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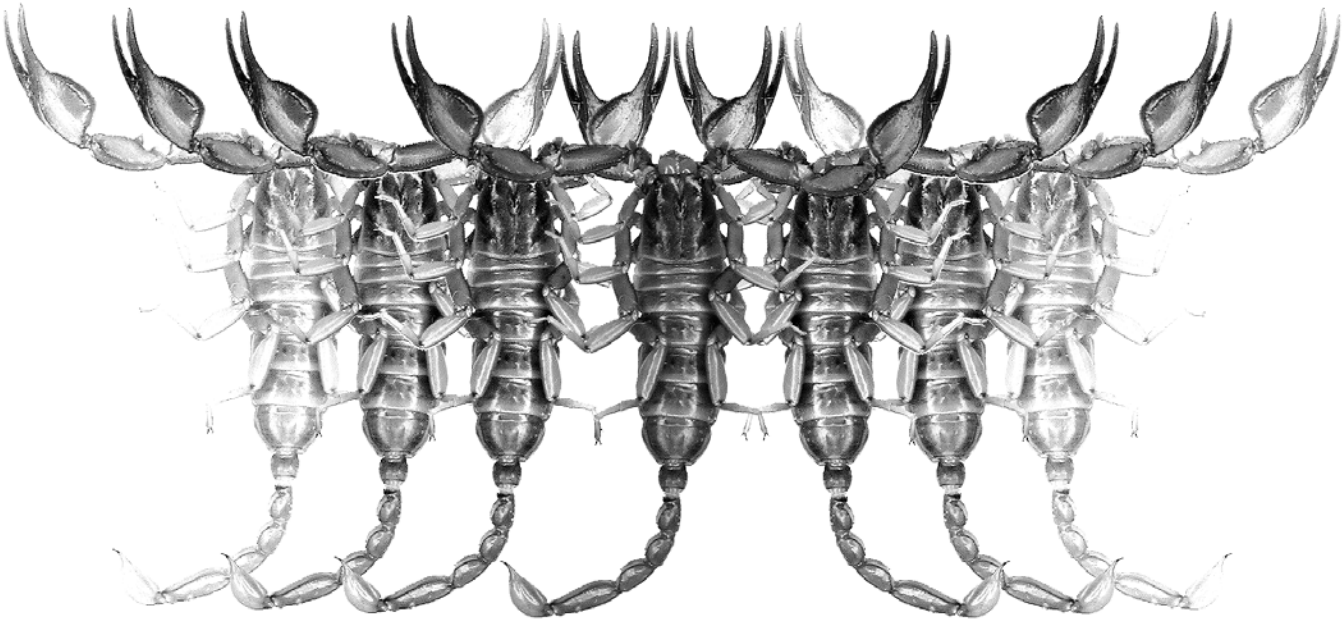

Two New *Hemiscorpius* Peters, 1861 (Scorpiones: Hemiscorpiidae) from Northern Oman

Graeme Lowe

January 2010 – No. 91

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- **MZUC**, Museo Zoologico "La Specola" dell'Universita de Firenze, Florence, Italy
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Publication date: 12 January 2010

Euscorpius — Occasional Publications in Scorpiology. 2010, No. 91

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Summary

Two new species of *Hemiscorpius*, *H. falcifer*, sp. nov. and *H. flagelliraptor*, sp. nov., are described from the Al Hajar Mountains of northern Oman. Although both are lithophilic or ultralithophilic scorpions beautifully adapted for living in rock crevices, they exhibit divergent morphologies and may not be closely related. *H. falcifer* is distinguished by: smaller size, relatively short compact metasoma, bulbous telson, relatively distal placement of lamellar double hook of hemispermatophore, pedipalp chela with wide, sub-triangular manus and exceptionally elongated fingers with single file dentition along distal half of movable finger (in adults); *H. flagelliraptor* is distinguished by: extremely elongated, sexually dimorphic metasoma, slender telson, proximal placement of lamellar double hook of hemispermatophore, slender pedipalp chela with double denticle rows along the distal half of movable finger. Although orthobothriotaxic, in other respects *H. flagelliraptor* appears most similar to the neobothriotaxic species *H. enischnochela* Monod et Lourenço, 2005 and *H. gaillardi* (Vachon, 1974) from Iran.

Introduction

The hemiscorpiines, a subfamily of Hemiscorpiidae, is a compact group of Old World katoikogenous scorpions distributed in East Africa, the Arabian Peninsula, Iraq and Iran (Fet, 2000; Soleglad, Fet & Kovařík, 2005). One member of this group, *Hemiscorpius lepturus* Peters, 1861, is well known for a potent cytotoxic venom that can cause cutaneous necrosis and severe systemic pathology (Radmanesh, 1998; Pipelzadeh et al., 2007). In their recent revision of the Iranian taxa, Monod & Lourenço (2005) recognized nine species, all placed in a single genus *Hemiscorpius* Peters, 1861. A second genus, *Habibiella* Vachon, 1974, was considered to be a junior synonym of *Hemiscorpius*. On the Arabian Peninsula, *Hemiscorpius* is poorly known. Pocock (1899a) described *H. arabicus* from Aden, Yemen, and this species or a closely related species, has also been recorded from central Saudi Arabia (Vachon, 1979; Hendrixson, 2006). Kinzelbach (1985) indicated on a stylized map that *H. arabicus* extends into the United Arab Emirates and Oman, but cited no specific records. Kraepelin (1900) described *Hemiscorpius maindroni* from Muscat, and so far this is the only species with confirmed records in Oman (Vachon, 1977). It is a common lapidicolous scorpion found in wadis in the Al Hajar Mountains of northern Oman. Here, two new species are added to the fauna of Oman. Both are sympatric with *H. maindroni* in the Al Hajar Mountains, but are segregated from that species by their specialization for lithophilic or ultralithophilic habitats.

Methods

Scorpions were collected by ultraviolet (UV) detection at night and preserved in the field by fixative injection (Williams, 1968). Locality data were recorded using Garmin portable GPS units. Specimens were examined under a dissecting microscope, either air dried or submerged in 70% isopropyl alcohol, under both white light epi-illumination and ultraviolet fluorescent illumination (Prendini, 2003; Volschenk, 2005). Photographs were taken with either a Canon EOS 40D digital camera (Figs. 1–6, 29–34), or Canon A-1 film camera (Figs. 53–56), and illustrations were rendered while viewing specimens through a drawing tube attached to a stereomicroscope (Figs. 7–28, 35–51). Measurements were made with an ocular reticule. Biometric definitions followed Lamoral (1979) and Sissom, Polis & Watt (1990), except as follows: carapace anterior width taken between most medial pair of lateral eyes; telson and vesicle lengths taken from anterior limit of vesicle, pedipalp chela length as chord length from external proximal limit of manus to fixed finger tip; pedipalp manus width and depth measured with articular condyles level; pedipalp width including dorsal patellar spur (Soleglad & Fet, 2003). The preocular length is defined as the distance from the median ocular tubercle to the anterior margin of the

carapace. Carinal terminology follows Stahnke (1970) with amendments by Prendini (2001c). Terminology of pedipalp finger proximal scalloping ("recess" and "hump") follows Levy & Amitai (1980). Formulae for telotarsal spiniform setae follows Francke (1975, 1977: 146), i.e., Pr1/Rr1 Pl1/Rl1 : Pr2/Rr2 Pl2/Rl2 : Pr3/Rr3 Pl3/Rl3 : Pr4/Rr4 Pl4/Rl4, where P = prolateral or anterior, R = retrolateral or posterior, r = right tarsus, l = left tarsus, and 1–4 denote legs I–IV. Macrosetal counts for metasomal carinae are listed in order for segments I, II, III, IV. Hemispermatophore terminology follows Lamoral (1979).

Abbreviations

Specimen depositories: NMB, Naturhistorisches Museum Basel, Basel, Switzerland; GL, personal collection of the author; ONHM, Oman Natural History Museum, Muscat, Oman; MCZ, Museum of Comparative Zoology, Harvard University, Cambridge; MZUF, Museo Zoologico "La Specola" dell'Università de Firenze, Florence, Italy; MRSN, Museo Regionale di Scienze Naturali, Torino, Italy; MNHN, Muséum National d'Histoire Naturelle, Paris, France; ZMH, Zoologisches Museum der Universität Hamburg, Hamburg, Germany; USNM, National Museum of Natural History, Washington, D.C., USA; ZISP, Zoological Institute, St. Petersburg, Russia. *Biometrics*: L, length; W, width; D, depth.

Systematics

Hemiscorpius falcifer, sp. nov.

Figures 1–26

Type material

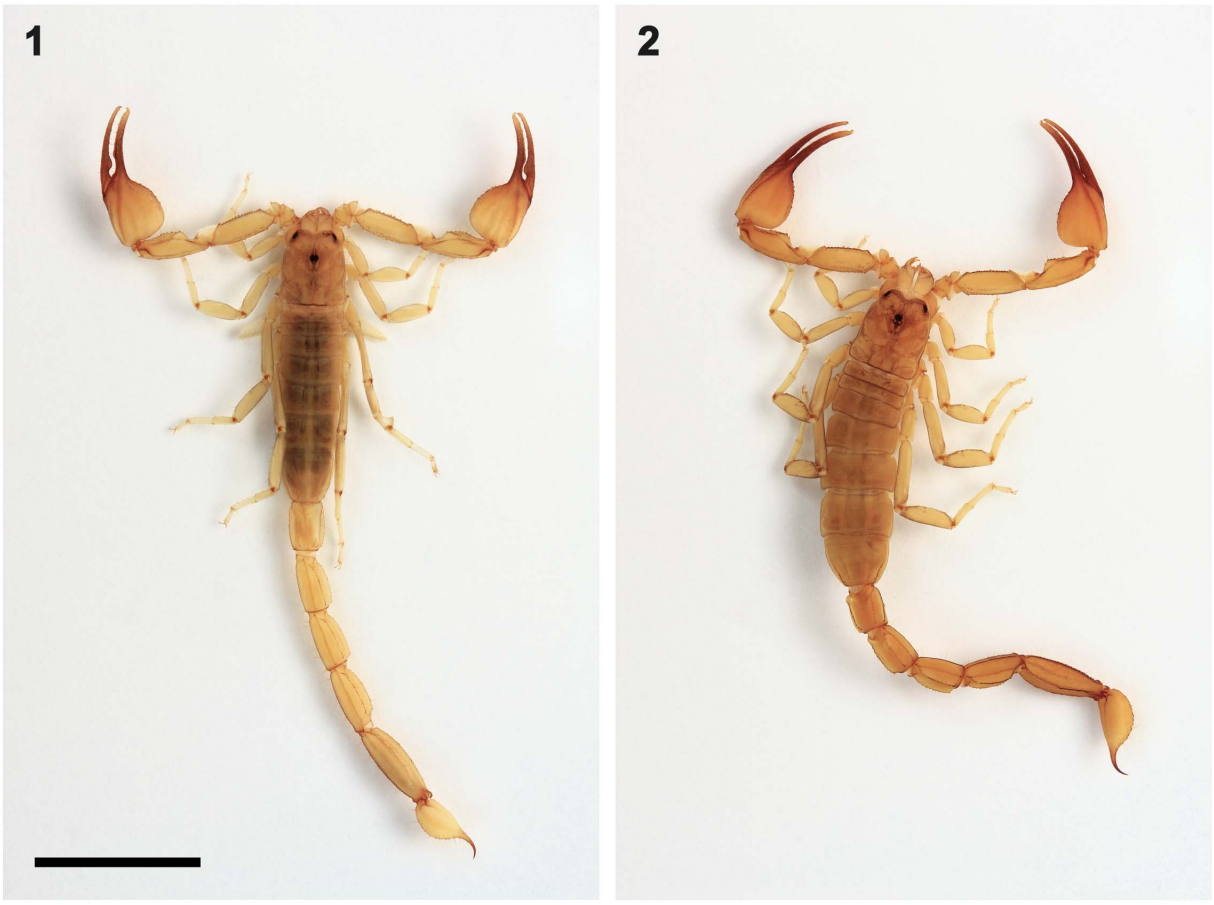
Holotype: adult ♂, **Oman,** Rte 13, between Wadi Mistal and Al Awabi, UV detection, rocky road cut, rocky cliff, 23°19.06'N 57°35.19'E, 400 m a.s.l., 26 September 1994, leg. G. Lowe & M. D. Gallagher (NMB).

Paratypes: **Oman**: 1 subadult ♂, Wadi Bani Kharus, UV detection, edge of wadi, rocky road cut, with a few trees, 23°15.09'N 57°31.07'E, 600 m a.s.l., 11 October 1993, 23:54 h, leg. G. Lowe, A. S. Gardner & S. M. Farook (ONHM); 1 ♀, Rte 13, between Wadi Mistal and Al Awabi, UV detection, on rock face, rocky cliff, road cut, 23°19.24'N 57°36.17'E, 26 September 1994, leg. G. Lowe & M. D. Gallagher (NMB); 1 ♂, near Izki, amongst rocks and spoil at side of graded track, clear moonless night, 22°53.55'N 57°47.12'E, 626 m a.s.l., 27 November 1994, 18:30–20:45 h, leg. J. Dundon (GL).

Etymology. The specific epithet derives from the Latin adjective, "*falcifer*" meaning "scythe bearing", a reference to the sickle-shaped raptorial pedipalp fingers.

Diagnosis. A member of the genus *Hemiscorpius* (Monod & Lourenço, 2005) differentiated as follows: adults up to 40 mm in length; color light tan yellow with deep reddish brown pedipalp fingers (Figs. 1–2); sternite VII with two weak carinae in male (Fig. 8), smooth in female; hemispermatophore with ental hook of distal lamina separated from capsular region by ¼ of total lamina length (Fig. 20), bearing two well developed, straight, spiniform processes of equal size (Fig. 21); dorsal carinae of metasoma I–IV with 2,2,2,2 elongate macrosetae; metasoma I with ventral median carina obsolete (Fig. 10); metasoma and telson not greatly elongated, without strong sexual dimorphism (Figs. 1–2, 10–11); adult metasomal segment L/W ratios: male: I 1.34, II 1.67, III 1.84, IV 2.4, V 3.2; female: I 1.08, II 1.37, III 1.56, IV 2.00, V 2.80; telson with slightly elongated, bulbous vesicle, slender aculeus (Figs. 10–11); pedipalp patella without external carina, with ventromedian carina (Figs. 15–16); pedipalp chela (Figs. 12–13, 18–19) with manus strongly flattened, broadened, sub-triangular, with smooth ventroexternal carina; chela fingers slender, elongated, curved; fixed finger length equal to or greater than manus length; proximal margins of pedipalp fingers deeply scalloped in males, movable finger with prominent basal hump, fixed finger with deep recess without denticles, leaving wide gap when fingers closed; dentate margin of movable finger of adults armed apically with single linear, serrate row of sharp denticles, row widening proximally into band several denticles across; apical denticle row divided into subrows by enlarged primary denticles, subrows flanked externally by single accessory denticles; internal accessory denticles numerous, irregularly spaced, not closely juxtaposed with primary denticles (Figs. 25–26); orthobothriotaxic type C (Figs. 12–19), chela manus with V_2 internal to V_1 relative to ventroexternal carina, *Dt* on base of fixed finger at proximal end of recess, *db* basal to *eb* on fixed finger; legs slender, leg III patella L/W 3.1–3.4.

