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TERGAL AND SEXUAL ANOMALIES IN BOTHRIURID SCORPIONS (SCORPIONES, BOTHRIURIDAE)

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ABSTRACT. New data concerning developmental anomalies observed among species of the family Bothriuridae (Scorpiones) are presented. Tergal malformations in *Bothriurus coriaceus*, *Brachistosternus roigalsinai* and *Bothriurus noa* are described and illustrated. Two new cases of intersexuality in scorpions, in specimens of *Brachistosternus pentheri* and *Bothriurus araguayae*, are reported and discussed.

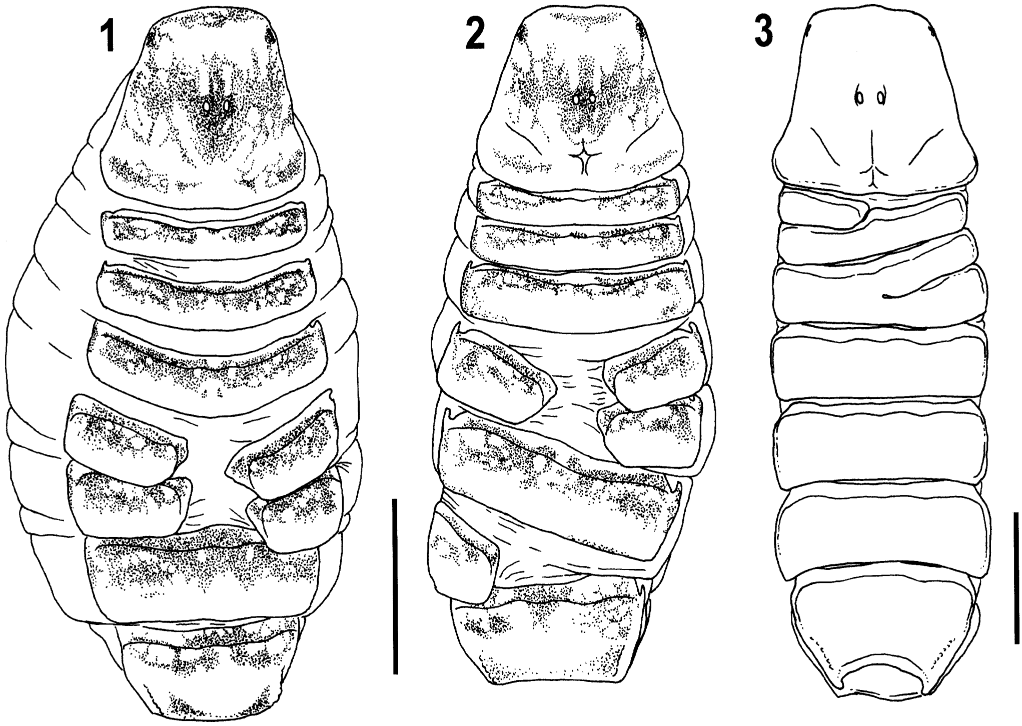
Keywords: Developmental anomalies, tergites, intersexuality, Scorpiones, Bothriuridae

There are numerous reports of developmental anomalies in scorpions (Table 1). Most reports relate to the duplication of posterior body segments (Vachon 1952; Hjelle 1990; Sissom & Shelley 1995, see the latter for overview); reference to other types of developmental anomalies in scorpions is scarce. One work includes information about anomalies of the legs and pedipalps (Armas 1977) and another describes a tergal and two carapacial malformations (Armas 1976). Most recently, Teruel (2004) presented a list and brief description of tergal (see below) and pedipalpal anomalies; however, only Armas (1977) illustrated the anomalies described, a prerequisite for understanding the anomalies reported.

Teruel (2004: 237) references a ‘‘cheliceral anomaly’’ on one specimen of a buthid, *Lychas obsti* Kraepelin 1913. This specimen has two teeth on the ventral surface of the fixed finger of one chelicera and one on the other, the latter expression being the typical condition for *Lychas* (Vachon 1963; Kovařík 1997). Teruel (2004) notes that this is interesting from a taxonomic viewpoint, because, traditionally, the number of ventral teeth on the fixed finger has been used as a strong character in the generic differentiation of the scorpions of the family Buthidae (Kraepelin 1899; Sissom 1990). Teruel (2004) suggested that using this character to identify buthids from Northwest Africa could present problems, because it could cause erroneous identifications. The two states clearly represent normal variation in morphology, and are not anomalous. Expression of both states in one specimen is clearly an abnormality and the existence of rare abnormalities does not necessitate the need to abandon these character systems. Furthermore, many systematists have observed this kind of variation on the chelicerae of several species, including cases where both chelicerae are different from the usual morphology of the species (Mattoni 2003; Prendini pers. comm.). They would not consider these represent any obstacle for identifying taxa in question, because these occurrences are rare in scorpion populations, and there are many additional characters that can assist with an identification.

