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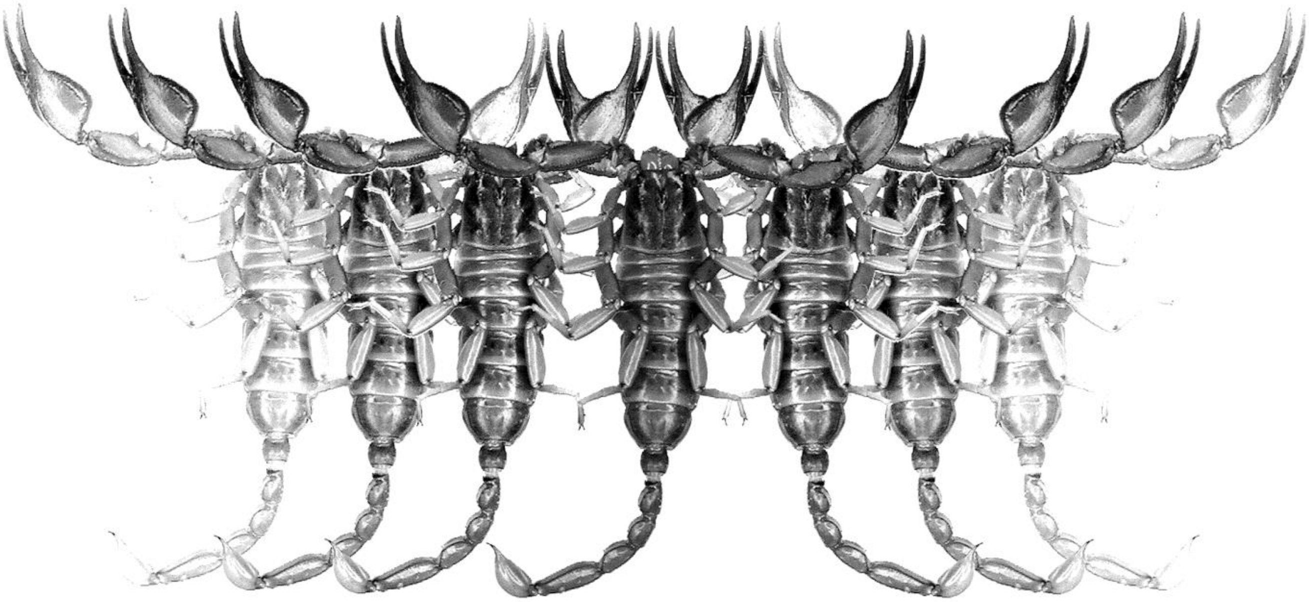

Etudes on Iurids, VIII. A New *Protoiurus* Species from the Hıdırellez Cave in Antalya, Turkey (Scorpiones: Iuridae)

Ersen Aydın Yağmur, Michael E. Soleglad, Victor Fet & František Kovařík

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Euscorpius **— Occasional Publications in Scorpiology. 2015, No. 200**

Etudes on iurids, VIII. A new *Protoiurus* species from the Hıdırellez Cave in Antalya, Turkey (Scorpiones: Iuridae)

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http://zoobank.org/urn:lsid:zoobank.org:pub:7777CE87-9416-4CDA-B354-70A6C3B905AD

Summary

A new iurid species, *Protoiurus kumlutasi* **sp. nov.** is described from the Hıdırellez Cave, located in the coastal southwestern Antalya Province, Turkey. This species was collected both inside and at the entrance of the cave, and does not exhibit any troglomorphic characteristics. Its closest relative is *P. kraepelini*, which shares the distinctive shape of pedipalp chela in mature males. The new species can be distinguished from *P. kraepelini*, however, by its hemispermatophore, which conforms to subtype *1a*. Additional hemispermatophores were analyzed from several specimens of *P. kraepelini* collected in close proximity to its type locality, further endorsing existence of unique subtype *1b* in this species. The description of the new species brings the number of species in the genus *Protoiurus* to six.

Introduction

Between May 2010 and April 2012, the first author (E.Y.) collected several scorpions from the Hıdırellez Cave, Antalya, Turkey. These specimens resembled *Protoiurus kraepelini* (von Ubisch, 1922) both in its dark coloration and the distinctive curvature of the chela fingers found in mature males. However, extensive hemispermatophore analysis confirmed that they belong to a different species, which can be separated by this structure alone. This analysis is presented in the current paper, with a description of a new species, *Protoiurus kumlutasi* **sp. nov**.