Comparisons. This species is distinguished from all other known members of the genus by the unique form of the pedipalp chela, with sub-triangular manus and long slender fingers that are deeply scalloped in males, and the single file dentition on the apical margin of the pedipalp movable finger in the adult (Figs. 12–18, 25–26). In other *Hemiscorpius*, the manus is not as broad, the fingers of males are not as deeply scalloped proximally, and the movable finger of adults has two parallel linear rows of denticles. *H. falcifer* is also easily distinguished from *Hemiscorpius* species with conspicuous, sexually dimorphic elongation of the metasoma. Hemispermatophores from other species of *Hemiscorpius* differ from that of *H. falcifer* in having an ental hook located more basally on the distal lamina, with less spiniform processes, and the inner process often smaller than the outer process.



Figures 1–2: *Hemiscorpius falcifer*, **sp. nov.** Habitus viewed under reflected white light illumination in alcohol. **1.** Holotype male, dorsal aspect. **2.** Paratype female, dorsal aspect. Scale bar: 10 mm.

Description of holotype male (adult)

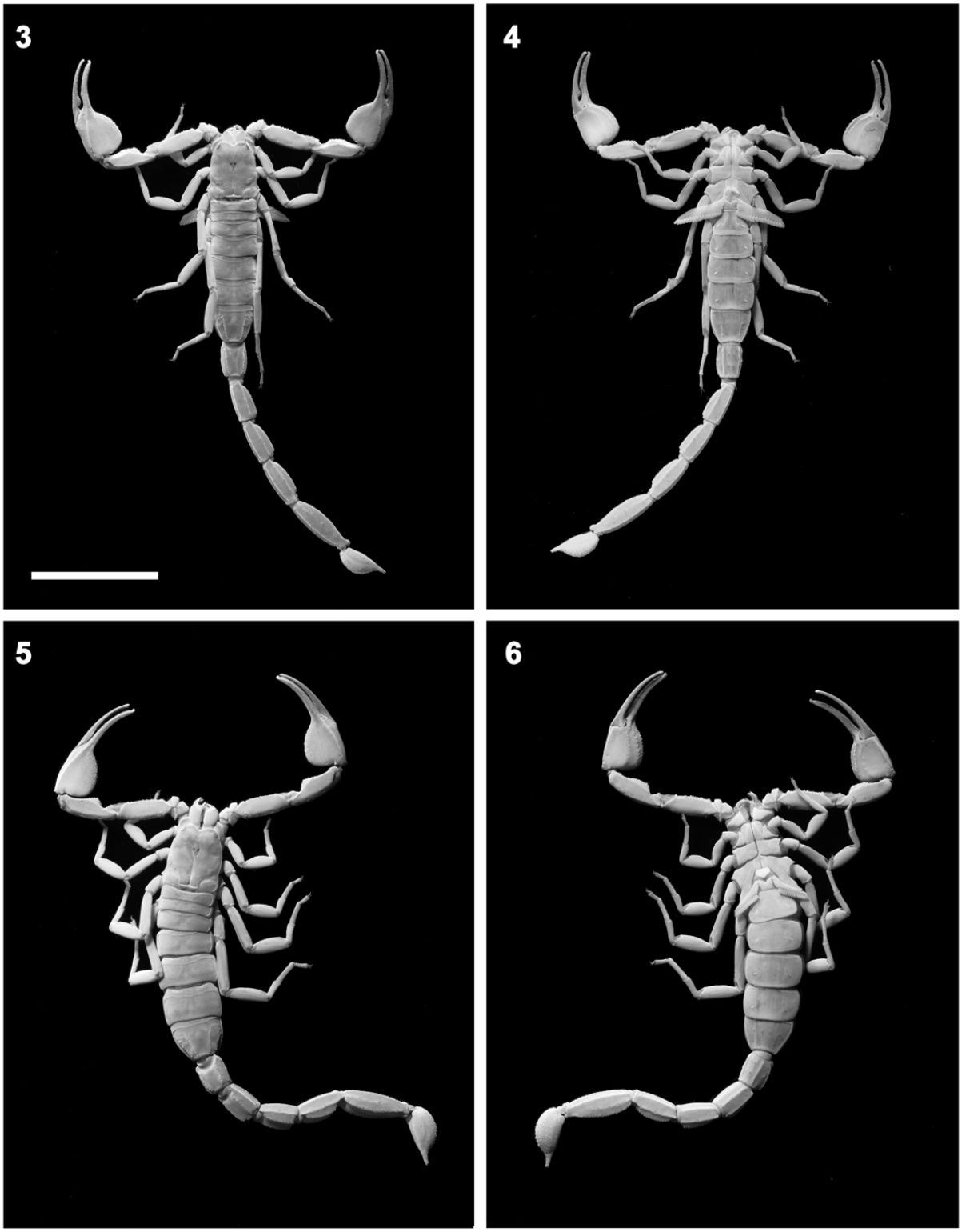
Coloration (Fig. 1). Base color uniform light tan yellow, with faint underlying pattern of dusky markings on chelicerae, carapace and tergites I–III; pedipalp fingers, articular condyles of leg segments, and aculeus of telson deep reddish brown; black pigmentation around median and lateral eyes.

Carapace (Fig. 7). Slightly elongated, 1.2 times wider than long; surface flat, densely, finely shagreened except for sulci; anterior margin bilobate with deep median emargination; lobes truncate, with obliquely linear margins bracketed by two pairs of macrosetae; lateral margins parallel, nearly straight; preocular length 0.36 times length of carapace; paired postocular macrosetae located two eye diameters behind median eyes; three lateral eyes on each side; median ocular tubercle recessed, eyes only slightly raised above surrounding surface of carapace; posterior median sulcus well developed, deeply excavated near posterior margin of carapace; posterior lateral sulci well developed.

Chelicerae (Fig. 9). Color pale yellowish, with darker reticular pigmentation on manus and fingers; denticles reddish; movable finger with 4 sharp external denticles: distal, subdistal, medial and basal; subdistal and basal denticles smaller than medial denticle; distal internal denticle about twice as large as external denticle, strongly curved; ventral margin of movable finger smooth; fixed finger armed with 4 rather slender, sharp denticles: distal, subdistal, and a basal pair fused into bicusp. *Chaetotaxy*: manus bearing 3 long reddish macrosetae near apical border; movable finger without macrosetae.

Coxosternal area (Fig. 4). Coxae smooth, lustrous, with few marginal macrosetae; coxae II–IV with fine, weak granulation on anterior margins; sternum wide, pentagonal, with deep posteromedian sulcus, bearing one pair of macrosetae; genital opercula divided, triangular; genital papillae present.

Mesosoma. *Tergites* (Fig. 3): all pretergites with surfaces sparsely, finely shagreened, almost smooth;



Figures 3–6: *Hemiscorpius falcifer*, **sp. nov.** Habitus viewed under ultraviolet fluorescence. **3.** Holotype male, dorsal aspect. **4.** Holotype male, ventral aspect. **5.** Paratype female, dorsal aspect. **6.** Paratype female, ventral aspect. Scale bar: 10 mm.

median border straight on pretergite I, convex on pretergites II–VI, straight on pretergite VII; tergites I–VI without carinae, surfaces densely, finely shagreened except for bilateral oval patches near anterior margin;

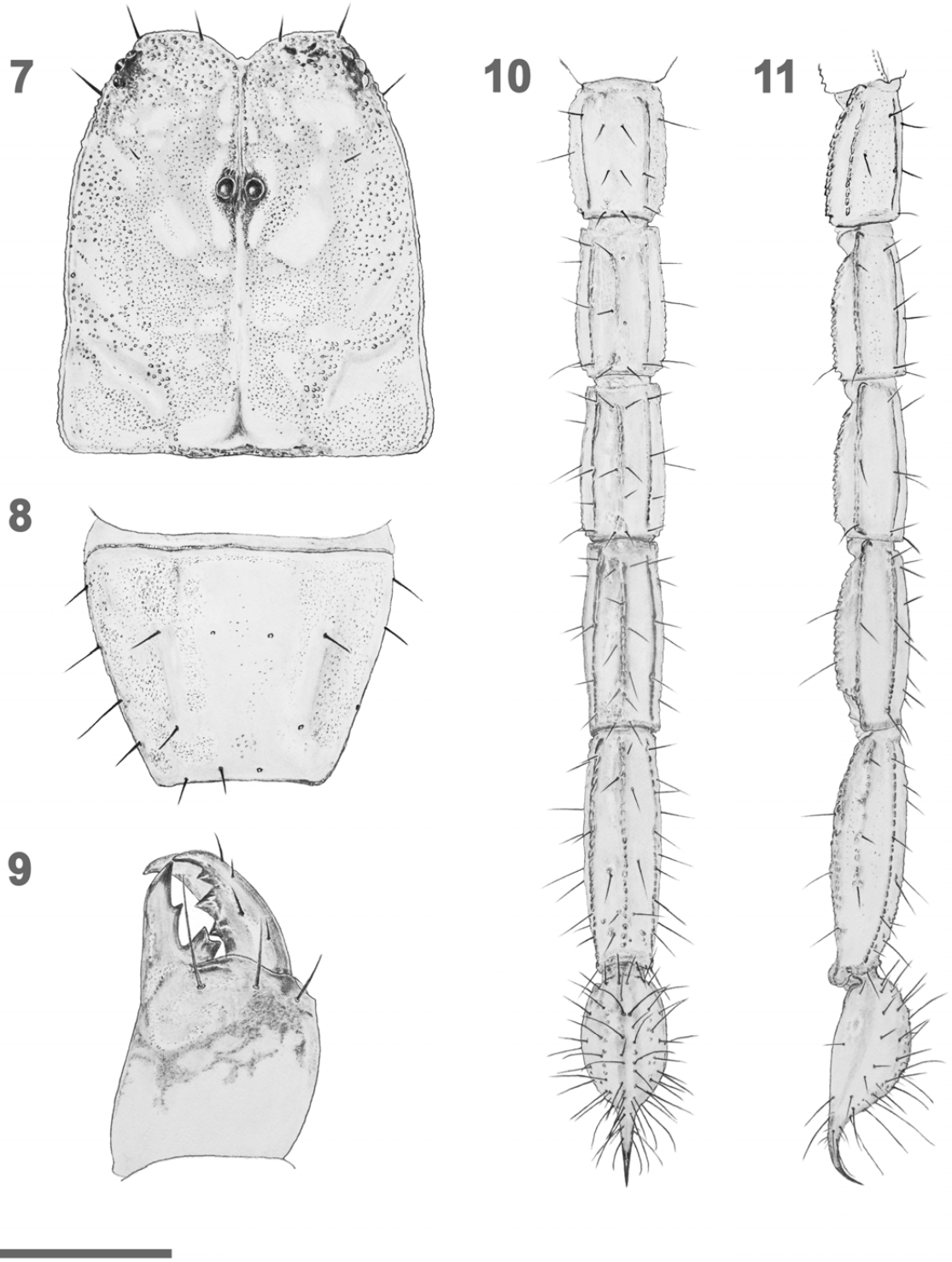
tergites I–II convex, tergites III–V laterally convex with flat medial depression, tergite VI with weak median hump on flat medial depression; tergite VII with larger median hump, and two pairs of strong, crenulated longitudinal carinae, each bearing a single posterior macroseta; lateral surfaces between carinae with coarse irregular granulation, posterior medial surface between carinae forming concave depression; dorsal hump of tergite VII extending over posterior 4/5 of segment, lateral carinae confined to posterior half of segment, breaking up into irregular granulation anteriorly. *Sternites* (Figs. 4, 8): sternite III smooth, lustrous in convex medial area, very minutely shagreened on concave lateral areas; IV–VI smooth, lustrous, with numerous minute punctuations on medial and posterior surfaces; lateral and anterolateral areas finely roughened; sternite VII (Fig. 8) with pair of weak, smooth, polished lateral carinae on posterior 3/5 of segment, bearing two macrosetae; medial surface between carinae smooth, minutely punctuate, with two pairs of macrosetae; lateral surfaces densely, finely roughened or shagreened, concave on posterior half. *Pectines* (Fig. 4): tips extending to distal ends of trochanter IV; pectine teeth, left 16, right 15; combs with three marginal lamellae, extended basal middle lamella, and four smaller elongate ovoid middle lamellae; basal middle lamella with medial border about twice as long as width of basal marginal lamella; basal piece of pectines divided anteriorly into two convex halves by a deep anteromedian invagination, posterior border essentially straight.

Hemispermatophore (Figs. 20–22). Lamelliform, distal lamina with ental hook bearing two prominent, straight, narrow spiniform processes of equal size; above hook, distal lamina long, basally narrow with apical portion widened, spatulate, terminating in straight distal crest; below hook, distal lamina wider and shorter, comprising about 1/4 of total length of lamina; capsular region complex, with distinct lamella and distal, basal, proximal and accessory lobes; distal lobe strongly curved at apex.

