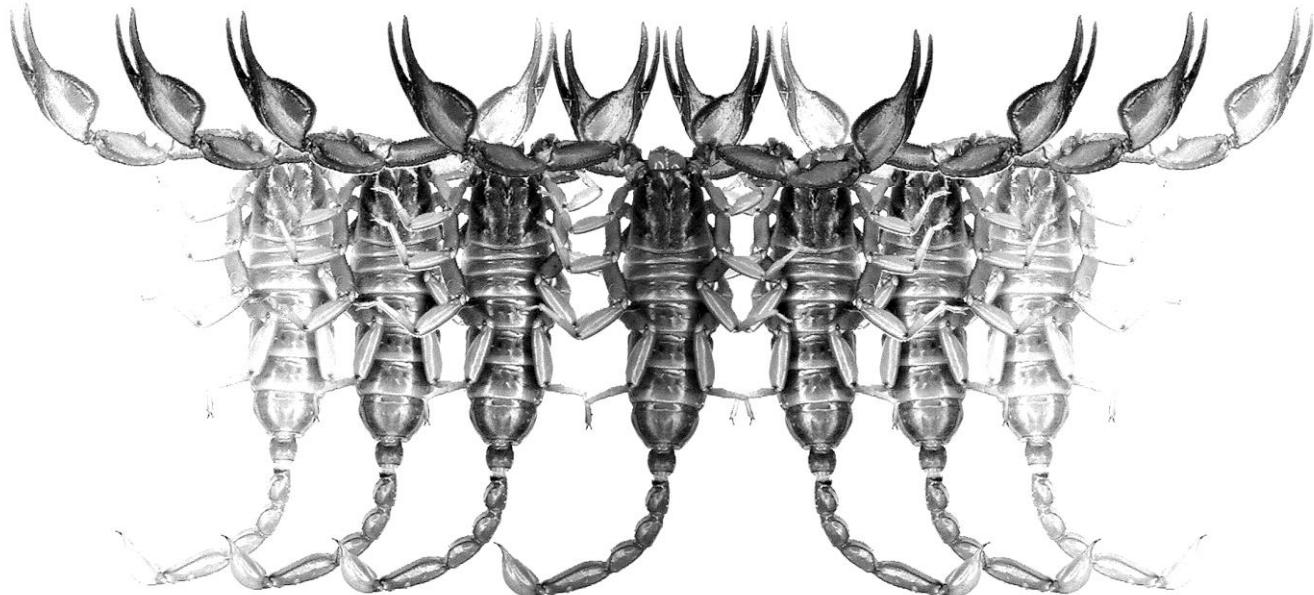


# *Euscorpius*

Occasional Publications in Scorpiology



A Review of the Genus *Leiurus* Ehrenberg, 1828  
(Scorpiones: Buthidae) with Description of Four New  
Species from the Arabian Peninsula

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# *Euscorpius*

## Occasional Publications in Scorpiology

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# A review of the genus *Leiurus* Ehrenberg, 1828 (Scorpiones: Buthidae) with description of four new species from the Arabian Peninsula

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## Summary

The taxonomy of buthid scorpions belonging to the genus *Leiurus* Ehrenberg, 1828 is reviewed. Four new species are described from the Arabian Peninsula: *L. macroctenus* sp. n. from coastal fog deserts in Oman; *L. haenggii* sp. n. from mountains of the Red Sea coast, Hadramaut and Dhofar, in Saudi Arabia, Yemen and Oman; *L. arabicus* sp. n. from the central Najd Plateau and eastern plains in Saudi Arabia; and *L. heberti* sp. n. from Jabal Samhan in Oman. *L. brachycentrus* (Ehrenberg, 1829) stat. n. from the Tihama plain of the Red Sea coast in Saudi Arabia and Yemen is restored from synonymy and redescribed. *Leiurus nasheri* Kovářík, 2007 was found to be a junior synonym of *L. brachycentrus* stat. n. *L. quinquestriatus hebraeus* (Birula, 1908) is elevated to species level as *L. hebraeus* (Birula, 1908) stat. n. Revised diagnoses are given for *L. quinquestriatus* (Ehrenberg, 1828), *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009, *L. jordanensis* Lourenço, Modrý et Amr, 2002, and *L. hebraeus* (Birula, 1908). Key characters used to diagnose and separate species include morphometrics, granulation, trichobothriotaxy, tarsal setation, dentition of metasomal carinae and color pattern. Detailed illustrations are provided and the affinities and biogeography of the genus are discussed.

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## In Memoriam

This paper is dedicated to the memory of Michael D. Gallagher (1921 – 2014), an extraordinary naturalist, friend and mentor, whose generous support and contributions greatly facilitated our studies on Arabian scorpions.

## Introduction

The genus *Leiurus* is widely distributed across North Africa, the Middle East and the Arabian Peninsula. For a long time it was considered monotypic, with a single variable species *L. quinquestriatus*, named for the presence of five carinae on the first two tergites, an unusual feature among the buthids. The species has medical importance as a large, common scorpion with venom containing highly potent, mammal-specific neurotoxins (Chippaux & Goyffon, 2008). However, in spite of its notoriety, the taxonomy of widespread *Leiurus* populations has received relatively little attention over the years. It is important to address this problem, not only to elucidate the systematics and biogeography of the genus, but also because there are potential public health implications of the comparative toxicology of *Leiurus* venoms.

The name *Leiurus* was created by Ehrenberg in Hemprich & Ehrenberg (1828, 1829, 1831) for a subgenus of *Androctonus* that included species with slender metasomal segments: *leptocheilys*, *macrocentrus*, *quinquestriatus*, *thebanus* and *tunetanus*. All of these species except *quinquestriatus* were subsequently transferred to other genera, or were synonymized with other species. *Leiurus* was elevated to genus level by Vachon (1949) who regarded it as monotypic with a single species *L. quinquestriatus*. Several subspecies have been included. Currently, *Androctonus* (*Liurus*) *quinquestriatus aculeatus* Ehrenberg (1831) is a synonym of the nominotypic subspecies (Birula, 1908; Fet, 1997), *Buthus quinquestriatus hebraeus* Birula, 1908, is recognized as valid (Levy, Amitai & Shulov, 1970; Levy & Amitai, 1980; Fet & Lowe, 2000), *Buthus quinquestriatus libycus* Birula, 1908 is synonymized with the nominotypic subspecies (Vachon, 1949), and *Androc-*

*tonus (Liurus) quinquestriatus brachycentrus* is synonymized with the nominotypic subspecies (Levy & Amitai, 1980). The status of *Leiurus quinquestriatus voelschowi* Pohl, 1967 is uncertain (Fet & Lowe, 2000).

*Leiurus* is no longer monotypic after the recent descriptions of several additional species with restricted geographic ranges: *L. jordanensis* Lourenço, Modrý et Amr, 2002; *L. savanicola* Lourenço, Qi et Cloudsley-Thompson, 2006; *L. nasheri* Kovářík, 2007, and *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009. Recognition of these distinctive species suggests that there may be considerable taxonomic diversity within *Leiurus* arising from local speciation. We confirm this by presenting results of a detailed study of *Leiurus* material mainly from the Arabian Peninsula, including large collections assembled by Prof. W. Büttiker from Saudi Arabia lodged in the Naturhistorisches Museum, Basel (Hendrixson, 2006), and by one of us (GL) during investigations of the scorpiofauna of Oman. We introduce new taxonomic characters, describe four new Arabian species, and elevate to species status *L. brachycentrus* stat. n., and *L. hebraeus* stat. n. For comparison, we also formulate revised diagnoses of several other species.

## Abbreviations

**Specimen depositories:** BMNH, Natural History Museum, London, UK; EV, private collection of Erich Volschenk, Perth, Australia; FKCP, private collection of František Kovářík, Prague, Czech Republic; GL, private collection of Graeme Lowe, Philadelphia, USA; MCZN, Museum of Comparative Zoology, Massachusetts, USA; MEB, private collection of Matt E. Braunwalder, Zürich, Switzerland; MHNG, Muséum d'Histoire Naturelle de Genève, Geneva, Switzerland; MNHN, Muséum National d'Histoire Naturelle, Paris, France; MTAS, Museum of Turkish Arachnology Society, Ankara, Turkey; MZUF, Museo di Storia Naturale "La Specola", Firenze, Italy; NHMB, Naturhistorisches Museum, Basel, Switzerland; ONHM, Oman Natural History Museum, Muscat, Oman; USNM, National Museum of Natural History, Washington, D.C., USA; WDS, private collection of W. David Sissom, Canyon, Texas, USA; ZISP, Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia; ZMHB, Zoologisches Museum, Humboldt-Universität, Berlin, Germany. **Biometrics:** L, length; W, width; D, depth. **Material:** juv, juvenile; juvs, juveniles.

## Materials & Methods

Material examined was either loaned from museums and private collections, or was collected by the authors by day, or by night with ultraviolet (UV) detection methods, and locality coordinates were recorded by GPS

(GL, Oman material; EY, Turkey & Syria material). Specimens were examined under a dissecting microscope, viewing reflected white light or blue-green fluorescence under UV LED illumination (Lowe et al., 2003). Biometrics were measured with digital calipers, ocular reticles or digital cameras (15,056 morphometric or meristic values were acquired from 350 specimens). We generally followed definitions of measurements in Lamoral (1979) and Sissom et al. (1990), except as follows: carapace anterior width taken between most medial pair of lateral eyes; pedipalp femur length taken from proximal limit of dorsointernal carina; pedipalp chela length taken as chord length from external proximal limit of manus to fixed finger tip; pedipalp manus width and depth taken with movable finger articular condyles level; telson and vesicle length taken from anterior limit of vesicle (Sissom et al., 1990). Pectine length was taken along the anterior margin of the comb (Stahnke, 1970: 302, Fig. 155). Mid-pectine sensillar margin (MPSM) length was taken as the long axis dimension of the surface occupied by peg sensillae on a pectine tooth near the middle of the comb (close to the distal end of the first marginal lamella) (c.f. Fig. 95B inset). Carinal terminology generally follows Vachon (1952) and Stahnke (1970). On metasomal segments I–IV, paired carinae are termed: dorsosubmedian, dorsolateral, lateral median (if present), ventrolateral and ventromedian. On metasomal segment V, paired carinae are termed: dorsolateral, ventrolateral and ventro-submedian, with the ventromedian carina unpaired. Terminology of leg surfaces after torsion, and of tarsal segments and their setation follows Haradon (1984). Hemispermatophore terminology follows Vachon (1952) and Lamoral (1979). Anatomical illustrations were prepared from white light or fluorescence images acquired under UV illumination (Prendini, 2003; Volschenk, 2005). Fluorescence images were rendered in blue-green, as they appear under UV. Habitus and cheliceral illustrations were rendered by merging color patterns imaged under white light with cuticular surface topography revealed by UV fluorescence. Photographs were clarified by focal plane stacking as described previously (Soleglad et al., 2011). Summary statistics of variables were expressed as range, and mean  $\pm$  SD (standard deviation). Significance and P values were computed using the *t* test or Kolmogorov-Smirnov (K-S) test. Coordinates of some locality names on labels of materials collected by W. Büttiker were cross-checked against published locality data in Ahrens (2000), Collingwood (1985), and Lewis & Büttiker (1979).

## Taxonomic Characters

The taxonomic status of Arabian vs. Middle Eastern and North African *Leiurus* populations was left unsettled in previous studies due to variation in the characters that

were considered (Levy et al., 1970; Levy & Amitai, 1980; Sissom, 1994; Hendrixson, 2006). We introduced new morphometric and granulation characters that together were capable of resolving subtle differences between these populations. Variation in key characters is summarized in Tab. 3. Utility of certain characters was enhanced by restricting their scope to females. This unmasked species differences that were obscured by exaggerated character development in males. For example, males have strongly developed, granulated median carinae on sternite III, and large pectine teeth with long mid-pectine sensillar margins across all species. However, in females these characters could exhibit diagnostic differences between some species. Degree of overlap of basal pectine teeth of males with anterior pectine margins aligned to posterior margins of coxae IV (Vachon, 1979b) varied between species. Species were also separable by taking ontogenetic variation into account, and quantifying large scale variation of biometrics from many specimens. For example, we could differentiate two closely similar species with overlapping variation (*L. haenggii* sp. n. vs. *L. arabicus* sp. n.) by combining morphometric ratios describing slenderness of three segments (leg, pedipalp and metasomal segments) into a single variable  $F_s$  (Fig. 46). Relative size of pectine teeth in males or females was useful for separating some species from others (e.g. *L. brachycentrus* vs. *L. macroctenus* sp. n.) (Figs. 95B–D). To compare granulation, we took advantage of UV fluorescence imaging which highlights the fine details of cuticular surface topography (Prendini, 2003; Volschenk, 2005). This method enabled us to visualize systematic differences in granulation across *Leiurus* populations that proved useful for species diagnosis (Figs. 92–93). Characters based on cuticular granulation have been applied throughout the history of scorpion systematics, but always in a qualitative and subjective manner. By combining UV fluorescence with digital image analysis, we demonstrated how to precisely quantify intra- and interspecific variation in granulation for use as a diagnostic tool (Fig. 94). Trichobothriotaxy has also been useful for differentiating some *Leiurus* species. The proximal location of chela fixed finger *db* relative to *est* was applied to diagnose *L. nasheri* (= *L. brachycentrus*) and *L. abdullahbayrami* (Kovařík, 2007; Yağmur et al., 2009). However, we have also observed this character state in ca. 20% of *L. hebraeus* and *L. macroctenus* (Fig. 95A), so it should be applied in conjunction with other characters.

Some characters used to differentiate individual species appeared to be autapomorphies correlated with substrate specialization. The lithophilous *L. heberti* sp. n. is characterized by greater elongation of limbs and metasomal segments (Fig. 55), sparser basitarsal bristle combs (Tab. 3B, Fig. 56), and weaker, non-lobate dentition on ventrolateral carinae of metasoma V (Figs.

87–90E). Larger, denser bristle combs were developed in *L. macroctenus*, a species adapted to sandy substrates (Tab. 3B, Fig. 21). Metasoma V ventrolateral dentition was more robust and lobate in species that burrow in firmer substrates such as *L. abdullahbayrami* (Figs. 87–90A) and *L. haenggii* (Figs. 87–90D), than in those adapted to sandy substrates such as *L. arabicus* (Figs. 87–90B) and *L. macroctenus* (Figs. 87–90G). Coloration is also related to substrate and could be a useful character in some cases. Fuscous or dark carapace and tergites were observed mostly in *L. haenggii*, *L. jordanensis*, some *L. arabicus*, and female *L. heberti*, but never in *L. macroctenus* sp. n.. All examined material of *L. quinquestriatus* and *L. hebraeus* had light colored tergites. Specific color patterns can occur in *L. jordanensis* with fuscous tergites and metasoma I–V, *L. brachycentrus* with fuscous markings on legs and pedipalps, and lack of dark pigment on metasoma V (Figs. 1, 5, 91E) and *L. savanicola* with fuscous markings on body and appendages (Lourenço et al., 2006).

## Systematics

### Genus *Leiurus* Ehrenberg, 1828

*Androctonus* (*Leiurus*) Ehrenberg in Hemprich & Ehrenberg, 1828, pl. I, fig. 5; Hemprich & Ehrenberg, 1829: 353 (in part).

#### REFERENCES

*Androctonus* (*Liurus*): Hemprich & Ehrenberg, 1831 (in part); Sundevall, 1833: 33.  
*Leiurus*: Vachon, 1949: 83–88; Vachon, 1950a: 199–200, 202, figs. 550–552; Vachon, 1950b: 393, fig. 589; Vachon, 1952: 203–208, 372–374, 399, figs. 550–552; Bücherl, 1964: 57; Stahnke, 1972: 130; Lamoral & Reynders, 1975: 509; Levy & Amitai, 1980: 14, 46–47; Francke, 1985: 9, 15; Vachon & Kinzelbach, 1987: 92; Sissom, 1990: 101; Nenilin & Fet, 1992: 17; Kovařík, 1998: 112; Fet & Lowe, 2000: 155; Soleglad & Fet, 2003a: 26–27, tab. 2, fig. 44; Soleglad & Fet, 2003b: 88, 91, tab. 9; Fet et al., 2005: 10–12, tab. 1, fig. 23, 29; Prendini & Wheeler, 2005: 481; Hendrixson, 2006: 81–82; Dupré, 2007: 7; Kovařík, 2009: 24; El-Hennawy, 2009: 122.

TYPE SPECIES. *Androctonus* (*Leiurus*) *quinquestriatus* Ehrenberg, 1828.

ETYMOLOGY. Two subgenera of *Androctonus* were created by Ehrenberg: *Leiurus* (= ‘slender tail’), including species with more elongated metasomal segments, and *Prionurus* (= ‘saw tail’) including species with heavier metasomal segments bearing serrated carinae.

**DIAGNOSIS.** Medium to large bathids (Sissom, 1990), adults 51–115 mm; carapace and tergites with granulated carinae; carapace with distinct anterior, supraciliary, central median, central lateral, posterior median and posterior lateral carinae; central lateral and posterior median carinae fused into a lyre configuration; tergites I–II, VII with 5 carinae, III–VI with 3 carinae; metasoma elongate, metasoma I–III with 10 carinae, median lateral carinae complete on I, reduced on II–III; metasoma IV with 8 carinae; metasoma V with 7 carinae, dorsolateral carinae weak, ventrolateral carinae strong with serrate or lobate dentition; telson with bulbous vesicle lacking subaculear spine or tubercle; pectines with fulcra; chelicerae with characteristic bathid dentition (Vachon, 1963), two denticles on ventral aspect of fixed finger; pedipalps orthobothriotoxic, type A $\beta$  (Vachon 1974, 1975); pedipalp femur with trichobothrium  $d_2$  on dorsal surface, pedipalp patella with  $d_3$  internal to dorsomedian carina; chela smooth with carinae reduced or obsolete, dentate margins of fingers armed with linear subrows of primary denticles; subrows flanked by internal and external accessory denticles; movable finger with two enlarged subdistal internal denticles; males without scalloping at base of pedipalp fingers; tergites without macrosetae; tibial spurs present on legs III–IV; basitarsi I–III with regular series of macrosetae on retrosuperior, retroinferior and inferior margins; ventral surfaces of telotarsi with paired rows of macrosetae; prolateral and retrolateral tarsal spurs present on all legs. **Sexual dimorphism:** compared to females, males have a narrower mesosoma, more robust carination on tergites and sternites III–V, more slender pedipalps and metasoma, longer pectines with larger teeth, and weaker dentition or granulation on ventromedian carinae of metasoma II–III.

**SPECIES COMPOSITION.** The broad geographic range and morphological variation of *Leiurus* populations have caused difficulty for taxonomists. For a long time, the genus was assumed to be represented by a single polytypic species spread over a vast area, although different authors disagreed about the definition and validity of various subspecies. More recently, several distinctive species were described from widely disparate localities: *L. jordanensis* Lourenço et al., 2002, from sandstone cliffs isolated by dunes in Jordan and northern Saudi Arabia; *L. savanicola* Lourenço et al., 2006, from Sahel/ savannah in Cameroon; *L. nasheri* Kovařík, 2007, from the humid Tihamah coastal plain in Yemen (= *L. brachycentrus* (Ehrenberg, 1829) stat. n.); and *L. abdullahbayrami* Yağmur et al., 2009, from semi-arid rocky steppe in Turkey and northern Syria. Here we add four new species from the Arabian Peninsula: *L. haenggii* sp. n., from mountain ranges along the Red Sea coast (Hijaz and Asir) in Saudi Arabia, the Hadramaut in Yemen, and Dhofar mountains of Oman; *L. arabicus* sp.

n., from arid plains and wadis of the central Najd plateau, extending to the east coast of Saudi Arabia; *L. macroctenus* sp. n., from coastal fog desert of Jiddat al Harasis in Oman; and *L. heberti* sp. n. from rocky wadis of the Jabal Samhan mountains in Dhofar, Oman. In addition, we propose revised diagnoses for: *L. hebraeus* (Birula, 1908) stat. n. from semi-arid/ arid steppe habitats in Israel, Jordan and Syria; *L. brachycentrus* stat. n. from the Tihamah plain along the Red Sea coast of western Yemen and southwestern Saudi Arabia; and for the type species *L. quinquestriatus* from the Nile Valley and surrounding deserts in Egypt and Sudan, bringing the total number of included species to ten. Our findings show that, like many other scorpion genera, *Leiurus* is comprised of an assemblage of allopatric or parapatric species spread across different regions separated by physiographic barriers, each adapted to local environments and substrates. Additional species diversity may emerge when other local populations are analyzed in more detail, for example those in southern Sinai, and in more central parts of North Africa.

#### Key to adult *Leiurus* species examined in this study

- 1 Medial intercarinal surfaces of tergites II–III smooth or sparsely, lightly shagreened ..... 2  
Medial intercarinal surfaces of tergites II–III heavily or densely, finely shagreened ..... 4
- 2 Males with metasoma III L/W > 2.10, metasoma IV L/W > 2.50; metasoma III ventromedian carinae with > 35 denticles ..... *L. heberti* sp. n.  
Males with metasoma III L/W < 2.10, metasoma IV L/W < 2.50; metasoma III ventromedian carinae with < 35 denticles ..... 3
- 3 Females with pedipalp patella L/W > 3.20,  $F_s$  > 23; female sternites III–IV with weak to moderate median carinae ..... *L. arabicus* sp. n.  
Females with pedipalp patella L/W < 3.20,  $F_s$  < 23; female sternites III–IV with weak to obsolete median carinae ..... *L. haenggii* sp. n.
- 4 Male pectines with mid-pectine sensillar margin L/ metasoma I W > 0.20 ..... 5  
Male pectines with mid-pectine sensillar margin L/ metasoma I W < 0.20 ..... 6
- 5 Female pectines with mid-pectine sensillar margin L/ metasoma I W > 0.15 ..... *L. macroctenus* sp. n.  
Female pectines with mid-pectine sensillar margin L/ metasoma I W < 0.15 ..... *L. brachycentrus* (Ehrenberg, 1829) stat. n.
- 6 Metasoma III ventromedian carinae with > 30 denticles; metasoma I–IV uniformly fuscous ..... *L. jordanensis* Lourenço, Modrý et Amr, 2002

- Metasoma III ventromedian carinae with < 30 denticles; metasoma I–IV yellow to yellow-orange.... 7
- 7 Sternite VII with medial intercarinal surface smooth ..... *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009  
Sternite VII with medial intercarinal surface shagreened ..... 8
- 8 Carapace with anteromedian intercarinal surface smooth or sparsely shagreened; posterior median furrow of carapace shallow or flat, lateral granule arcs reduced or absent; females with pectine basal piece heavily shagreened, median carinae of sternites IV–V moderate, usually granular; males with pedipalp patella L/W > 3.1, metasomal segment L/W: II > 1.55, III > 1.7, IV > 2.05 .....  
..... *L. quinquestriatus* (Ehrenberg, 1828)  
Carapace with anteromedian intercarinal surface shagreened; posterior median furrow of carapace moderately deep, flanked by lateral granule arcs; females with pectine basal piece smooth or lightly shagreened, median carinae of sternites IV–V weak, smooth or obsolete; males with pedipalp patella L/W < 3.1, metasomal segment L/W: II < 1.55, III < 1.7, IV < 2.05 ... *L. hebraeus* (Birula, 1908) **stat. n.**

***Leiurus brachycentrus* (Ehrenberg, 1829)**  
**stat. n.**

(Figs. 1–11, 59E–F, 87C, 88C, 89C, 90C, 91E, 92G, 93G, 95, 98–100, Tab. 3B)

*Androctonus (Leiurus) quinquestriatus brachycentrus*  
Ehrenberg, 1829: 353–354.

**SYNONYMS**

*Buthus beccarii* Simon, 1882: 246–248, pl. VIII, fig. 19.  
*Leiurus nasheri* Kovařík, 2007: 137–141, tab. 1, figs. 1–8; **syn. n.**

**REFERENCES**

- Androctonus (Leiurus) quinquestriatus brachycentrus*: Gervais, 1844: 46; Braunwalder & Fet, 1998: 33.  
*Buthus beccarii*: Simon 1890: 122.  
*Buthus quinquestriatus*: Kraepelin, 1891: 58–60 (in part); Thorell, 1893: 359–360 (in part); Kraepelin, 1899: 27–28 (in part); Werner, 1934: 269 (in part);  
*Buthus quinquestriatus brachycentrus*: Birula, 1908: 126; Birula, 1910: 118; Borelli, 1915: 461; Birula, 1937: 102–105; Moritz & Fischer, 1980: 311.  
*Buthus (Buthus) 5-striatus brachycentrus*: Birula, 1910: 171; Birula, 1917a: 228.  
*Leiurus quinquestriatus brachycentrus*: Vachon 1966: 211; Levy, Amitai & Shulov, 1970: 231–233, 240; Pérez, 1974: 24; El-Hennawy, 1992: 126.  
*Androctonus quinquestriatus brachycentrus*: Vachon, 1979a: 50; Lourenço, Modrý & Amr, 2002: 637; Lourenço, Qi & Cloudsley-Thompson, 2006: 98.

*Leiurus quinquestriatus hebraeus*: Levy & Amitai, 1980: 48–53 (in part).

*Leiurus quinquestriatus*: El-Hennawy, 1992: 101, 125–126 (in part); Sissom, 1994: 20–23 (in part); Braunwalder & Fet, 1998: 33; Kovařík, 1998: 112 (in part); Fet & Lowe, 2000: 155 (in part); El-Hennawy, 2009: 122 (in part).

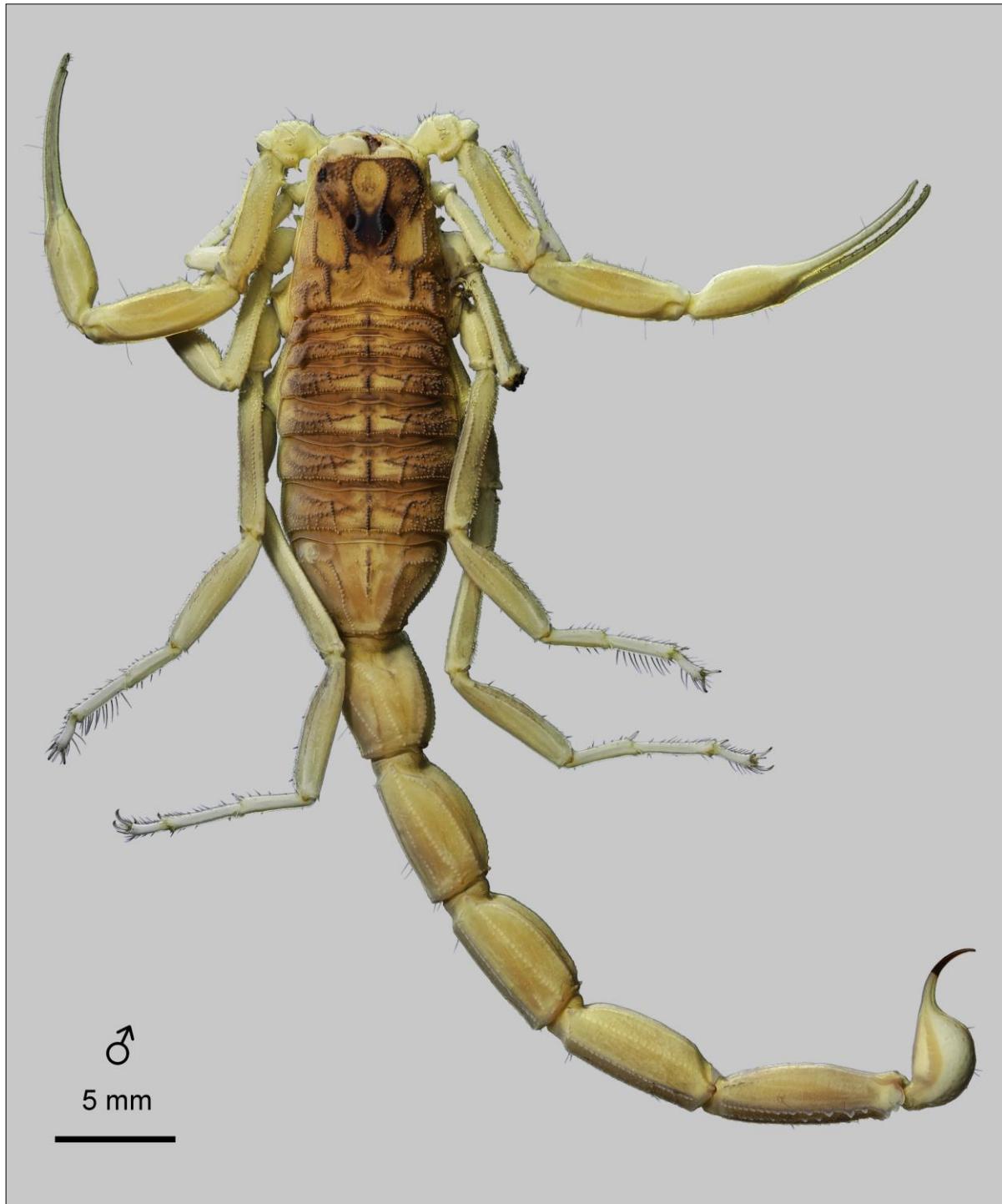
*Leiurus nasheri*: Yağmur et al., 2009: 1, 5, 7–8.

**TYPE MATERIAL.** Holotype ♂, **Yemen**, “Lohaie” (= Al Luhayyah: 14°42.53'N 43°12'E), 1824–1825, leg. F.W. Hemprich & C.G. Ehrenberg (ZMHB No. 141) (examined); 4 ♀ (holotype and paratypes of *Leiurus nasheri*), 10 km W of Al Mansuriah, Al Hudaydah, 14°43'N 43°12'E, 110 m a.s.l., 8.IV.2007, leg. P. Kabátek & D. Král (FKCP) (examined).

**OTHER MATERIAL EXAMINED.** **Saudi Arabia:** 1 ♂, Ad Darb, 17°43'22"N 42°15'09"E, 70 m a.s.l., 10.IV.1979, leg. W. Büttiker (NHMB 17ag). **Yemen:** 2 ♀ Ta'izz gov., 28.X.2007, N of Al Makha by road, 13°23'37"N 43°16'22"E, 5 m a.s.l. (locality No. 7), 2 ♀, leg. D. Král (FKCP).

**ETYMOLOGY.** The name refers to the telson which is relatively robust compared to that of *L. quinquestriatus*, with an aculeus that in males is clearly shorter than the vesicle.

**DIAGNOSIS.** Small to medium sized *Leiurus*, 60–72 mm in length, carapace L 6.3–8.0 mm; base color yellow; legs, pedipalps, metasoma and telson with pattern of fuscous markings; metasoma V without dark pigment except on carinae; carapace with anterior median carinae extending to anterior marginal granule row; area of carapace between anterior median carinae lacking dark pigment, with sparse, fine granules, area between posterior median carinae with shallow median furrow, nearly flat, flanked by lateral arcs of fine granules; medial intercarinal surfaces of tergites II–III with dense, coarse to fine granulation; posterior margin of coxa III with row of small granules; metasoma moderately slender, metasoma II L/W 1.51–1.66, metasoma III L/W 1.66–1.83, metasoma IV L/W 2.03–2.19; ventromedian carinae of metasoma II and III with 14–16 denticles; metasoma V with enlarged subtriangular or lobate denticles on ventrolateral carinae; pedipalps moderately slender, patella L/W ♂ 3.00–3.25, ♀ 2.72; leg III patella L/D 2.72–3.25; pectine teeth ♂ 31–35, ♀ 25–28; pectines medium sized, very broad in males, pectine L/carapace L ♂ 1.18, ♀ 0.96, mid-pectine sensillar margin L/metasona I W ♂ 0.210–0.234, ♀ 0.115; basal 6 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece very lightly, finely shagreened, nearly smooth; leg III basitarsus with 11–15 retrosuperior setae; pedipalp

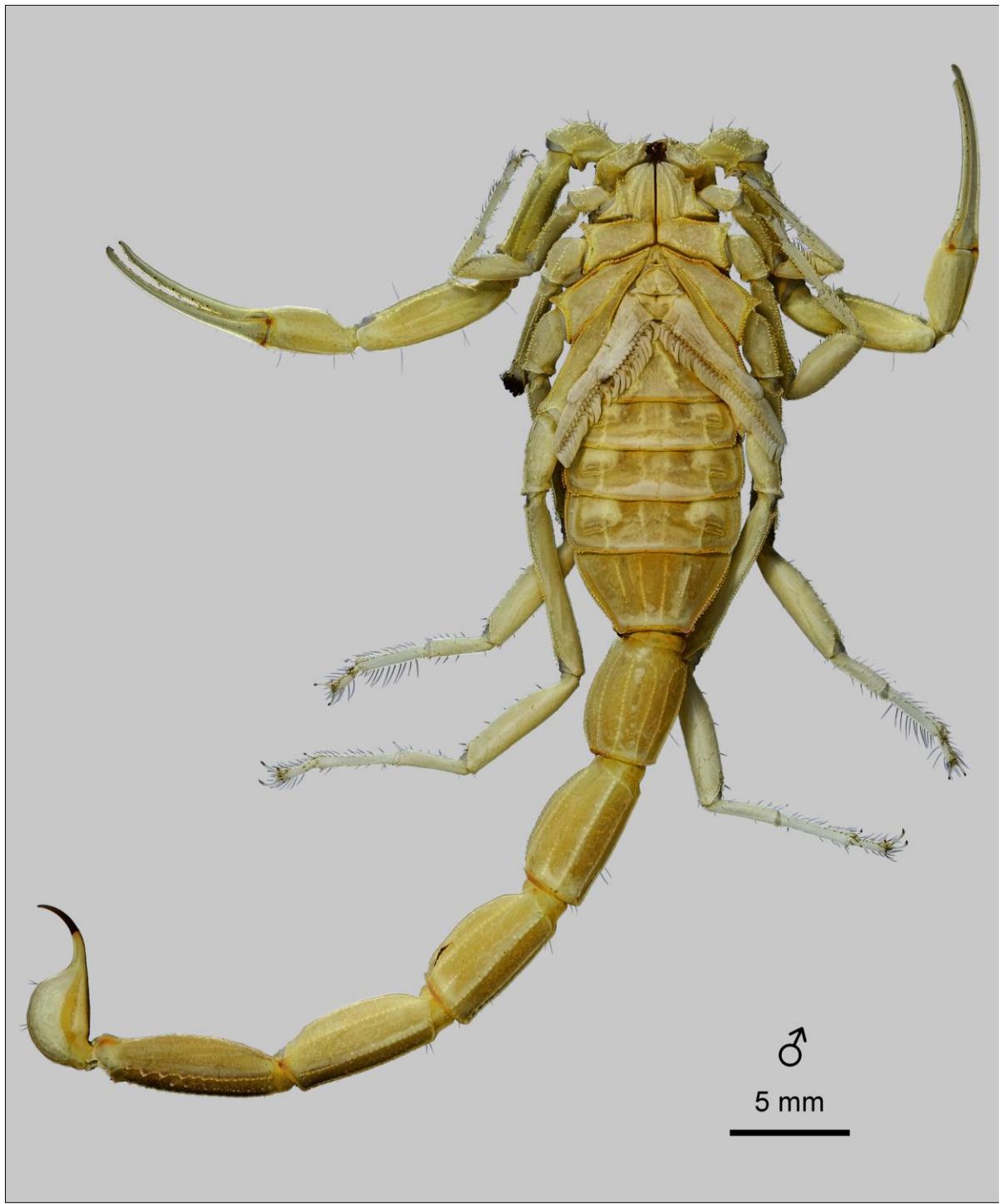


**Figure 1:** *Leurus brachycentrus* (Ehrenberg, 1829) stat. n., male. Habitus, dorsal aspect. Ad Darb, Saudi Arabia (NHMB 17ag).

chela fixed finger with trichobothrium *db* proximal to *est*; sternite VII with area between median carinae smooth in females, densely, finely shagreened in males; sternite carination: *males*, sternite III with median carinae strong, sternites IV–V with lateral carinae strong, median carinae weak; *females*, sternite III with median

carinae obsolete, sternites IV–V with lateral carinae very weak, median carinae obsolete.

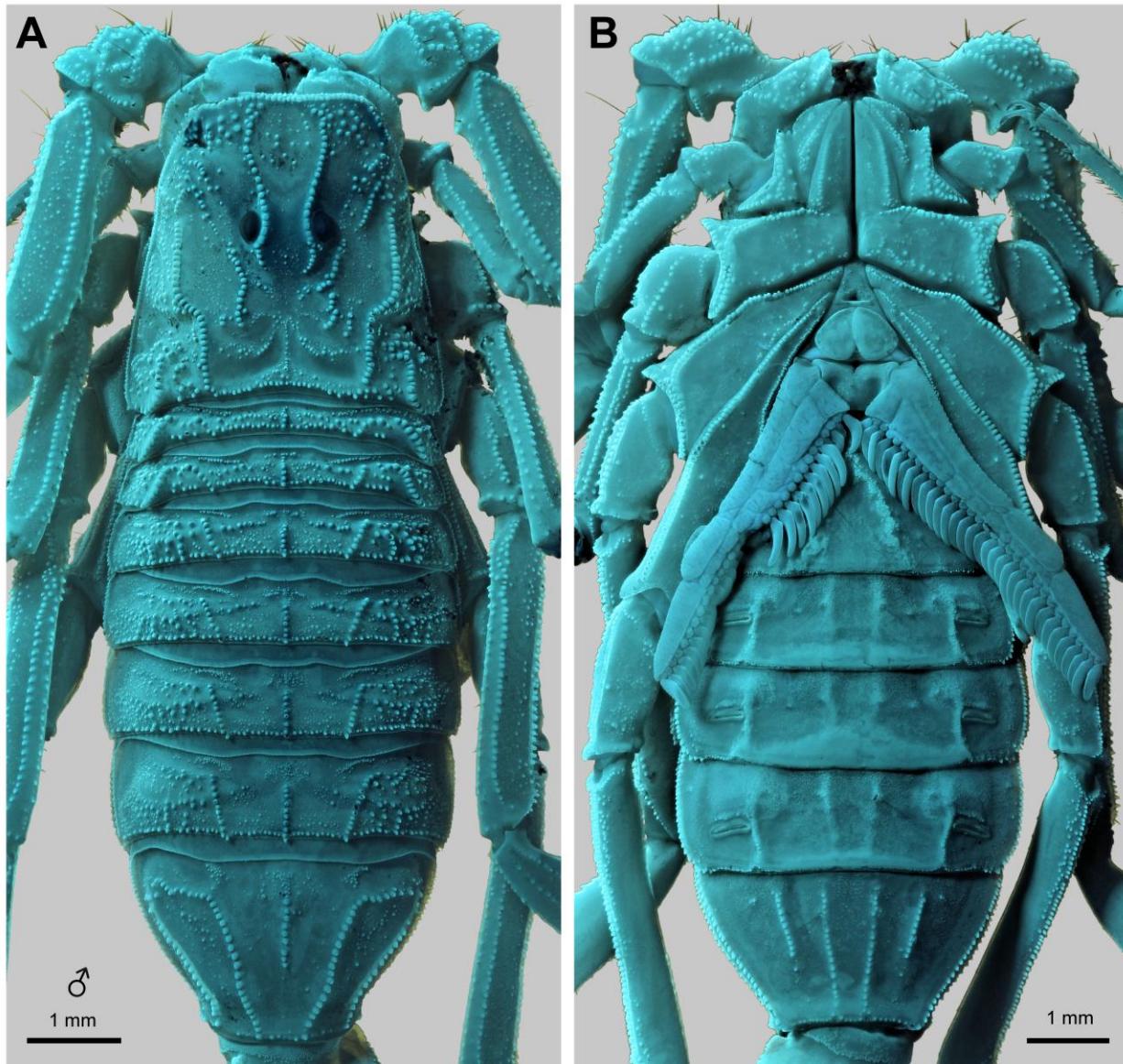
COMPARISONS. *L. brachycentrus* stat. n. is differentiated from other *Leiurus* by a combination of small size, distinctive color pattern, granular medial intercarinal surfaces of tergites II–III, proximal position of chela tri-



**Figure 2:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., male. Habitus, ventral aspect. Ad Darb, Saudi Arabia (NHMB 17ag).

chobothrium *db* relative to *est*, large male pectine teeth, morphometrics of pedipalp, legs and metasoma, and sternite carination. Among the Arabian species, *L. macroctenus* sp. n. is most similar in its morphometrics, large male pectine teeth, weak or obsolete carinae on

sternites III–V in females, and *db* basal to *est* in a minority of specimens. It differs by its larger size, darker fuscous pigment on metasoma V, larger numbers of setae on basitarsal bristle combs, higher pectinal tooth counts, and larger female pectine teeth. *L. savanicola*



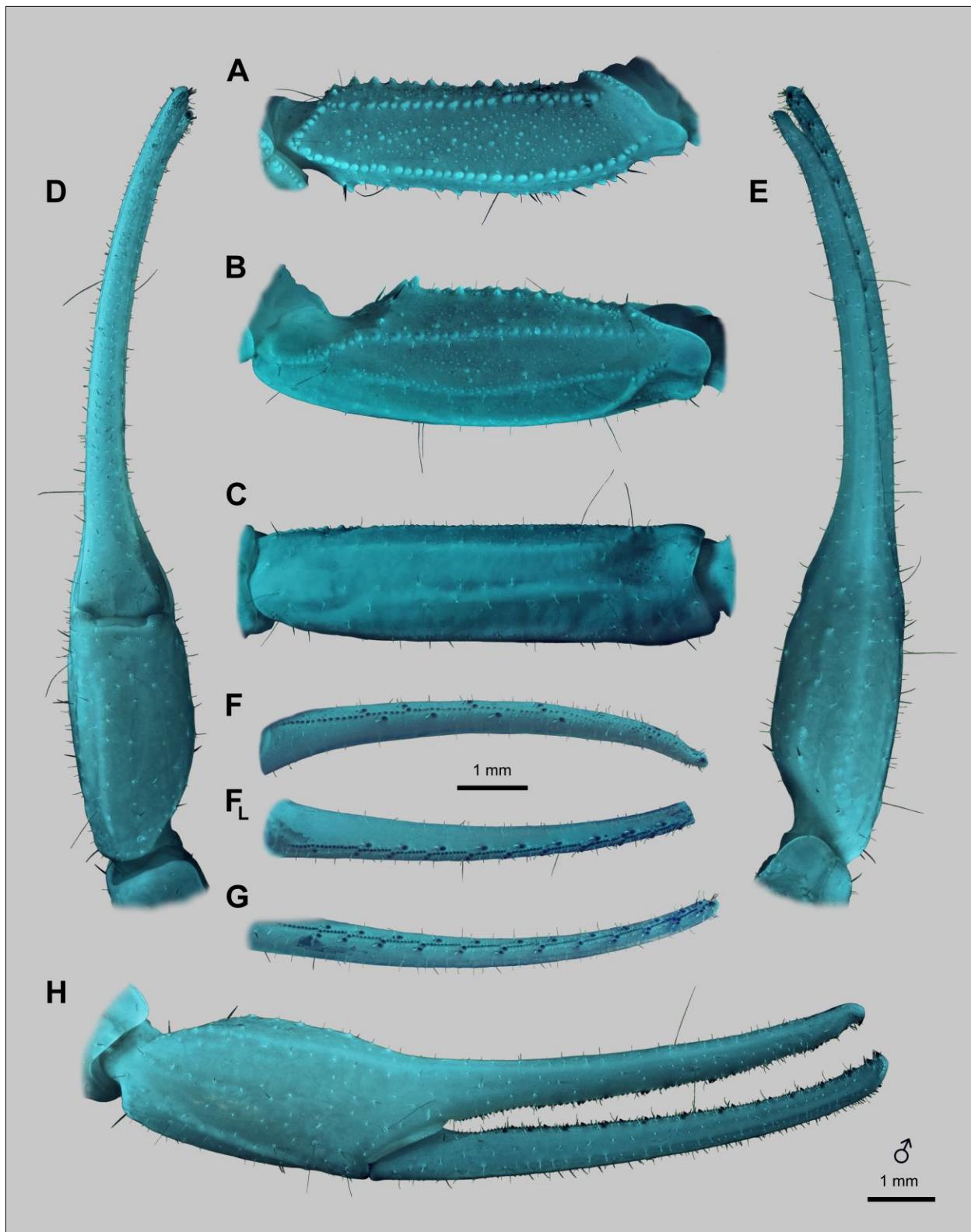
**Figure 3:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Ad Darb, Saudi Arabia (NHMB 17ag).

from northern Cameroon is another small to medium sized species with maculate pigmentation. It differs in having darker fuscous pigment on metasoma V, distal position of *db* relative to *est*, and uniform serrate dentition on ventrolateral carinae of metasoma V.

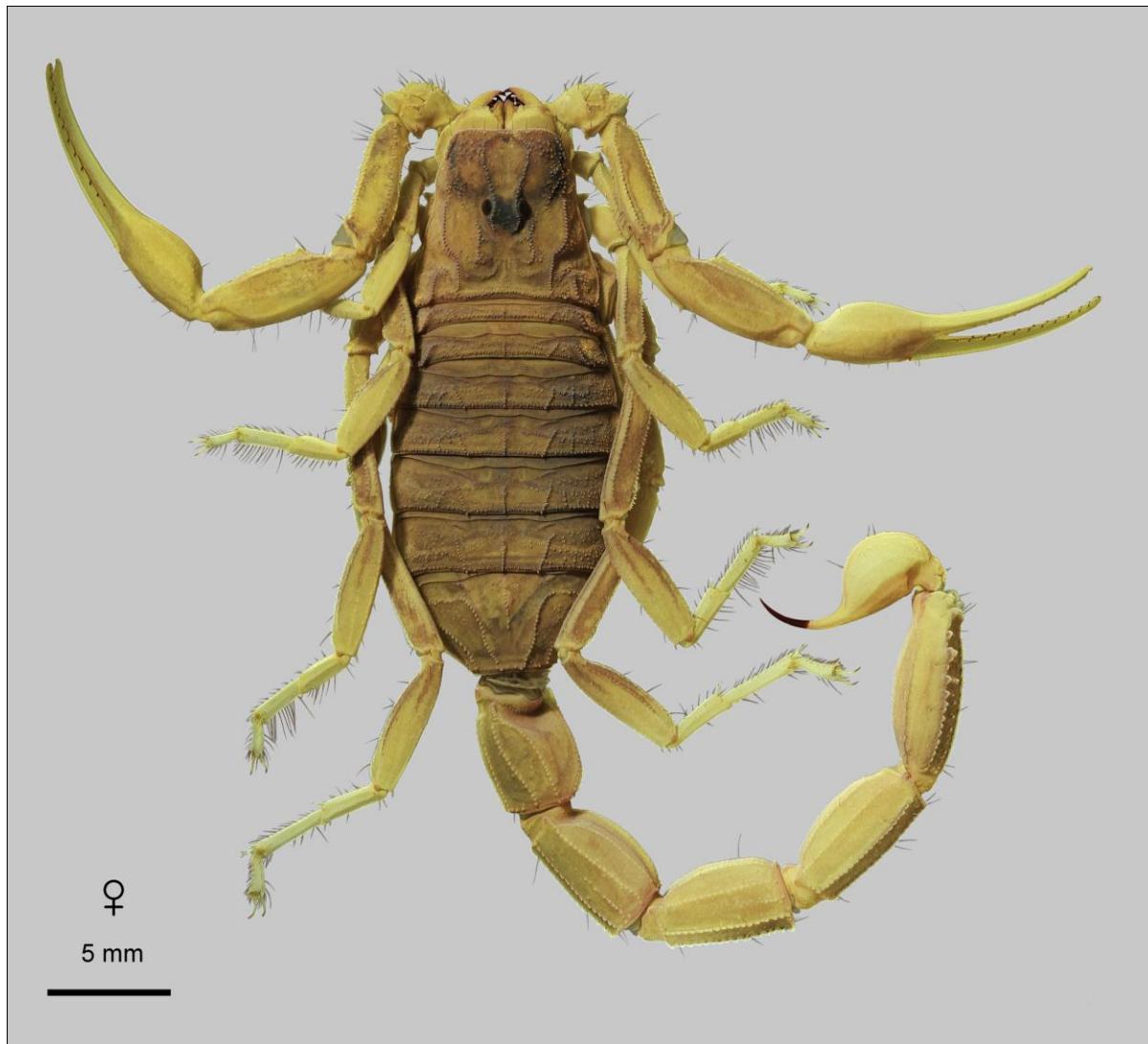
#### REDESCRIPTION (adult male, Ad Darb).

**Coloration.** Base color yellow, with distinctive pattern of fuscous markings; carapace with dark pigment on median ocular tubercle, fuscosity extending forward on lateral interocular triangle external to anterior median carinae, and on central median, central lateral, lateral ocular, posterior median and posterior lateral carinae; medial areas between anterior median, central median

and posterior median carinae yellow; pretergites lightly fuscous, with darker medial band flanked by pale spots in some segments; tergites I–VI with darkly marked median and lateral carinae, and fuscous anterolateral areas, posterior median areas yellow; tergite VII with fuscosity underlying median and inner lateral carinae; metasoma I–VI yellow with variable dark pigment on ventromedian and ventrolateral carinae, more intense posteriorly; metasoma V yellow to yellow-brown, with variable dark pigment on ventromedian, ventrosubmedian, ventrolateral and dorsolateral carinae; pedipalp femur and patella with faint to moderate fuscosity on dorsal and internal surfaces, external surface lighter; pedipalp chela with weak or very faint fuscosity on



**Figure 4:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., male. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **F<sub>L</sub>.** Fixed finger dentition, left chela. **G.** Movable finger dentition. **H.** Chela, external aspect. Ad Darb, Saudi Arabia (NHMB 17ag).



**Figure 5:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., female. Habitus, dorsal aspect. Al Mansuriah, Yemen.

manus; femur of all legs with faint to moderate fuscosity on distal 2/3 of prolateral surface and retrosuperior carina; tibia of all legs with band of faint to moderate fuscosity on proximal 1/2 of inferior prolateral surfaces and superior prolateral carina.

**Carapace.** Subrectangular, W/L 1.03, with steeply sloped lateral flanks; upper surface with posterior and medial plateau areas, moderately raised ocular tubercle; interocular triangle convex laterally, weakly depressed medially; anterior margin straight, entire width bearing fine granules or denticles, bordered by row of large granules; 10 medium to long macrosetae on anterior margin, carapace otherwise devoid of macrosetae; 5 lateral eyes (3 large, 2 small) on each side; *carination*: anterior median, superciliary, central lateral, posterior median and posterior lateral carinae strong, coarsely

granular; granules of anterior median carinae extend forward continuously, contacting anterior marginal row of granules; central lateral and posterior median carinae fused into lyre configuration; central median carinae coarsely granular, anterior portion linear and angled outward, posterior portion outwardly curved; posterior lateral carinae strong, caudal end extended laterally and downward, projecting past posterior margin of carapace; lateral ocular carinae weak or moderate, with smaller granules; *granulation*: sparse patches of 10–15 large granules on each anterolateral corner of interocular triangle, 10–13 small granules on area on front of lateral ocular carinae; surface between anterior median carinae micro-shagreened with scattered small granules; lateral flanks with moderately dense cover of medium and fine granules; other intercarinal surfaces finely shagreened

with scattered small granules; posterior median furrow shallow, almost flat, with median line of fine granules or microgranules, flanked by lateral arcs of small granules; posterior margin of carapace between posterior lateral carinae bordered by row of medium to small granules.

**Chelicera.** Dorsal surface of manus smooth to slightly shagreened, with 4 short, pale microsetae, 2 near apical margin, 2 subapical, each surrounded by granules; dorsointernal carina at base of fixed finger moderately strong with small granules proximally, terminating distally in prominent granules projecting over front of manus; single macroseta in middle of dorsointernal carina; dorsal surface of movable finger smooth, with 4 pale microsetae; fingers with characteristic buthid dentition (Vachon, 1963); movable finger dorsal margin with 5 teeth; dorsal distal tine, subdistal, median and 2 basal teeth fused in bicusp; ventral margin with 3 teeth: ventral distal tine, median and basal teeth; fixed finger margin with 4 teeth: distal tine, subdistal, median and basal teeth; ventral aspect of fixed finger with 2 teeth.

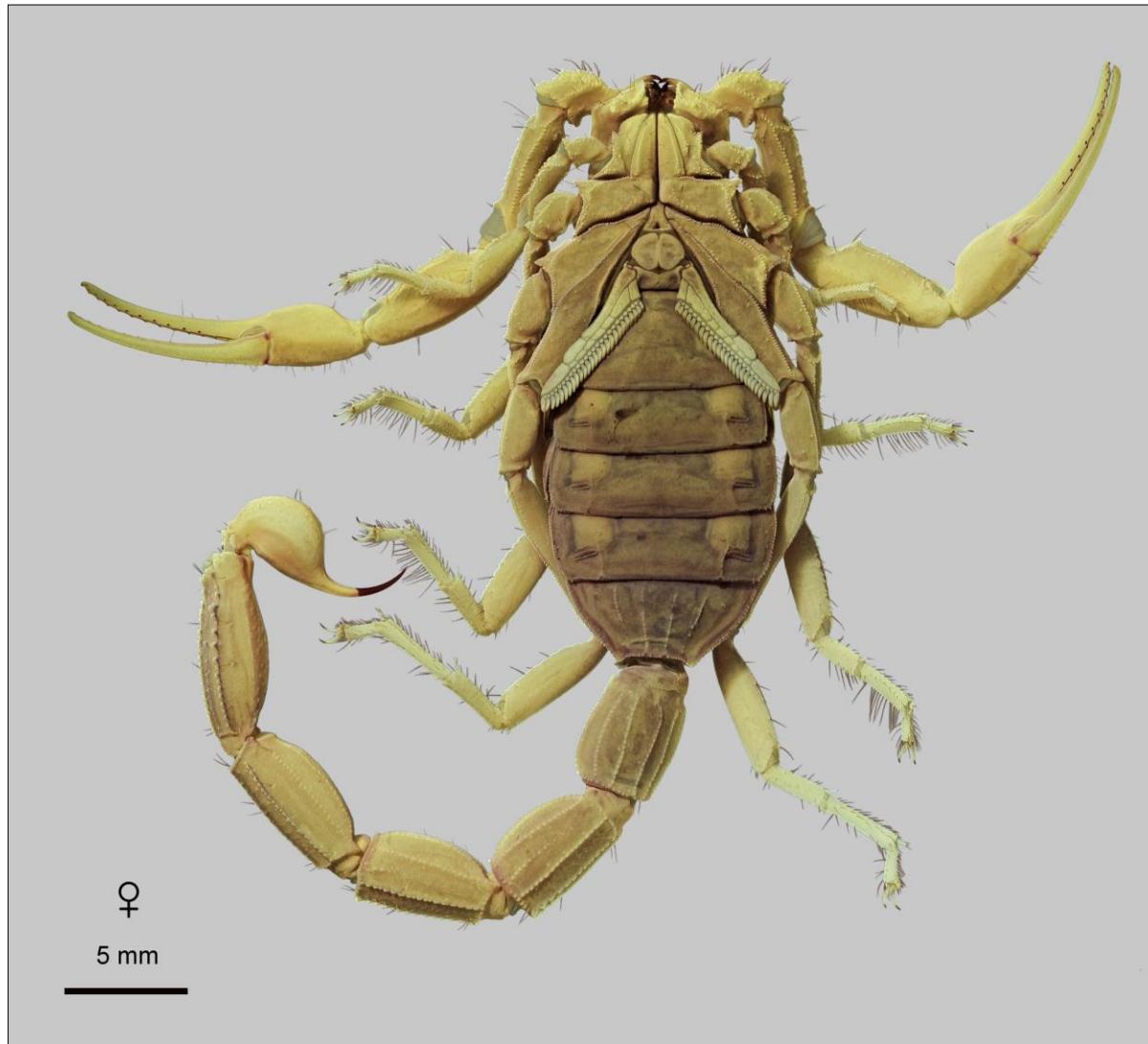
**Coxosternal area.** Coxa I coarsely granulated, II with sparse medium or fine granules, III lightly shagreened or smooth except for proximal series of medium to small granules along posterior margin, IV lightly shagreened with several isolated medium granules; coxal endite II with strong, coarsely granulated carina; coxae II–III with medium to coarse granulation on anterior carinae, distal margins bearing coarse granules; proximal 1/3 of anterior carina of coxa III with medium tuberculate granulation; 3 macrosetae along anterior carinae of coxae II–III; anterior carina of coxa IV with regular medium to coarse granulation, with single proximal macroseta; posterior margin of coxa IV with finely granulated carina on proximal half; sternum weakly granulated, subtriangular with straight lateral margins, deep posteromedian pit, 2 short macrosetae; genital opercula smooth with 3 short macrosetae, posterolateral margins convex.

**Pectines.** Basal piece with concave anterior margin and small median groove and pit, slightly roughened, bearing 3 macrosetae; pectines broad, tips extending to proximal 1/3 to 1/2 of coxa IV; combs with 3 marginal lamellae, left comb with small accessory lamella distal to first marginal lamella, 8–9 middle lamellae, 31–33 teeth; basal middle lamella with proximal margin extended, protruding, 1.30–1.35 times longer than distal margin; marginal and middle lamellae with moderate cover of short reddish macrosetae; fulcra with 3–8 setae; pectine teeth relatively large, mid-pectine sensillar margin L/ pectine L 0.112, mid-pectine sensillar margin L/ metasoma I W 0.210.

**Mesosoma.** *Tergites:* pretergites smooth; tergites I–II with 5 granular carinae; median and inner lateral carinae linear with medium to coarse granules; outer lateral carinae aligned with posterior lateral carinae of carapace, angled outward, very strong with large, uni-

form granules, hind ends extending past posterior margins of tergites, without lateral extensions; medial intercarinal surfaces densely granulated, with small to medium granules, and shagreened; lateral flanks moderately sloped, heavily granulated; tergites III–VI with 3 straight coarsely granulated carinae; medial intercarinal surfaces finely granulated or shagreened; short transverse anterior series of granules present on III–IV, obsolete on V–VI; tergites III–VI with fine granulation on anterior median patch and short transverse strips on either side; lateral surfaces of III–VI moderately sloped, heavily granulated, III with short longitudinal rows of granules; tergite VII with 5 strong, granular carinae; inner and outer lateral carinae joined anteriorly by transverse granule rows; medial intercarinal surfaces smooth; patches of fine granulation on anterior ends of median and lateral carinae; posterior margins of tergites I–VI rimmed with linear rows of small to medium sized granules; posterior margin of tergite VII with 3 small granules between inner lateral carinae, and 1–2 small granules laterally; *sternites:* sternite III with median carinae strong, thick, finely granulated; sternites IV–VI with moderate to strong, finely granulated lateral carinae, weak, finely granulated median carinae; sternite VII with strong, crenulate-granulate median and lateral carinae; lateral margins of sternites IV–VII armed with fine, regular denticulate granules; medial intercarinal surface of III finely shagreened; medial and mediolateral intercarinal surfaces IV–V finely shagreened anteriorly, smooth posteriorly, VI finely shagreened except for posterior margin, medial intercarinal surface of VII finely shagreened anteriorly, smooth posteriorly; lateral intercarinal surfaces of III smooth or very weakly, finely shagreened, IV–VI shagreened anteriorly, smooth posteriorly; mediolateral and lateral surfaces of VII sparsely, finely shagreened; *setation:* sternite III with 5 macrosetae on median carinae (one shared), single small setae on areas external to median carinae; sternites IV–VII with 2 paired macrosetae on median carinae, one pair in middle of sternite, other on posterior margin; lateral carinae on IV–VI with single posterior marginal macroseta; intercarinal macrosetae: one pair of lateral marginal setae, one outer pair of mediolateral setae on IV–VI, one pair of lateral setae on VII; intercarinal posterior marginal macrosetae on III–VII: 4, 3, 3, 0, 0.

**Metasoma.** Moderately long, slender, total metasoma and telson L/ carapace L 6.29; *carination:* segment I with 10 complete carinae; segments II–III with 8 complete carinae, median lateral carinae restricted to posterior 0.34–0.50 of II, posterior 0.22 of III; metasoma IV with 8 carinae, V with 7 carinae; carinae on segments I–IV crenulate-granulate; dorsosubmedian carinae moderate on I–III, weak on IV; dorsolateral carinae moderate on I–IV, ventrolateral carinae moderate to strong; median lateral carinae granulate, moderate on I–III; ventromedian carinae moderate on I–IV, crenulations on



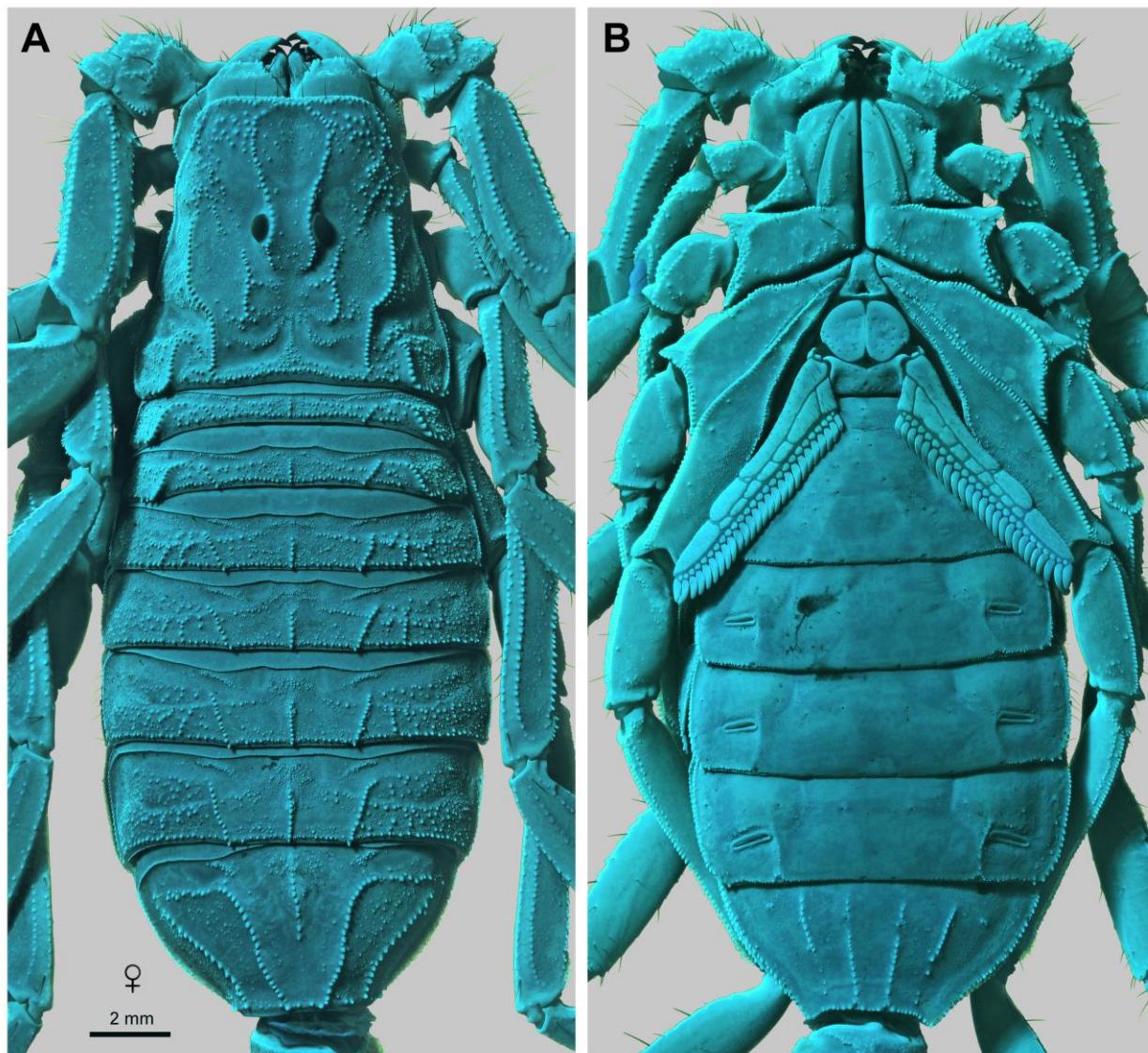
**Figure 6:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., female. Habitus, ventral aspect. Al Mansuriah, Yemen.

II–III very weak anteriorly; 14–20 granules on ventromedian carinae of metasoma II–III; metasoma V with dorsolateral carinae very weak, faintly granulated, ventrolateral carinae strong, with blunt subtriangular denticles increasing in size posteriorly, ventrosubmedian carinae marked by series of non-contiguous small to large dentate granules along anterior 5/8 of ventral surface, ventromedian carina strong, with closely spaced medium to large rounded, dentate granules increasing in size posteriorly; lateral anal margin with 3 blunt lobes divided by deep incisions, ventral anal margin with 9 irregular, narrow to wide transverse crenulations; *intercarinal surfaces*: segments I–IV smooth to lightly shagreened, segment V lightly shagreened dorsally and laterally, more densely shagreened ventrally; *setation*: segments I–IV: ventromedian carinae with 3 macrosetae (one posterior marginal), ventrolateral carinae with 2

macrosetae slightly external to carina; metasoma V with 5 macrosetae on lateral surface (2 lateral anal), 4 pairs on ventral surface.

**Telson.** Vesicle smooth, rather elongate with steep posterior slope; ventral surface bearing scattered fine microsetae and several short macrosetae with associated shallow indentations; aculeus shorter than vesicle.

**Pedipalp.** *Femur*: moderately slender, L/W 3.54; dorsoexternal, dorsointernal and ventrointernal carinae strong with coarse, closely spaced dentate granules; internal carina strong, with irregular small and large dentate granules; external carina weak to moderate, with well spaced coarse dentate granules; external surface smooth, other intercarinal surfaces lightly shagreened; linear cluster of 14–15 accessory macrosetae on lower distal external surface; *patella*: moderately slender, L/W 3.25; dorsointernal carina strong with coarse granulation;

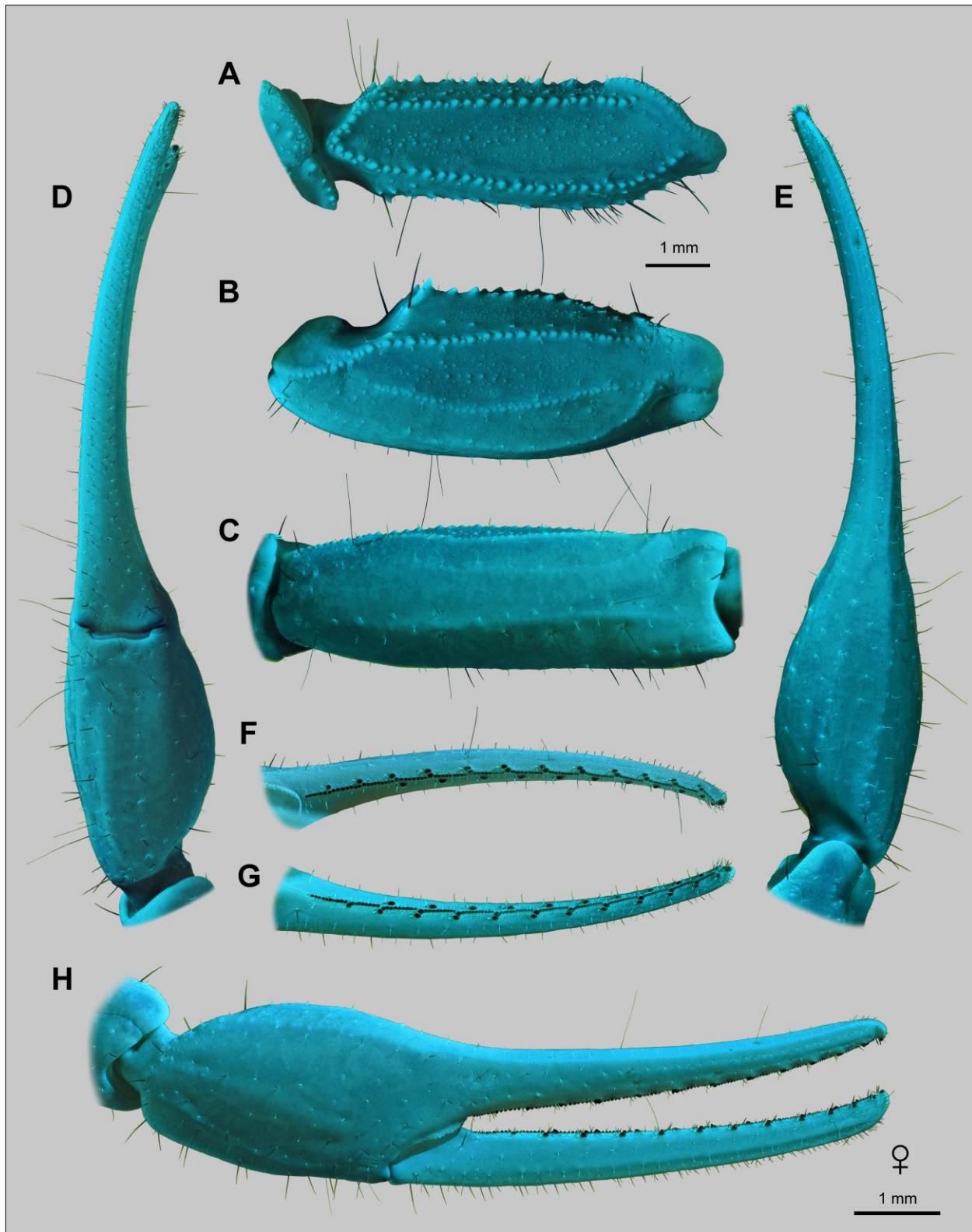


**Figure 7:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Al Mansuriah, Yemen.

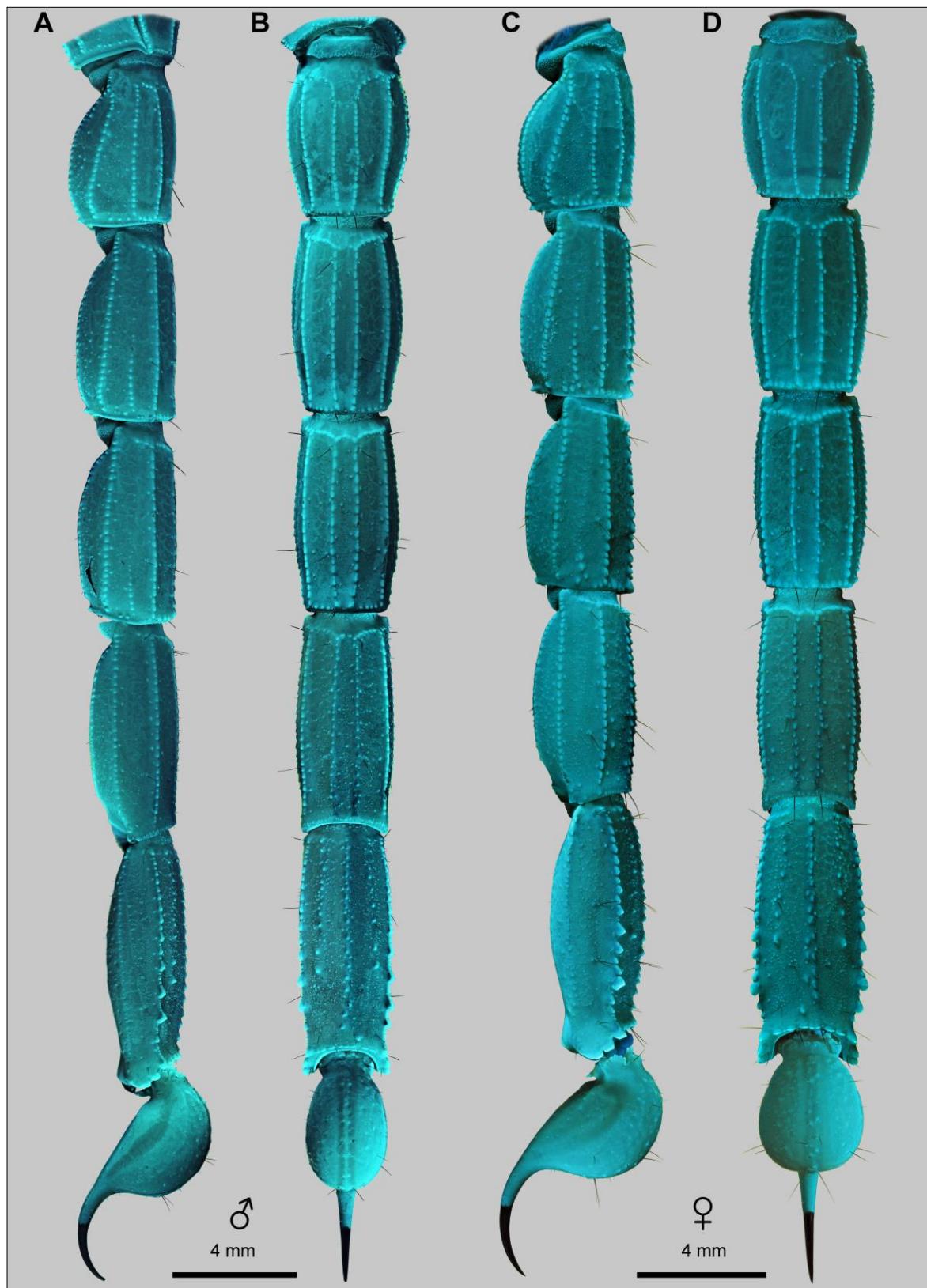
dorsomedian carina moderate with fine granulation; dorsoexternal carina very weak, almost smooth; external carina weak, smooth; ventroexternal carina weak, almost smooth; ventromedian carina weak with fine granules; ventrointernal carina strong, with well spaced medium granules and ventral patellar spur; internal carina strong with large dentate granules interspersed with medium granules and dorsal patellar spur; external surfaces smooth, other intercarinal surfaces very lightly sha-greened; *chela*: slender, L/W 6.09, fingers relatively short, movable finger L/ manus ventral L 1.93; dorsal internal carina weak to obsolete, marked by few isolated granules on manus; dorsal marginal carina weak, with faint granulation at base of manus; external secondary carina weak, smooth; ventroexternal carina moderate,

smooth; other carinae obsolete; all intercarinal surfaces smooth; manus and fixed finger with sparse short macrosetae; movable finger with numerous short macrosetae on ventral aspect, culminating in dense subapical brush; 12 primary denticle subrows on movable fingers, fixed fingers damaged or with anomalous dentition; all subrows except proximal flanked by internal and external accessory denticles. *Trichobothriotaxy*: ortho-bothriotaxic, type A $\beta$  (Vachon, 1974), *db* on fixed finger proximal to *est*.