The only references to tergal anomalies in scorpions are the works of Armas (1976), who described a specimen of *Didymocentrus trinitarius* Franganillo 1930 (Diplocentridae) with fusion of the carapace and the first tergite, and Teruel (2004) who described anomalies in one male of *Microtityus jaumei* Armas 1974 (Buthidae), that possessed a double anomaly, with tergite V completely divided on the posterior half, and tergite VII fused dorsally to metasomal segment I. Teruel (2004) also reported two female diplocentrids (*Cazierius parvus* Armas 1984 and *C. gundlachii* (Karsch 1880) and one euscorpiid (*Euscorpius flavicaudis* (DeGeer 1778)), possessing totally divided tergites.

The references to sexual malformations are restricted to 5 reports, involving hermaphroditism (with male and female genitalia), gynandromorphism (with both sexes discretely combined) and intersexualism (where the en-



Figures 1–3.—Carapace and tergites of malformed scorpions. 1–2. Females of *Bothriurus coriaceus*; 1. specimen from 4 km N Los Vilos; 2. specimen from Cuesta de Chacabuco. 3. female of *Brachistosternus roigalsinai*, carapace and tergites. Scale = 5 mm.

tire body is intermediate between sexes). Matthiesen (1968) described a hermaphrodite specimen of the buthid *Tityus bahiensis* (Perty 1833). Cokendolpher & Sissom (1988) described two gynandromorphic diplocentrids (a *Cazierius gundlachii* (Karsch 1880) and *Bioculus comondae* Stahnke 1968). Armas (1990) reported a case of one hermaphrodite *Alayotityus juraguaensis* Armas 1973 and a gynandromorphic specimen of *Tityopsis inaequalis* (Armas 1974) (Buthidae). Maury (1983) described an adult hermaphrodite of *Brachistosternus pentheri* Mello-Leitão 1931 (Bothriuridae) showing intersexual and gynandromorphic characteristics, and with both embryos and hemispermatophores. Another interesting malformation was reported in two males of the bothriurid *Bothriurus bonariensis* (C.L. Koch 1842), found mating with females in the field, yet presenting only one hemispermatophore, the right paraxial organ (that produces the hemispermatophore) being absent in both specimens (Peretti 2000). The last two reports, together with the pedipalps anomaly reported by Teruel (2004) on *Centromachetes pocockii* (Kraepelin 1894) and *Urophonius granulatus* Pocock 1898, are the only references to malformations among Bothriuridae.

The main goal of this contribution is to describe and illustrate the tergal anomalies that were found in specimens of three Bothriuridae species, and to report two more cases of intersexuality in scorpions.

The specimens studied are preserved in 80 % ethanol and belong to the following collections: AMNH = American Museum of Natural History (New York, USA); MACN-Ar = Museo Argentino de Ciencias Naturales ‘‘Bernardino Rivadavia’’ (Buenos Aires, Argentina) and CDA = Cátedra de Diversidad Animal I, Universidad Nacional de Córdoba (Córdoba, Argentina). Illustrations were produced using a Leica MS5 stereomicroscope equipped with a camera lucida. Photographs were taken with an Olympus Stylus 400 digital camera under long-wave ultraviolet light.

Specimens examined.—*Bothriurus cori-*

aceus Pocock 1893. CHILE: Santiago Region, Chacabuco Province: 1 ♀, Cuesta de Chacabuco, S side, elev. 3900 ft, dry mountainside (32°59′ S, 70°44′ W), 14 I 1985, N. Platnick, O.F. Francke, AMNH; Coquimbo Region, Choapa Province: 1 ♀, 4 km N Los Vilos (31°72′ S, 71°31′ W), 5 I 1985, N. Platnick, O. F. Francke, AMNH. *Bothriurus noa* Maury. ARGENTINA: Tucumán Province: 1 ♀ (paratype), Tafí del Valle (26°52′ S, 65°51′ W), 1970 m, 16 I 1981, E. Maury, MACN-Ar 7571. *Brachistosternus* (*Leptosternus*) *roigalsinai* Ojanguren-Affilastro 2002. CHILE: Atacama Region, Huasco Province: 1 ♀, Llanos de Challe National Park, (28°09′39.8″ S, 71°03′20.0″ W), 205 m, XII 1997, J. Cepeda-Pizarro, CDA. *Brachistosternus* (*L.*) *pentheri*. ARGENTINA: Mendoza Province: 1 ♂ (?), Reserva de la Biósfera Ñacuñán (34°02′ S, 67°54′ W), 540 m, 20 XI 2003, C. Mattoni, L. Prendini, J. Ochoa, CDA. *Bothriurus araguayae* Vellard 1934. BRAZIL: Sao Paulo State: 1 ♂ (?), Estaçao Ecológica de Itirapina, Municipio de Itirapina (22°15′ S, 47°49′ W), pitfall, 27 VIII 1999, G. Machado.