Metasoma (Figs. 10–11). Segment I with 6 carinae, ventromedian carina obsolete; segments II–IV with 7 carinae; dorsosubmedian carinae on I–IV strongly developed, granulate or crenulate; dorsolateral carinae strongly developed, smooth to weakly crenulate on I–III, smooth on IV; ventrolateral carinae strong, smooth on I–III, smooth with weak posterior granulation on IV; ventromedian carina obsolete on I, very weak and smooth on II–III, moderate and smooth to weakly crenulate on IV; metasoma V with 5 carinae: median lateral carinae moderate, weakly crenulate or granulate; ventrolateral carinae strong, crenulate, ventromedian carina strong, weakly crenulate to granulate; intercarinal surfaces of all segments concave, smooth, matte; dorsal surfaces distinctly concave and excavated; metasoma V with ventral surface having few scattered granules associated with macrosetae; lower lateral surface of V smooth, upper lateral surface finely shagreened. *Chaetotaxy*: all metasomal segments with long, reddish macrosetae; I–IV with 2 pairs of macrosetae on dorsosubmedian carinae, 3 pairs on dorsolateral carinae; ventrolateral carinae with 3 pairs of macrosetae on I–II, 4 pairs on III–IV; ventromedian carina flanked by paired macrosetae: 3 pairs on I, 3 pairs plus 1 unpaired on II–III, 4 pairs plus 2 unpaired on IV; metasoma V with 3 pairs of macrosetae on dorsolateral carinae, 2 or 3 macrosetae on lateral row of granules, 6 or 7 on ventrolateral carinae, 4 pairs on ventral surface; two additional long macrosetae on ventral anal arc.

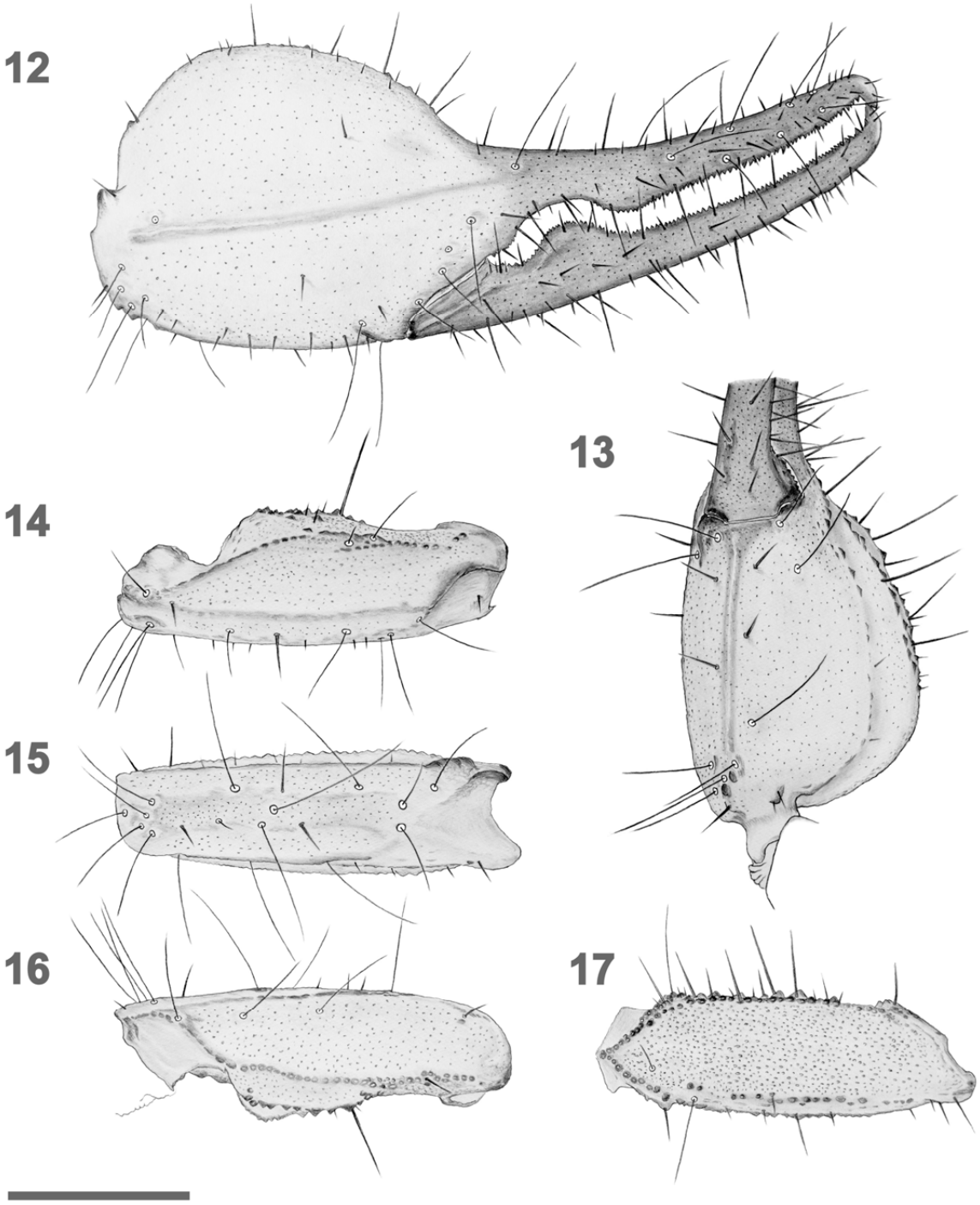
Telson (Figs. 10–11). Vesicle ovoid, moderately bulbous, clearly wider than metasoma V; vesicle smooth dorsally, with weakly convex lateral surfaces separated by a shallow median trough; macrosetae absent on dorsal surface; lateral surface smooth of vesicle smooth, ventral surface coarsely granular; ventral and lateral surfaces, and base of aculeus bearing numerous long reddish macrosetae, interspersed with white microsetae; total of 62 macrosetae mostly arranged bilaterally into four longitudinal series: 23 ventromedian (9 pairs, 5 unpaired), 17 ventrolateral (7 pairs, 3 unpaired), 16 lateral (8 pairs) and 6 lateral (3 pairs); aculeus with straight basal section, curved distal section terminating perpendicular to dorsal plane of vesicle.

Pedipalp (Figs. 12–17, 19, 25–26). *Femur* (Fig. 17): 3.0 times longer than wide, tricarinate, with dorsoexternal, dorsointernal and ventrointernal carinae well developed, granulose; external surface strongly convex with irregularly arrayed large granules; femur densely, finely shagreened, internal surface studded with 10 enlarged reddish granules and several smaller granules, bearing several short or long reddish macrosetae associated with enlarged granules (7 setae on left femur, 8 on right); dorsal surface without granules, ventral surface without granules except for basal group of several very weak granules; trichobothria *e* and *i* ringed by granules. *Patella* (Figs. 14–16): 2.7 times longer than wide, with 5 strong carinae; dorsoexternal and ventroexternal carinae smooth, dorsointernal and ventrointernal carinae coarsely granular; ventrointernal carina prominent with large granules or crenulations; ventromedian carina weaker with smaller granules; external carina absent; dorsal and ventral surfaces of patella smooth to minutely shagreened, external surface smooth, with lustrous, micropunctuated central strip; internal surface densely shagreened; dorsal and ventral patellar spurs rudimentary, blunt and rounded, studded with cluster of granules, lacking macrosetae; ventrointernal carina with 3 reddish macrosetae. *Chela* (Figs. 12, 13, 19): flattened,



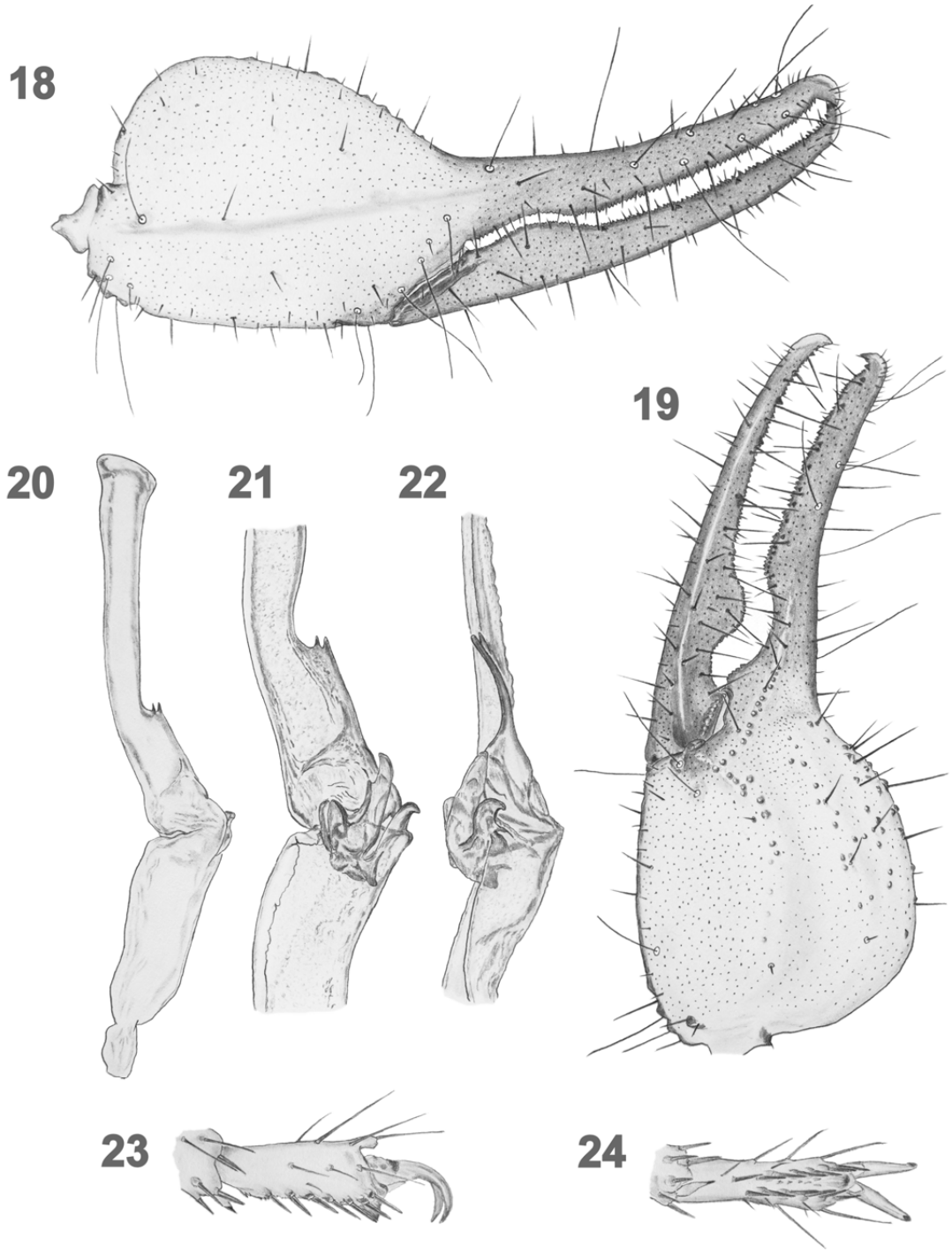
Figures 7–11: *Hemiscorpius falcifer*, **sp. nov.** Holotype male. **7.** Carapace. **8.** Sternite VII. **9.** Right chelicera, dorsal aspect (for clarity, internal brush of macrosetae not shown). **10.** Metasoma and telson, ventral aspect. **11.** Metasoma and telson, right lateral aspect. Scale bar: 7, 8: 2 mm; 9, 1 mm; 10, 11: 4.17 mm.

with greatly expanded sub-triangular manus, long curved fingers, movable finger 1.6 times longer than manus ventral length; digital and ventroexternal carina strongly developed on manus, smooth, lustrous; on fixed finger, digital carina weak, only visible proximally; other carinae obsolete, positions of ventrointernal and inner



Figures 12–17: *Hemiscorpius falcifer*, **sp. nov.** Holotype male. **12.** Right pedipalp chela, external aspect. **13.** Right pedipalp chela, ventral aspect of manus. **14.** Right pedipalp patella, dorsal aspect. **15.** Right pedipalp patella, external aspect. **16.** Right pedipalp patella, ventral aspect. **17.** Right pedipalp femur, dorsal aspect. Scale bar: 2 mm.

accessory carinae marked by series of enlarged polished granules; dorsointernal aspect of manus with scattered coarse granules; intercarinal surfaces smooth, lustrous, micropunctuated; pedipalp fingers slender, curved, conspicuously scalloped at base, proximal fixed finger with a deep, arcuate recess opposed by a prominent, lobate basal hump on movable finger; dentate margin of movable finger forming minor hump just distal to recess; when tips of fingers are closed, dentate margins separated along their whole length by gap, widest prox-



Figures 18–24: *Hemiscorpius falcifer*, **sp. nov. 18.** Paratype female, right pedipalp chela, external aspect. **19–24**, holotype male. **19.** Right pedipalp chela, ventrointernal aspect. **20.** Right hemispermatophore, dorsal aspect. **21.** Left hemispermatophore, capsular region, ventral aspect. **22.** Left hemispermatophore, capsular region, ental aspect. **23.** Right telotarsus III, retrolateral aspect. **24.** Right telotarsus III, ventral aspect. Scale bar: 18, 1.87 mm; 19: 2 mm; 20, 1.04 mm; 21, 22: 0.71 mm; 23, 24: 0.86 mm.

imally between hump and recess; both chela fingers with abundant long, reddish macrosetae radiating orthogonal to axis of finger, and small, white microsetae. *Finger dentition* (Figs. 25–26): dentate margins on distal half of both fingers armed with single linear row of sharp, serrate primary denticles; linear row resolved into sub-

rows, separated by slightly enlarged primary denticles each flanked by enlarged external accessory denticle (3 subrows plus compound proximal row on fixed finger, 4 subrows plus compound proximal row on movable finger); compound denticle row widened on proximal half of both fingers into strip of parallel, intercalated series of denticles, up to 5 denticles wide on basal hump of movable finger; dentition absent on recess of fixed finger, present as single row on small hump just proximal to recess; primary denticle counts of distal subrows on left movable finger, from distal to proximal (excluding enlarged primary denticles): 4, 7, 7, 10; left fixed finger: 10, 8, 7; fixed and movable fingers with internal accessory denticles of variable size ranging from small denticles to enlarged sharp, conical teeth, irregularly arranged apically, absent from proximal scalloped margin; fixed finger with 12 internal accessory denticles including 5 larger denticles adjacent to insertion sockets of long reddish macrosetae, movable finger with 15 internal accessory denticles, including 6 adjacent to macrosetae; near basal hump internal accessory denticles blend with multiple rows of primary denticles; tips of both fingers terminating in conspicuously enlarged tooth with milky whitish apical cap, fixed finger with external subdistal groove receiving tooth on movable finger; fixed finger with single enlarged subdistal internal denticle, movable finger with 2 subdistal internal denticles.