**Legs.** Moderately elongated, femur III L/ carapace L 1.09, patella III L/D 3.58; inferior carinae strongly denticulate on femur I–IV, moderately denticulate on patella I–III, weakly denticulate on patella IV; tibia III–IV with long spurs; retrolateral tarsal spurs simple, non-



**Figure 8:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., female. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **G.** Movable finger dentition. **H.** Chela, external aspect. Al Mansuriah, Yemen.



**Figure 9:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n.. Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Male, Ad Darb, Saudi Arabia. Female, Al Mansuriah, Yemen.



**Figure 10:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., male. Tarsi. **A–D.** Left telotarsus and distal basitarsus, ventral aspect. **A.** Leg I. **B.** Leg II. **C.** Leg III. **D.** Leg IV. **E.** Right basitarsus III retrolateral aspect. Upper scale bar: **A–D**, lower scale bar: **E.** Ad Darb, Saudi Arabia (NHMB 17ag).

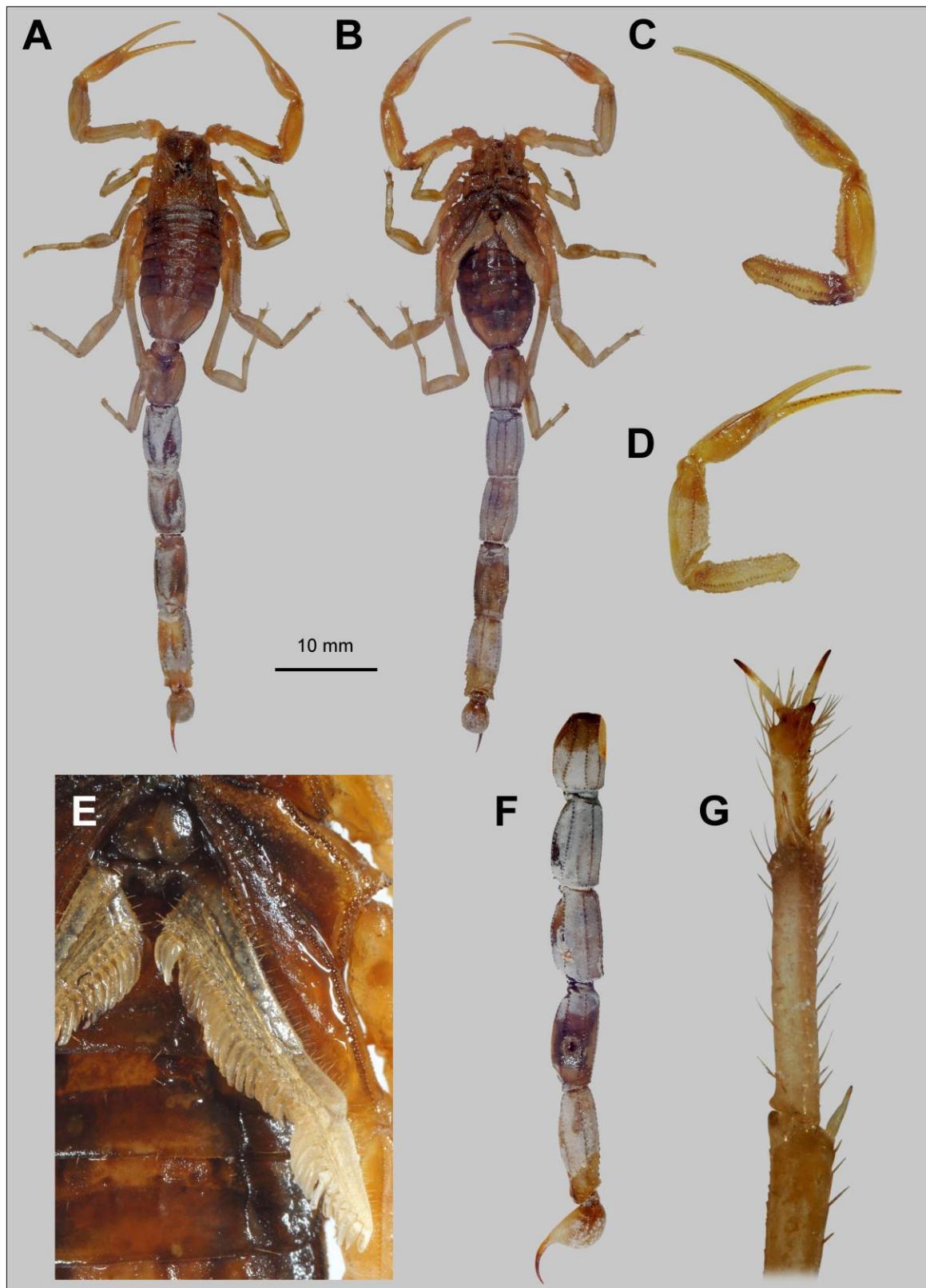
setose; prolateral tarsal spurs basally bifurcate, bearing 1–3 macrosetae (1 on I–II, 2 on III, 2–3 on IV); basitarsi I–III with well developed bristle-combs, clearly wider than basitarsal segment; basitarsus III setal counts (left/right): retrosuperior 13/11, retroinferior 11/11 (including basal accessory seta), inferior 12/12; ventral surface of telotarsi with long, slender tapered macrosetae.

**Measurements of male from Ad Darb (NHMB 17ag) (mm).** Total L 59.50; metasoma + telson L 40.00; carapace L 6.36, W 6.54, carapace preocular L 2.75; metasomal segments (L/ W /D) I 4.99/ 4.00/ 3.53, II 6.02/ 3.63/ 3.27, III 6.28/ 3.44/ 3.12, IV 7.02/ 3.20/ 2.92, V 7.74/ 3.11/ 2.58; telson L 6.75; vesicle L 3.87, W 2.58, D 2.65; pedipalp chela L 11.27, manus ventral L 3.78, manus W 1.85, manus D 2.25, fixed finger L 6.49, movable finger L 7.31; pedipalp femur L 5.93, W 1.68, patella L 6.79, W 2.09; pectine L 7.52, mid-pectine sensillar margin L 0.841; leg III femur L 6.97; leg III patella L 5.89, D 1.65.

**Measurements of holotype male (ZMHB No. 141) (mm).** Total L 61.0; carapace L 6.8, W 7.0, metasomal segments (L/ W /D) I 5.30/ 4.30/ 3.50, II 6.15/ 3.90/ 3.45, III 6.50/ 3.75/ 3.40, IV 7.05/ 3.35/ 3.30, V 7.90/ 3.30/ 3.00; telson L 6.90; vesicle L 4.20, W 2.85, D 2.75; pedipalp chela L 10.80, manus ventral L 3.90, manus W 2.20, manus D 2.20, fixed finger L 6.60, movable finger L 7.90; pedipalp femur L 5.40, W 1.70, patella L 7.30, W 2.15; pectine L 8.55, mid-pectine

sensillar margin L 1.025; leg III femur L 5.20; leg III patella L 6.00, D 1.65. Pectine teeth: 34–35.

**Female (paratype of *L. nasheri*).** Differs from male as follows: body wider, carapace W/L 1.11; carapace, tergites and coxae with weaker, more finely granulate carinae, intercarinal surfaces more finely granulated or shagreened; genital opercula with slightly sinuous posterolateral margin; pectine basal piece wider with small anteromedian notch; pectines narrower, shorter, 7–8 middle lamellae; proximal margin of basal middle lamella not extended, 1.15–1.28 times longer than distal margin; pectine tips not extending past distal end of trochanter IV, teeth smaller, with short sensillar margins, mid-pectine sensillar margin L/ pectine L 0.070, mid-pectine sensillar margin L/ metasoma I W 0.115; 25–28 pectine teeth; basal pectine teeth do not overlap if anterior pectine margins aligned to posterior margins of coxae IV; sternite III–VI with median carinae obsolete, medial surfaces smooth; sternites IV–V with lateral carinae weak, smooth, lateral surfaces weakly shagreened; sternite VI with moderate, finely granulated lateral carinae, sternite VII with moderate, crenulate-granulate median and lateral carinae, intercarinal surfaces finely roughened; spiracles on VI with fine granules along anterior margins; ventromedian carinae on metasoma II–III more strongly crenulate, with larger denticles; telson with sparse, fine granules on ventral surface of vesicle; metasoma and pedipalp segments less



**Figure 11:** *Leiurus brachycentrus* (Ehrenberg, 1829) stat. n., holotype male (ZMHB No. 141). **A.** Dorsal habitus. **B.** Ventral habitus. **C.** Right pedipalp, dorsal aspect. **D.** Right pedipalp, ventral aspect. **E.** Left pectine. **F.** Metasoma, lateral aspect. **G.** Right leg IV, telotarsus, basitarsus and distal tibia, ventral aspect. Scale bar: **A, B**, 10 mm.

slender; pedipalp fixed fingers with 11 primary denticle subrows; prolateral tarsal spurs with 1, 2, 2–3, 3 setae on legs I–IV.

**Measurements of female (mm).** Total L 61.00; metasoma + telson L 38.00; carapace L 7.04, W 7.84, carapace preocular L 3.39; metasomal segments (L/ W/ D) I 4.82/ 4.10/ 3.50, II 5.54/ 3.67/ 3.47, III 5.78/ 3.47/ 3.60, IV 6.59/ 3.25/ 3.12, V 7.47/ 3.56/ 2.97; telson L 7.16; vesicle L 3.95, W 3.12, D 2.88; pedipalp chela L 12.20, manus ventral L 4.25, manus W 2.36, manus D 2.80, fixed finger L 7.05, movable finger L 8.57; pedipalp femur L 5.79, W 1.89, patella L 7.11, W 2.61; pectine L 6.78; mid-pectine sensillar margin L 0.474; leg III femur L 7.08; leg III patella L 5.77, D 1.94.

**Variation.** Fuscous intercarinal markings were darker in female from Al Mansuria, much weaker in male from Ad Darb. Chela trichobothrium *db* was always proximal to *est*, but its position was variable, *db-est* distance/ pedipalp fixed finger L -0.0497 – -0.0056 (-0.0208 ± 0.0132;  $n = 11$  fingers).

**DISTRIBUTION.** Known only from the Tihamah plain along the Red Sea coast of western Yemen and southwestern Saudi Arabia. In addition to the material examined, we have also included the type locality of *Buthus beccarii* (Moka = Al Mukhah, 13°19'11"N 43°14'24"E) (Simon, 1882). Borelli (1915) listed a male and female from Aden as *L. q. brachycentrus*, but we have not confirmed this record.

**ECOLOGY.** All collections are from low elevation coastal sites (< 110 m a.s.l.). The well developed tarsal bristle combs and long setation suggest adaptation to an arenicolous life on sandy soils of coastal dunes. The Tihamah plain is a hot environment with daily high temperatures of ca. 43°C, and 40–60 % relative humidity, and the southern sites lie in the zone of coastal fog desert.

**REMARKS.** There has been some ambiguity about the type locality. It was cited as ‘district of Gedda (Gumfudam)’ by Levy et al. (1970: 233), and ‘Jidda (Gumfudam)’ by Levy & Amitai (1980: 47), and later transcribed as ‘Jeddah, Arabia’ by Sissom (1994: 23). This is misleading because ‘Gumfudam’ (= Al Qun-fudhah, Saudi Arabia) is ca. 325 km SE of Jeddah. In *Symbolae Physicae*, Ehrenberg (1831) described *brachycentrus* as a form of *A. quinquestriatus* from Arabian desert ‘prope Gumfudam’ (= near Al Qun-fudhah), but then writes: ‘In Arabiae felitis prope Lohaiam 3 species collegimus: *Androctonus* (*Liurus*) *tunetanum* γ *intermedium* cum *quinquestriato* β *brachycentro* et *Prionurum liosoma*.’ Thus the type locality is

actually ‘Lohaie’ (= Al Luhayyah, ca. 867 km SE of Jeddah), in Arabia Felix (= Yemen) (see also Birula, 1908; Braunwalder & Fet, 1998). According to Moritz & Fischer (1980), and confirmed here, the label stored with the type of *L. brachycentrus* stat. n. reads ‘Arabia Felix’.

The taxonomic status of *L. brachycentrus* has long been uncertain. Ehrenberg (1829, 1831) originally differentiated subspecies *brachycentrus* from the nomino-typic form by two diagnostic characters: short aculeus, equal in length to telson vesicle, and absence of dark pigment on metasoma V. The subspecies was accepted by Birula (1908, 1917) and Borelli (1915). Birula (1937) published a more detailed redescription based on a series of specimens from Al Hudaydah, but did not study the type, and we consider his material to represent a different species, *L. haenggii* sp. n. Vachon (1979) has suggested that lighter coloration on metasoma V may also occur in other *Leiurus* populations. Levy et al. (1970) mentioned *L. q. brachycentrus* but did not render an opinion because they did not examine Arabian material. Later, Levy & Amitai (1980) synonymized *L. q. brachycentrus* with the nominate subspecies. However, they did not examine the type and assumed that *L. brachycentrus* was represented by specimens from Jeddah. We examined several *Leiurus* from Jeddah and found that they belong to different species. Our analysis of the holotype of *L. brachycentrus*, and similar specimens from the surrounding region on the Tihamah plain, demonstrates that this is a valid species.

Simon (1882) described *Buthus beccarii* based on a single male collected from Moka (=Al Mukha) on the southern Red Sea coast of Yemen. Kraepelin (1891, 1899) listed it as a synonym of *L. quinquestriatus*, and Birula (1908) considered it a synonym of *Buthus quinquestriatus brachycentrus*. This is consistent with its type locality on the southern Tihamah coastal plain, and with certain mentioned characters, i.e. relatively smaller size (total length 56.7 mm), tan yellow color with dark carinae, pectinal tooth count 34, and anterior median carinae extending continuously to anterior margin of carapace. As previously noted (Kraepelin, 1891; Levy et al., 1970), the rostral limit of the anterior median carinae can vary in *Leiurus*, and is not by itself a reliable diagnostic character. Nevertheless, in specimens of *L. brachycentrus* that we examined, the carinae did form continuous arcs of granules extending to the anterior transverse marginal row of granules, with very little gap (typically less than one granule diameter; Figs. 3A, 7A). In other species there was often a substantial gap, or the arrangement of granules became irregular near the anterior margin causing a break up of the carinae. Considering these characters and the locality, we regard *B. beccarii* to be a synonym of *L. brachycentrus* stat. n.

*Leiurus macroctenus* sp. n.

(Figs. 12–22, 58A, 59A–B, 87G, 88G, 89G, 90G, 91B, 92H–I, 93H, 95, 98–100, Tabs. 1, 3B, 4)  
<http://zoobank.org/urn:lsid:zoobank.org:act:55E2C048-986D-43A2-AF63-5874138435D6>

## REFERENCES

- Buthus quinquestriatus*: Finnegan, 1932: 91–92 (in part; record from Wadi Ghabartan).
- Leiurus quinquestriatus*: Gallagher, 1978: 36–37; Lowe, 1993: 2; Kovařík 1998: 112 (in part); Fet & Lowe, 2000: 155 (in part); Lowe, 2001: 176; Fet et. al., 2003: 3; Soleglad & Fet, 2003b: 149, fig. B-1, B-2; Hendrixson 2006: 84–91, fig. 18 (in part, record from Oman).
- Leiurus quinquestriatus hebraeus*: Kamenz & Prendini, 2008: 40.
- Leiurus* sp.: Lowe, 2010a: 23; Lowe, 2010b: 26, 37.

HOLOTYPE. Adult ♂, **Oman**, Nejd Desert; S of Thumrait, UV detection, fine silty soil, open plain with rock outcrops and small wadis, 17°30.76'N 54°02.76'E, 580 m a.s.l., 16.X.1993, 19:28 h, leg. G. Lowe, NHMB.

PARATYPES. **Oman**: 2 ♂, Thamarit, Dhofar, sand & rock (limestone), 17°38'N 54°01'E, 350 m a.s.l., I.1980, leg. J.N. Barnes & M.D. Gallagher MDG 5954 (MNHN); 2 ♀, Thamarit, Dhofar, sand & rock, 17°38'N 54°01'E, 350 m a.s.l., I.1980, leg. J.N. Barnes & M.D. Gallagher MDG 5952, 5953 (MNHN); 1 immature ♀, nr Thamarit, Dhofar, under object on gravel in wadi, 17°41'N 54°03'E, 440 m a.s.l., 22.II.1980, leg. J.N. Barnes & M.D. Gallagher MDG 5973 (MNHN); 1 ♂, nr Thamarit, Dhofar, 17°42'N 54°02'E, 440 m a.s.l., 4.III.1980, leg. J.N. Barnes & M.D. Gallagher MDG 5972 (MNHN); 1 juv, nr Thamarit, Dhofar, on sand, 17°40'N 54°02'E, 450 m a.s.l., 22.III.1980, leg. J.N. Barnes 50A (MNHN); 1 juv, nr Thamarit, Dhofar, under object on sand, 17°40'N 54°02'E, 450 m a.s.l., 22.III.1980, leg. J.N. Barnes 54 (NHMB); 1 juv, nr Thamarit, Dhofar, 17°40'N 54°02'E, 450 m a.s.l., 22.III.1980, leg. J.N. Barnes 52 (NHMB); 1 juv, nr Thamarit, Dhofar, under object on sand, 17°40'N 54°02'E, 450 m a.s.l., 22.III.1980, leg. J.N. Barnes 37 (MNHN); 1 ♂, nr Thamarit, Dhofar, under rock, 17°41'N 54°02'E, 450 m a.s.l., 23.III.1980, leg. J.N. Barnes (NHMB); 1 juv, nr Thamarit, Dhofar, under object on sand, 17°40'N 54°00'E, 450 m a.s.l., 24.III.1980, leg. J.N. Barnes 35 (NHMB); 1 ♀, nr Thamarit, Dhofar, under object on sand, 17°40'N 54°00'E, 450 m a.s.l., 24.III.1980, leg. J.N. Barnes 33 (NHMB); 1 juv, nr Thamarit, Dhofar, on sand, 17°40'N 54°02'E, 450 m a.s.l., 24.III.1980, leg. J.N. Barnes 55, (NHMB); 1 juv, nr Thamarit, Dhofar, on gravel, 17°40'N 54°02'E,

450 m a.s.l., 30.III.1980, leg. J.N. Barnes 58 (NHMB); 1 ♂, 3 mi. NW of Thamarit, under sack on sand, 17°43'N 54°00'E, 420 m a.s.l., 8.III.1980, leg. M.D. Gallagher MDG 5971 (MNHN); 1 ♂, 4 mi. NE of Thamarit, Dhofar, in soft sand under sack in green wadi, 17°42'N 54°03'E, 8.III.1980, leg. J.N. Barnes & M.D. Gallagher MDG 5975 (MNHN); 1 ♂, nr Al Ashkara, 22°00'N 59°40'E, XII.1980, leg. A.B. Paltrinieri (NHMB 17bq); 1 ♂, Yalooni, Jiddat al Harasis, in house, sand on stony plateau, 19°57'N 57°07'E, 154 m a.s.l., 22.IV.1982, leg. M.D. Gallagher MDG 6428/1,2 (ONHM); 1 ♂, Wadi Haytam, sandy depression in rocks, 19°11'N 57°00'E, 13.V.1983, leg. M.D. Gallagher MDG 6770 (NHMB); 1 ♂, Thamarit, under rock on soft sand, 17°42'N 53°59'E, 24.V.1983, leg. J.N. Barnes 126 (BMNH); 1 ♂, Thamarit, under rock on soft sand, 17°42'N 53°59'E, 24.V.1983, leg. J.N. Barnes 125 (ONHM); 1 ♂, Yalooni, Jiddat al Harasis, 19°57'N 57°06'E, 154 m a.s.l., 17.XII.1984, leg. M.D. Gallagher (NHMB); 1 juv, Qarhat Mu'ammar, 21°38'N 59°18'E, 130 m a.s.l., 28.II.1986, leg. W. Büttiker (NHMB 17bt); 1 ♀, Ra's al Hadd, on sand under object, 0.5 km from sea, 22°31.8'N 59°46'E, 5 m a.s.l., 3.II.1988, 10:00 h, leg. M.D. Gallagher MDG 8020 (NHMB 17br); 1 juv, Huqf, central Oman, under rock on sand, 20°53'N 57°36'E, 15.III.1988, 14:00 h, M.D. Gallagher MDG 8031 (NHMB 17bs); 1 ♂, between Bani bu Ali & Al Ashkharah, 3 km W Qumaylah turning, under rubbish on sand, 21°56'N 59°35'E, 17.I.1991, leg. S.M. Farook & A.S. Gardner (MNHN); 1 ♂, 1 ♀, 3 km N of Khubah, 22°16'N 59°48'E, 11.II.1993, leg. A.S. Gardner (NHMB); 6 ♂, between Khabbah & Daffah, under stones on limestone plateau, 22°15'N 59°48'E, 29.VIII.1993, leg. A.S. Gardner & S.M. Farook (NHMB); 6 ♂, 4 ♀, 5 juvs, S of Thumrait, Nejd Desert, UV detection, near or partly in burrows, fine silty soil, open plain rock outcrops & small wadis, 17°30.76'N 54°02.76'E, 580 m a.s.l., 16.X.1993, 19:28 h, leg. G. Lowe (NHMB); 4 ♂, 4 ♀, 4 juvs, S of Thumrait, Nejd Desert, UV detection, on soil & at mouths of burrows, fine silty soil, open plain rock outcrops & small wadis, 17°30.8'N 54°02.94'E, 580 m a.s.l., 16.X.1993, 20:57 h, leg. G. Lowe (NHMB, ONHM 1 ♀, WDS 1 ♂); 1 ♂, Salalah-Thumrait road, Nejd Desert, UV detection, on ground, hills near main road, 17°25.56'N 54°03.14'E, 600 m a.s.l., 16.X.1993, 21:49 h, leg. G. Lowe (NHMB); 1 juv, E of Thumrait, road to Marmul, UV detection, open desert plain, sparse vegetation, 17°38.99'N 54°08.29'E, 500 m a.s.l., 19.X.1993, 21:10 h, leg. G. Lowe (NHMB); 3 ♂, 2 ♀, E of Thumrait, road to Marmul, UV detection, open plain, low rocky hills, 17°38.33'N 54°07.77'E, 500 m a.s.l., 19.X.1993, 21:31 h, leg. G. Lowe (ONHM); 3 ♂, 1 juv, S of Thumrait, Nejd Desert, UV detection, open alluvial plain with rock outcrops and small wadis, on fine soil & partially in burrows, 17°30.77'N 54°02.82'E, 600 m a.s.l., 19.X.



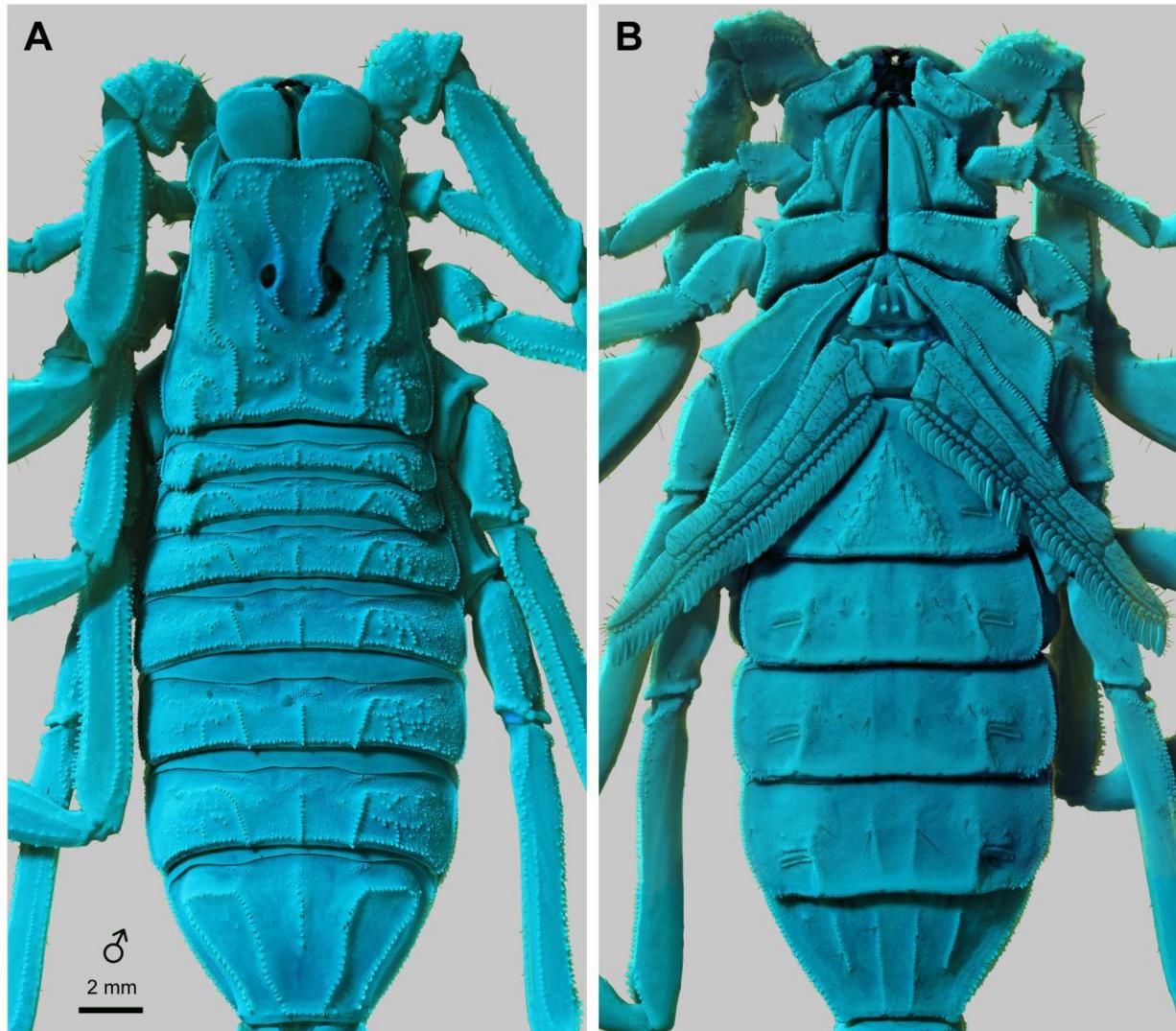
**Figure 12:** *Leiurus macroctenus* sp. n., holotype male. Habitus, dorsal aspect. Thumrait, Oman.



**Figure 13:** *Leiurus macroctenus* sp. n., holotype male. Habitus, ventral aspect. Thumrait, Oman.

1993, 23:02 h, leg. G. Lowe (NHMB); 2 juvs, Yalooni, UV detection, on gravel plain with *Prosopis* woodland, 19°57'N 57°06'E, 150 m a.s.l., 21.X.1993, leg. M. Fisher (NHMB); 2 juvs, Yalooni, on sand, amongst fallen twigs, clear moonless sky, slight breeze, 19°56'N 57°05'E, 154 m a.s.l., 15.III.1994, 22:00 h, leg. M.D. Gallagher MDG 8564.3-4 (NHMB); 1 ♀, 2 km N of Yalooni, Jiddat Al Harasis, under barrel with beetles on sand, 19°58'N 57°07'E, 154 m a.s.l., 17.III.1994, 13:30 h, leg. M.D. Gallagher MDG 8569 (NHMB); 1 juv, nr Ad Daffah, low dunes, below rocky escarpment, 22°15'N 59°48'E, 24.XI.1994, leg. A.S. Gardner (NHMB); 1 juv, Jabal Qara, hilltop, UV detection, 17°14.51'N 54°04.25'E, 800 m a.s.l., 30.IV.1995, leg. J. Dundon (NHMB); 1 ♂, Jabal Qara, hilltop, UV detection, 17°14.51'N 54°04.25'E, 800 m a.s.l., 30.IV.1995, leg. J. Dundon (USNM); 1 ♀, 2 juvs, Masirah Island, north Masirah, east coast, low rock littered slopes, compact silty soil, UV detection, 20°34.48'N 58°55.36'E, 25 m a.s.l., 20.IX.1995, 19:50 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 ♂, 1 ♀, Masirah Island, north Masirah, east coast, UV detection near edge of wide wadi with small side wadis, from edges of slopes, 20°35.68'N 58°53.98'E, 20 m a.s.l., 20.IX.1995, 21:10 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 ♂, 3 ♀, Masirah Island, north Masirah, east coast, wadi with row of trees & flowing water close to beach with hermit crabs, UV detection on gravelly ground away from trees, 20°39.78'N 58°54.28'E, 5 m a.s.l., 20.IX.1995, 22:30 h, leg. G. Lowe & M.D. Gallagher (MNHN); 1 ♂, 3 ♀, 6 juvs, Masirah Island, north Masirah, east coast, UV detection on sand and gravel, by row of trees along wadi with flowing water, 20°40.14'N 58°54.4'E, 20.IX.1995, 23:20 h, leg. G. Lowe & M.D. Gallagher (GL); 1 ♀, 2 juvs, Masirah Island, north Masirah, east coast, UV detection, near beach, gravelly/ silty flat with shrubs, 20°41.01'N 58°54.63'E, 21.IX.1995, 0:05 h, leg. G. Lowe & M.D. Gallagher (BMNH); 1 ♂, 5 ♀, 3 juvs, Masirah Island, south Masirah, base of Jabal Suwayr, seepage area with trees & standing water at base of Jabal rock and boulder slopes, UV detection on sand & gravel plain below not far from beach, 20°11.65'N 58°39.42'E, 20 m a.s.l., 21.IX.1995, 18:10 h, leg. G. Lowe & M.D. Gallagher (NHMB); 3 ♂, 8 ♀, 3 juvs, Masirah Island, south Masirah, Wadi Qitaar, UV detection on sand deposits along edges of wide sandy wadi, 20°13.78'N 58°38.4'E, 20 m a.s.l., 21.IX.1995, 21:20 h, leg. G. Lowe & M.D. Gallagher (NHMB); 6 ♂, 11 ♀, 5 juvs, Masirah Island, south Masirah, UV detection on sand, area with shrubs by low rocky hills, 20°16.05'N 58°38'E, 25 m a.s.l., 21.IX.1995, 22:30 h, leg. G. Lowe & M.D. Gallagher (ONHM); 2 ♂, 3 ♀, 5 juvs, Masirah Island, UV detection on sand in wide wadi system, densely vegetated with low shrubs, 20°23.48'N 58°41.32'E, 30 m a.s.l., 21.IX.1995, 23:50 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 ♂, Masirah Island, north Masirah,

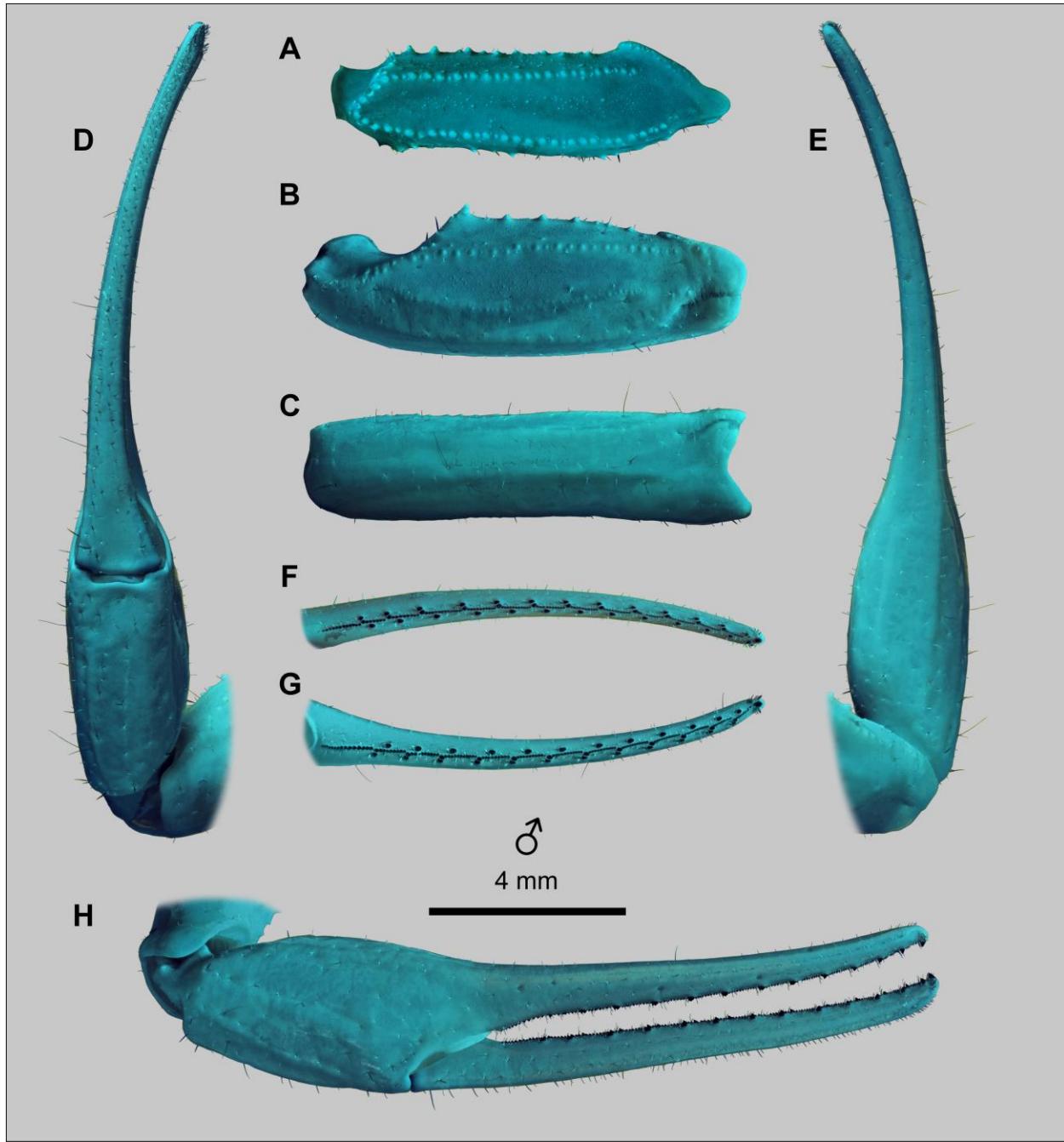
west coast, SE of Dafiyat, under wood debris on ground, gravel flat, 20°35.28'N 58°50.76'E, 22.IX.1995, 0:50 h, leg. G. Lowe & M.D. Gallagher (BMNH); 1 ♀, nr Duqm, cliff with nearby wadi and trees, 19°36.06'N 57°37.29'E, 50 m a.s.l., 23.IX.1995, 18:50 h, leg. G. Lowe & M.D. Gallagher (MZUF); 1 ♂, 3 juvs, nr Duqm, UV detection, 19°30.59'N 57°34.9'E, 95 m a.s.l., 23.IX.1995, 18:40 h, leg. G. Lowe & M.D. Gallagher (NHMB); 2 ♂, 1 juv, nr Duqm, UV detection, vegetated wadi, 19°33.53'N 57°37.38'E, 75 m a.s.l., 23.IX.1995, 23:00 h, leg. G. Lowe & M.D. Gallagher (MNHN); 1 ♂, 1 ♀, E. of Duqm, UV detection on ground, densely vegetated wadi, 19°39'N 57°40'E, 30 m a.s.l., 23.IX.1995, 23:50 h, leg. G. Lowe & M.D. Gallagher (NHMB); 11 ♂, 8 ♀, 10 juvs, N edge of Wadi Dirif, UV detection on sandy substrate, rocky knoll overlooking wadi and on open flats of wadi, 18°57.51'N 57°21.73'E, 20 m a.s.l., 24.IX.1995, 18:40 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 ♂, 1 ♀, Wadi Dirif, above beach zone, UV detection, fine silty soil by rock outcrops, 18°57.57'N 57°20.63'E, 5 m a.s.l., 24.IX.1995, 23:30 h, leg. G. Lowe & M.D. Gallagher (MCZN); 4 ♂, 2 juvs, Wadi Dirif, W edge of wadi, UV detection on sand, 18°57.2'N 57°20.63'E, 10 m a.s.l., 24.IX.1995, 23:40 h, leg. G. Lowe & M.D. Gallagher (BMNH); 13 juvs, Wadi Dirif, E edge of wadi, UV detection, rock outcrops on sand, 18°57.1'N 57°20.71'E, 10 m a.s.l., 25.IX.1995, 0:25 h, leg. G. Lowe & M.D. Gallagher (ONHM); 6 ♂, 6 ♀, Wadi Dirif, E edge of wadi, UV detection on sand, with rocks, 18°57.1'N 57°20.71'E, 10 m a.s.l., 25.IX.1995, 0:25 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 juv, Wadi Dirif, dunes by road, UV detection on sand, 18°57.07'N 57°20.09'E, 20 m a.s.l., 24.IX.1995, 22:50 h, leg. G. Lowe & M.D. Gallagher (NHMB); 4 juvs, Wadi Shuwaymiyah, UV detection, base of cliff along southern edge of wadi, sand and loose rock along base, 17°54.9'N 55°34.63'E, 25.IX.1995, 22:00 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 ♂, 2 ♀, coast W of Shuwaymiyah, UV detection on sand, wide sandy wadi along coast, gentle slopes up to cliffs on edges, 17°53.91'N 55°39.16'E, 5 m a.s.l., 25.IX.1995, 23:40 h, leg. G. Lowe & M.D. Gallagher (FKCP); 2 ♂, 2 juvs, plateau between Shalim & Ash Shuwaymiyah, UV detection, open rocky windswept plateau with sparse shrubs ground with bare rock and patches of soil, strong wind, 18°02.44'N 55°36.91'E, 265 m a.s.l., 26.IX.1995, 1:32 h, leg. G. Lowe & M.D. Gallagher (GL); 1 ♂, 2 ♀, 2 juvs, Saiwan, Rudist outcrop, 20°42.94'N 57°36.96'E, 20.II.1996, leg. A.S. Gardner (ONHM); 1 ♂, Marmul, 18°10.09'N 0°14.76'E (FKCP); 1 ♂, 30 km N of Haima, near Haylat Harashif, dry level sand desert, in large open area, arid gravel desert, 20°11.43'N 56°33.58'E, 6. XII. 1996, leg. M.D. Gallagher MDG 8798 (FKCP); 1 ♂, 3 ♀, Khawr Dirif, on sand under small plants and rocks, 18°56.7'N 57°20.73'E, 5 m a.s.l., 7.XII.1996, leg. I.D. Harrison & M.D. Gallagher MDG 8802 (USNM); 3 ♂,



**Figure 14:** *Leiurus macroctenus* sp. n., holotype male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Thumrait, Oman.

3 ♀, 5 juvs, 20km N of Liqbi, Sahil al Jazr, sand and scrub, 18°24.17'N 56°33.95'E, 15 m a.s.l., 8.XII.1996, leg. I.D. Harrison & M.D. Gallagher MDG 8805 (NHMB); 11 ♂, 1 ♀, 1 juv, Thumrait, wadi area SE of Thumrait and golf course, 17°42'N 53°59'E, 11-12.II- 9.X.1997, leg. J.N. Barnes (ONHM, EV 1 ♂); 1 ♂, Huqf, on open sand between bushes at foot of low hills, three quarter moon, strong wind, 20°25.7'N 57°26.42'E, 18.IV.1997, M.D. Gallagher MDG 8859 (ONHM); 3 ♂, 2 ♀, 4 juvs, Ra's Al Ghubbah, hiding under shrubs from three quarter moon, on sand over rock slope from beach, 20°07.95'N 57°49.77'E, 5 - 20 m a.s.l., 19.IV.1997, 19:00–21:00 h, leg. M.D. Gallagher & I.D. & M. Harrison MDG 8866 (NHMB); 8 ♂, 2 ♀, Duhai, low aeolianite hilltop & slope to sand, to edge of trees, 500 m<sup>2</sup> area, 21°06.26'N 58°22.29'E, 70 m a.s.l., 21.X.1997, leg. M.D. Gallagher

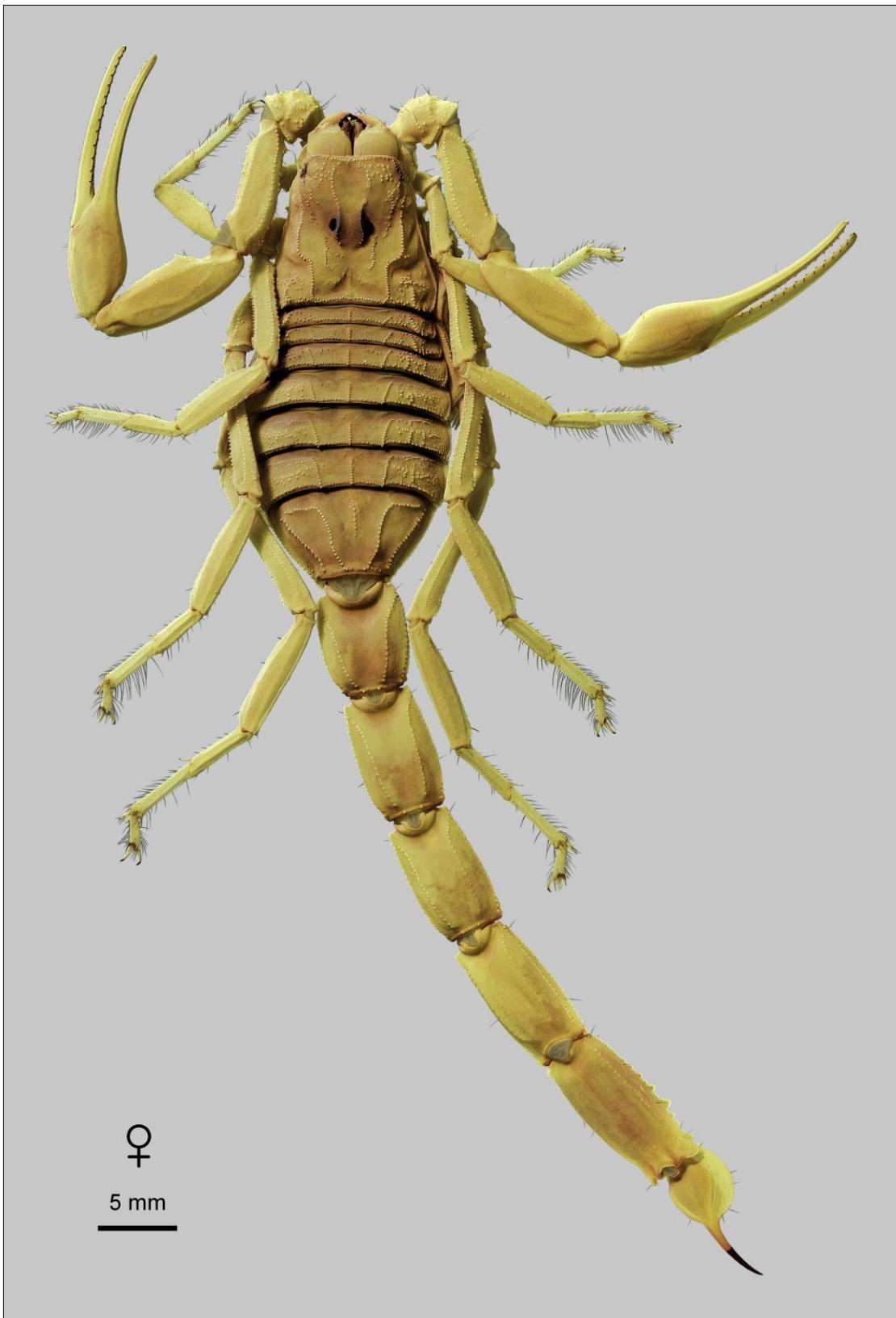
& I.D. Harrison MDG 8889, (ONHM 2 ♀, GL); 4 ♀, 1 juv, NE of Ras Al Jibsh, slope of sand and scrub hummocks, between sea and rocky mountains, on rocks, sand and under scrub, 21°35.4'N 59°25.1'E, 100 m a.s.l., 19. II.1998, leg. J. Peterson, I.D. Harrison & M.D. Gallagher MDG 8945 (MZUF); 6 ♂, 1 ♀, 2 juvs, N of Al Ashkharah, beach sand, scrub and rocks, most hiding in scrub from three quarter moon, 21°54.7'N 59°36.78'E, 2 m a.s.l., 7.IV.1998, leg. I.D., S. & R. Harrison. & M.D. Gallagher (NHMB); 1 ♂, E. of Hayma, on sparse vegetation, 19°46.05'N 56°35.77'E, 3.X.1998, leg. I.D. Harrison (NHMB); 3 ♂, 1 ♀, 1 juv, between Al Ashkharah and A'Seelal, under small bushes, 21°55.4'N 59°37.67'E, 21.XI.1998, leg. I.D. Harrison (MNHN); 1 juv, Jiddat al Harasis nr Habab (site F/9), under rocks in road cut, 19°42.28'N 56°48.72'E, 250 m a.s.l., 29.XII.



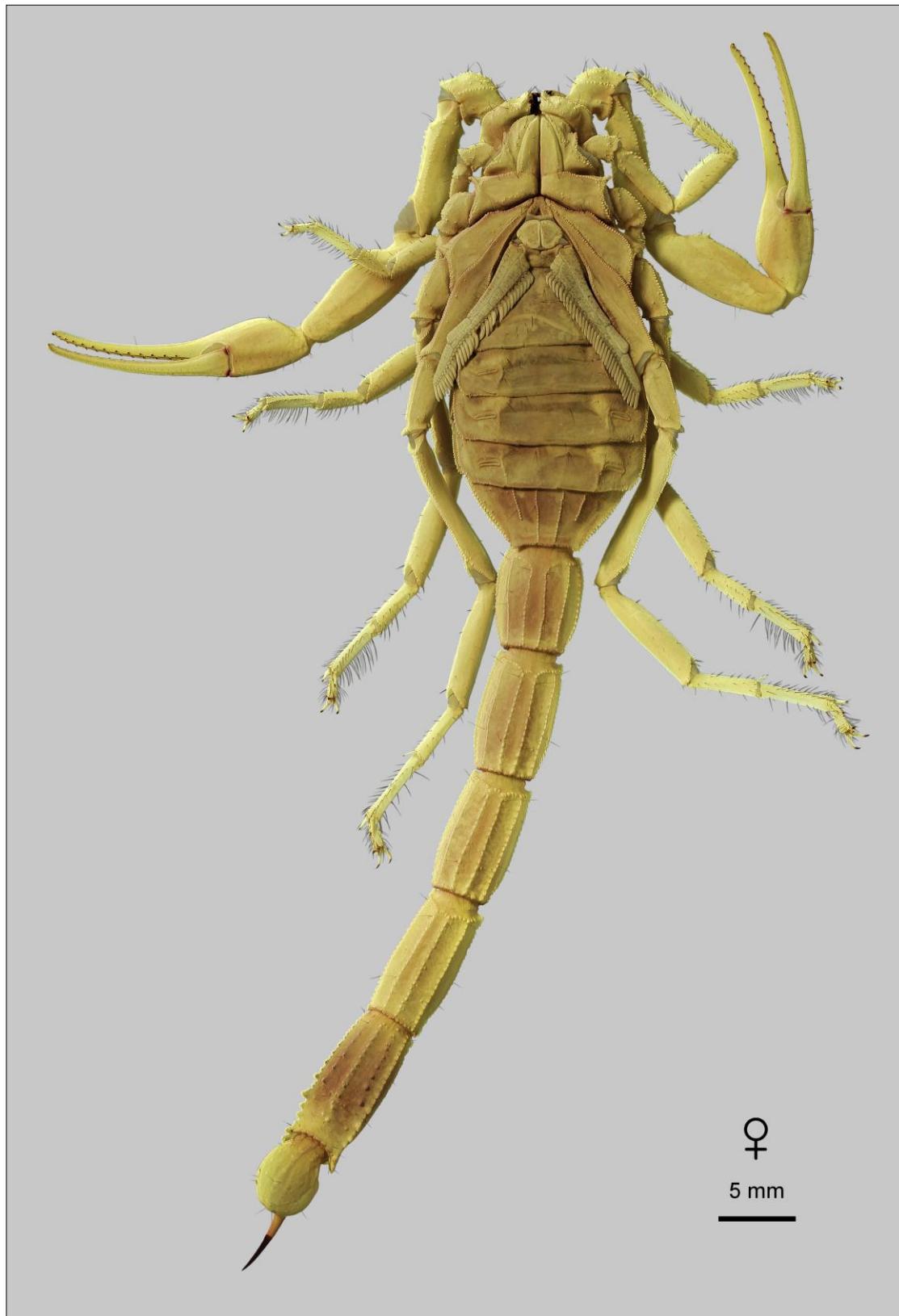
**Figure 15:** *Leiurus macroctenus* sp. n., holotype male. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **G.** Movable finger dentition. **H.** Chela, external aspect. Thumrait, Oman.

1998, 14:45 h, leg. A. Winkler & B. Winkler (NHMB); 5 ♂, 2 juvs, nr Al Ashkharah, on grass, on sandy plain between sea & mountains, 21°54'N 59°36'E, 15.IV.1999, leg. I.D. & S.E. Harrison (NHMB); 1 ♀, nr Ras Khaysat al Liiyakh, ca. 20 km N Ras Madrakah, Al Wusta region, sitting under small plant 30 cm × 30 cm, 19°13.5'N 57°45'E, 21.IX.2000, leg. R. Harrison & S.

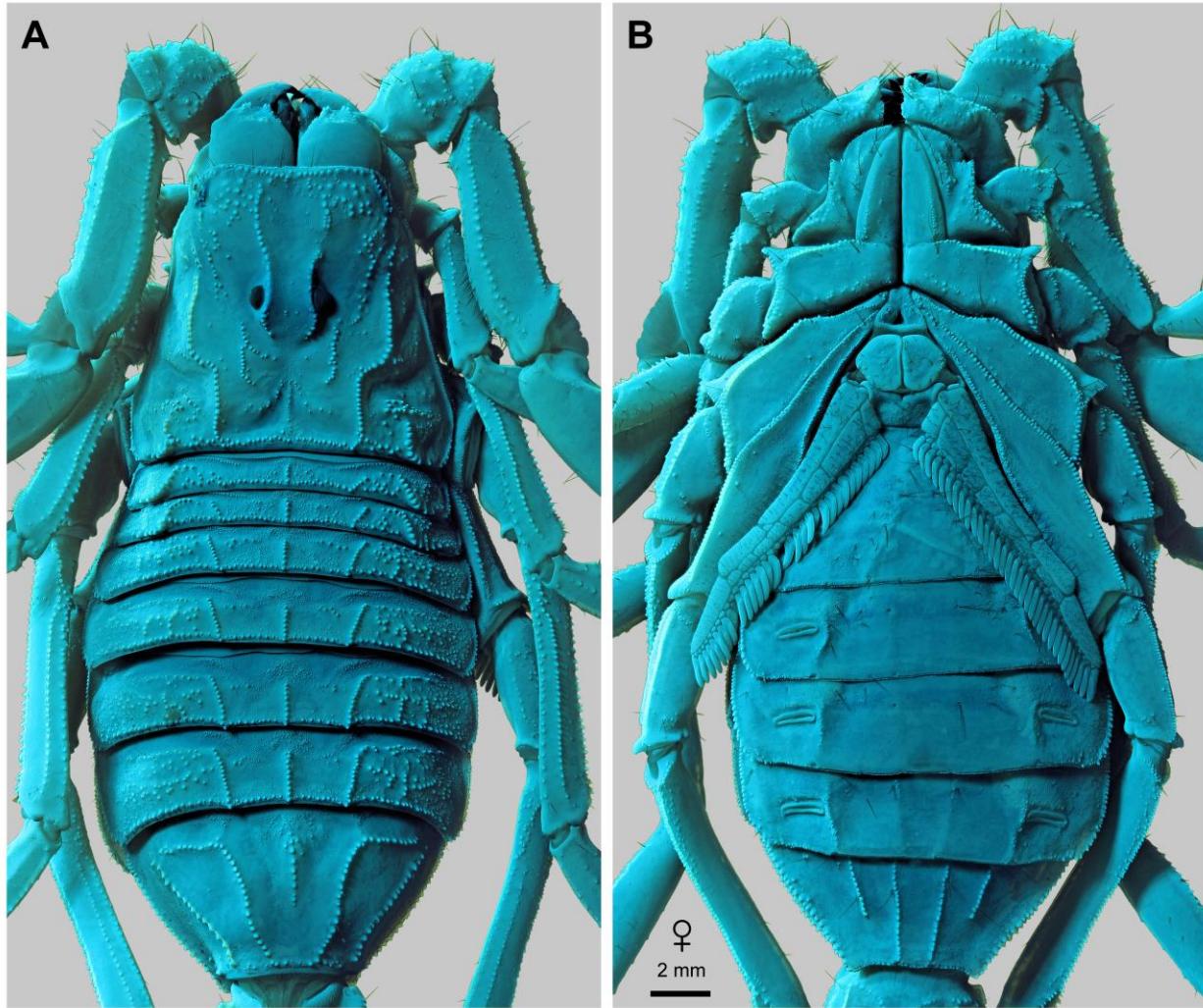
Harrison (ONHM); 1 ♂, Al Hayl, by rock, in rock/pebble strewn sand on low ridge overlooking wide sandy wadi, 20°42'N 58°15'E, 11.XI.2001, leg. I.D. Harrison (ONHM); 2 ♂, Wadi Abaytham, under rock on low ridge overlooking wadi, sparse vegetation on ridge, denser in wadi, 18°58'N 57°36'E, 12.XI.2001, leg. I.D. Harrison (MCZN); 1 ♀, S Duqm (site F/24), UV detec-



**Figure 16:** *Leiurus macroctenus* sp. n., paratype female. Habitus, dorsal aspect. Wadi Qitaar, Masirah Island, Oman.



**Figure 17:** *Leiurus macroctenus* sp. n., paratype female. Habitus, ventral aspect. Wadi Qitaar, Masirah Island, Oman.



**Figure 18:** *Leiurus macroctenus* sp. n., paratype female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Wadi Qitaar, Masirah Island, Oman.

tion, in small dunes, mouth of burrow, 19°26.75'N 57°35.78'E, 147 m a.s.l., 26.XII.2001, 19:00–20:00 h, leg. A. Winkler (NHMB); 1 juv, S Duqm (site F/24), UV detection, in small dunes, mouth of burrow, 19°26.75'N 57°35.78'E, 147 m a.s.l., 27.XII.2001, 04:00–05:00 h, leg. A. Winkler (NHMB); 1 ♀ subadult, 3 juvs, Al-Saadonat, 19°20.37'N 57°35.47'E, 97 m a.s.l., 18.III.2014, leg. D. Hoferek (FKCP); 1 ♂, 1 ♀, UV detection 20:00–22:00 h, Wadi Dirif, 18°56.51'N 57°20.73'E, 7 m a.s.l. 19.III.2014, leg. D. Hoferek (FKCP); 4 ♀, UV detection 20:00–22:00 h, Shalím, 18°02.46'N 55°36.93'E, 290 m a.s.l., 20.III.2014, leg. D. Hoferek (FKCP).

**ETYMOLOGY.** The name *macroctenus* (= ‘large comb’) refers to the large size of the pectine teeth in both sexes, which distinguishes this species from other members of the genus.

**DIAGNOSIS (adults).** Medium to large *Leiurus*, 61–88 mm in length, carapace L 7.1–10.2 mm, base color yellow to pale orange, carapace with limited fuscosity on median interocular tubercle; metasoma V slightly fuscous to dark except for posterior end; carapace with area between anterior median carinae smooth or bearing sparse medium to fine granules, area between posterior median carinae with moderately deep median furrow flanked by lateral arcs of medium to fine granules; medial intercarinal surfaces of tergites II–III densely shagreened and granulated; posterior margin of coxa III smooth or with sparse, fine granules; metasoma robust to moderately slender, metasoma II L/W 1.48–1.82, metasoma III L/W 1.59–2.03, metasoma IV L/W 1.87–2.40; ventromedian carinae of metasoma II and III with 14–23 denticles (78/80 carinae); metasoma V with enlarged subtriangular or lobate denticles on ventrolateral carinae;

pedipalps moderately slender, patella L/W ♂ 2.83–3.64, ♀ 2.55–3.32; leg III patella L/D ♂ 3.43–4.48, ♀ 3.38–4.00; pectine teeth ♂ 33–43, ♀ 30–37; pectines large, broad, pectine L/ carapace L ♂ 1.15–1.52, ♀ 1.03–1.26, mid-pectine sensillar margin L/ metasoma I W ♂ 0.216–0.254, ♀ 0.156–0.203; basal 3–6 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece lightly, finely shagreened; leg III basitarsus with 15–26 retrosuperior setae; pedipalp chela fixed finger with trichobothrium *db* either distal or proximal to *est*; sternite VII with area between median carinae smooth or slightly roughened anteriorly; sternite carination: *males*: sternite III with median carinae strong, sternites IV–V with lateral carinae moderate to strong, median carinae weak or obsolete, shagreened; *females*: sternite III with median carinae weak and finely granulated, or smooth and obsolete, sternites IV–V with lateral carinae weak or moderate, finely granulated, median carinae obsolete.

**COMPARISONS.** *L. macroctenus* sp. n. is distinguished from most other species of *Leiurus* by its large pectine teeth, a distinction that is more pronounced when comparing females, and by strongly overlapping basal pectine teeth of males. The male of *L. brachycentrus* also has large pectine teeth, but the teeth of females are much smaller than those of female *L. macroctenus*. The number of retrosuperior setae in the basitarsal bristle combs of *L. macroctenus* is significantly higher than in other species, which is likely an adaptation to soft sandy substrates.

#### DESCRIPTION (holotype male).

**Coloration.** Base color pale orange or yellow; melanic pigmentation confined to patches around median ocular tubercle and carinae of interocular triangle; ventromedian carinae of metasoma II–IV without pigmentation; metasoma V darkened except for distal portion of segment.

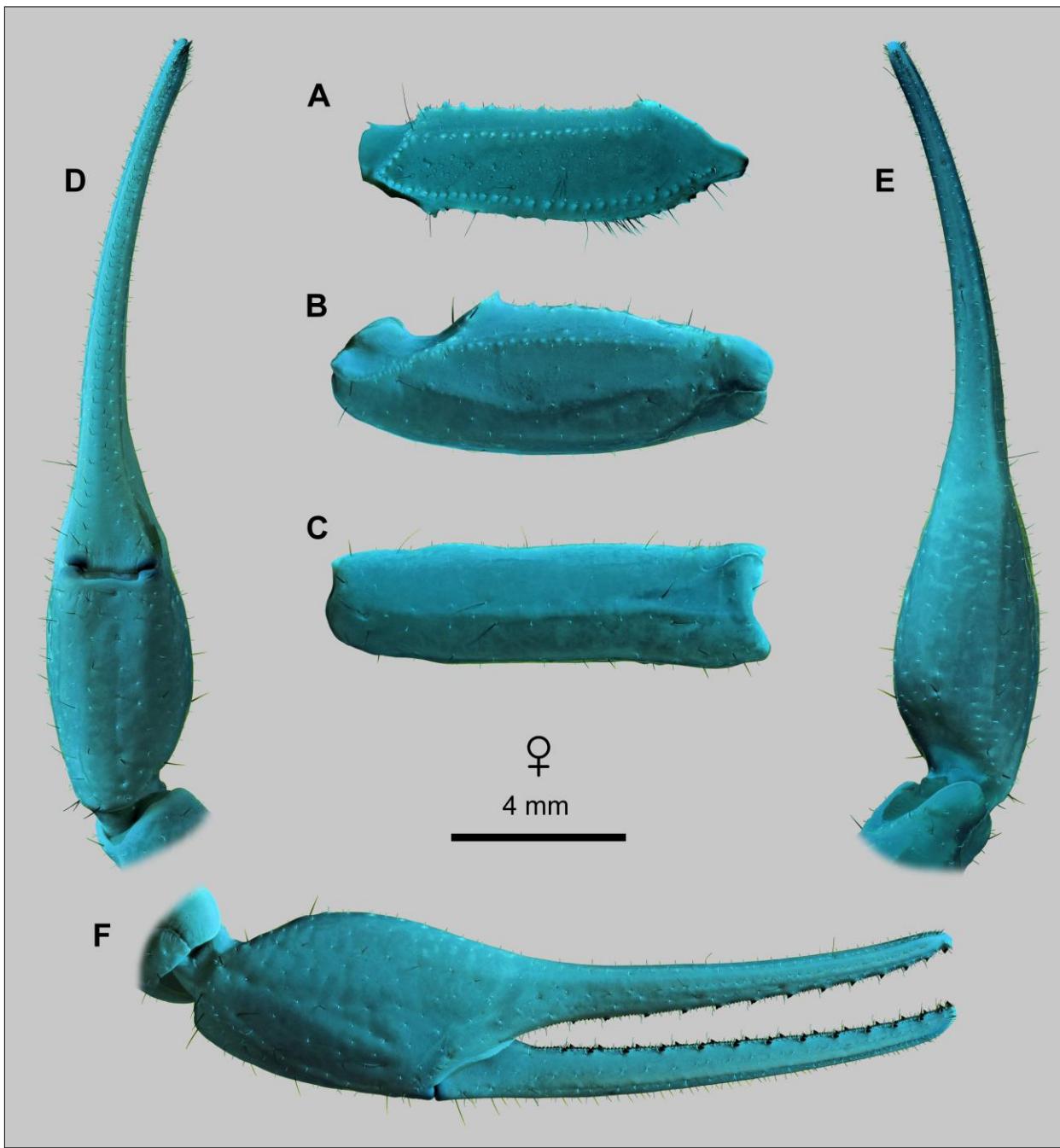
**Carapace.** Subrectangular, W/L 0.97, with steep lateral flanks; top nearly flat, with median eyes strongly raised; interocular triangle convex laterally, depressed medially; anterior margin very slightly emarginate, minutely denticulate laterally with several fine median granules, bordered by row of coarse granules; 11 short macrosetae on anterior margin, carapace otherwise devoid of macrosetae; 5 lateral eyes (3 large, 2 small) on each side; *carination*: anterior median, central lateral, posterior median and posterior lateral carinae strongly developed, coarsely granular; supraocular section of supraciliary carinae with weaker granulation (likely due to abrasion), postocular section coarsely granular; anterior median carinae not extending to anterior margin of carapace, separated from anterior marginal row of granules; central lateral and posterior median carinae fused into lyre configuration; central median carinae coarsely

granular, bifurcated, posterior branch weakly curved; posterior lateral carinae curved with lateral extension, projecting past posterior margin of carapace; lateral ocular carinae moderate, with small, spaced granules; *granulation*: sparse patches of 11 medium to large granules on anterolateral corners of interocular triangle, 7–8 small and large granules in front of lateral ocular carinae; surface between anterior median carinae sparsely, finely shagreened with few isolated small granules; other intercarinal surfaces smooth or faintly microshagreened or with isolated small granules; posterior median furrow very shallow, nearly flat, with few fine granules or micro-shagreened along median line, flanked by lateral arcs of small to medium granules; posterior margin of carapace between posterior lateral carinae rimmed by regular row of small contiguous granules.

**Chelicera.** Dorsal surface of manus smooth, glabrous, with 6 short, pale microsetae, 3 near apical margin, 3 subapical, each surrounded by granules; dorsointernal carina at base of fixed finger strong, well granulated, terminating anteriorly with prominent granules projecting over front of manus; single long macroseta in middle of dorsointernal carina; dorsal surface of movable finger smooth, with 4 pale microsetae; fingers with characteristic buthid dentition (Vachon, 1963); movable finger dorsal margin with 5 teeth: dorsal distal tine, subdistal, median and 2 basal teeth fused in bicusp; ventral margin with 3 teeth: ventral distal tine, median and basal teeth; fixed finger margin with 4 teeth: distal tine, subdistal, median and basal teeth; ventral aspect of fixed finger with 2 teeth.

**Coxosternal area.** Coxae smooth; coxal endite II with weak, finely granulated carina; coxae II–III with coarsely granular anterior carinae, distal margins bearing medium to coarse granules; proximal 1/3 of anterior carina of coxa III finely granulate; 3 long macrosetae along anterior carina of coxa II, 3 macrosetae along anterior carina of coxa III; anterior carina of coxa IV with regular small to medium granulation, with single proximal macroseta; posterior margin of coxa IV with very finely granulated carina on proximal half; sternum with scattered fine granules, subtriangular with slightly convex, nearly straight lateral margins, deep postero-median longitudinal sulcus and pit with finely granulated posterior lip, two short macrosetae; genital opercula smooth with 4 short macrosetae.

