfamily Orthochirinae, to accommodate this genus and its kin. Recently, Lourenço (2001) was the first to publish SEM images of similar pits in the South African genus *Karasbergia*, which appeared to carry specialized chemoreceptory setae.

Material and Methods

Material. Adult females and males of *Orthochirus scrobiculosus* (Grube, 1873) were collected by Victor Fet on April 18, 2002 at Repetek, Turkmenistan (East Karakum Desert) at night using UV "black light". Scorpions were preserved in 96% ethanol and brought to Marshall University, West Virginia, USA.

Microscopy. Metasomas were removed from the animals and treated as follows. Specimens were fixed for 12 hours in 0.1 M sodium cacodylate with 2.5% gluteraldehyde (freshly prepared). After rinse/soak for 12 hours in plain 0.1 M sodium cacodylate, specimens were post-fixed for 2 hours in freshly prepared 1% osmium tetroxide again in sodium cacodylate. Specimens were rinsed three times with distilled water and dehydrated in an ethanol series (50, 75, 95, and two changes of 100%) before being dried and coated with gold/palladium (ca. 10 nm thickness) in a Hummer sputter coater. SEM images were acquired with a JEOL JSM-5310LV. Acceleration voltage (10-20 kV), spot size, and working distance were adjusted as necessary to optimize resolution, adjust depth of field, and to minimize charging.

Results

SEM images. *Orthochirus* metasoma at magnifications from 15x to 5,000x is illustrated (Figs. 1-5). On the ventral and lateral surface of metasomal segments, especially segments IV-V and the telson, we observed arrays of multiple cuticular pits, with a single socketed seta emanating from each. Pits varied in diameter and depth, their mutual position was irregular. Number of pits counted on adult females (n=4) was: on metasomal segment V (lateral and ventral surfaces), 735 ± 74; on segment IV, 623 ± 109; total on segments IV and V, 1358 ± 178. Density of pits (counted in 1 mm^2 frames) was on metasomal segment V, 15.9 ± 2.30 per mm^2 (n=12); on segment IV, 12.2 ± 1.08 per mm^2 (n=12); average on segments IV and V, 14.0 ± 2.57 per mm^2.

The hexagonal structure of cuticle (Fig. 3) was well observable within pits, forming a honeycomb pattern with hexagonal cells of ca. 10 µm across; these are believed to demarcate the cuticular contribution of single epithelial cells. The socketed setae emanating from the pits varied considerably in length and shape, from longer and straighter ones to short and curved ones (Figs. 2-3). Setae ranged in size between 50 and 100 µm. All observed pit setae had an apical pore (Figs. 3-5), characteristic for chemosensory setae in scorpions and other arthropods (Farley, 2001). Some setae were broken, with the lumen of the inner canal visible.

Behavior. Multiple observations of *O. scrobiculosus* metasoma in nature by V.F. (over 20 localities in Turkmenistan and Uzbekistan, Central Asia, 1972, 1975-1987, 2002) confirm the peculiar posture reported by Levy & Amitai (1980). The metasoma in rest is pressed flat on the back, with the pit arrays directed up and forward, while in other buthids (e.g. species of *Mesobuthus, Liobuthus*) metasoma may be stretched or curled next to the body in rest position. The telson, small and slender in *Orthochirus*, in rest is folded into a matching groove on the dorsal surface of metasomal segment V. Moreover, the posterior portion of metasoma, pressed close to the carapace, fits into an abrupt cut in the anterior portion of the carapace. Finally, the movements of metasoma during prey search in *Orthochirus* differed from that in other buthids, exhibiting "jerky" side-to-side motion as reported by Lourenço (2001).