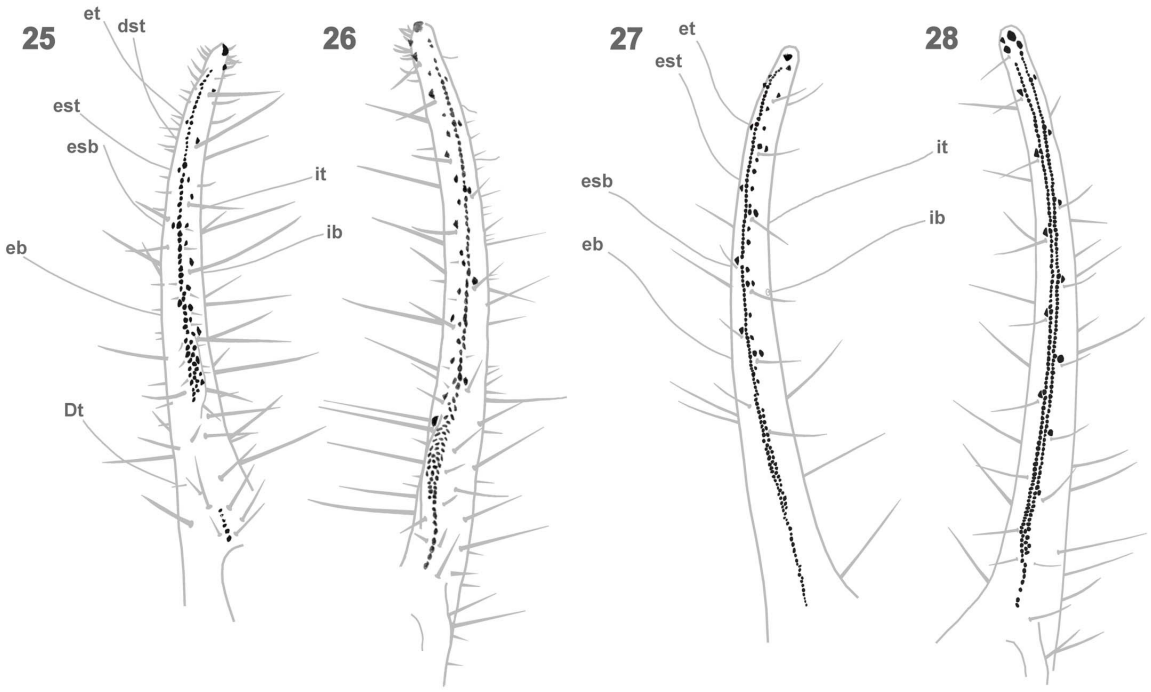
Trichobothrial pattern (Figs. 12–17, 25). Orthobothriotaxic, type C (Vachon, 1974); patella with trichobothria d_2 and *i* positioned close together along dorsointernal carina; external surface of patella with esb_2 slightly proximal to esb_1; chela manus with V_2 internal to V_1 relative to axis of ventroexternal carina; *Dt* positioned on base of fixed finger at proximal end of recess; dorsal and external trichobothria of fixed finger placed distal to recess, *db* proximal to *eb*; *ib* and *it* on distal half of fixed finger.

Legs (Figs. 1, 3–4, 23–24). Thin, moderately elongate, laterigrade; basitarsi with series of several long reddish macrosetae on dorsal and ventral margins; dorsal, prolateral and retrolateral surfaces of telotarsi with long setae; soles of telotarsi with two parallel ventral rows of long, thickened, apically directed, reddish spiniform setae, with setation formula: 4/6 4/5: 5/6 5/6: 6/7 6/7: 7/7 6/7; ungues stout, curved.

Measurements of holotype male (mm). Total L 40.00; carapace L 4.58, W 3.83; preocular L 1.67; pectine L 4.00; hemispermatophore hook notch to median transverse cleavage 1.02, hook notch to distal crest 1.61, median transverse cleavage to basal cleavage 2.22; metasoma and telson L 24; metasoma I L 2.92, W 2.17; metasoma II L 3.33, W 2.00; metasoma III L 3.46, W 1.88; metasoma IV L 4.17, W 1.75; metasoma V L 5.50, W 1.71; telson L 4.67, vesicle W 1.96, D 1.67; pedipalp femur L 4.33, W 1.42; pedipalp patella L 4.29, W 1.58; pedipalp chela L 8.34, chela manus ventral L 3.44, manus L 4.17, chela W 2.75, chela D 2.63, fixed finger L 4.38, movable finger L 5.50. *Selected morphometric ratios*: carapace W/L 0.84, pedipalp femur L/carapace L 0.94, pedipalp femur L/W 3.05, pedipalp patella L/W 2.72, pedipalp movable finger L/chela manus ventral L 1.60, pedipalp movable finger L/carapace L 1.20, pedipalp chela L/W 3.03, pedipalp chela manus ventral L/chela W 1.25, manus L/W 1.52, patella III L/W 3.27, metasomal segment L/W: I 1.35, II 1.67, III 1.84, IV 2.38, V 3.22.

Paratype female (adult). (Figs. 2, 5–6, 18). Similar to holotype male, but differs as follows: carapace and tergites slightly wider; tergites smoother, lustrous; lateral carinae of tergite VII less crenulated; sternite VII smooth, lateral carinae obsolete; pectines smaller, shorter, marginal tips extending only to basal ¼ of trochanter IV; pectine teeth: left 14, right 14; combs with extended basal middle lamella, six small, round middle lamellae; basal middle lamella with medial border over three times as long as width of basal marginal lamella, forming more oblique angle with margin; genital opercula fused into cordate plate without median suture; metasomal segments slightly less elongate, telson vesicle slightly more elongate; vesicle with coarse ventral granulation more clearly arranged as pair of ventromedian rows bearing macrosetae, and ventrolateral granules; pedipalps with slightly heavier carination, chela with manus less expanded; scalloping at base of fingers much weaker with low basal hump, shallow recess; some primary denticles present on margin of recess; when tips of fingers closed, only narrow gap remaining between hump and recess, widening distally; telotarsal spiniform seta formula: 5/6 4/6: 5/6 5/6: 6/7 6/7: 6/8 6/8.

Measurements of paratype female (mm). Total L 39.5; carapace L 4.83, W 4.25, preocular L 1.75; pectine L 2.88; metasoma I L 2.52, W 2.33; metasoma II L 2.88, W 2.10; metasoma III L 3.13, W 2.01; metasoma IV L 3.71, W 1.88; metasoma V L 5.25, W 1.88; telson L 5.29, vesicle W 2.08, D 1.81; pedipalp femur L 4.38, W 1.42; pedipalp patella L 4.50, W 1.67; pedipalp chela L 8.69, chela manus ventral L 3.44, chela W 2.46, chela D 2.35, fixed finger L 4.58, movable finger L 5.63. *Selected morphometric ratios*: carapace W/L 0.88, pedipalp femur L/carapace L 0.91, pedipalp femur L/W 3.09, pedipalp patella L/W 2.70, pedipalp movable finger L/chela manus ventral L 1.64, pedipalp movable finger L/carapace L 1.17, pedipalp chela L/W 3.53, pedipalp chela manus ventral L/chela W 1.40, manus L/W 1.76, patella III L/W 3.15, metasomal segment L/W: I 1.08, II 1.37, III 1.56, IV 1.97, V 2.79.



Figures 25–28: Pedipalp chela finger dentition of new *Hemiscorpius* species. **25–26**, *Hemiscorpius falcifer*, **sp. nov.**, holotype male. **25.** Fixed finger. **26.** Movable finger. 27–28, *Hemiscorpius flagelliraptor*, **sp. nov.**, holotype male. **27.** Fixed finger. **28.** Movable finger. Positions of visible trichobothria are indicated on fixed fingers.

Variation. Two smaller paratype males (Izki: total L 32 mm; Wadi Bani Kharus: total L 34 mm) are likely to be subadults. They are similar to the holotype adult male, with conspicuous scalloping of pedipalp fingers. They differ as follows: pedipalp fingers shorter relative to manus; small internal accessory denticles and granules more numerous and dense on apical portion of fixed and movable fingers, in the Wadi Bani Kharus specimen forming a secondary linear internal row; fixed finger lacking dentition on margin proximal to recess, small proximal hump weak or absent; Wadi Bani Kharus specimen with transverse row of 7 granules along posterior margin of tergite VII, between median carinae, and telson vesicle narrower than metasoma V; in both paratype males, all metasomal segments are less elongate than those of the holotype. Morphometric ratios of paratype males: pedipalp femur L/carapace L 0.87–0.91, pedipalp movable finger L/chela manus ventral L 1.28–1.48, pedipalp movable finger L/carapace L 1.05–1.11, pedipalp chela L/W 2.83–2.90, telson vesicle W/ metasoma V W 0.92–1.14; metasomal segment L/W: I 1.08–1.15, II 1.22–1.39, III 1.39–1.52, IV 1.78–2.00, V 2.44–2.87. Telotarsal setation: 4–5/5–6: 5/6: 5–6/6: 5–6/6–7.

Distribution (Fig. 57). Known only from wadis and foothills of the Al Hajar Al Gharbi, the western Al Hajar Mountains of northern Oman.

Ecology. All known specimens were collected by ultraviolet detection at night from very rocky habitats at low elevation (< 700 m a.s.l.) below Jabal Akhdar (Fig. 56). The holotype was taken off the bare rock face of a road cut, and was capable of rapid locomotion on the rock surface. Ultralithophilic specializations of *Hemiscorpius falcifer* include dorsoventral compression of the body, long laterigrade legs, and tenuous, elongated pedipalp fingers with serrate dentition and enlarged apical teeth. The fingers are more relatively more elongated than those of all other known species of *Hemiscorpius* (Fig. 52). Other scorpions found at or near the type locality included *Hemiscorpius flagelliraptor*, sp. nov., *Hemiscorpius maindroni*, *Hottentotta jayakari* (Pocock, 1895), *Compsobuthus nematodactylus* Lowe, 2009, *Compsobuthus maindroni* (Kraepelin, 1900), and *Orthochirus glabrifrons* (Kraepelin, 1903).

Hemiscorpius flagelliraptor, sp. nov.

Figures 27–51, 53–54

Type material

Holotype: adult ♂, **Oman**, Route 13, between Wadi Mistal and Al Awabi, UV detection, vertical escarpment of rocky road cut fractured into large blocks, resting stationary in crevice, 23°19.24'N 57°36.17'E, ca. 450 m a.s.l., 26 September 1994, leg. G. Lowe & M. D. Gallagher (NMB).

Paratypes: **Oman**: 1 adult ♀, Musandam Peninsula, mountain road south of Khawr Najd, UV detection, rocky road cut, stationary in crevice, 26°05.26'N 56°19.42'E, 245 m a.s.l., 30 September 1994, leg. G. Lowe (NMB); 1 immature ♂, Jabal Bani Jabir, rocky plateau, UV detection, on bare rock by burial tower, 22°49.6'N 59°01.59'E, 1640 m a.s.l., 14 September 1995, 19:40 h, leg. G. Lowe, M. D. Gallagher & J. Dundon (ONHM); 1 immature ♂, Wadi Bani Awf, UV detection, steep rocky slope, in crevice between big boulders, 23°14.15'N 57°26.74'E, ca. 638 m a.s.l., 29 December 2001, 19:00–21:00 h, leg. A. Winkler (NMB).

Etymology. The specific epithet is a combination of Latin nouns, "*flagellum*", referring to the long, whip-like metasoma, and "*raptor*" meaning a predator or robber.

Diagnosis. A member of the genus *Hemiscorpius* (Monod & Lourenço, 2005) differentiated as follows: large scorpions, adults up to 90 mm in length, body strongly compressed dorsoventrally; base color light yellow to brownish yellow with dark reddish brown to black pedipalp fingers (Figs. 29–30, 53–54); carapace and tergites pale, or with pattern of dusky markings; sternite VII with two strong carinae (Fig. 36); hemispermatophore with ental hook of distal lamina separated from capsular region by 1/6 of total lamina length (Fig. 49), bearing large outer process, very small inner process (Fig. 51); dorsosubmedian carina of metasoma I–IV with 0–1,1,1–2,2–3 long macrosetae; metasoma I with well developed ventromedian carina (Fig. 38); metasoma and telson long, slender, with strong sexual dimorphism, extremely elongated in males (Figs. 38–40); adult metasomal segment L/W ratios: male: I 3.76, II 5.03, III 5.44, IV 6.65, V 6.96; female: I 2.40, II 2.91, III 3.30, IV 3.98, V 4.84; telson vesicle of male posteriorly truncate, slightly bilobate, aculeus short, stout (Fig. 38); pedipalps slender, adult morphometrics: femur L/W 3.8–4.0, patella L/W 3.1–3.3, chela L/W 3.8–4.7; patella with strong external carina, weak ventromedian carina (Figs. 44–45); chela manus with granular ventroexternal carina (Fig. 42); chela fingers slender, fixed finger almost the same length as manus (Fig. 41); base of chela fingers weakly scalloped, without gap when fingers closed (Fig. 41); dentate margin of movable finger with two parallel linear rows of sharp conical denticles, partially merging at proximal scallop (Fig. 28); denticle rows divided into eight subrows by slightly enlarged primary denticles, flanked by external and internal accessory denticle; orthobothriotaxic type C (Figs. 41–46), chela manus with V_1 and V_2 equidistant from ventroexternal carina, *Dt* positioned well forward on fixed finger, distal to recess; fixed finger *db* slightly distal to *eb*; legs elongate, leg III patella length/width 3.5–3.9.