Two of the females (both *B. coriaceus*) were pregnant when preserved.

Tergal malformations.—The *B. coriaceus* specimen from Cuesta de Chacabuco (Fig. 1) shows completely longitudinally divided tergites IV and V. Both parts of each tergite represent almost exactly in shape and size the corresponding half of the tergite; only a small central portion is lacking from the posterior edge. The *B. noa* female shows the same kind of anomaly but only on tergite III.

The specimen of *B. coriaceus* from 4 km N Los Vilos (Fig. 2) also presents some divided tergites, with a different arrangement: tergite IV is completely divided but tergite V is fused sinistraly with the dextral half of tergite VI. The recognition of each part of the tergites is difficult because tergites V and VI are almost the same size.

The *Brachistosternus* (*L.*) *roigalsinai* specimen (Fig. 3) displays a different kind of malformation: the sinistral half of tergite I is free, and the dextral half is joined to the sinistral half of tergite II (one can recognize the tergite because I and II differ in size). The dextral half of tergite II is joined anteriorly to the tergite III.

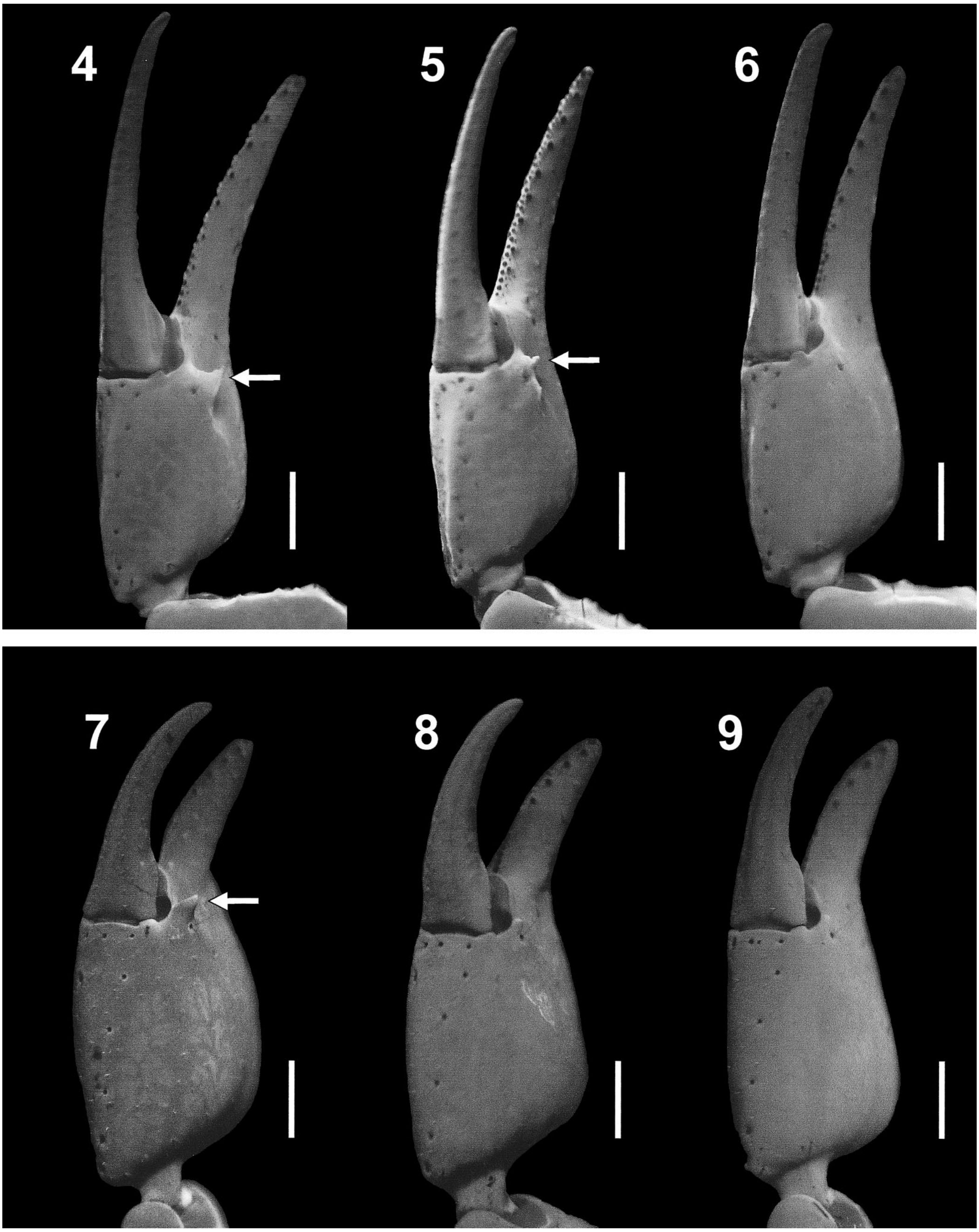
All observed specimens with tergal anomalies do not show any other evident malformation, except for the specimen of *B. coriaceus* from Chacabuco that has a slightly abnormal telson vesicle, with the left ventral side a little depressed.