**Pectines.** Basal piece with concave anterior margin divided by small median groove, surface finely shagreened medially, almost smooth laterally; 4 short macrosetae on anterior margin, 1 posteromedial; pectines long, tips extending past proximal 4/5 of trochanter IV; pectines with 3 marginal lamellae, small accessory lamella distal to first marginal lamella, 9 middle lamellae, 38–39 teeth; marginal and middle lamellae with dense cover of short reddish macrosetae; fulcra with 3–6 setae; pectine teeth long; when anterior mar-

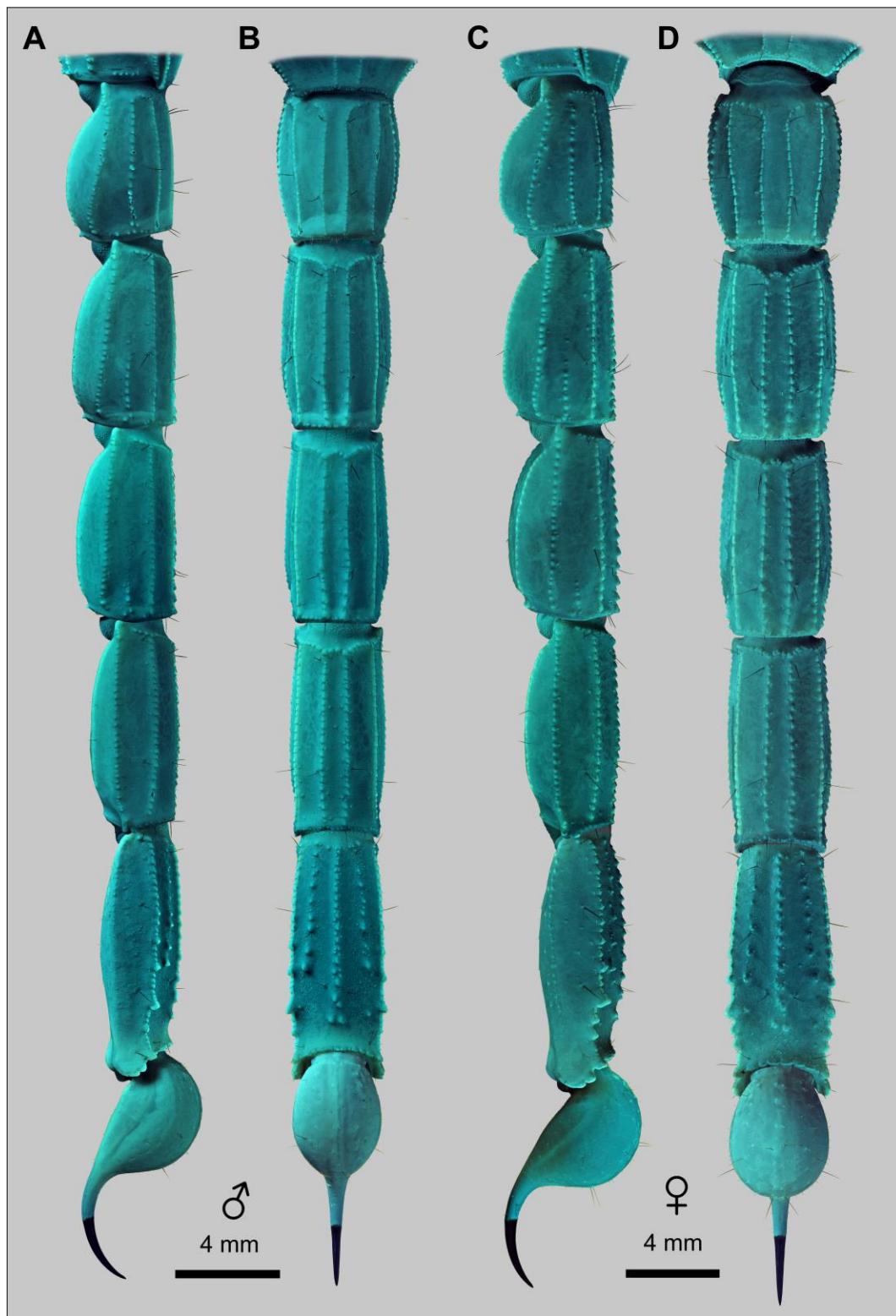


**Figure 19:** *Leiurus macroctenus* sp. n., paratype female. Right pedipalp. A. Femur, dorsal aspect. B. Patella, dorsal aspect. C. Patella, external aspect. D. Chela, ventral aspect. E. Chela, dorsal aspect. F. Chela, external aspect. Wadi Qitaar, Masirah Island, Oman.

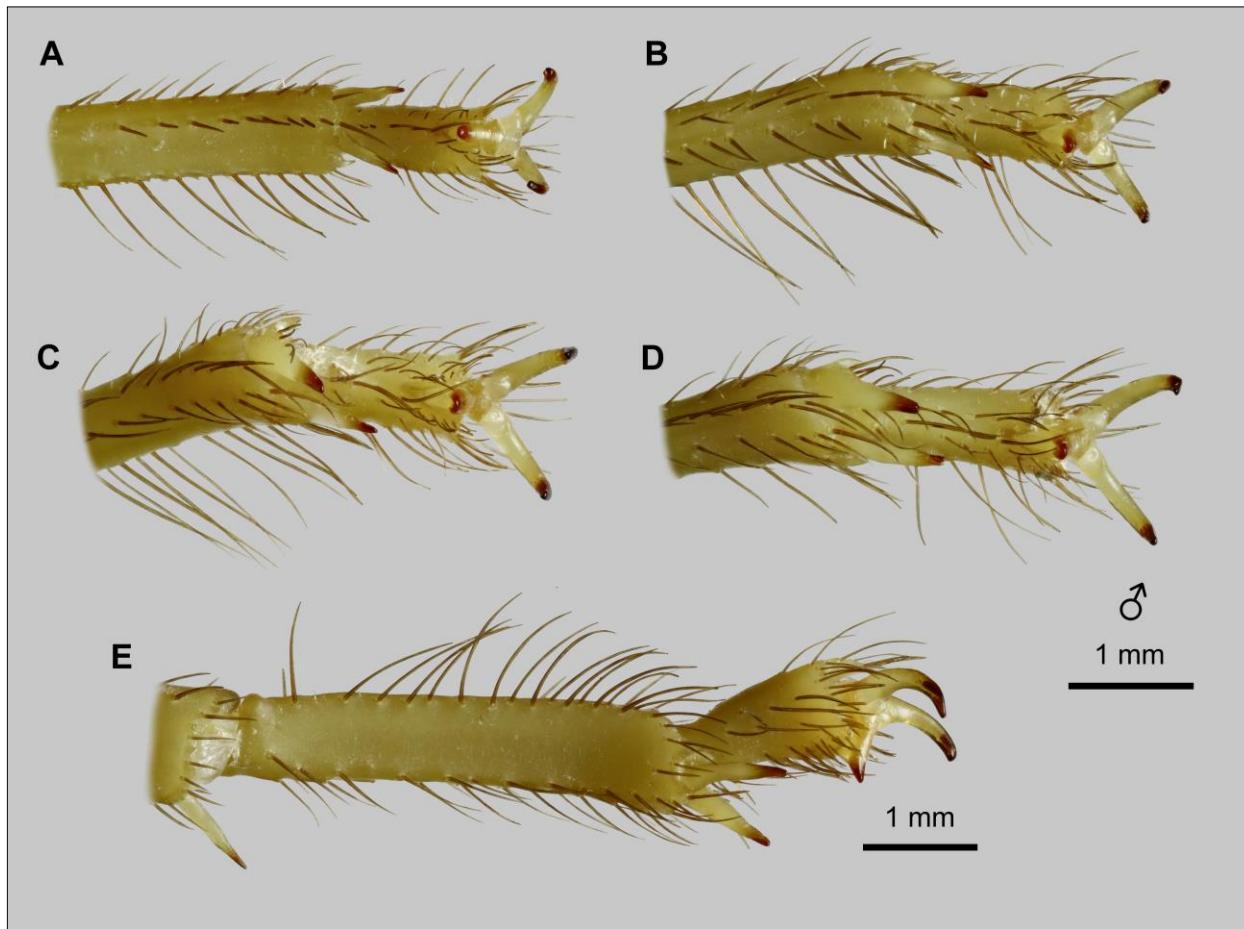
gins of left and right pectines aligned with posterior edges of coxae IV, basal 4 teeth overlap, without gap between basal middle lamellae, pectine teeth contact median carinae of sternite III; pectine teeth relatively large, mid-pectine sensillar margin L/ pectine L 0.096, mid-pectine sensillar margin L/ metasoma I W 0.231.

**Mesosoma.** *Tergites*: pretergites smooth; tergites I–II with 5 granular carinae; median and inner lateral cari-

nae linear with medium granules; outer lateral carinae aligned with posterior lateral carinae of carapace, strongly raised with enlarged posterior granules, hind ends with short lateral extensions, projecting past posterior margins of tergites; lateral flanks steeply sloped, with sparse granulation; medial intercarinal surfaces with dense, fine granulation or shagreened, with transverse anterior series of fine granules; tergites III–VI



**Figure 20:** *Leiurus macroctenus* sp. n. Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Male holotype, Thumrait, Oman. Female paratype, Wadi Qitaar, Masirah Island, Oman.

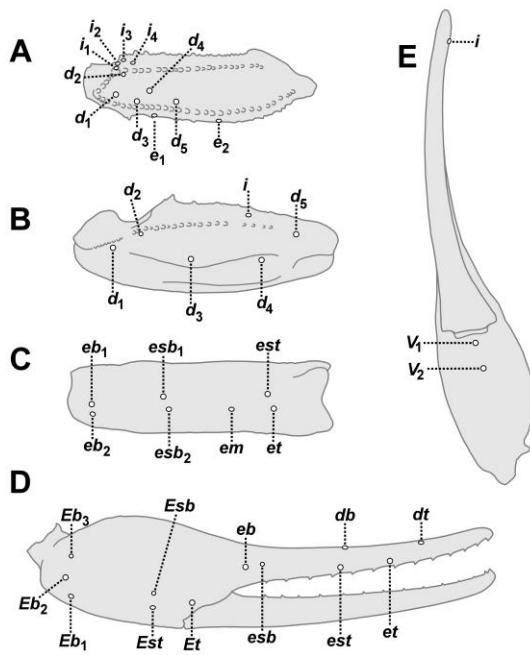


**Figure 21:** *Leiurus macroctenus* sp. n., holotype male. Tarsi. **A–D.** Left telotarsus and distal basitarsus, ventral aspect. **A.** Leg I. **B.** Leg II. **C.** Leg III. **D.** Leg IV. **E.** Right basitarsus III retrolateral aspect. Upper scale bar: **A–D**, lower scale bar: **E**. Thumrait, Oman.

with 3 linear or slightly curved carinae with medium to large, erect granules; medial intercarinal surfaces densely shagreened, with few larger granules, transverse anterior series of fine granules becoming more diffuse in posterior tergites; heavier fine granulation on median patch in front of median carina; lateral surfaces moderately sloped, shagreened, with many medium size granules; tergite VII with 5 strong, coarsely granular carinae; inner and outer lateral carinae joined anteriorly by transverse granule rows; intercarinal surfaces smooth or very faintly shagreened, fine granulation on antero-median and paired anterolateral patches; posterior margins of tergites I–VI rimmed with linear rows of medium sized granules; posterior margin of tergite VII with 3 small granules between inner lateral carinae; *sternites*: sternite III with moderately strong, broad, finely granulated median carinae; sternites IV–V with strong, finely granulated lateral carinae, very weak, almost obsolete densely shagreened median carinae; sternite VI with strong, coarsely granulated lateral carinae, moderate, finely granulated median carinae; sternite VII with

strong, coarsely granulated median and lateral carinae; lateral margins of sternites IV–VII armed with regular denticulate granules; medial intercarinal surface of sternite III densely shagreened throughout, of IV–VI densely shagreened anteriorly; lateral intercarinal surfaces on IV–VI heavily shagreened anteriorly, lightly on post-spiracular area; *setation*: sternite III with 5–6 macrosetae on median carinae, 4–5 on external side of median carinae; sternites IV–VII with 2 paired macrosetae on median carinae, one pair in middle of sternite, other on posterior margin; lateral carinae on IV–VI with posterior marginal macrosetae, mid-carinal setae on IV; intercarinal macrosetae: one middle pair of lateral marginal setae on sternites IV–VI; paired mediolateral setae 3 on IV, 2 on V, 1 on VI; one pair of latero-marginal setae on VII; intercarinal posterior marginal macrosetae on III–VII: 4, 4, 2, 2, 0.

**Hemispermatophore (topoparatype male).** Trunk elongate, slender; flagellum long, filiform, pars recta 0.4 times length of trunk, pars reflecta half length of trunk; inner lobe a broad lamina, gently tapering apically;



**Figure 22:** *Leirus macroctenus* sp. n., paratype female. Trichobothrial map of pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, external aspect. **E.** Chela, ventral aspect. Wadi Qitaar, Masirah Island, Oman.

median and outer lobes narrower at base, sharply tapering to thin apical processes; inner lobe longer than median and outer lobes; outer lobe flexed at apex; basal lobe thin, curved hook; measurements: trunk L (to base of flagellum) 7.2 mm, pars recta 2.9 mm, inner lobe (from base of flagellum) 810 µm, median lobe 410 µm, outer lobe 530 µm, basal lobe 200 µm.

**Metasoma.** Long, slender; total metasoma and telson L/ carapace L 5.4; *carination*: segment I with 10 complete carinae; segments II–III with 8 complete carinae, median lateral carinae restricted to posterior 0.25–0.38 of II, posterior 0.20 of III; metasoma IV with 8 carinae, V with 7 carinae; carinae on segments I–IV with crenulate or denticulate granulation; dorsosubmedian carinae moderate on I, moderate to weak on II–III, weak on IV; dorsolateral, ventrolateral and ventromedian carinae moderate on I, strong on II–IV; median lateral carinae moderate on I–III; ventromedian carinae on II–III with 16–19 granules, posterior granules larger; metasoma V with dorsolateral carinae very weak, faintly granulated on anterior 1/3, obsolete on posterior 2/3; ventrolateral carinae strong with dentate granules increasing in size posteriorly, larger subtriangular denticles alternating with series of smaller crenulations, ventrosubmedian carinae marked by series of small to medium dentate granules on anterior 2/3 of segment, ventromedian carina strong, armed with small to large dentate granules; lateral anal margin with 3 lobes,

ventral lobe well separated from dorsal lobes, ventral anal margin with 13 irregular, narrow to wide transverse crenulations; *intercarinal surfaces*: segments I–IV smooth, segment V smooth dorsally, finely sparsely shagreened laterally and ventrally; *setation*: segments I–IV: ventromedian carinae with 3 macrosetae (one posterior marginal), ventrolateral carinae with 2 external macrosetae; metasoma V with 5 macrosetae on lateral surface (2 lateral anal), 4 pairs on ventral surface.

**Telson.** Vesicle smooth, bulbous; ventral surface with scattered fine microsetae and several short macrosetae; aculeus slightly shorter than vesicle.

**Pedipalp.** *Femur*: slender, L/W 3.52; dorsoexternal, dorointernal and ventrointernal carinae strong with coarse, closely spaced dentate granules; internal carina moderate with large dentate granules spaced well apart; external carina obsolete, smooth ridge with isolated medium granules; ventral surface smooth with isolated small proximal granules, external surface smooth, dorsal and internal surfaces weakly, sparsely shagreened; linear cluster of 17–20 accessory macrosetae on lower distal external surface; *patella*: slender, L/W 3.20; dorsointernal carina moderate with coarse non-contiguous granulation; dorsomedian carina weak, almost smooth; dorsoexternal, external, ventroexternal carinae weak, smooth, ventromedian carina obsolete; ventrointernal carina weak, with well spaced medium granules and ventral patellar spur; internal carina moderate, with well spaced small to medium dentate granules and dorsal patellar spur; all intercarinal surfaces smooth; *chela*: slender, L/W 6.34, movable finger L/ manus ventral L 2.2; dorsal marginal and ventroexternal carinae weak, smooth, other carinae obsolete; all intercarinal surfaces smooth; manus and fixed finger with sparse short macrosetae; movable finger with numerous short macrosetae on ventral aspect, culminating in dense subapical brush; 13 primary denticle subrows on movable fingers, 12–13 on fixed fingers; 12 subrows flanked by internal and external accessory denticles. *Trichobothriotaxy*: orthobothriotaxic, type Aβ (Vachon, 1974), *db* on fixed finger distal to *est*.

**Legs.** Moderately long, slender, femur III L/ carapace L 1.13, patella III L/D 4.00; inferior carinae strongly denticulate on femur I–IV and patella I–III, almost smooth on patella IV; tibia III–IV with long spurs; retrolateral tarsal spurs simple, non-setose; pro-lateral tarsal spurs basally bifurcate, bearing 1–5 macrosetae; basitarsi I–III with well developed bristle-combs, at least as wide as basitarsal segment; basitarsus III setal counts (left/ right): retrosuperior 20/20, retroinferior 15/14 (including basal accessory seta), inferior 15/12; ventral surface of telotarsi with numerous, long fine macrosetae.

**Measurements of holotype male (mm).** Total L 72.50; metasoma + telson L 45.50; carapace L 8.36, W 8.08, carapace preocular L 3.72; metasomal segments

	males			females		
	Thumrait	central coast	Masirah Island	Thumrait	central coast	Masirah Island
Pedipalp chela L/ manus W	6.19 – 7.11 6.51 ± 0.29 (11)	5.87 – 6.31 6.13 ± 0.13 (9)	6.01 – 6.78 6.23 ± 0.22 (10)	5.35 – 6.57 5.95 ± 0.40 (13)	5.13 – 5.80 5.51 ± 0.26 (12)	5.27 – 6.13 5.56 ± 0.22 (16)
Patella III L/D	3.86 – 4.48 4.06 ± 0.19 (9)	3.43 – 4.10 3.75 ± 0.22 (9)	3.58 – 4.00 3.83 ± 0.16 (10)	3.66 – 4.00 3.84 ± 0.11 (8)	3.45 – 3.88 3.63 ± 0.12 (12)	2.12 – 2.54 2.35 ± 0.12 (16)
Metasoma I L/W	1.10 – 1.30 1.23 ± 0.06 (11)	1.12 – 1.30 1.20 ± 0.06 (8)	1.21 – 1.37 1.28 ± 0.05 (10)	1.12 – 1.29 1.22 ± 0.05 (13)	1.09 – 1.23 1.16 ± 0.04 (12)	3.38 – 4.00 3.70 ± 0.16 (16)
Metasoma II L/W	1.57 – 1.72 1.66 ± 0.05 (11)	1.50 – 1.70 1.58 ± 0.07 (9)	1.57 – 1.79 1.67 ± 0.07 (10)	1.52 – 1.73 1.64 ± 0.06 (13)	1.49 – 1.62 1.56 ± 0.04 (12)	1.15 – 1.32 1.22 ± 0.04 (16)
Metasoma III L/W	1.67 – 2.03 1.84 ± 0.11 (11)	1.60 – 1.82 1.70 ± 0.07 (9)	1.64 – 1.94 1.78 ± 0.08 (10)	1.67 – 1.95 1.79 ± 0.08 (13)	1.59 – 1.78 1.68 ± 0.06 (12)	1.48 – 1.73 1.62 ± 0.07 (16)
Metasoma IV L/W	2.14 – 2.40 2.25 ± 0.07 (11)	1.94 – 2.22 2.07 ± 0.08 (9)	2.11 – 2.33 2.20 ± 0.07 (10)	2.07 – 2.34 2.18 ± 0.07 (13)	1.92 – 2.14 2.05 ± 0.07 (12)	1.60 – 1.87 1.75 ± 0.06 (16)
Metasoma V L/W	2.40 – 2.67 2.50 ± 0.07 (11)	2.19 – 2.49 2.36 ± 0.10 (9)	2.32 – 2.74 2.53 ± 0.11 (10)	2.15 – 2.63 2.42 ± 0.13 (13)	2.20 – 2.39 2.27 ± 0.07 (12)	1.87 – 2.30 2.13 ± 0.11 (16)

**Table 1:** Variation in adult morphometric ratios among different populations of *Leiurus macroctenus* sp. n. in Oman (ranges, mean ± SD, sample sizes in parentheses). Higher values indicate more slender segments.

(L/ W/ D) I 5.90/ 4.59/ 3.96, II 7.05/ 4.13/ 3.81, III 7.17/ 3.84/ 3.65, IV 7.87/ 3.55/ 3.32, V 9.09/ 3.66/ 3.02; telson L 8.20; vesicle L 4.40, W 3.22, D 3.11; pedipalp chela L 15.02, manus ventral L 4.93, manus W 2.37, manus D 2.84, fixed finger L 8.96, movable finger L 10.84; pedipalp femur L 7.47, W 2.12, patella L 8.94, W 2.79; pectine L 11.09; leg III femur L 9.46; leg III patella L 7.91, D 1.978.

**Paratype female (Thumrait).** Differs from male as follows: larger, more robust, wider body, carapace W/L 1.06; weaker carination on carapace, tergites and coxae; pectines narrower, shorter, tips extending to proximal 1/5 of trochanter IV, teeth smaller with shorter sensillar margins, mid-pectine sensillar margin L/ pectine L 0.084, mid-pectine sensillar margin L/ metasoma I W 0.189; 33–34 pectine teeth, basal pectine teeth non-overlapping; sternite III with weak, narrow, finely granular median carinae; sternites IV–V with strong but narrower, more finely granulated lateral carinae, median carinae obsolete; sternites VI with narrower, finely granulated lateral carinae, weaker, narrower median carinae with regular small granules; VII with slightly stronger, granular carinae; intercarinal surfaces of sternites III–VI smooth medially, finely micro-shagreened anterolaterally; ventromedian carinae on metasoma II–III more strongly crenulate or dentate, with larger posterior denticles; pedipalp chela more robust, L/W 5.35.

**Measurements of paratype female (mm).** Total L 84.00; metasoma + telson L 49.00; carapace L 9.70, W 10.29, carapace preocular L 4.19; metasomal segments (L/ D/ W) I 6.27/ 4.54/ 5.17, II 7.56/ 4.44/ 4.58, III 7.79/ 4.28/ 4.37, IV 8.74/ 3.85/ 4.08, V 10.00/ 3.58/ 4.34;

telson L 9.00; vesicle L 4.83, D 3.65, W 3.71; pedipalp chela L 17.18, manus ventral L 5.43, manus W 3.21, manus D 3.85, fixed finger L 9.93, movable finger L 12.22; pedipalp femur L 8.54, W 2.59, patella L 10.09, W 3.30; pectine L 11.71; leg III femur L 10.32; leg III patella L 8.60, D 2.19.

**Variation.** Base color varied with location and substrate, being pale yellow in samples from Thumrait and Jiddat al Harasis, and light brown or orange in some coastal sites including Masirah Island. Morphometric variation was observed in subpopulations sampled from three separate regions: inland Nejd desert around Thumrait, central coast of Oman (Ras ad Duqm south to Ras Sawqirah) and Masirah Island. Variation in size was sex-dependent: males from central coast were on average smaller with less size variation (carapace L  $7.60 \pm 0.22$  mm) than males from Thumrait ( $8.21 \pm 0.50$  mm) or Masirah Island ( $7.78 \pm 0.49$  mm); female mean sizes were similar for these populations, but sample variance was smallest in central coast and greatest in Thumrait populations. Variation in specific morphometric ratios among different populations is summarized in Table 1. Samples from the central coast (Ras ad Duqm south to Ras Sawqirah) had on average less slender legs, pedipalp chelae and metasomal segments compared to samples from Thumrait and Masirah Island. In contrast, the morphometrics of Thumrait and Masirah Island populations were broadly overlapped. Overall morphometric variation is summarized in Table 4. **Sexual dimorphism:** compared to females, the males had on average more slender pedipalps and larger pectine teeth (Tab. 4B). The number of denticles on ventromedian carinae of metasoma III was significantly lower in males ( $16.79 \pm 1.61$ )

than females ( $18.81 \pm 1.47$ ) ( $P = 0.00027$ , t test). *Diagnostic characters*: (1) leg III retrosuperior setae (bristle-comb): the number of setae exhibited a unimodal distribution with no significant difference between males and females; setal count =  $19.96 \pm 2.61$  (mean  $\pm$  SD,  $n = 100$ , sexes pooled), with 95/100 (95%) of basitarsi bearing 17 or more setae); (2) female pectine teeth: sensillar margins were relatively long over the length of the pectine, but shorter for the basal tooth; mid-pectine sensillar margin L/ carapace L  $0.09 - 0.11$  ( $0.10 \pm 0.01$ ,  $n = 28$ ), basal-pectine sensillar margin L/ carapace L  $0.03 - 0.08$  ( $0.06 \pm 0.01$ ,  $n = 28$ ). Basal teeth were also very different in proportions, with a longer trunk and shorter sensillar margin: mid-pectine trunk L/ sensillar margin L  $0.31 - 0.49$  ( $0.38 \pm 0.04$ ,  $n = 30$ ), basal-pectine trunk L/ sensillar margin L  $0.56 - 1.45$  ( $0.96 \pm 0.23$ ,  $n = 28$ ). Fig. 95B plots the range of covariation of the ratios of mid-pectine sensillar margin L/ carapace L, and mid-pectine sensillar margin L/ metasoma I W, showing the large morphometric difference from other *Leiurus*. The large pectine teeth are a more robust diagnostic character in females. In males, the enlargement of pectine teeth as a secondary sexual characteristic obscures the inter-species difference; (3) pedipalp fixed finger db was distal to est in 142/175 (81%), and proximal in 33/175 (19%) of fixed fingers (Fig. 95A).

**DISTRIBUTION.** Known only from the central and north-eastern coast (including Masirah Island, reaching as far north as Ras Al Hadd), and the south-central plains (Jiddat al Harasis and Nejd Desert) of Oman. The elevation range of records is 2 – 800 m, with the lowest on the coast, and the highest in the Jabal Qara hills.

**ECOLOGY.** These are arenicolous scorpions from coastal and adjacent inland alluvial plains and steppes in Oman. In the Nejd desert north of Jabal Qara, *L. macroctenus* was observed in burrows excavated in fine sedimentary soil around rock outcroppings. Individuals were often waiting in nocturnal ambush positions at the burrow entrance with carapace and pedipalps protruding, chela fingers open, while their mesosoma and metasoma were protected inside the burrow. In sandy wadis on Masirah Island, they were observed at night resting on open sand with tarsi spread in a wide circle, a characteristic behavior of psammophilous scorpions localizing moving prey by substrate vibrations detected by basitarsal slit sensillae (Brownell, 1977; Brownell & Farley, 1979). Adaptation to sandy substrates is suggested by the well developed basitarsal bristle combs that are broader and denser than those of other *Leiurus*. On the mainland, *L. macroctenus* was absent from the Wahiba Sands and Rub' al Khali. It could be excluded from those dunes by intraguild predation from the larger *Apistobuthus*, which is absent from Masirah Island. The

Wahiba Sands also present an ecological barrier to the dispersal of other terrestrial fauna (Munton 1988).

### *Leiurus haenggii* sp. n.

(Figs. 23–34, 46, 58C, 59C–D, 87D, 88D, 89D, 90D, 91A, 92E–F, 93C–D, 94D–E, 95, 98–100, Tabs. 3B, 4)  
<http://zoobank.org/urn:lsid:zoobank.org:act:E2D4F137-9FEA-4A9D-A0B5-07100870F6AA>

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*Buthus quinquestriatus brachycentrus*: Birula 1937: 102–105.  
*Buthus (Buthus) quinquestriatus*: Whittick, 1941: 43 (record from Yemen); Roewer, 1943: 206 (in part, record from Yemen).  
*Leiurus quinquestriatus voelschowi*: Kovařík, 1997: 180 (in part, record from Yemen).  
*Leiurus quinquestriatus*: Stahnke, 1972: 130 (in part); Lamoral & Reynders, 1975: 509–510 (in part); Vachon, 1979a: 49–50 (in part), figs. 37, 46–48, 64–66; Kinzelbach, 1985: map II (in part); El-Hennawy, 1992: 101, 125–126 (in part); Sissom, 1994: 20–23 (in part), figs. 38–44; Kovařík, 1998: 112 (in part); Fet & Lowe, 2000: 155 (in part); Hendrixson, 2006: 84–91 (in part), fig. 18 (in part), fig. 19; Kovařík, 2007: 140, figs. 9–10; Kaltsas & al., 2008: 218–219 (in part); El-Hennawy, 2009: 122 (in part); El-Hennawy, 2014: 45 (in part).  
*Leiurus quinquestriatus hebraeus*: Levy & Amitai, 1980: 48–53 (in part).

**HOLOTYPE.** Adult ♀, **Saudi Arabia**, Ta'if, X.1975, leg. W. Büttiker (NHMB 17k).

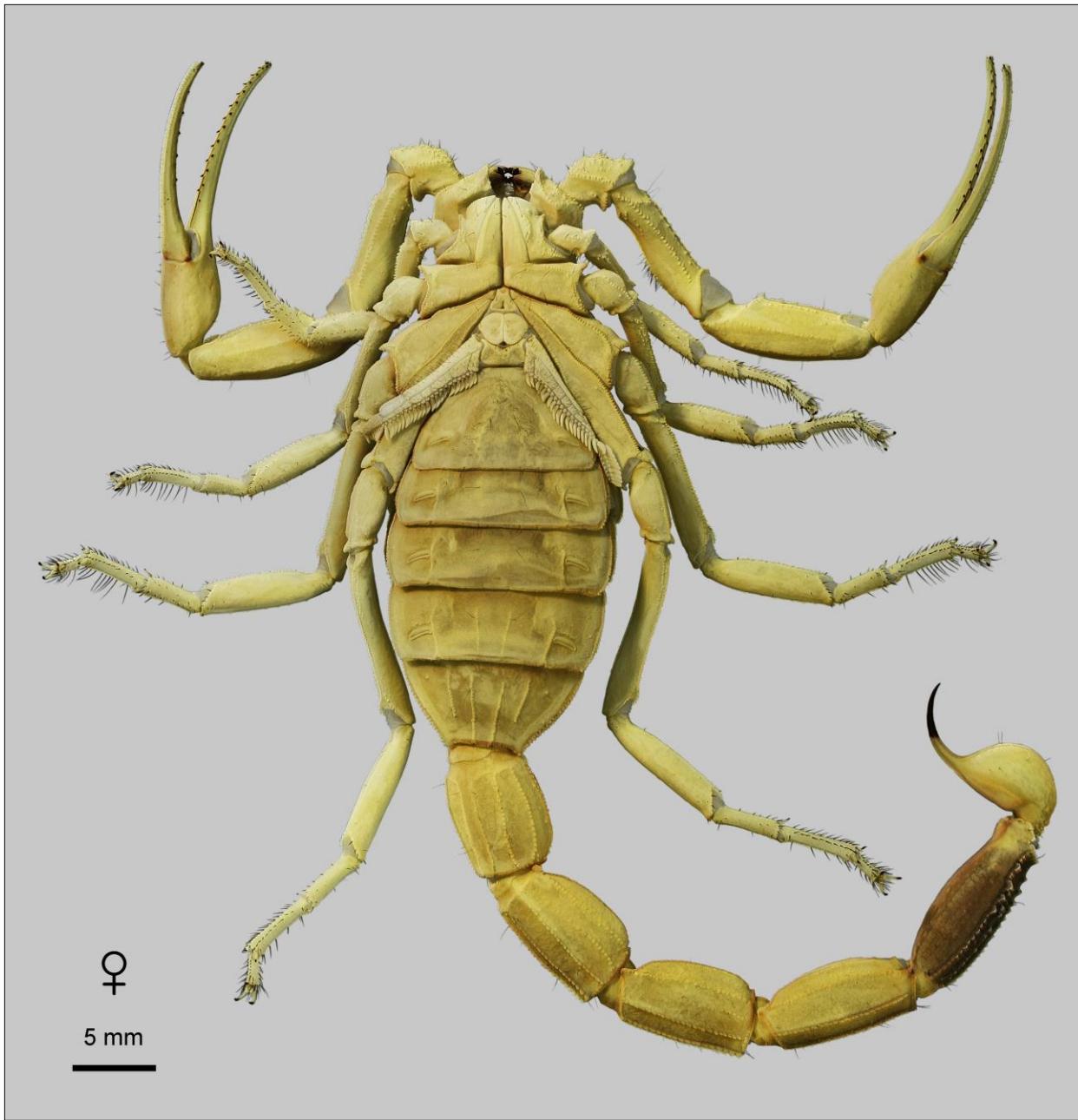
**PARATYPES. Oman:** 1 ♂, Wadi Ghaiz, Dhofar, under rock,  $16^{\circ}58'N\ 53^{\circ}52'E$ , 60 m a.s.l., 11.IV.1980, leg. J.N. Barnes, MDG 5995 (NHMB); 1 ♀, Sarfait Area, Dhofar,  $16^{\circ}40'N\ 53^{\circ}06'E$ , 1985, leg. Sultan of Oman Land Forces (NHMB); 1 ♀, Sarfait, Jabal Qara,  $16^{\circ}43'N\ 53^{\circ}07'E$ , 1300 m a.s.l., 4.IX.1989, leg. R.P. Whitcomb (NHMB); 1 ♀, Jabal Qara, Dhofar, edge of dry Nejd,  $17^{\circ}19'N\ 54^{\circ}16'E$ , 850 m a.s.l., 6.IX.1989, leg. M.D. Gallagher MDG 8146 (ONHM); 1 ♂, Salalah, Dhofar,  $17^{\circ}05'N\ 54^{\circ}10'E$ , X.1993, leg. F. Barter (NHMB); 1 ♀, Jabal Qara; north slopes, Nejd, UV detection rocky wadi, rocky wadi & rocky slopes,  $17^{\circ}17.83'N\ 54^{\circ}05.11'E$ , 800 m a.s.l., 16.X.1993, 22:38 h, leg. G. Lowe (GL); 1 ♂, 1 ♀, 1 juv, Jabal Qara; Salalah-Thumrait road, UV detection, rocky wadi, edge of Nejd Desert, dry zone,  $17^{\circ}17.26'N\ 54^{\circ}05.36'E$ , 800 m a.s.l., 17.X.1993, 20:53 h, leg. G. Lowe (NHMB); 2 ♂, 2 juvs, Jabal Qara; Salalah-Thumrait road, UV detection, wide rocky wadi, nr edge of wadi & rocky flats,  $17^{\circ}17.58'N\ 54^{\circ}05.11'E$ , 800 m a.s.l., 17.X.1993, 20:53 h, leg. G. Lowe (NHMB).



**Figure 23:** *Leiurus haenggii* sp. n., holotype female. Habitus, dorsal aspect. Ta'if, Saudi Arabia (NHMB 17k).

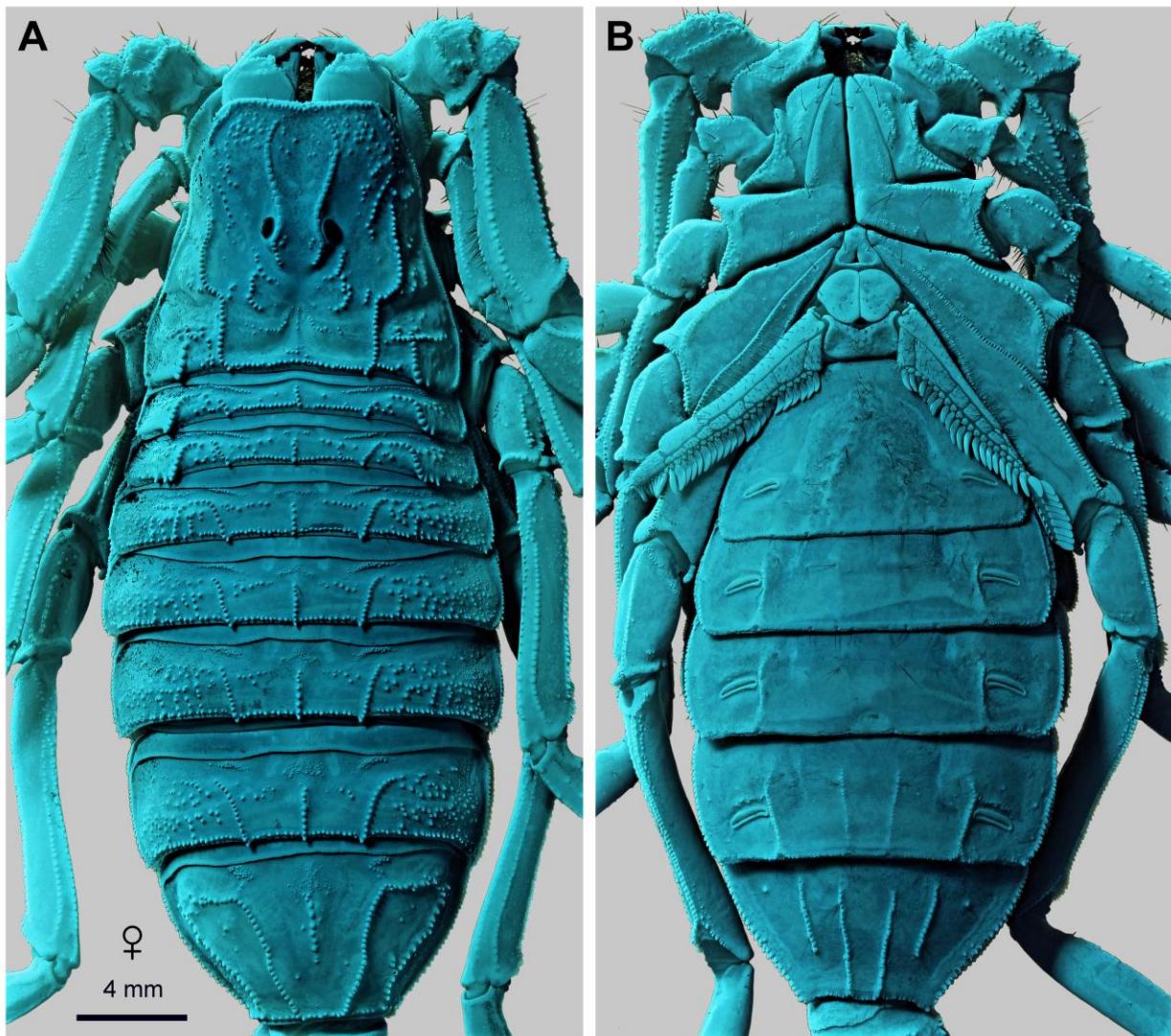
54°04.97'E, 800 m a.s.l., 17.X.1993, 21:45 h, leg. G. Lowe (NHMB); 1 ♀, main road above Khor Rori Beach, east of Taqah, UV detection on ground, densely vegetated wadi, warm & humid with many insects, 17°03.22'N 54°25.33'E, 50 m a.s.l., 18.X.1993, 21:24 h, leg. G. Lowe (NHMB); 2 ♀, Salalah Plain; road to Ayn Hamran, 3.5 km off main coast road, UV detection, open plain with scattered *Prosopis*, 17°03.54'N 54°16.4'E, 50

m a.s.l., 18.X.1993, 22:29 h, leg. G. Lowe (GL); 1 ♀, Jabal Qara, UV detection, on rock by line of date palms, 17°01.89'N 54°05.46'E, 29.IV.1995, 21:30 h, leg. J. Dundon (BMNH); 2 ♂, 1 ♀, 1 juv, Jabal Qara, UV detection, 17°07.54'N 54°08.97'E, 142 m a.s.l., 30. IV.1995, leg. J. Dundon (GL); 1 ♀, Khor Rori Beach (site F/23), UV detection, rocky slope of densely vegetated wadi between rocks, 17°03.18'N 54°25.51'E,



**Figure 24:** *Leiurus haenggii* sp. n., holotype female. Habitus, ventral aspect. Ta'if, Saudi Arabia (NHMB 17k).

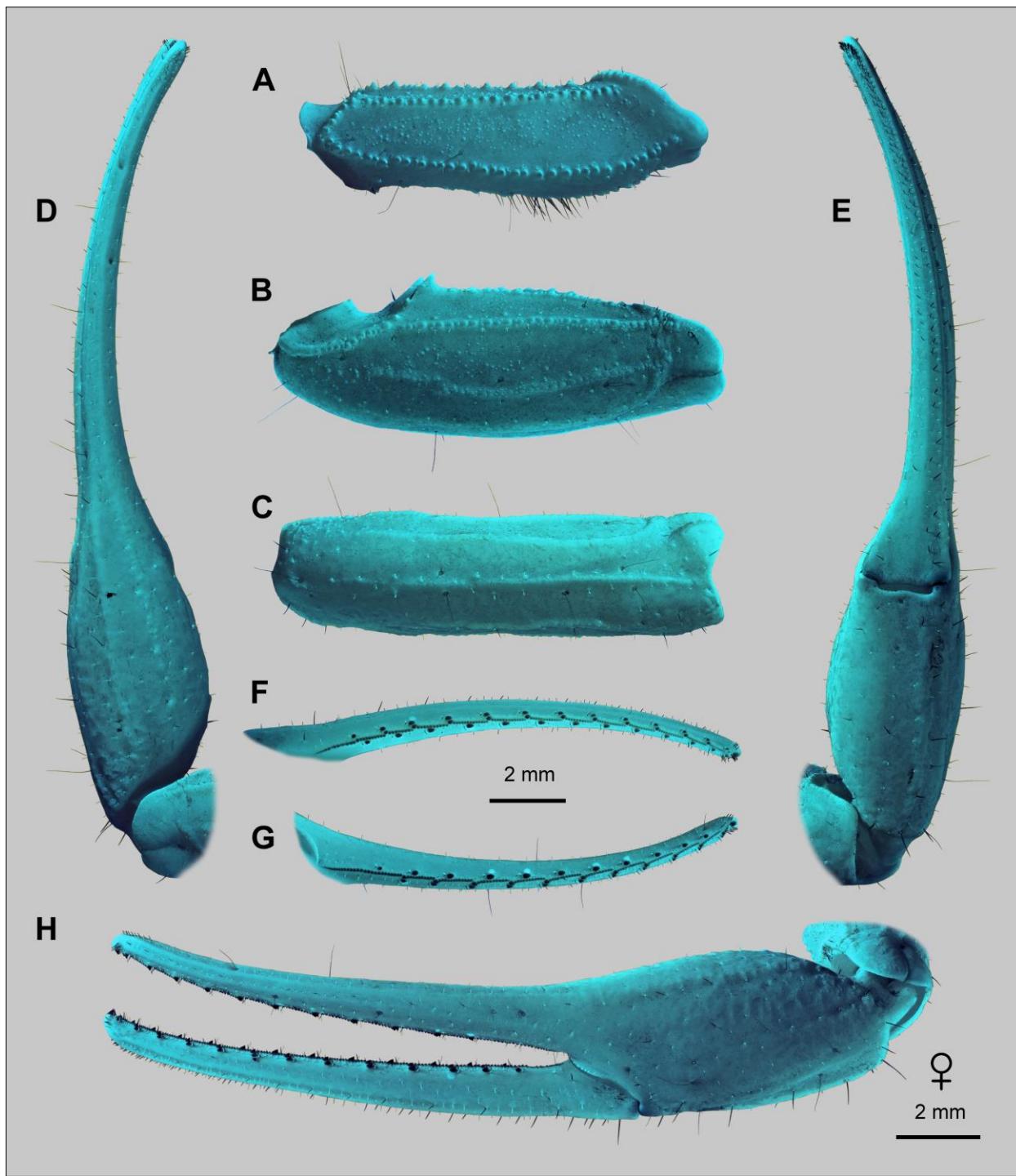
22 m a.s.l., 24.XII.2001, 02:25–04:45 h, leg. A. Winkler (ONHM); 2 ♀, Wadi Khor Rori, Dhofar, 17°02'59.7"N 54°25'28.4"E, 22 m a.s.l., IX.2013, leg. T. Mazuch and P. Novák (FKCP); 1 juv., UV detection 22:00–23:00 h, Taqah, 17°03.26"N 54°25.50"E, 26 m a.s.l., 21.III.2014, leg. D. Hoferek (FKCP); 1 ♂, 1 ♀, 2 juvs, UV detection 20:00–22:00 h, Mirbat, 17°02.19"N 54°38.75"E, 54 m a.s.l., *Adenium* steppe, 22.III.2014, leg. D. Hoferek (FKCP). **Saudi Arabia:** 1 ♀, leg. W. Büttiker (NHMB 17ae2); 1 juv ♀, Wadi Turabah, camp 2, 20°28.6'N 41°10.05"E, 1580 m a.s.l., leg. W. Büttiker (NHMB 17ah); 3 ♂, Wadi Wajj, 18 km SW Taif, 21°10'N 40°16"E, 1810 m a.s.l., leg. W. Büttiker (NHMB 17as); 1 ♀, Wadi Wajj, 18 km SW Taif, 21°10'N 40°16"E, 1810 m a.s.l., leg. W. Büttiker (NHMB 17x); 1 ♀, 1 juv ♀, Taif, 21°18'N 40°24"E, 1670 m a.s.l., X.1975, leg. W. Büttiker (NHMB 17k); 1 juv ♀, Abha Gizan km 53, Wadi Ad Dilla, 17°51'N 42°22.8"E, 300 m a.s.l., 21.IV.1976, leg. W. Büttiker & W. Witt (NHMB 17s); 1 ♀, 15 km W of Khamis Mushayt, 18°18.4'N 42°35.7"E,



**Figure 25:** *Leiurus haenggii* sp. n., holotype female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Ta'if, Saudi Arabia (NHMB 17k).

2050 m a.s.l., 18.II.1977, leg. W. Büttiker (NHMB 17u); 1 ♀, Adnan, 20°26'N 41°31'E, 1650 m a.s.l., 21.IX.1978, leg. W. Büttiker (NHMB 17am); 2 ♀, Wadi Maraba, 17°53.76'N 42°23.4'E, 320 m a.s.l., 1.X.1978, leg. W. Büttiker (NHMB 17al); 2 ♂, Wadi Qatan, 18°06.86'N 44°09.03'E, 1350 m a.s.l., 25.XI.1979, leg. W. Büttiker (NHMB 17ad, 17af); 1 ♀, Wadi Qatan, 18°06.86'N 44°09.03'E, 1350 m a.s.l., 25.XI.1979, leg. W. Büttiker (NHMB 17z); 1 ♀, Wadi Jeddah, 25°52'N 48°48'E, 26.XI.1979, leg. W. Büttiker (NHMB 17y); 1 ♀, Adama, 19°20.33'N 42°01.37'E, 1770 m a.s.l., 1980, leg. W. Büttiker (NHMB 17as2); 1 ♂, Wadi Gaanah, 18°25.8'N 41°53.6'E, 470 m a.s.l., 13.II.1980, leg. W. Büttiker (NHMB 17ab); 1 juv ♂, Wadi Yamaniyah, 21°39'N 40°19'E, 1100 m a.s.l., 31.III.1980, leg. W. Büttiker (NHMB 17ax); 2 ♀, Wadi Turabah, 20°29'N 41°12'E,

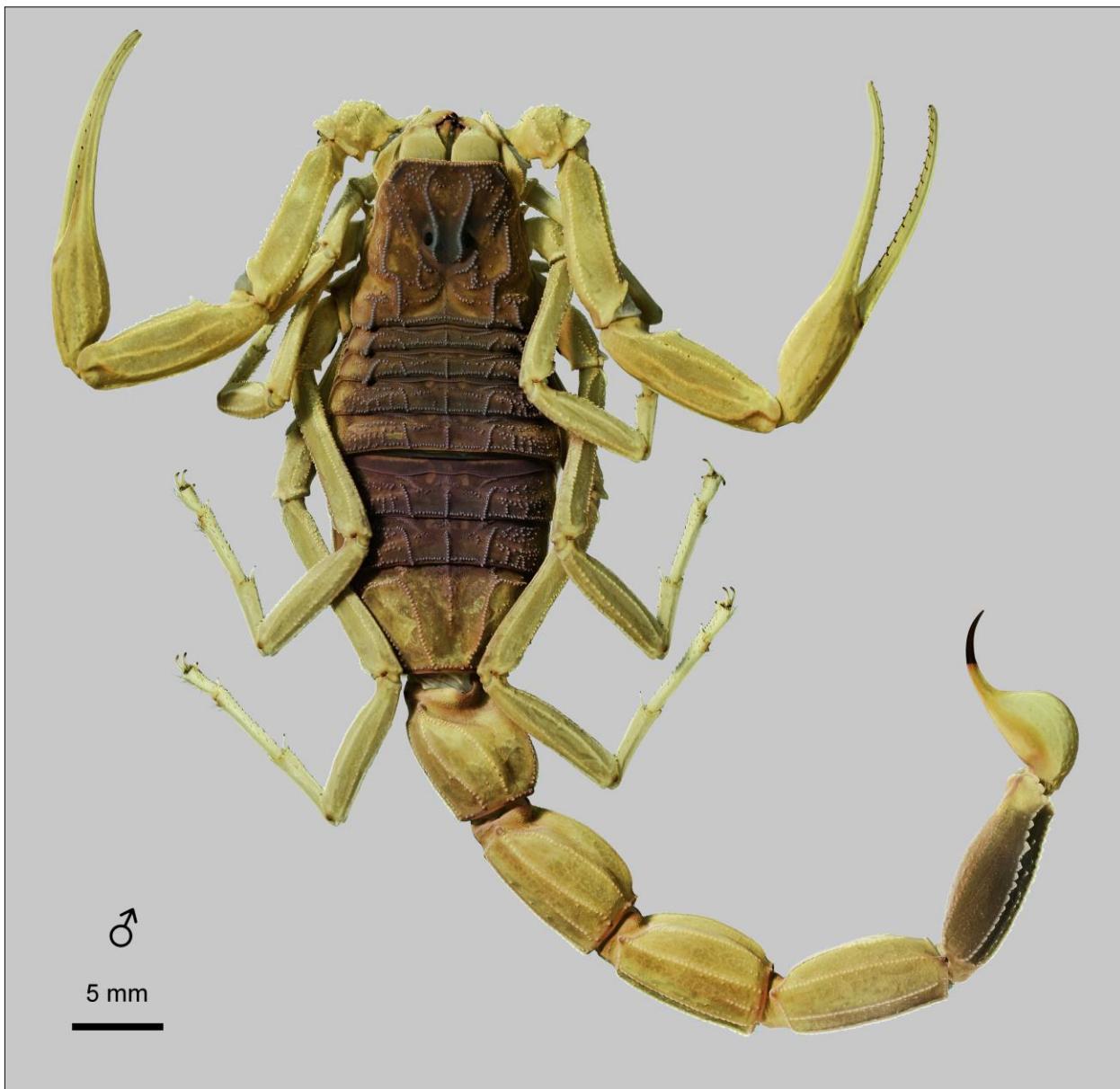
1480 m a.s.l., 4.IV.1980, leg. W. Büttiker (NHMB 17am2); 2 juv ♂, 4 juv ♀, Adama, 19°20.33'N 42°01.37'E, 1770 m a.s.l., 17.IV.1980, leg. W. Büttiker (NHMB 17ap2); 2 juv ♂, Adama, 19°20.33'N 42°01.37'E, 1770 m a.s.l., 17.IV.1980, leg. W. Büttiker (NHMB 17ar2); 1 ♀, Wadi Shuqub, 20°43'N 41°10'E, 1480 m a.s.l., 21.IV.1980, leg. W. Büttiker (NHMB 17bb); 1 juv ♂, 2 juv ♀, Wadi Turabah, 20°29'N 41°12'E, 1510 m a.s.l., 15.IX.1980, leg. W. Büttiker (NHMB 17ad2); 1 ♀, Wadi Qatan, 18°06.86'N 44°09.03'E, 1350 m a.s.l., 23.IX.1980, leg. W. Büttiker (NHMB 17bf); 1 juv ♀, Wadi Sanakah, 18°01'N 44°07'E, 1320 m a.s.l., 21.IV.1980, leg. W. Büttiker (NHMB 17az); 2 ♂, 10 km NE of Biljurshi, 19°54.57'N 41°34'E, 2050 m a.s.l., 7.X.1980, leg. W. Büttiker (NHMB 17ak2); 1 juv ♀, Biljurshi, 19°50.06'N 41°32'E.



**Figure 26:** *Leiurus haenggii* sp. n., holotype female. Pedipalp. **A.** Right femur, dorsal aspect. **B.** Right patella, dorsal aspect. **C.** Right patella, external aspect. **D.** Left chela, dorsal aspect. **E.** Left chela, ventral aspect. **F.** Left movable finger dentition. **G.** Left fixed finger dentition. **H.** Left chela, external aspect. Ta'if, Saudi Arabia (NHMB 17k).

54°E, 1840 m a.s.l., 7.X.1980, leg. W. Büttiker (NHMB 17ay); 2 ♂, 1 ♀, Hesua, camp 1, 18°05'N 42°21'E, 1930 m a.s.l., 27.IX.1981, leg. W. Büttiker (NHMB 17ab2); 1 ♂, 1 ♀, 2 juv ♂, Al Faraah, 20°57'N 40°12'E, 700 m a.s.l., 15.II.1982, leg. W. Büttiker (NHMB 17aj2); 1 ♂,

Wadi Wajj, 18 km SW of Taif, 21°10'N 40°16'E, 1810 m a.s.l., 23.IV.1982, leg. W. Büttiker (NHMB 17aw); 1 juv ♂, 1 juv ♀, Wadi Maharish, 21°21.5'N 40°13'E, 1000 m a.s.l., 7.I.1983, leg. W. Büttiker (NHMB 17au); 1 ♂, 1 ♀, 1 juv ♀, Wadi Bani Malek, 21°34.48'N 39°17.



**Figure 27:** *Leiurus haenggii* sp. n., paratype male. Habitus, dorsal aspect. Wadi Asidah, Saudi Arabia (NHMB 17al2).

15°E, 8.II.1983, leg. W. Büttiker (NHMB 17ah2); 1 juv ♂, Wadi Ellah, 22°35'N 41°35'E, 1480 m a.s.l., 9.IX.1983, leg. W. Büttiker (NHMB 17be); 1 ♂, 1 juv ♀, Wadi Asidah, 20°25'N 41°12'E, 1560 m a.s.l., 10.IX.1983, leg. W. Büttiker (NHMB 17al2); 1 ♀, Wadi Tayyah, 18°32'N 42°14'E, 825 m a.s.l., 15.IX.1983, leg. W. Büttiker (NHMB 17av); 1 juv ♀, Wadi Dhiyan, 19°54.5'N 41°30.4'E, 1050 m a.s.l., 8.III.1984, leg. W. Büttiker (NHMB 17bc); 1 juv ♂, 1 juv ♀ exuvium, Baha, 20°00.65'N 41°28'E, 2170 m a.s.l., 3.VIII.1984, leg. W. Büttiker (NHMB 17at); 1 juv, Al Foqah, 19°50'N 41°51'E, 1630 m a.s.l., 10.IX.1984, leg. W. Büttiker (NHMB); 1 juv ♂, 2 juv ♀, Al Foqah, 19°59'N 41°51'E, 1630 m a.s.l., 20.X.1984, leg. W. Büttiker (NHMB 17aq2); 1 juv, Jebel Lebaba, 18°01.65'N 42°01.93'E, 420 m a.s.l., 24.III.1985, leg. J. Grainger (NHMB); 1 ♂, Jebel Warjan, 23°59'N 39°10'E, 2100 m a.s.l., 2.IV.1985, leg. S. Collenette (NHMB); 1 ♀, Fare, 22°45'N 39°48.4'E, 850 m a.s.l., 25.IV.1985, leg. W. Büttiker (NHMB 17ba); 1 ♀, Jebel Al Lawz, 28°41.52'N 35°17.88'E, 2200 m a.s.l., 5.VI.1985, leg. J. Grainger (NHMB 17an2); 1 ♂, 1 juv ♀, Shumaisy, 25°06'N 38°43'E, 740 m a.s.l., 12.XI.1986, leg. W. Büttiker (NHMB 17bh). **Yemen:** 1 ♂, 1 ♀, captive bred (Sanáa), M. Heule (GL); 1 juv ♀, Jebel Bagim, nr Sadah, 16°55.5'N 43°47'E, 2000 m a.s.l., 27.IX.1985, W. Büttiker (NHMB



**Figure 28:** *Leiurus haenggii* sp. n., paratype male. Habitus, ventral aspect. Wadi Asidah, Saudi Arabia (NHMB 17al2).

17bd); 1 ♂, Wadí Dhahr, 15 km NW of Sanáa, 15°24.52'N 44°07.39'E, leg. Šťastný (FKCP); 1 ♂, Wadithar, 14°26.6'N 44°45.5'E, 17.XI.2003, leg. P. Kabátek (GL); 1 ♀, 4 juvs, Jabal Lawz, SE Sanáa, 15°23'N 44°29'E, 2828 m a.s.l., leg. P. Kabátek (FKCP); 2 ♀, 5 juvs, Al Bayda gov., At Taghiq vill. env., NW of Al Bayda by road (Locality No. 16), 14°08.43'N 45°25.88'E, 1968 m a.s.l., 4.-5.XI.2007, leg. D. Král (FKCP); 1 ♀ (FKCP).

**DIAGNOSIS** (adults). Medium to large *Leiurus*, 65–97 mm in length, carapace L 7.4–11.2 mm; base color yellow to orange-yellow, with varied fuscous pigmen-

tation on carapace, tergites and metasoma V; interocular triangle fuscous or dark; metasoma V light brown to black except for posterior end; carapace with area between anterior median carinae bearing scattered medium to coarse granules, area between posterior median carinae with deep median furrow flanked by arcs of coarse granules; medial intercarinal surfaces of tergites II–III sparsely granulated, lightly shagreened or smooth; posterior margin of coxa III smooth or with sparse fine granules; metasoma robust to moderately slender, metasoma II L/W 1.46–1.80, metasoma III L/W 1.55–1.96, metasoma IV L/W 1.90–2.46; ventromedian carinae of metasoma II and III with 15–28 denticles

(85/91 carinae); metasoma V with enlarged subtriangular or lobate denticles on ventrolateral carinae; pedipalps moderately slender, patella L/W ♂ 3.01–3.52, ♀ 2.60–3.14; leg III patella L/D ♂ 3.51–4.02, ♀ 3.21–3.70; pectine teeth ♂ 28–39, ♀ 24–32; pectines long, narrow, pectine L/ carapace L ♂ 1.10–1.27, ♀ 0.91–1.15, midpectine sensillar margin L/metasoma I W ♂ 0.138–0.175, ♀ 0.093–0.116; basal 1–3 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece smooth in females, smooth or slightly shagreened in males; leg III basitarsus with 10–15 retrosuperior setae; pedipalp chela fixed finger with trichobothrium *db* distal to *est*; sternite VII with area between median carinae smooth or with sparse fine granulation anteriorly, more heavily in males; sternite carination: *males*, sternite III with median carinae robust, sternites IV–V with lateral carinae robust, median carinae moderate or weak; *females*, sternite III with median carinae weak or obsolete, sternites IV–V with lateral carinae moderate, median carinae weak or obsolete.

**ETYMOLOGY.** A patronym in honor of Dr. Ambros Hänggi, Naturhistorisches Museum, Basel, for his many contributions to science and his long support of the authors studies of Arabian scorpions.

**COMPARISONS.** *L. haenggii* sp. n. differs from *L. quinquestriatus* and resembles *L. arabicus* sp. n. in the following characters: posterior medial area of carapace with shallow to moderately deep median furrow, not flat, flanked by lateral granule arcs; medial intercarinal surfaces of tergites II–III between granule clusters smooth to sparsely shagreened or granulated (Figs. 94D–E); medial intercarinal surfaces of sternites smooth or lightly, finely shagreened; pectine basal piece smooth or very slightly granulated. It differs from *L. arabicus* sp. n. by having more robust leg, pedipalp and metasomal segments (Fig. 46), and smooth or weakly granulated median carinae on sternites III–V of females (Figs. 92E–F).

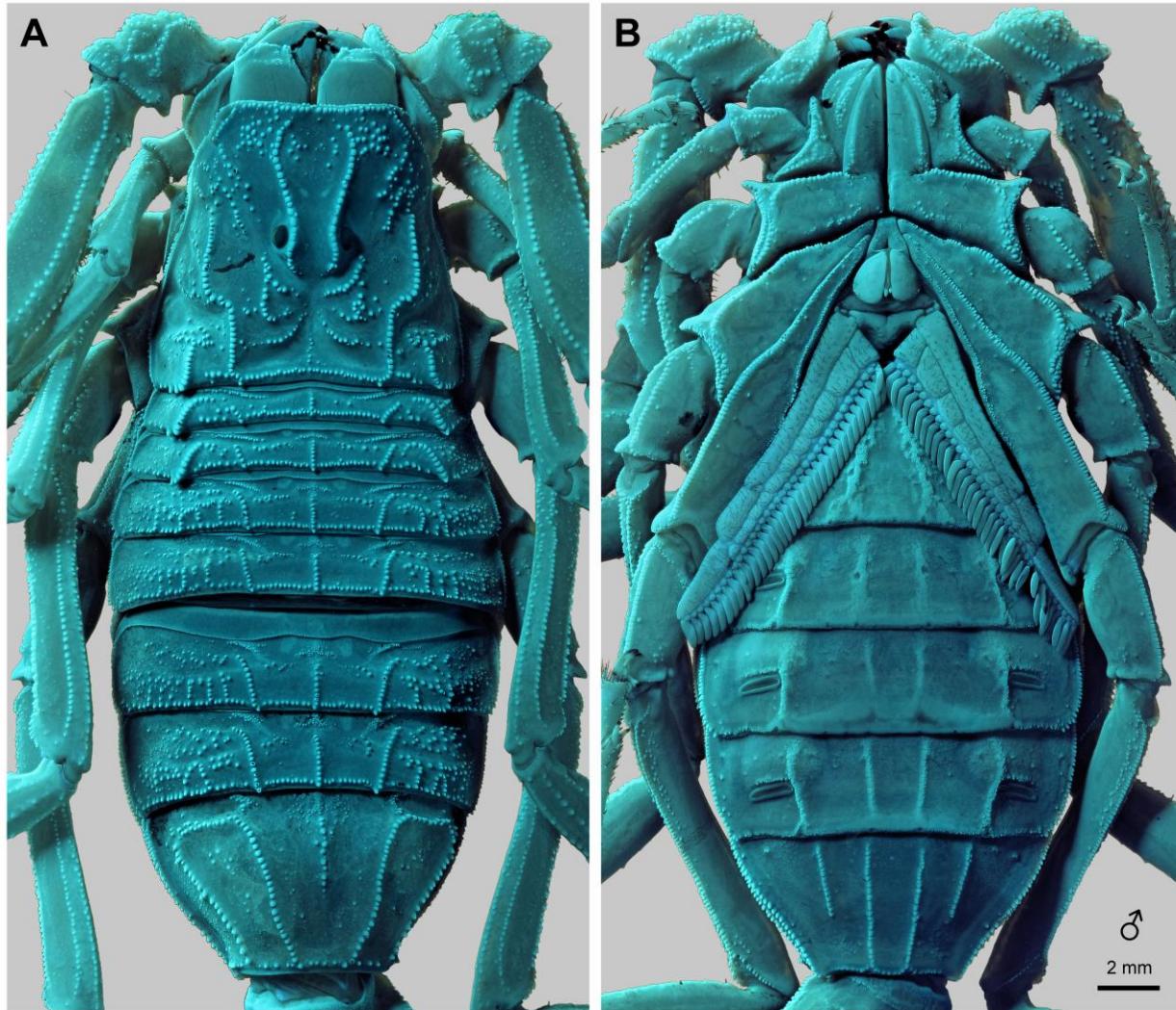
#### DESCRIPTION (holotype female).

**Coloration.** Base color yellow or yellow-orange, carapace and tergites with extensive dark pigmentation; carapace dark on anterior interocular area, carinae, and posterior margin, light around posterior median furrow, lateral flanks outside lateral carinae pale; pretergites I–VI dark posteriorly, maculate anteriorly, III–VI with pair of pale median spots; tergites I–VI fuscous on medial and mediolateral intercarinal surfaces, with pair of pale anterior median spots, lateral flanks pale; tergite VII with slight fusosity in anterior median area; ventromedian carinae of metasoma III–IV with dark stripes; metasoma V dark except for posterior end.

**Carapace.** Subrectangular, broad, W/L 1.17, with moderately sloped lateral flanks; upper surface with nearly flat posterior and medial plateau, strongly raised ocular tubercle; interocular triangle convex laterally, depressed medially; anterior margin very slightly emarginate, nearly straight, medially microdenticulate, bordered by row of medium sized granules; 5 short macrosetae on anterior margin, carapace otherwise devoid of macrosetae; 5 lateral eyes (3 large, 2 small) on each side; *carination*: anterior median, superciliary, central lateral, posterior median and posterior lateral carinae moderate to strong, coarsely granular; anterior median carinae not extending to anterior margin of carapace, separated from anterior marginal row of granules; central lateral and posterior median carinae fused into lyre configuration; central median carinae coarsely granular, anterior part nearly straight, angled outward, posterior part outwardly curved; posterior lateral carinae strong, hind end without lateral extension, projecting only slightly past posterior margin of carapace; lateral ocular carinae moderate, with medium, spaced granules; *granulation*: sparse patches of 17–20 small to large granules on anterolateral corners of interocular triangle, 9–10 small to medium granules in front of lateral ocular carinae; surface between anterior median carinae smooth except for 10 small to medium granules dispersed in anterior area; other intercarinal surfaces smooth except for few isolated small to medium granules; posterior median furrow shallow, broad, with few median microgranules, flanked by lateral arcs of small granules; posterior margin of carapace between posterior lateral carinae rimmed by regular series of medium granules.

**Chelicera.** Dorsal surface of manus smooth, with 6 short, pale microsetae, 3 near apical margin, 3 subapical, each surrounded by granules; 2–3 finer microsetae on anterolateral margins; dorsointernal carina at base of fixed finger moderately strong, granulated, terminating anteriorly with prominent granules projecting over front of manus; single macroseta in middle of dorsointernal carina; dorsal surface of movable finger smooth, with 5 pale microsetae; fingers with characteristic buthid dentition (Vachon, 1963); movable finger dorsal margin with 5 teeth: dorsal distal tine, subdistal, median and 2 basal teeth fused in bicuspid; ventral margin with 3 teeth: ventral distal tine, median and basal teeth; fixed finger margin with 4 teeth: distal tine, subdistal, median and basal teeth; ventral aspect of fixed finger with 2 teeth.

**Coxosternal area.** Coxae smooth; coxal endite II with weak, finely granulated carina; coxae II–III with moderately granular anterior carinae, distal margins with coarse granules; proximal 1/3 of anterior margin of coxa III with sparse microgranulation, almost smooth; 3 long macrosetae along anterior carina of coxa II, 4 macrosetae along anterior carina of coxa III; anterior carina of coxa IV with regular small to medium granulation, with



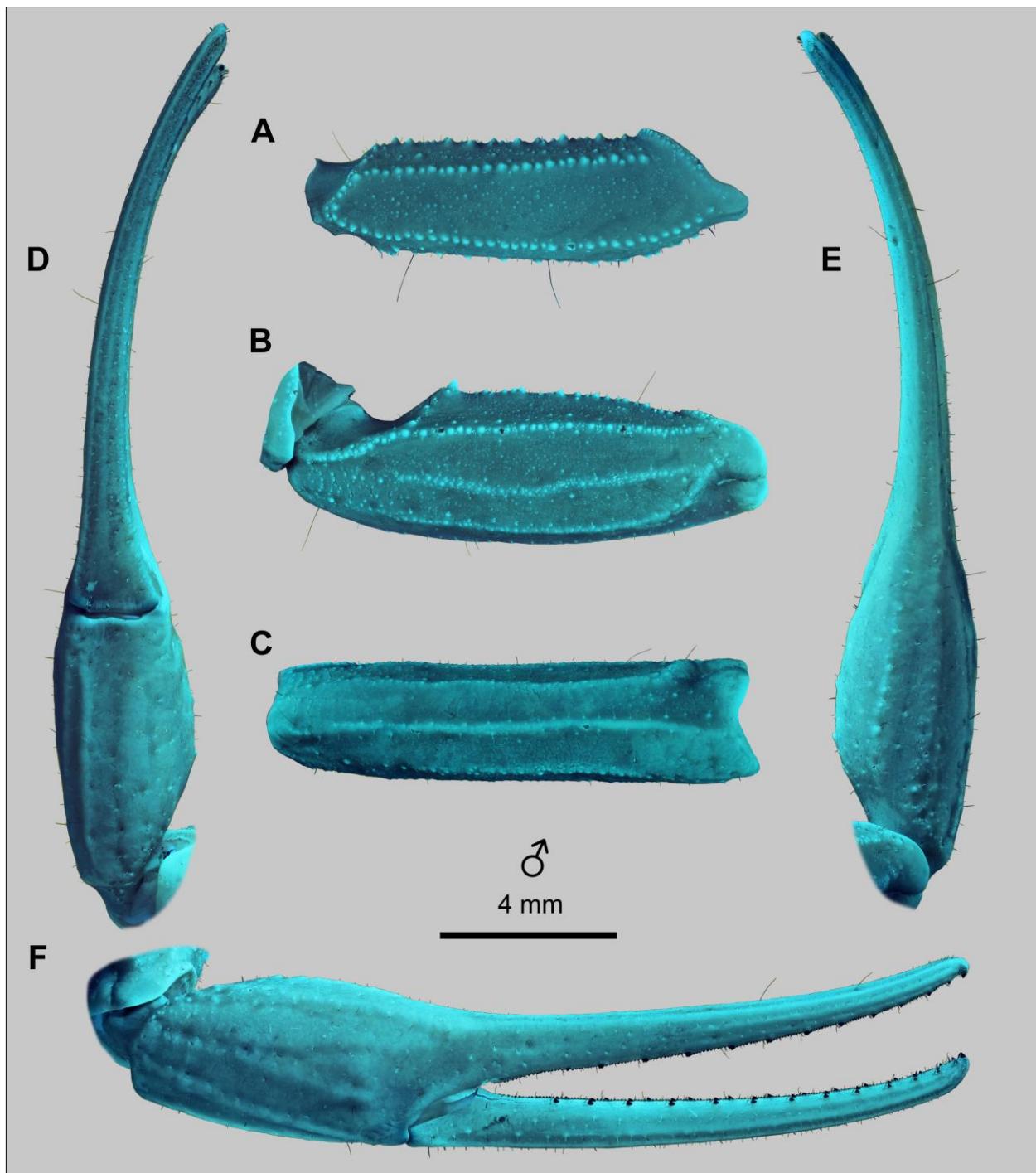
**Figure 29:** *Leiurus haenggii* sp. n., paratype male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Wadi Asidah, Saudi Arabia (NHMB 17al2).

1–2 proximal macrosetae; posterior margin of coxa IV with finely granulated carina on proximal half; sternum smooth, subtriangular with slightly concave lateral margins, deep posteromedian longitudinal sulcus and pit, 2 short macrosetae; genital opercula smooth with 5–6 short macrosetae, posterolateral margins weakly concave.

**Pectines.** Basal piece with concave anterior margin divided by small median emargination, lacking granules, bearing 9 macrosetae; pectines narrow, tips not extending past distal end of coxa IV; both combs with 3 marginal lamellae and small accessory lamella distal to first marginal lamella, 9 middle lamellae, 30–30 teeth; marginal and middle lamellae with moderate cover of long reddish macrosetae; fulcra with 3–5 setae; pectine teeth relatively small, mid-pectine sensillar margin L/

pectine L 0.063, mid-pectine sensillar margin L/ metasoma I W 0.105.