The Hıdırellez Cave is located at 36°10'21"N, 29°38'40"E, on the northern slope of Limanağzı Peninsula, 2.5 km south of Kaş Town, and 150 m south of a small harbor. The cave entrance lies at 33 m a.s.l.; mouth of the cave is about 20 m in diameter and leads into an 80 m deep vertical room. This main room is very humid and shady, with an area about 500 m^2; its walls and stones are covered with moss. A hall stretches westward from main room; no light reaches this hall, which leads to another large (about 200 m^2) and flat room, about 30 m high, and very wet. Stalactites are present in this room, and its ground surface is covered by bat guano. Albayrak & Aşan (1998) and Bilgin et al. (2008) reported bat species *Miniopterus schreibersii* and *Myotis myotis* from Hıdırellez Cave. Figures 1–2 show the cave entrance and a live specimen of *P. kumlutasi*.

In addition to the description of *P. kumlutasi*, this paper presents further analysis of the hemispermatophore of *P. kraepelini* based on new material, mostly collected close to the type locality of this species. This new analysis verifies that the hemispermatophore of this species does indeed conform to subtype *1b* as originally reported by Soleglad et al. (2012), in contrast to subtype *1a* found in *P. kumlutasi* (and in all other *Protoiurus*). An updated map showing the distribution of all *Protoiurus* and *Iurus* species is provided along with a discussion of the biogeography and phylogeny of these interesting scorpions.

List and distribution of six Protoiurus *species*

Protoiurus asiaticus (Birula, 1903) (**Turkey**: Adana, Adıyaman, Kahramanmaraş, Mersin, and Niğde Provinces)

Figure 1: Outside the Hıdırellez Cave, Kaş District, Antalya Province, Turkey, showing the vertical entrance to the cave. Two live females of *Protoiurus kumlutasi* **sp. nov.** sitting at the cave entrance.

Figure 2: Entrance inside the Hıdırellez Cave, Kaş District, Antalya Province, Turkey.

Protoiurus kadleci (Kovařík, Fet, Soleglad et Yağmur, 2010) (**Turkey**: Antalya and Mersin Provinces)
Protoiurus kraepelini (von Ubisch, 1922) (**Turkey**: Antalya, Isparta, Konya, Karaman, Mersin, and Muğla Provinces; **Greece**: Megisti Island)
Protoiurus kumlutasi Yağmur, Soleglad, Fet et Kovařík, **sp. nov. (Turkey**: Antalya Province)
Protoiurus rhodiensis Soleglad, Fet, Kovařík et Yağmur (**Greece**: Rhodes Island)
Protoiurus stathiae Soleglad, Fet, Kovařík et Yağmur (**Greece**: Karpathos Island)

Methods and Material

Abbreviations

AZMM: Alaşehir Zoological Museum, Celal Bayar University of Manisa, Alaşehir, Manisa Province, Turkey; FKCP, personal collection of František Kovařík, Prague, Czech Republic; NHMW, Naturhistorisches Museum Wien, Vienna, Austria.

Terminology and conventions

The systematics adhered to in this paper follows the classification as established in Fet & Soleglad (2005), as modified in Fet & Soleglad (2008), Kovařík et al. (2010), and Soleglad et al. (2012). Terminology describing pedipalp chelal finger dentition follows that described and illustrated in Soleglad & Sissom (2001), that of the sternum follows that in Soleglad & Fet (2003a), and the metasomal and pedipalp carination, and leg tarsus armature follows that described in Soleglad & Fet (2003b). Hemispermatophore terminology follows that described in Kovařík et al. (2010: 42); types and subtypes of iurid hemispermatophores are as defined by Soleglad et al. (2012). Trichobothrial nomenclature and hypothesized homologies are those described and illustrated in Vachon (1974). Techniques using maximized morphometric ratios follow those described in Kovařík et al. (2010: appendix C). Statistical differences are stated in standard deviation (SD) ranges (i.e., mean-SD – mean+SD) and the percentage of difference in the mean values (i.e., mean value difference (MVD)).