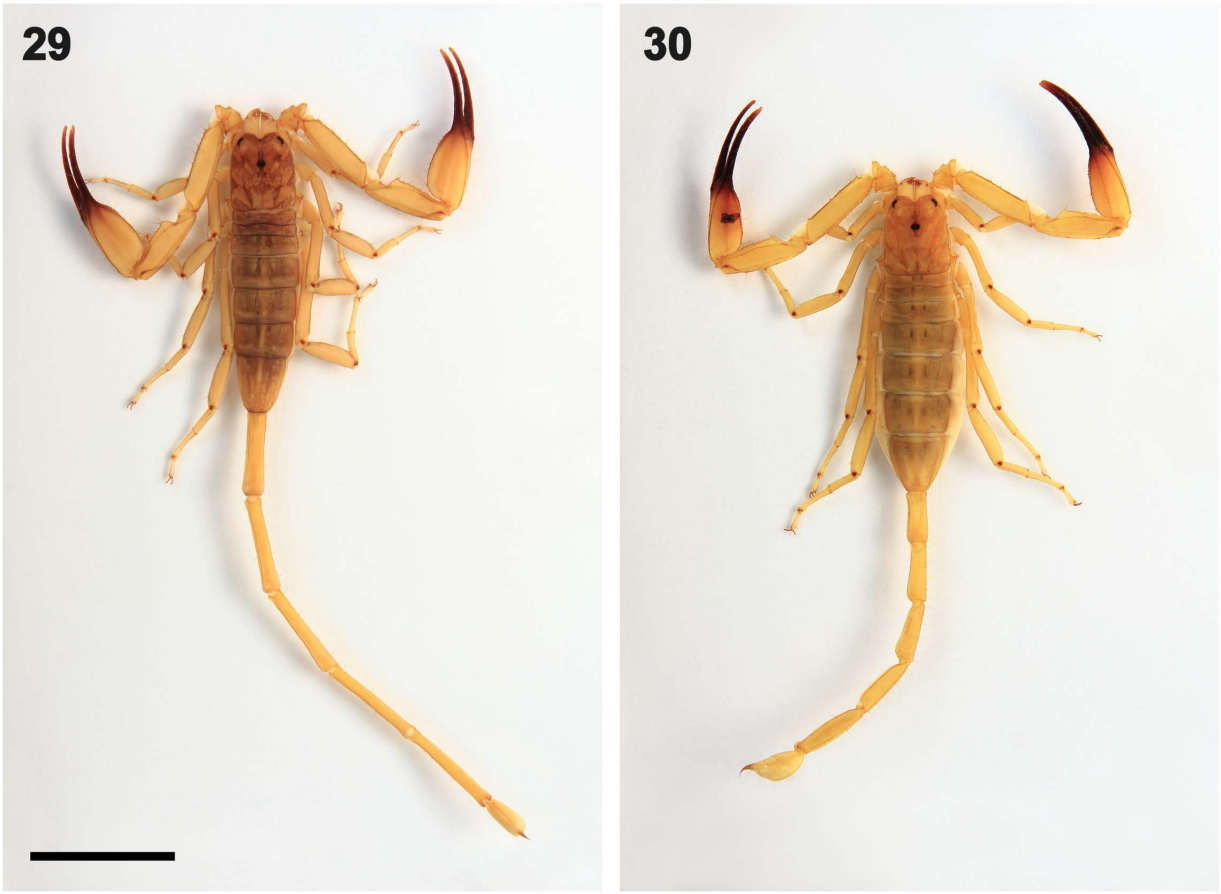
Comparisons. In body form, *H. flagelliraptor* is most similar to *H. enischnochela* Monod et Lourenço, 2005 from Iran. Both are relatively large species with slender pedipalps and a highly elongated metasoma with pronounced sexual dimorphism (Figs. 29–34). Another species from Iran, *H. gaillardi* (Vachon, 1974), also has slender pedipalps and a long metasoma, although the male is unknown. All three species share a strongly developed granular external carina on the pedipalp patella (Fig. 44). However, both of the Iranian species are differentiated from *H. flagelliraptor* by neobothriotaxy of the pedipalp patella (14–15 external, 10-12 ventral trichobothria). Other species exhibiting metasomal elongation with strong sexual dimorphism are *H. lepturus* Peters, 1861, *H. acanthocerus* Monod et Lourenço, 2005, and *H. maindroni* Kraepelin, 1900). However, these species are smaller, their metasomal segments less elongate, their pedipalps much shorter, and the external carina of the pedipalp patella is much weaker, smooth or obsolete.

Description of holotype male (adult)

Coloration (Fig. 29, 53–54). Base color brownish yellow, with pattern of underlying dusky markings on carapace and tergites; traces of dusky markings on legs; pedipalp fingers deep reddish brown to black, with pale milky apical caps on tips; reddish brown color extending onto distal part of manus, including carinae; articular condyles on legs and aculeus of telson reddish brown; all macrosetae dark reddish color.

Carapace (Fig. 35). Rectangular, parallel-sided, medially flat with shallow sloping lateral flanks; surface matte, densely shagreened or finely granulose, except for smooth patches posteromedial to lateral eyes and around posterior median and posterior lateral sulci; anterior margin bilobate, margins of lobes truncate, obliquely linear; 3 macrosetae on each lobe, plus 2 macrosetae on anterolateral margin under each set of three lateral eyes; additional paired macrosetae on top of carapace, behind interocular triangle and behind median eyes; preocular length 0.38 times length of carapace; median ocular tubercle recessed, eyes only slightly raised above surrounding carapace; three lateral eyes on each side; anterior median sulcus a fine groove, anteriorly bifurcated, extending posteriorly over median ocular tubercle between pair of granular superciliary carinae; central median sulcus shallow; posterior median sulcus deep, narrow.

Chelicerae (Fig. 37). Color pale yellow, with reddish denticles; movable finger with 4 robust external denticles: distal, subdistal, medial and basal; subdistal and basal denticles smaller than medial denticle; distal internal denticle less than twice as large as external

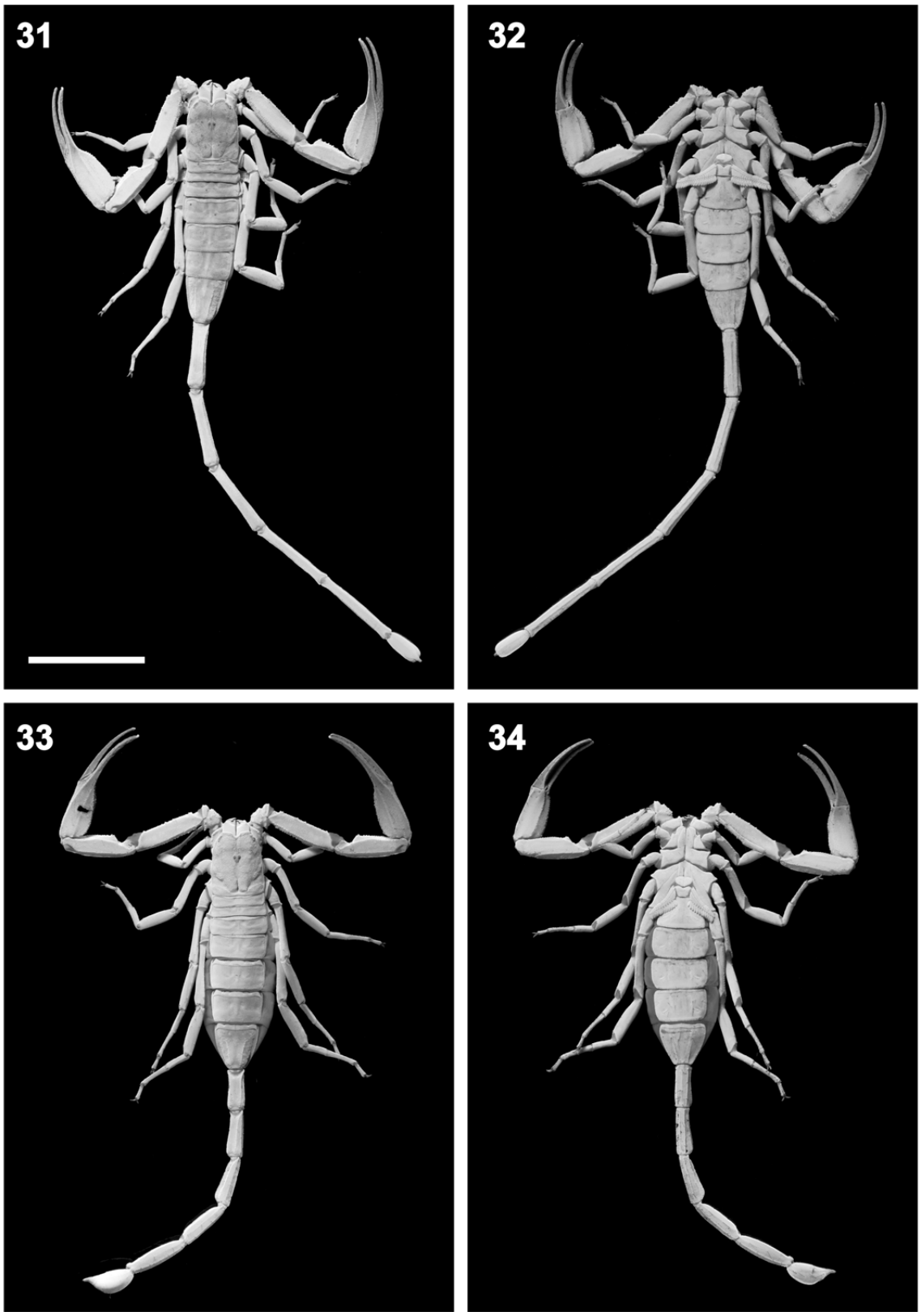


Figures 29–30: *Hemiscorpius flagelliraptor*, **sp. nov.** Habitus viewed under reflected white light illumination in alcohol. **29.** Holotype male, dorsal aspect. **30.** Paratype female, dorsal aspect. Note: in alcohol, specimens became a darker orange color. Scale bar: 15 mm.

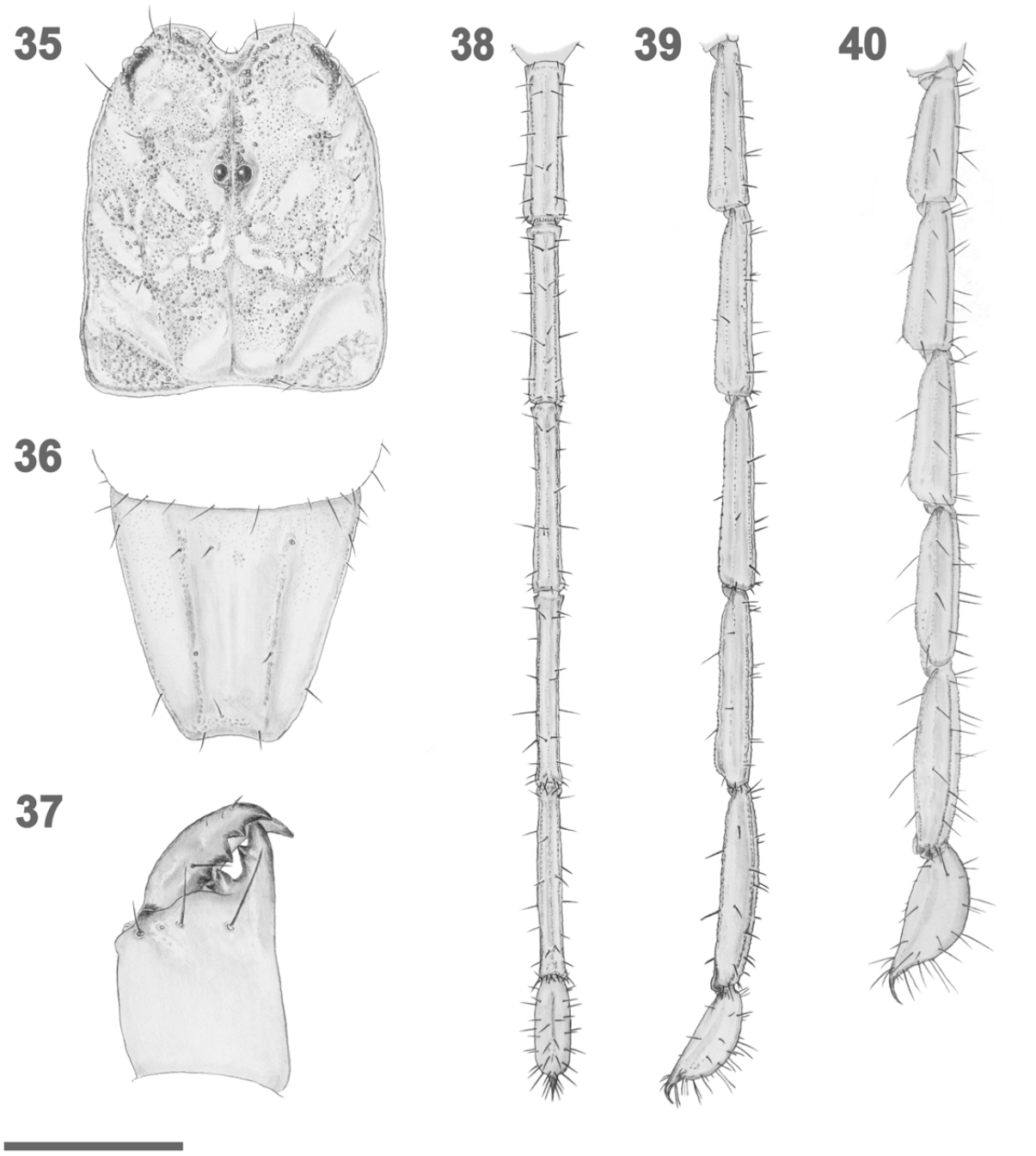
denticle, only weakly curved; ventral margin of movable finger smooth; fixed finger with 4 denticles: distal, subdistal, and basal pair fused into bicusp. *Chaetotaxy*: manus bearing 3 long reddish macrosetae near apical border; movable finger with one long reddish macroseta on external surface, at level of basal denticle.

Coxosternal area (Fig. 32). All coxae smooth, with sparse short or long macrosetae; anterior margin of coxa II weakly granulated; sternum pentagonal, twice as long as wide, slightly widened anteriorly, with deep median longitudinal sulcus, micro-shagreened anteriorly; 11 reddish macrosetae on sternum; two separate subtriangular genital opercula, overlapped posteriorly, covering pair of genital papillae.