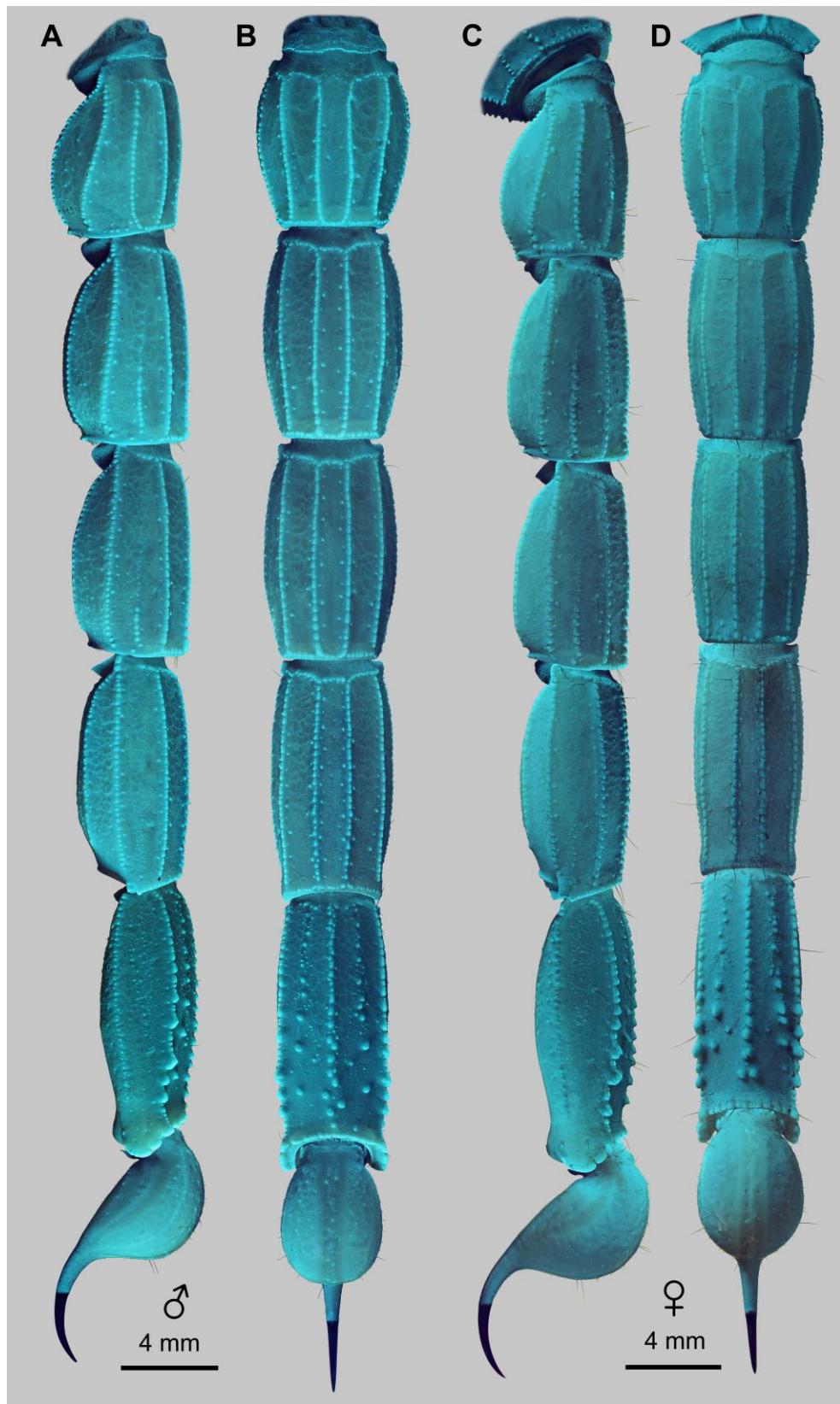
**Mesosoma. Tergites:** pretergites smooth; tergites I–II with 5 granular carinae; median and inner lateral carinae linear with medium to coarse granules; outer lateral carinae aligned with posterior lateral carinae of carapace, angled outward, strong, uniformly granular, hind ends extending past posterior margins of tergites, without lateral extensions on I, with short extensions on II; medial intercarinal surfaces smooth, with sparse medium or coarse granules; lateral flanks moderately sloped with sparse fine granulation; tergites III–VI with 3 straight carinae with medium granules; medial intercarinal surfaces smooth, with short transverse anterior series of granules; very fine granulation on anterior median patch and short transverse strips on either side;



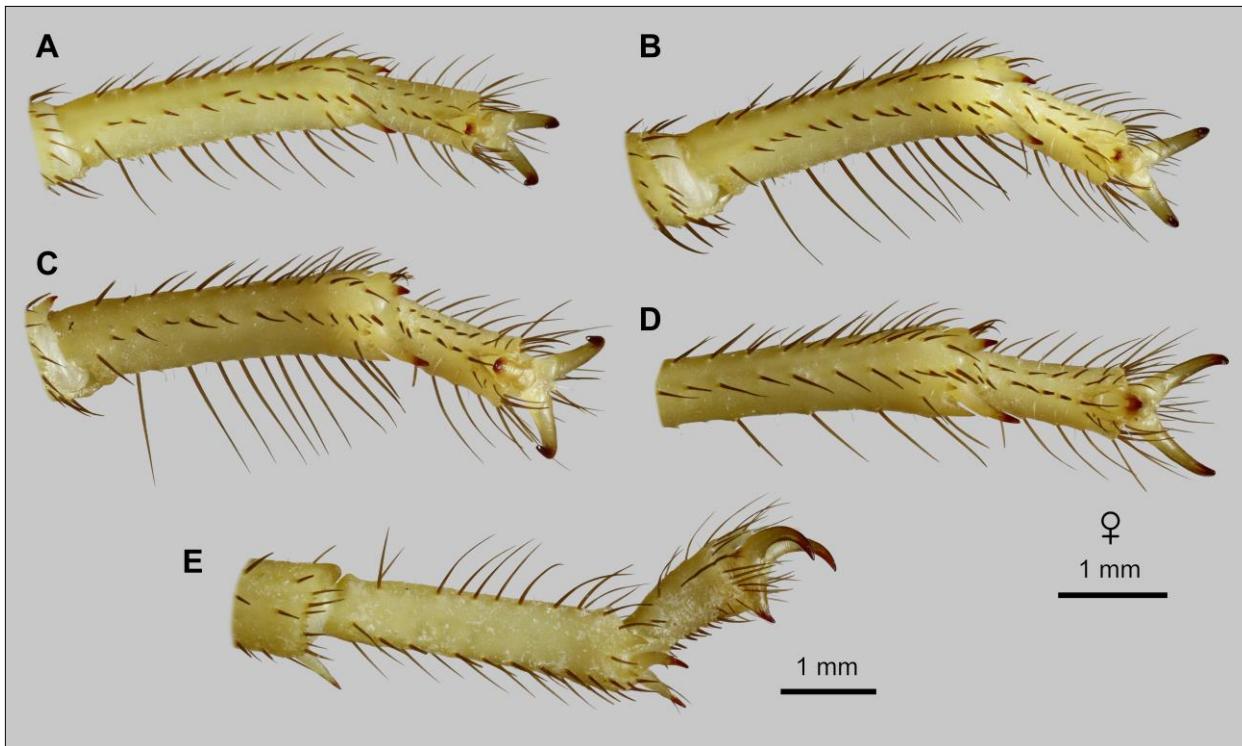
**Figure 30:** *Leiurus haenggii* sp. n., paratype male. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Chela, external aspect. Wadi Asidah, Saudi Arabia (NHMB 17al2).

lateral surfaces moderately sloped, well granulated, III–IV with short longitudinal rows of granules; tergite VII with 5 strong, granular carinae; inner and outer lateral carinae joined anteriorly by transverse granule rows; intercarinal surfaces smooth, with few isolated fine

granules; fine granulation on anterior median patch and isolated lateral patches on either side; posterior margins of tergites I–VI rimmed with regular rows of small to medium sized granules; posterior margin of tergite VII with regular small granules; sternites: sternite III with



**Figure 31:** *Leiurus haenggii* sp. n. Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Male paratype, Wadi Asidah, Saudi Arabia (NHMB 17al2). Female holotype, Ta'if, Saudi Arabia (NHMB 17k).

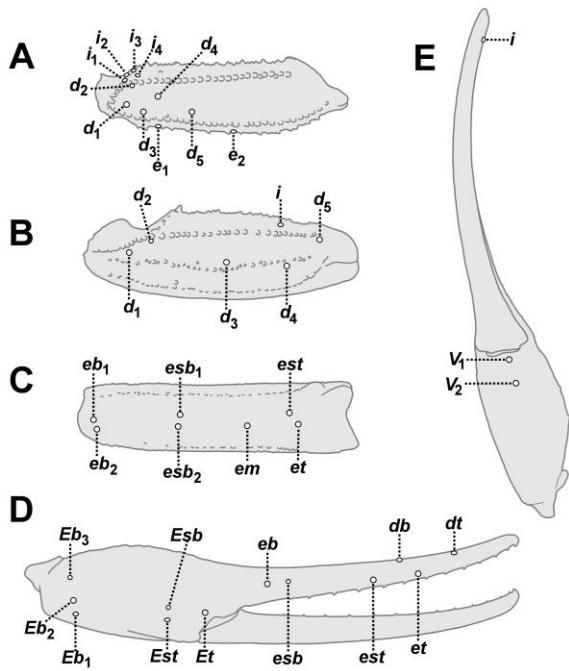


**Figure 32:** *Leiurus haenggii* sp. n., holotype female. Tarsi. **A–D.** Left telotarsus and distal basitarsus, ventral aspect. **A.** Leg I. **B.** Leg II. **C.** Leg III. **D.** Leg IV. **E.** Right basitarsus III retrolateral aspect. Upper scale bar: **A–D**, lower scale bar: **E**. Ta'if, Saudi Arabia (NHMB 17k).

median carinae very weak, smooth, almost obsolete; sternites IV–V with weak, finely granulated lateral carinae, obsolete median carinae; sternite VI with moderate, finely crenulate lateral carinae, weak finely granulated median carinae; sternite VII with strong, crenulate-granulate median and lateral carinae; lateral margins of sternites IV–VII armed with regular denticulate granules; medial intercarinal surfaces of all sternites smooth, lateral intercarinal surfaces smooth posteriorly, smooth to faintly shagreened anteriorly on IV–VI; *setation*: sternite III with 5 macrosetae on median carinae, 6–7 on areas external to median carinae; sternites IV–VII with 2 paired macrosetae on median carinae, one pair in middle of sternite, other on posterior margin; lateral carinae on IV–V with mid-carinal and posterior marginal macrosetae, on VI with posterior marginal macrosetae; intercarinal macrosetae: one pair of lateral marginal setae on sternites IV–VI; 2 pairs of mediolateral setae on IV–V, one pair on VI; one pair of latero-marginal setae on VII; intercarinal posterior marginal macrosetae on III–VII: 7, 5, 4, 0, 0.

**Metasoma.** Moderately long, with robust segments, total metasoma and telson L/ carapace L 5.61; *cari-*nation: segment I with 10 complete carinae; segments II–III with 8 complete carinae, median lateral carinae restricted to posterior 1/2 of II, posterior 1/2 to 1/3 of III; metasoma IV with 8 carinae, V with 7 carinae; carinae

on segments I–IV granulate or crenulate-granulate; dorso-submedian carinae granulate, moderate on I–III, weak on IV; dorsolateral carinae granulate, moderate, ventro-lateral carinae granulate-crenulate, moderate to strong on I–IV; median lateral carinae granulate, moderate on I–II, moderate posteriorly, weak anteriorly on III; ventro-median carinae moderate on I, strong on II–IV; granules on II–IV larger, taller posteriorly; ventromedian carinae with 20–21 granules on metasoma II, 25–26 on III; metasoma V with dorsolateral carinae very weak, faintly granulated, ventrolateral carinae strong with rounded dentate granules increasing in size posteriorly, with several large subtriangular, lobate denticles, ventro-submedian carinae marked by prominent series of medium to large rounded, dentate granules along length of segment, ventromedian carina strong, with medium to large rounded, dentate granules increasing in size posteriorly; lateral anal margin with 3 lobes, ventral anal margin with 10 irregular, narrow to wide transverse crenulations; *intercarinal surfaces*: segments I–IV smooth, segment V smooth dorsally, lightly shagreened or finely granulate laterally and ventrally; *setation*: segments I–IV: ventromedian carinae with 3 macrosetae (one posterior marginal), ventrolateral carinae with 2 macrosetae slightly external to carina; metasoma V with 5 macrosetae on lateral surface (2 lateral anal), 4 pairs on ventral surface.



**Figure 33:** *Leiurus haenggii* sp. n., paratype male. Trichobothrial map of pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, external aspect. **E.** Chela, ventral aspect. Wadi Asidah, Saudi Arabia (NHMB 17al2).

**Telson.** Vesicle smooth, bulbous; ventral surface bearing scattered fine microsetae and several short macrosetae with associated shallow indentations; aculeus slightly shorter than vesicle.

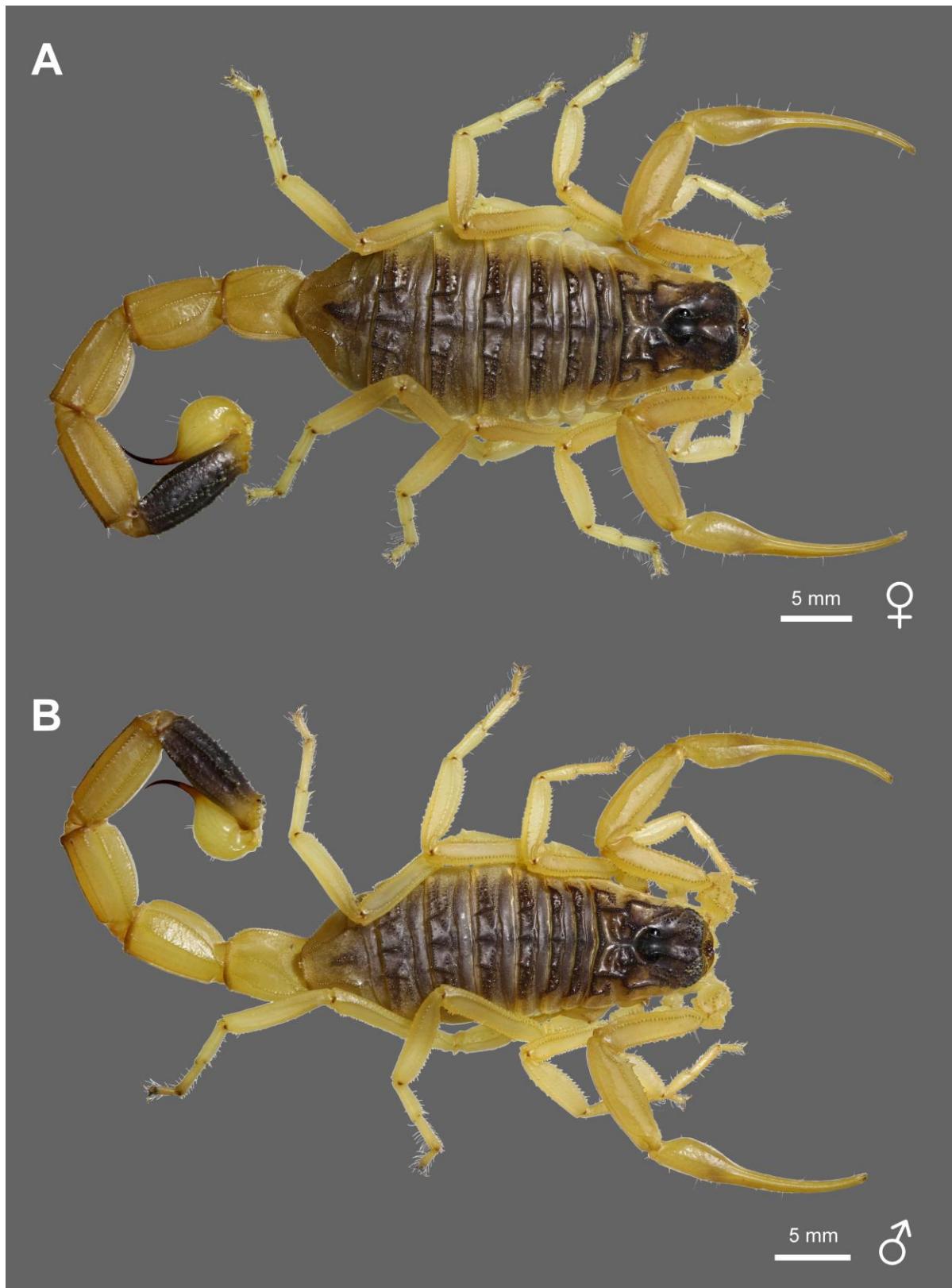
**Pedipalp.** *Femur*: moderately slender, L/W 3.28; dorsoexternal, dorsointernal and ventrointernal carinae strong with coarse, closely spaced dentate granules; internal carina strong, with small and large dentate granules spaced well apart; external carina moderate, with well spaced coarse dentate granules; all intercarinal surfaces smooth; linear cluster of 29–30 accessory macrosetae on lower distal external surface; *patella*: moderately slender, L/W 2.89; dorsointernal carina moderate with medium granulation; dorsomedian and dorsoexternal carinae moderate with fine granulation; external carina moderate, smooth; ventroexternal carina weak, with fine granulation; ventromedian carina moderate, with medium to fine granulation; ventrointernal carina moderate, medium to small dentate granules and ventral patellar spur; internal carina moderate, with several larger dentate granules interspersed with closely spaced small granules, and dorsal patellar spur; all intercarinal surfaces smooth or with sparse, fine granules; *chela*: slender, L/W 5.94, movable finger L/ manus ventral L 2.10; dorsal marginal and external secondary carinae weak, smooth; ventroexternal carina moderate,

smooth; other carinae obsolete; all intercarinal surfaces smooth; manus and fixed finger with sparse short macrosetae; movable finger with numerous short macrosetae on ventral aspect, culminating in dense subapical brush; 12 primary denticle subrows on left movable finger (right movable finger of holotype with anomalous dentition, 6 subrows), 11–12 on fixed fingers; all subrows except proximal flanked by internal and external accessory denticles. *Trichobothriotaxy*: orthobothrioxic, type Aβ (Vachon, 1974), *db* on fixed finger distal to *est*.

**Legs.** Moderately elongated, femur III L/ carapace L 1.05, patella III L/D 3.61; inferior carinae strongly denticulate on femur I–IV, moderately denticulate on patella I–III, weakly denticulate, almost smooth on patella IV; tibia III–IV with long spurs; retrolateral tarsal spurs simple, non-setose; prolateral tarsal spurs basally bifurcate, bearing 2–3 macrosetae; basitarsi I–III with well developed bristle-combs, at least as wide as basitarsal segment; basitarsus III setal counts (left/right): retrosuperior 11/10, retroinferior 13/12 (including basal accessory seta), inferior 12/13; ventral surface of telotarsi with robust, short tapered macrosetae.

**Measurements of holotype female (mm).** Total L 85.00; metasoma + telson L 54.00; carapace L 9.62, W 11.24, carapace preocular L 4.69; metasomal segments (L/ W /D) I 6.92/ 6.01/ 5.10, II 8.19/ 5.30/ 4.89, III 8.42/ 5.00/ 4.81, IV 9.64/ 4.65/ 4.55, V 10.81/ 4.60/ 4.18; telson L 10.48; vesicle L 5.58, W 3.11, D 3.92; pedipalp chela L 18.46, manus ventral L 6.13, manus W 3.11, manus D 3.50, fixed finger L 10.77, movable finger L 12.88; pedipalp femur L 9.37, W 2.86, patella L 10.53, W 3.64; pectine L 10.04, mid-pectine sensillar margin L 0.633; leg III femur L 10.06; leg III patella L 8.58, D 2.38.

**Paratype male (Wadi Asidah).** Differs from holotype female as follows: body narrower, carapace W/L 1.13; carapace, tergites and coxae with stronger, more coarsely granulate carinae; genital opercula with convex posterolateral margin; pectine basal piece narrower, with deeper anteromedian fold; pectines wider, longer, 11–13 middle lamellae, tips extending to proximal 1/3–1/2 of trochanter IV, teeth larger with longer sensillar margins, mid-pectine sensillar margin L/ pectine L 0.084, mid-pectine sensillar margin L/ metasoma I W 0.146; 36–38 pectine teeth; 3 basal pectine teeth overlap if anterior pectine margins aligned to posterior margins of coxae IV; sternite III with strong, thick, granulated median carinae; sternites IV–V with stronger, more heavily granulated lateral carinae, IV with moderate, V with weak granulated median carinae; sternites VI–VII with all carinae strong, coarsely granulated; spiracles on IV–VI with fine granules along anterior margins; intercarinal surfaces of sternites III–VI roughened, shagreened in anterior median areas; ventromedian carinae on metasoma II–III more weakly crenulate, with smaller



**Figure 34:** *Leiurus haenggii* sp. n.. **A.** Paratype female. **B.** Paratype male. Habitus in vivo, dorsal aspect. Captive bred from Sana'a, Yemen (M. Heule).

denticles; dorsal surface of metasoma V more heavily shagreened; pedipalp femur and patella with stronger carination, pedipalp chela manus with weak dorsointernal carina with small granules.

**Measurements of paratype male (NHMB 17al2) (mm).** Total L 82.50; metasoma + telson L 55.00; carapace L 9.00, W 10.20, carapace preocular L 4.46; metasomal segments (L/ W/ D) I 6.90/ 6.42/ 5.47, II 8.39/ 5.73/ 5.10, III 8.68/ 5.36/ 4.93, IV 9.77/ 4.95/ 4.64, V 10.46/ 4.59/ 4.01; telson L 9.75; vesicle L 5.11, W 3.87, D 3.68; pedipalp chela L 18.59, manus ventral L 5.97, manus W 3.06, manus D 3.33, fixed finger L 11.13, movable finger L 13.02; pedipalp femur L 9.62, W 3.00, patella L 10.62, W 3.53; pectine L 11.17; midpectine sensillar margin L 0.939; leg III femur L 10.70; leg III patella L 8.81, D 2.38.

**Variation.** *Color:* the dark dorsal color pattern of the holotype was the most common form, but other variants were observed. There may be less intense, diffuse fuscosity on carapace and tergites, with brown color extending onto lateral flanks of tergites I–VI (Adnan, Adama). Intercarinal fuscosity on the carapace may be limited to the anterior area in front of the median ocular tubercle, with posterior areas light (Wadi Maraba, Jeddah), and tergites may be pale (Jeddah). Dark pigment on metasoma V and ventral carinae of metasoma II–IV can vary from faded yellow-brown to dark black, and the posterior yellow area on metasoma V may extend forward up to 1/3 the length of the segment, with the dark zone terminating in trident pattern towards the posteroventral area (Jeddah, Wadi Qatan). Juveniles usually exhibit darker color patterns. *Morphosculpture:* female sternite carination was typically weak or obsolete, with minor variation: median carinae of sternite III obsolete in 9 cases, very weak in 7, weak in 3, median carinae of sternites IV (or V) obsolete in 17 (or 16) cases, weak in 2 (or 3). *Morphometrics and meristics:* see Table 4. Metasomal segments were typically robust, but were more elongated in a few examples: males from Wadi Ghaiz and Jeddah, and a female from Wadi Qatan had metasomal segments as slender as *L. arabicus* sp. n. The number of denticles on ventromedian carinae of metasoma III was significantly higher in males ( $22.93 \pm 2.81$ ) than females ( $20.16 \pm 3.24$ ) ( $P = 0.0085$ , t test).

**DISTRIBUTION.** Records indicate a wide distribution in the western Arabian Peninsula, along the chain of mountains running parallel to the Red Sea coast of Saudi Arabia and Yemen (Al Hijaz and Asir mountains). A series of specimens was also collected from the Dhofar mountains in Oman, and the species is likely to occur in the intervening Hadramaut ranges along the southern coast of Yemen. Records span a wide range of elevations (22 – 2,828 m a.s.l.), ranging from coastal plains to the Asir highlands.

**ECOLOGY.** Specimens in Oman were found at night by UV detection on rock and gravel substrates in densely vegetated wadis, from coastal plains to mountains. The species probably shelters in scrapes excavated in soil beneath rocks. Similar lapidicolous habitats may be occupied in the mountains of Yemen and western Saudi Arabia.

**REMARKS.** Birula (1937) referred a series of specimens from Hodeida (= Al Hudaydah, Yemen) to *L. quinquestriatus brachycentrus*. We consider these to represent *L. haenggii*, based on the following reported characters: larger size (adult female 86.4 mm, adult male 72.6 mm), dark coloration of carapace, mesosoma and metasoma V, and nearly smooth intercarinal surfaces on tergites.

#### *Leiurus arabicus* sp. n.

(Figs. 25–46, 58C, 87B, 88B, 89B, 90B, 91F, 92B–C, 93A–B, 94D, 95, 98–100, Tabs. 3A, 4)

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#### REFERENCES

*Leiurus quinquestriatus:* Vachon, 1979a: 49–50 (in part); Kinzelbach, 1985: map II (in part); El-Hennawy, 1992: 101, 125–126 (in part); Kovařík, 1998: 112 (in part); Fet & Lowe, 2000: 155 (in part); Hendrixson, 2006: 84–91 (in part), fig. 18 (in part), figs 20b, 20c, pl. 14; Kaltsas et al., 2008: 218–219 (in part); El-Hennawy, 2009: 122 (in part); El-Hennawy, 2014: 45 (in part).

*Leiurus quinquestriatus hebraeus:* Levy & Amitai, 1980: 48–53 (in part).

**HOLOTYPE.** Adult ♀, **Saudi Arabia**, Kushm Dibi, 19.X.1979, leg. A. Barkham (NHMB 17aq).

**PARATYPES.** **Bahrain:** 2 ♀, Al Amar, 25°59'N 50°32'E, 20 m a.s.l., XI.1985, leg. D. Lickfold (NHMB 17bg). **Saudi Arabia:** 1 ♀, 1 juv ♀, Kashm Khafs, 25°36'N 46°27'E, 720 m a.s.l., leg. W. Büttiker (NHMB 17ac2); 1 juv ♂, Khushm Dibi, 24°17'N 46°09'E, 750 m a.s.l., leg. W. Büttiker (NHMB 17ac); 1 juv ♂, Wadi Durmah, Stn 11, végétation riche, 24°37'N 46°06'E, 580 m a.s.l., 2.I.1976, leg. W. Büttiker (NHMB 17m); 1 ♀, Wadi Tumair, Stn 13, oasis, désert de pierres sèches, 25°43'N 45°51'E, 650 m a.s.l., 20.II.1976, leg. W. Büttiker (NHMB 17o); 2 ♀, 1 juv ♂, 3 juv ♀, Wadi Mizbil, Stn 18, désert de pierres sèches, 24°30'N 46°25'E, 700 m a.s.l., 25.II.1977, leg. W. Büttiker (NHMB 17l); 1 juv ♀, Wadi Mutaiwijah, Stn 21, Mecca Road, végétation relativement riche, 24°34'N 46°11'E, 600 m a.s.l., 18.III.1977, leg. W. Büttiker (NHMB 17p); 1 ♂, Jeddah, 21°31'N 39°13.15'E, 1.IX.1977, leg. W. Büttiker (NHMB 17q); 1 juv ♀, Wadi Mizbil, 24°29'N



**Figure 35:** *Leiurus arabicus* sp. n., holotype female. Habitus, dorsal aspect. Kushm Dibi, Saudi Arabia (NHMB 17aq).

46°25'E, 610 m a.s.l., 24.XII.1977, leg. W. Büttiker (NHMB 17ao); 1 ♀, Jubail, 27°00.28'N 49°39.68'E, 8 m a.s.l., III.1978, leg. W. Büttiker (NHMB 17v); 1 juv ♂, Jebel Banban, 25°23'N 46°36'E, 660 m a.s.l., 16.III.1978, leg. W. Büttiker (NHMB 17n); 1 juv ♂, Khushm Dibi, 24°17'N 46°09'E, 750 m a.s.l., 19.V.1978, leg. W. Büttiker (NHMB 17t); 1 ♂, Riyadh, 23°20'N

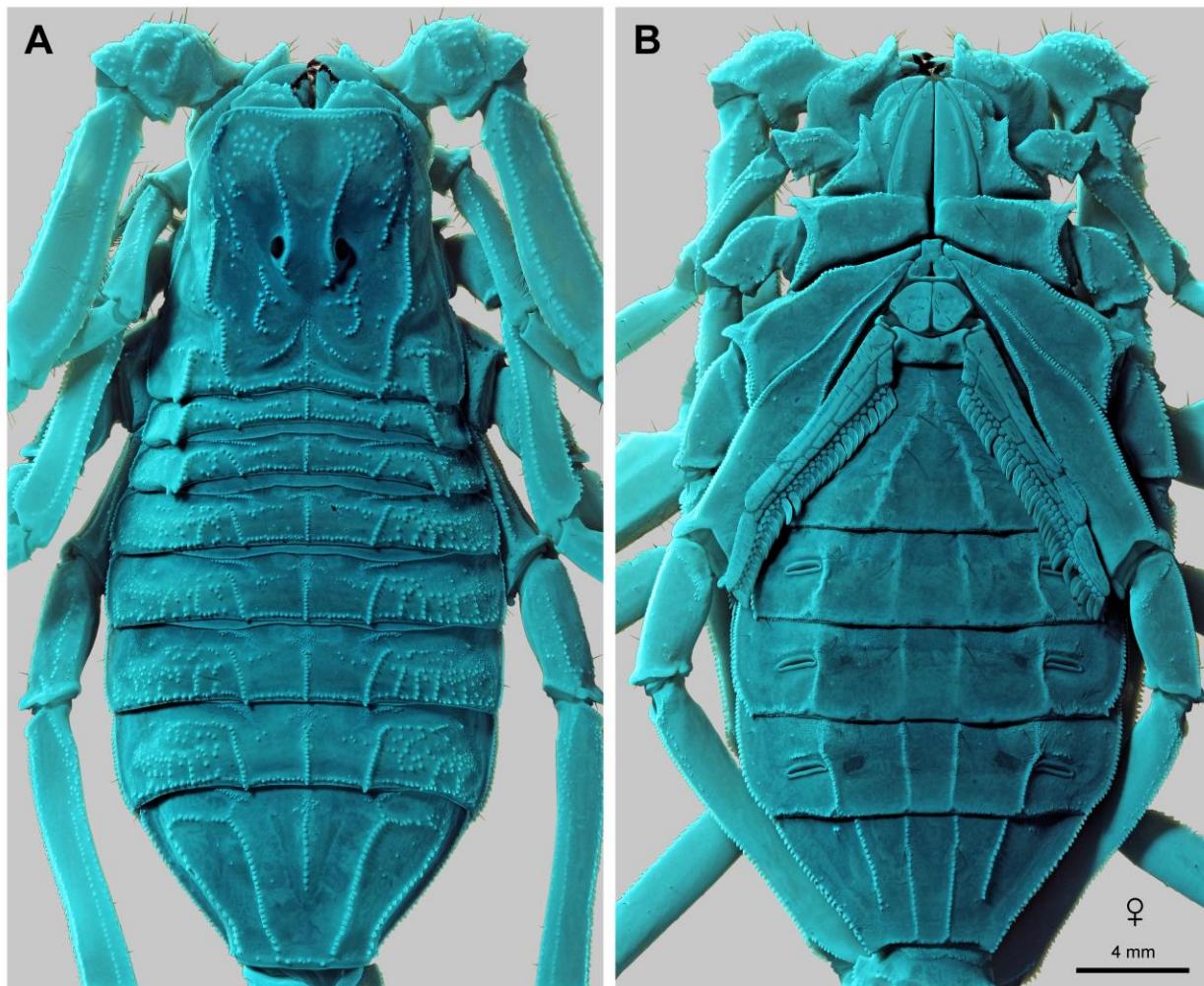
45°20'E, IX.1978, leg. B. Vincett (NHMB 17ap); 1 ♂, 2 ♀, Wadi Khumrah, Station 12, 24°55'N 46°11'E, 9.XI.1978, leg. W. Büttiker (NHMB 17r); 1 ♀, Wadi Khumrah, 24°56'N 46°08'E, 830 m a.s.l., 17.VIII.1979, leg. W. Büttiker (NHMB 17w); 1 ♀, Riyadh, 23°20'N 45°20'E, Sep 1979, leg. W. Büttiker (NHMB 17ar); 1 ♂, Kushm al Buwayhiyat, 25°12'N 46°52'E, 720 m a.s.l.,



**Figure 36:** *Leiurus arabicus* sp. n., holotype female. Habitus, ventral aspect. Kushm Dibi, Saudi Arabia (NHMB 17aq).

23.IX.1979, leg. A. Barkham (NHMB 17an); 1 juv ♂, 1 juv ♀, Khushm Dibi, 24°13.61'N 46°06.5'E, 19.X.1979, leg. A. Barkham (NHMB 17ae); 3 ♂, Khushm Dibi, 24°13.61'N 46°06.5'E, 19.X.1979, leg. A. Barkham (NHMB 17aq); 2 juv ♀, Jeddah, 21°31'N 39°13.15'E, 1.XI.1979, leg. W. Büttiker (NHMB 17ak); 1 ♂, Riyadh, 23°20'E 45°20'E, 3.XI.1979, leg. W. Büttiker (NHMB 17ai); 1 juv ♀, Jebel Buwayb, 25°21'N 46°45'E, 700 m

a.s.l., 29.XI.1979, leg. W. Büttiker (NHMB 17aa); 1 ♂, 1 ♀, Wadi Tuweig, 24°32.6'N 46°32.7'E, 680 m a.s.l., 7.II.1980, leg. W. Büttiker, NHMB Sc 495; 1 ♀, Wadi Khumrah, 24°56'N 46°08'E, 830 m a.s.l., Jun 1980, leg. W. Büttiker (NHMB 17bj); 1 ♂, Hudnah, 25°34.09'N 39°21.66'E, 800 m a.s.l., 1981, leg. W. Büttiker (NHMB 17bk); 3 ♀, 3 juv ♀, Khushm Dibi, 24°17'N 46°09'E, 750 m a.s.l., 23.I.1981, leg. W. Büttiker (NHMB 17ag2);

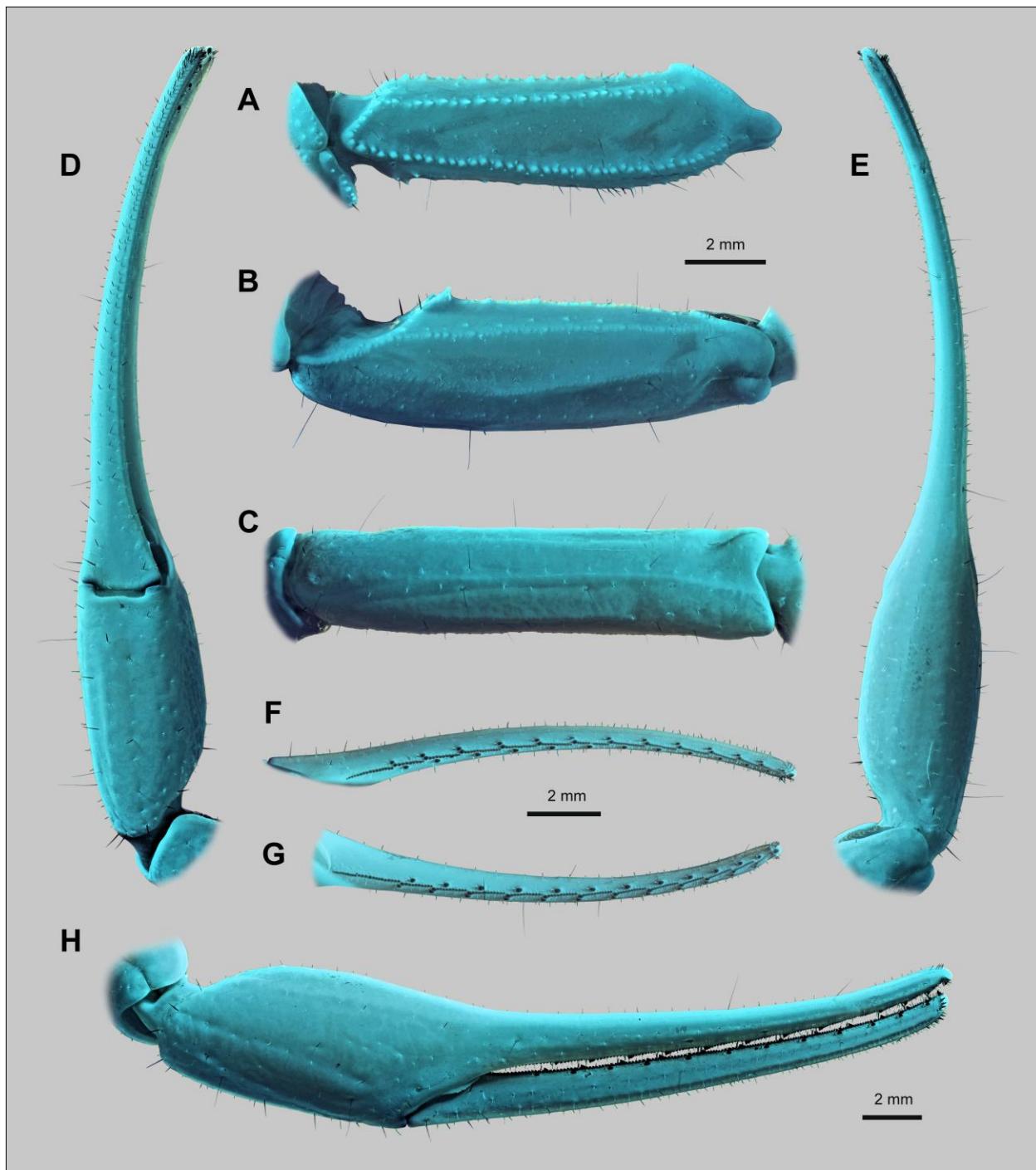


**Figure 37:** *Leiurus arabicus* sp. n., holotype female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Kushm Dibi, Saudi Arabia (NHMB 17aq).

1 juv ♂, Wadi Khumrah, 24°56'N 46°08'E, 830 m a.s.l., 4.IV.1981, leg. W. Büttiker (NHMB 17bl); 1 ♂, Kashm al-Atash, 24°07'N 46°19'E, 630 m a.s.l., 10.IX.1981, leg. W. Büttiker (NHMB 17aa2); 1 ♀, 2 juv ♂, 1 juv ♀, Khushm Dibi, 24°17'N 46°09'E, 30.IX.1981, leg. W. Büttiker (NHMB 17af2); 1 ♀, 1 juv ♂, 3 juv ♀, Riyadh, 24°18.6'N 46°28.2'E, 5.XI.1981, leg. W. Büttiker (NHMB 17bm); 1 ♂, Jeddah, Al Odaybi, 21°31.01'N 39°13.15'E, 20 m a.s.l., 13.XI.1983, leg. M.F. Ismar (NHMB 17ai2); 2 ♀, Jeddah, 21°31'N 39°13.15'E, 4.XII.1984, leg. K. Yip (NHMB 17bi); 1 ♀, halfway between Ranja and Qalat Bishah, 20°37.81'N 42°39.57'E, 1080 m a.s.l., 25.II.1985, leg. J. Dobricek (NHMB 17ao2).

**DIAGNOSIS** (adults). Medium to large *Leiurus*, 74–100 mm in length, carapace L 8.9–11.6 mm; base color yellow to orange-yellow, with variable dark pigmentation on carapace and tergites, either uniformly dark on

carapace and tergites I–VI, or yellow to brown with dark color around median ocular tubercle and light interocular triangle; metasoma V dark except for posterior end; area of carapace between anterior median carinae smooth or with scattered medium to fine granules, area between posterior median carinae with shallow to moderately deep median furrow flanked by arcs of fine or coarse granules; medial intercarinal surfaces of tergites II–III usually smooth or with sparse granulation; posterior margin of coxa III smooth or with sparse fine granules; metasoma moderately slender, metasoma II L/W 1.65–1.89, metasoma III L/W 1.86–2.12, metasoma IV L/W 2.31–2.58; ventromedian carinae of metasoma II and III with 17–27 denticles (41/44 carinae); metasoma V with enlarged subtriangular or triangular denticles on ventrolateral carinae; pedipalps slender, patella L/W 3.35–3.91; leg III patella L/D 3.82–4.38; pectine teeth ♂ 34–40, ♀ 28–33; pectines long, narrow, pectine L/ carapace L ♂ 1.27, ♀ 1.03–1.19, mid-pectine sensillar margin



**Figure 38:** *Leiurus arabicus* sp. n., holotype female. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **G.** Movable finger dentition. **H.** Chela, external aspect. Kushm Dibi, Saudi Arabia (NHMB 17aq).

L/metasoma I W ♂ 0.159, ♀ 0.093–0.120; 1–2 basal pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece smooth in females, smooth or slightly shagreened in males; leg III basitarsus with 7–19 retrosuperior setae;

pedipalp chela fixed finger with trichobothrium *db* usually distal to *est*; sternite VII with area between median carinae smooth or very faintly shagreened anteriorly, more heavily in males; sternite carination: males, sternite III with median carinae moderate to

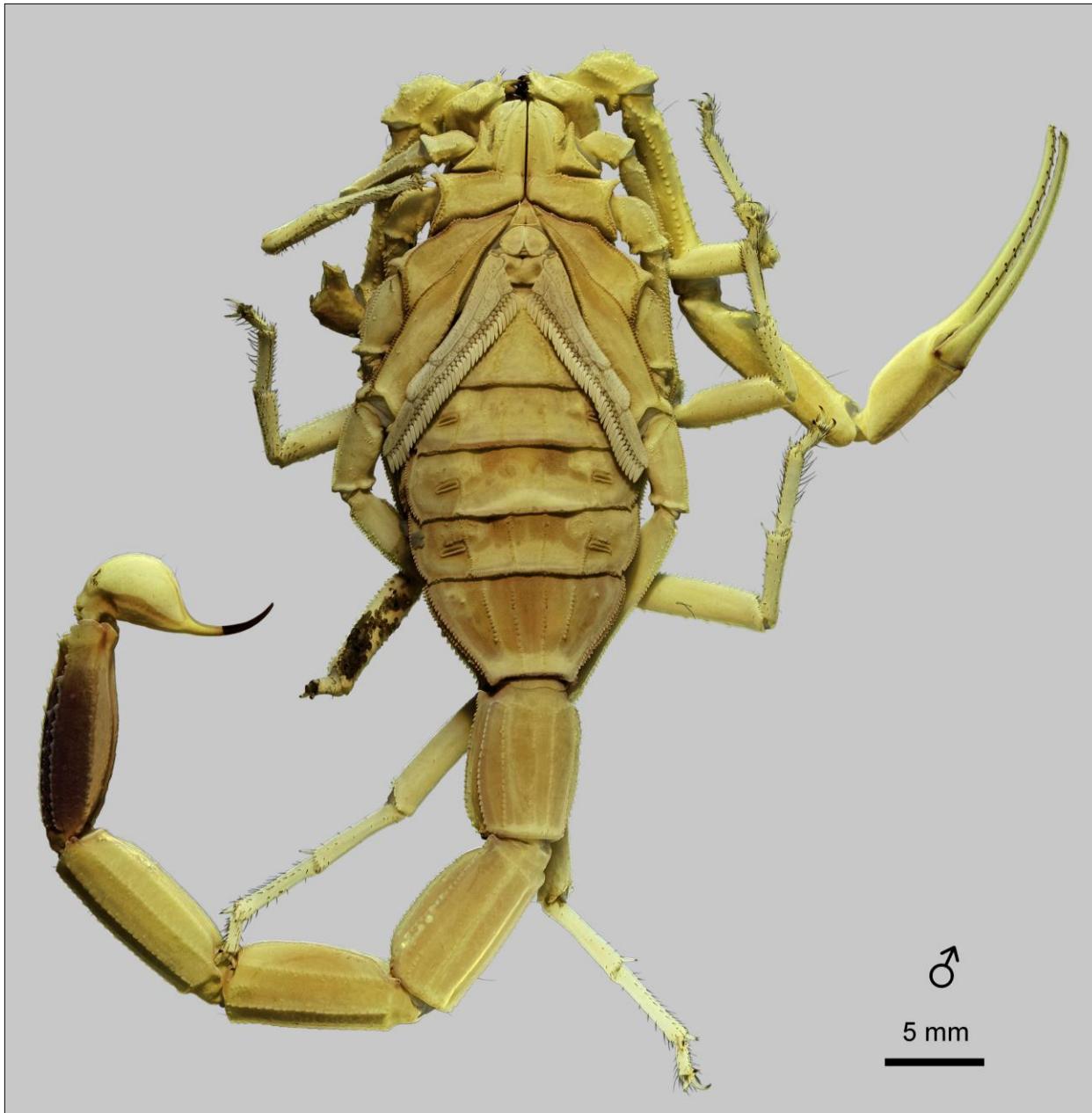


**Figure 39:** *Leiurus arabicus* sp. n., paratype male. Habitus, dorsal aspect. Riyadh, Saudi Arabia (NHMB 17ap).

strong, sternites IV–V with lateral carinae strong, median carinae weak to moderate; females, sternite III with median carinae weak to moderately strong, sternites IV–V with lateral carinae strong, median carinae weak to moderate.

**COMPARISONS.** *L. arabicus* sp. n. differs from *L. quinquestriatus*, and resembles *L. haenggii* sp. n. in the characters indicated under comparison with the latter species. It differs from *L. haenggii* by having more slender pedipalp, leg and metasomal segments, and

moderate to strongly granulated median carinae on sternites III–V of females (Figs. 25B vs. 37B, 92B–C vs. 92E–F). These differences are more apparent when comparing adult females, and tend to be obscured in adult males which have as secondary sexual characteristics, elongation of pedipalp and metasomal segments and stronger carination or granulation of sternites. Morphometric ratios of *L. haenggii* and *L. arabicus* are overlapped in younger instars, but diverge with increasing age and separate in adults (Figs. 46B–D). Biometric separation of adult females of the two species



**Figure 40:** *Leiurus arabicus* sp. n., paratype male. Habitus, ventral aspect. Riyadh, Saudi Arabia (NHMB 17ap).

was obtained from the product of three morphometric ratios quantifying slenderness of pedipalp, leg and metasomal segments:  $F_s = (\text{pedipalp patella L/W}) \times (\text{leg III patella L/D}) \times (\text{metasoma III L/W})$  (Fig. 46A). The interocular triangle was always dark or fuscous in *L. haenggii*, whereas in *L. arabicus* it was either pale (typical form in central Najd) or dark (Arabian Gulf coast and Jeddah).

**ETYMOLOGY.** The specific epithet refers to the Arabian Peninsula where this species is endemic.

#### DESCRIPTION (holotype female).

**Coloration.** Base color yellow; carapace with central mask of dark reddish-brown pigmentation around median ocular tubercle between central lateral and lateral ocular carinae, pigment extending forward to lateral eyes; interocular triangle yellow, with faint fuscosity along anterior median carinae and anterior carapace margin; posterior median area of carapace with weaker fuscosity; median and anterior areas of tergites with irregular faint fuscosity, pretergites mottled brown; metasoma V dark brown except for posterior end, dorsal surface less intensely pigmented but more fuscous med-

ially; ventral aspect of metasoma IV with pair of dark longitudinal stripes along ventromedian carinae.

**Carapace.** Subrectangular, W/L 1.14, with steeply sloped lateral flanks; upper surface with nearly flat posterior and medial plateau, strongly raised ocular tubercle; interocular triangle convex laterally, depressed medially; anterior margin straight, medially microgranulated, laterally smooth, bordered by gently curved row of medium sized granules; 8 short macrosetae on anterior margin, carapace otherwise devoid of macrosetae; 5 lateral eyes (3 large, 2 small) on each side; *carination*: anterior median, supraciliary, central lateral, posterior median and posterior lateral carinae moderate to strong, coarsely granular; anterior median carinae not extending to anterior margin of carapace, separated from anterior marginal row of granules; central lateral and posterior median carinae fused into lyre configuration; central median carinae coarsely granular, anterior part straight, angled outward, posterior part outwardly curved; posterior lateral carinae strong, hind end with little or no lateral extension, projecting past posterior margin of carapace; lateral ocular carinae moderate, with small, spaced granules; *granulation*: sparse patches of 12–14 large granules on anterolateral corners of interocular triangle, 6–8 small granules in front of lateral ocular carinae; surface between anterior median carinae smooth, with one small granule and few microgranules; other intercarinal surfaces smooth except for few isolated small to medium granules; posterior median furrow shallow with broken median line of fine granules, flanked by lateral arcs of small to medium granules; posterior margin of carapace between posterior lateral carinae rimmed by irregular row of small to medium granules.

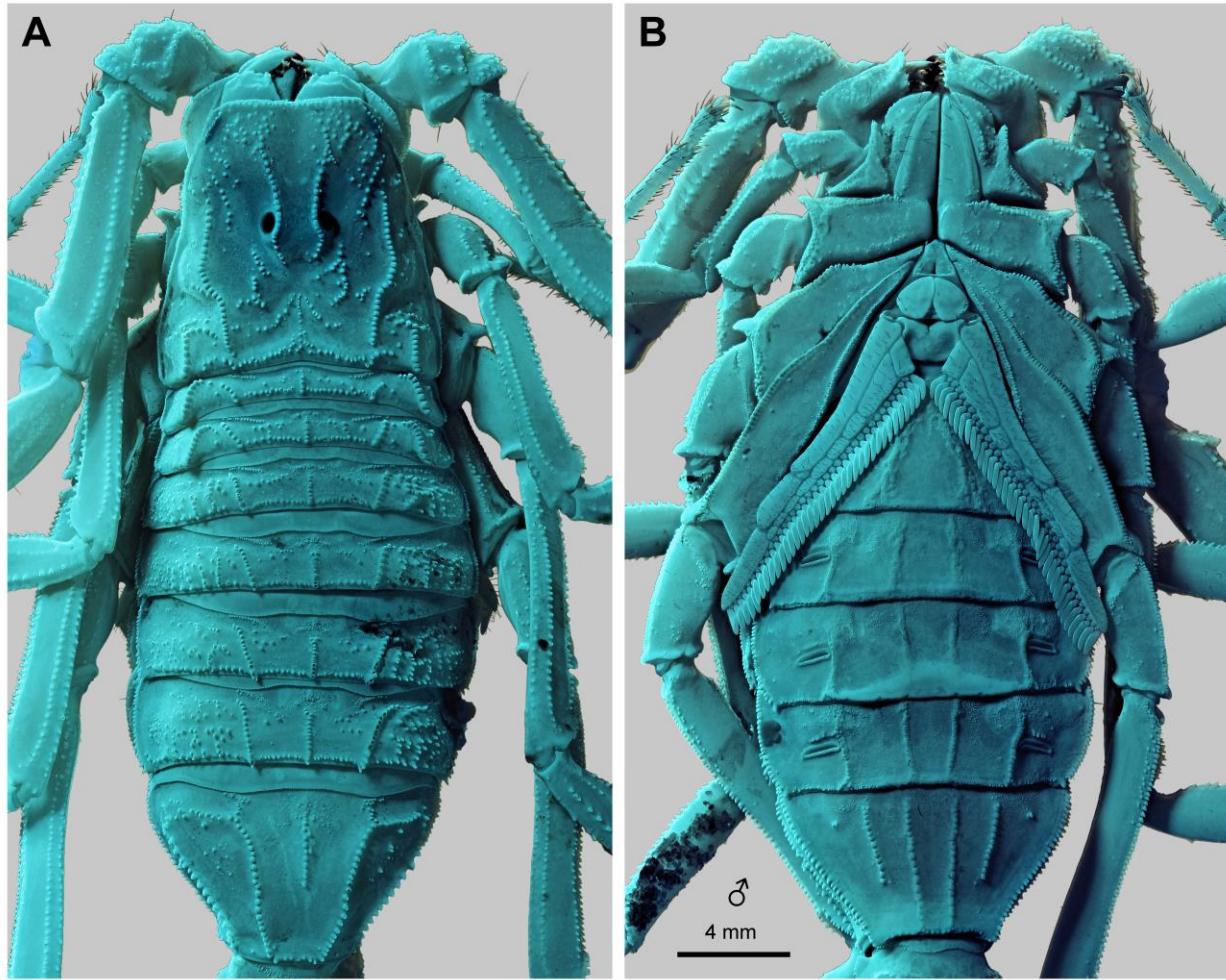
**Chelicera.** Dorsal surface of manus smooth, with 6 short, pale microsetae, 4 near apical margin, 2 subapical, each surrounded by granules; dorsointernal carina at base of fixed finger very strong, well granulated, terminating anteriorly with prominent granules projecting over front of manus; single macroseta in middle of dorsointernal carina; dorsal surface of movable finger smooth, with 4 pale microsetae; fingers with characteristic buthid dentition (Vachon, 1963); movable finger dorsal margin with 5 teeth: dorsal distal tine, subdistal, median and 2 basal teeth fused in bicuspid; ventral margin with 3 teeth: ventral distal tine, median and basal teeth; fixed finger margin with 4 teeth: distal tine, subdistal, median and basal teeth; ventral aspect of fixed finger with 2 teeth.

**Coxosternal area.** Coxae smooth; coxal endite II with weak, finely granulated carina; coxae II–III with coarsely granular anterior carinae, distal margins bearing medium to coarse granules; proximal 1/3 of anterior carina of coxa III almost smooth; 3 long macrosetae along anterior carina of coxa II, 4 macrosetae (3 long, 1 short) along anterior carina of coxa III; anterior carina of

coxa IV with regular small to medium granulation, with single proximal macroseta; posterior margin of coxa IV with finely granulated carina on proximal half; sternum smooth, subtriangular with indented lateral margins, deep posteromedian longitudinal sulcus and pit, two short macrosetae; genital opercula smooth with 5–6 short macrosetae.

**Pectines.** Basal piece with concave anterior margin divided by small median groove, lacking granules, bearing 6 macrosetae; pectines narrow, tips not extending past distal end of coxa IV; both combs with 3 marginal lamellae (right comb with small accessory lamella distal to first marginal lamella), 7–8 middle lamellae, 31–31 teeth; marginal and middle lamellae with sparse to moderate cover of short reddish macrosetae; fulcra with 3–5 setae; pectine teeth relatively small, mid-pectine sensillar margin L/ pectine L 0.056, mid-pectine sensillar margin L/ metasoma I W 0.107.

**Mesosoma, Tergites:** pretergites smooth; tergites I–II with 5 granular carinae; median and inner lateral carinae linear with medium granules; outer lateral carinae aligned with posterior lateral carinae of carapace, angled outward, strongly raised with enlarged posterior granules, hind ends projecting past posterior margins of tergites, without lateral extensions; medial intercarinal surfaces smooth, with transverse anterior series of small or medium granules; lateral flanks steeply sloped with sparse granulation; tergites III–VI with 3 straight or slightly curved carinae with medium granules; medial intercarinal surfaces smooth, with short transverse anterior series of granules; very fine granulation on anterior median patch and in transverse strips on either side; lateral surfaces moderately sloped, heavily granulated, with short longitudinal rows of granules; tergite VII with 5 strong, granular carinae; inner and outer lateral carinae joined anteriorly by transverse granule rows; intercarinal surfaces smooth, with few isolated fine granules; fine granulation on anterior median patch and transverse strips on either side; posterior margins of tergites I–VI rimmed with linear rows of medium sized granules; posterior margin of tergite VII smooth except for sparse granules between inner lateral carinae; *sternites*: sternite III with moderately strong, broad, finely granulated median carinae; sternites IV–V with strong, finely granulated lateral carinae, weak, lightly shagreened median carinae; sternite VI with strong, coarsely granulated lateral carinae, moderate, finely granulated median carinae; sternite VII with strong, coarsely granulated median and lateral carinae; lateral margins of sternites IV–VII armed with regular denticulate granules; medial intercarinal surfaces of all sternites smooth or very faintly shagreened anteriorly, lateral intercarinal surfaces smooth posteriorly, lightly shagreened anteriorly on IV–VI; *setation*: sternite III with 4–5 macrosetae on median

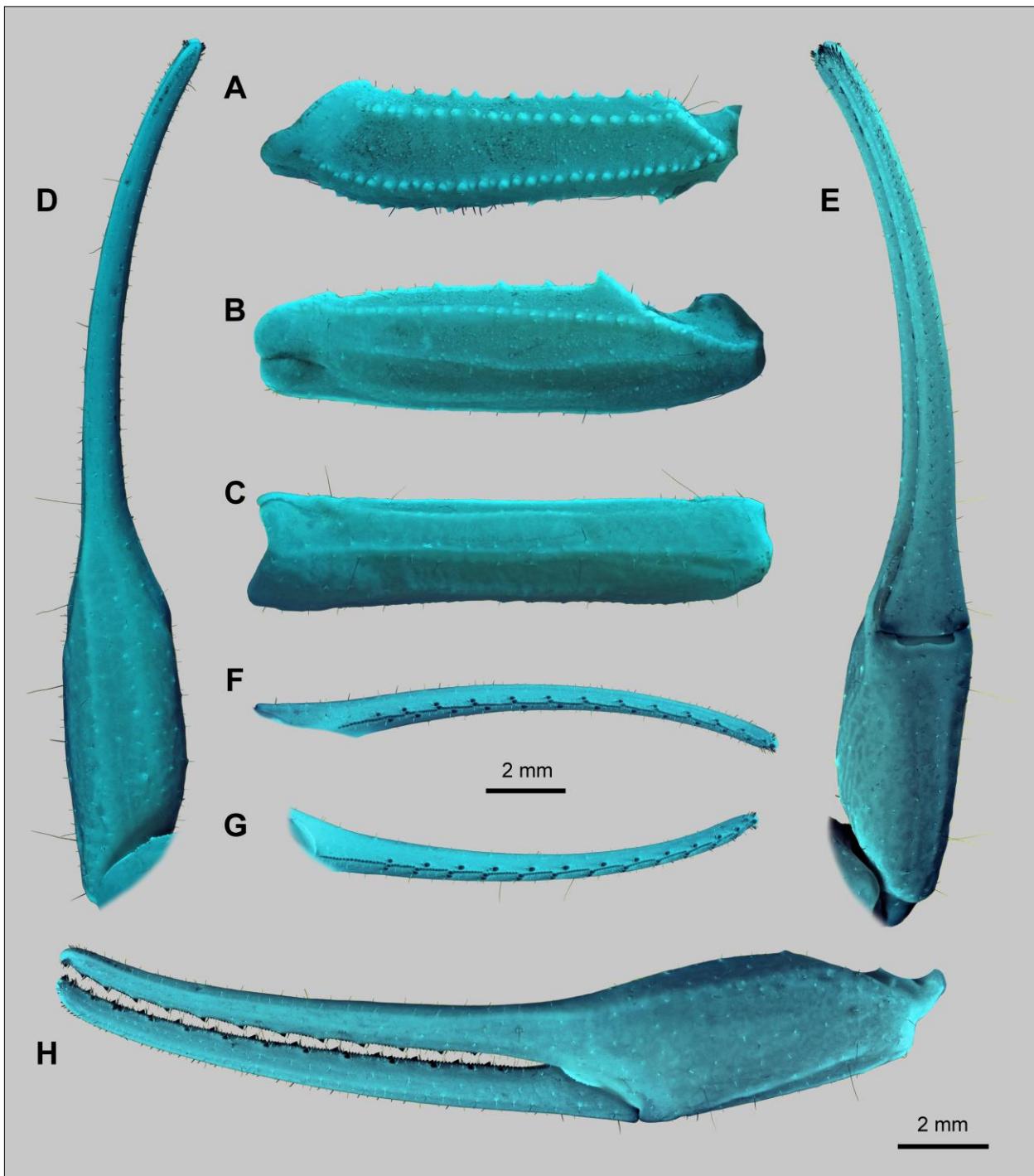


**Figure 41:** *Leiurus arabicus* sp. n., paratype male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Riyadh, Saudi Arabia (NHMB 17ap).

carinae, 5–6 on areas external to median carinae; sternites IV–VII with 2 paired macrosetae on median carinae, one pair in middle of sternite, other on posterior margin; lateral carinae on IV–VI with posterior marginal macrosetae, mid-carinal seta present or absent; intercarinal macrosetae: one anterior pair of lateral marginal setae on sternites IV–VI; two outer pairs of mediolateral setae on IV–V, one pair on VI; one pair of lateromarginal setae on VII; intercarinal posterior marginal macrosetae on III–VII: 9, 6, 4, 1, 0.

**Metasoma.** Long, slender; total metasoma and telson L/ carapace L 5.9; *carination*: segment I with 10 complete carinae; segments II–III with 8 complete carinae, median lateral carinae restricted to posterior 0.28 of II, posterior 0.23 of III; metasoma IV with 8 carinae, V with 7 carinae; carinae on segments I–IV with crenulate granulation; dorsosubmedian carinae moderate on I–II, weak on III–IV; dorsolateral and ventrolateral carinae moderate on I–IV; median lateral carinae mod-

erate on I–II, moderate posteriorly, weak anteriorly on III; ventromedian carinae moderate on I and IV, moderate anteriorly, strong posteriorly on II–III, with posterior granules taller but shorter; 20–21 granules on ventromedian carinae of metasoma II–III; metasoma V with dorsolateral carinae very weak, faintly granulated, ventrolateral carinae strong with dentate granules increasing in size posteriorly, with several large triangular denticles, ventrosubmedian carinae marked by series of small to medium dentate granules on anterior 2/3 of segment, ventromedian carina strong, armed with small to large dentate granules; lateral anal margin with 3 lobes, ventral anal margin with 10 irregular, narrow to wide transverse crenulations; *intercarinal surfaces*: segments I–IV smooth, segment V smooth dorsally, finely shagreened laterally, smooth to slightly shagreened ventrally; *setation*: segments I–IV: ventromedian carinae with 3 macrosetae (one posterior marginal), ventrolateral carinae with 2 macrosetae slightly external to carina;

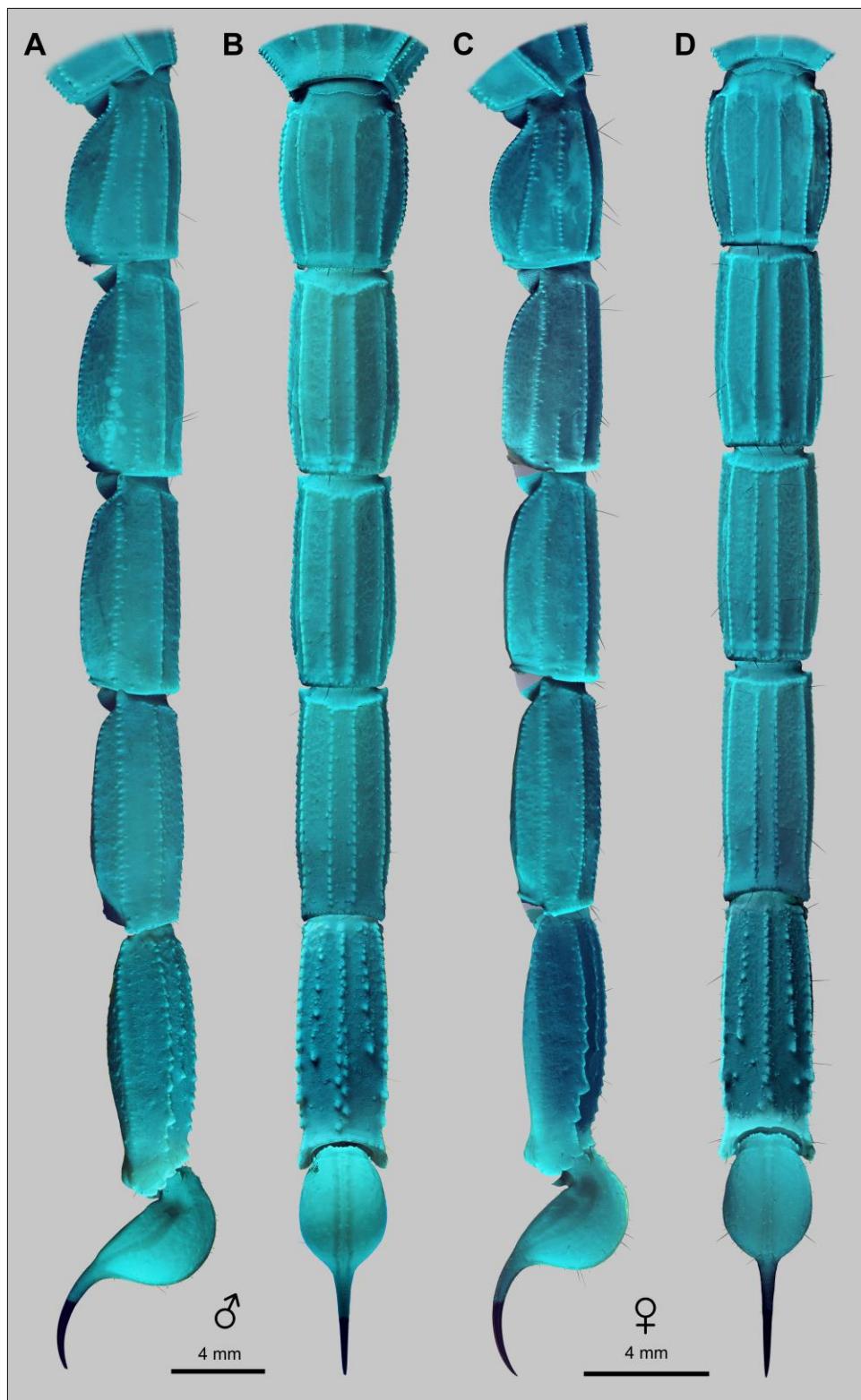


**Figure 42:** *Leiurus arabicus* sp. n., paratype male. Left pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, dorsal aspect. **E.** Chela, ventral aspect. **F.** Movable finger dentition. **G.** Fixed finger dentition. **H.** Chela, external aspect. Riyadh, Saudi Arabia (NHMB 17ap).

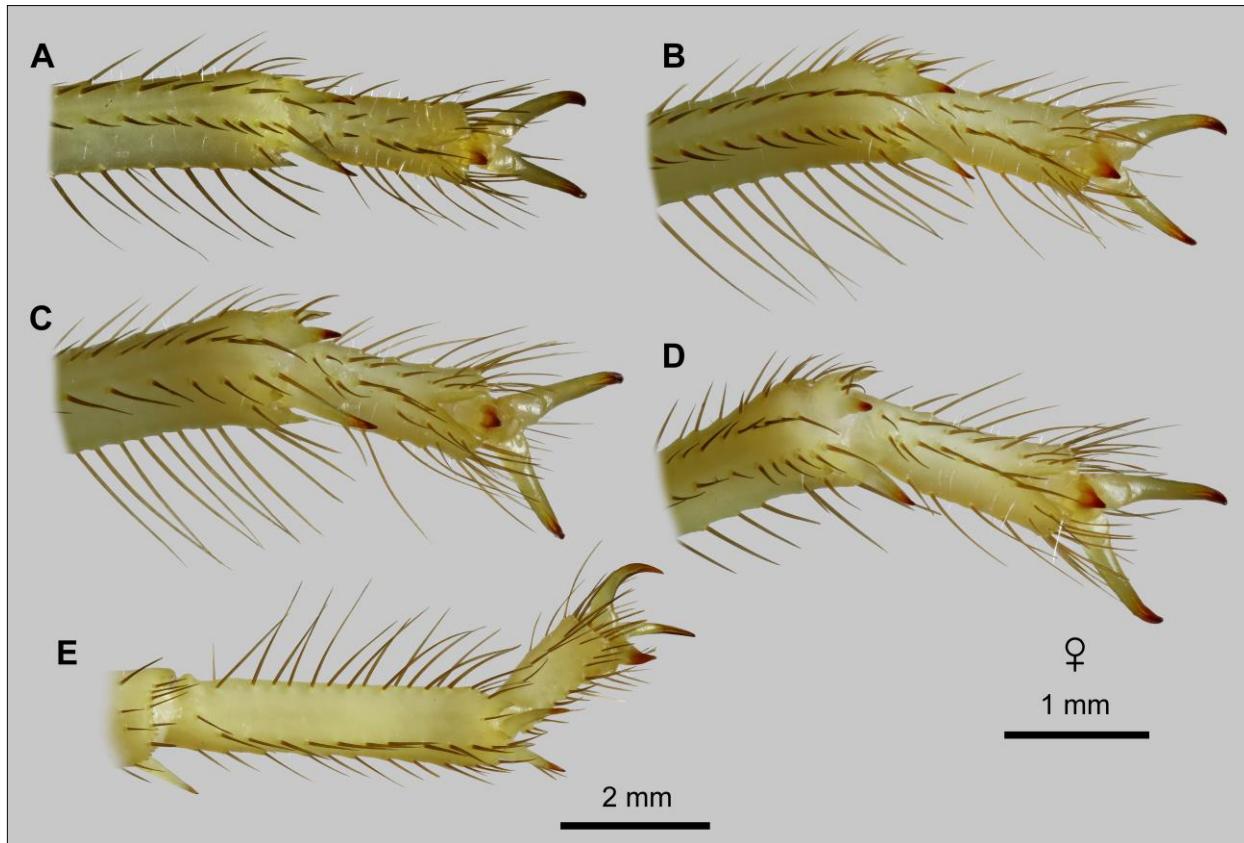
metasoma V with 5 macrosetae on lateral surface (2 lateral anal), 4 pairs on ventral surface.

**Telson.** Vesicle smooth, bulbous; ventral surface bearing scattered fine microsetae and several short macrosetae with associated shallow indentations; aculeus approximately same length as than vesicle.

**Pedipalp.** *Femur:* slender, L/W 3.82; dorsoexternal, dorsointernal and ventrointernal carinae strong with coarse, closely spaced dentate granules; internal carina strong, with large dentate granules spaced well apart; external carina weak to obsolete, a smooth ridge with isolated dentate granules distally; all intercarinal sur-



**Figure 43:** *Leiurus arabicus* sp. n. Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Male paratype, Riyadh, Saudi Arabia (NHMB 17ap). Female holotype, Kushm Dibi, Saudi Arabia (NHMB 17ap).