Map generation software package

Maps were generated from Earth Explorer 6.1, with positional and altitude data compiled through Google Maps.

Material Examined

We examined a total of 36 specimens. The type series (holotype and paratypes) of the new species is presented here, and repeated under the species description.

Protoiurus kadleci (Kovařík, Fet, Soleglad et Yağmur, 2010) (2 specimens)

Turkey: *Antalya Province*: Alanya District, north of Alanya Town, Taşatan Plateau (36.6384 N, 32.0598 E), 8 February 2013, leg. E.A. Yağmur & S. Örgel, 2 ♂ (AZMM).

Protoiurus kumlutasi, sp. nov. (23 specimens)

Turkey: *Antalya Province*: Kaş District, Hıdırellez Cave (36.1725 N, 29.6442 E), 30 May 2010, leg. Yusuf Kumlutaş, 1 subad. ♂ (AZMM) (inside cave); 13 August 2010, leg. E. A. Yağmur & E. Yağmur, 1 ♂, 1 subad. ♀ (AZMM) (inside cave); 15 October 2011, leg. E. A. Yağmur & R.S. Kaya, 1 ♂ (NHMW 21.958), 1 ♂, 2 subad. ♂, 1 juv. ♂, 1 subad. ♀ (AZMM) (cave entrance); 7 August 2011, leg. E. A. Yağmur & E. Yağmur, 1 ♂, 1 ♀ (FKCP), 1 subad. ♂, 1 juv. ♂, 1 subad. ♀ (AZMM) (inside cave); 12 April 2012, leg. E. A. Yağmur & R.S. Kaya, 2 ♂, 3 subad. ♂, 4 subad. ♀ (AZMM).

Protoiurus kraepelini (von Ubisch, 1922) (11 specimens)

Turkey: *Antalya Province*: Kemer District, Göynük Canyon, Likya road (36.6883, 30.5231), 4 July 2011, leg. E. A. Yağmur & F. Yeşilyurt, 1 ♂ (AZMM), Kemer District, Kiriş Village road (36.5956, 30.5622), 14 April 2014, leg. E. A. Yağmur & E. Yağmur, 1 ♂ (AZMM), Finike District, Alacadağ Mts., Türbe road (36.4367, 30.0394), 18 September 2014, leg. E. A. Yağmur & A. Avcı, 2 ♂ (AZMM), Finike District, Alacadağ Mts., Türbe road (36.4103, 30.0689), 18 September 2014, leg. E. A. Yağmur & A. Avcı, 5 ♂ (AZMM), Kaş District, Kaş Town, (36.2247, 29.6278), 1 May 2010, leg. A. Avci, 1 ♂ (AZMM), Akseki District, 12 km S of Akseki, 11–12 May 2006, leg. F. Kovařík, 1 ♂ (FKCP).

Character Analysis

Hemispermatophore revisited

During our initial examination of specimens from the Hıdırellez Cave, we considered these specimens to be *P. kraepelini*. This examination did not involve a single collection event, but instead involved five different field trips to the cave from May 2010 to April 2012. Since Soleglad et al. (2012) had used the hemispermatophore structure and its morphometric analysis as the primary character in the cladistic analysis of subfamily Iurinae, we thought it important that a hemi-