Mesosoma. *Tergites* (Fig. 31): pretergites smooth to finely roughened, with slightly sinuous median borders; tergites I–III without carinae, IV with weak trace of median carina, V–VI with low, hump-like median ridge; tergite VII elongate, with a hump-like median ridge and pair of strong, granulose lateral carinae; all tergites densely shagreened to finely granular; I–VI with coarser granules posteriorly, posterior margins rimmed with coarse granules, bearing medial pair of marginal macrosetae. *Sternites* (Figs. 32, 36): sternite III medially convex, medial and posterior surface smooth, lustrous, concave anterolateral surfaces finely shagreened; IV–VI smooth, lustrous; sternite VII with matte, roughened surface, weak trace of median carina, and pair of well developed, nearly smooth lateral carinae; all sternites with scattered macrosetae; non-marginal chaetotaxy: III 21, IV 11, V 10, VI 8, VII 8; marginal chaetotaxy: III 14, IV 21, V 25, VI 22, VII, 22. *Pectines* (Figs. 32, 54): tips extending to middle of trochanter IV; pectinal tooth count, left 17, right 18; combs with three marginal lamellae, extended basal middle lamella, and 9 smaller, columnar or rounded middle lamellae; all lamellae with numerous scattered macrosetae of varying lengths, non-basal middle lamellae bearing 1–2 setae, all fulcra bearing 2 setae except for distal two, which bear one; teeth on combs large, angulate, with extensive sensillar



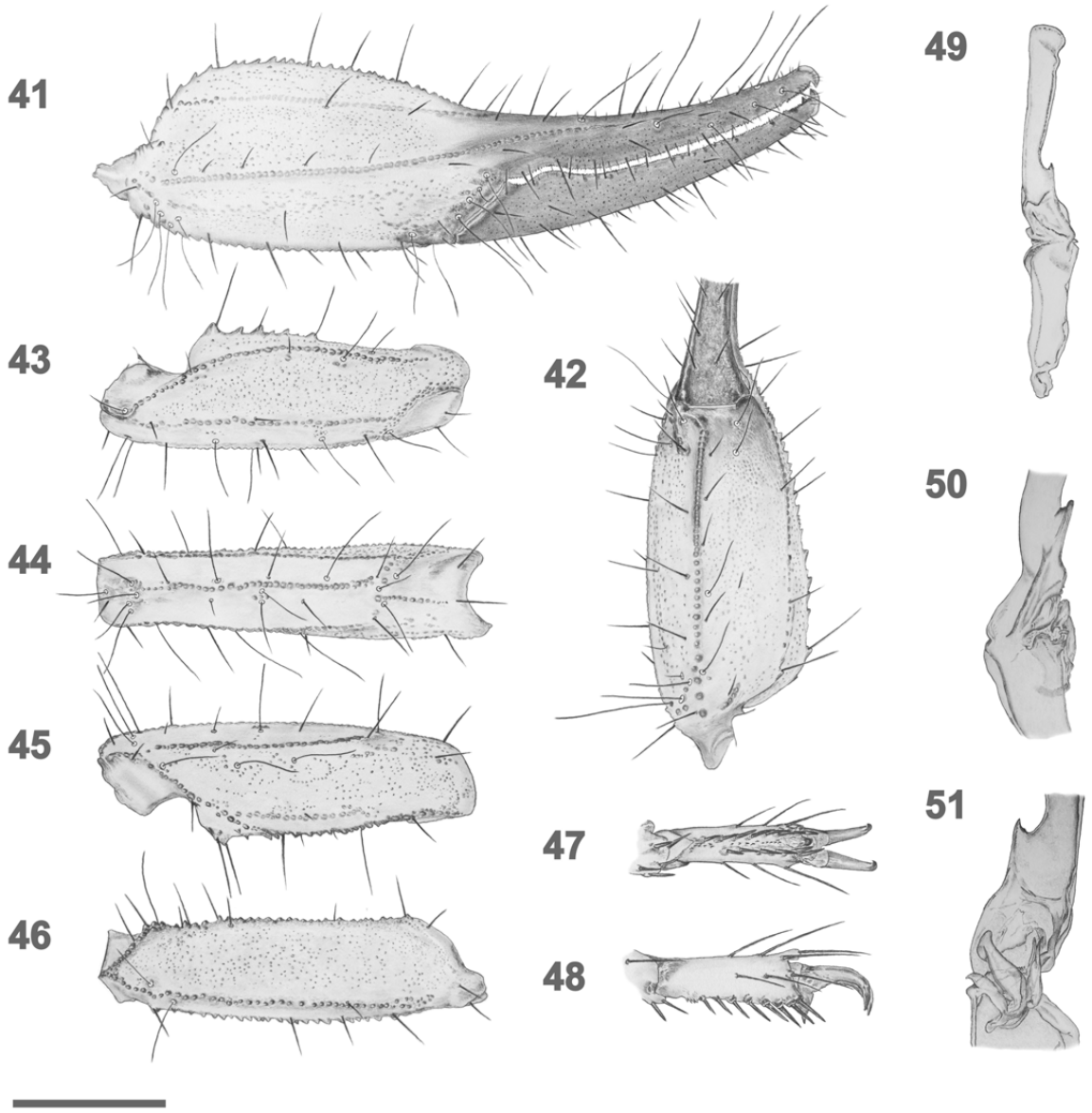
Figures 31–34: *Hemiscorpius flagelliraptor*, **sp. nov.** Habitus viewed under ultraviolet fluorescence. **31.** Holotype male, dorsal aspect. **32.** Holotype male, ventral aspect. **33.** Paratype female, dorsal aspect. **34.** Paratype female, ventral aspect. Scale bar: 15 mm.



Figures 35–40: *Hemiscorpius flagelliraptor*, **sp. nov. 35–39**, holotype male. **35.** Carapace. **36.** Sternite VII. **37.** Right chelicera, dorsal aspect (for clarity, internal brush of macrosetae not shown). **38.** Metasoma and telson, ventral aspect. **39.** Metasoma and telson, right lateral aspect. **40.** Paratype female, metasoma and telson, right lateral aspect. Scale bar: 35, 36: 4 mm; 37, 1.92 mm; 38, 39: 9.5 mm; 40: 7.6 mm.

area; basal piece of pectines longer than wide, with wide, V-shaped anteromedian invagination, bearing pair of long macrosetae

Hemispermatophore (Figs. 49–51). Lamelliform; ental hook of distal lamina with a well developed outer tooth and very small, vestigial inner tooth; distal lamina long, gradually expanded apically, with truncate distal crest; section of distal lamina below hook wide and short, comprising about 1/6 total length of lamina; folds of median transverse trough lined with denticular micro-sculpture; inner lobe with prominent flange at apex;



Figures 41–51: *Hemiscorpius flagelliraptor*, **sp. nov. 41.** Right pedipalp chela, external aspect. **42.** Right pedipalp chela, ventral aspect of manus. **43.** Right pedipalp patella, dorsal aspect. **44.** Right pedipalp patella, external aspect. **45.** Right pedipalp patella, ventral aspect. **46.** Right pedipalp femur, dorsal aspect. **47.** Right telotarsus III, ventral aspect. **48.** Right telotarsus III, retrolateral aspect. **49.** Right hemispermatophore, dorsal aspect. **50.** Right hemispermatophore, capsular region, ental aspect. **51.** Right hemispermatophore, capsular region, ventral aspect. Scale bar: 41 – 46: 4 mm; 47, 48: 1.92 mm; 49, 3.72 mm; 50, 51: 2.07 mm.

capsular region complex, with lamella and distal, basal, proximal and accessory lobes.

Metasoma (Figs. 38–39). Extremely slender, greatly elongated, total length of all segments plus telson 7.3 times carapace length; segments I–IV with 7 prominent, rib-like carinae; dorsal carinae on I–IV strong, denticulate; lateral carinae strong on I–III, moderate on IV, all weakly crenulate; ventrolateral carinae on I–IV strong, thickened, weakly crenulate; ventral median carinae strong on I, strong and thickened on II–IV, smooth to faintly granular; metasoma V with 5 denticulate carinae: dorsolateral and ventrolateral carinae strong, ventral median carina strong and heavily thickened; surfaces of all segments matte, roughened or sparsely shagreened, fine texture transversely microplicate with many transverse elliptic microgranules; all intercarinal surfaces concave, dorsal surfaces on I–III

forming longitudinal troughs; chaetotaxy: all carinae bearing paired, straight reddish macrosetae of varying lengths (asterisk denotes short setae): dorsal, 0, 1*, 1*, 2, 3, plus pair of small posterior terminal setae on I–III; lateral, 2*+1 on I–IV, 3 on V; ventrolateral, 3, 3, 3, 3 (plus additional short pair on posterior margin); ventromedian, 3, 3, 3, 4, 5; lateral surfaces of V, 2 pairs; anal arc, 5 ventral setae.

Telson (Figs. 38–39). Vesicle narrow, elongate; sides not parallel, gently convex, slightly widened posteriorly; posterior end truncated, very weakly bilobate; dorsal surface shagreened, with very weak transverse rugosity; lateral and ventral surface weakly granular; dorsolateral furrow smooth; aculeus with short, stout base, and narrow, vertical tip; ventral and lateral surfaces bearing bilateral series of straight, long reddish macrosetae, interspersed with small, fine whitish setae; *chaetotaxy*: ventromedian macrosetae, 7 pairs; ventrolaterals, 7 pairs; laterals, 6 pairs; dorsolaterals, 3 pairs; macrosetae on base of aculeus: one long ventral pair, one short lateral pair, 2 dorsal pairs.

Pedipalp (Figs. 41–46). *Femur* (Fig. 46): 3.8 times longer than wide, strongly compressed dorsoventrally, tetracarinate; external, dorsoexternal, dorsointernal and ventrointernal carinae all strongly developed, with large conical granulation; carinal chaetotaxy: external, 4 macrosetae; dorsoexternal, 3; dorsointernal, 6; ventrointernal, 2 (including distal marginal seta); entire dorsal surface heavily shagreened with small to moderate sized, polished granules; dorsoexternal surface matte, with scattered proximal granules, 2–3 large granules below trichobothrium *e*; ventral surface curved, mostly with dense fine granulation or shagreened, cluster of larger polished granules at base; internal surface rough, lightly shagreened, with 11 medium to large, conical, reddish granules, 7 with associated macrosetae; cluster of 5 granules around trichobothrium *i*. *Patella* (Figs. 43–45): 3.18 times longer than wide, dorsoventrally compressed, with 6 well developed carinae; external, dorsoexternal and dorsointernal carinae strong with large conical granulation; external carina split distally by trichobothrium et_2; ventroexternal carina moderate, coarsely granular; ventrointernal carina strong with large, dentate granules; ventromedian carina weak with small granules, confined to the middle 1/3 of segment; internal surface of patella convex in proximal half, with row of 5 enlarged, dentate granules; dorsal and ventral patellar spurs forming large conical teeth; other intercarinal surfaces flat or weakly concave; intercarinal texture: dorsal surface heavily shagreened with uniform, dense granulation; dorsoexternal surface smooth, matte, with only a few very small granules; ventroexternal surface sparsely shagreened, granules on ventral surface more dense, non–uniform and weak; internal surface with sparse, fine granules; carinal macrosetae: external, 4; dorsoexternal, 2; dorsointernal, 2; upper ventrointernal, 4; lower ventrointernal, 1 (small); ventroexternal, 3–4; intercarinal macrosetae: ventral surface, 1 externo-distal seta; internal surface, 4 setae associated with dentate granules (including patellar spurs), ventroexternal surface, 1 seta; distal external margin of patella, 2 setae. *Chela* (Figs. 41–42): manus flattened, elongated; fingers curved, about same length as manus (movable finger 1.13 times chela manus ventral L); digital carina strong, granulose on manus, weakly granular to smooth on base of fixed finger; dorsal secondary carina moderate, granulose; dorsal marginal carina strong, with conical granules on manus, weakly granular on base of fixed finger; ventroexternal carina strong, with heavy, reddish granulation, granules contiguous proximally, fused distally; ventrointernal carina moderate, weaker proximally with separated small and large granules, stronger distally with fused granules; inner accessory carina obsolete, marked by row of separate, large granules; dorsointernal surface of manus with distal row of 4–5 enlarged granules; all intercarinal surfaces matte; ventral surface nearly flat, covered with fine, flat, polished granulates, denser medially; lower internal surface gently concave, with irregular fine granulation; upper internal surface slightly convex with irregular, small to medium sized granules; dorsal surfaces flat, moderately shagreened, covered with irregularly spaced, fine granules; external surface convex, with more dense, coarse granulation; chela fingers elongate, curved, dentate margins strongly scalloped at base; base of fixed finger with single, well developed recess opposed by a single basal hump on the fixed finger; with tips of fingers closed, dentate margins in contact along their length except for a narrow proximal gap between hump and recess. *Finger dentition* (Figs. 27– 28): *movable finger* (Fig. 28): dentate margin armed with two parallel, serrate rows of sharp, conical primary denticles extending over almost entire length of finger, including basal hump; inner row terminating at proximal end of basal hump, leaving short single row of 6 outer denticles at base of finger; outer row resolved into 6 subrows on distal part of finger, separated by slightly enlarged primary denticles each closely flanked by an enlarged external accessory denticle; proximally, outer primary denticles fused into single continuous row, flanked by one external accessory denticle on basal hump; inner row primary denticles resolved into 5 subrows on distal finger, separated by slightly enlarged primary denticles each closely flanked by an enlarged internal accessory denticle; proximal part of finger with inner primary denticles forming single continuous row, flanked by two external accessory denticles on basal hump; inner and outer rows not aligned, enlarged denticles alternating; tip of movable finger with enlarged apical tooth, thick milky cap, and three enlarged subdistal denticles (2 internal, 1 external); primary den-