The pigmentation pattern of the malformed tergites is normal on the *Bothriurus coriaceus* and *B. noa* specimens, and apparently in the *Brachistostenus* (*L.*) *roigalsinai* female as well. However, in the latter case the specimen is not well fixed, and not all the pigmentation has been preserved.

Tergal malformations include division of tergites and fusion of tergal parts to one another. Armas (1976) described a fusion of tergite I to carapace, and Teruel (2004) observed division of tergites and fusion to metasomal segment I. All the specimens with anomalous tergites examined here were adult females. Teruel (2004) observed the same pattern but with four females and one male, and the specimen referred by Armas (1974) is an adult male. I have examined 226 specimens of *B. coriaceus* (57 females, 62 males and 107 juveniles), and found this kind of anomaly only on the two females referred to here (Mattoni 2003). Despite the few cases reported in scorpions, the presence of tergal malformations only on adults suggests that they arise during last molt.

The causes of these tergal malformations are completely unknown, but they do not seem to affect the life of the scorpion or its mating. The pigmentation pattern in the tergites of all the specimens appears not to be altered.

Sexual malformations.—*Brachistosternus* (*L.*) *pentheri:* The specimen has intermediate sexual characteristics: the small size and number of pectinal teeth (26/30, left/right) suggest that it is from a female, males posess larger and more numerous teeth (in the *B. pentheri* population from Ñacuñan the females usually have 25–32 teeth, and the males 32–41, Roig Alsina & Maury 1984); the telson is also more similar in shape to that of a female; the pedipalp chela has almost all the morphometric characteristics of a male, but the internal apophysis near the base of the movable finger (a sexual secondary structure present only on the males) is extremely reduced to approximately half of normal size (Figs. 4–6); the carapace surface is densely covered with blunt granules, as in regular males (females display fewer granules), but the tergites are smooth as



Figures 4–9.—Right pedipalp chelae, ventrointernal view. 4–6. *Brachistosternus pentheri*; 4. male; 5. intersexual specimen; 6. female. 7–9. *Bothriurus araguayae*; 7. male; 8. intersexual specimen; 9. female. Scale = 1 mm. The arrows show the secondary sexual structures.

in females (males display a fine granulation); sternites I–III present sparse granulation, and IV and V are smooth (on more typical males, all sternites are granular, whereas those of females are smooth); and the ventral surfaces of metasomal segments I to III are smooth as observed in females (these surfaces are granular on males). The specimen presents a paired glandular surface on the dorsal side of metasomal segment V (another sexual secondary structure of males, Cekalovic 1973; Peretti 1997), but these glands are less well developed, being shorter than in regular males. The specimen also has well developed hemispermatophores, with sperm in the seminal duct, and testis tubules present; female genitalia (ovari-uterus, seminal receptacles and genital atrium) could not be found.