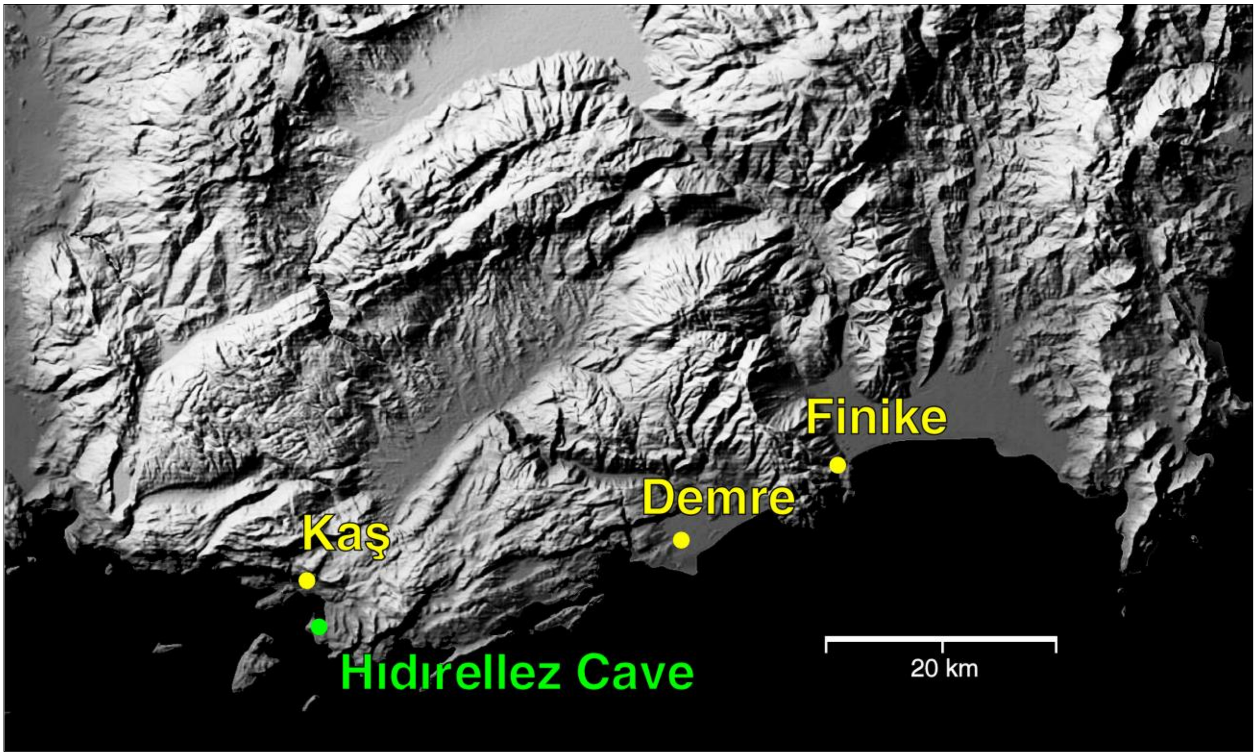


Figure 3: Hıdırellez Cave, Antalya Province, Kaş District, Turkey, type locality of *Protoiurus kumlutasi* **sp. nov.** Demre area is *P. kraepelini* neotype locality and Finike is its historic locality (i.e., that originally reported for the holotype by von Ubisch, 1922, now lost). Kaş is the closest locality to the Hidirellez Cave from where a hemispermatophore of *P. kraepelini* has been examined.

spermatophore should be available from the cave specimens (thus ensuring we had an adult male). In addition, we concentrated solely on specimens collected from the *interior* of the cave, assuming the specimens from its entrance to be *P. kraepelini*. Although we collected hemispermatophores from a large male collected at the cave entrance, we did not obtain a hemispermatophore from a specimen found from the cave interior until the last field trip (April 2012).

Both sets of extracted hemispermatophores (from specimens from the cave entrance and interior) were examined. Surprisingly, all hemispermatophores were consistent with subtype *1a*, **not** *1b*, the latter being found exclusively in species *P. kraepelini*. The subtype *1a* has been found in all other *Protoiurus*: in the easternmost Anatolian species *P. asiaticus*, in *P. kadleci*, and the two Greek island species, *P. rhodiensis* and *P. stathiae*. This result was not expected since the new specimens were very similar to *P. kraepelini* (see discussion below). In addition, the Hıdırellez Cave is situated very close to both the neotype and historical type localities of *P. kraepelini*, within 60 km (see map in Figure 3).

Although we previously had examined *P. kraepelini* hemispermatophores from several localities across Turkey (Soleglad et al., 2012), we decided to concentrate on male specimens closer to the type locality, wanting to ensure that *P. kraepelini* did indeed exhibit subtype *1b* as previously believed. [It is important to note that the neotype of *P. kraepelini* designated by Kovařík et al. (2010: 80) was a female, and no sexually mature males from that area had been examined.] Additional material was collected by the first author (E.Y.) from no less than five new localities, two in close proximity to the historical (lost) type locality and one near the neotype locality. Hemispermatophores were extracted from nine adult males belonging to this new material (23 specimens). All hemispermatophores were consistent with subtype *1b*, originally assigned to *P. kraepelini* by Soleglad et al. (2012). Important to note here, that seven of these hemispermatophores were extracted from specimens collected in Kaş Town and Alacadağ Mountains (Türbe road), close to both type localities. See Figs. 6–10 for photographs of some of these hemispermatophores.