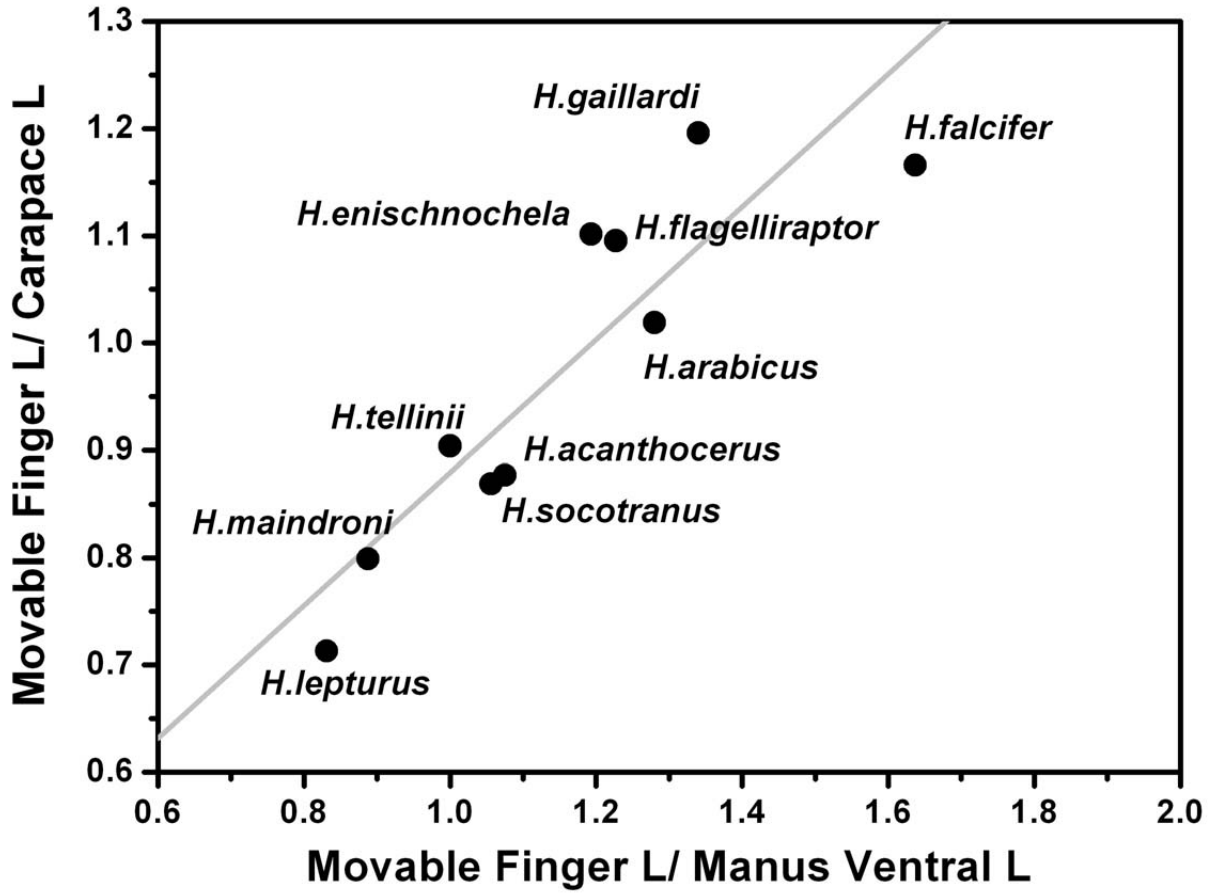


Figure 52: Plot of pedipalp chela morphometric ratios measuring the relative elongation of pedipalp fingers (movable finger L/ carapace L vs. movable finger L/ manus ventral L) for females of 10 species of *Hemiscorpius*. Gray line is a linear fit by least squares regression (Pearson's correlation coefficient R = 0.893).

ticle counts of distal subrows of movable finger, from distal to proximal (excluding enlarged primary denticles, left/right): outer: 6/7, 10/11, 17/18, 17, 16/17, 13/14; inner: 8/6, 13, 15/17, 17/15, 15; *fixed finger* (Fig. 27): dentate margin armed with single serrate row of sharp, conical primary denticles extending over entire length distal to basal recess; this primary row overlapped by secondary inner row of denticles confined to basal 1/3 of finger, extending along basal recess as single row; outer denticle row resolved distally into 4 subrows separated by slightly enlarged primary denticles each closely flanked by enlarged external accessory denticle; proximally, outer primary denticles forming single continuous row, flanked by two external accessory denticles; inner side of dentate margin armed with 6 large, conical, regularly spaced inner accessory denticles alternating with external accessory denticles; numerous additional inner accessory denticles of various sizes at irregular positions along finger (16 on both chelae); secondary inner row of denticles not divided into subrows, denticles on basal recess reduced in size; primary denticle counts of distal subrows of fixed finger: 6, 8, 13, 17/15; fixed finger with enlarged apical tooth bearing milky cap of thickened cuticle, and external subdistal groove for receiving movable finger apical tooth; one enlarged internal subdistal denticle. *Chaetotaxy*: manus with numerous straight, reddish macrosetae, mostly on or adjacent to carinae; carinal setae (left/right): dorsal secondary 4/3, dorsal marginal 6, digital 5/6, ventroexternal 10/9, ventrointernal 4/3, inner accessory 4; one seta on granule row above inner accessory row; one seta associated with basal ventromedian granule cluster; dorsal intercarinal surface devoid of setae; chela fingers bearing numerous long, straight reddish macrosetae: external and major internal accessory denticles of both fingers with an associated seta; additional setae on fixed finger (left/right): external 6/5, dorsal 6, internal 6/5; on movable finger, ventral 22/21, internal 10, external 10/7.

Trichobothrial pattern (Figs. 27, 41–46). Orthobothriotaxic, type C (Vachon, 1974); patella with d_2 and i closely positioned along dorsointernal carina; d_2 associated with a row of 2–3 enlarged granules; on

external surface of patella, eb_2, esb_1, *est* and et_1 located dorsal to external carina; et_2 sandwiched between overlapping distal end of external carina and basal end of distal external carina; em_1 and em_2 separated by triad of large granules; esb_2 slightly proximal to esb_1; chela manus with V_2 and V_1 equidistant from ventroexternal carina; *Dt* positioned well forward on fixed finger, distal to recess; all external trichobothria of fixed finger placed distal to recess; dorsal and external series nearly aligned: *db*, *dsb*, *dst* slightly distal to *eb*, *esb*, *est*, respectively; *et* slightly distal to *dt*; *ib* and *it* placed well forward in distal half of fixed finger.

Legs (Figs. 31–32, 47–48). Moderately elongate, laterigrade; basitarsi with series of short and long setae on dorsal and ventral margins, ventrodistal setae stout, spiniform; soles of telotarsi equipped with a median row of fine spicules, and two rows of long, apically directed, stout reddish spiniform setae, setation formula: 5/7 5/7: 6/8 6/8: 6/8 7/8: 7/8 7/8; ungues short, stout, curved.

Measurements of holotype male (mm). Total L 89.0; carapace L 8.23, W 7.0; preocular L 3.11; pectine L 5.60; hemispermatophore hook notch to median transverse cleavage 1.55, hook notch to distal crest 3.52, median transverse cleavage to basal cleavage 3.40; metasoma and telson L 60.0; metasoma I L 8.94, W 2.38; metasoma II L 10.06, W 2.00; metasoma III L 10.23, W 1.88; metasoma IV L 10.84, W 1.63; metasoma V L 11.35, W 1.63; telson L 7.22, vesicle W 2.08, D 2.29; pedipalp femur L 9.80, W 2.58; pedipalp patella L 9.92, W 2.92; pedipalp chela L 16.70, chela manus ventral L 7.91, manus L 9.07, chela W 4.38, chela D 4.14, fixed finger L 7.91, movable finger L 8.94. *Selected morphometric ratios*: carapace W/L 0.85, pedipalp femur L/carapace L 1.19, pedipalp femur L/W 3.80, pedipalp patella L/W 3.18, pedipalp movable finger L/chela manus ventral L 1.13, pedipalp movable finger L/carapace L 1.09, pedipalp chela L/W 3.81, pedipalp chela manus ventral L/chela W 1.81, manus L/W 2.07, patella III L/W 3.55, metasomal segment L/W: I 3.76, II 5.03, III 5.44, IV 6.65, V 6.96.

Paratype female (Figs. 30, 33–34, 40). Differs from holotype male as follows: body pale, lacking fuscous pigmentation except for limited medial area within interocular triangle (this probably not sex specific); tergites smoother, less densely shagreened, with extensive smooth, lustrous areas on segments III–VI; tergite VII with weaker median hump and median carinae; sternite VII less elongated, wider anteriorly, with two weak, smooth carinae; pectines smaller, anterior margin not extending past proximal 1/4 length of trochanter IV; pectines with fewer teeth, left 12, right 12; combs with extended basal middle lamella and four smaller rounded middle lamellae; fulcra bearing one long seta, not two; teeth on combs smaller, symmetric, with peg sensillae confined to small band on apical margin; basal piece with shallower anteromedian invagination; genital opercula fused along median suture into an oval plate; sternum parallel–sided; all metasomal segments much less slender, dorsal surfaces less deeply concave; metasomal carinae all well developed, but less prominent; ventromedian carina smooth on metasoma I and II; dorsal carinae with 1, 1, 2, 2, 4 long macrosetae; telson ovoid, less elongate, with more bulbous vesicle; aculeus slightly longer; pedipalps with intercarinal surfaces more lightly shagreened or granulated, slightly lustrous; pedipalp segments more slender, manus substantially narrower; chela fingers more gently scalloped at base, no gap between recess and hump with tips of fingers closed; trichobothrium *Dt* located more proximally on fixed finger, near midpoint of recess; shorter spiniform setae on telotarsi, setation formula: 5/7 4/7: 6/7 6/7: 6/8 6/8: 7/8 7/8.

Measurements of paratype female (mm). Total L 72.5; carapace L 8.48, W 7.10; preocular L 3.10; pectine L 4.82; metasoma L 40.0; metasoma I L 5.50, W 2.29; metasoma II L 6.19, W 2.13; metasoma III L 6.54, W 1.98; metasoma IV L 6.97, W 1.75; metasoma V L 8.08, W 1.67; telson L 7.22, vesicle W 2.50, D 2.67; pedipalp femur L 9.63, W 2.41; pedipalp patella L 9.72, W 2.95; pedipalp chela L 16.98, chela manus ventral L 7.57, manus L 8.94, chela W 3.65, chela D 3.40, fixed finger L 8.51, movable finger L 9.29. *Selected morphometric ratios*: carapace W/L 0.84, pedipalp femur L/carapace L 1.14, pedipalp femur L/W 4.00, pedipalp patella L/W 3.30, pedipalp movable finger L/chela manus ventral L 1.23, pedipalp movable finger L/carapace L 1.10, pedipalp chela L/W 4.65, pedipalp chela manus ventral L/chela W 2.07, manus L/W 2.45, patella III L/W 3.90, metasomal segment L/W: I 2.40, II 2.91, III 3.30, IV 3.98, V 4.84.

Variation. Two presumably immature paratype males were examined (carapace L 5.70 and 6.88 mm); body color of male from Wadi Bani Auf similar to holotype, of male from Jabal Bani Jabir uniform yellow, lacking fuscous markings; pedipalp less slender and legs shorter; pedipalp femur L/W 3.10–3.36, patella L/W 2.62–2.88, chela L/W 3.49–4.75; telotarsi with shorter, more stout ungues; total length of metasoma 34 mm; all metasomal segments less slender, L/W ratios: I 2.53–3.01, II 3.01–3.74, III 3.50–4.06, IV 4.52–5.16, V 4.74–6.03; dorsosubmedian carinae with 0–1, 1, 1–2, 2–3, 3–4 pairs of long macrosetae; male from Jabal Bani Jabir with trichobothrium *Dt* located on pedipalp fixed finger slightly proximal to midpoint of recess. Pectine teeth: Wadi Bani Auf: left 15, right 16; Jabal Bani Jabir: left 13, right 13. The pronounced elongation of the metasoma in immature males indicates that strong sexual dimorphism begins to develop well before maturity.

Figures 53–56: *In vivo* habitus and typical lithophilic habitats of *Hemiscorpius* in Oman. **53–54**: *Hemiscorpius flagelliraptor*, **sp. nov.**, holotype male, photographed < 24 h after collection. **53.** Dorsal aspect. **54.** Ventral aspect. **55.** Towering limestone cliffs in the Musandam Peninsula. **56.** Rocky escarpments surrounding Wadi Bani Kharus.

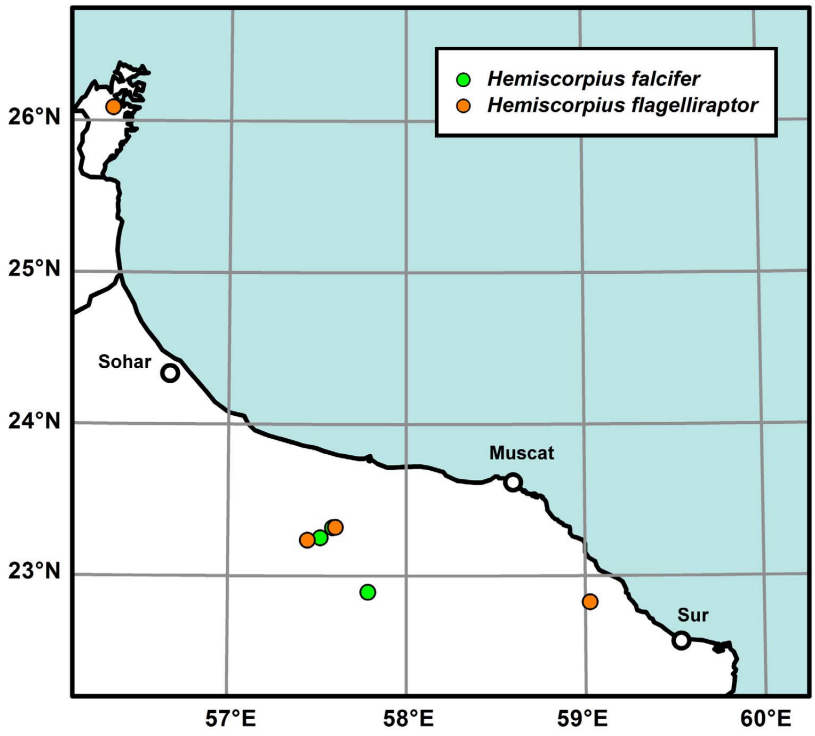


Figure 57: Plot of collection sites of new species of *Hemiscorpius* in northern Oman. Green circles: *Hemiscorpius falcifer*, **sp. nov.**; orange circles: *Hemiscorpius flagelliraptor*, **sp. nov**. Orthographic projection with center 24°N 58 °E.

Distribution (Fig. 57). Known only from the Al Hajar Mountains of northern Oman, ranging from the Musandam Peninsula to Al Hajar Ash Sharqi.

Ecology. The types were all collected by ultraviolet detection at night from very rocky habitats (Fig. 55). Both adults were found resting in sheltered positions on ledges or crevices of rocky road cuts at lower elevations. The immatures were also collected from sites with an abundance of broken rock. This scorpion appears to be a sit-and-wait predator, positioning itself inside the openings of rock crevices to ambush passing prey. The morphology of *H. flagelliraptor* is consistent with an ultralithophilic scorpion specialized for life in rock crevices (Polis, 1990; Prendini, 2001a). The two adults were agile, capable of rapid locomotion on rock, and would likely have evaded capture if they had not been secured on the first attempt. Other scorpions found at the type locality or nearby were: *Hemiscorpius falcifer*, sp. nov., *Hemiscorpius maindroni*, *Hottentotta jayakari* (Pocock, 1895), *Compsobuthus nematodactylus* Lowe, 2009, *Compsobuthus maindroni* (Kraepelin, 1900) and *Orthochirus glabrifrons* (Kraepelin, 1903). At higher elevation on Jabal Bani Jabir, additional associated species were: *Microbuthus* sp., *Hottentotta* sp. and *Nebo omanensis* Francke, 1980. The immature male from Jabal Bani Jabir has eight white ectoparasitic mites attached to the articular membranes behind tergites II–IV.