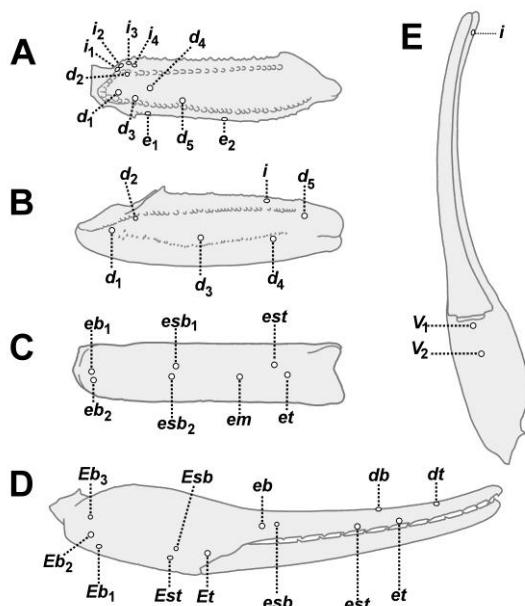


**Figure 44:** *Leiurus arabicus* sp. n., holotype female. Tarsi. **A–D.** Left telotarsus and distal basitarsus, ventral aspect. **A.** Leg I. **B.** Leg II. **C.** Leg III. **D.** Leg IV. **E.** Right basitarsus III retrolateral aspect. Upper scale bar: **A–D**, lower scale bar: **E**. Kushm Dibi, Saudi Arabia (NHMB 17aq).

faces smooth; linear cluster of 18–21 accessory macrosetae on lower distal external surface; *patella*: slender, L/W 3.60; dorsointernal carina moderate with coarse granulation; dorsomedian carina weak with fine granulation; dorsoexternal, external and ventroexternal carinae weak, smooth; ventromedian carina weak, with fine granules; ventrointernal carina weak, with well spaced medium to small granules and ventral patellar spur; internal carina moderate, with closely spaced small granules and dorsal patellar spur; all intercarinal surfaces smooth; *chela*: slender, L/W 6.93, movable finger L/manus ventral L 2.3; dorsal marginal and dorsal secondary carinae weak, smooth; digital carina weak, smooth, obsolete on manus; external secondary and ventroexternal carinae weak, smooth; other carinae obsolete; all intercarinal surfaces smooth; manus and fixed finger with sparse short macrosetae; movable finger with numerous short macrosetae on ventral aspect, culminating in dense subapical brush; 13 primary denticle subrows on movable fingers, 11–13 on fixed fingers; all subrows except proximal flanked by internal and external accessory denticles. *Trichobothriotaxy*: orthobothriotaxic, type Aβ (Vachon, 1974), db on fixed finger distal to *est*.

**Legs.** Moderately long, slender, femur III L/carapace L 1.14, patella III L/D 4.12; inferior carinae strongly denticulate on femur I–IV and patella I–III, very weakly denticulate, almost smooth on patella IV; tibia III–IV with long spurs; retrolateral tarsal spurs simple, non-setose; prolateral tarsal spurs basally bifurcate, bearing 1–3 macrosetae; basitarsi I–III with well developed bristle-combs, at least as wide as basitarsal segment; basitarsus III setal counts (left/right): retrosuperior 15/17, retroinferior 13/13 (including basal accessory seta), inferior 15/13; ventral surface of telotarsi with robust, short tapered macrosetae.

**Measurements of holotype female (mm).** Total L 89.00; metasoma + telson L 58.00; carapace L 9.85, W 11.18, carapace preocular L 4.97; metasomal segments (L/W/D) I 7.35/ 5.59/ 4.95, II 8.82/ 4.72/ 4.33, III 9.29/ 4.59/ 4.23, IV 10.30/ 4.05/ 3.90, V 11.51/ 4.13/ 3.84; telson L 9.73; vesicle L 5.15, W 3.80, D 3.53; pedipalp chela L 20.24, manus ventral L 6.22, manus W 2.92, manus D 3.47, fixed finger L 12.36, movable finger L 14.29; pedipalp femur L 10.70, W 2.80, patella L 11.71, W 3.25; pectine L 10.68, mid-pectine sensillar margin L 0.60; leg III femur L 11.19; leg III patella L 9.45, D 2.29.



**Figure 45:** *Leiurus arabicus* sp. n., holotype female. Trichobothrial map of pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, external aspect. **E.** Chela, ventral aspect. Kushm Dibi, Saudi Arabia (NHMB 17aq).

**Paratype male (Riyadh).** Differs from holotype female as follows: less intense fuscosity on carapace and metasoma V, tergites yellow, metasoma IV without dark markings on ventromedian carinae; body narrower, carapace W/L 1.04; stronger carinae on carapace, tergites and coxae; medial intercarinal surfaces of tergites very faintly shagreened; pectine basal piece narrower, anterior margin more strongly incised, with deep median pit; pectines wider, longer, tips extending to basal 1/3 of trochanter IV, teeth larger with longer sensillar margins, mid-pectine sensillar margin L/ pectine L 0.078, mid-pectine sensillar margin L/ metasoma I W 0.159; 37–38 pectine teeth; 1–2 basal pectine teeth overlap if anterior pectine margins aligned to posterior margins of coxae IV; sternite III with stronger, thicker, granulated median carinae; sternites IV–V with stronger, thicker, more heavily granulated lateral and median carinae; sternites VI–VII with all carinae stronger, more coarsely granulated; intercarinal surfaces of sternites III–VI roughened, micro-shagreened, anterior lateral areas more heavily, densely shagreened; ventromedian carinae on metasoma II–III more weakly crenulate, with smaller posterior denticles; metasoma V with dorsal surface slightly roughened, ventral surface more densely shagreened; pedipalp patella more slender, L/W 3.82, with larger denticles and spurs on ventrointernal and internal carinae; pedipalp chela more slender, L/W 7.18, with slightly stronger carination, dorsal marginal and dorsal secondary carinae weakly granulated on manus.

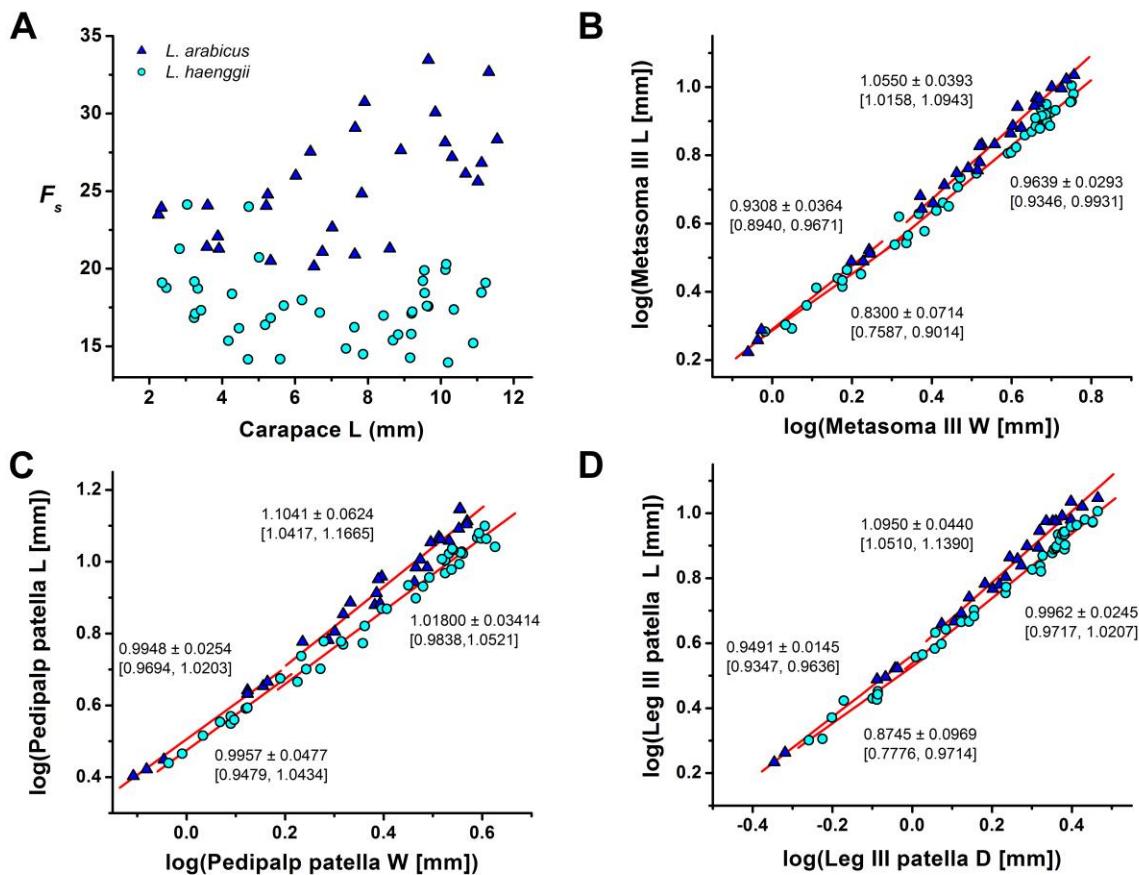
**Measurements of paratype male (NHMB 17ap) (mm).** Total L 84.00; metasoma + telson L 56.00; carapace L 9.23, W 9.58, carapace preocular L 4.34; metasomal segments (L/ W/ D) I 7.37/ 5.76/ 4.92, II 8.90/ 5.00/ 4.52, III 9.20/ 4.72/ 4.29, IV 10.30/ 4.30/ 3.99, V 10.70/ 4.10/ 3.76; telson L 9.47; vesicle L 4.87, W 3.80, D 3.43; pedipalp chela L 18.75, manus ventral L 6.27, manus W 2.61, manus D 2.98, fixed finger L 11.14, movable finger L 13.03; pedipalp femur L 9.89, W 2.70, patella L 11.19, W 2.93; pectine L 11.73; mid-pectine sensillar margin L 0.918; leg III femur L 11.05; leg III patella L 9.06, D 2.07.

**Variation (females).** *Color:* the holotype represents a light color phase from the central plateau region of Saudi Arabia. A dark color phase is represented by material from the Arabian Gulf coast and from Jeddah on the Red Sea Coast: carapace and tergites I–VI dark except for narrow band along lateral margins, tergite VII dark on anterior median area, dark stripes on ventromedian and ventrolateral carinae of metasoma II–IV, diffuse intercarinal fuscosity may be present on IV. *Morphosculpture:* area between anterior median carinae of carapace mostly smooth but sometimes with scattered fine granules; proximal 1/3 of anterior carina of coxa II smooth to finely granulated (weaker granulation than distal 2/3); basal piece of pectines smooth to lightly shagreened; anterior mediolateral intercarinal surfaces of sternites weakly to moderately shagreened; intercarinal surfaces of pedipalp femur and patella smooth to lightly, finely shagreened; inferior carina of leg IV patella smooth to weakly denticulate; *morphometrics and meristics:* see Table 4.

**DISTRIBUTION.** The studied material is mostly from the Najd plateau region of central Saudi Arabia and wadis around the Tuwayq escarpment (light color phase), with a few samples from the east coast (Al Amar and Jubail on the Arabian Gulf) and from Jeddah on the Red Sea coast (both dark color phases). Jeddah lies at the northern end of the Tihamah plain, a distinctive ecological region separated from the Najd by escarpments of the Hijaz and Asir mountain ranges. It is possible that the seemingly disjunct record in Jeddah is due to artificial dispersal from dark phase populations in the east via the heavily traveled Mecca Road. The elevation range of records is 20 – 800 m, with the lowest on the east coast, and the highest on the Najd plateau.

**ECOLOGY.** Most collections were made from vegetated wadis and oases in arid, stony desert in the region around Riyadh. The species is probably arenicolous, inhabiting burrows in sandy desert soils.

**REMARKS.** *L. arabicus* and *L. haenggii* appear to be closely related parapatric forms distributed in adjacent ecological regions and habitats of the Arabian Peninsula,



**Figure 46:** Morphometric differentiation between female *Leiurus arabicus* sp. n. and *L. haenggii* sp. n. **A.** Scatter plot of the compound morphometric ratio (slenderness factor)  $F_s = a.b.c$  (where  $a$  = metasoma III L/W,  $b$  = pedipalp patella L/W,  $c$  = leg III patella L/D) vs. Carapace L ( $N = 30$  *L. arabicus*,  $N = 43$  *L. haenggii*). The distribution of ratios of the two species were overlapped for juveniles and young, and were increasingly separated in subadults and adults, as segments of *L. arabicus* become more slender by allometric growth. **B, C, D.** Log-log scatter plots of metasoma III L vs. W, pedipalp patella L vs. W, and leg III patella L vs. D, respectively. Linear regression was applied separately to data sets split into upper and lower size ranges for each species (red lines). Numbers show fitted slope  $\pm$  standard deviation (SD), with SD ranges in brackets. Slopes were similar between *L. arabicus* and *L. haenggii* over the lower size range, and diverged over the upper size range. For all three segments, allometry was significantly diphasic in *L. arabicus*, and only weakly so, or monophasic, in *L. haenggii*.

i.e. rocky mountains along the Red Sea coast and Hadramaut vs. alluvial desert plains of the central Nadj plateau and eastern plains extending to the Gulf coast, respectively. Our samples permitted a differential diagnosis based on a combination of pedipalp, leg and metasomal morphometrics, and sternite carination in adult females. However, there remains the possibility that additional sampling could reveal hybridization in transition zones between the two eco-regions. This can be tested in the future by analyzing additional collections from a wider area.

***Leiurus heberti* sp. n.**  
(Figs. 47–57, 46, 58B, 59G–H, 87E, 88E, 89E, 90E, 91C, 92D, 93E, 95B–D, 98–100, Tabs. 2, 3B)  
<http://zoobank.org/urn:lsid:zoobank.org:act:2E5906DA-1108-4669-B2B7-8831B60EA4D1>

HOLOTYPE. Adult ♂, Oman, Wadi Andur, UV detection, rocky boulder wadi, along base of cliff, east edge of wadi,  $17^{\circ}40.08'N$   $54^{\circ}39.27'E$ , 405 m a.s.l., 26.IX.1995, 22:50 h, leg. G. Lowe & M.D. Gallagher (NHMB).

PARATYPES. Oman: 1 adult ♂, 1 immature ♂, Wadi Andur, UV detection, rocky boulder wadi, along base of cliff, east edge of wadi,  $17^{\circ}40.08'N$   $54^{\circ}39.27'E$ , 405 m a.s.l., 26.IX.1995, 22:50 h, leg. G. Lowe & M.D. Gallagher (NHMB); 1 adult or subadult ♀, Jabal Samhan, 15 km W of Jufa,  $17^{\circ}11.169'N$   $54^{\circ}56.571'E$ , 380 m a.s.l., 24.IX.2011, leg. W. Grosser (FKCP).

DIAGNOSIS (adults). Medium to large *Leiurus*, 73–83 mm in length, carapace L 8.4–8.9 mm; base color yellow, carapace darkly pigmented on interocular area and carinae, tergites with weak, variable fuscosity or pale; metasoma V dark except for posterior end; area of cara-

pace between anterior median carinae with sparse medium or fine granules; area between posterior median carinae with shallow median furrow flanked by lateral arcs of medium or fine granules; medial intercarinal surfaces of tergites II–III sparsely granular, finely shagreened or smooth; posterior margin of coxa III smooth; metasoma very long, slender, metasoma II L/W ♂ 1.91–1.95, ♀ 1.74, metasoma III L/W ♂ 2.19–2.30, ♀ 1.92, metasoma IV L/W ♂ 2.70–2.94, ♀ 2.30; ventromedian carinae of metasoma II and III with 36–46 (♂) or 20–25 (♀) denticles; ventrolateral carinae of metasoma V with small triangular denticles in male, enlarged subtriangular or lobate denticles in female; pedipalps very slender, patella L/W ♂ 4.28–4.48, ♀ 3.09; leg III patella L/D ♀ 4.35–4.54, ♂ 3.23; pectine teeth ♂ 36–37, ♀ 33–34; pectines long, narrow, pectine L/carapace L ♂ 1.38–1.44, ♀ 1.05, mid-pectine sensillar margin L/metasoma I W ♂ 0.198–0.225, ♀ 0.114; basal 1–3 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; fulcra mostly with 3–4 setae; pectine basal piece smooth except for anterior median patches of fine granules; leg III basitarsus with 8–11 retrosuperior setae; pedipalp chela fixed finger with trichobothrium *db* distal to *est*; sternite VII with area between median carinae smooth or very faintly shagreened anteriorly; sternite carination: *males*, sternite III with median carinae strong, sternites IV–V with lateral carinae strong, median carinae moderate to strong; *females*, sternite III with median carinae obsolete, sternites IV–V with lateral carinae weak, median carinae obsolete.

**COMPARISONS.** *L. heberti* sp. n. appears most closely related to *L. haenggii* sp. n. from Yemen, southwestern Oman, and western Saudi Arabia. The two species share similar carination and granulation of the carapace, tergites and sternites, with transverse arcs of granules between posterior median carinae on the carapace, and moderately developed basitarsal bristle combs. *L. haenggii* sp. n. differs from *L. heberti* sp. n. as follows: (i) males with less elongated pedipalps, legs and metasoma II–V; (ii) carinae on metasoma I–IV more robust with coarser granulation; (iii) males with larger, lobate dentition on ventrolateral carinae of metasoma V; (iv) dark pigmentation typically extends over posterior area of carapace and most of tergites; (v) lower range of pectinal tooth counts. *L. jordanensis* Lourenço, Modrý et Amr, 2002, from Jordan and northern Saudi Arabia also has long, slender pedipalps and metasomal segments, but can be differentiated from *L. heberti* sp. n. as follows: (i) different color pattern, with dark brown carapace, pedipalps, tergites and metasoma, and contrasting yellow telson and pedipalp fingers; (ii) larger size, adult female carapace length up to 11.4 mm; (iii) telson with vesicle elongated, not bulbous; (iv) lower range of pectinal tooth

counts: ♂ 33–37, ♀ 27–31; (v) basitarsi I–III with 10–20 retrosuperior setae.

**ETYMOLOGY.** A patronym in honor of Blaine Hébert, California, for his friendship and support of arachnology, science education and music.

#### DESCRIPTION (holotype male).

**Coloration.** Base color pale orange-yellow; carapace with dark pigmentation on interocular triangle, and around median ocular tubercle; carinae of carapace and tergites darkened; faint intercarinal fuscosity on posteromedial area of carapace and medial areas of tergites; metasoma V black except for most distal portion; all appendages pale yellow.

**Carapace.** Subrectangular, W/L 1.03, with steeply sloped lateral flanks; upper surface with nearly flat posterior and medial plateau areas, well raised ocular tubercle; interocular triangle convex laterally, weakly depressed medially; anterior margin distinctly emarginate, microdenticulate except for lateral ends, bordered by row of large granules; 6 short macrosetae on anterior margin, carapace otherwise devoid of macrosetae; 5 lateral eyes (3 large, 2 small) on each side; *carination*: anterior median, superciliary, central lateral, posterior median and posterior lateral carinae strong, coarsely granular; anterior median carinae separated by clear gap from anterior marginal granules; central lateral and posterior median carinae fused into lyre configuration; central median carinae coarsely granular, anterior and posterior portions nearly collinear, not strongly curved, with only slight inward bend on posterior ends; posterior lateral carinae strong, hind end with slight lateral bend, projecting past posterior margin of carapace; lateral ocular carinae weak with medium granules; *granulation*: sparse patches of 8–10 medium or large granules on each anterolateral corner of interocular triangle, 8–9 small granules on area in front of lateral ocular carinae; surface between anterior median carinae smooth with 8 scattered small granules; lateral flanks almost smooth, with few sparse granules; other intercarinal surfaces smooth with few fine granules; posterior median furrow shallow, almost flat, with median line of several fine granules or microgranules, flanked by lateral arcs of small granules; posterior margin of carapace between posterior lateral carinae bordered by row of medium granules.

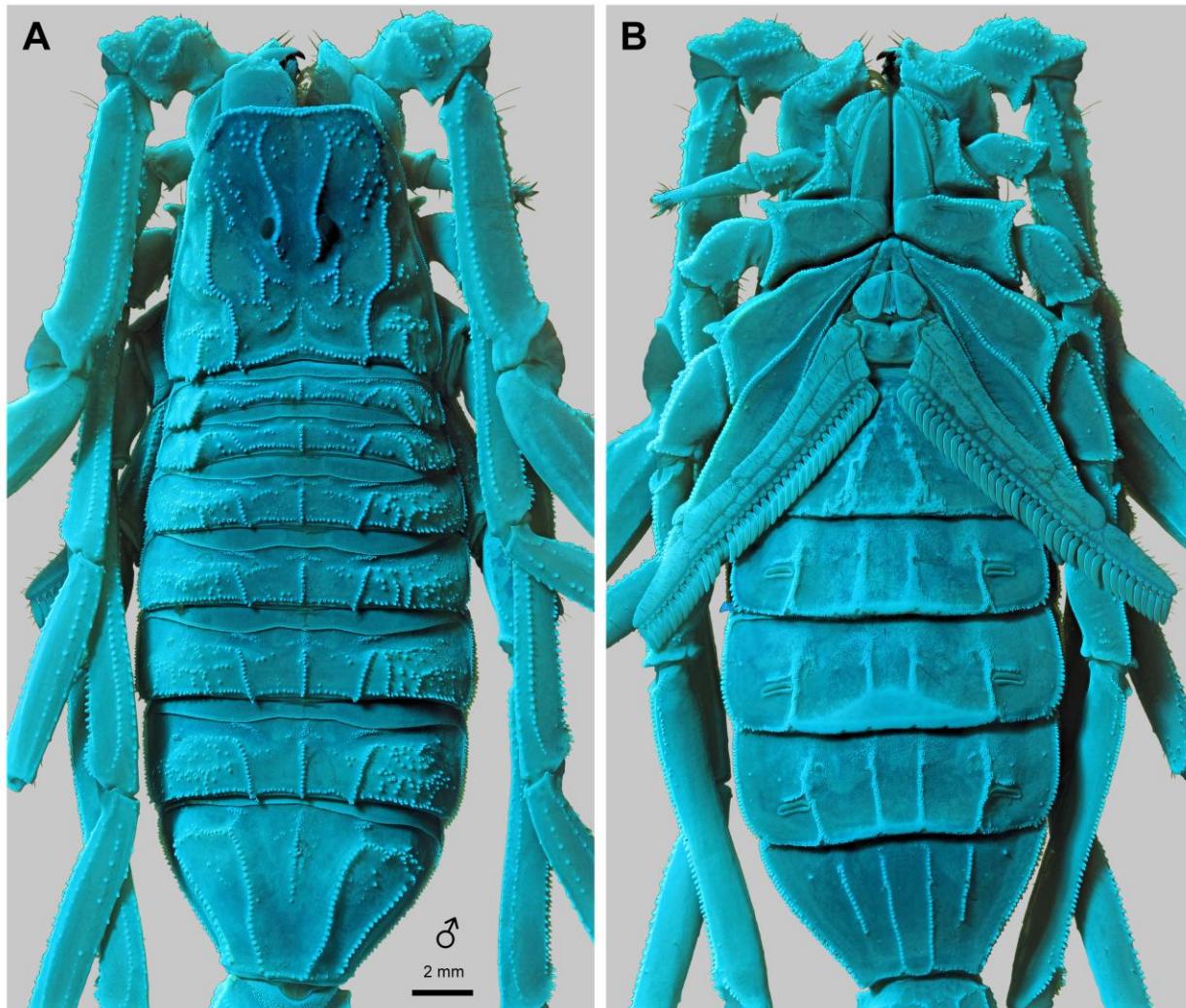
**Chelicera.** Dorsal surface of manus smooth, with 6 short, pale microsetae, 4 near apical margin, 2 subapical, each surrounded by clusters of granules; dorsointernal carina at base of fixed finger moderately strong, terminated anteriorly by large granules projecting over front of manus; single dark macroseta midway along dorsointernal carina; dorsal surface of movable finger smooth, with 4 pale microsetae; fingers with charac-



**Figure 47:** *Leiurus heberti* sp. n., holotype male. Habitus, dorsal aspect. Wadi Andur, Oman.



**Figure 48:** *Leurus heberti* sp. n., holotype male. Habitus, ventral aspect. Wadi Andur, Oman.



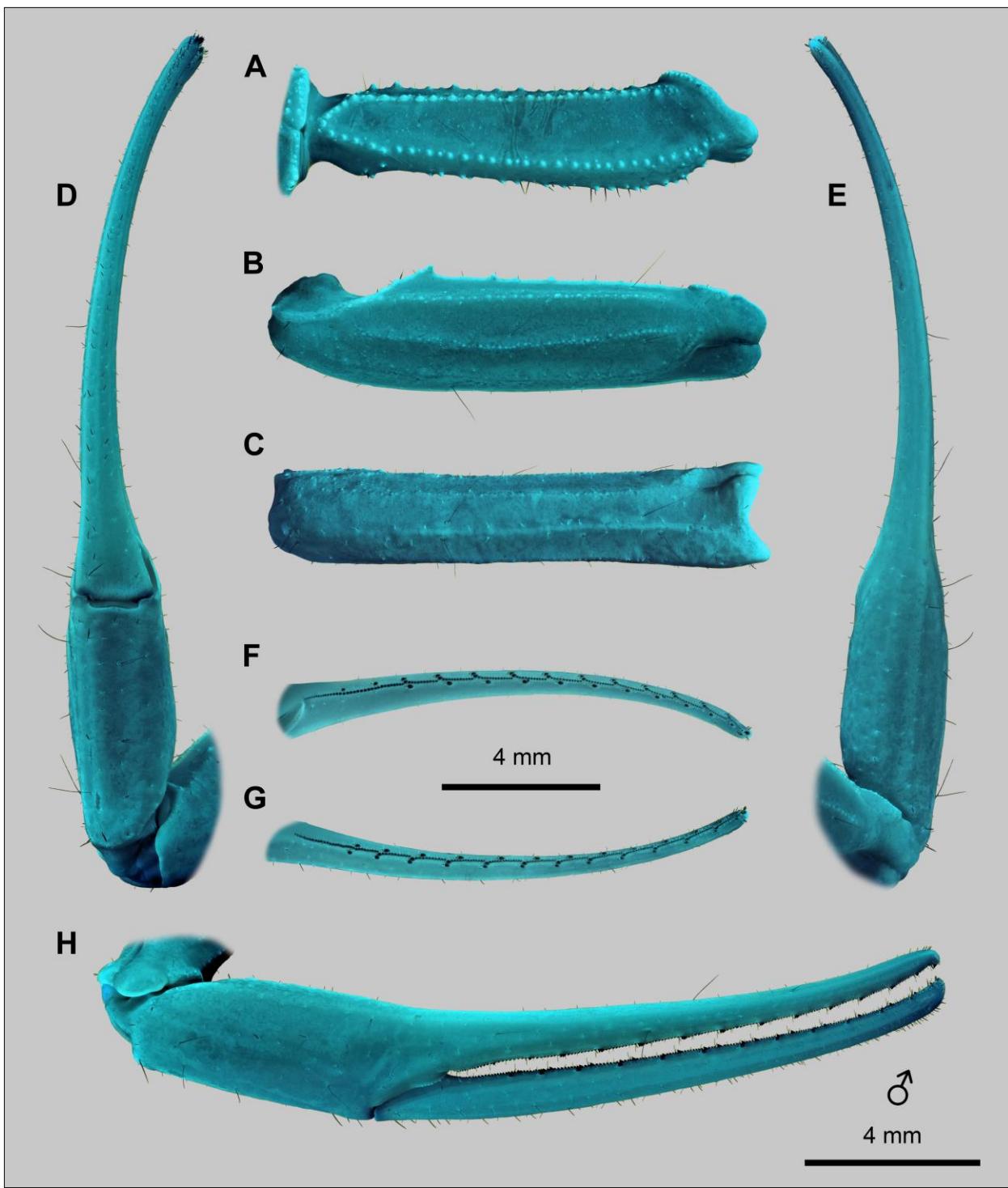
**Figure 49:** *Leiurus heberti* sp. n., holotype male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Wadi Andur, Oman.

teristic buthid dentition (Vachon, 1963); movable finger dorsal margin with 5 teeth: dorsal distal tine, subdistal, median and 2 basal teeth fused in bicusp; ventral margin with 3 teeth: ventral distal tine, median and basal teeth; fixed finger margin with 4 teeth: distal tine, subdistal, median and basal teeth; ventral aspect of fixed finger with 2 teeth.

**Coxosternal area.** Coxa I smooth except for coarse granules on distal margin, II smooth with sparse fine granules along posterior margin, III smooth, IV smooth to faintly shagreened; coxal endite II with weak, finely granulated carina; coxae II–III with medium to coarse granulation on anterior carinae, distal margins bearing coarse granules; proximal part of anterior carina of coxa III with fine denticulation; 3 macrosetae along anterior carinae of coxae II–III; anterior carina of coxa IV with regular coarse granulation, becoming fine proximally,

with single proximal macroseta; posterior margin of coxa IV with finely granulated carina on proximal half; sternum smooth, with anterior clusters of fine granules, scattered fine granules, one pair of macrosetae, and deep posteromedian furrow; genital opercula subtriangular with convex margins, sparse microgranulation in lateral areas, 5–6 short macrosetae.

**Pectines.** Basal piece with deep anterior median pit, with patches of fine granules anteromedially, otherwise smooth; 6 short macrosetae along anterior margin, 3 more in center; pectines long, tips extending past proximal 7/8 of trochanter IV; 3 marginal lamellae, small accessory lamella distal to first marginal lamella, 11 middle lamellae, 37–37 teeth; marginal lamellae, middle lamellae and fulcra with dense cover of short reddish macrosetae; fulcra with 3–4 setae; if anterior margins of left and right pectines aligned with posterior



**Figure 50:** *Leiurus heberti* sp. n., holotype male. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **G.** Movable finger dentition. **H.** Chela, external aspect. Wadi Andur, Oman.

edges of coxae IV, only most basal pair of teeth slightly overlap, with wide gap between basal middle lamellae, and teeth contact only anterior half of median carinae of sternite III; pectine teeth of moderate size, mid-pectine

sensillar margin L/ pectine L 0.080, mid-pectine sensillar margin L/ metasoma I W 0.198.

**Mesosoma.** *Tergites:* pretergites smooth; tergites I–II with 5 granular carinae; median and inner lateral cari-



**Figure 51:** *Leiurus heberti* sp. n., paratype female. Habitus, dorsal aspect. Jabal Samhan, Oman.

nae linear with medium granules; outer lateral carinae aligned with posterior lateral carinae of carapace, angled outward, strong with large, granules, hind ends extending past posterior margins of tergites without (on I) or with short (on II) lateral extensions; medial intercarinal surfaces smooth with few medium granules, and linear transverse series of fine granules on anterior margin; lateral flanks steeply sloped with sparse microgranulation; tergites III–VI with 3 straight coarsely granulated carinae; medial intercarinal surfaces mostly smooth with traces of microgranulation; fine granules present in anterior median patch and short transverse strips on either side; lateral surfaces of III–VI moderately sloped, with numerous medium to coarse granules, some arranged in short longitudinal rows;

tergite VII with 5 strong, granular carinae; inner and outer lateral carinae joined anteriorly by transverse series of granules becoming more irregular laterally; medial intercarinal surface smooth, sparse anterior median and anterior lateral patches of microgranules; mediolateral surface smooth with 2–3 isolated small granules; lateral surfaces smooth; posterior margins of tergites I–VI rimmed with linear rows of small to medium sized granules; posterior margin of tergite VII with 5 granules between inner lateral carinae, and 0–2 small granules laterally; sternites: sternite III with median carinae strong, thick, densely finely granulated; sternites IV–V with thick, densely granulated carinae, lateral carinae strong, median carinae moderate; sternite VI with median carinae strong, with dense fine gran-

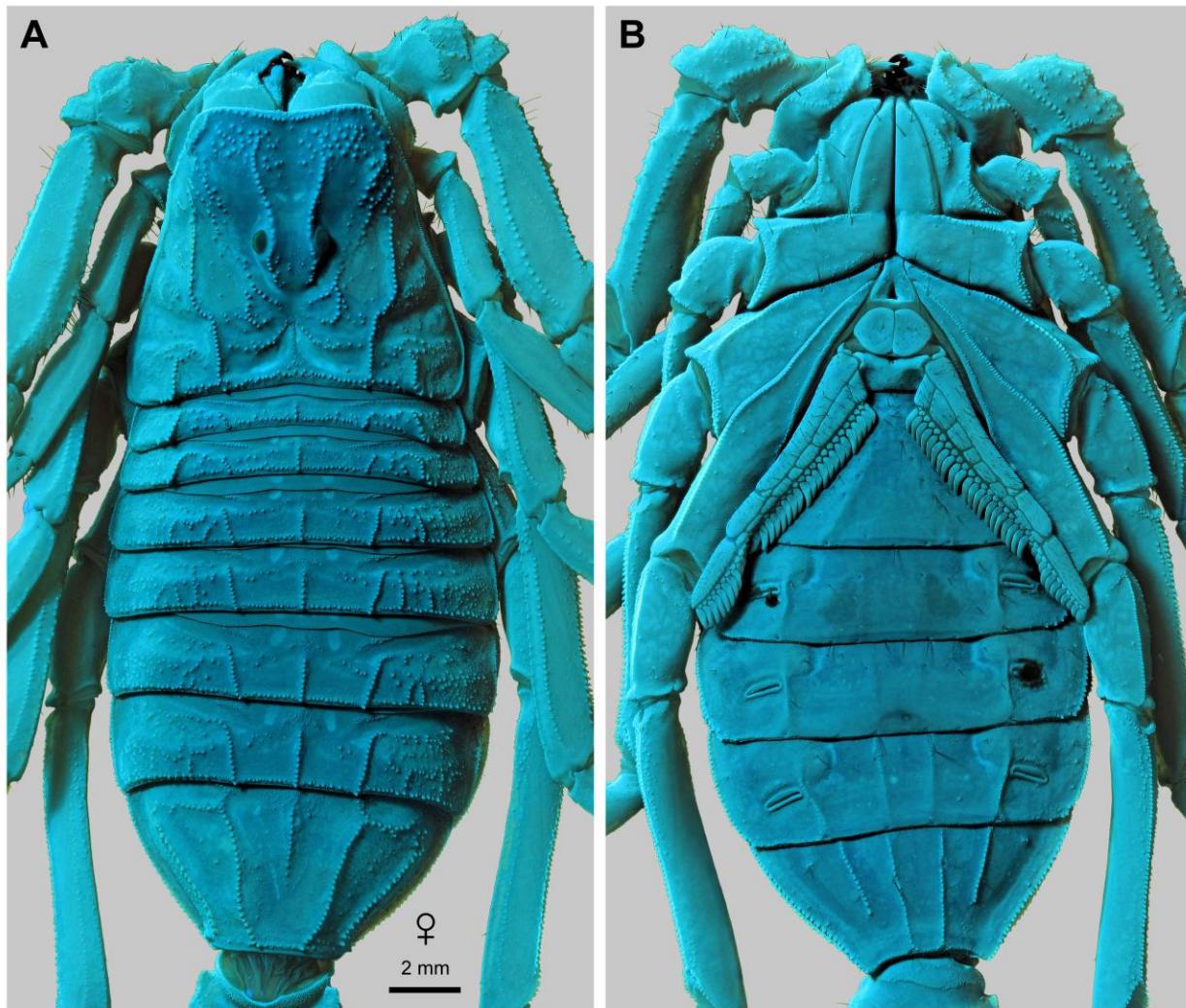


**Figure 52:** *Leiurus heberti* sp. n., paratype female. Habitus, ventral aspect. Jabal Samhan, Oman.

ulation, lateral carinae strong with dense, fine granulation in anterior half, coarse serial granulation in posterior half; lateral margins of sternites IV–VII armed with regular medium to large denticulate granules; medial intercarinal surface of III lightly shagreened anteriorly, heavily on posterior margin, of IV densely shagreened, smooth along posterior margin, of V densely shagreened anteriorly, with broad, smooth posterior margin, of VI densely shagreened anteriorly, nearly smooth towards posterior margin; mediolateral surfaces on IV–VI heavily shagreened anteriorly, lightly in posterior area; lateral surfaces of IV–VI smooth; sternite VII with 4 strong, narrow, coarsely granular carinae, intercarinal surfaces smooth except for lightly shagreened area anterior to median carinae; setation: sternite III with 4 macrosetae on median carinae, 4 along

external margins; sternites IV–VII with 2 paired macrosetae on median carinae, one in middle of sternite, other on posterior margin; lateral carinae on IV–VI with single posterior marginal macroseta; intercarinal macrosetae: one pair of lateral submarginal setae, one pair of outer mediolateral setae on IV–VI, one pair of lateral setae on VII; intercarinal posterior marginal macrosetae on III–VII: 4, 3, 2, 0, 0.

**Hemispermatophore.** Trunk elongate, slender; flagellum long, filiform, pars recta 0.4 times length of trunk, pars reflecta 0.6 times length of trunk; inner lobe a broad lamina, gently tapering with blunt apex; median and outer lobes shorter, partially fused, sharply tapering to thin, flexed apical processes; basal lobe a prominent, digitate hook; measurements (topoparatype): trunk L (to base of flagellum) 7.6 mm, pars recta 2.9 mm, pars re-

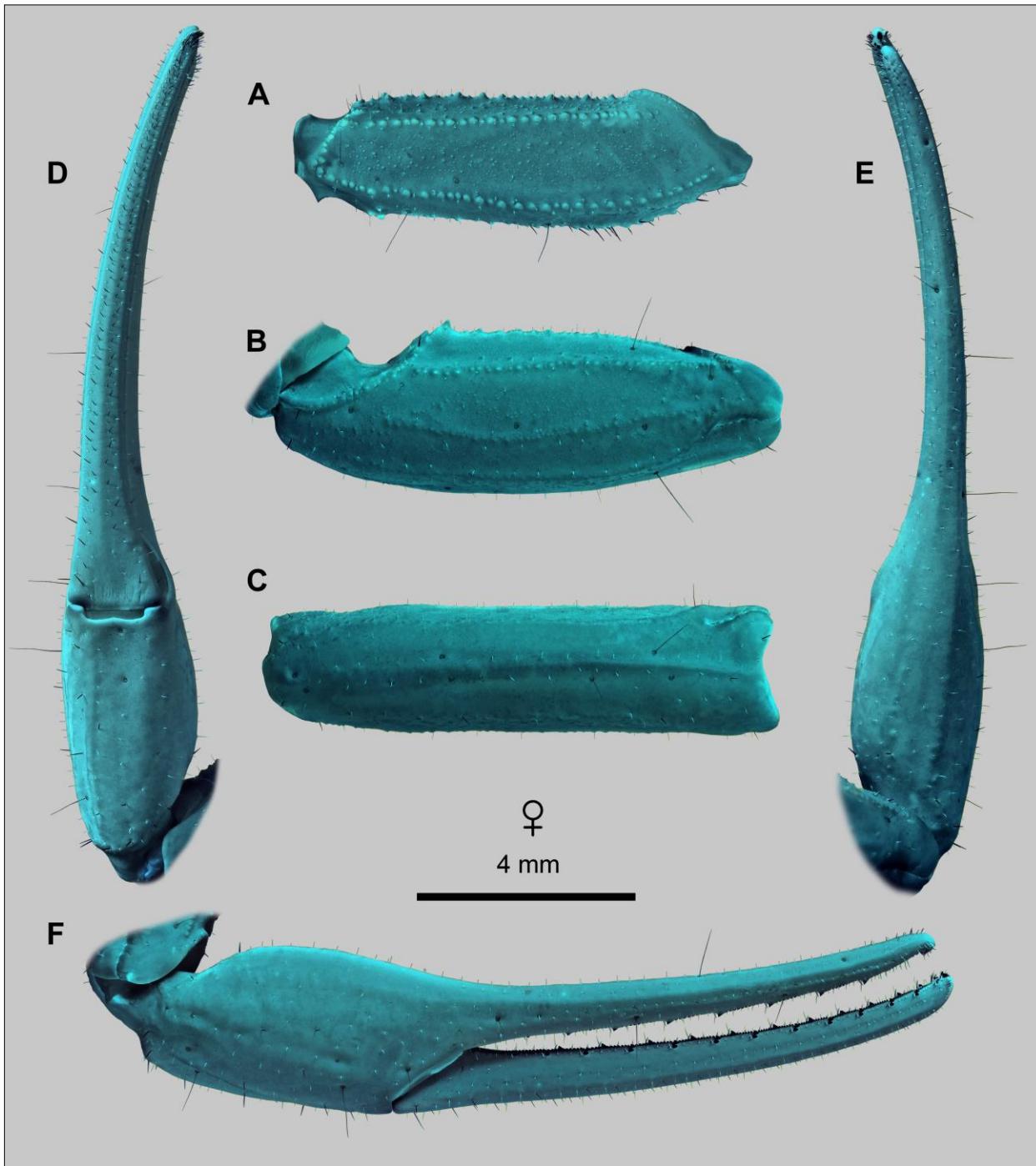


**Figure 53:** *Leiurus heberti* sp. n., paratype female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Jabal Samhan, Oman.

flecta 4.5 mm, inner lobe (from base of flagellum) 837 µm, median lobe (from juncture with inner lobe) 694 µm, outer lobe (from juncture with median lobe) 300 µm, basal lobe 216 µm.

**Metasoma.** Very long, slender, total metasoma and telson L/ carapace L 6.1; *carination*: segment I with 10 complete carinae; segments II–III with 8 complete carinae, median lateral carinae restricted to posterior 1/4 of II, posterior 1/7 of III; metasoma IV with 8 carinae, V with 7 carinae; carinae on segments I–IV finely crenulate-granulate; dorsosubmedian carinae moderately granulate on I, weakly granulate-crenulate on II–III, with irregular fine granulation on posterior 2/3 of IV; dorsolateral carinae moderately serrate or crenulate on I–II, weakly granulate-crenulate on III–IV, weak and finely granular on V; ventrolateral carinae moderate, finely granulate-crenulate on I–IV; median lateral carinae

moderate, granulate on I–III; ventromedian carinae moderate to strong on I–IV, crenulations on II–III uniform, not enlarged posteriorly; 42–43 granules on ventromedian carinae of metasoma II–III; metasoma V with dorsolateral carinae weak, finely granular; ventrolateral carinae strong, with small and large triangular dentate granules, larger posteriorly, forming scalloped margin; ventrosubmedian carinae on V weak, confined to anterior 2/3 of segment, marked by small and large dentate granules; ventromedian carina strong, with small to large dentate granules, increasing in size posteriorly; lateral anal margin with 3 large rounded lobes; ventral anal margin with 11 irregular, transverse crenulations; *intercarinal surfaces*: smooth on segments I–III, smooth to minutely shagreened on IV, sparsely, finely shagreened on V; *setation*: ventromedian and ventrolateral carinae on segments I–IV each bearing 2 exterior macro-



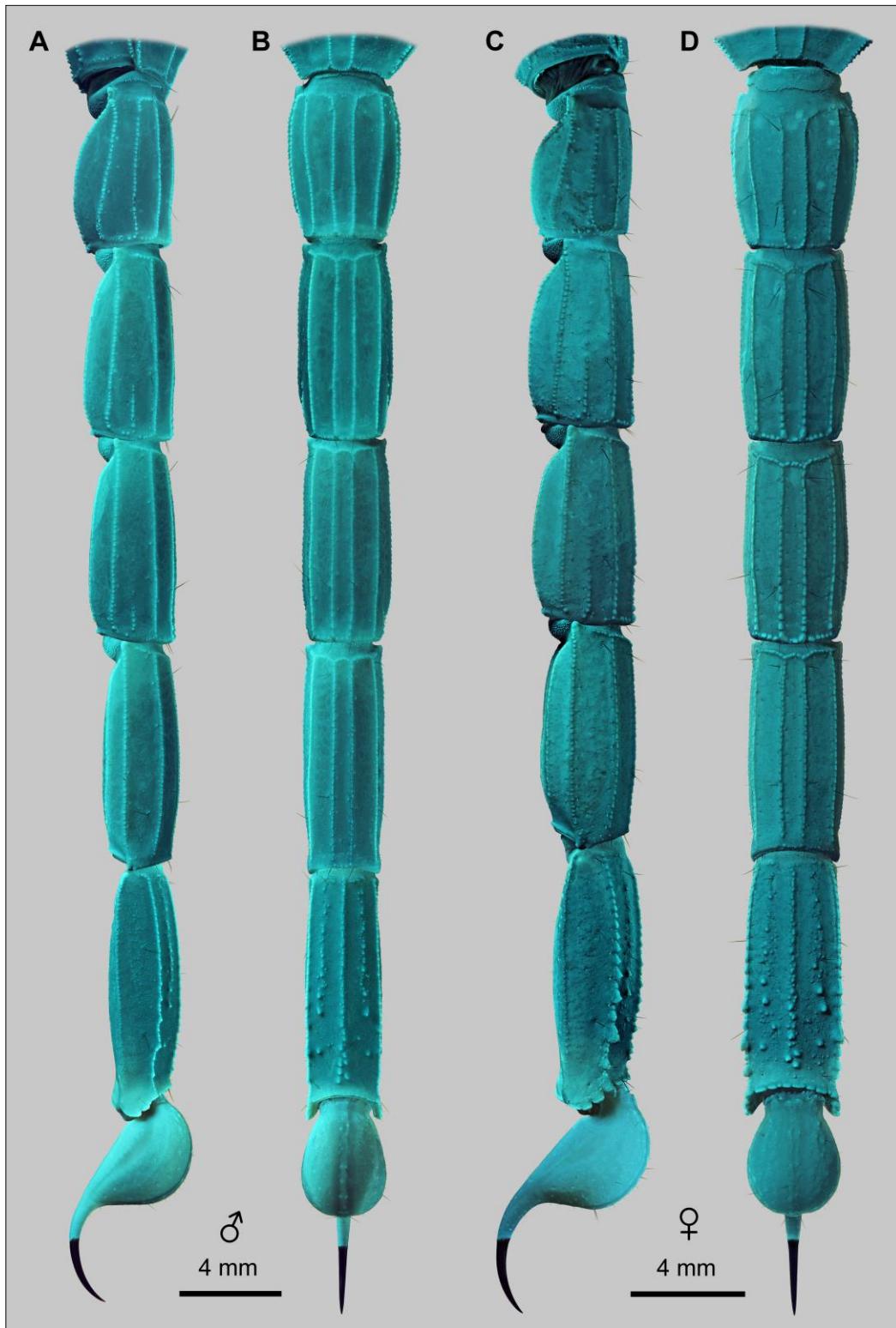
**Figure 54:** *Leiurus heberti* sp. n., paratype female. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Chela, external aspect. Jabal Samhan, Oman.

setae; metasoma V with 4 macrosetae on lateral surface, 2 on ventrosubmedian carinae.

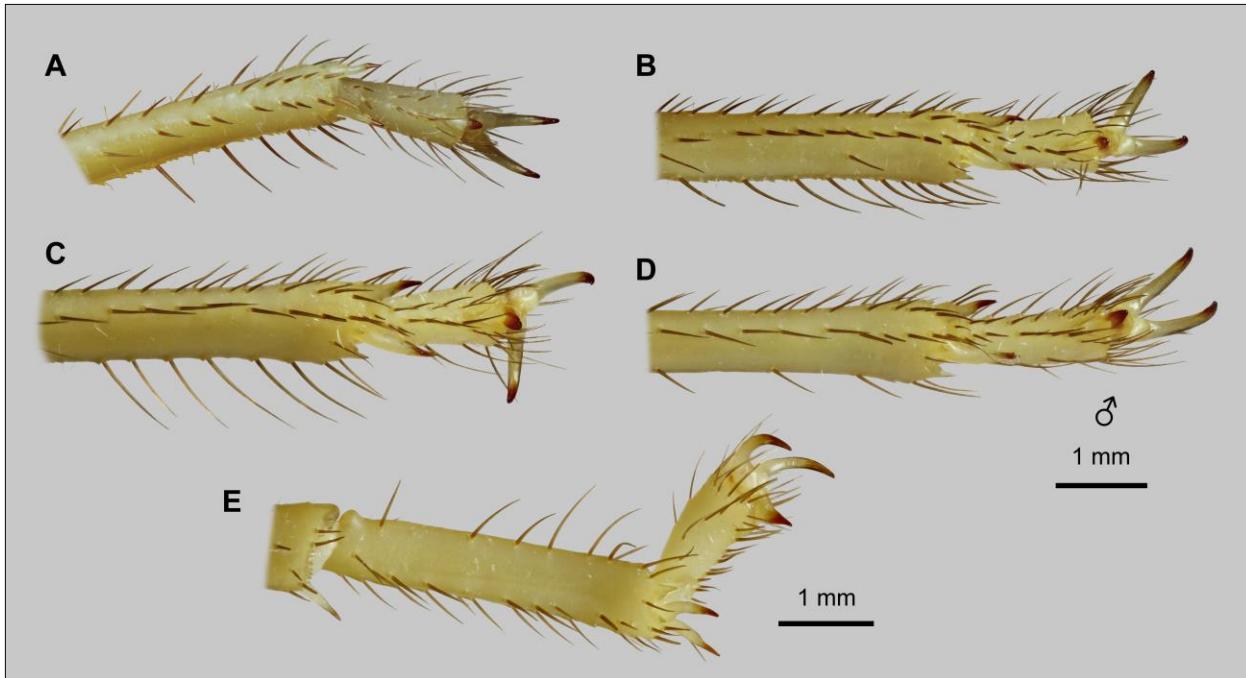
**Telson.** Vesicle smooth, bulbous; ventral surface with scattered fine microsetae and several short macrosetae; aculeus slightly shorter than vesicle.

**Pedipalp.** *Femur*: slender, L/W 4.3; dorsoexternal, dorsointernal and ventrointernal carinae strong with reg-

ular large conical granules; internal carina strong, with irregular large dentate granules; external carina obsolete, a smooth ridge with isolated large dentate granules; dorsal and internal surfaces finely, sparsely shagreened, ventral and external surfaces nearly smooth; linear group of 15–17 short macrosetae on distal 1/3 of segment along lower external surface, nearly level with or distal



**Figure 55:** *Leiurus heberti* sp. n. Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Male holotype, Wadi Andur, Oman. Female paratype, Jabal Samhan, Oman.



**Figure 56:** *Leiurus heberti* sp. n., holotype male. Tarsi. A–D. Left telotarsus and distal basitarsus, ventral aspect. A. Leg I. B. Leg II. C. Leg III. D. Leg IV. E. Right basitarsus III retrolateral aspect. Upper scale bar: A–D, lower scale bar: E. Wadi Andur, Oman.

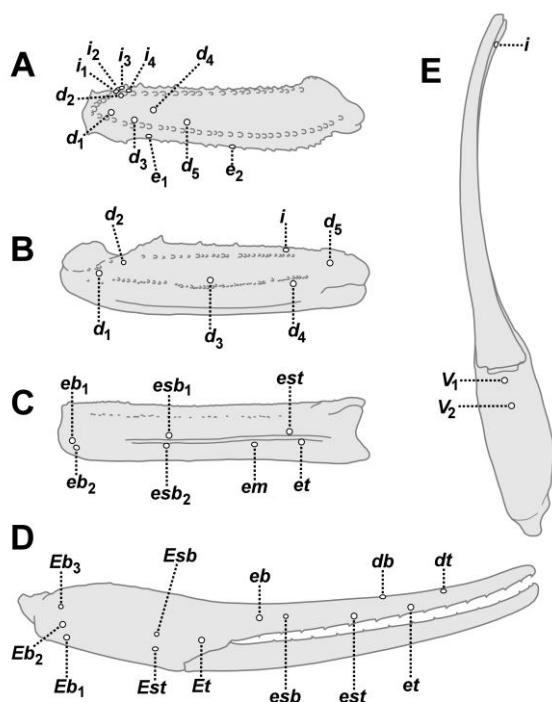
to trichobothrium  $e_2$ , part of total of 20–21 distal external accessory macrosetae; *patella*: slender, L/W 4.48; dorsointernal carina moderate, with medium to fine granules; dorsomedian carina weak, finely granular; dorsoexternal and external carinae weak, smooth; ventroexternal and ventromedian carinae weak, with fine granules; ventrointernal carina obsolete, marked by non-contiguous coarse conical granules; internal carina moderate, with widely spaced large conical granules separated by fine granulation; both internal and ventrointernal carinae with proximal patellar spur; all patellar surfaces smooth; *chela*: slender, L/W 8.24, with tenuous upwardly curved fingers, movable finger L/ manus ventral L 2.34; dorsal marginal and ventroexternal carinae faint, smooth, other carinae obsolete; all chela surfaces smooth; manus and fixed finger with sparse short macrosetae; movable finger with numerous short macrosetae on ventral aspect, culminating in dense subapical brush; 12 primary denticle subrows on fixed and movable fingers (left fixed finger regenerated, with 8 subrows); all denticle subrows flanked by internal and external accessory denticles, except proximal subrow of fixed finger without internal accessory denticle; *Trichobothriotaxy*: orthobothriotaxic, type A $\beta$  (Vachon, 1974), *db* on fixed finger distal to *est* (*db* missing on right fixed finger, *et* missing on left fixed finger, both present in paratypes).

**Legs.** Long, slender, femur III L/ carapace L 1.27, patella III L/D 4.54; inferior carinae strongly denticulate

on femur I–IV and patella I–III, very weakly denticulate, almost smooth on patella IV; tibia III–IV with long spurs; retrolateral pedal spurs simple, non-setose; pro-lateral pedal spurs basally bifurcate, bearing 2–3 macrosetae; basitarsi I–III with weakly developed bristle-combs, basitarsus III setal counts (left/right): retro-superior 9/8, retroinferior (including basal accessory seta) 12/13, inferior 14/12; ventral surface of telotarsi with sparse paired rows of stout, finely tapered macrosetae. Right leg I of holotype malformed, vestigial.

**Measurements of holotype male (mm).** Total L 83.00; metasoma + telson L 54.00; carapace L 8.79, W 9.34, carapace preocular L 4.00; metasomal segments (L/ D /W) I 7.00/ 4.30/ 4.96, II 8.36/ 3.93/ 4.37, III 8.87 / 3.67 / 3.86, IV 9.95 / 3.31 / 3.38, V 10.57 / 3.08 / 3.27; telson L 8.75; vesicle L 4.94, D 3.27, W 3.48; pedipalp chela L 18.21, manus ventral L 5.69, manus W 2.21, manus D 2.57, fixed finger L 11.36, movable finger L 13.29; pedipalp femur L 9.98, W 2.32, patella L 11.12, W 2.48; pectine L 12.17, mid-pectine sensillar margin L 0.98; leg III femur L 11.18; leg III patella L 9.37, D 2.06.

**Paratype female (Jabal Samhan).** Smaller than holotype male, presumably sub-adult; differs as follows: metasoma, pedipalps and legs not conspicuously elongated: metasoma II L/W 1.74, metasoma III L/W 1.92, metasoma IV L/W 2.30, metasoma V L/W 2.47, pedipalp femur L/W 3.25, pedipalp patella L/W 3.09, pedipalp chela L/ carapace L 1.72, pedipalp chela L/



**Figure 57:** *Leiurus heberti* sp. n., holotype male. Trichobothrial map of pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, external aspect. **E.** Chela, ventral aspect. Wadi Andur, Oman.

manus W 6.12, leg III patella L/D 3.23; wider mesosoma; pectines shorter, tips extending to base of trochanter IV, teeth smaller with shorter sensillar margin, 33–34 in number; basal pectine teeth not overlapped when anterior pectinal margins aligned with posterior margins of coxae IV; median carinae obsolete on sternites III–V, weak on VI; lateral carinae moderate, smooth on sternites IV–V, moderate, finely granular on VI; sternite VII with finer median and lateral carinae; sternites with smooth intercarinal surfaces; coarser granules and crenulation on ventromedian and ventrolateral carinae on metasoma II–III, with more enlarged denticles on posterior half of segments; metasoma II–III with 20–25 granules on ventromedian carinae; metasoma V with larger denticles on ventrolateral carinae, posterior denticles enlarged, triangular; pedipalp femur with 27 distal external accessory macrosetae.

**Measurements of sub-adult female (mm).** Total L 73.00; metasoma + telson L 48.00; carapace L 8.43, W 9.55, carapace preocular L 4.10; metasomal segments (L/D/W) I 5.76/4.11/4.77, II 7.01/3.87/4.03, III 7.33/3.86/3.82, IV 8.15/3.54/3.54, V 9.28/3.12/3.76; telson L 8.70; vesicle L 4.38, D 3.12, W 3.30; pedipalp chela L 14.50, manus ventral L 4.31, manus W 2.37, manus D 2.72, fixed finger L 9.08, movable finger L 10.40; pedipalp femur L 7.96, W 2.45, patella L 9.04, W 2.93; pectine L 8.86; mid-pectine sensillar margin L 0.54; leg

III femur L 8.88; leg III patella L 7.11, D 2.20. **Meristics:** pedipalp movable fingers with 12/12 (left/right) subrows of primary denticles, fixed fingers with 11/8 subrows (anomalous fusion of rows on right finger); basitarsus III seta counts (left/right): retro-superior 15/11, retroinferior 14/13, inferior 13/14.

**Variation.** Comparison of the holotype to two smaller paratype males showed an increasing slenderness of pedipalps, legs and metasoma with increasing size (Tab. 2). The smaller of the two paratype males is more similar to *L. haenggii* sp. n. in morphometrics and the presence of 4 enlarged denticles on ventrolateral carinae of metasoma V. Median carinae on sternites III–V are weak or obsolete on the smaller paratype male. The larger paratype male, like the holotype, has weakly developed bristle combs on basitarsi I–III, with seta counts (left/right): retrosuperior 9/10, retroinferior 12/12, inferior 13/13.

**DISTRIBUTION.** Known only from the Jabal Samhan mountains of Dhofar Province, Oman.

**ECOLOGY.** The male types were collected by ultraviolet detection among rocks and boulders along the edge of a lightly vegetated wadi on the northern side of the Jabal Samhan mountains. All were very agile and aggressive when captured. The only known female paratype was collected near the base of the Jabal Samhan escarpment facing the southern coastal plain. Both sites are at lower elevations (ca. 400 m a.s.l.), and it is not known if this species occurs at higher elevations in these mountains whose peaks reach over 2,000 m a.s.l. The compressed body, elongated legs, pedipalps and metasoma, and weakly developed basitarsal bristle combs are consistent with a lithophilous ecomorphotype.

#### *Leiurus hebraeus* (Birula, 1908) stat. n.

(Figs. 60–71, 87F, 88F, 89F, 90F, 91G, 92K, 93I–J, 94D–E, 95, 98–99, Tabs. 3A, 5)

*Buthus quinquestriatus hebraeus* Birula, 1908: 124–129.

#### REFERENCES

- Scorpio occitanus*: Audouin in Savigny, 1826: 173, pl. VIII, fig. 1 (in part); Audouin in Savigny, 1827: 410–411, pl. VIII, fig. 1 (in part).
- Buthus quinquestriatus*: Kraepelin, 1891: 58–60, pl. I, fig. 7, pl. II, fig. 38 (in part); Pocock, 1891: 242–243 (in part); Pavesi, 1895: 4; Kraepelin, 1899: 27–28 (in part); Simon, 1892: 83 (?); Davydov, 1898: 41–43; Schenkel, 1932: 380; Werner, 1934: 269 (in part); Werner, 1935: 211; Bodenheimer, 1937: 235; Whittick, 1955; Whittick, 1970.
- Buthus quinquestriatus hebraeus*: Birula, 1910: 118.
- Buthus (Buthus) 5-striatus hebraeus*: Birula, 1910: 170.
- Buthus (Buthus) quinquestriatus*: Birula, 1917a: 23, 213 (in part); Whittick, 1941: 43 (in part).

	Paratype 1	Paratype 2	Holotype
Carapace L	6.30	8.68	8.79
Pedipalp femur L/W	3.86	4.28	4.30
Pedipalp patella L/W	3.52	4.28	4.48
Pedipalp chela L/manus W	7.74	7.76	8.24
Leg III femur L/ Carapace L	1.15	1.16	1.27
Leg III patella L/ Carapace L	0.97	0.99	1.07
Leg III patella L/D	4.23	4.35	4.54
Pedipalp femur L/ Carapace L	1.08	1.09	1.14
Metasoma I L/W	1.37	1.41	1.41
Metasoma II L/W	1.87	1.95	1.91
Metasoma III L/W	2.00	2.19	2.30
Metasoma IV L/W	2.50	2.70	2.94
Metasoma V L/W	2.75	3.11	3.23

**Table 2:** Variation in male morphometric ratios with increasing size in *Leiurus heberti* sp. n.

*Leiurus quinquestriatus*: Vachon, 1950a: 197 (in part); Stahnke, 1972: 130 (in part); Lamoral & Reynders, 1975: 509–510 (in part); Wahbeh, 1976: 89; Levy & Amitai, 1980: 47–48 (in part); Warburg et al., 1980: 206; Kinzelbach, 1984: 100, Fig 2; Kinzelbach, 1985: map II (in part); Amr et al., 1988: 373; El-Hennawy, 1988: 14–15, 18; El-Hennawy, 1992: 101, 125–126 (in part); Amr & El-Oran, 1994: 186; Kovařík, 1998: 112 (in part); Kabakibi et al., 1999: 80, fig. 1; Amr & Abu Baker, 2004: 237–238, 241; Yağmur et al., 2009: 2–3 (in part), fig. 10–11; Shehab et al., 2011: 335–337, fig. 2D, tabs. 1–2.

*Leiurus quinquestriatus hebraeus*: Vachon, 1966: 212; Levy, Amitai & Shulov, 1970: 231–242 (in part); Levy & Amitai, 1980: 48–53, fig. 47–51, map 3, Appendix (in part); El-Hennawy, 1992: 101, 126; Sissom, 1994: 23; Fet & Lowe, 2000: 156–157; Yağmur et al., 2009: 12; Khalil & Yağmur, 2010: 2.

*Leiurus quinquestriatus voelschowi*: Pohl, 1967: 209–215, figs. 1–4; Kovařík, 1997: 180 (in part, record from Jordan).

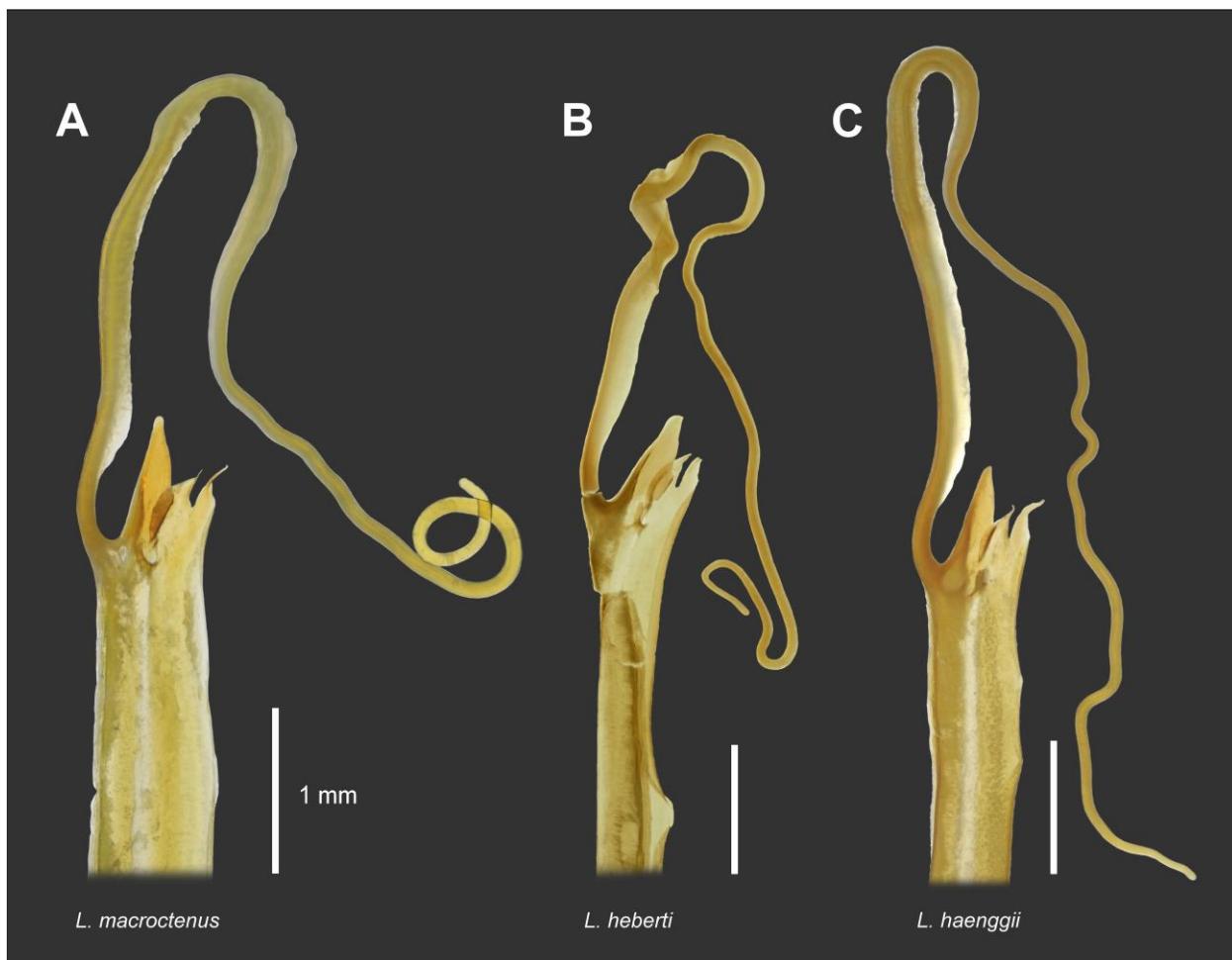
*Leirus* (sic) *quinquestriatus hebraeus*: Levy & Amitai, 1980: Appendix.

TYPE MATERIAL. Lectotype adult ♀, 4 immature paralectotypes, **Jordan**, Wadi 'Arrud (ZISP 578) (not examined, Figs. 70–71).

OTHER MATERIAL EXAMINED. **Israel**: 3 ♂, 7 ♀, 15 juvs, Palaestina (ev. Jordanien) (NHMB 17a); 1 ♀, Palaestina (ev. Jordanien), Jericho, 31°30.6'N 35°16.8'E, IV.1927, leg. O. Wohlberedt (NHMB 17-Ia); 2 ♀, ca. 11 km S of Beersheba, Hadarom, 31°06.19'N 34°49.41'E, 350 m a.s.l., 15.IV.1983, leg. A.M. de Saint Michel (MEB 034); 1 ♂, 2 juvs, between Nesher & Yagur, Haifa District, 32°45.22'N 35°03.69'E, 27 m a.s.l., 20.IX.1984, leg. M.R. Warburg (MEB 197); 1 ♂, 1 ♀, Haifa area, 32°48'N 34°59'E, 300 m a.s.l., 30.XI.1984,

leg. M.R. Warburg (MEB 198); 1 ♂, 3 ♀, 3 juvs, Negev desert, Vadi Hazaz near Sede Boqer (Haluqim Ridge), XI.–XII.2004, leg. J. Král (FKCP); 1 ♂, 2 ♀, Negev desert, Sede Boqer, IX.2007, leg. J. Král and M. Forman (FKCP). **Jordan**: 1 ♂, 4 ♀, Madaba, 31°43'N 35°48'E, 764 m a.s.l., 22.III.1983, leg. M.A. Jafar (MEB 346); 1 ♀, Tabaqat, 32°27'N 35°37'E, –200 m a.s.l., 4.V.1995, leg. V. Sejva (GL); 1 ♀, Kurayyima Udoli, 32°16.75'N 35°35.87'E, 23.VII.2000 (GL). **Syria**: 4 ♂, Bosra, V.1994, leg. D. Modrý (FKCP); 1 ♀, Seydmaya, V. 1994, leg. D. Modrý (FKCP).

DIAGNOSIS (adults). Small to medium sized *Leiurus*, 58–77 mm in length, carapace L 6.5–9.3 mm; base color yellow to orange-brown, with variable fuscosity on carapace and tergites; metasoma V either clear or fuscous except for posterior end; carapace with area between anterior median carinae finely shagreened, with scattered medium to fine granules, area between posterior median carinae with shallow median furrow flanked by arcs of medium or fine granules; medial intercarinal surfaces of tergites II–III shagreened, with variable medium to fine granulation; posterior margin of coxa III smooth or with sparse fine granules; metasoma robust, metasoma II L/W 1.38–1.64, metasoma III L/W 1.49–1.69, metasoma IV L/W 1.71–2.03; ventromedian carinae of metasoma II and III with 14–19 denticles (46/48 carinae); metasoma V with enlarged subtriangular or lobate denticles on ventrolateral carinae; pedipalps relatively stout, patella L/W ♂ 2.81–2.95, ♀ 2.48–2.83; leg III patella L/D 3.13–3.71; pectine teeth ♂ 33–37, ♀ 27–32; pectines medium sized, pectine L/ carapace L ♂ 1.14–1.29, ♀ 0.92–1.21, mid-pectine sensillar margin L/ metasoma I W ♂ 0.169–0.180, ♀ 0.100–0.136; basal 1–2 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece very lightly, finely shagreened, almost smooth in females, almost smooth or weakly granulated in males; leg III basitarsus



**Figure 58:** Hemispermatophores of new *Leiurus* species. **A.** *L. macroctenus* sp. n., paratype male, Duhai, Oman. **B.** *L. heberti* sp. n., holotype male, Wadi Andur, Oman. **C.** *L. haenggii* sp. n., paratype male, Jabal Qara, Oman. Distal portions hemispermatophores illustrated to show flagellum and lobes (right hemispermatophores, convex aspect). Scale bars: 1 mm.