The map in Figure 5 shows the localities of all specimens of subfamily Iurinae whose hemispermatophores (59 in total) have been examined, identified by types and subtypes according to Soleglad et al (2012). For type *1*, we have examined 41 hemispermatophores from 19 localities, 33 of which have been measured. Figure 4 shows four diagnostic characters differentiating subtypes *1a* and *1b*, two of which are morphometric ratios. As can be seen from the two histograms, a complete absolute range separation is pre-

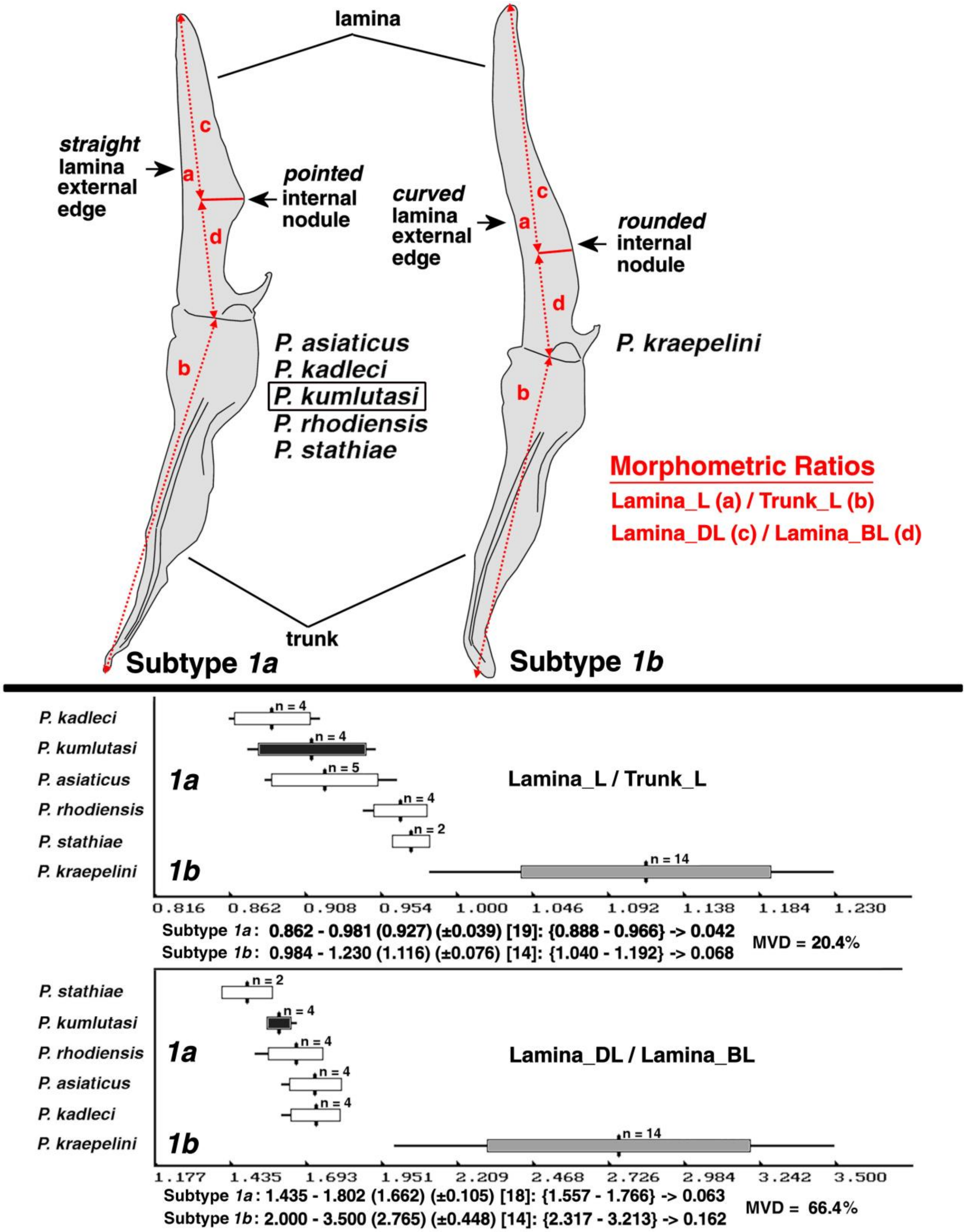


Figure 4: Comparison of hemispermatophore subtypes *1a* and *1b* in *Protoiurus*. **Top.** Diagrammatic outlines of subtypes *1a* and *1b* showing two diagnostic structural differences and the method of measurement for two morphometric ratios (i.e., **a**, **b**, **c**, and **d**). **Bottom.** Statistical analysis of two diagnostic morphometric ratios. *P. kumlutasi* **sp. nov.** is indicated with black bar, and *P. kraepelini* (subtype *1b*) is indicated with gray bar. L = length, DL = distal_length, BL = basal_length. Histogram: thin horizontal bar = minimum and maximum range; wide horizontal bar = standard deviation range; and vertical bar = mean; n = number of samples. Statistical data group: minimum–maximum (mean) (±standard deviation) [number of samples]: {standard deviation range} → coefficient of variability. MVD = mean value difference.