Discussion

Monod & Lourenço (2005) diagnosed *Hemiscorpius* by the following combination of characters: (i) trichobothria *ib* and *it* positioned midway on fixed finger of pedipalp, (ii) metasoma I–IV with single ventromedian carina (iii) 3 pairs of lateral eyes; (iv) depressed median ocular tubercle; (v) movable finger of chelicera with distal external and distal internal denticles nearly equal in size, (vi) pedipalp fingers with 2 primary rows of denticles that may be proximally fused; (vii) trichobothrium *db* located on internal surface of fixed finger; (viii) trichobothrium *Db* positioned on dorsal surface of manus; (ix) trichobothrium *Dt* positioned at proximal end of fixed finger; (x) ventral surface of pedipalp manus lacking accessory trichobothria; (xi) telson vesicle of male elongated and laterally compressed; (xii) hemispermatophores with a double lamellar hook and a complex median capsular structure.

The majority of aforementioned characters are well satisfied by the two new species described here. However, characters (ii), (vi) and (xi) do not fit *H. falcifer*, which has ventromedian carina obsolete on metasoma I, pedipalp movable finger with single row of primary denticles, and male telson vesicle ovoid, not elongated and laterally compressed. The former two character states are interpreted as derived conditions associated with ultralithophilic adaptation, and the latter as a plesiomorphic condition shared with some other

species (e.g. *H. arabicus*). The strong, sexually dimorphic elongation of the metasoma and telson in some *Hemiscorpius* is presumably a derived condition. The relatively strong scalloping of male pedipalp fingers in *H. falcifer* might be a plesiomorphic condition, since this is also observed in some other hemiscorpiid genera, for example, *Liocheles* and *Hadogenes* (Prendini, 2001b; Volschenk, Locket & Harvey, 2001). Thus, *H. falcifer* might occupy a more basal position in the phylogeny of *Hemiscorpius*. The long pedipalp fingers with single file dentition on the movable finger of *H. falcifer* may be a specialized lithophilic adaptation. In the immature male from Wadi Bani Kharus, two parallel rows of denticles can be seen along part of the movable finger, so the single file condition may only become fully expressed when the animals mature. Other features of this species that might be derived include reduction of the dorsoexternal carina and loss of the external carina on the pedipalp patella, loss of the dorsal secondary carina on the manus, internal displacement of trichobothrium V_2 (associated with expansion of the manus), and reduction of the ventromedian carina on metasoma I–II.

In *H. flagelliraptor*, character (xii) is not very well fit because the inner process of the double lamellar hook is strongly reduced, although still discernible (Fig. 51). The double hook is presumed to be a synapomorphy for *Hemiscorpius*, but it is unclear whether the condition in *H. flagelliraptor* represents an apomorphy (i.e. attenuation of inner process of a double hook) or a plesiomorphy (i.e. lack of development of the double hook). This species is very similar to, and may be closely related to *H. enischnochela* and *H. gaillardi*, but in those species the hemispermatophore is unknown (Monod & Lourenço, 2005), so it is possible that they could exhibit a similar attenuation of the inner process of the hook. This issue needs to be investigated further by the collection of adult males of those two species, and a larger sample of adult male *H. flagelliraptor*, to quantify variation in the development of the double hook.

The genus *Habibiella* was created by Vachon (1974) for *H. gaillardi*, primarily on the basis of neobothriotaxy (pedipalp patella with 2 supernumerary trichobothria on external surface, and extensive series of supernumerary trichobothria on the ventral surface), and perhaps also motivated by the distinctive morphology of *H. gaillardi* compared to then known *Hemiscorpius* species (e.g. large size, strong elongation of pedipalps). A similar morphology and neobothriotaxy is seen in *H. enischnochela*, but Monod & Lourenço (2005) decided to place *Habibiella* in synonymy with *Hemiscorpius*. They argued that strong, sexually dimorphic elongation of the metasoma in *H. gaillardi* and *H. enischnochela* is shared with the orthobothriotaxic species *H. lepturus*, *H. acanthocerus* and *H. maindroni*. If it is indeed the case that *H. enischnochela* and *H. gaillardi* are more closely related to the orthobothriotaxic *H. flagelliraptor* than to other members of the genus, then this would support the synonymy of Monod & Lourenço (2005).

The species *H. persicus* Birula, 1903, is much smaller than *H. flagelliraptor*, with only moderate elongation of the male metasoma and telson. It does share several characters with *H. flagelliraptor*: strongly developed ventromedian carinae on metasoma I–III, pedipalp patella with strongly developed dorsoexternal and external carinae, well developed dorsal secondary carina on pedipalp chela; proximal margins of pedipalp fingers distinctly scalloped, and two rows of denticles along the length of the movable finger including the proximal hump. The shared characters involving carinal retention, not loss, are likely to be symplesiomorphies, and the two species may not be closely related. The male *H. persicus* differs from *H. flagelliraptor* in having a more inflated manus (L/W 1.7–1.9), and chela trichobothrium *Dt* positioned on manus, not fixed finger.

The flattening of the pedipalp chelae and strong elongation of the pedipalp fingers in both *H. flagelliraptor* and *H. falcifer* are likely to be morphological correlates of the lithophilic or ultralithophilic microhabitats from which these species were collected. Many unrelated scorpions that shelter in rocky fissures have evolved long, slender pedipalp fingers as convergent lithophilic adaptations (Polis, 1990; Prendini, 2001a; Lowe, 2009). The long, serrate fingers of *H.falcifer* are quite striking compared to all other known species of *Hemiscorpius*. In Fig. 52, two morphometric ratios that measure finger elongation, i.e. movable finger L/ carapace L (which quantifies finger elongation relative to body size) and movable finger L/ chela manus ventral L (which quantifies finger elongation relative to the chela), are plotted for female samples of ten members of the genus (i.e. *H. lepturus*, *H. socotranus* Pocock, 1899, *H. tellinii* Borelli, 1904, *H. maindroni*, *H. enischnochela*, *H. acanthocerus*, *H. flagelliraptor*, *H. falcifer*, *H. arabicus*, *H. gaillardi*). These two ratios were strongly correlated (Pearson's correlation coefficient R = 0.893), indicating that fingers become larger with elongation relative to the chela. The ultralithophiles, *H. falcifer* and *H. flagelliraptor*, and the presumed ultralithophiles *H. enischnochela* and *H. gaillardi*, are clustered in the upper right sector of the plot, corresponding to greatest finger elongation. Notably, *H. falcifer* is the species with the most extreme finger elongation relative to the chela manus. On the other hand, *H. lepturus* and *H. maindroni* appear in the lower left sector of the plot, indicating that these species are the least specialized for lithophilic habitats. Indeed, during field work in Oman, the author has collected *H. maindroni* in lapidicolous situations (i.e. under rocks on the ground in wadis), but never off rocky escarpments and road cuts.

The addition of *H. falcifer* and *H. flagelliraptor* to the fauna of northern Oman significantly extends the list

of specialized lithophilic or ultralithophilic scorpions endemic to the Al Hajar Mountains, that also includes *Babycurus exquisitus* Lowe, 2000, and *Compsobuthus nematodactylus* Lowe, 2009. These ancient mountains contain a high diversity rocky substrates spanning a wide range of altitudes, and are likely to be inhabited by other novel, rock-adapted scorpions.

Appendix

Comparative material examined. *Hemiscorpius lepturus*: Iraq: 1 ♂, 3 ♀, Baghdad, 33°08.4'N 44°13.2'E, 18 August 1902 (MCZ); Iran: 1 ♂, Fars Province, 35 km E Gach Saran, Camp 11, 30°16.02'N 51°13.74'E, 6 October 1964, leg. J. Neal (USNM); 1 ♂, 3 ♀, Fars Province, 35 km E Gach Saran, Camp 11, 30°16.02'N 51°13.74'E, 6 February 1964, leg. J. Neal (USNM). *Hemiscorpius persicus*: syntypes, 1 adult ♂, Iran, Baluchistan, Province Sarbaz, village Riss, 24 February 1901, leg. N. A. Zarudny (ZISP 1120); 1 subadult ♂ (incorrectly determined by Birula, 1903, as ♀), Iran, Baluchistan, Province Sarbaz, between village Riss and Kaptegin-dukan, 24–26 February 1901, leg. N. A. Zarudny (ZISP 1121). *Hemiscorpius socotranus*: Somalia: 1 ♀, Bender Cassim, September 1931 (MZUF C.98). *Hemiscorpius tellinii*: holotype ♀, Ethiopia, Halibaret, Eritrea, leg. Tellini (MRSN Sc 254). *Hemiscorpius maindroni*: syntypes: Muscat, leg. M. Maindron (ZMH, MNHN; 3 types from ZMH examined, 2 immature ♂, 1 immature ♀). *Hemiscorpius arabicus*: syntypes: 1 ♂, Yemen: Aden, 1893, leg. E. W. Oates, BMNH 1893.1.11.62; 1 ♀, Aden, 1895, leg. Col. Yerbury (BMNH 1895.5.22.17-23).

Key to females of *Hemiscorpius*

The two new species can be distinguished from other *Hemiscorpius* by the following dichotomous key, which is based on examination of the comparative material listed above and data given in Monod & Lourenço (2005). The key was constructed for females, for which more species are represented in available material than males. *H.persicus* is not included in the key as females were unavailable for study. However, assuming males and females share characters of pedipalp patella carination and trichobothriotaxy (as in other species with both sexes known), female *H.persicus* is likely to group with the large species because the pedipalp patella has a strongly developed external carina, and is likely to be differentiated from them by its smaller size (adult carapace L < 5 mm) and very basal positioning of trichobothrium *Dt*, on the manus. Some of the morphometric criteria in the key may require revision when more samples of *Hemiscorpius* species become available for study.

1 Large species, adult carapace L > 6.5 mm; pedipalp patella with strong, granulated external carina; metasoma very elongated, metasoma I L/W > 2.0, metasoma V L/W > 3.8; pedipalp chela with trichobothrium *Dt* placed forward on basal 1/3 of fixed finger **2**
Small to medium sized species, adult carapace L < 6.0 mm; pedipalp patella with weak or obsolete external carina; metasoma not elongated or moderately elongated, metasoma I L/W < 2.0, metasoma V L/W < 3.8; pedipalp chela trichobothrium *Dt* placed at base of fixed finger or on distal manus **4**

2 Orthobothriotaxic, pedipalp patella with 13 external, 3 ventral trichobothria; distributed in northern Oman . . . . . *H. flagelliraptor*, sp. nov.
Neobothriotaxic, pedipalp patella with >13 external and 10–12 ventral trichobothria; distributed in Iran **3**

3 Pedipalp patella with 14 external trichobothria . . . . . *H. enischnochela* Monod et Lourenço, 2005
Pedipalp patella with 15 external trichobothria . . . . . *H. gaillardi* (Vachon, 1974)

4 Medium sized species, carapace L > 5.5 mm; metasoma I L/W > 1.40; pedipalp patella with well developed, granular dorsoexternal carina **5**
Small species, carapace L < 5.5 mm; metasoma I L/W > 1.40; pedipalp patella with dorsoexternal carina well developed and granular, or weak and smooth **6**

5 Superciliary carinae finely granular . . . . . *H. acanthocerus* Monod et Lourenço, 2005
Superciliary carinae smooth . . . . . *H. lepturus* Peters, 1861

6 Pedipalp patella with dorsoexternal carina well developed, granular; metasoma I with distinct ventromedian carina; metasoma I L/W 1.36 . . . . . *H. tellinii* Borelli, 1904
Pedipalp patella with dorsoexternal carina weak or smooth; metasoma I with ventromedian carina obsolete; metasoma I L/W < 1.3 . . . . . **7**

7 Metasoma V L/W > 3.2; pedipalp movable finger L/ manus ventral L < 0.95 . . . . . *H. maindroni* Kraepelin, 1901
Metasoma V L/W < 2.8; pedipalp movable finger L/ manus ventral L < 0.95 . . . . . **8**

8 Pedipalp movable finger L/ manus ventral L > 1.5; distal half of movable finger of adult pedipalp chela with primary denticles arranged in single file;

pedipalp chela manus with trichobothrium V_2 internal to V_1 relative to axis of ventroexternal carina . . . . . *H. falcifer*, sp. nov.
Pedipalp movable finger L/ manus ventral L < 1.4; distal half of movable finger of adult pedipalp chela with primary denticles arranged in two parallel rows; pedipalp chela manus with trichobothria V_2 and V_1 equidistant from axis of ventroexternal carina **9**

9 Telson vesicle bulbous; metasoma I L/W 1.0; pedipalp chela L/W 3.15, movable finger L/ manus ventral L 1.1 . . . . . *H. socotranus* Pocock, 1899
Telson vesicle elongate; metasoma I L/W 1.2; pedipalp chela L/W 3.40; movable finger L/ manus ventral L 1.3 . . . . . *H. arabicus* Pocock, 1899

Acknowledgments

The author is very grateful to: H.H. The Minister of National Heritage and Culture, Sultanate of Oman, for sponsorship to study scorpions of Oman; Khair Bin Antar Salim, Director of Museums, Said Ali Said Al-Farsi and Saddiqa Rhamdan at the Ministry of National Heritage and Culture for invaluable support during the authors visits and field trips to collect type materials; Michael D. Gallagher for guidance and help in the field, sustained support and mentorship; Mohammed Abdullah Al Dahoori for assistance in Khasab; Andrew S. Gardner, Seyad Farook and Jim Dundon for participation in collecting forays in the Al Hajar Mountains that yielded important type material; Alex Winkler for collecting and contributing type material; Victor Fet for relaying loans of *H. persicus* from Zoological Institute, St. Petersburg; the curators of institutions who generously arranged loans of *Hemiscorpius* for comparative study: Naturhistorisches Museum Basel (Ambros Hänggi, Matt E. Braunwalder), Museo Zoologico "La Specola" dell'Università de Firenze (Sarah Whitman), Museo Regionale di Scienze Naturali, Torino (Lisa Levi), Zoologisches Museum der Universität Hamburg (Hieronymus Dastych), Academy of Natural Sciences, Philadelphia (Donald Azuma), National Museum of Natural History, Washington, D. C. (Scott Larcher), Museum of Comparative Zoology, Harvard University, Cambridge (Laura Leibensperger), Zoological Institute, St. Petersburg (Viktor Krivochatsky), Natural History Museum, London (Janet Beccaloni), and Muséum National d'Histoire Naturelle, Paris (the late Jacqueline Heurtault); and František Kovařík and Matthew R. Graham for critical reviews of the manuscript.

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