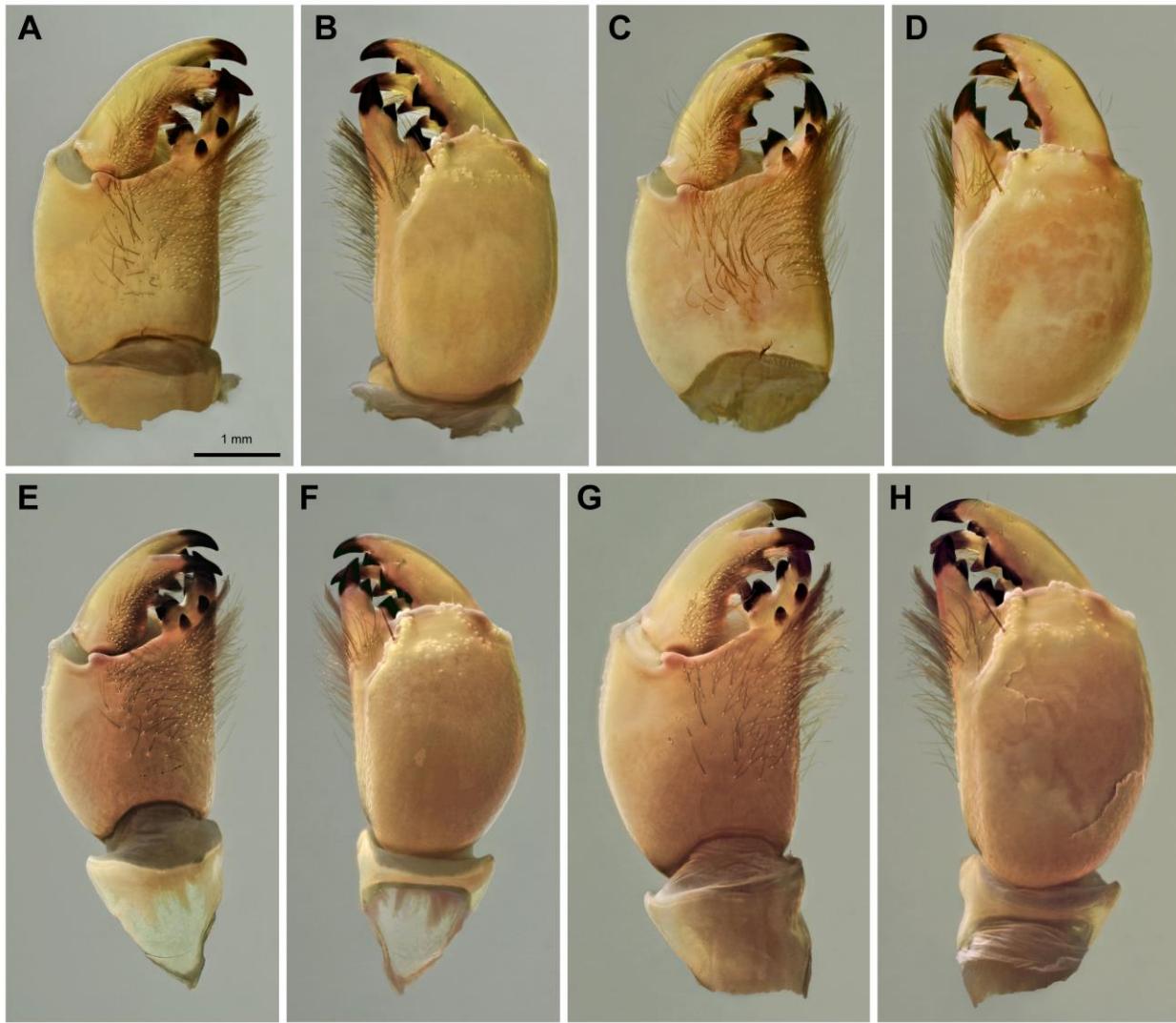
with 7–12 retrosuperior setae; pedipalp chela fixed finger with trichobothrium *db* either distal or proximal to *est*; sternite VII with area between median carinae densely, finely microgranulated or shagreened; sternite carination: *males*, sternite III with median carinae moderate to strong, sternites IV–V with lateral carinae strong, median carinae weak to moderate; *females*, sternite III with median carinae weak or obsolete, sternites IV–V with lateral carinae weak to moderate, median carinae obsolete.

#### MEASUREMENTS.

**Male, Israel (NHMB 17a) (mm).** Total L 58.0; metasoma + telson L 36.0; carapace L 6.74, W 7.22, carapace preocular L 3.05; metasomal segments (L/ D /W) I 4.98/ 4.01/4.34, II 5.82/ 3.63/3.97, III 6.08/ 3.56/3.85, IV 6.92/ 3.44/3.59, V 7.67/ 2.89/3.49; telson L 7.00; vesicle L 3.85, D 2.78, W 2.87; pedipalp chela L 11.62, manus ventral L 3.51, manus W 1.93, manus D

2.14, fixed finger L 6.79, movable finger L 7.98; pedipalp femur L 5.98, W 2.03, patella L 7.36, W 2.55; pectine L 7.83, mid-pectine sensillar margin L 0.735; leg III femur L 6.87; leg III patella L 5.79, D 1.825; chela *db*–*est* (left/ right) distance 0.292/ 0.958; pectine teeth (left/ right) 35/ 35.

**Female, Israel (NHMB 17a) (mm).** Total L 76.0; metasoma + telson L 44.0; carapace L 8.09, W 8.91, carapace preocular L 3.82; metasomal segments (L/ D /W) I 5.70/ 4.30/4.83, II 6.44/ 4.15/4.30, III 6.48/ 4.05/4.10, IV 7.53/ 3.82/3.84, V 9.06/ 3.49/4.06; telson L 8.41; vesicle L 4.53, D 3.28, W 3.49; pedipalp chela L 14.34, manus ventral L 4.28, manus W 2.41, manus D 2.56, fixed finger L 8.20, movable finger L 10.03; pedipalp femur L 6.88, W 2.23, patella L 8.32, W 3.05; pectine L 8.83, mid-pectine sensillar margin L 0.653; leg III femur L 8.15; leg III patella L 6.92, D 2.00; chela *db*–*est* (left/ right) 0.354/ 0.417; pectine teeth (left/ right) 30/ 30.



**Figure 59:** Chelicerae of *Leiurus* species. **A, B.** *L. macroctenus* sp. n., paratype male, Thumrait, Oman. Right chelicera, ventral (**A**) and dorsal (**B**) aspect. **C, D.** *L. haenggii* sp. n., paratype male, Jabal Qara, Oman. Right chelicera, ventral (**C**) and dorsal (**D**) aspect. **E, F.** *L. brachycentrus* (Ehrenberg, 1829), female, Al Mansuriah, Yemen. Right chelicera, ventral (**E**) and dorsal (**F**) aspect. **G, H.** *L. heberti* sp. n., holotype male, Wadi Andur, Oman. Right chelicera, ventral (**G**) and dorsal (**H**) aspect. Scale bar in **A**: 1 mm (also applies to **B–H**).

DISTRIBUTION. Israel, Jordan, Syria, Lebanon.

REMARKS. Birula (1908) separated *L. q. hebraeus* from the nominotypic subspecies by 11 characters. We assessed these characters by comparing 20 adult *L. hebraeus* from Israel and Jordan with 26 adult *L. quinquestriatus* from Egypt and Sudan:

(1) weaker carapace carination and granulation, (2) granulated ocular tubercle, (3) more coarsely shagreened tergites, (4) non-granulated intercarinal surfaces on the metasoma: (1) – (4) were unreliable when granulation was visualized in fine detail by UV fluorescence;

(5) ventromedian carinae of metasoma II–III with denticles increasing in size posteriorly (vs. uniform in

size): this was confirmed for *L. hebraeus*, but also observed in some *L. quinquestriatus*, and hence was not diagnostic;

(6) smaller number of denticles (15–17) on ventromedian carinae of metasoma III (vs. 18–27): this was well supported with no overlap, i.e. 46/46 carinae of *L. quinquestriatus* with 19 or more denticles, 24/24 carinae of *L. hebraeus* with 18 or fewer denticles;

(7) lower range of denticles (18–31) on ventrolateral carinae of metasoma V (vs. 23–38): due to the broad overlap of ranges, this was not diagnostic;

(8) more stout pedipalp and metasomal segments: this was supported by smaller morphometric ratios, pedipalp patella L/W and metasoma III–IV L/W;



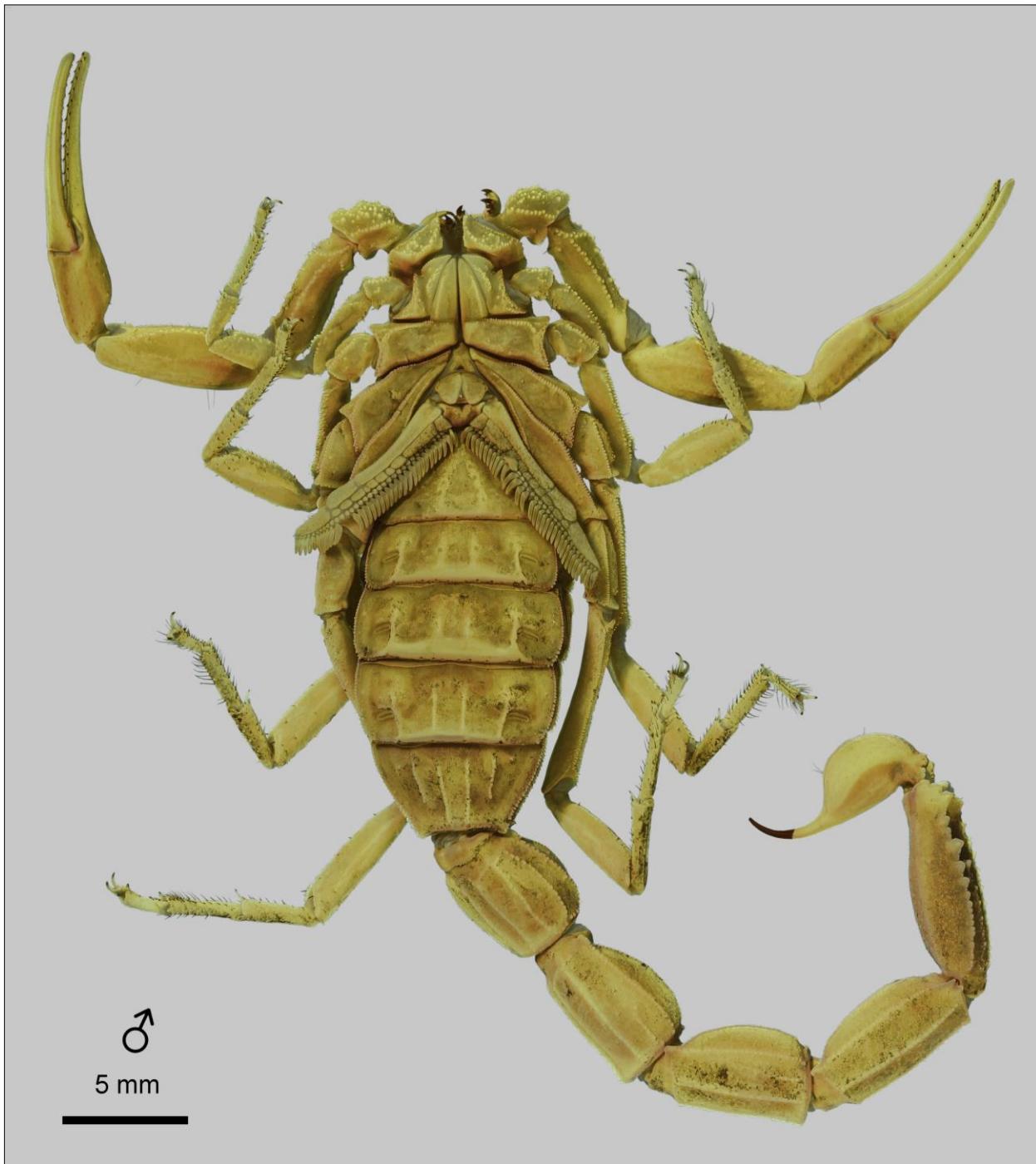
**Figure 60:** *Leiurus hebraeus* (Birula, 1908) stat. n., male. Habitus, dorsal aspect. Israel (NHMB 17a).

(9) metasoma I only barely wider than metasoma II (vs. significantly wider): this was not diagnostic, due to significant overlap of the ratio metasoma I W/ metasoma II W (*L. quinquestriatus* 1.10–1.21, *L. hebraeus* 1.09–1.14);

(10) telson vesicle longer than aculeus (chord length), vesicle width equal to aculeus length (vs. about the same length or shorter, and width < aculeus length):

there was a trend for *L. quinquestriatus* to have a relatively longer aculeus and a shorter, more bulbous vesicle than *L. hebraeus*, but there was significant overlap in the ratio of vesicle L/ telson L (*L. quinquestriatus* 0.48–0.56, *L. hebraeus* 0.52–0.61);

(11) pedipalp movable finger short, less than twice manus length, with 12 denticle subrows (vs. long, slender, > twice manus length, and 13 subrows): this



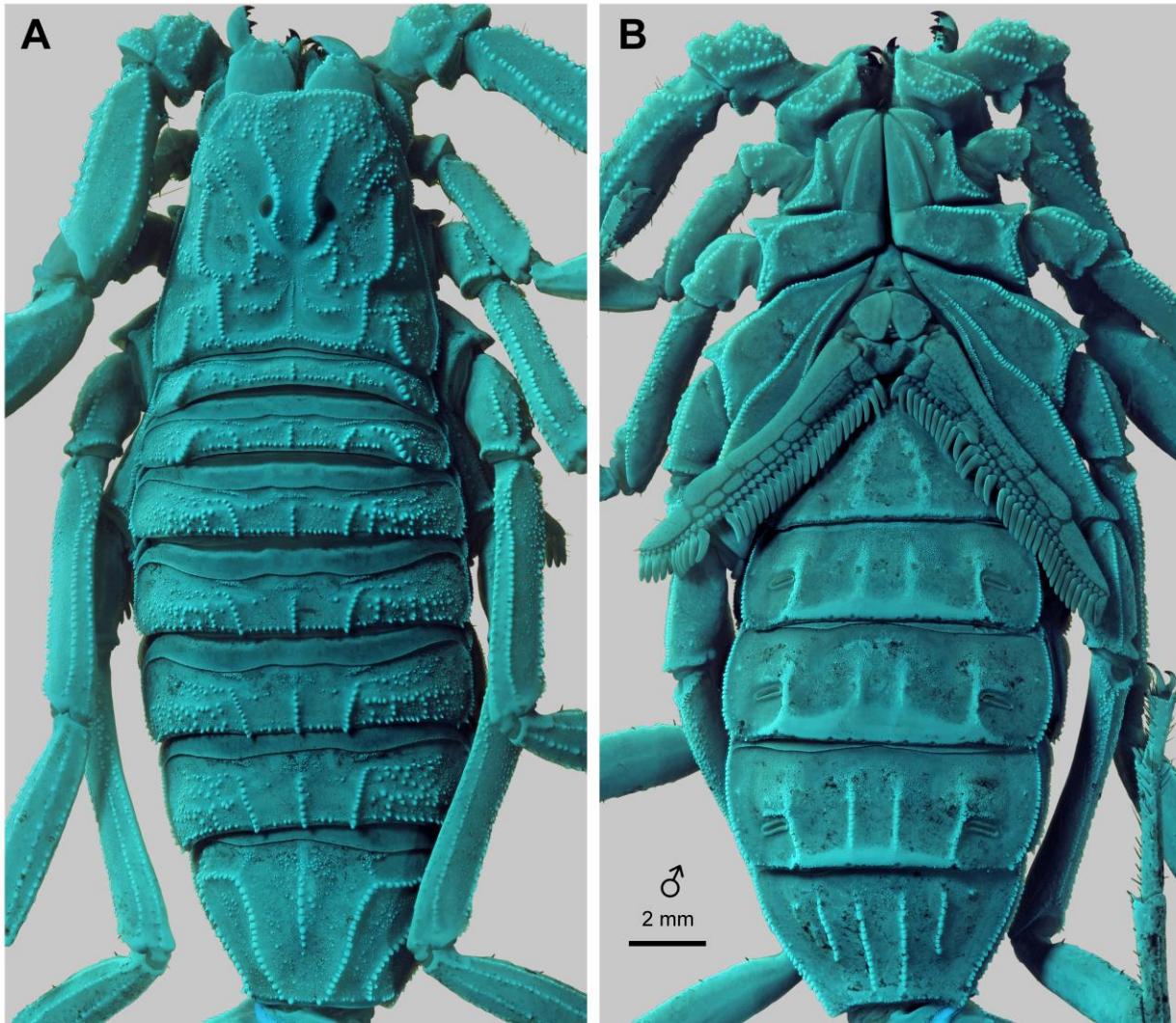
**Figure 61:** *Leiurus hebraeus* (Birula, 1908) stat. n., male. Habitus, ventral aspect. Israel (NHMB 17a).

was not diagnostic, because although the movable finger was on average relatively shorter in *L. hebraeus* vs. *L. quinquestriatus*, there was broad overlap in the ratio movable finger L (chord)/ manus ventral L, and movable fingers had either 12 or 13 subrows in both species.

Levy et al. (1970) accepted characters (5) and (10) of Birula (1908), and proposed 3 additional characters to differentiate *L. q. hebraeus*:

(12) posterior median area of carapace granulated, with paired granule arcs (vs. smooth or sparsely granulated): this difference was confirmed for most specimens, although some *L. quinquestriatus* have weak arcs of fine granulation;

(13) lateral flanks of tergite V with irregular granulation (vs. short rows of granules, resembling carinae): this rather subjective character was quite variable, and



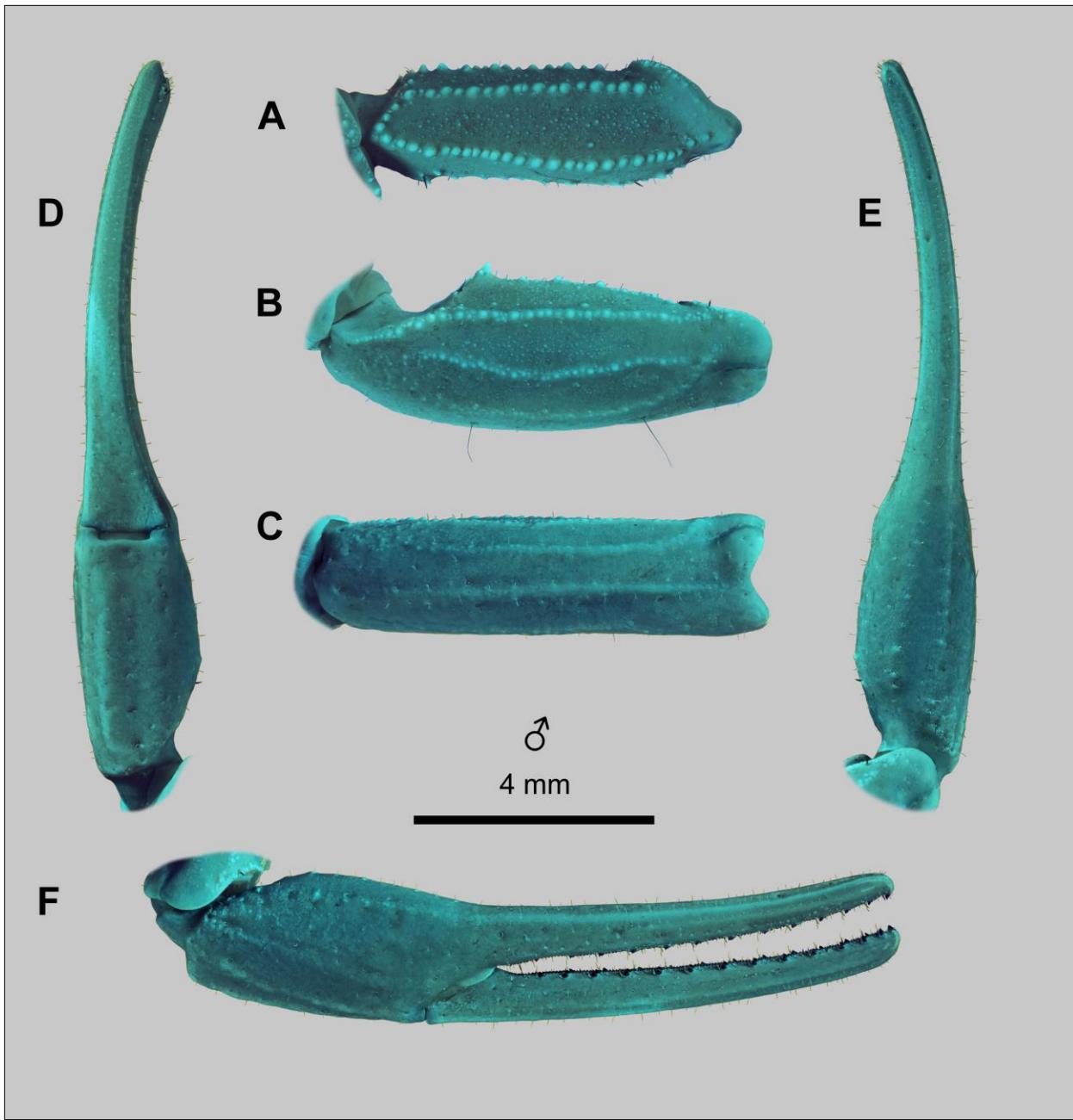
**Figure 62:** *Leiurus hebraeus* (Birula, 1908) stat. n., male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Israel (NHMB 17a).

short granule rows could be discerned or not in both *L. hebraeus* and *L. quinquestriatus*;

(14) weak or obsolete carinae on sternites (slightly more distinct on posterior segments) (vs. distinct, elevated strong carinae on sternites IV–VII): this difference applies to males, however females have weaker carinae and some *L. quinquestriatus* females can have weak to obsolete carination on sternites IV–V.

Thus, from the above list, only characters (6), (14) (males only), and perhaps (12), were potential diagnostic characters separating *L. hebraeus* from *L. quinquestriatus*. Four examined adult and subadult males from southern Sinai resembled *L. quinquestriatus* in having slender pedipalp and metasomal segments, and reduced granulation between the posterior median carinae of the carapace. However, they grouped with the northern populations from Israel and Jordan in other

morphometrics (i.e. lower metasoma I W/ II W, lower pedipalp movable finger L/ manus ventral L, higher vesicle L/ telson L) and meristics (number of denticles on ventromedian carinae of metasoma II–III). Levy et al (1980) also noted that the southern populations of *L. q. hebraeus* had more slender appendages. Partial overlap of characters suggests that there could be two subspecies, *L. q. quinquestriatus* and *L. q. hebraeus*, with a hybrid zone in southern Sinai. However, there appears to be a physical barrier preventing gene flow between these populations because *Leiurus* is excluded from the sandy coastal plain connecting North Africa and the Sinai Peninsula (Levy & Amitai, 1980). Genetic isolation is supported by divergent evolution of distinct polypeptide toxins in their venoms (Smertenko et al., 2001) and different physicochemical profiles of venom proteins (Nascimento et al., 2006). Here, we propose to diagnose



**Figure 63:** *Leiurus hebraeus* (Birula, 1908) stat. n., male. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Chela, external aspect. Israel (NHMB 17a).

the African and Middle Eastern populations as distinct species by a combination of morphological characters. The southern Sinai populations occur in a different habitat (i.e. rocky mountains), and may belong to other undescribed species.

***Leiurus quinquestriatus* (Ehrenberg, 1828)**  
(Figs. 72–82, 87H, 88H, 89H, 90H, 91D, 92J, 93K, 94–95, 96C, 98–99, Tabs. 3A, 5)

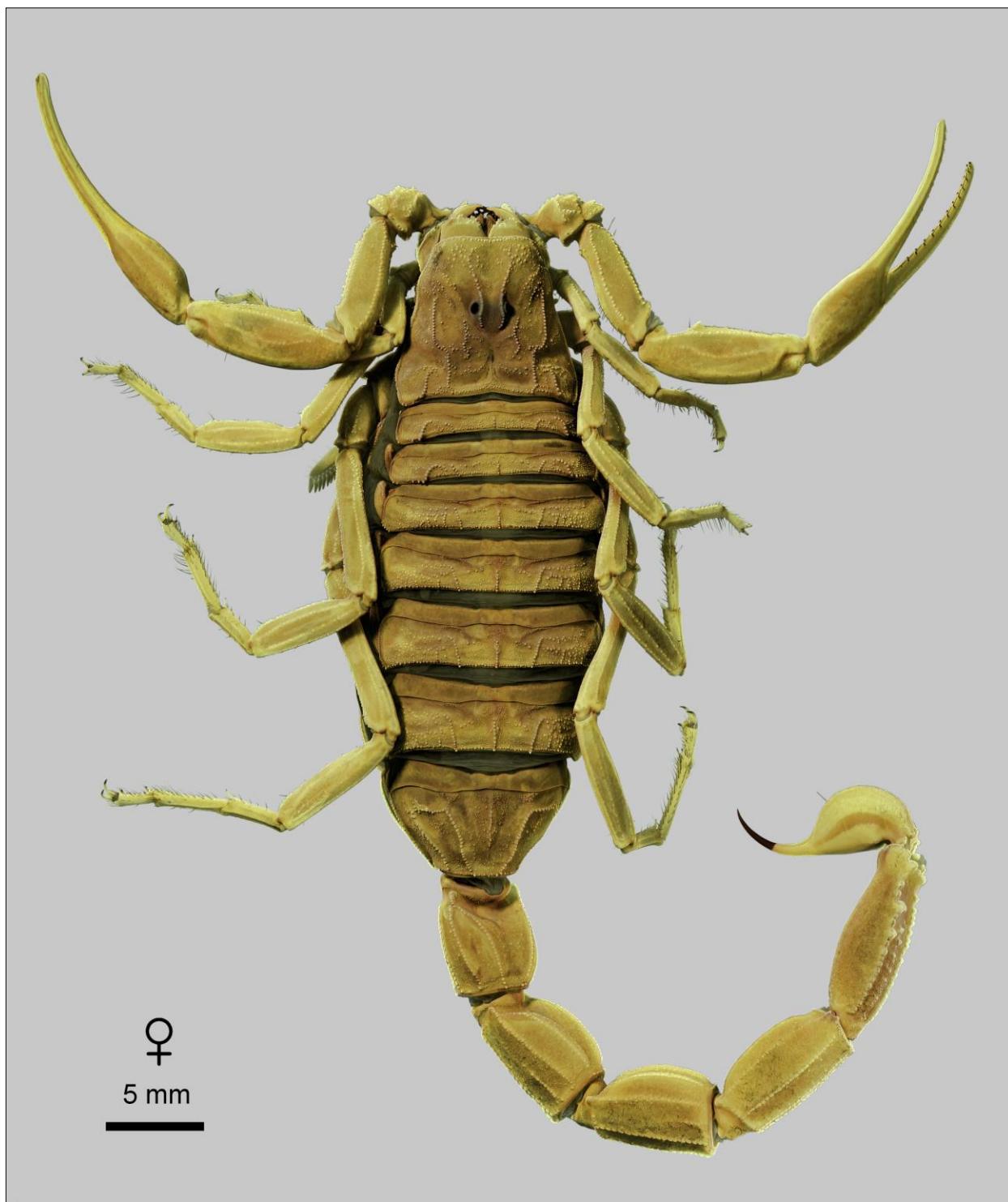
*Androctonus (Leiurus) quinquestriatus* Ehrenberg in Hemprich & Ehrenberg, 1828, pl. I, fig. 5.

#### SYNONYMS

*Androctonus (Liurus) quinquestriatus aculeatus* Ehrenberg in Hemprich & Ehrenberg, 1831.

#### REFERENCES

*Scorpio occitanus*: Audouin in Savigny, 1826: 173, pl. VIII, fig. 1 (in part); Audouin in Savigny, 1827: 410–411, pl. VIII, fig. 1 (in part).



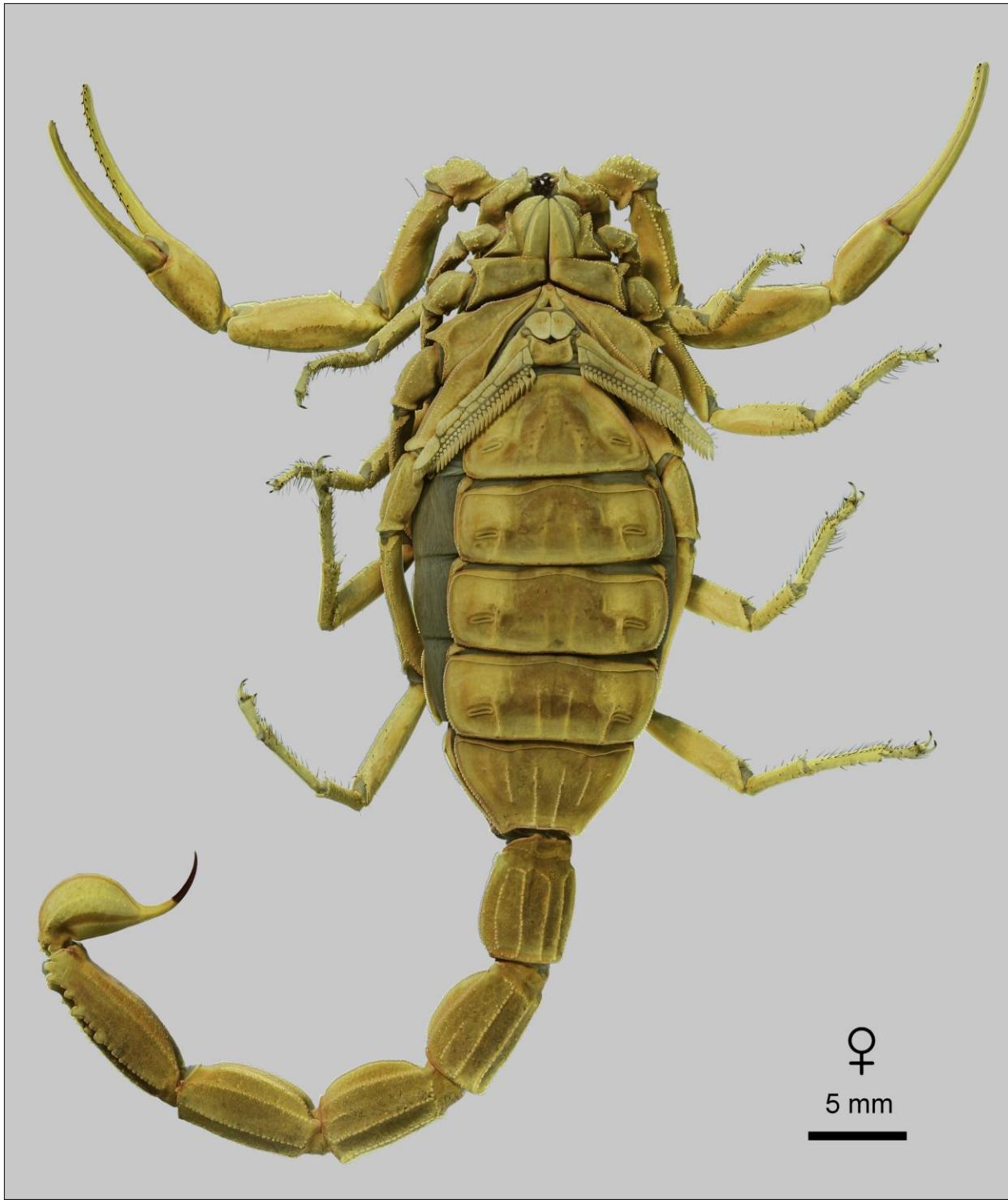
**Figure 64:** *Leiurus hebraeus* (Birula, 1908) stat. n., female. Habitus, dorsal aspect. Israel (NHMB 17a).

*Androctonus (Leiurus) 5-striatus*: Hemprich & Ehrenberg, 1829: 353.

*Androctonus (Liurus) quinquestriatus aculeatus*: Ehrenberg in Hemprich & Ehrenberg, 1831.

*Androctonus quinquestriatus*: C. L. Koch, 1841a: 43–44, pl. CCLXV, fig. 622; C. L. Koch, 1850: 90.

*Androctonus (Liurus) quinquestriatus aculeatus*: Gervais, 1844: 46.



**Figure 65:** *Leiurus hebraeus* (Birula, 1908) stat. n., female. Habitus, ventral aspect. Israel (NHMB 17a).

*Scorpio (Androctonus) quinque-striatus*: Gervais, 1844: 46, pl. XXIV, fig. 2.

*Androctonus troilus*: C. L. Koch, 1850: 90.

*Buthus quinquestriatus*: Koch, 1875: 7; Simon, 1879: 100; Karsch, 1881: 89; Pavesi, 1883: 96; Kraepelin,

1891: 58–60, pl. I, fig. 7, pl. II, fig. 38 (in part); Pocock, 1891: 242–243 (in part); Thorell, 1893: 359–360 (in part); Pocock, 1895: 299; Birula, 1898: 134; Kraepelin, 1899: 27–28 (in part); Kraepelin, 1901: 266–267; Werner, 1902: 598; Tullgren, 1909:



**Figure 66:** *Leiurus hebraeus* (Birula, 1908) stat. n., female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Israel (NHMB 17a).

3; Birula, 1910: 118, 119–120 (in part); Simon, 1910: 70–71, fig. 9; Borelli, 1915: 461; Birula, 1917b: 4–5, figs. 1a, 2; Lampe, 1917: 191; King, 1925: 82; Borelli, 1927: 351–352; Gough & Hirst, 1927: 5, fig. 8; Borelli, 1929: 297; Schenkel, 1932: 381; Táborsky, 1934: 40 (in part); Werner, 1934: 269 (in part); Moriggi, 1941: 84; Abd-el-Wahab, 1957: 111–121, figs. 1–5.

*Buthus (Buthus) quinquestriatus quinquestriatus*: Birula, 1908: 124–129; Birula, 1917a: 223.

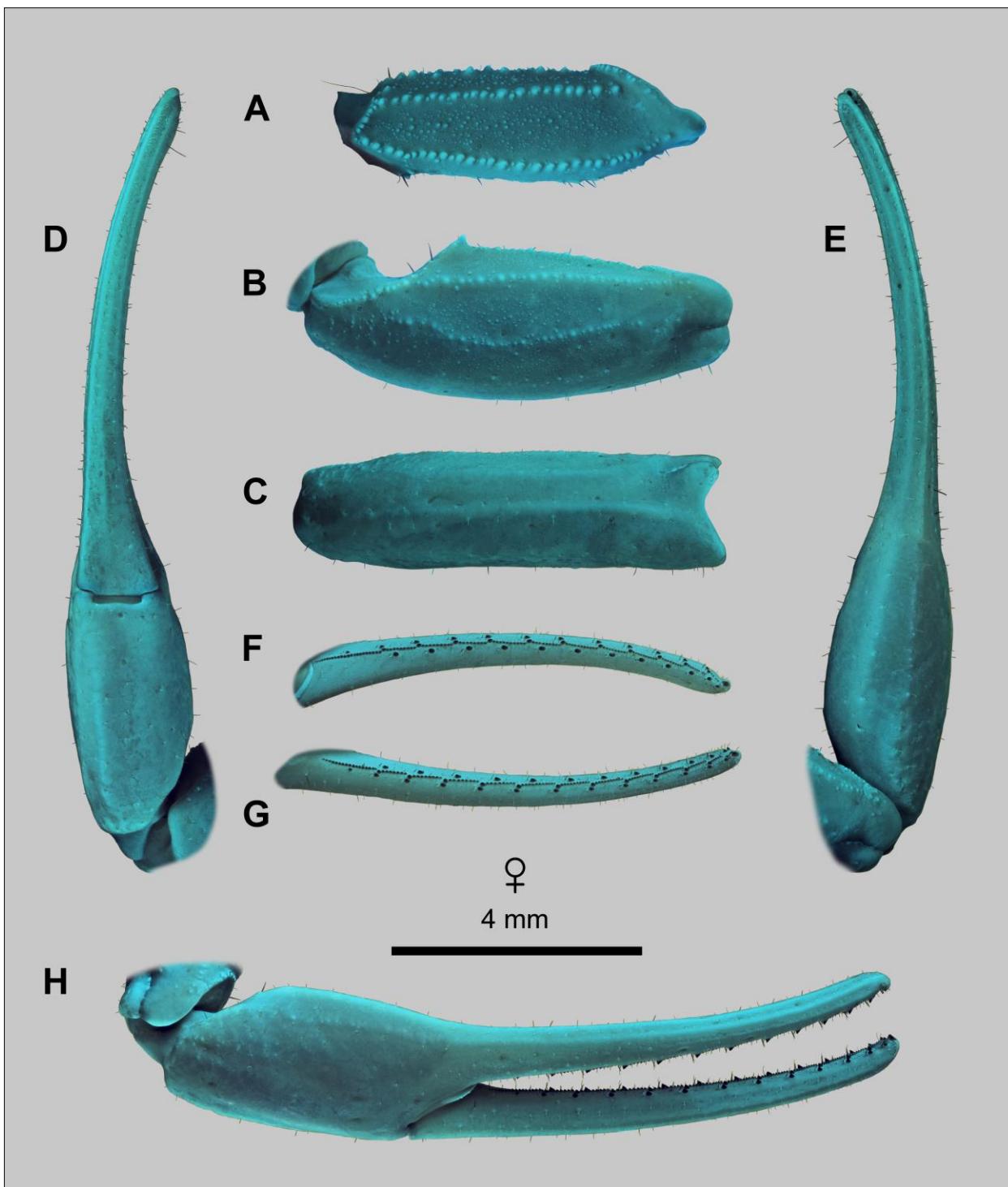
*Buthus quinquestriatus quinquestriatus*: Birula, 1910: 118.

*Buthus (Buthus) quinquestriatus*: Birula, 1917a: 23, 213 (in part); Birula, 1927: 79–80; Whittick, 1941: 43 (in part); Roewer, 1943: 206 (in part).

*Leiurus quinquestriatus*: Vachon, 1949: 83, 88–93 (in part); Vachon, 1950a: 197 (in part); Vachon, 1952:

208–213, 369, 411, 441, 445, 449–452, figs. 639, 678, 686 (in part); Vachon, 1966: 211; Stahnke, 1972: 130 (in part); Probst, 1973: 329; Pérez, 1974: 24 (in part); Lamoral & Reynders, 1975: 509–510 (in part); Levy & Amitai, 1980: 47–48 (in part); Kinzelbach, 1985: map II (in part); El-Hennawy, 1987: 18; El-Hennawy, 1992: 98, 125–126 (in part); Kovařík, 1992: 183; Sissom, 1994: 20–23 (in part); Braunwalder & Fet, 1998: 32; Kovařík, 1998: 112 (in part); Fet & Lowe, 2000: 155 (in part); Lourenço et al. 2006: 98, 100 (in part), fig. 1–3; El-Hennawy, 2005: 76; El-Hennawy, 2008: 118, 121, tab IV; Lourenço & Cloudsley-Thompson, 2009: 126; Yağmur et al., 2009: 2–3 (in part); Kovařík & Ojan-guren, 2013: 158, figs. 836–838.

*Leiurus quinquestriatus quinquestriatus*: Vachon, 1949: 88–93 (in part); Pérez, 1974: 24; Fet & Lowe, 2000:

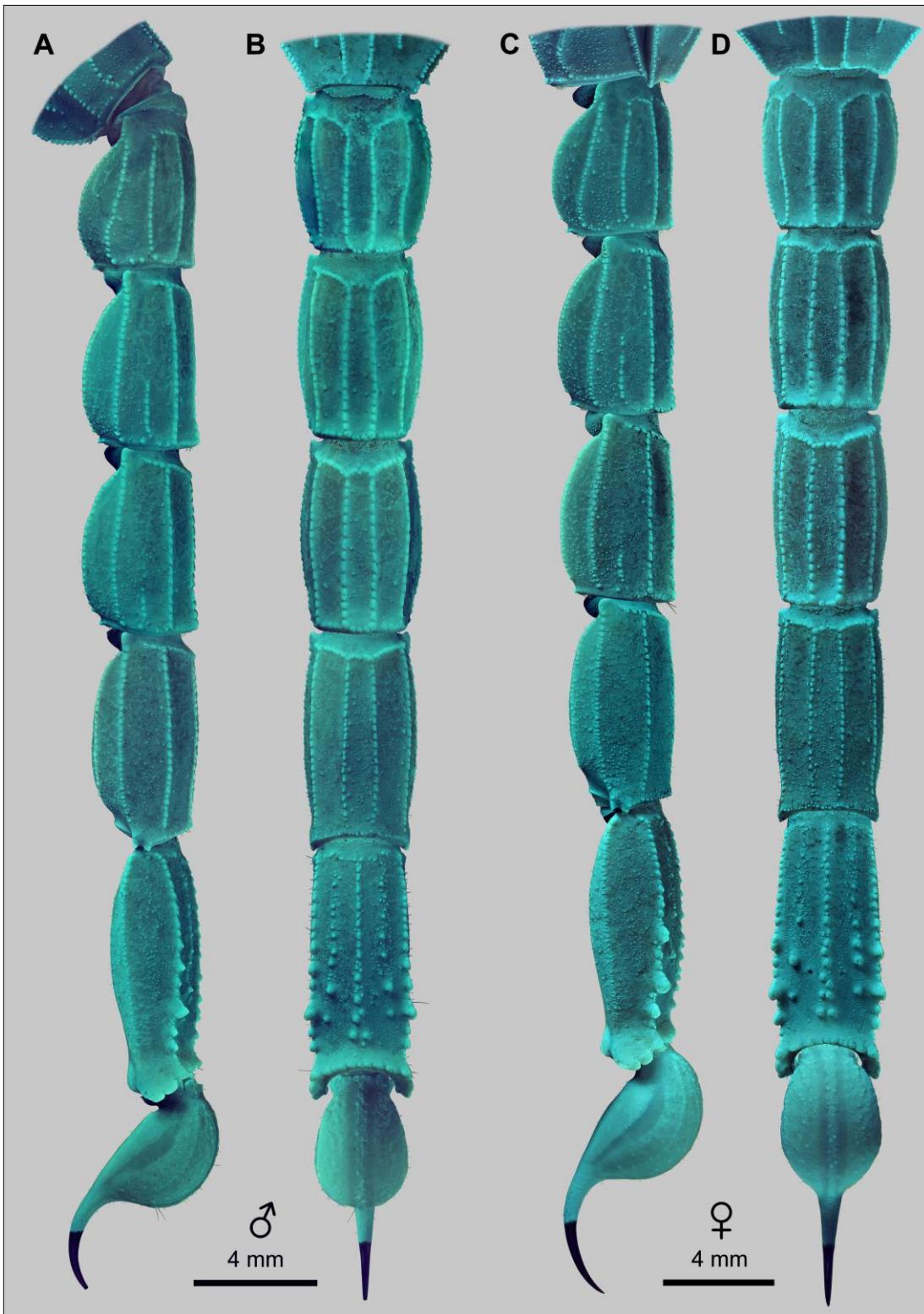


**Figure 67:** *Leiurus hebraeus* (Birula, 1908) stat. n., female. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **G.** Movable finger dentition. **H.** Chela, external aspect. Israel (NHMB 17a).

155; Lourenço et al. 2002: 641; Lourenço et al. 2006: 97; Yağmur et al., 2009: 12.  
*Androctonus (Leiurus) quinquestriatus*: Braunwalder & Fet, 1998: 33.

NOTE: The above synonymy and reference listing omits records from Libya, Algeria and the southern Sinai, as we did not revise the status of those populations.

TYPE MATERIAL. 8 original syntypes (2 ♂, 2 ♀, 4



**Figure 68:** *Leiurus hebraeus* (Birula, 1908) stat. n.. Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Male and female, Israel (NHMB 17a).



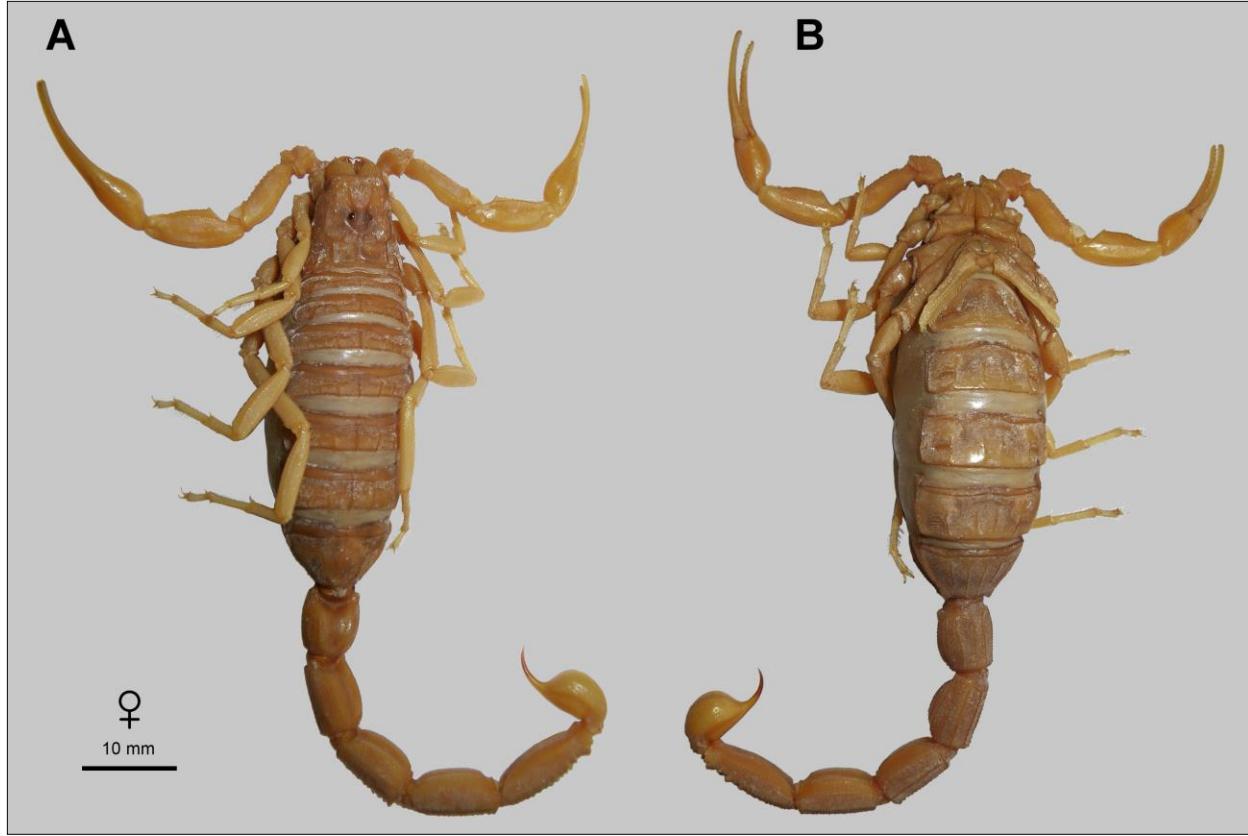
**Figure 69:** *Leiurus hebraeus* (Birula, 1908) stat. n., female. Tarsi. **A–D.** Left telotarsus and distal basitarsus, ventral aspect. **A.** Leg I. **B.** Leg II. **C.** Leg III. **D.** Leg IV. **E.** Right basitarsus III retrolateral aspect. **A–D:** female, Israel (NHMB 17a). **E:** female, Jericho, Israel (NHMB 17I-a).

juv): **Egypt**, Sinai; Arabian Desert; **Sudan**, Dongola (= Dunqulah, Nubia); 1823–1824, leg. F.W. Hemprich & C.G. Ehrenberg (ZMHB No. 140) (examined, Fig. 82).

**OTHER MATERIAL EXAMINED.** **Egypt:** 2 juvs, Lish, 29°33'N 31°08'E, 54 m a.s.l., leg. A. Hrdlička (USNM); 1 ♂, 1 ♀, Kena (= Qena), 26°09.77'N 32°42.69'E (NHMB 17g); 2 ♀, Girga, 26°19.74'N 31°52.8'E (NHMB 17h); 2 ♂, 2 ♀, Kharga Oasis, 25°15'N 30°35'E (NHMB 17i); 2 ♂, 2 ♀, 1 juv ♀, Cairo, 30°03'N 31°15'E, leg. Zschokke (NHMB 17c); 1 ♂, 5 ♀, 2 juvs ♂, 2 juvs ♀, Cairo environs, 30°03'N 31°15'E, leg. E. Graeter (NHMB 17d); 3 ♀ (NHMB 17f); 1 ♂, 3 ♀, 2007 (GL). **Sudan:** 1 ♂, 4 ♀, Malha, West Darfur, 15°04.63'N 26°09'E, 900 m a.s.l., 20.I.1986, leg. H. Dumont (MEB 364); 2 ♂, 7 ♀, 12 juvs, Sabaloka Mt., ca 16°20'N 32°30'E, 24.X.–14.XI.2011, leg. P. Pokorný (FKCP).

**DIAGNOSIS (adults).** Medium to large *Leiurus*, 69–90 mm in length, carapace L 7.8–11.0 mm, color uniformly yellow or with variable fuscous markings on carapace and tergites; metasoma V yellow, or darkened except for

posterior end; carapace with area between anterior median carinae lacking dark pigment, smooth or slightly roughened, with few sparse granules, area between posterior median carinae flat or with shallow median depression, lateral arcs of granules either very fine or absent; medial intercarinal surfaces of tergites II–III densely shagreened with fine granules, granulation weaker and sparser in females (Figs. 93K, 94); posterior margin of coxa III smooth, or with scattered fine granules; metasoma moderately slender, metasoma II L/W 1.51–1.96, metasoma III L/W 1.67–2.22, metasoma IV L/W 2.07–2.63; ventromedian carinae of metasoma II and III with 19–26 denticles (90/92 carinae); metasoma V with enlarged subtriangular or lobate denticles on ventrolateral carinae; pedipalps slender, patella L/W ♂ 3.17–3.85, ♀ 2.88–3.61; leg III patella L/D 3.24–4.38; pectine teeth ♂ 30–39, ♀ 26–38; pectines medium sized, pectine L/ carapace L ♂ 1.11–1.40, ♀ 0.89–1.38, mid-pectine sensillar margin L/ metasoma I W ♂ 0.142–0.184, ♀ 0.078–0.156; basal 1–3 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece densely sha-



**Figure 70:** *Leiurus hebraeus* (Birula, 1908) stat. n., lectotype female, designated here (ZISP 578). Habitus. **A.** Dorsal aspect. **B.** Ventral aspect. Wadi 'Arrud, Jordan.

greened, usually with more coarse medial granules in males; leg III basitarsus with 8–16 retrosuperior setae; pedipalp chela fixed finger with trichobothrium usually *db* distal to *est*; area of sternite VII between median carinae with dense, fine granulation or shagreened anteriorly, more heavily in males; sternite carination: *males and females*: sternite III with median carinae strong, densely granular or shagreened, sternites IV–V with lateral carinae strong, median carinae moderate.

#### MEASUREMENTS.

**Male syntype (Fig. 82C, subadult) (mm).** Total L 63.0; metasoma + telson L 41.5; carapace L 6.6, W 7.8; metasomal segments (L/ W) I 5.4/ 4.2, II 6.3/ 3.6, III 6.3 / 3.5, IV 7.3 / 3.2, V 8.6 / 3.0; telson L 7.6; pedipalp chela L 13.1, manus W 1.9, movable finger L 8.9; pedipalp femur L 7.2, W 1.7, patella L 8.0, W 2.2; pectine L 8.5, mid-pectine sensillar margin L 0.85; pectine teeth 30–30. **Adult female syntype (Fig. 82A) (mm).** Total L 90.0; metasoma + telson L 56.7; carapace L 10.3, W 11.6; metasomal segments (L/ W) I 7.4/ 5.8, II 8.5/ 5.3, III 8.6 / 5.2, IV 10.1 / 4.7, V 11.4 / 4.4; telson L 10.7; pedipalp chela L 18.7, manus W 3.3, movable finger L 13.5; pedipalp femur L 10.1, W 2.8, patella L

10.8, W 3.5; pectine L 9.7, mid-pectine sensillar margin L 0.90; pectine teeth 30.

**Male, Kena, Egypt (NHMB 17g) (mm).** Total L 74.00; metasoma + telson L 48.00; carapace L 8.28, W 8.57, carapace preocular L 3.69; metasomal segments (L/ D /W) I 6.31/ 4.30/ 5.15, II 7.50/ 4.57/ 4.55, III 7.71/ 3.78/ 4.28, IV 8.62/ 3.41/ 3.87, V 9.28/ 3.22/ 3.68; telson L 7.62; vesicle L 3.76, D 3.04, W 3.04; pedipalp chela L 15.60, manus ventral L 4.49, manus W 2.35, manus D 2.57, fixed finger L 9.90, movable finger L 11.40; pedipalp femur L 8.22, W 2.31, patella L 9.50, W 2.81; pectine L 9.98, mid-pectine sensillar margin L 0.898; leg III femur L 8.77; leg III patella L 7.59, D 2.00; chela *db*–*est* distance (left/ right) 0.958/ 0.917; pectine teeth (left/ right) 35/ 35.

**Female, Kena, Egypt (NHMB 17g) (mm).** Total L 80.00; metasoma + telson L 53.00; carapace L 9.46, W 10.80, carapace preocular L 4.44; metasomal segments (L/ D /W) I 6.62/ 5.18/ 5.75, II 7.96/ 4.64/ 5.04, III 8.16/ 4.49/ 4.79, IV 8.99/ 3.93/ 4.35, V 10.11/ 3.59/ 4.34; telson L 9.33; vesicle L 4.63, D 3.51, W 3.62; pedipalp chela L 17.03, manus ventral L 5.14, manus W 2.63, manus D 3.14, fixed finger L 9.99, movable finger L 12.14; pedipalp femur L 8.88, W 2.75, patella L 10.12, W 3.44;



**Figure 71:** *Leurus hebraeus* (Birula, 1908) stat. n., lectotype female and four paralectotypes, designated here (ZISP 578). Wadi 'Arrud, Jordan. Label text in Russian: "Det. A. Birula, 5 ex. Coll. 25.IV.1897, Petro-Arabia, Wadi-Arrud, Southern shore of the Dead Sea, Davyдов."

pectine L 9.53, mid-pectine sensillar margin L 0.653; leg III femur L 9.71; leg III patella L 8.29, D 2.17; chela *db-est* distance (left/ right) 0.917/ 1.125; pectine teeth (left/ right) 28/ 28.

DISTRIBUTION. Egypt, Sudan.

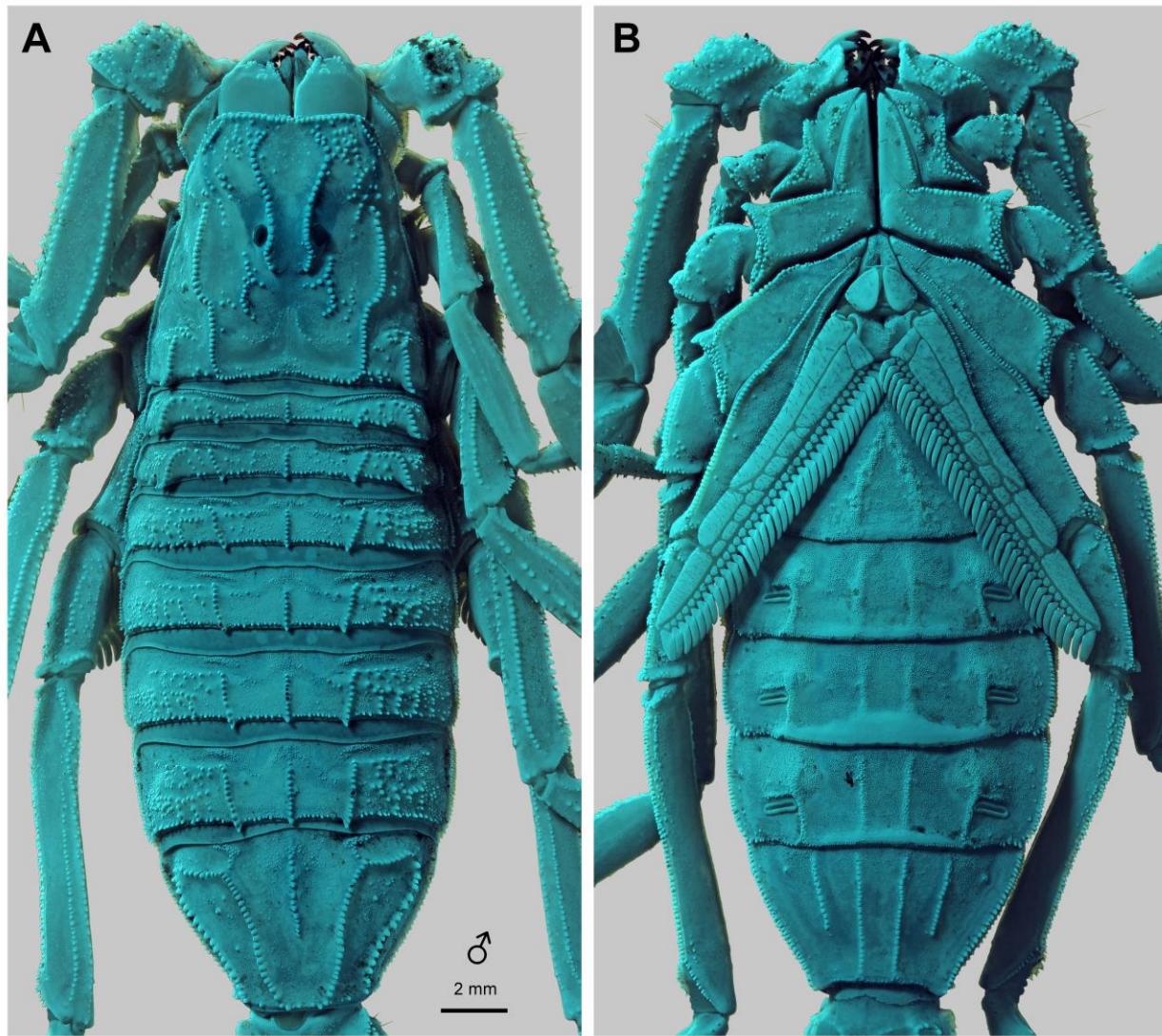
REMARKS. The syntypes include assorted material from the Sinai, the Nile Valley in Egypt and Sudan, and



**Figure 72:** *Leiurus quinquestriatus* (Ehrenberg, 1828), male. Habitus, dorsal aspect. Kena, Egypt (NHMB 17g).



**Figure 73:** *Leiurus quinquestriatus* (Ehrenberg, 1828), male. Habitus, ventral aspect. Kena, Egypt (NHMB 17g).



**Figure 74:** *Leiurus quinquestriatus* (Ehrenberg, 1828), male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Kena, Egypt (NHMB 17g).

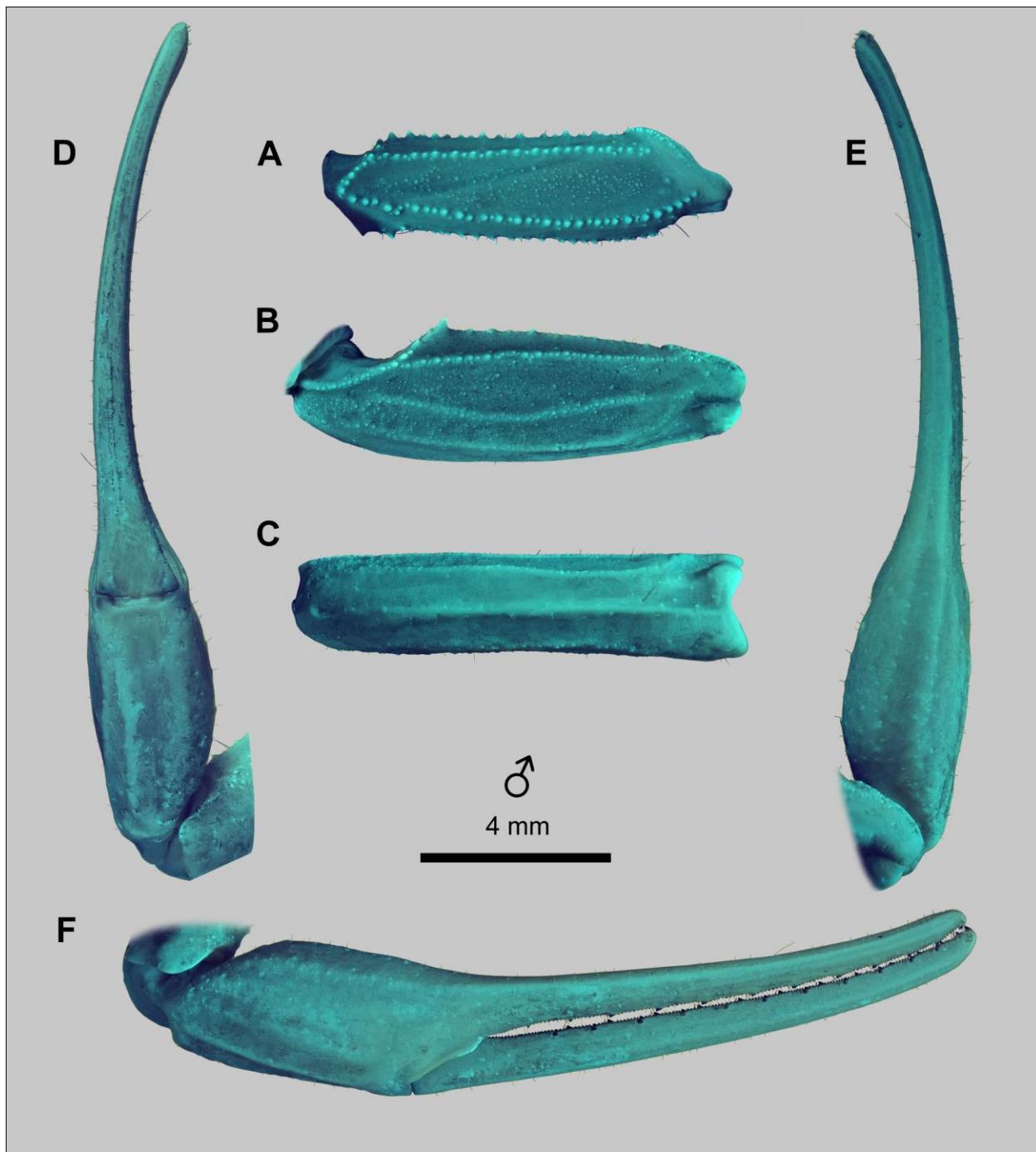
the desert region of Egypt east of the Nile. These could represent more than one species if the populations in the Sinai are distinct from those of the Nile Valley. However, since individual specimens do not have locality labels, they cannot be referred to specific populations. We refrain from designating a lectotype until the taxonomic status of these populations is clarified by further study.

***Leiurus abdullahbayrami*** Yağmur, Koç et Kunt, 2009  
(Figs. 83–84, 87A, 88A, 89A, 90A, 91H, 92A, 94F, 95, 98–99, Tab. 3A)

*Leiurus abdullahbayrami* Yağmur, Koç & Kunt, 2009: 2–16, figs. 1–22, tab. 1–2.

#### REFERENCES

- Buthus quinquestriatus*: Simon, 1892: 83 (?).  
*Leiurus quinquestriatus*: Kinzelbach, 1984: 98, Fig 2; Kinzelbach, 1985: map II (in part); Crucitti & Cicuzza, 2000: 283, 287, fig. 15; Crucitti & Vignoli, 2002: 451–452.  
*Leiurus quinquestriatus voelschowi*: Kovařík, 1996: 54.  
*Leiurus abdullahbayrami*: Khalil & Yağmur, 2010: 3–5; Ozkan et al., 2011: 414–419, fig. 2; İnanç & Arikán, 2014: 38.
- TYPE MATERIAL. Holotype adult ♂, Turkey, hill 1 km E of Sarısalıkm Village, 37°05'46.5"N 37°16'51.3"E, 1029 m a.s.l., 14.VIII.2004, leg. E.A. Yağmur (MTAS/But:0908-01).



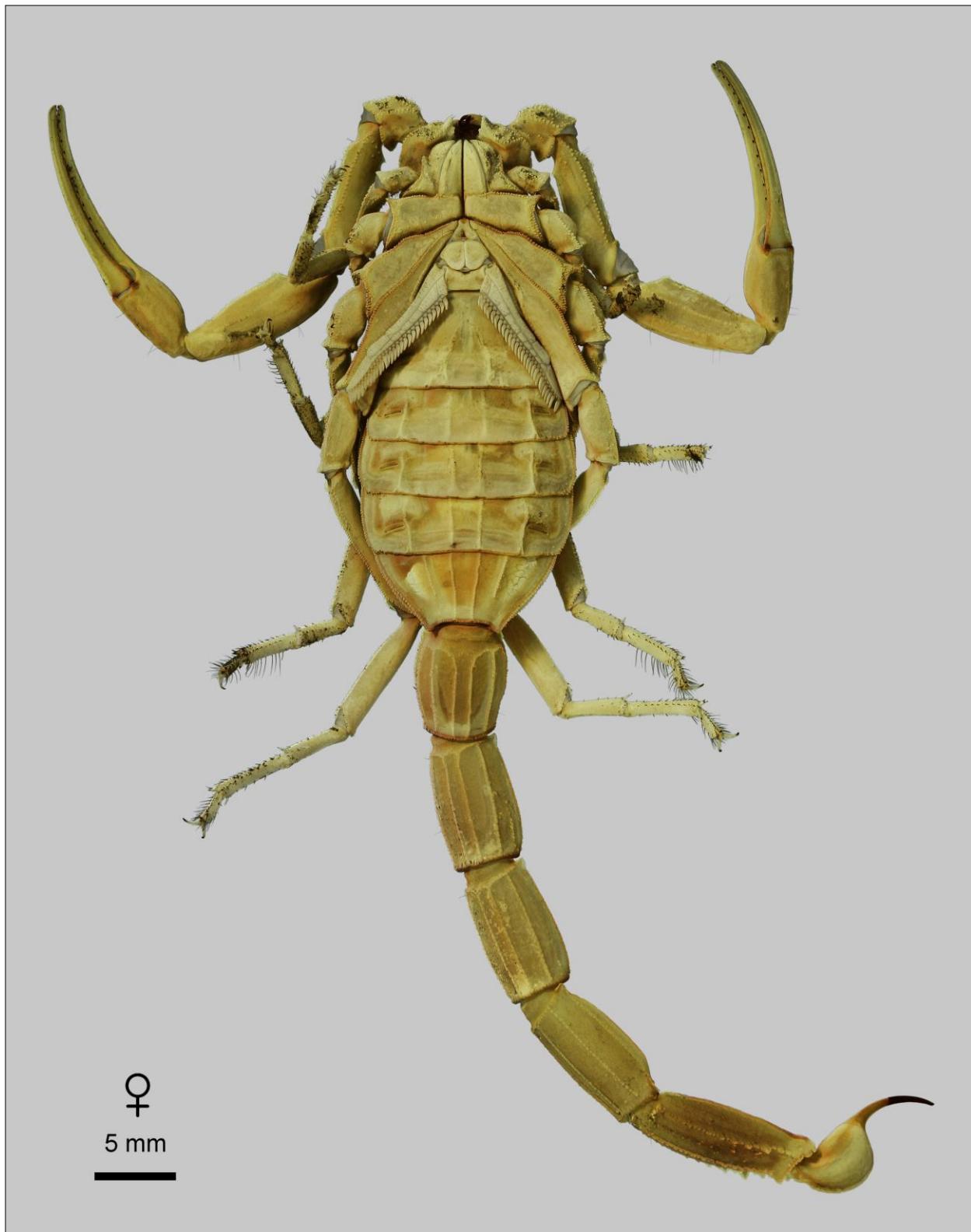
**Figure 75:** *Leiurus quinquestriatus* (Ehrenberg, 1828), male. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Chela, external aspect. Kena, Egypt (NHMB 17g).