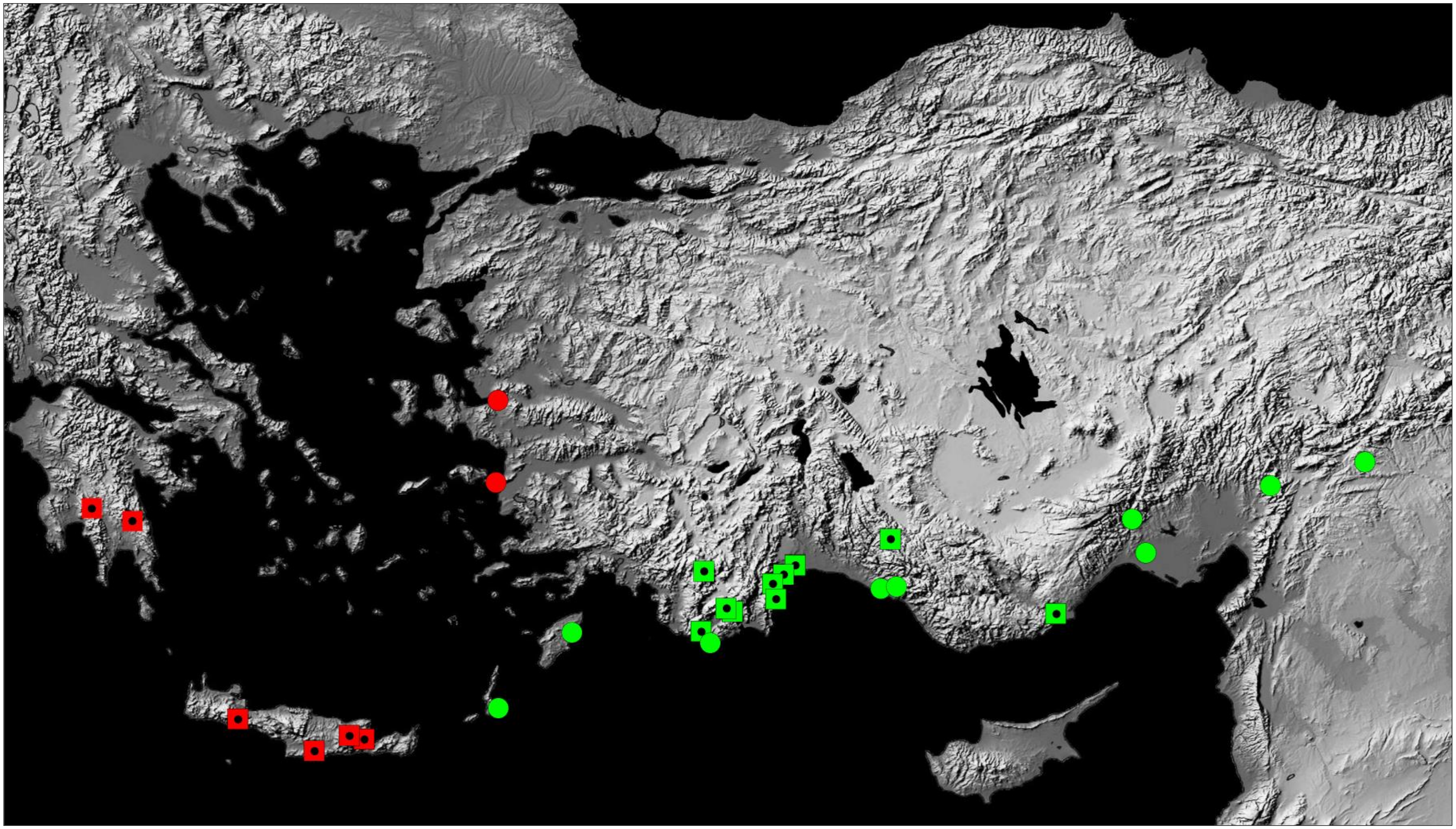