Discussion

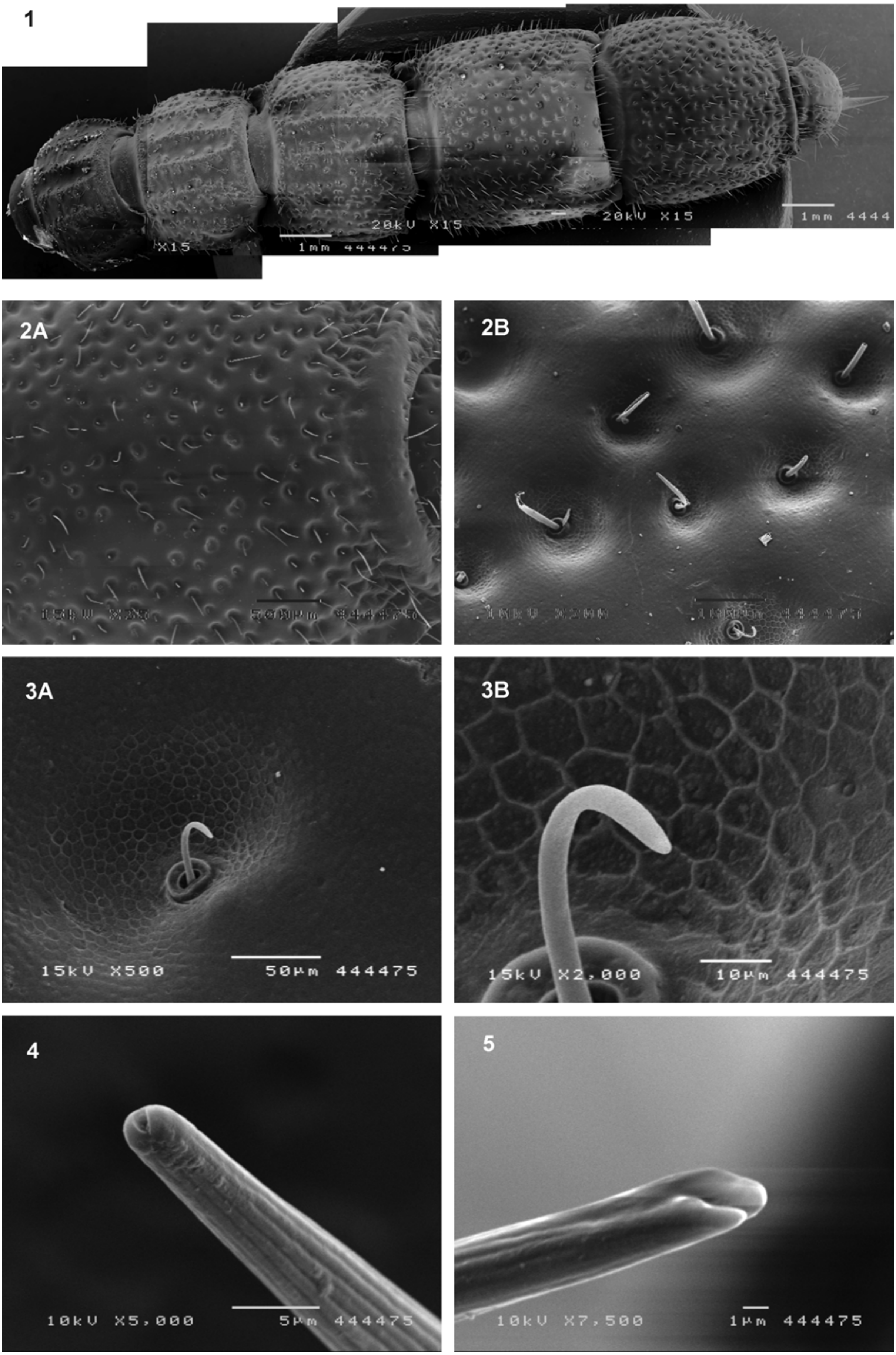
Cuticular sensory organs are common in all arachnids. In scorpions, short, curved chemosensory setae are scattered all over the animal's body (Foelix & Mueller-Vorholt, 1983; Farley, 2000; Gaffin & Brownell, 2001). However, the observations of these setae were sporadic, concentrating largely on leg tarsi which bear contact chemosensory setae. No SEM study so far addressed the possible concentration of chemosensory setae on metasoma of *Orthochirus*.

Brownell (2001) wrote: "...terrestrial arachnids can claim some of the most elaborate chemosensory organs among the Arthropoda. ...Taken together, the Arachnida reveal an evolutionary trend toward specialization of chemosensory appendages in arthropods, one that begins with gustation by leg-like appendages contacting the substrate [in scorpions and solpugids] and ends with olfaction by antenna directed into the air [in amblypygids, uropygids, and solpugids]." Surprisingly, we see in the case of *Orthochirus* that the "antennalization" (Brownell, 2001) could possibly take place in scorpions as well, in addition to their remarkable contact chemoreception by pectinal organs, with their thousands of peg sensilla (up to 120,000 per male; Gaffin & Brownell, 2001).

The setate pits themselves are, of course, a common structural feature of arthropod cuticle, e.g. in beetles' elytra. It remains to be seen if the metasomal pitted array of setae in *Orthochirus* and other "pitted" scorpions (genera *Microbuthus, Butheolus, Karasbergia*) has a principally different physiological role compared to the "non-pitted" metasoma of most buthid species. The observed side-to-side metasomal motion

o

Fig. 1-5: *Orthochirus scrobiculosus;* **1.** Metasoma, segments I-V and telson, ventral surface (15x). **2.** pitted ventral surface of the metasomal segment V (**A**. 35x; **B**. 200x). **3.** metasoma V, a short pit seta (**A**. 500x; **B**. 2,000x). **4.** metasoma V, tip of pit seta (5,000x). **5.** metasoma I, tip of pit seta (5,000x).


1
20kV X15
20kV X15
2A
2B
3A
15kV X500
50µm 444475
3B
15kV X2,000
10µm 444475
4
10kV X5,000
5µm 444475
5
10kV X7,500
1µm 444475

during prey search seems to agree with a possible special functional role.