The presence of male, seemingly functional, sexual organs suggests that this specimen is an adult male with intersexual external morphology. Some of these characters are similar to those observed by Maury (1983) in a hermaphrodite *B. pentheri* male: poorly developed apophyses on the pedipalp chela, reduced dorsal glands on metasomal segment V, intermediate granulation on the carapace and tergites. The specimen described here presents more feminine external characters, like the pectines and telson, than those described by Maury (1983). The main difference between these specimens is the simultaneous presence of well developed embryos and hemispermatophores in Maury's specimen, which identifies it as a true hermaphrodite.

Bothriurus araguayae: The specimen exhibits many external characteristics of a female: smooth carapace and tergites (males typically present a fine and even granulation); absence of a sexual secondary gland on the dorsal side of the telson (present in adult males); metasomal segment V more robust than males, (which have slender segments, Lourenço & Maury 1979); and without an apophysis on the internal surface of the chela, behind the movable finger, that is present in the males, and is replaced in this specimen by a blunt granule (more pronounced than in regular females) (Figs. 7–9). The male characteristics of the specimen are as follows: both hemispermatophores present, pectines with larger and with more pectinal teeth, and genital operculum formed by two triangular isosceles plates (these are equilateral in females). I could not observe sperm in the seminal vesicles, because of the poor preservation of the reproductive organs. As in the previous case, I regard the *B. araguayae* specimen as a male, with intersexual external characteristics.

The main differences between the intersexual specimens of both species are related to secondary sexual structures: the internal apophysis on the chela, which is absent in the *B. araguayae* specimen, and present, but reduced, in the *B. pentheri* specimen; and the metasomal glands, which are absent on the *B. araguayae*, and present, but reduced, in the *B. pentheri*.

These secondary sexual structures have a clear function during mating: the apophyses on the male chelae help to secure the female chelae during mating (Maury 1975; Peretti 1993), and the metasomal glands produce a secretion that reduces female resistance during mating (Peretti 1997). Further observations are necessary to understand the incidence of such developmental anomalies in scorpion populations, and the influence that they might have on life history (e.g., in reproductive biology), because of possible disadvantages of intersexual males in comparison with normal males.

The cause of these mutations among scorpions is unknown. Among other arthropods, intersexual specimens have been demonstrated to be the result of bacterial infection (Bouchon et al. 1998; Rigaud & Juchault 1998). We suspect that the intersexual phenomenon is not limited to the species described here but has been largely ignored in other species in which it may occur. Many external characters are widely used for determining the gender of scorpions, but only the dissection of a specimen can unequivocally confirm its sex, thereby allowing the identification of intersexual and hermaphrodite specimens. Also, one anomalous specimen can lead to a mistake, that was the case with the ''male'' of *Alayotityus juraguaensis* described by Armas (1984), a specimen with external female characteristics and with one paraxial organ, that led to Armas to say that this was the only species on the genus without sexual dimorphism. But in fact, as later discovered by Armas (1990), the specimen was a hermaphrodite, with one hemispermatophore and ovari-uterus.

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Table 1.—Reported cases and kind of anomalies in families of scorpions. The number of registered species showing the anomaly is in parentheses. The taxonomy presented in the table in accordance with Fet et al. (2000). However, see Stockwell (1989), Prendini (2000) and Soleglad & Fet (2003) for alternative hypotheses.

Anomaly	Family and species	Main references
Duplication of metasoma	Euscorpiidae (2)	Sissom & Shelley 1995
	Buthidae (8)	Vachon 1952; Sisson & Shelley 1995
Tergite division and/or fusion	Diplocentridae (3)	Armas 1976; Teruel 2004
	Bothriuridae (3)	This work
	Buthidae (1)	Teruel 2004
	Euscorpiidae (1)	Teruel 2004
Leg malformation	Buthidae (4)	Armas 1977
Pedipalp chela compression on females	Bothriuridae (2)	Teruel 2004
	Buthidae (18)	
	Chactidae (1)	
	Chaerilidae (1)	
	Diplocentridae (3)	
	Euscorpiidae (3)	
	Hemiscorpiidae (1)	
	Liochelidae (1)	
	Iuridae (1)	
	Scorpionidae (1)	
Pedipalp fusion	Buthidae (1)	Cao & Solórzano 1991
Males with intersexual characters	Bothriuridae (2)	Maury 1983; this work
Males with one paraxial organ	Bothriuridae (1)	Peretti 2000
Hermaphrodite	Bothriuridae (1)	Maury 1983
	Buthidae (2)	Matthiesen 1968, Armas 1990
	Bothriuridae (1)	Maury 1983
Gynandromorphy	Buthidae (1)	Armas 1990
	Diplocentridae (2)	Cokendolpher & Sissom 1988

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