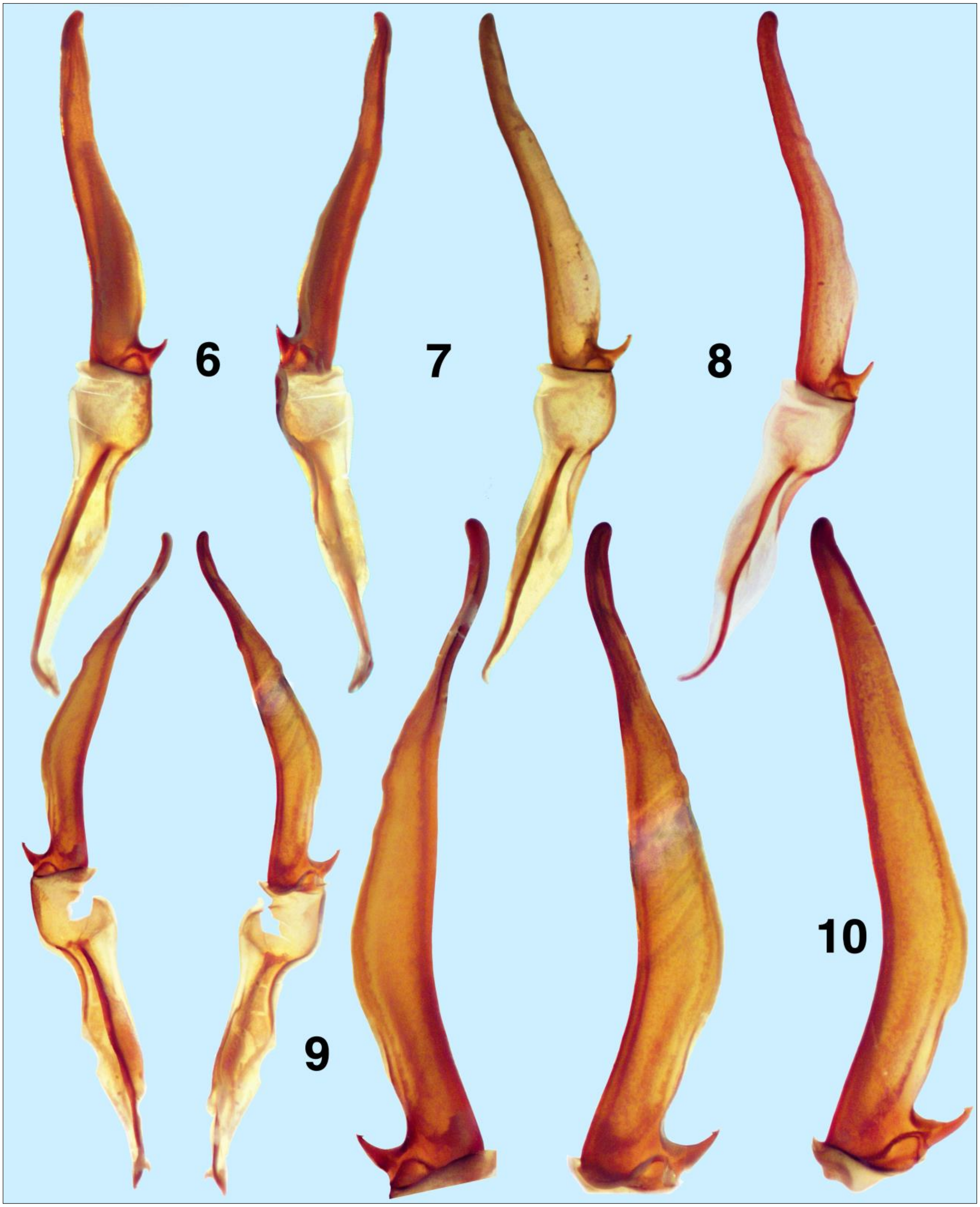