Scorpion metasoma ends with a venomous gland in its telson, and is naturally thrust forward due to its role in defense and attack. In many non-buthid scorpions (e.g. family Scorpionidae) metasoma is shortened, and the role of venom is decreased as well as its potency. In Buthidae, on the contrary, potency and specificity of venom toxins reaches the known scorpion maximum. The Old World desert Buthidae, including *Orthochirus*, are a monophyletic group (Fet *et al*., 2003), with a number of derived features. *Orthochirus* has a potent venom (Kozlov *et al*., 2000), and routinely uses its metasoma for both attack and defense – with the ventral surface of its posterior metasomal segments "directed into the air" when in rest posture. It is not too farfetched to envision evolution of a concentrated chemosensory array on this surface, given that chemosensory setae are readily available on scorpion's body.

Or, quoting Brownell (2001) on arachnid chemoreception, "God has a plan after all!"

Conclusions

Are scorpions evolving a new organ? It is tempting to think of the *Orthochirus* "face shield" as a budding equivalent of insect antennae. We know that the chelate pedipalps in scorpions combine functions of predation and antenna-like mechanoreception (with their arrays of trichobothria). Could the scorpion "antennalize" its "tail", strategically positioned for a strike in front of the cephalothorax, to double as an antenna-like chemoreceptory device?

Acknowledgments

We thank Drs. Michael Norton and Suzanne Strait for their help and guidance. This study was supported by Marshall University's Department of Biological Sciences and Department of Chemistry. Travel of V.F. to Central Asia in 2002 was supported by the National Geographic Society Research and Exploration grant No. 7001-01. We also thank Drs. Philip Brownell and Douglas Gaffin for many informative discussions on scorpion chemoreception.

Bibliography

BIRULA, A. A. 1917. *Faune de la Russie et des pays limitrophes fondee principalement sur les collections du Musée Zoologique de l'Académie des Sciences de Russie. Arachnides (Arachnoidea).* 1(1), Petrograd. xx, 227 pp.

BROWNELL, P. H. 2001. A comparison of major chemosensory organs in arachnids (God has a plan after all!). *Abstracts of the XV International Congress of Arachnology,* Badplaas, South Africa.

FARLEY, R. 2000. Scorpiones. Pp. 117-222. In: Harrison, F. & R.F. Foelix (eds.): *Microscopic Anatomy of Invertebrates. Vol. 8A. Chelicerate Arthropoda.* New York: Wiley-Liss.

FET, V., B. GANTENBEIN, A. V. GROMOV, G. LOWE & W. R. LOURENÇO 2003. The first molecular phylogeny of Buthidae (Scorpiones). *Euscorpius*, **4**: 1-10.

FET, V. & G. LOWE 2000. Family Buthidae. Pp. 54-286. In: Fet, V., Sissom, W.D., Lowe, G. & Braunwalder, M.E. *Catalog of the Scorpions of the World (1758-1998).* New York: New York Entomological Society.

FOELIX, R.F. & G. MUELLER-VORHOLT 1983. The fine structure of scorpion sensory organs. II. Pecten sensilla. *Bulletin of the British Arachnological Soc*iety, **6**: 68-74.

GAFFIN, D. & P. H. BROWNELL 2001. Chemosensory behavior and physiology. Pp. 184-203. In: Brownell, P.H. & Polis, G.A. (eds.): *Scorpion Biology and Research*. Oxford: Oxford University Press.

GRUBE, A. 1873. Ueber eine Zusendung transkaukasischer Arachniden und Myriopoden. *Jahresbericht der Schlesischen Gesellschaft für Vaterländische Naturkunde in Breslau*, **51**: 56-57.

KOZLOV, S., A. LIPKIN, E. NOSYREVA, A. BLAKE, J. D. WINDASS & E. GRISHIN 2000. Purification and cDNA cloning of an insecticidal protein from the venom of the scorpion *Orthochirus scrobiculosus*. *Toxicon*, **38**(3): 361-371.

LEVY, G. & P. AMITAI 1980. *Fauna Palaestina. Arachnida I. Scorpiones*. Jerusalem: Israel Acad. Sci. Hum., 130 pp.

LOURENÇO, W. R. 2001. Taxonomic considerations on the genera *Butheolus* Simon, *Nanobuthus* Pocock and *Neobuthus* Hirst (Scorpiones, Buthidae) with the description of a new species of *Neobuthus* from Ethiopia. Pp. 171-183. In: Prakash, I. (ed.): *Ecology of Desert Environments. (A Festschrift for Prof. J. L. Cloudsley-Thompson on his 80th Birthday).* Jodhpur: Scientific Publishers.

SHULOV, A. & P. AMITAI 1960. Observations sur les scorpions *Orthochirus innesi* E. Sim., 1910 ssp. *negebensis* nov. *Archives de l'Institut Pasteur d'Algérie*, **38**: 117-129.