OTHER MATERIAL EXAMINED. **Syria:** 1 ♀, Aleppo, 36°06'N, 37°10.8'E, leg. E. Graeter (NHMB 17e); 1♀, 1♂, Al-Hasakah Province, eastern Abd Al-Aziz Mountain, 40 km SW Al-Hasakah, 12.VII.2009, 36°23'20"N 40°22'01"E, 674 m a.s.l., leg. N. Khalil (MTAS); 1♀, Homs Province, Al-Mukharram Region,

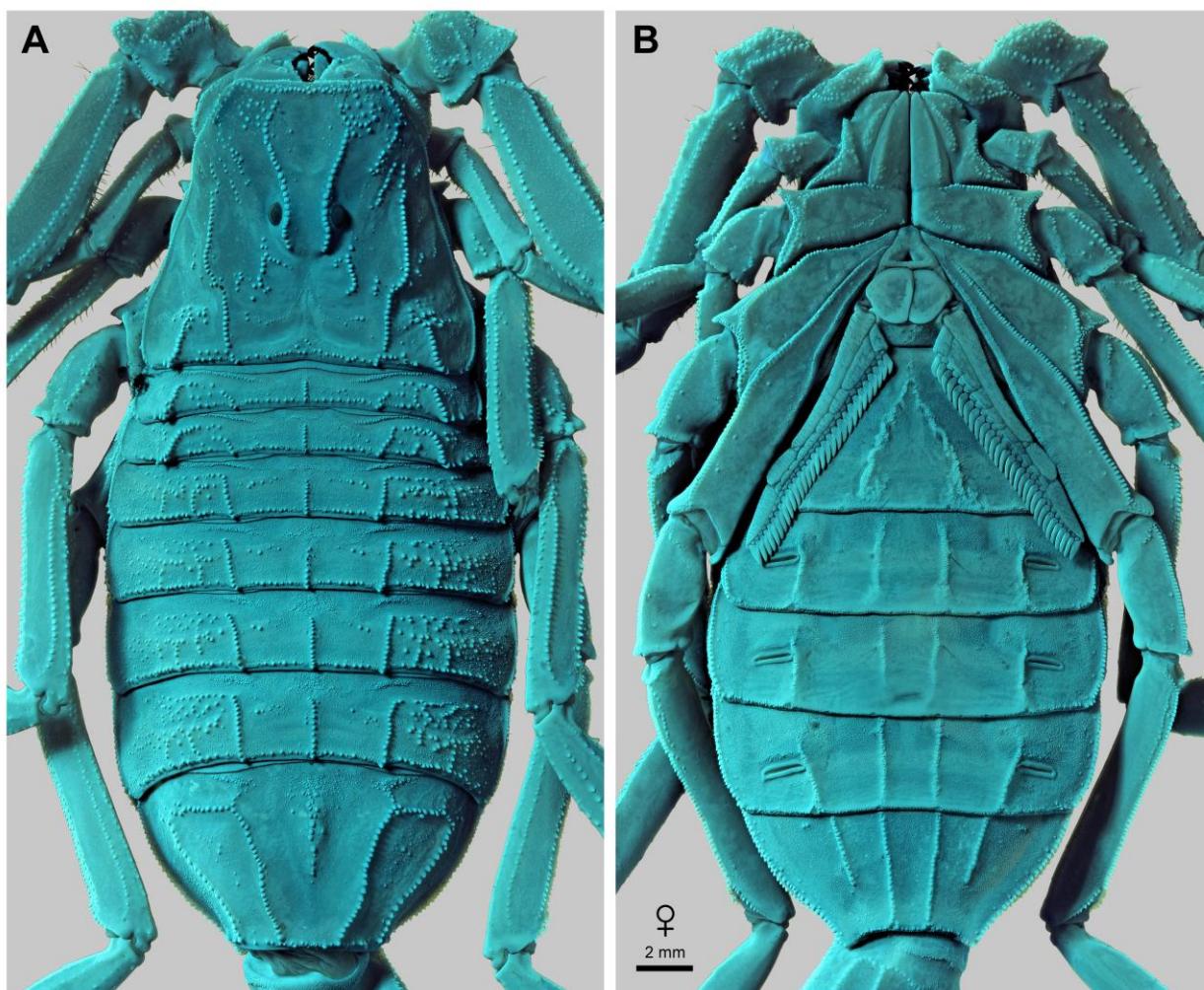
Al-Sankari Village, 4.VII.2009, 34°48'46"N 37°09'32"E, 655 m a.s.l., leg. N. Khalil (MTAS). **Turkey:** 1 ♂, 1 km S of Tanır Village, Nizip District, Gaziantep Province, 37°06'34"N 37°49'57"E, 529 m a.s.l., 30.V.2003, leg. E.A. Yağmur & S. Kesmezoğlu (MTAS); 1 ♀, hill E of Sarisalkım Village, Şahinbey District, Gaziantep Prov-



**Figure 76:** *Leiurus quinquestriatus* (Ehrenberg, 1828), female. Habitus, dorsal aspect. Kena, Egypt (NHMB 17g).



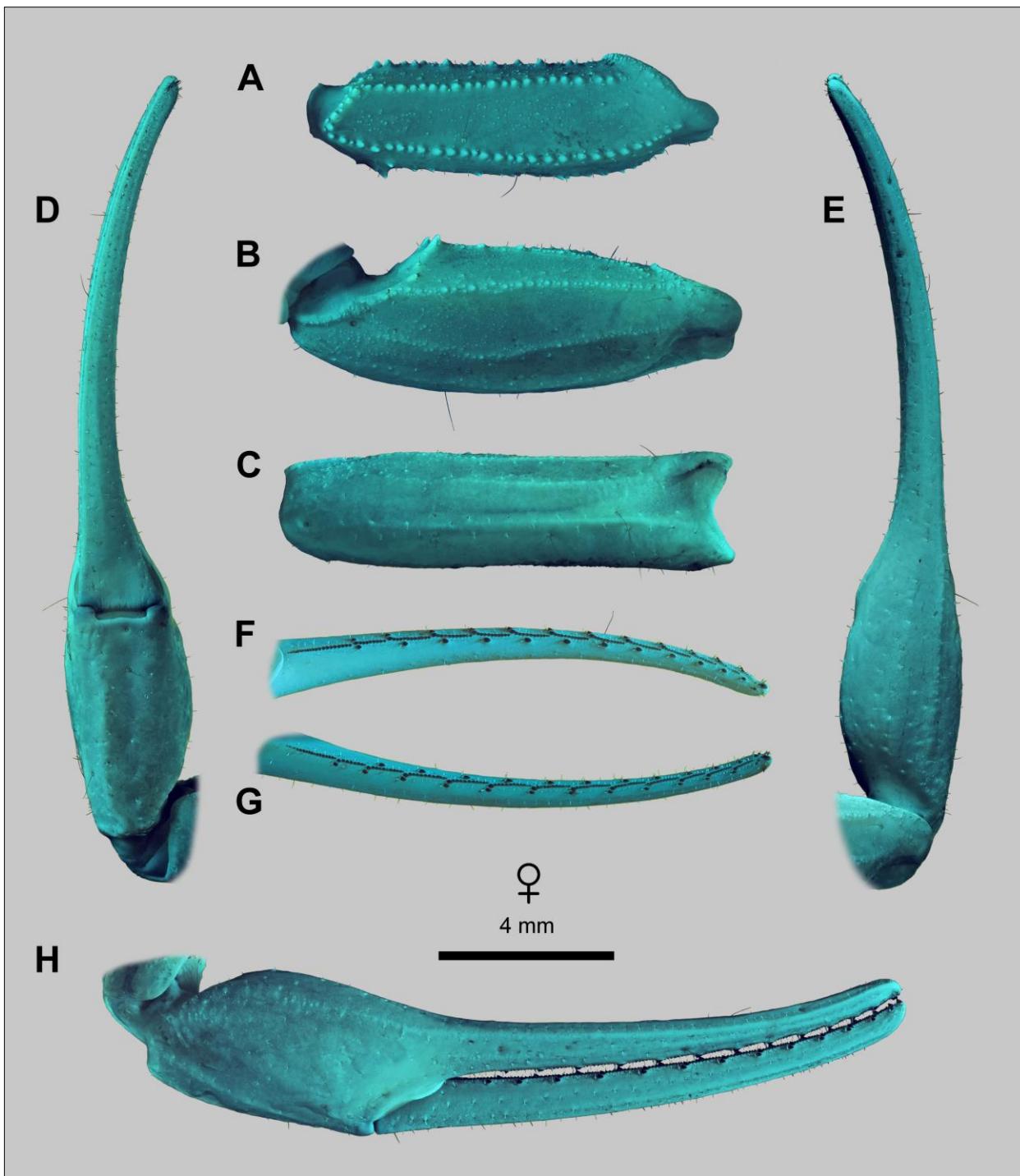
**Figure 77:** *Leiurus quinquestriatus* (Ehrenberg, 1828), female. Habitus, ventral aspect. Kena, Egypt (NHMB 17g).



**Figure 78:** *Leiurus quinquestriatus* (Ehrenberg, 1828), female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Kena, Egypt (NHMB 17g).

ince, 37°05'47"N 37°16'51"E, 1024 m a.s.l., 30.VII. 2003, leg. E.A. Yağmur (MTAS); 1 ♂, 2 ♀, Şirvan Hill, Sarısaltık Village, Şahinbey District, Gaziantep Province, 37°05'27"N 37°15'52"E, 1076 m a.s.l., 6.IX.2003, leg. E.A. Yağmur (MTAS); 1 ♀, hill E of Sarısaltık Village, Şahinbey District, Gaziantep Province, 37°05'47"N 37°16'51"E, 1024 m a.s.l., 14.VIII.2004, leg. E.A. Yağmur (MTAS); 1 ♀, 1 km S of Kayacık Village fork in road, Oğuzeli District, Gaziantep Province, 36°50'41"N 37°34'29"E, 619 m a.s.l., 11.IX. 2004, leg. E.A. Yağmur & M. Yalçın (MTAS); 1 ♂, 1 km S of Kızılhisar Village, Şahinbey District, Gaziantep Province, 36°59'52"N 37°18'17"E, 900 m a.s.l., 14.IX.2004, leg. E.A. Yağmur & C. Toprak (MTAS); 1 ♂, Köksalan Village, Şehitkamil District, Gaziantep Province, 37°15'44"N 37°14'32"E, 956 m a.s.l., 9.IV.2005, leg. E.A. Yağmur, M. Yalçın & F. Değirmenci (MTAS); 1 ♀, 2 km N of Sarıkaya Village, Şahinbey District, Gaziantep Province, 37°07'06"N 37°03'07"E, 1178 m a.s.l., 7.V.2005, leg.

E.A. Yağmur, M. Yalçın & F. Değirmenci (MTAS); 1 ♀, 3 km SW of Hasancalı Village, Musabeyli District, Kilis Province, 36°52'47.2"N 36°47'42.4"E, 755 m a.s.l., 27.IV.2006, leg. E.A. Yağmur & M. Özkörük (MTAS); 1 ♂, 1 ♀, 1 km E of Küplüce Village, Central District, Kilis Province, 36°44'92"N 37°15'19"E, 624 m a.s.l., 29.IV.2006, leg. E.A. Yağmur & M. Yalçın (MTAS); 1 ♂, 1 km NE of Çaybaşı Village, Oğuzeli District, Gaziantep Province, 36°47'47"N 37°35'15"E, 546 m a.s.l., 25.VI.2006, leg. E.A. Yağmur & M. Özkörük (MTAS); 1 ♀, 1 km W of Aydınluk Village fork in road, Central District, Adıyaman Province, 37°46'08"E, 38°20'54"N 11.VIII.2006, leg. E.A. Yağmur & A. Avcı (MTAS); 1 ♂, 1 ♂, 4 km E of Kaşlıca Village, Tut District, Adıyaman Province, 37°48'34"N 37°59'21"E, 1183 m a.s.l., 8.VI.2007, leg. E. A. Yağmur & G. Çalışır (MTAS); 1 ♂, 1 km S of Eski Sarkaya Village, Sehitkamil District, Gaziantep Province, 37°12.733'N 37°7.75'E, 1000 m a.s.l., 23.VI.2007, leg. E.A. Yağmur &



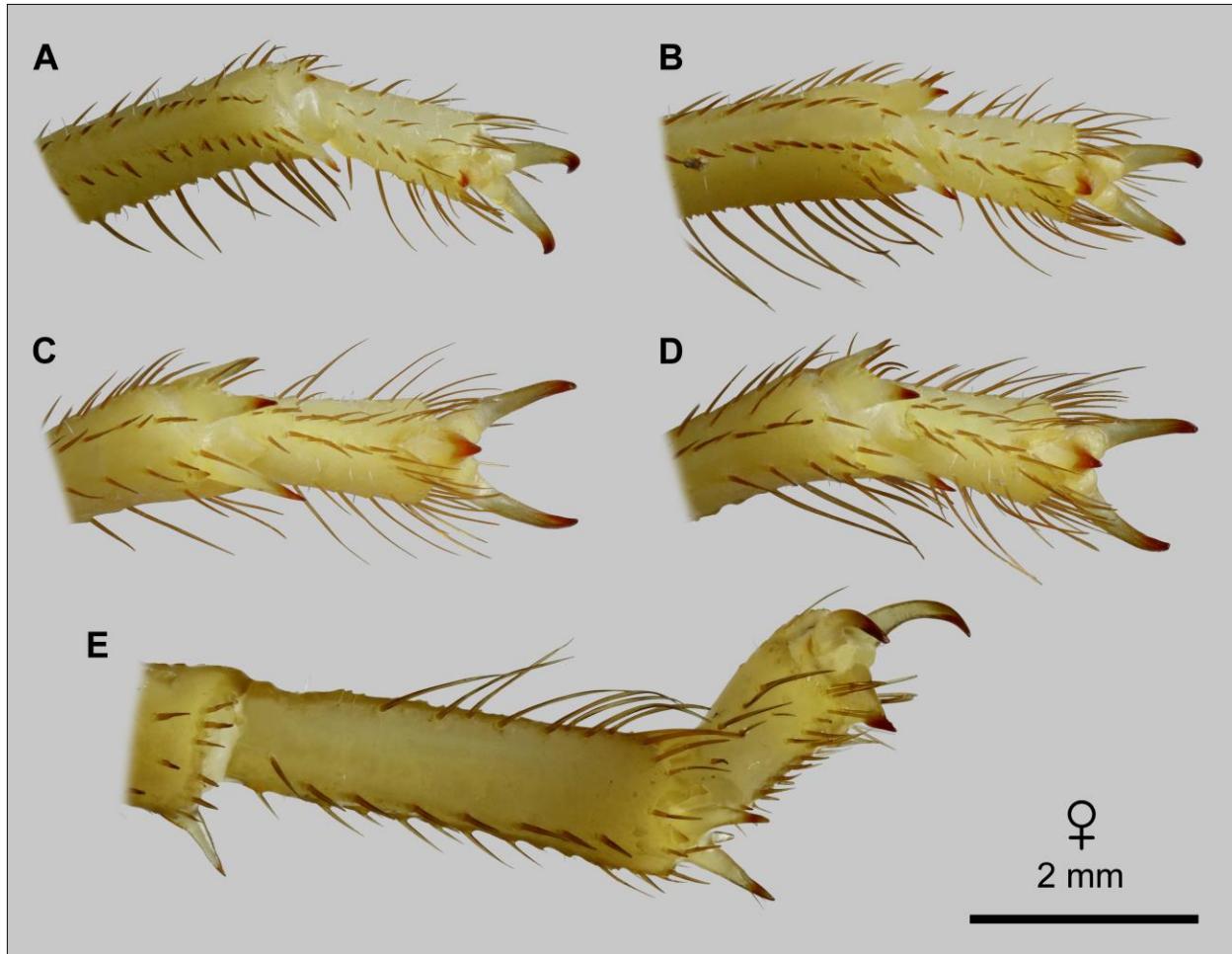
**Figure 79:** *Leiurus quinquestriatus* (Ehrenberg, 1828), female. Right pedipalp. **A.** Femur, dorsal aspect. **B.** Patella, dorsal aspect. **C.** Patella, external aspect. **D.** Chela, ventral aspect. **E.** Chela, dorsal aspect. **F.** Fixed finger dentition. **G.** Movable finger dentition. **H.** Chela, external aspect. Kena, Egypt (NHMB 17g).

M. Yalçın (GL); 1 ♀, 0.5 km N of Hörük Village fork in road, Pazarcık District, Kahramanmaraş Province, 37°30'10"N 37°33'46"E, 795 m a.s.l., 24.VI.2007, leg. E.A.Yağmur & M. Yalçın(MTAS); 1 ♀, Çörten Village, Central District, Kilis Province, 36°46'35"N, 37°18'00",

27.VI.2007, E.M.Z. Yıldız (MTAS); 1 ♂, 2 km E of Yamaçoba Village, Şehitkamil District, Gaziantep Province, 37°10'27.3"N 37°05'33.1"E, 1099 m a.s.l., 1.VII.2007, leg. E.A. Yağmur & M. Yalçın (MTAS); 1 ♂, Konakdere Hamlet, Gökçay Village, Central District,



**Figure 80:** *Leiurus quinquestriatus* (Ehrenberg, 1828). Metasoma. **A.** Male, lateral aspect. **B.** Male, ventral aspect. **C.** Female, lateral aspect. **D.** Female, ventral aspect. Kena, Egypt (NHMB 17g).

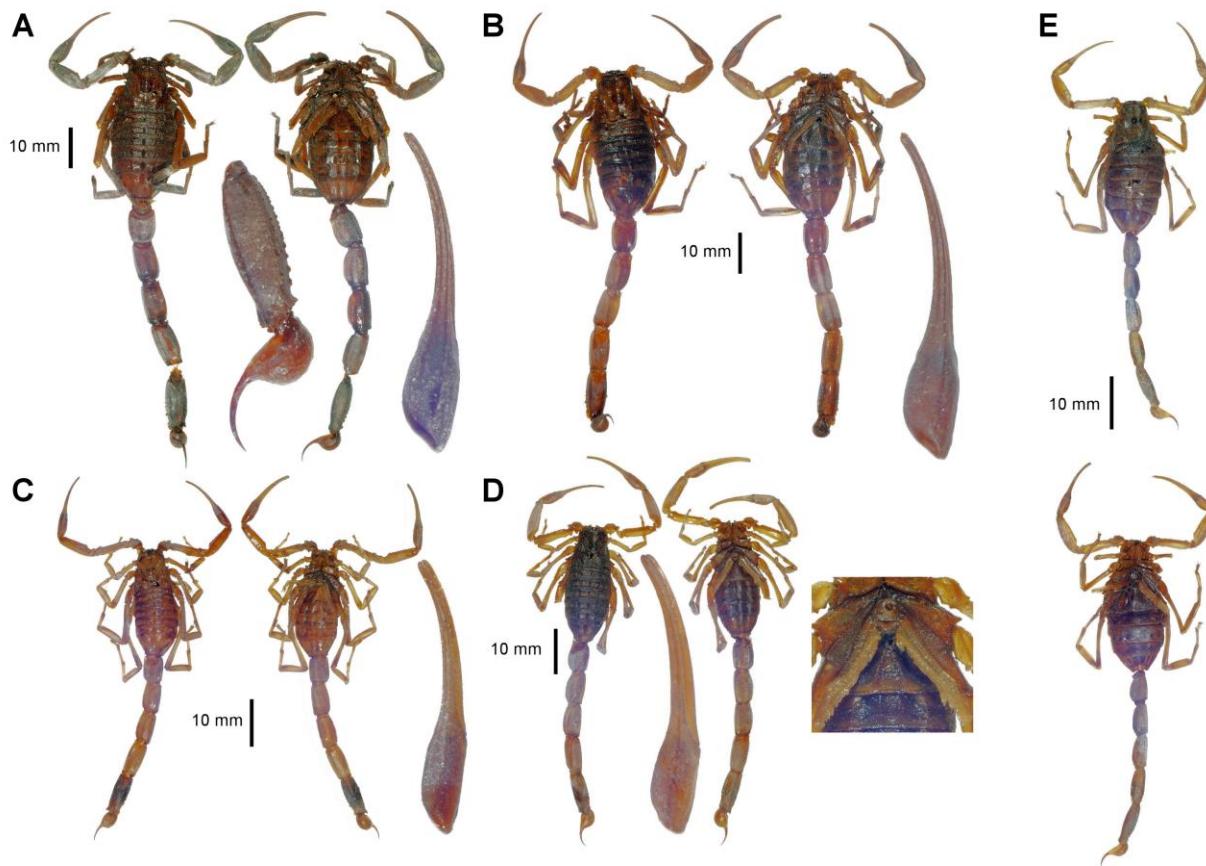


**Figure 81:** *Leiurus quinquestriatus* (Ehrenberg, 1828), female. Tarsi. **A–D.** Left telotarsus and distal basitarsus, ventral aspect. **A.** Leg I. **B.** Leg II. **C.** Leg III. **D.** Leg IV. **E.** Right basitarsus III retrolateral aspect. Kharge Oasis, Egypt (NHMB 17i).

Adiyaman Province, 37°57'24.9"N 38°17'55.3"E, 1155 a.s.l., 29.VII.2007, leg. E. A. Yağmur & A. Avci (MTAS); 1 ♀, İncesu Village, Şehitkamil District, Gaziantep Province, 37°13'16"N 37°18'05"E, 942 m a.s.l., 4.V.2008, leg. E.A. Yağmur & E. Tezcan (MTAS); 1 ♀, 2 km E of Çaybaşı Village, Oğuzeli District, Gaziantep Province, 36°47.783'N 37°35.25'E, 546 m a.s.l., 18.VII. 2010, leg. E.A. Yağmur & M. Özkörük (GL); 1 ♂, 1 ♂, 1 km W of Çakiryiğit Village, Reyhanlı District, Hatay Province, 36°15'42"N 36° 36'22"E, 225 m a.s.l., 06. VII.2011, leg. E. A. Yağmur, M. Özkörük (MTAS).

**DIAGNOSIS** (adults). Medium sized *Leiurus*, 51–68 mm in length, carapace L 6.2–8.8 mm; base color yellow with variable fuscous markings on carapace and tergites; metasoma V dark except for posterior end; area of carapace between anterior median carinae smooth or with a few small granules anteriorly, area between posterior median carinae with shallow to moderately deep median furrow flanked by arcs of fine or coarse granules; medial

intercarinal surfaces of tergites II–III with shagreened or with dense, fine granulation; posterior margin of coxa III smooth; metasoma stout, metasoma II L/W 1.26–1.46, metasoma III L/W 1.35–1.64, metasoma IV L/W 1.28–1.85; ventromedian carinae of metasoma II and III with 10–17 denticles (12/12 carinae); metasoma V with enlarged subtriangular or lobate denticles on ventrolateral carinae; pedipalps stout, patella L/W 2.39–2.86; leg III patella L/D 2.96–3.90; pectine teeth ♂ 36–42, ♀ 30–35; pectines medium sized, pectine L/ carapace L ♂ 1.07–1.30, ♀ 1.01–1.22, mid-pectine sensillar margin L/ metasoma I W ♂ 0.129–0.206, ♀ 0.093–0.162; basal 4–5 pectine teeth of males overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece smooth in females, with fine granules antero-medially, otherwise smooth in males; leg III basitarsus with 12–18 retrosuperior setae; pedipalp chela fixed finger with trichobothrium db usually proximal to est; sternite VII with area between median carinae smooth; sternite carination: *males*, sternite III with median cari-



**Figure 82:** *Leiurus quinquestriatus* (Ehrenberg, 1828), 5 of 8 syntypes (ZMHB No. 140). Females: **A**, #12C01-3; **B**, #12C04-6. Males: **C**, #12C07-9; **D**, #12C10-3. Juvenile: **E**, #12C14-6. Egypt; Sudan. Scale bars (10 mm) apply to the habitus photos. Body lengths: **A**, 90 mm; **B**, 88 mm; **C**, 63 mm; **D**, 69 mm; **E**, 65 mm. Not shown are three additional fragmented juvenile syntypes.

nae weak to moderate, sternites IV–V with lateral carinae weak to moderate, median carinae weak to obsolete; *females*, sternite III with median carinae obsolete, sternites IV–V with lateral carinae weak, median carinae obsolete.

DISTRIBUTION. Turkey, Syria.

***Leiurus jordanensis* Lourenço, Modrý et Amr, 2002**  
(Figs. 85–86, 92L, 93L, 95B, 95D, 98–99, Tab. 3B)

*Leiurus jordanensis* Lourenço, Modrý & Amr, 2002: 637–641, figs. 2–7, tab. I.

REFERENCES

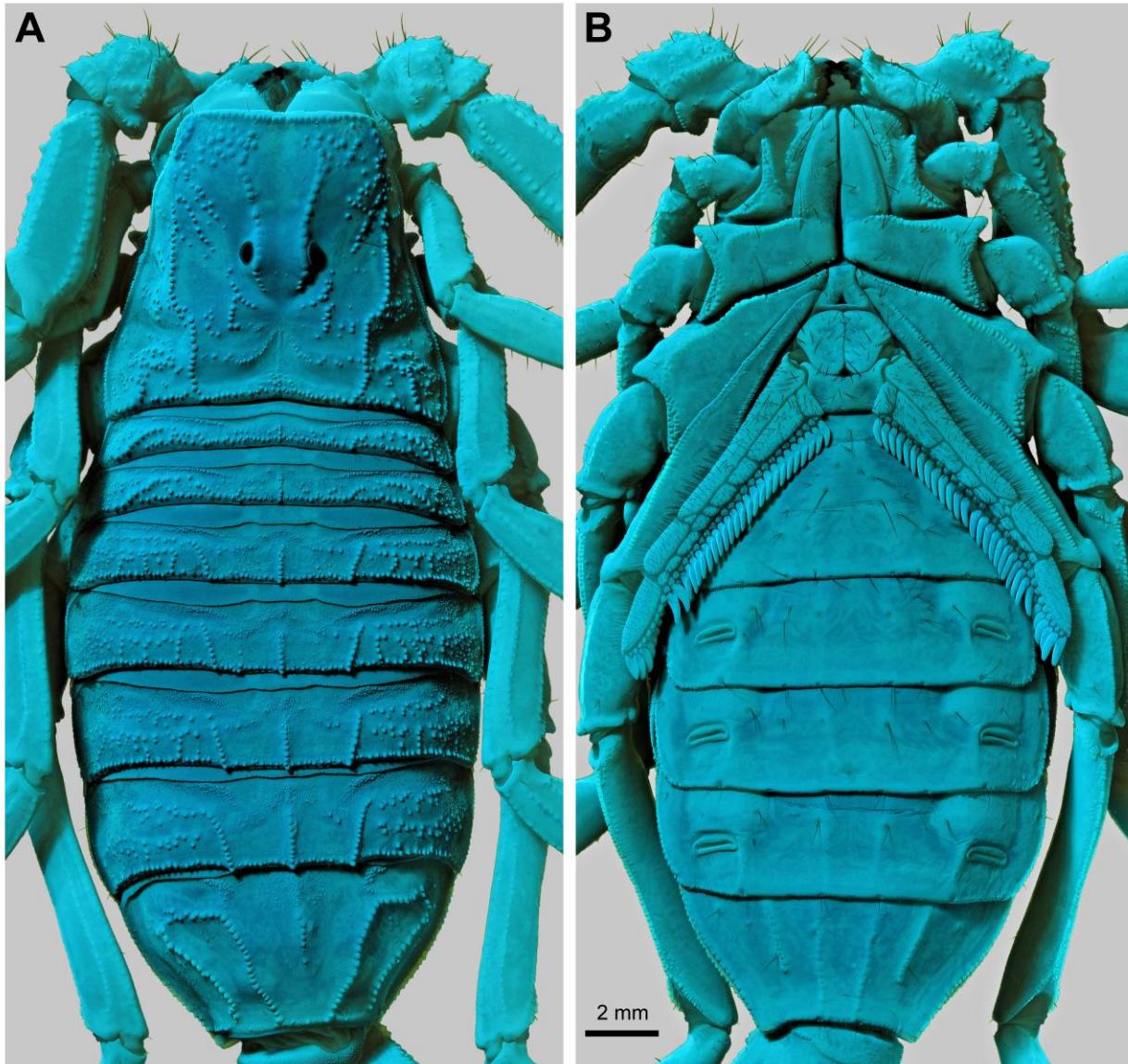
*Leiurus jordanensis*: Amr & Abu Baker, 2004: 238; Hendrixson, 2006: 82–84, figs. 17, 20a, pl. 12–13; Lourenço et al., 2006: 98, 100; Kovařík, 2007: 140–141; El-Hennawy, 2009: 122; Yağmur et al., 2009: 1, 5, 7–8; El-Hennawy, 2014: 45.

TYPE MATERIAL. Adult holotype ♀, **Jordan**, NW of Al-Mudawwarah, 29°19'22.3"N, 35°59'24.3"E, ca. 700

m a.s.l., 14.VII.2000, leg. D. Modrý (MHNG) (not examined).

MATERIAL EXAMINED. **Jordan**: 2 subadult ♀, Wadi Ramm, 29°35'N 35°36'E, 27.V.2008, leg. P. Kabátek (FKCP). **Saudi Arabia**: 2 ♀, al-Tawil, 29°58'N 39°34'E, 2.XI.1984, leg. W. Büttiker (NHMB 179a); 1 subadult ♂, 1 ♀, al-Tawil, 29°58'N 39°34'E, 2.XI.1984, leg. W. Büttiker (NHMB 179b).

DIAGNOSIS (adult). Large *Leiurus*, 74–115 mm in length, carapace L 8.5–11.3 mm; carapace and tergites with variable fuscosity; metasoma I–IV yellow to fuscous; metasoma V dark except for posterior end, telson contrasting yellow; area of carapace between anterior median carinae smooth or with isolated granules; area between posterior median carinae with moderately deep median furrow flanked by arcs of fine or coarse granules; medial intercarinal surfaces of tergites II–III moderately shagreened; posterior margin of coxa III irregularly granulate; metasoma long, slender, metasoma II L/W 1.75–1.89 (♀), metasoma III L/W 1.95–2.19 (♀), metasoma IV L/W 2.54–2.64 (♀); ventromedian carinae of metasoma II and III with 31–36



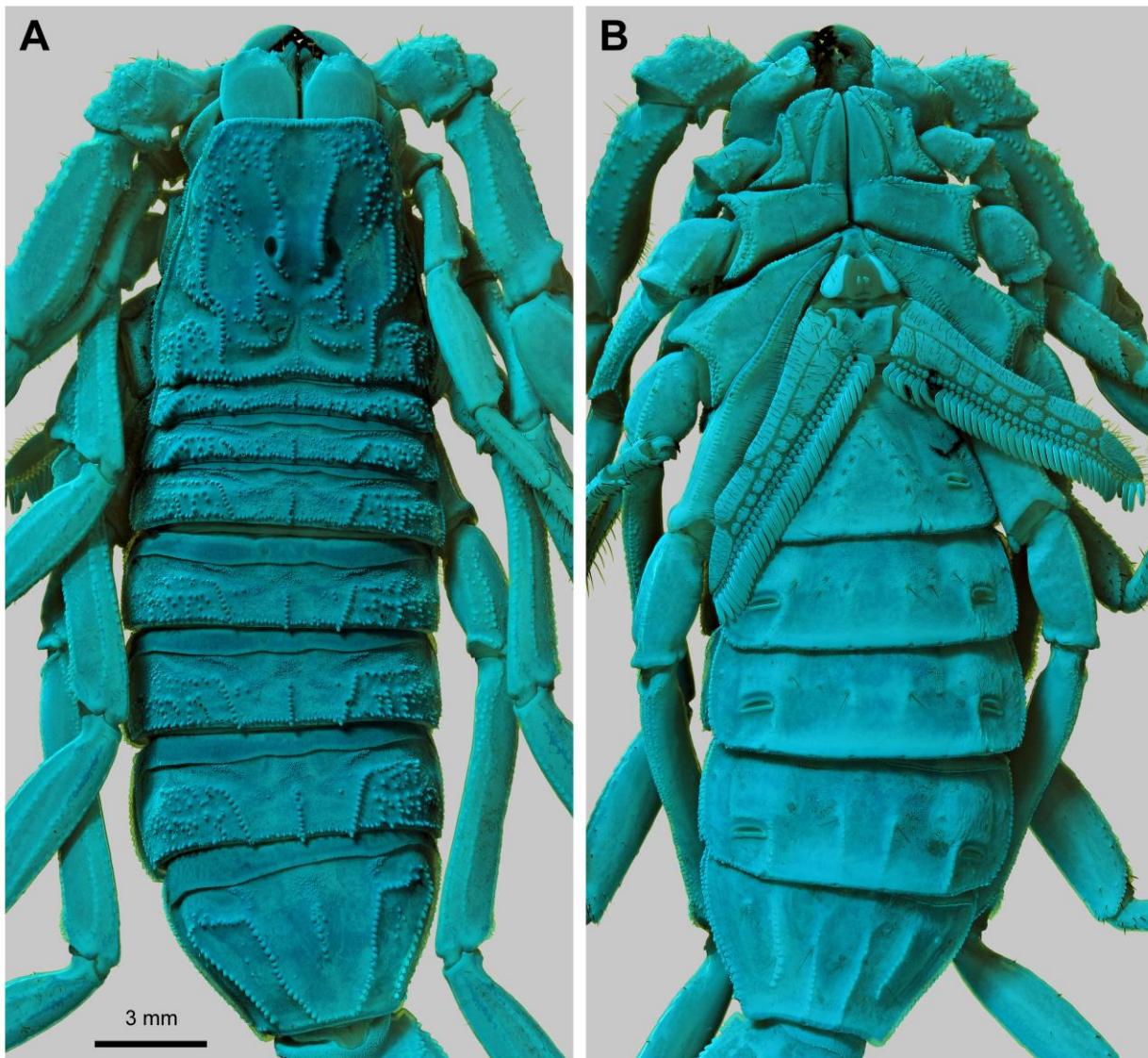
**Figure 83:** *Leiurus abdullahbayrami* Yağmur, Koç et Kunt, 2009, female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Çaybaşı Village, Turkey.

denticles (4/4 ♀ carinae); metasoma V with slightly enlarged subtriangular denticles on ventrolateral carinae; pedipalps slender, patella L/W 3.48–4.00 (♀); leg III patella L/D 3.86–4.13 (♀); pectine teeth ♂ 33–37, ♀ 27–31; pectines medium sized, pectine L/ carapace L 1.08–1.10 (♀), mid-pectine sensillar margin L/metasoma I W ♂ 0.167 (subadult), ♀ 0.101–0.126 ; basal pectine teeth of males do not overlap if anterior pectine margins aligned to posterior margins of coxae IV; pectine basal piece lightly to moderately shagreened in females; leg III basitarsus with 18–20 retrosuperior setae; pedipalp chela fixed finger with trichobothrium *db* distal to *est*; sternite VII with area between median carinae finely granulated anteriorly; sternite carination: *males and*

*females*, sternite III with median carinae strong, granular, sternites IV–V with lateral carinae strong, granular, median carinae moderate.

#### MEASUREMENTS.

**Female, al-Tawil, Saudi Arabia (NHMB 179) (mm).** Total L 114; metasoma + telson L 67; carapace L 11.23, W 13.04, carapace preocular L 5.15; metasomal segments (L/ D /W) I 8.87/ 5.55/6.58, II 10.54/ 5.10/5.59, III 10.99/ 4.82/5.01, IV 12.09/ 4.26/4.58, V 13.60/ 3.78/4.25; telson L 11.64; vesicle L 6.32, D 4.17, W 4.19; pedipalp chela L 23.90, manus ventral L 7.70, manus W 3.30, manus D 3.78, fixed finger L 13.86, movable finger L 16.52; pedipalp femur L 12.88, W



**Figure 84:** *Leiurus abdullahbayrami* Yağmur, Koç et Kunt, 2009, male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Eski Sarkaya Village, Turkey.

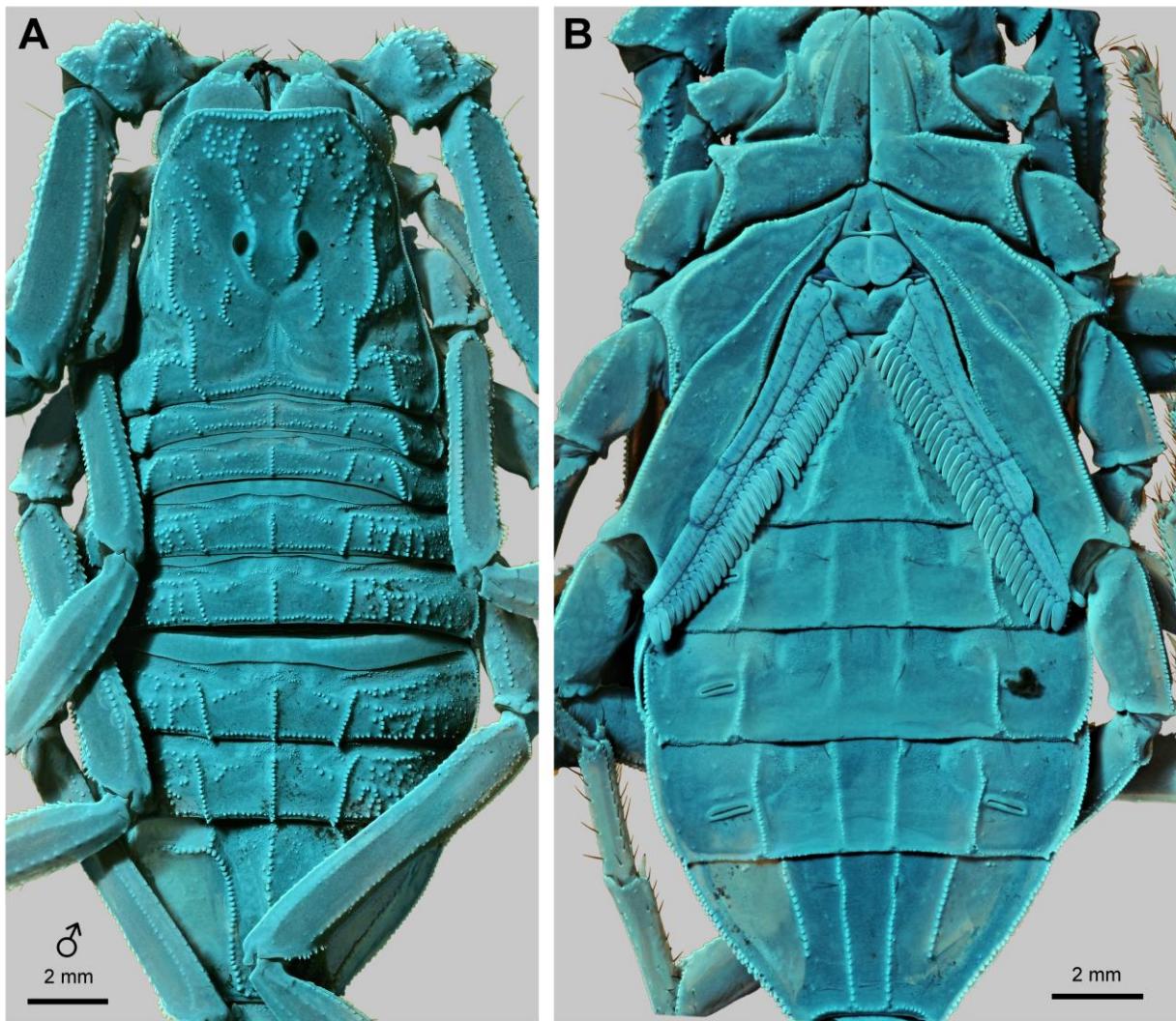
3.34, patella L 13.55, W 3.81; pectine L 12.24, mid-pectine sensillar margin L 0.776; leg III femur L 13.23; leg III patella L 10.61, D 2.57; chela *db-est* distance (left/ right) 1.00/ 0.875; pectine teeth (left/ right) 27–29.

DISTRIBUTION. Jordan, Saudi Arabia.

### Generic Affinities

Most Saharo-Sindian buthids, including *Leiurus*, belong to the *Buthus* group, an ancient Laurasian clade with a wide distribution across semi-arid and arid regions of the Palearctic (Fet et al., 2005). Within this group, only three genera in addition to *Leiurus* are known to possess five carinae on tergites I–II:

*Cicileiurus* Teruel 2007, *Odontobuthus* Vachon, 1950 (ranging from the eastern Arabian Peninsula and Iraq, across Iran, to the Indus delta of Pakistan) and *Apistobuthus* Finnegan, 1932 (from sand dunes of northwest Iran and the Arabian Peninsula). In all four genera, tergites I–II bear obliquely oriented outer lateral carinae that are aligned with parallel carinae along the posterior lateral margins of the carapace (Figs. 96C, 96E, 96F, 97). This detailed correspondence suggests a complex homologous structure. A second character shared by all four genera is fusion of centrolateral and posteromedian carinae of the carapace into a lyre configuration. We propose that both conditions are derived characters supporting a common ancestry because they are absent from the majority of other

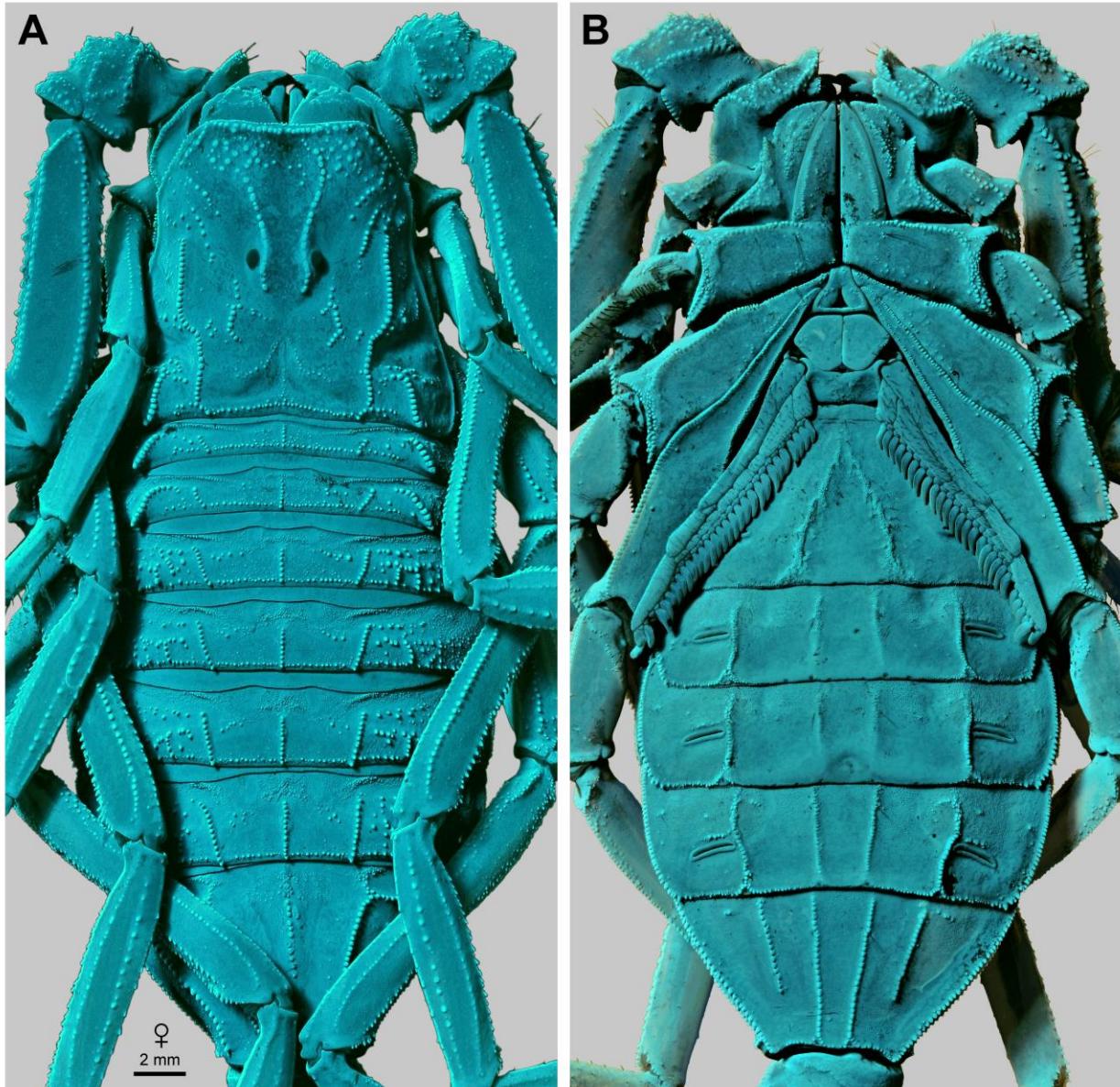


**Figure 85:** *Leiurus jordanensis* Lourenço, Modrý et Amr, 2002, male. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Al-Tawil, Saudi Arabia

*Buthus* group genera, and from sister buthoid clades (Fet et al., 2005). The posterior lateral carinae on the carapace are strongly developed, less oblique and well separated from the posterior median carinae in *Leiurus* and *Cicileiurus*, and are weakly developed, more oblique and fused with the posterior median carinae in *Odontobuthus* and *Apistobuthus*. The polarity of this transformation is unclear, but if the latter condition is plesiomorphic then it suggests that *Leiurus* may be derived from buthids that originally dispersed to Africa from Asia or Arabia.

*Cicileiurus* may represent an offshoot of the *Leiurus* lineage that became specialized for rocky mountain habitats. It is differentiated from other buthid genera by two characters, that could reflect functional adaptations: (1) elevated preocular area of the carapace, a feature shared with *Apistobuthus*, which possibly serves to

house a larger mass of cheliceral muscles for maceration of hard prey, or substrate manipulation (Newlands, 1972; Prendini, 2001); and (2) a single mid-ventral row of spiniform setae on the telotarsi, which is possibly a lithophilous adaptation. Teruel (2007) tentatively related *Cicileiurus* to *Cicileus* Vachon, 1948, based on their small size, tenuous pedipalps and metasomal segments, and the positions of trichobothria *db*, *dt*, *est* and *et* on the distal third of the fixed finger. However, a morphometric survey of 203 *Buthus* group species from 38 genera showed that these characters are not predictive of taxonomy at the generic level (Fig. 98). Distal placement of *db* and *est* was well correlated with elongation of the pedipalp fingers, which occurred independently in different genera that included diverse species having short and long fingers (Figs. 98A–C). If the positions of *db* and *est* were reliable indicators of generic affiliation,



**Figure 86:** *Leiurus jordanensis* Lourenço, Modrý et Amr, 2002, female. **A.** Carapace and tergites. **B.** Coxosternal area and sternites. Al-Tawil, Saudi Arabia.

then genera should be arrayed in horizontal bands in the scatter plots of Figs. 98A–B. Instead, we found that the major genera were spread along lines of negative slope, with trichobothrial positions correlated with finger length (see e.g. *Leiurus* and *Compsobuthus* data in Figs. 98A–B). In particular, fixed finger trichobothriotaxy did not group *Cicileiurus* and *Cicileus* separately from other genera with elongated pedipalp fingers. *Cicileiurus* and the two species of *Cicileus* (*C. exilis* (Pallary, 1928) and *C. cloudsleythompsoni* Lourenço, 1999) bracketed members of 9 other genera – *Androctonus*, *Butheoloides*, *Buthus*, *Compsobuthus*, *Hottentotta*, *Iranobuthus*, *Leiurus*, *Mesobuthus* and *Saharobuthus* – in the positions of both

*db* and *est*. Body size as quantified by carapace length, and elongation of pedipalps as quantified by pedipalp femur L/W ratio, were uncorrelated variables, neither of which grouped *Cicileiurus* and *Cicileus* apart from other genera (Fig. 98D). Carination of the carapace and tergites of *Cicileus* is quite distinct from that of *Cicileiurus* and *Leiurus*. The carapace lacks posterolateral carinae and a lyre configuration, and tergites I–II lack outer lateral carinae. Carination of *Cicileus* resembles more the carination of *Compsobuthus*, with carinae extended posteriorly into prominent spiniform processes (Figs. 96A, B). The genus *Sassanidotus* also appears related to *Compsobuthus* by fusion of the cen-

	<i>L. quinquestriatus</i>	<i>L. hebraeus</i> stat. n.	<i>L. abdullahbayrami</i>	<i>L. arabicus</i> sp.n.
size (mm) ♀	80–90 (11)	64–77 (15)	51–77 (30)	74–100 (10)
carapace anteromedian intercarinal surface	smooth with few isolated granules	shagreened with scattered medium or fine granules	smooth with few isolated granules	smooth with few isolated granules
carapace posteromedian furrow	very shallow or obsolete	shallow or moderately deep	shallow or moderately deep	shallow or moderately deep
carapace posteromedian granule arcs	reduced or absent	present	present	present
tergites II–III medial intercarinal surfaces	densely, finely shagreened	heavily shagreened	heavily shagreened	smooth or lightly shagreened
coxa III posterior margin	smooth or sparsely granulated	smooth or sparsely, finely granulated	smooth	smooth or sparsely granulated
sternite III median carinae	weak to moderate	weak or obsolete	obsolete	weak to moderate
sternite III medial intercarinal surface	densely, finely granular/ shagreened	smooth	smooth	smooth or very lightly shagreened anteriorly
sternites IV–V median carinae	weak to moderate	weak or obsolete	obsolete	weak to moderate
sternite VII medial intercarinal surface	densely, finely shagreened	densely, finely shagreened	smooth	smooth or lightly shagreened anteriorly
metasoma II L/W ♀	1.51–1.96 (20)	1.39–1.64 (15)	1.26–1.46 (14)	1.65–1.89 (10)
metasoma III L/W ♀ = a	1.65–2.22 (20)	1.49–1.69 (15)	1.35–1.54 (14)	1.86–2.12 (10)
metasoma IV L/W ♀	2.07–2.63 (20)	1.71–2.03 (15)	1.64–1.85 (14)	2.31–2.58 (10)
metasoma II L/W ♂	1.61–1.79 (7)	1.38–1.52 (5)	1.30–1.43 (13)	1.78 (1)
metasoma III L/W ♂	1.71–2.03 (7)	1.57–1.67 (5)	1.41–1.64 (13)	1.95 (1)
metasoma IV L/W ♂	2.11–2.53 (7)	1.89–1.98 (5)	1.28–1.84 (13)	2.40 (1)
metasoma II ventromedian carina <sup>1</sup> denticles (♂, ♀)	17–28 (46)	7–19 (24)	11–16 (6)	18–30 (22)
metasoma III ventromedian carina <sup>1</sup> denticles (♂, ♀)	19–26 (46)	14–18 (24)	10–15 (6)	16–31 (22)
metasoma V ventrolateral carina, posterior dentition	enlarged, sub-triangular or lobate	enlarged, sub-triangular or lobate	enlarged, sub-triangular or lobate	enlarged, triangular or subtriangular
metasoma V color	light, or dark except posterior	light, or fuscous except posterior	dark except posterior	dark except posterior
pedipalp patella L/W ♀ = b	2.88–3.61 (20)	2.48–2.83 (15)	2.39–2.67 (14)	3.35–3.91 (10)
pedipalp patella L/W ♂	3.17–3.63 (7)	2.77–2.95 (9)	2.47–2.86 (13)	3.82 (1)
leg III patella L/D ♀ = c	3.24–4.31 (19)	3.13–3.71 (15)	2.96–3.90 (14)	3.82–4.36 (10)
F <sub>s</sub> = a.b.c (♀)	16.57–33.74 (20)	12.76–16.75 (15)	10.81–15.29 (14)	25.62–33.46 (30)
pectinal tooth count <sup>2</sup> ♀	26–38 (41)	27–32 (29)	30–35 (114)	28–33 (50)
pectinal tooth count <sup>2</sup> ♂	30–39 (14)	33–37 (10)	36–42 (54)	34–40 (37)
MPSM L/ met I W <sup>3</sup> ♀	0.078–0.156 (20)	0.100–0.136 (15)	0.093–0.162 (14)	0.093–0.120 (10)
MPSM L/ met I W <sup>3</sup> ♂	0.142–0.184 (7)	0.169–0.180 (3)	0.129–0.206 (13)	0.159 (1)
pectine basal piece	heavily shagreened	very lightly shagreened/ smooth	smooth	smooth
basitarsus III retrosuperior setae (♀+♂)	8–16 (27)	7–12 (20)	12–18 (27)	7–19 (11)
pedipalp chela db vs. est (♀+♂)	distal	proximal or distal	proximal	distal

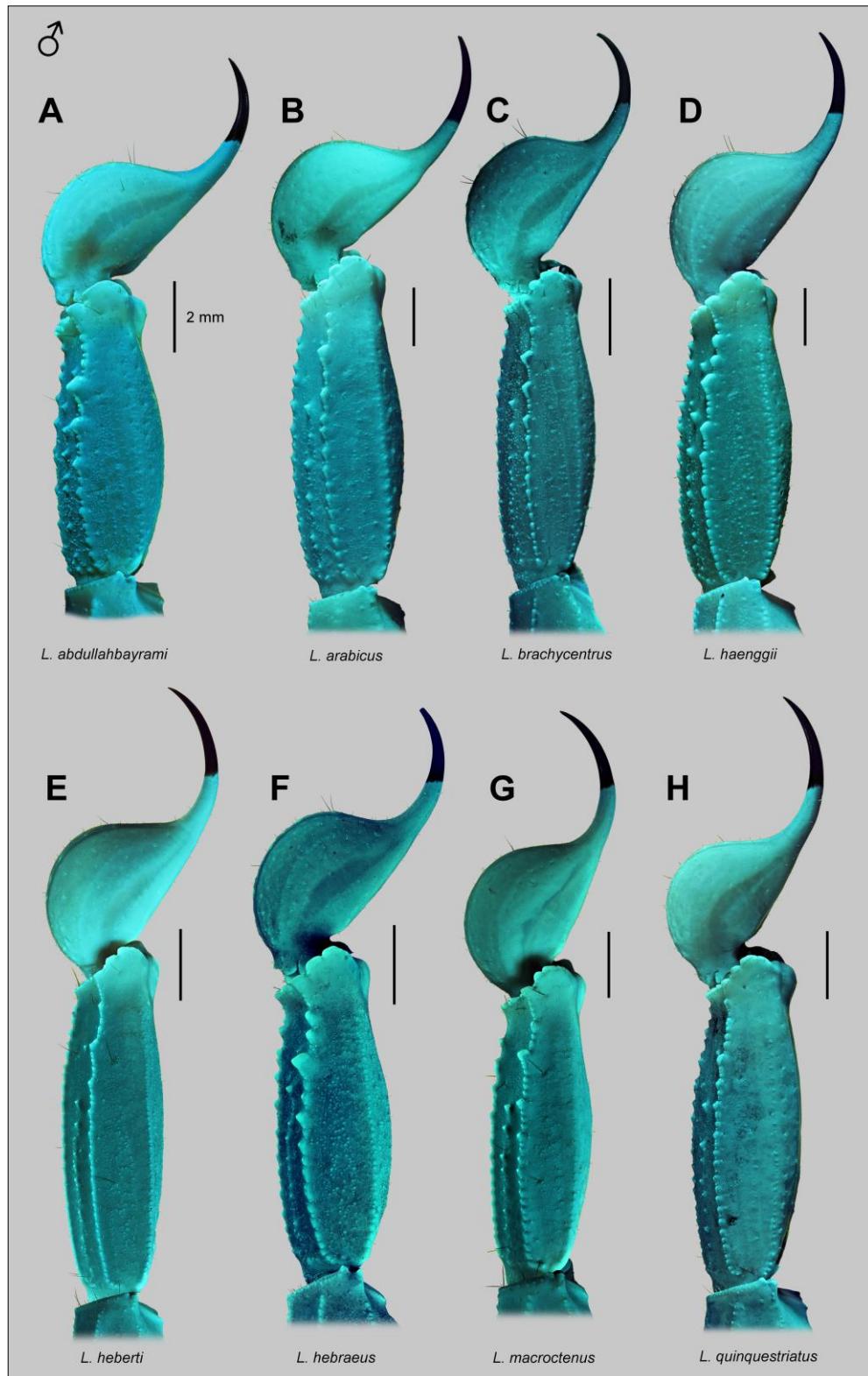
<sup>1</sup> number of carinae, left or right, are indicated; <sup>2</sup> number of combs, left or right, are indicated, including immatures; <sup>3</sup>MPSM = mid-pectine sensillar margin.

**Table 3A:** Summary of key characters separating four *Leiurus* species examined in this study (adult females unless otherwise specified). Numeric values indicate ranges with sample sizes in parentheses.

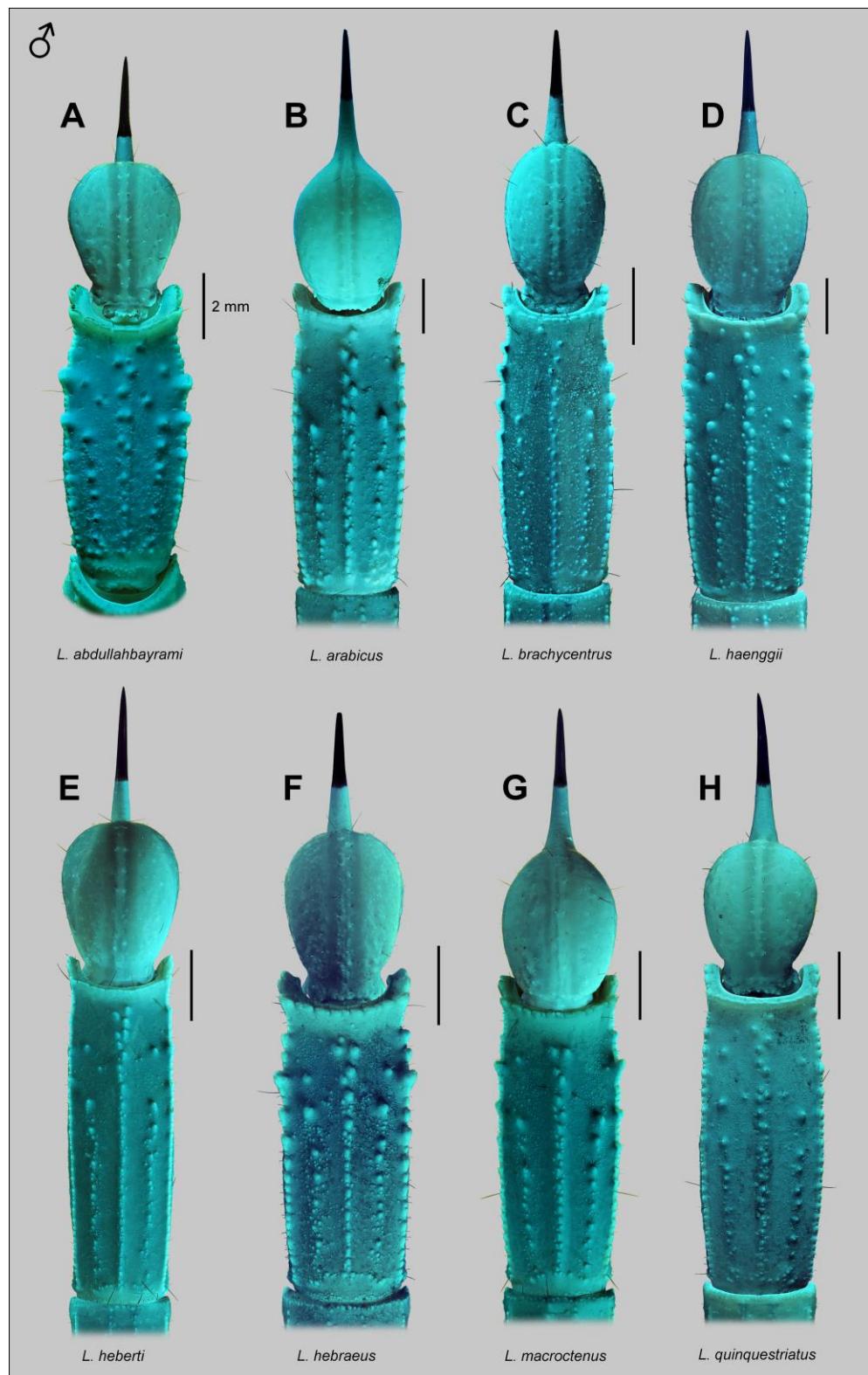
	<i>L. haenggii</i> sp. n.	<i>L. heberti</i> sp. n.	<i>L. brachycentrus</i> stat. n.	<i>L. macroctenus</i> sp. n.	<i>L. jordanensis</i>
size (mm) ♀	65–97 (17)	73 (1 subadult ♀)	60–72 (5)	62–88 (49)	74–115 (3)
carapace anteromedian intercarinal surface	smooth with few isolated granules	smooth with few isolated granules	sparsely shagreened, with small granules	smooth with scattered medium or fine granules	smooth with few isolated granules
carapace posteromedian furrow	moderately deep	moderately deep	very shallow or obsolete	shallow or moderately deep	moderately deep
carapace posteromedian granule arcs	present	present	present	present	present
tergites II–III medial intercarinal surfaces	smooth or lightly shagreened	smooth or lightly shagreened	heavily shagreened, granulated	heavily shagreened	moderately shagreened
coxa III posterior margin	smooth or sparsely granulated	smooth or sparsely granulated	regularly granulated	smooth or sparsely, finely granulated	irregularly granulated
sternite III median carinae	weak to obsolete	weak or obsolete	obsolete	weak or obsolete	moderate to strong
sternite III medial intercarinal surface	smooth or lightly shagreened	smooth	smooth	smooth	smooth
sternites IV–V median carinae	weak to obsolete	weak or obsolete	smooth and weak, or obsolete	obsolete	moderate
sternite VII medial intercarinal surface	smooth or lightly shagreened anteriorly	smooth or lightly shagreened anteriorly	smooth	smooth	finely granulated anteriorly
metasoma II L/W ♀	1.42–1.68 (19)	1.74 (1)	1.51 (1)	1.48–1.81 (49)	1.75–1.89 (3)
metasoma III L/W ♀ = a	1.55–1.83 (19)	1.92 (1)	1.67 (1)	1.59–1.95 (49)	1.95–2.19 (3)
metasoma IV L/W ♀	1.90–2.34 (19)	2.30 (1)	2.03 (1)	1.87–2.34 (49)	2.54–2.64 (2)
metasoma II L/W ♂	1.46–1.80 (11)	1.91–1.95 (2)	1.63–1.66 (2)	1.50–1.82 (51)	
metasoma III L/W ♂	1.62–1.97 (11)	2.19–2.30 (2)	1.69–1.83 (2)	1.60–2.03 (51)	
metasoma IV L/W ♂	1.97–2.46 (11)	2.70–2.94 (2)	2.17–2.19 (2)	1.94–2.40 (51)	
metasoma II ventromedian carina <sup>1</sup> denticles (♂, ♀)	9–28 (46)	36–43 (4) (♂)	15–16 (4)	14–21 (40)	31–33 (4)
metasoma III ventromedian carina <sup>1</sup> denticles (♂, ♀)	16–31 (45)	39–42 (4) (♂)	14–15 (4)	14–27 (40)	31–36 (4)
metasoma V ventrolateral carina, posterior dentition	enlarged, sub-triangular or lobate	enlarged, subtriangular	enlarged, sub-triangular or lobate	enlarged, sub-triangular or lobate	slightly enlarged, subtriangular
metasoma V color	light, fuscous to dark except posterior	dark except posterior	light, with dark carinae	light or dark except posterior	uniformly fuscous
pedipalp patella L/W ♀ = b	2.60–3.14 (19)	3.09 (1)	2.72 (1)	2.55–3.32 (49)	3.48–4.00 (4)
pedipalp patella L/W ♂	3.01–3.52 (11)	4.28–4.48 (2)	3.00–3.25 (2)	2.83–3.64 (51)	
leg III patella L/D ♀ = c	3.21–3.70 (19)	3.23 (1)	2.97 (1)	3.38–4.00 (43)	3.86–4.13 (3)
F <sub>s</sub> = a.b.c (♀)	13.95–20.29 (19)	19.13 (1)	13.50 (1)	15.56–23.86 (43)	26.21–32.21 (3)
pectinal tooth count <sup>2</sup> ♀	24–33 (100)	33–34 (2)	25–28 (10)	30–37 (97)	27–31 (12)
pectinal tooth count <sup>2</sup> ♂	28–39 (74)	36–37 (4)	31–35 (4)	33–43 (104)	33–37 (4)
MPSM L/ met I W <sup>3</sup> ♀	0.093–0.116 (18)	0.114 (1)	0.115 (1)	0.156–0.203 (30)	0.101–0.126 (3)
MPSM L/ met I W <sup>3</sup> ♂	0.138–0.178 (10)	0.198–0.225 (2)	0.210–0.234 (2)	0.216–0.254 (11)	0.167 (1 subadult ♂)
pectine basal piece	smooth	smooth	very lightly shagreened/ smooth	lightly shagreened	moderately shagreened
basitarsus III retrosuperior setae (♀+♂)	10–15 (30)	8–11 (3)	11–15 (3)	13–26 (100)	18–20 (3)
pedipalp chela db vs. est (♀+♂)	distal	distal	proximal	proximal or distal	distal

<sup>1</sup> number of carinae, left or right, are indicated; <sup>2</sup> number of combs, left or right, are indicated, including immatures; <sup>3</sup>MPSM = mid-pectine sensillar margin.

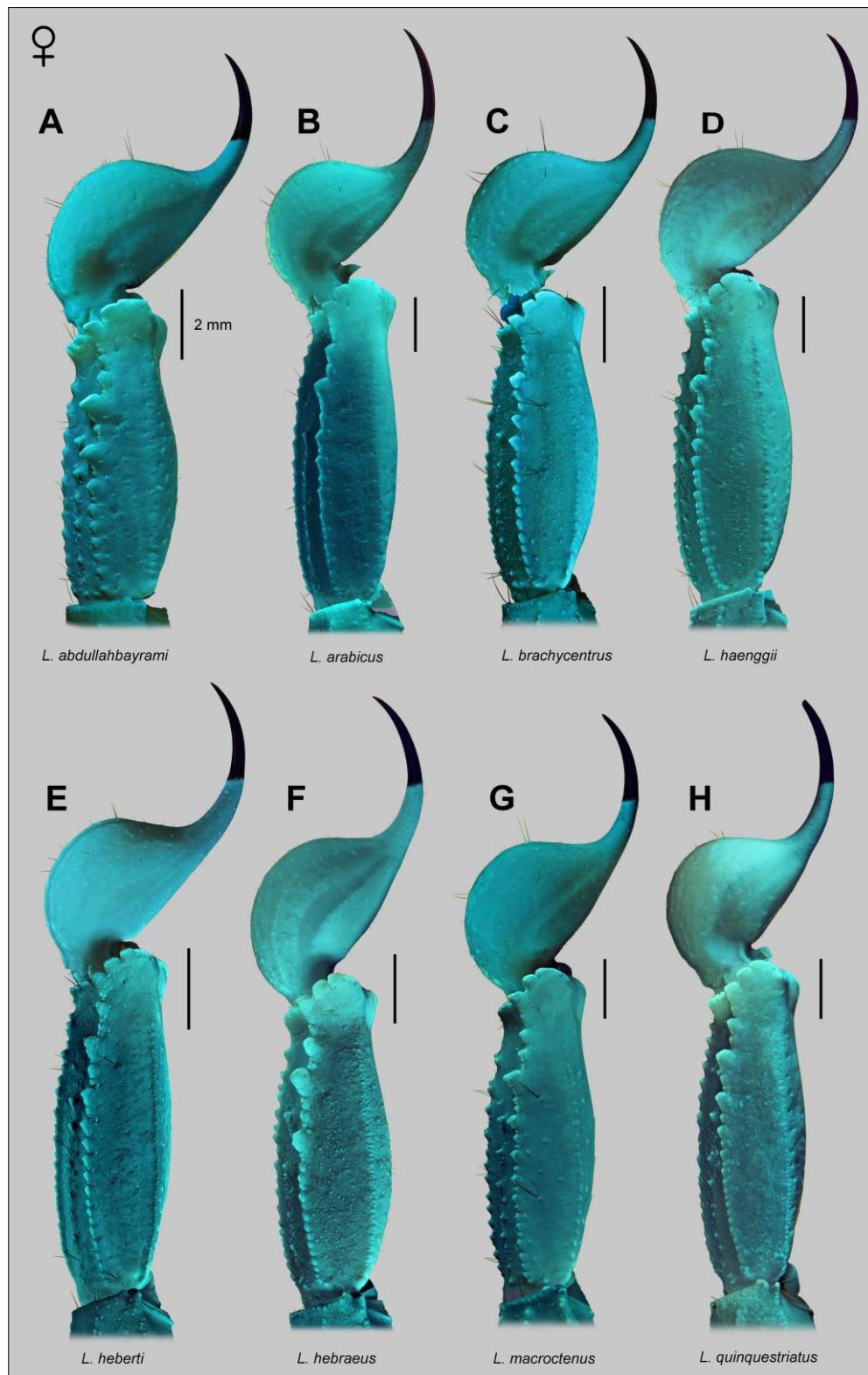
**Table 3B:** Summary of key characters separating five *Leiurus* species examined in this study (adult females unless otherwise specified). Numeric values indicate ranges with sample sizes in parentheses.



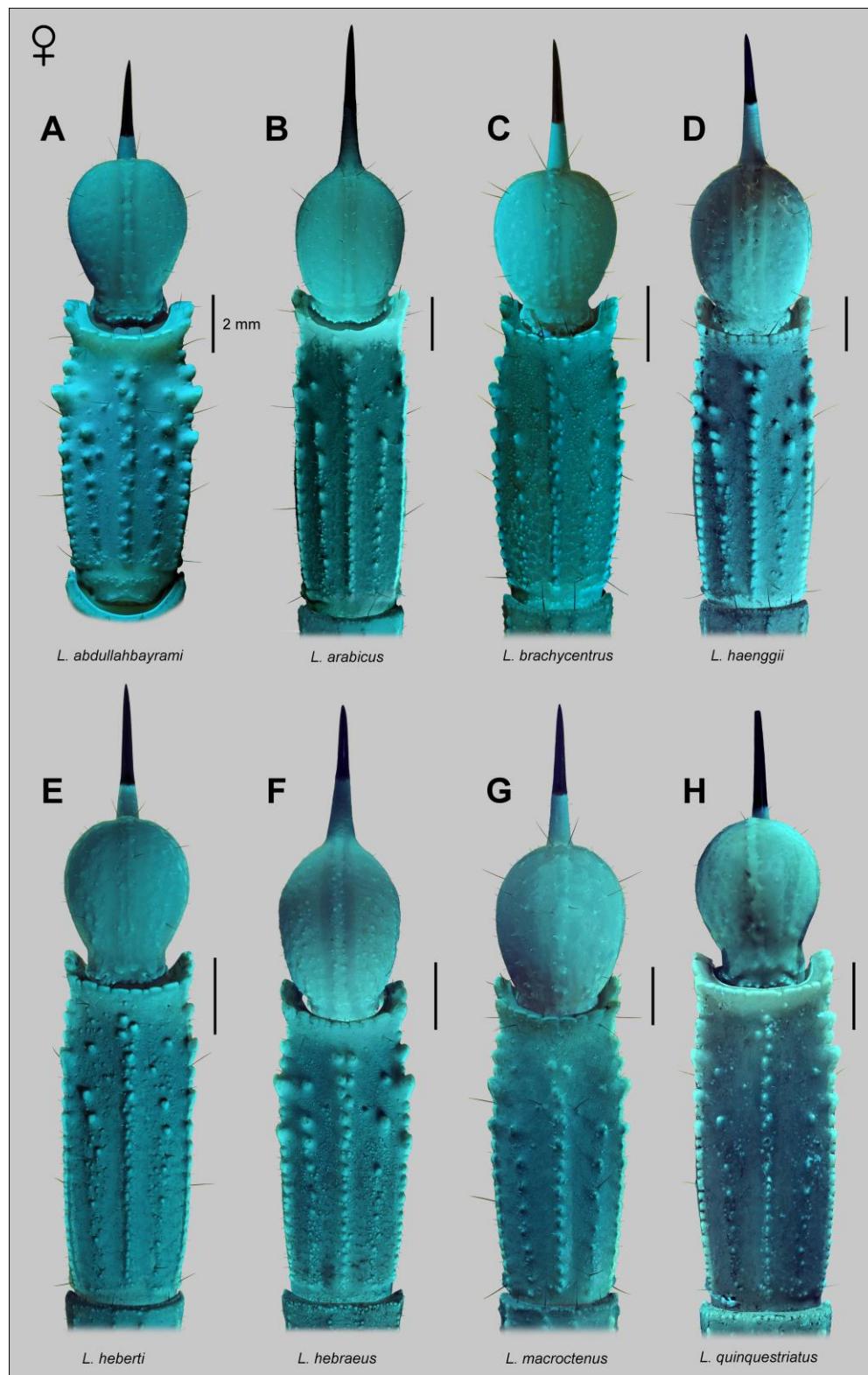
**Figure 87:** Metasoma V and telson of *Leiurus* spp. Males, lateral aspect. **A.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009. **B.** *L. arabicus* sp. n.. **C.** *L. brachycentrus* (Ehrenberg, 1829) stat. n.. **D.** *L. haenggii* sp. n. **E.** *L. heberti* sp. n. **F.** *L. hebraeus* (Birula, 1908) stat. n.. **G.** *L. macroctenus* sp. n.. **H.** *L. quinquestriatus* (Ehrenberg, 1828). Locality data as in Figs. 9, 20, 31, 43, 55, 67, 79. Scale bars: 2 mm.



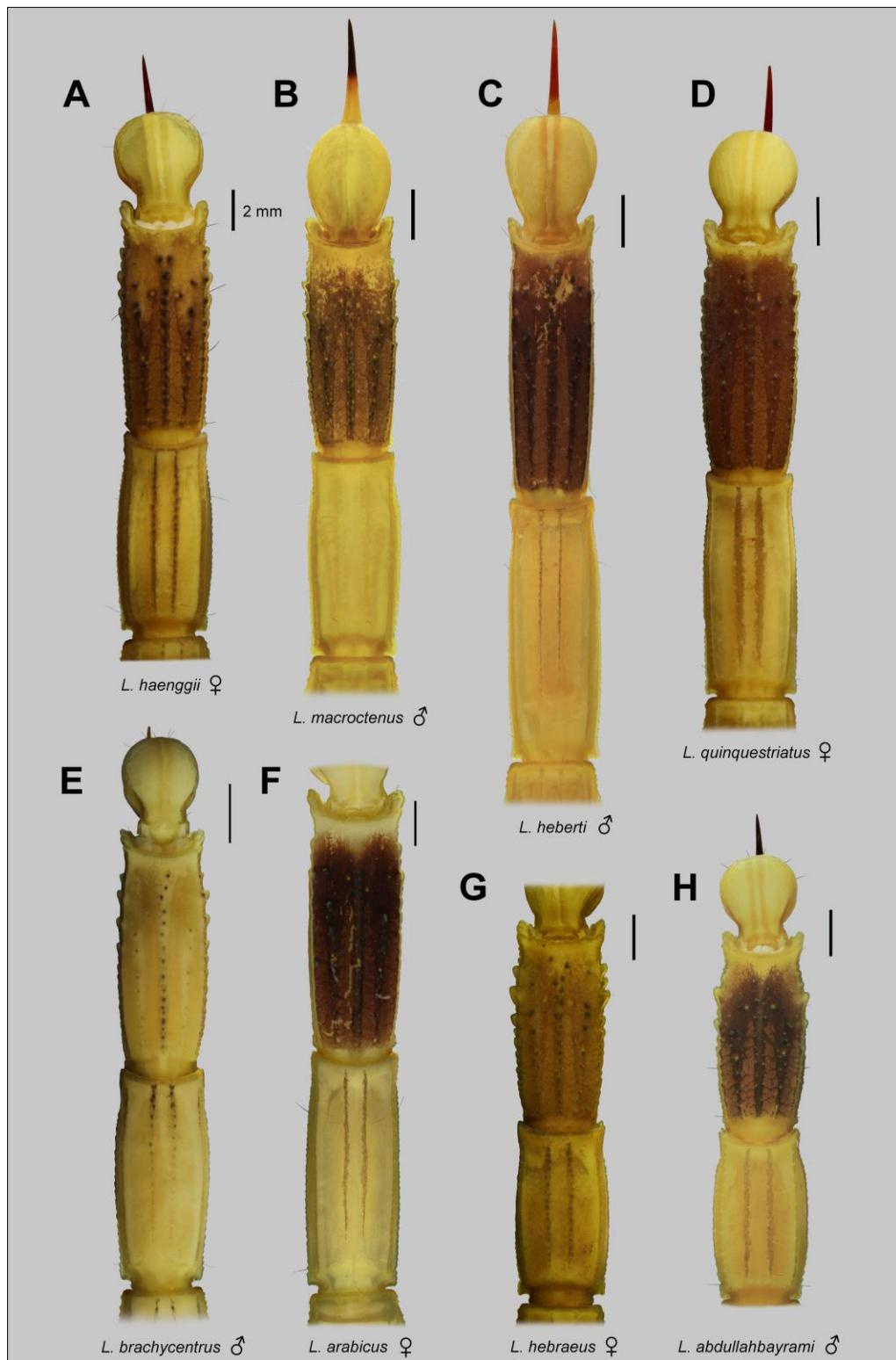
**Figure 88:** Metasoma V and telson of *Leiurus* spp. Males, ventral aspect. **A.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009. **B.** *L. arabicus* sp. n.. **C.** *L. brachycentrus* (Ehrenberg, 1829) stat. n.. **D.** *L. haenggii* sp. n.. **E.** *L. heberti* sp. n. **F.** *L. hebraeus* (Birula, 1908) stat. n.. **G.** *L. macroctenus* sp. n.. **H.** *L. quinquestriatus* (Ehrenberg, 1828). Locality data as in Figs. 9, 20, 31, 43, 55, 67, 79. Scale bars: 2 mm.



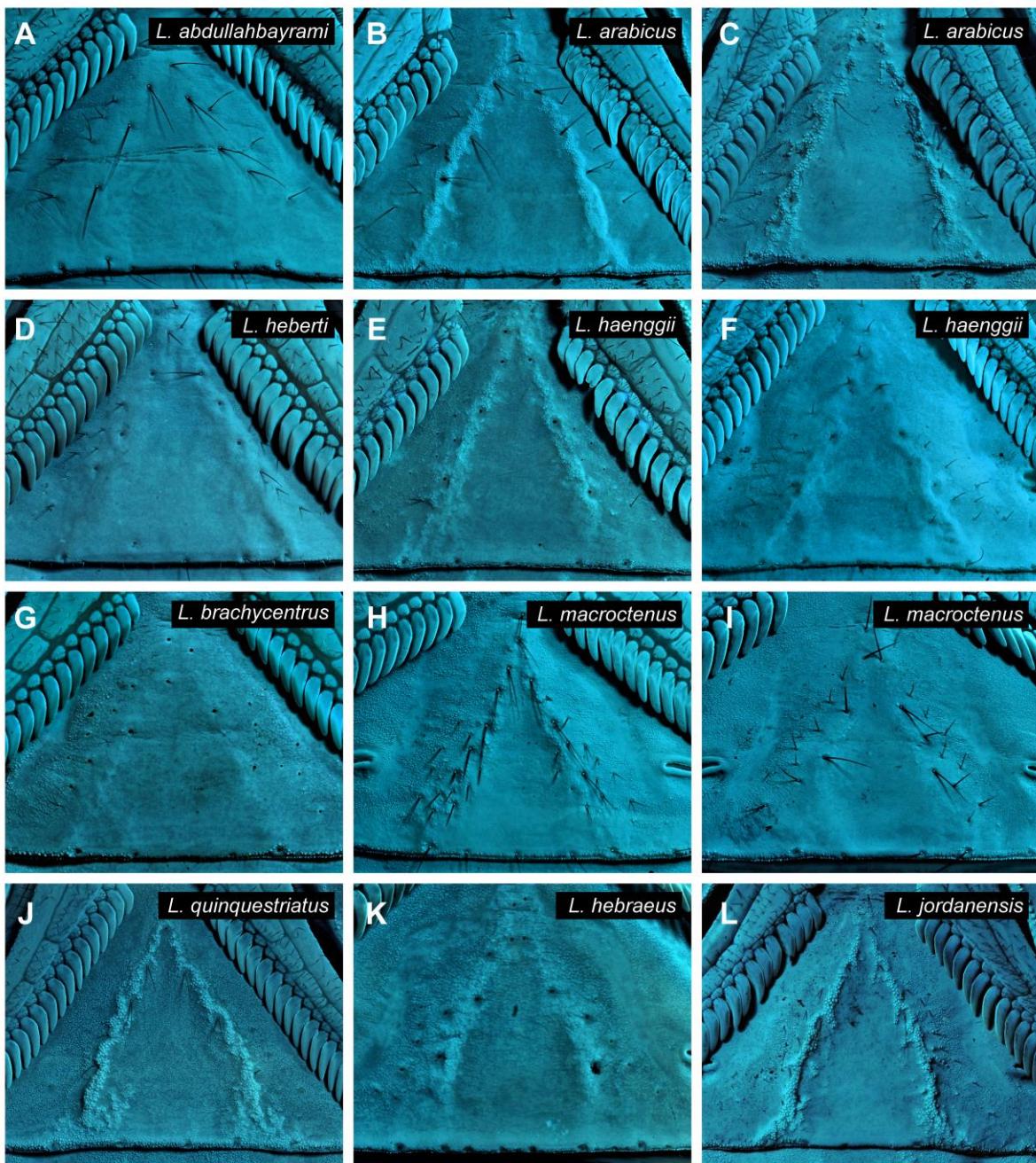
**Figure 89:** Metasoma V and telson of *Leiurus* spp. Females, lateral aspect. **A.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009. **B.** *L. arabicus* sp. n. **C.** *L. brachycentrus* (Ehrenberg, 1829) stat. n. **D.** *L. haenggii* sp. n. **E.** *L. heberti* sp. n. **F.** *L. hebraeus* (Birula, 1908) stat. n. **G.** *L. macroctenus* sp. n. **H.** *L. quinquestriatus* (Ehrenberg, 1828). Locality data as in Figs. 9, 20, 31, 43, 55, 67, 79. Scale bars: 2 mm.



**Figure 90:** Metasoma V and telson of *Leiurus* spp. Females, ventral aspect. **A.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009. **B.** *L. arabicus* sp. n. **C.** *L. brachycentrus* (Ehrenberg, 1829) stat. n.. **D.** *L. haenggii* sp. n. **E.** *L. heberti* sp. n. **F.** *L. hebraeus* (Birula, 1908) stat. n. **G.** *L. macroctenus* sp. n. **H.** *L. quinquestriatus* (Ehrenberg, 1828). Locality data as in Figs. 9, 20, 31, 43, 55, 67, 79. Scale bars: 2 mm.



**Figure 91:** Pigmentation patterns of metasoma IV, V of *Leiurus* species, ventral aspect. **A.** *L. haenggii* sp. n., holotype female, Ta'if, Saudi Arabia (NHMB 17k). **B.** *L. macroctenus* sp. n., holotype male, Thumrait, Oman. **C.** *L. heberti* sp. n., holotype male, Wadi Andur, Oman. **D.** *L. quinquestriatus* (Ehrenberg, 1828), female, Cairo, Egypt (NHMB 17d). **E.** *L. brachycentrus* (Ehrenberg, 1829) stat. n., male, Ad Darb, Saudi Arabia (NHMB 17ag). **F.** *L. arabicus* sp. n., holotype female, Kushm Dibi, Saudi Arabia (NHMB 17aq). **G.** *L. hebraeus* (Birula, 1908) stat. n., female, Israel (NHMB 17a). **H.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009, male, Eski Sarkaya Village, Turkey. Scale bars: 2 mm.



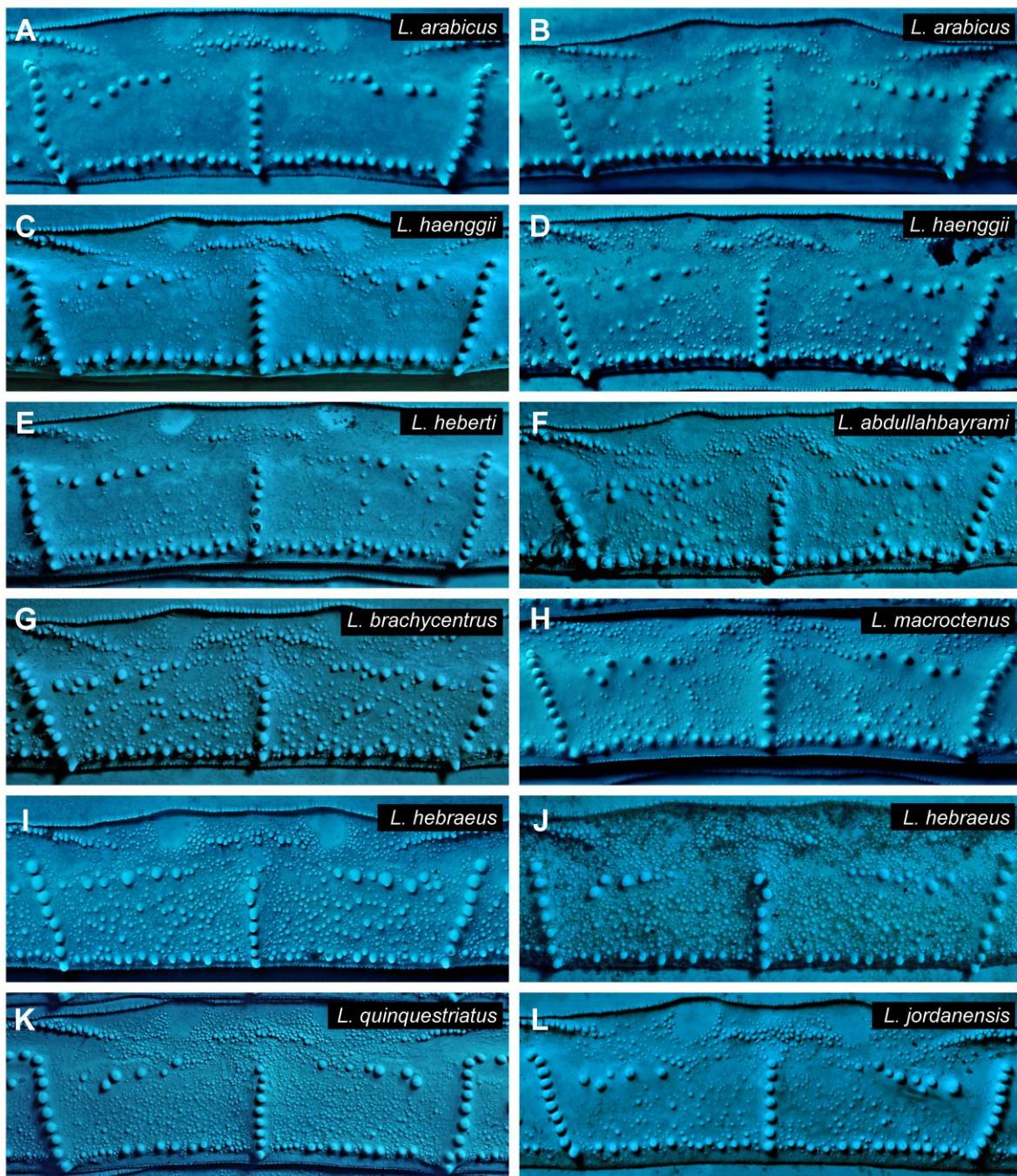
**Figure 92:** Sternite III of *Leiurus* spp., female. **A.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009, Caybasi Village, Turkey. **B.** *L. arabicus* sp. n., holotype, Kushm Dibi, Saudi Arabia (NHMB 17aq). **C.** *L. arabicus* sp. n., paratype, Al Āmar, Bahrain (NHMB 17bg). **D.** *L. heberti* sp. n., paratype, Jabal Samhan, Oman. **E.** *L. haenggii* sp. n., paratype, Wadi Turabah, Saudi Arabia (NHMB 17al). **F.** *L. haenggii* sp. n., paratype, Adnan, Saudi Arabia (NHMB 17am). **G.** *L. brachycentrus* (Ehrenberg, 1829) stat. n., Al Mansuriah, Yemen. **H.** *L. macroctenus* sp. n., paratype, Masirah Island, Oman. **I.** *L. macroctenus* sp. n., paratype, Thumrait, Oman. **J.** *L. quinquestriatus* (Ehrenberg, 1828), Kharga Oasis, Egypt (NHMB 17i). **K.** *L. hebraeus* (Birula, 1908) stat. n., Israel (NHMB 17a). **L.** *L. jordanensis* Lourenço, Modry et Amr, 2002, al-Tawil, Saudi Arabia.

tromedian and posteromedian carinae of the carapace (Fig. 96D), but it lacks posterior spiniform processes and so may not be closely related to *Cicileus*.

## Biogeography

The genus *Leiurus* has a wide distribution across North Africa, the Arabian Peninsula and the Middle

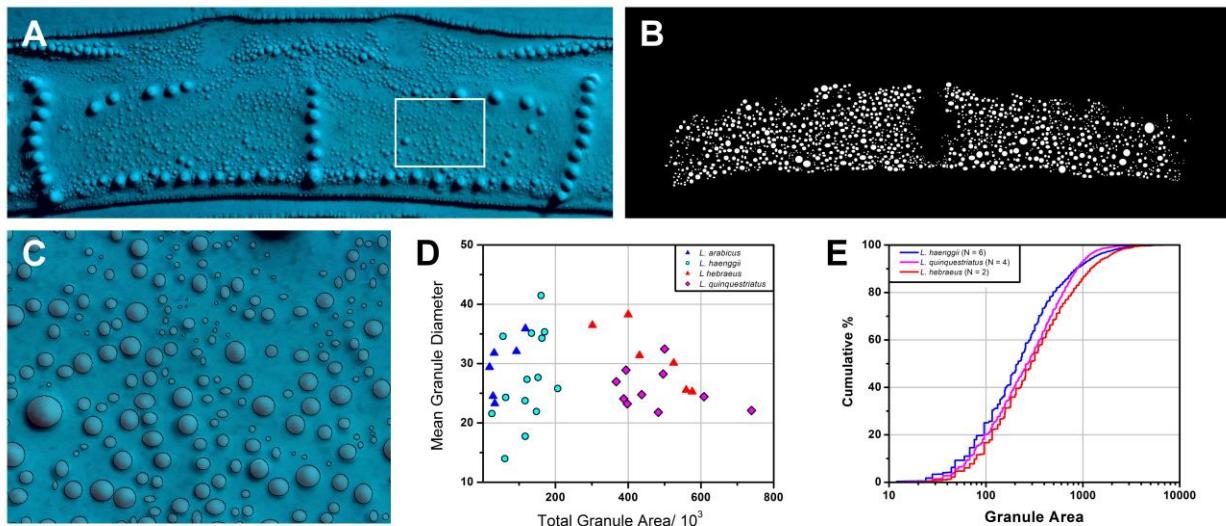
East, ranging in longitude from 3.2°E (S. Algeria; Vachon, 1949, 1952) to 59.8°E (N. Oman), and in latitude from 9.3°N (Garoua, Cameroon) to 37.9°N (Turkey), suggesting a long history of speciation. If we assume a vicariance model, then *Leiurus* may have originated in the northeastern sector of the Afro-Arabian continent, prior to the tectonic events in the Oligocene and early Miocene (ca. 30–25 Mya) that initiated sepa-



**Figure 93:** Medial intercarinal areas of tergite III of female *Leiurus* spp. **A.** *L. arabicus* sp. n., paratype, Jeddah, Saudi Arabia. **B.** *L. arabicus* sp. n., paratype, Wadi Khumrah, Saudi Arabia (NHMB 17bj). **C.** *L. haenggii* sp. n., paratype, Yemen. **D.** *L. haenggii* sp. n., paratype, Wadi Maraba, Saudi Arabia (NHMB 17al). **E.** *L. heberti* sp. n., paratype, Jabal Samhan, Oman. **F.** *L. abdullahbayrami* Yağmur, Koç et Kunt, 2009, Caybasi Village, Turkey. **G.** *L. brachycentrus* (Ehrenberg, 1829) stat. n., Al Mansuriah, Yemen. **H.** *L. macroctenus* sp. n., paratype, Masirah Island, Oman. **I.** *L. hebraeus* (Birula, 1908) stat. n., Israel (NHMB 17a). **J.** *L. hebraeus* Birula, 1908, Kurayyima, Jordan. **K.** *L. quinquestriatus* (Ehrenberg, 1828), Kharga Oasis, Egypt (NHMB 17i). **L.** *L. jordanensis* Lourenço, Modry et Amr, 2002, al-Tawil, Saudi Arabia.

ration of the Arabian Plate from the African Plate (Bosworth et al, 2005; Ghebreab, 1998). Formation of the Red Sea basin by continental rifting would have divided Arabian from African populations at a time when they

were likely inhabiting tropical savannah and steppe ecosystems. Subsequently, desert-adapted *Leiurus* species could have evolved in each region during periods of continental aridification, e.g. during the polar cooling in



**Figure 94:** Comparative analysis of granulation on tergite III of female *Leiurus*. **A.** UV fluorescence image of tergite III medial intercarinal surface of *L. quinquestriatus* (Egypt). **B.** Mask of granulation pattern on medial intercarinal surface from image in Figure 94A. **C.** Enlarged view of tergite III granulation in rectangular area indicated in Figure 94A. Granules were identified as local maxima of fluorescence intensity with contour shadows cast by directional UV illumination, and were modeled by elliptical regions-of-interest (ROIs). Parameters of granule ROIs were measured in ImageJ 1.44 (Rasband, 1997–2011). Area of granulometric analysis was restricted to surfaces bounded by the lateral and posterior marginal carinae, and a line passing through oblique, anterior transverse rows of enlarged granules (granules along carinae and bounding lines were omitted). **D.** Scatter plot of mean granule diameter vs. total granule area for 4 species of *Leiurus* (*L. arabicus* sp. n., *L. haenggii* sp. n., *L. hebraeus* stat. n. and *L. quinquestriatus*). Each point represents granulometric data derived from tergite III of one scorpion specimen (bilaterally, as shown in Figure 94B). Data were extracted from 18,423 ROIs from 36 scorpions. For each specimen, total granule area (a measure of density of granulation) was computed as sum of areas of all ROIs, and mean ROI diameter (a measure of coarseness of granulation) as the mean value of the maximum diameters of all granule ROIs. For comparative analysis, images from different size scorpions were resampled to equalize the distance between left and right posterior marginal granules of the lateral carinae (arbitrarily set to 4,000 units or pixels; linear dimensions expressed as [pixel], areas as [pixel<sup>2</sup>]). The total granule area separated the species into 2 groups: i.e. sparsely granulated (*L. arabicus*, *L. haenggii*) and densely granulated (*L. hebraeus*, *L. quinquestriatus*). In contrast, the distributions of ROI diameter were broadly overlapping. **E.** To obtain a more sensitive comparison of the coarseness of granulation, normalized cumulative distributions of single ROI areas for 3 species of *Leiurus* were computed (inset indicates number of scorpions analyzed). Relative horizontal positions of these curves indicated increasing coarseness of granulation, in rank order: *L. haenggii* < *L. quinquestriatus* < *L. hebraeus* (N<sub>granules</sub> = 2103, 5202, 2190 respectively). This ranking was confirmed by a Kolmogorov-Smirnov test which detected significant differences between the distributions of log (granule area) ( $P < 0.001$ ).

the mid-Miocene (15 Mya) (Flower & Kennett, 1994), or more recently during dry glacial periods in the Pleistocene. Absence of *Leiurus* from Asia might have been due to the barrier of the Tethys Sea prior to the Neogene (23 Mya). However, after separation, the Arabian Plate rotated counterclockwise, rifting ceased in the Gulf of Suez, and the *Gomphotherium* Land Bridge formed to connect Africa to Eurasia (Harzhauser et al., 2007). Although this connection has existed since ca. 15 Mya, *Leiurus* does not appear to extend past Syria into Iraq, and has not been detected in Iran in recent intensive UV detection surveys of its scorpiofauna. If *Leiurus* was derived from buthids that dispersed from Asia to Africa, then its redispersal back into Eurasia may have been inhibited by competitive exclusion by scorpions already occupying similar niches in that region. In contrast, other major Saharo-Sindian buthid genera such as *Androctonus*, *Compsobuthus*, *Hottentotta* and *Orthochirus* extend more widely across North Africa, Arabia

and into Eurasia. An African origin for *Leiurus* is also suggested by the presence in North Africa of *Cicileiurus* Teruel, 2007, a closely related monotypic genus (Teruel, 2007). Both *Cicileiurus monticola* Teruel, 2007 in the northern Moroccan Atlas mountains, and *L. savanicola* in the southern Sahel-Savannah transition belt, could be relict descendants of pre-Saharan ancestors of *Leiurus* living in a tropical or subtropical climate.

On the Arabian Peninsula, the distribution of *Leiurus* species (Fig. 100) correlates with certain key characters that suggest two possible lineages within the genus:

(1) *L. haenggii*, *L. arabicus* and *L. heberti* are distributed either along the chain of mountains stretching along the western (Hijaz, Asir) or southwestern (Hadramaut, Dhofar) coast of the Arabian Peninsula (*L. haenggii*, *L. heberti*), or on adjacent plains in the central plateau and eastern desert regions (*L. arabicus*). These species share the character of smooth or sparsely gran-

	<i>L. arabicus</i> sp. n.		<i>L. haenggii</i> sp. n.		<i>L. macroctenus</i> sp. n.	
	♂	♀	♂	♀	♂	♀
Carapace W/ L	1.04 (1)	1.06 – 1.19 1.15 ± 0.04 (10)	1.02 – 1.15 1.09 ± 0.04 (11)	1.12 – 1.25 1.19 ± 0.04 (18)	0.90 – 1.09 0.99 ± 0.04 (50)	0.94 – 1.21 1.06 ± 0.05 (47)
Pedipalp femur L/W	3.66 (1)	3.43 – 4.10 3.68 ± 0.21 (10)	3.21 – 3.94 3.52 ± 0.20 (11)	2.93 – 3.60 3.28 ± 0.19 (19)	3.22 – 3.99 3.56 ± 0.19 (51)	3.00 – 4.08 3.42 ± 0.23 (49)
Pedipalp patella L/W	3.82 (1)	3.35 – 3.91 3.57 ± 0.20 (10)	3.01 – 3.53 3.32 ± 0.17 (11)	2.60 – 3.14 2.95 ± 0.15 (19)	2.83 – 3.64 3.13 ± 0.16 (51)	2.55 – 3.32 2.93 ± 0.16 (49)
Pedipalp chela L/manus W	7.18 (1)	5.96 – 7.08 6.66 ± 0.36 (10)	6.07 – 7.90 6.65 ± 0.54 (11)	5.17 – 6.55 6.00 ± 0.36 (19)	5.62 – 7.11 6.26 ± 0.31 (51)	5.13 – 6.57 5.69 ± 0.36 (49)
Pedipalp movable finger L/ manus ventral L	2.08 (1)	2.00 – 2.31 2.17 ± 0.11 (10)	2.05 – 2.39 2.19 ± 0.12 (11)	2.01 – 2.50 2.23 ± 0.15 (19)	2.10 – 2.48 2.22 ± 0.08 (51)	2.11 – 2.50 2.27 ± 0.10 (49)
Pedipalp movable finger L/ carapace L	1.41 (1)	1.35 – 1.47 1.42 ± 0.04 (10)	1.18 – 1.50 1.36 ± 0.12 (11)	1.28 – 1.49 1.36 ± 0.06 (19)	1.16 – 1.37 1.26 ± 0.05 (51)	1.19 – 1.39 1.26 ± 0.05 (49)
Pedipalp chela manus W/ carapace L	0.28 (1)	0.273 – 0.327 0.305 ± 0.017 (10)	0.262 – 0.340 0.290 ± 0.022 (11)	0.292 – 0.352 0.319 ± 0.016 (19)	0.244 – 0.323 0.281 ± 0.014 (51)	0.269 – 0.347 0.309 ± 0.018 (49)
Leg III patella L/D	4.38 (1)	3.82 – 4.36 4.09 ± 0.20 (10)	3.51 – 4.02 3.69 ± 0.18 (10)	3.21 – 3.70 3.47 ± 0.15 (19)	3.43 – 4.48 3.88 ± 0.20 (48)	3.39 – 4.00 3.72 ± 0.15 (43)
Pectine L/ carapace L	1.27 (1)	1.03 – 1.19 1.11 ± 0.06 (10)	1.10 – 1.27 1.20 ± 0.04 (11)	0.99 – 1.15 1.05 ± 0.04 (19)	1.15 – 1.52 1.29 ± 0.08 (51)	1.03 – 1.26 1.14 ± 0.06 (49)
Metasoma I L/W	1.28 (1)	1.13 – 1.32 1.23 ± 0.07 (10)	1.06 – 1.38 1.17 ± 0.09 (11)	1.06 – 1.20 1.12 ± 0.04 (18)	1.10 – 1.37 1.24 ± 0.05 (50)	1.09 – 1.32 1.20 ± 0.06 (49)
Metasoma II L/W	1.78 (1)	1.65 – 1.89 1.75 ± 0.09 (10)	1.46 – 1.80 1.58 ± 0.12 (11)	1.42 – 1.68 1.54 ± 0.08 (19)	1.50 – 1.82 1.65 ± 0.07 (51)	1.48 – 1.81 1.62 ± 0.07 (49)
Metasoma III L/W	1.95 (1)	1.86 – 2.12 1.96 ± 0.07 (10)	1.62 – 1.97 1.75 ± 0.13 (11)	1.55 – 1.83 1.68 ± 0.08 (19)	1.60 – 2.03 1.78 ± 0.09 (51)	1.59 – 1.95 1.75 ± 0.09 (49)
Metasoma IV L/W	2.40 (1)	2.31 – 2.58 2.40 ± 0.09 (10)	1.97 – 2.46 2.18 ± 0.16 (11)	1.90 – 2.34 2.08 ± 0.12 (19)	1.94 – 2.40 2.17 ± 0.10 (51)	1.87 – 2.34 2.12 ± 0.10 (49)
Metasoma V L/W	2.61 (1)	2.36 – 2.81 2.62 ± 0.14 (10)	2.28 – 2.86 2.56 ± 0.17 (11)	2.22 – 2.68 2.37 ± 0.13 (19)	2.19 – 2.74 2.48 ± 0.11 (51)	2.12 – 2.63 2.35 ± 0.12 (49)

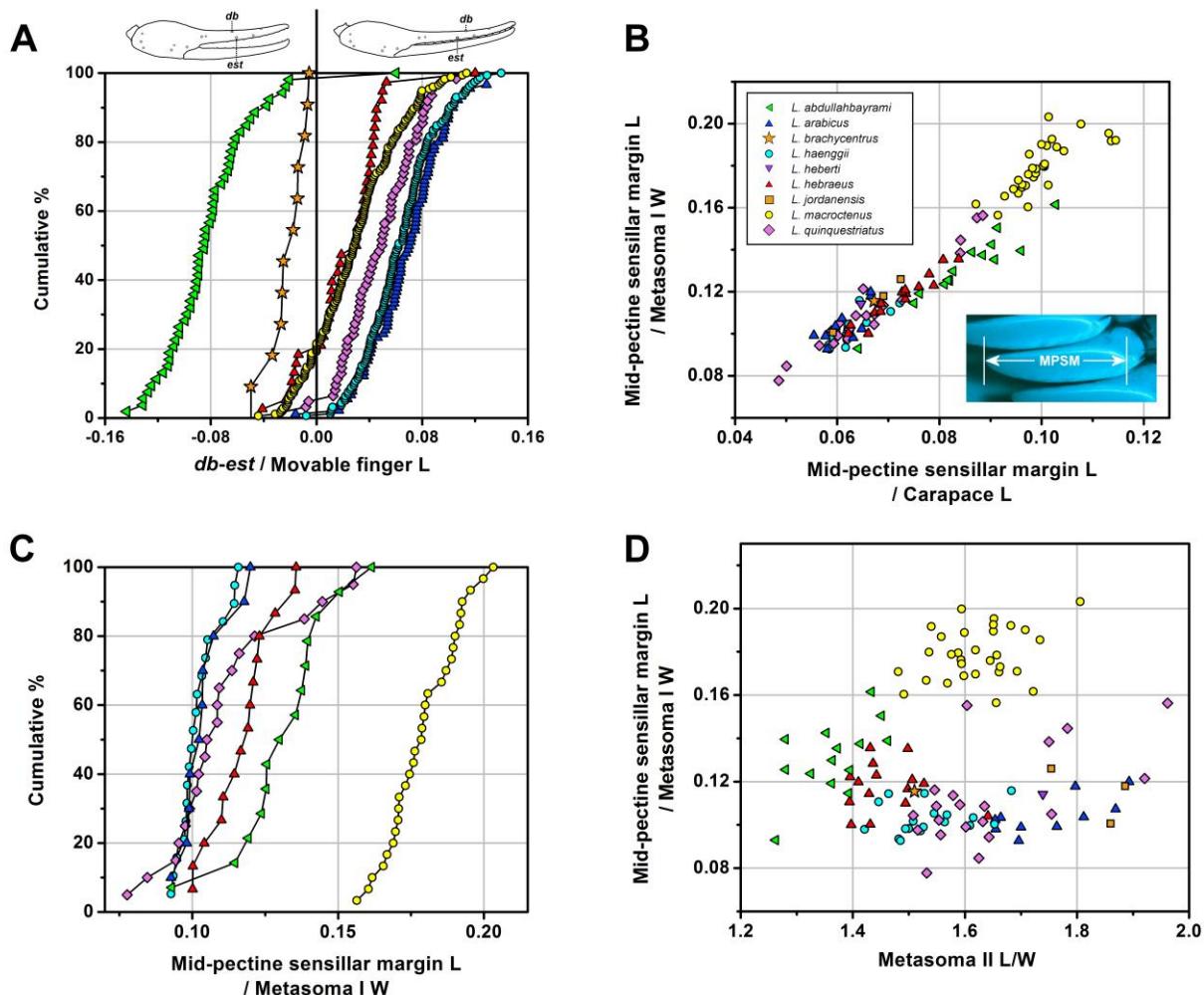
**Table 4A:** Variation in meristics and morphometric ratios for *Leiurus arabicus* sp. n., *L. haenggii* sp. n. and *L. macroctenus* sp. n.. Indicated are ranges, mean ± SD with sample sizes in parentheses. Sample sizes of pedipalp finger denticle subrow counts, db – est distances and pectinal tooth counts include both left and right appendages. Data from adults except for db–est distance/ movable finger L, and pectine teeth, which also include juveniles and immatures.

	<i>L. arabicus</i> sp. n.		<i>L. haenggii</i> sp. n.		<i>L. macroctenus</i> sp. n.	
	♂	♀	♂	♀	♂	♀
Mid-pectine sensillar margin L/ metasoma I W	0.160 (1)	0.093 – 0.120 0.104 ± 0.009 (10)	0.138 – 0.178 0.160 ± 0.013 (10)	0.093 – 0.116 0.103 ± 0.007 (18)	0.216 – 0.254 0.236 ± 0.011 (11)	0.156 – 0.203 0.179 ± 0.012 (30)
Mid-pectine sensillar margin L/ carapace L	0.100 (1)	0.055 – 0.067 0.061 ± 0.004 (10)	0.094 – 0.112 0.105 ± 0.006 (10)	0.058 – 0.072 0.064 ± 0.004 (19)	0.116 – 0.151 0.136 ± 0.011 (12)	0.087 – 0.115 0.100 ± 0.006 (30)
Mid-pectine sensillar margin L/ pectine L	0.078 (1)	0.051 – 0.060 0.055 ± 0.003 (10)	0.084 – 0.094 0.088 ± 0.004 (10)	0.054 – 0.067 0.061 ± 0.004 (19)	0.096 – 0.111 0.103 ± 0.005 (12)	0.080 – 0.098 0.089 ± 0.004 (30)
Basitarsus III, retroinferior setae	14 (1)	11 – 16 13.50 ± 1.65 (10)	11 – 15 13.09 ± 1.45 (11)	10 – 15 12.37 ± 1.26 (19)	11 – 16 13.78 ± 1.27 (51)	11 – 17 13.69 ± 1.36 (49)
Basitarsus III, inferior setae	15 (1)	13 – 17 14.60 ± 1.17 (10)	11 – 16 13.82 ± 1.54 (11)	10 – 17 13.12 ± 1.60 (19)	11 – 17 14.18 ± 1.45 (51)	12 – 18 14.31 ± 1.31 (49)
Pedipalp movable finger denticle subrows	13 (1)	9 – 13 12.65 ± 1.00 (17)	11 – 13 12.60 ± 0.58 (25)	6 – 13 12.36 ± 1.16 (39)	5 – 14 12.44 ± 1.57 (94)	4 – 14 12.39 ± 1.43 (82)
Pedipalp fixed finger denticle subrows	12 – 13 (2)	11 – 13 12.19 ± 0.54 (16)	11 – 13 12.32 ± 0.69 (25)	7 – 13 12.10 ± 1.07 (41)	8 – 13 12.28 ± 0.68 (95)	6 – 13 11.85 ± 1.42 (82)
<i>db – est</i> distance/ movable finger L	0.029 – 0.129 0.066 ± 0.026 (34)	-0.016 – 0.111 0.062 ± 0.031 (56)	0.011 – 0.116 0.060 ± 0.025 (68)	0.019 – 0.118 0.059 ± 0.026 (90)	-0.023 – 0.095 0.027 ± 0.032 (96)	-0.031 – 0.114 0.032 ± 0.031 (76)
Pectine teeth	34 – 40 37.14 ± 1.46 (37)	28 – 33 31.00 ± 1.49 (50)	28 – 39 34.77 ± 2.40 (74)	24 – 33 28.87 ± 2.06 (100)	33 – 43 37.92 ± 1.84 (104)	30 – 37 33.12 ± 1.36 (97)

**Table 4B:** Variation in meristics and morphometric ratios for *Leiurus arabicus* sp. n., *L. haenggii* sp. n. and *L. macroctenus* sp. n.. Indicated are ranges, mean ± SD with sample sizes in parentheses. Sample sizes of pedipalp finger denticle subrow counts, *db – est* distances and pectinal tooth counts include both left and right appendages. Data from adults except for *db – est* distance/ movable finger L, and pectine teeth, which also include juveniles and immatures.

	<i>L. hebraeus</i>		<i>L. quinquestriatus</i>	
	♂	♀	♂	♀
Carapace W/L	1.00 – 1.07 1.04 ± 0.03 (5)	1.04 – 1.15 1.09 ± 0.04 (15)	1.03 – 1.10 1.06 ± 0.03 (7)	1.09 – 1.21 1.15 ± 0.03 (19)
Pedipalp femur L/W	2.95 – 3.38 3.11 ± 0.17 (5)	2.69 – 3.14 2.97 ± 0.13 (15)	3.41 – 4.35 3.71 ± 0.33 (7)	2.84 – 3.70 3.43 ± 0.24 (19)
Pedipalp patella L/W	2.81 – 2.95 2.89 ± 0.05 (5)	2.48 – 2.83 2.69 ± 0.11 (15)	3.17 – 3.63 3.40 ± 0.16 (7)	2.88 – 3.61 3.22 ± 0.24 (19)
Pedipalp chela L/manus W	5.85 – 6.38 6.04 ± 0.20 (5)	4.78 – 6.05 5.61 ± 0.36 (15)	6.13 – 7.40 6.90 ± 0.49 (7)	5.65 – 7.39 6.42 ± 0.49 (19)
Pedipalp movable finger L/manus ventral L	2.04 – 2.27 2.11 ± 0.10 (5)	2.00 – 2.34 2.12 ± 0.09 (15)	2.13 – 2.54 2.32 ± 0.13 (7)	2.14 – 2.53 2.34 ± 0.09 (19)
Pedipalp movable finger L/carapace L	1.16 – 1.20 1.19 ± 0.02 (5)	1.11 – 1.24 1.17 ± 0.05 (15)	1.25 – 1.38 1.33 ± 0.06 (7)	1.12 – 1.46 1.32 ± 0.07 (19)
Pedipalp chela manus W/carapace L	0.276 – 0.289 0.285 ± 0.005 (5)	0.277 – 0.333 0.302 ± 0.015 (15)	0.26 – 0.30 0.27 ± 0.01 (7)	0.253 – 0.314 0.287 ± 0.015 (19)
Leg III patella L/D	3.17 – 3.70 3.47 ± 0.20 (5)	3.13 – 3.71 3.42 ± 0.16 (15)	3.63 – 4.38 3.96 ± 0.24 (7)	3.24 – 4.31 3.77 ± 0.27 (19)
Pectine L/carapace L	1.15 – 1.29 1.22 ± 0.06 (5)	0.93 – 1.21 1.05 ± 0.06 (15)	1.11 – 1.40 1.22 ± 0.10 (7)	0.89 – 1.38 1.04 ± 0.14 (19)
Metasoma I L/W	1.07 – 1.17 1.12 ± 0.05 (5)	1.00 – 1.19 1.11 ± 0.06 (15)	1.15 – 1.30 1.23 ± 0.05 (7)	1.06 – 1.36 1.19 ± 0.08 (19)
Metasoma II L/W	1.38 – 1.52 1.45 ± 0.06 (5)	1.39 – 1.64 1.46 ± 0.07 (15)	1.61 – 1.79 1.68 ± 0.06 (7)	1.51 – 1.96 1.64 ± 0.13 (19)
Metasoma III L/W	1.57 – 1.67 1.61 ± 0.05 (5)	1.49 – 1.69 1.58 ± 0.07 (15)	1.71 – 2.03 1.84 ± 0.10 (7)	1.67 – 2.22 1.83 ± 0.16 (19)
Metasoma IV L/W	1.89 – 1.98 1.94 ± 0.04 (5)	1.71 – 2.03 1.92 ± 0.08 (15)	2.11 – 2.53 2.30 ± 0.14 (7)	2.07 – 2.63 2.24 ± 0.17 (19)
Metasoma V L/W	2.17 – 2.52 2.29 ± 0.16 (5)	1.95 – 2.45 2.19 ± 0.16 (15)	2.45 – 2.83 2.59 ± 0.14 (7)	2.05 – 2.88 2.42 ± 0.20 (19)
Mid-pectine sensillar margin L/metasoma I W	0.169 – 0.180 0.175 ± 0.006 (3)	0.100 – 0.136 0.117 ± 0.011 (15)	0.142 – 0.184 0.164 ± 0.015 (7)	0.078 – 0.156 0.109 ± 0.020 (19)
Mid-pectine sensillar margin L/carapace L	0.109 – 0.119 0.115 ± 0.005 (3)	0.062 – 0.084 0.072 ± 0.006 (15)	0.091 – 0.117 0.102 ± 0.009 (7)	0.049 – 0.089 0.066 ± 0.011 (19)
Mid-pectine sensillar margin L/pectine L	0.092 – 0.094 0.093 ± 0.001 (3)	0.061 – 0.075 0.069 ± 0.005 (15)	0.076 – 0.090 0.084 ± 0.006 (7)	0.049 – 0.072 0.063 ± 0.006 (19)
Basitarsus III, retrosuperior setae	7 – 11 8.80 ± 2.05 (5)	8 – 12 10.13 ± 1.13 (15)	11 – 14 12.57 ± 1.27 (7)	11 – 16 13.95 ± 1.62 (19)
Basitarsus III, retroinferior setae	9 – 14 10.80 ± 1.92 (5)	9 – 14 11.53 ± 1.13 (15)	12 – 13 12.57 ± 0.54 (7)	10 – 15 12.37 ± 1.34 (19)
Basitarsus III, inferior setae	12 – 15 13.20 ± 1.10 (5)	10 – 15 12.80 ± 1.37 (15)	11 – 15 13.00 ± 1.73 (7)	10 – 15 12.74 ± 1.15 (19)
Pedipalp movable finger denticle subrows	12 – 13 12.30 ± 0.48 (10)	12 – 13 12.37 ± 0.49 (30)	11 – 13 12.21 ± 0.58 (14)	11 – 13 12.31 ± 0.52 (39)
Pedipalp fixed finger denticle subrows	11 – 13 12.10 ± 0.74 (10)	11 – 13 12.17 ± 0.53 (30)	11 – 13 12.14 ± 0.66 (14)	11 – 13 12.11 ± 0.39 (38)
db – est distance/ movable finger L	-0.014 – 0.045 0.024 ± 0.024 (10)	-0.041 – 0.045 0.013 ± 0.027 (28)	0.016 – 0.087 0.060 ± 0.025 (14)	-0.008 – 0.081 0.043 ± 0.025 (40)
Pectine teeth	33 – 37 35.10 ± 1.20 (10)	27 – 32 29.21 ± 1.26 (29)	34 – 39 35.69 ± 1.60 (13)	26 – 38 29.54 ± 2.43 (39)

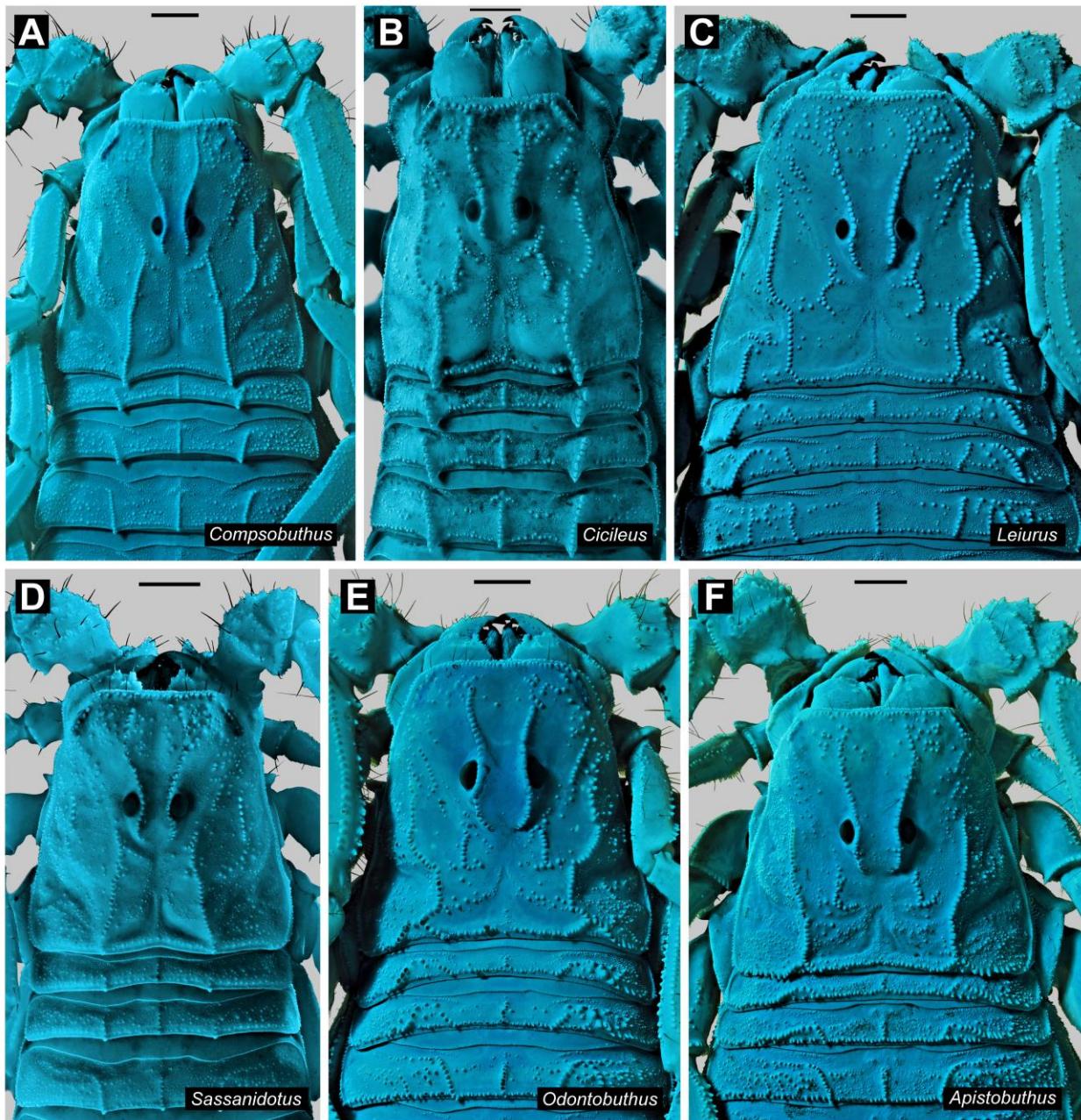
**Table 5:** Variation in meristics and morphometric ratios for *Leiurus hebraeus* stat. n. and *L. quinquestriatus*. Indicated are ranges, mean ± SD with sample sizes in parentheses. Sample sizes of pedipalp finger denticle subrow counts, db – est distances and pectinal tooth counts include both left and right appendages. Data from adults except for db – est distance/ movable finger L, and pectine teeth, which also include juveniles and immatures.



**Figure 95:** Variation in key diagnostic biometrics of adult *Leiurus* spp. **A.** Cumulative distributions of position of trichobothrium *db* relative to *est* on pedipalp fixed finger for: *L. abdullahbayrami* (53), *L. brachycentrus* stat. n. (11), *L. hebraeus* stat. n. (38), *L. macroctenus* sp. n. (176), *L. quinquestriatus* (61), *L. haenggii* sp. n. (158), *L. arabicus* sp. n. (87) (number of fingers measured in parentheses). Data for males and females were pooled. The *db-est* distances were normalized to pedipalp movable finger length (chord length from finger tip to external articular condyle), with positive values indicating *db* distal to *est*, negative values indicating *db* proximal to *est*. Distributions of *L. haenggii* ( $\mu = 0.06367$ ) and *L. arabicus* sp. n. ( $\mu = 0.06671$ ) were not significantly different ( $P = 0.405148$ , *t* test), indicating a close relationship between these species. Distribution of *L. quinquestriatus* ( $\mu = 0.047313$ ) was significantly different from those of *L. haenggii* and *L. arabicus* ( $P = 0.000102$  and  $0.000030$  respectively). **B.** Scatter plot of morphometric ratios of mid-pectine sensillar margin L (MPSM, indicated in inset) to metasoma I W, and to carapace L, showing differences in relative pectinal tooth size in females of nine species of *Leiurus*. **C.** A subset of the female data in Figure 95B, plotted as cumulative distributions of morphometric ratio of mid-pectine sensillar margin L to metasoma I W. Distributions of *L. haenggii* ( $\mu = 0.102268$ ) and *L. arabicus* ( $\mu = 0.10432$ ) were not significantly different ( $P > 0.1$ , K-S test). **D.** Scatter plot of morphometric ratios of mid-pectine sensillar margin L to metasoma I W (relative size of pectine teeth), and metasoma II L/W (slenderness of metasoma II) for females of nine species of *Leiurus*. **A, C, D:** symbol key as in Figure 95B.

ulated tergites II–III. The faulting and uplift of the Arabian Peninsula coastal ranges during Oligocene–Miocene rifting created montane habitats for colonization by *Leiurus*. These mountains have served as refugia for a rich biota during xeric periods, and *L. haenggii* may be such a relict from tropical or pluvial periods. Other scorpions endemic to these mountains include *Butheolus anthracinus* (Pocock, 1895), *Butheolus arabicus* Lourenço et Qi, 2006, *Butheolus gallag-*

*heri* Vachon, 1980, *Butheolus thalassinus* Simon, 1882, *Compsobuthus acutecarinatus* (Simon, 1882), *Compsobuthus brevimanus* (Werner, 1936), *Compsobuthus krali* Kovařík, 2012, *Compsobuthus manzonii* (Borelli, 1915), *Compsobuthus vachoni* Sissom, 1994, *Hottentotta salei* Vachon, 1980, *Nebo flavipes* Simon, 1882, *Nebo franckei* Vachon 1980, *Nebo grandis* Francke, 1980, *Nebo poggesii* Sissom, 1994, *Nebo whitei* Vachon, 1980 and *Nebo yemenensis* Francke, 1980. The Arabian sand



**Figure 96:** Carapace and tergites I–III of representatives of six genera of the *Buthus* group. **A.** *Compsobuthus acutecarinatus* (Simon, 1882), male, Jabal Qara, Oman. **B.** *Cicileus exilis* (Pallary, 1928), male, Hoggar, Algeria. **C.** *Leiurus quinquestriatus* (Ehrenberg, 1828), female, Egypt. **D.** *Sasanidotus gracilis* (Birula, 1900), female, Hormozgan Prov., Iran. **E.** *Odontobuthus bidentatus* Lourenço & Pézier, 2002, male, Omidiyeh, Iran. **F.** *Apistobuthus susanae* Lourenço 1998, male, Albadji, Iran. Scale bars: A, B, D: 1 mm; C, E, F: 2 mm.

deserts may date back to the time of mid-Miocene aridification, and were expanded considerably during the Quaternary (< 1.8 Mya) when climatic oscillations of pluvial/ glacial periods liberated sedimentary deposits that were repeatedly exposed by lowered sea levels and transported over the peninsula by Shamal winds (Glennie, 1996). The parapatric species most similar to

*L. haenggii* in morphology is *L. arabicus*. Ontogenetic divergence of the morphometrics of *L. arabicus* to a more psammophilous ecomorphotype (Fig. 46) is consistent with its derivation from the *L. haenggii* lineage by adaptation to sandy deserts on the peninsula.

The third member of this group, *L. heberti*, is also likely to be a product of parapatric divergence from the

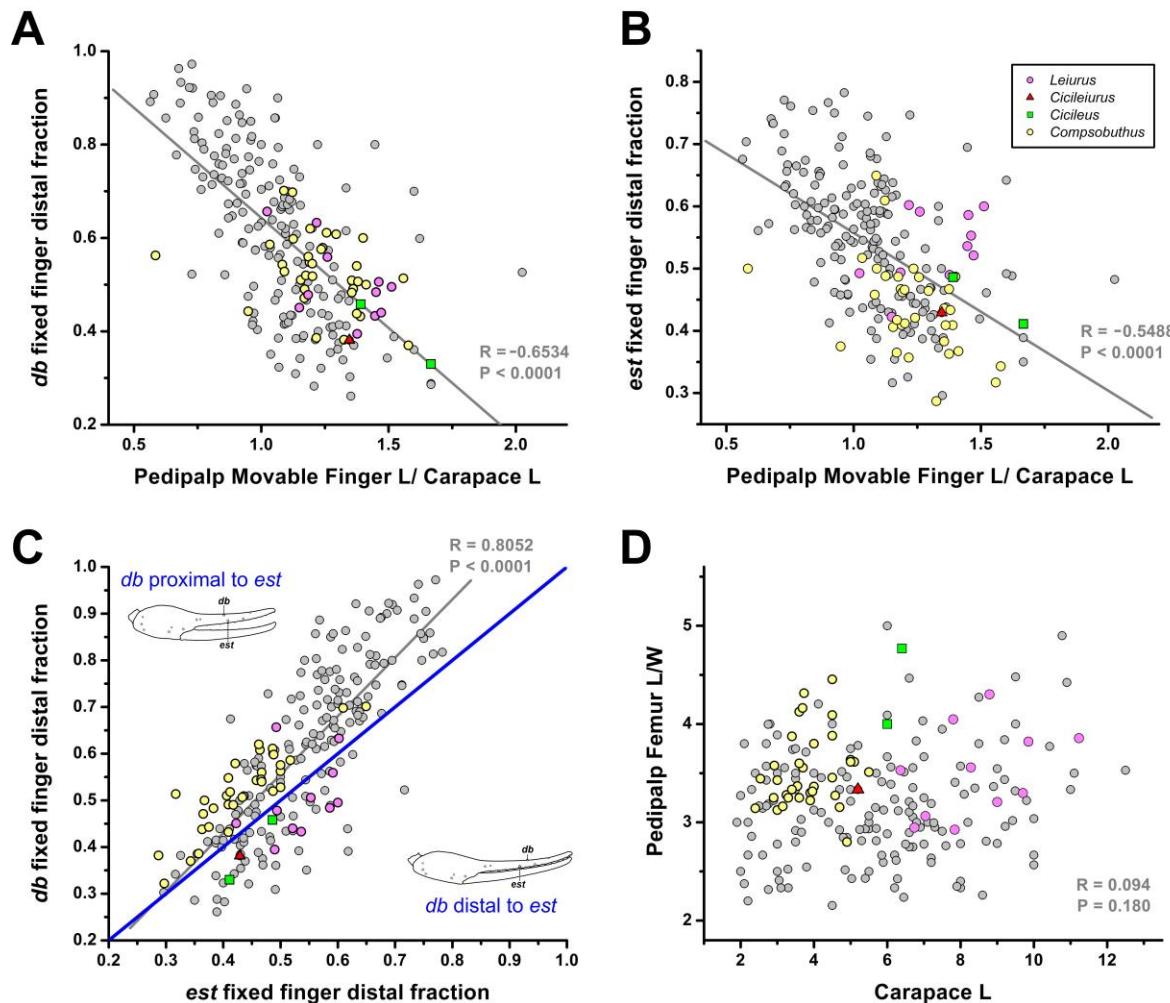


**Figure 97:** Carapace and tergites I–III of *Cicileurus monticola* Teruel, 2007, holotype female, Atlas Mountains, Morocco. Scale bar: 2 mm.

*L. haenggii* lineage, as it appears to be restricted to the Jabal Samhan mountains located at the extreme southeastern end of the montane corridor occupied by *L. haenggii* (Fig. 100). The south-facing escarpment of Jabal Samhan differs markedly from the adjacent Jabal Qara mountains that are inhabited by *L. haenggii*. It is classified geologically as a ‘type 1’ scarp, defined as one that is displaced inland from its coastal fault due to erosion, and rises steeply to a high summit (ca. 2,100 a.s.l.). Proterozoic basement rocks have been exposed on Jabal Samhan by an interplay between erosion and flexural rebound uplift of the underlying fault in response to unloading by erosion (Petit et al., 2007). Its limestone plateau is more arid, supports less stabilizing vegetation, and is incised with deeper, ravine-like wadis with vertical rock faces. In contrast, Jabal Qara is a ‘type 2’ scarp, defined as one that resides near its coastal fault and ascends more gently to a lower relief (ca. 1,000 m a.s.l.). It is more humid and vegetated, does not have basement rock outcrops, and lacks flexural rebound. These two types of scarp were shaped differently by erosion due to strong orographic precipitation driven by Southwest Monsoon winds that, at various times in the Quaternary, extended further inland than the present day circulation which deposits only fog condensate on the coastal ranges. Vertical cliffs and rocky fissures that

were exposed on Jabal Samhan provided abundant substrate favoring the evolution of lithophilous scorpion fauna such as *L. heberti* sp. n.. A similar process of speciation by stenotopic, lithophilous adaptation might also account for the restricted distribution of *L. jordanensis* which is found at the opposite, northwestern end of the Arabian Peninsula.

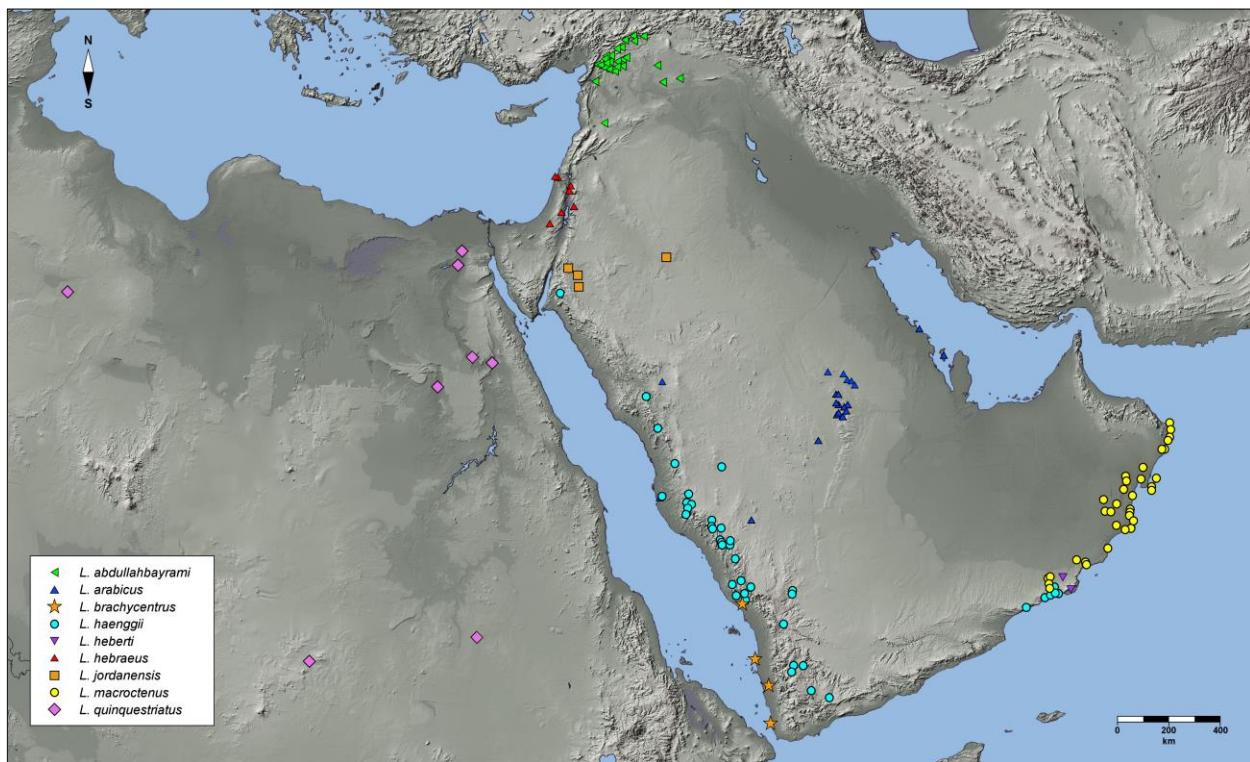
(2) *L. brachycentrus* and *L. macroctenus* are distributed along coastal zones in the southern part of the Arabian Peninsula. These ‘macrodont’ species have exceptionally large pectine teeth (in males of both species, and in females of *L. macroctenus*), a putative synapomorphy. They are isolated from each other by the Asir mountains, which suggests a vicariant splitting of populations on the Arabian Plate by rifting and uplift of the western mountain ranges during the Miocene. Alternatively, *L. brachycentrus* may have colonized the narrow Tihamah coastal plain in the late Miocene (10–5.3 Mya), well after orogenesis commenced. Around this time, it is thought that a land bridge at the south end of the Red Sea (Bab-el-Mandeb) connected the two continents, allowing dispersal of fauna from North Africa to Arabia. This hypothesis predicts that *L. brachycentrus* should have a closer affinity to *L. quinquestriatus*, than to *L. macroctenus*. The latter species probably represents an older lineage that coexisted with ancestral *L. haenggii* prior to separation of the Arabian Plate. The present day distribution of *L. macroctenus* is circumscribed by a series of vicariant barriers. Dispersal is blocked in the southwest by the Dhofar, Hadramaut and Asir mountains, in the west and northwest by the sands of the Rub’ al Khali, and in the northeast by the Al Hajar mountains and Wahiba Sands. The northwestern range of *L. macroctenus* may have been restricted during the Quaternary by the formation of the Rub’ al Khali dunes. Although *L. macroctenus* has developed psammophilous adaptations, it may have been excluded from those dunes by competition or intraguild predation from larger, more aggressive ‘ultrapsammophilous’ types of scorpions, i.e. *Apistobuthus pterygocercus* Finnegan, 1932 and *Buthacus nigroaculeatus* Levy et al., 1973, that were better adapted to the soft, fine aeolian substrates (Polis & McCormick, 1987). In the late Pleistocene and Holocene, alternating periods of hyperaridity in the Rub’ al Khali (20–10 kya, 5 kya–present) may have favored these ultrapsammophiles over *L. macroctenus*, which is mainly confined to the coastal fog deserts. On Masirah Island, *L. macroctenus* is common in dune habitats, presumably because other competing psammophilous scorpions are absent. Morphological similarity of island and mainland *L. macroctenus* populations suggests recent island colonization either by rafting, or during a glacial period of lowered sea level. The much smaller buthid scorpion, *Compsobuthus polisi* Lowe, 2001, exhibits a similar distribution and it may have dispersed



**Figure 98:** Selected morphometrics of *Leiurus*, *Cicileurus*, *Cicileus* and *Compsobuthus* compared to other *Buthus* group scorpions. **A–B.** Scatter plots of the fraction of fixed finger length distal to *db* (A) and *est* (B) vs. the ratio of movable finger length to carapace length. Each point represents one sex of one species. Larger ordinate values correspond to more basal positions of the trichobothria, and larger abscissa values to longer pedipalp fingers. There was a significant inverse correlation between relative length of the portion of the fixed finger distal to *db* and *est* ( $R = -0.6534$ ,  $-0.5488$ , respectively), and the relative length of the movable finger (the latter being a measure of elongation of both fixed and movable fingers). Highlighted symbols show that *Leiurus* (light magenta circles), *Cicileurus* (red triangle), *Cicileus* (green squares) and *Compsobuthus* (yellow circles) are located in the lower right halves of the plots, i.e. all have relatively elongated fingers and more distal placement of both *db* and *est*. Gray circles are data from other *Buthus* group species. **C.** Scatter plot of the fraction of fixed finger length distal to *db* vs. the fraction distal to *est*. The strong positive correlation ( $R = 0.8052$ ) indicates a tendency for *db* and *est* to move together towards more distal locations as the fixed finger becomes more elongated. Species above the diagonal (solid blue) have *db* proximal to *est*, and those below have *db* distal to *est*. Solid gray lines in A–C are fits by least squares regression through all points. **D.** Scatter plot of pedipalp femur L/W (a measure of pedipalp elongation) vs. carapace L (a measure of body size). These two variables were not significantly correlated ( $R = 0.094$ ). Data were compiled from the literature and specimens in the authors collections for 38 genera and 203 species representing the majority of taxa in the *Buthus* group, including both males ( $N = 124$ ) and females ( $N = 97$ ). Genera (and number of species) included: *Afghanobuthus* (1), *Androctonus* (11), *Apistobuthus* (2), *Baloorthochirus* (1), *Birulatus* (2), *Buthacus* (13), *Butheoloides* (11), *Butheolus* (5), *Buthiscus* (1), *Buthus* (26), *Cicileurus* (1), *Cicileus* (2), *Compsobuthus* (33), *Congobuthus* (1), *Darchenia* (1), *Gint* (1), *Hemibuthus* (1), *Hottentotta* (31), *Leiurus* (10), *Liobuthus* (1), *Lissothus* (3), *Mesobuthus* (7), *Neobuthus* (2), *Odontobuthus* (6), *Orthochirus* (12), *Pantobuthus* (1), *Pectinibuthus* (1), *Plesiobuthus* (1), *Polisius* (1), *Razianus* (3), *Saharobuthus* (1), *Somalibuthus* (1), *Vachoniolus* (4), *Vachonus* (1).

to Masirah in a similar timeframe. These two sympatric scorpions probably coexist by partitioning into different microhabitats and utilizing different resources.

**COMPARATIVE MATERIAL EXAMINED.** *Apistobuthus susanae*: Iran: 1 ♂, Albaji, Ahvaz-Andimeshk road, 20 km to Ahvaz, 31°20'44"N 48°38'36"E, VIII.



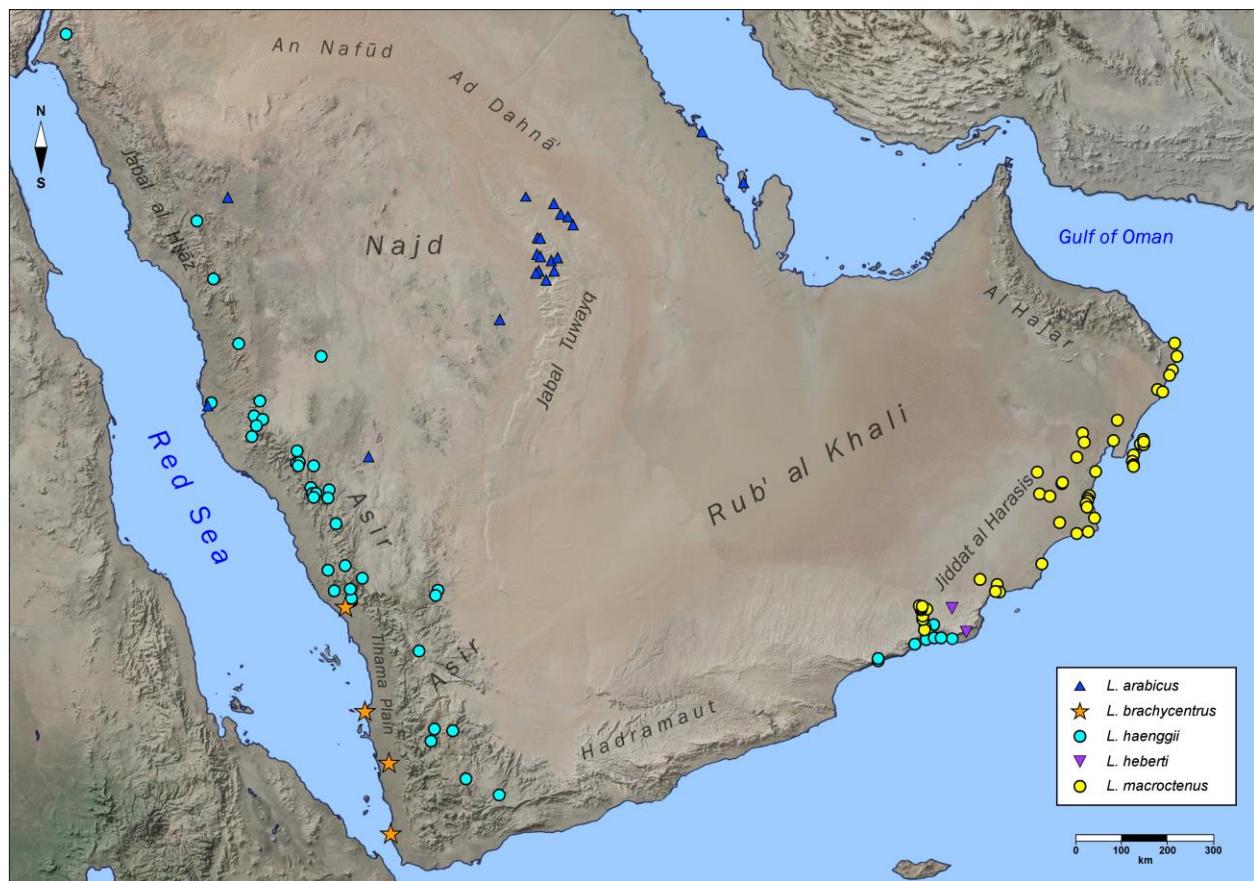
**Figure 99:** Geographic plot of locality data of material examined for nine species of *Leiurus* distributed over northeast Africa, the Levant and Arabian Peninsula. Map colored by elevation with shaded relief. Additional locality data for: *L. abdullahbayrami* from Yağmur et al., 2009; for *L. brachycentrus* Ehrenberg, 1829 stat. n., from Simon, 1882 (*Buthus beccarii*).

2005, leg. Masihipour (GL). *Compsobuthus acutecarinatus*: **Oman**: 1 ♂, Jabal Qara, Nejd Desert, wadi below Ayun, 17°13.4'N 53°54.36', 20.X.1993, leg. G. Lowe (NHMB). *Cicileus exilis*: **Algeria**: 1 ♂, Hoggar, 26.II.1993, leg. Bednář (FKCP). *Odontobuthus bidentatus*: **Iran**: 1 ♂, Omidiyah, Khoozestan Prov., 30°57' 49"N 49°31'47" E, 56 m a.s.l., leg. Hayader & Bahrani (GL). *Sassanidothus gracilis*: **Iran**: 1 ♀, 45 km to Khamir Port (Bandare Khamir), Hormozgan Prov., 26° 50'41.2"N 55°22'06.9"E, 17 m a.s.l. (Locality No. HO-153), XI.2008, leg. Masihipour, Hayder & Bahrani (FKCP). *Leiurus* sp. (insufficient material to assign to species): **Egypt**: 3 immature ♂, Sinai, leg. P. & F. Sarasin (NHMB 17b); 1 ♂, St. Caterina, 28°34.2'N 33° 56.1'E, 1650 m a.s.l., IV.1995, leg. Šlapetov & Modrý (FKCP).

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**Figure 100:** Geographic plot of locality data of material examined for five species of *Leiurus* from the Arabian Peninsula. Map colored by terrain with shaded relief, indicating major physiographic regions.

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