Figure 5: Geographic distribution of *Iurus* and *Protoiurus* specimens whose hemispermatophores were examined (59 hemispermatophores from 40 specimens representing 27 localities). Green icons (*Protoiurus*) represent type *1* hemispermatophores: circles, subtype *1a*; squares with dot, subtype *1b*. Red icons (*Iurus*) represent type *2* hemispermatophores: circles, subtype *2a*; squares with dot, subtype *2b*.



Figures 6–10: *Protoiurus kraepelini* hemispermatophores illustrating subtype *1b* (photographed submerged in alcohol). **6.** Kaş Town, Antalya, Turkey, dorsal and ventral views. **7–8.** Alacadağ Mountains, Türbe road, Finike, Antalya, Turkey, dorsal views. **9–10.** Akseki, Antalya, Turkey. **9.** Left hemispermatophore, dorsal and ventral views. Note, external portion of the median area is missing. Close-up of median area and lamina of left hemispermatophore, dorsal and ventral views. **10.** Right hemispermatophore, dorsal view.

sent and *P. kumlutasi* is consistent with the other species exhibiting subtype *1a* (see Figs. 23–24). Based on this new analysis, we conclude that the hemispermatophore subtype *1a* is a major diagnostic character for new species *P. kumlutasi*, while, as previously reported, *P. kraepelini* exhibits subtype *1b*.

Systematics

Order **SCORPIONES** C. L. Koch, 1850
Suborder Neoscorpiones Thorell et Lindström, 1885
Infraorder Orthosterni Pocock, 1911
Parvorder Iurida Soleglad et Fet, 2003
Superfamily Iuroidea Thorell, 1876
Family Iuridae Thorell, 1876
Subfamily Iurinae Thorell, 1876

Genus ***Protoiurus*** Soleglad, Fet, Kovařík et Yağmur, 2012

Protoiurus kumlutasi Yağmur, Soleglad, Fet et Kovařík, **sp. nov.**

(Figs. 11–24; Table 1)
http://zoobank.org/
urn:lsid:zoobank.org:act:277D3491-C951-43B6-8F02-267FBBA57E87

Type material: *Holotype* ♂, TURKEY. ***Antalya Province***: Kaş District, Hıdırellez Cave (36.1725 N, 29.6442 E) (inside cave), 12 April 2012, leg. E. A. Yağmur & R.S. Kaya (AZMM).

Paratypes: same locality as holotype, 12 April 2012, leg. E. A. Yağmur & R. S. Kaya, 1 ♂, 3 subad. ♂, 4 subad. ♀ (AZMM); 30 May 2010, leg. Yusuf Kumlutaş, 1 subad. ♂ (AZMM) (inside cave); 13 August 2010, leg. E. A. Yağmur & E. Yağmur, 1 ♂, 1 subad. ♀ (AZMM) (inside cave); 15 October 2011, leg. E. A. Yağmur & R. S. Kaya, 1 ♂ (NHMW 21.958), 1 ♂, 2 subad. ♂, 1 juv. ♂, 1 subad. ♀ (AZMM) (cave entrance); 7 August 2011, leg. E. A. Yağmur & E. Yağmur, 1 ♂, 1 ♀ (FKCP), 1 subad. ♂, 1 juv. ♂, 1 subad. ♀ (AZMM) (inside cave).

Diagnosis. Medium to large sized species, 89 mm. Dark brown carapace and mesosoma, legs, metasoma, and pedipalps orange-brown. Pectinal tooth counts, 10–14 (11.79) [29] for males, and 9–12 (10.73) [15] for females. Chelal movable finger lobe in adult males located on distal half, lobe ratio 0.52–0.63; a strong proximal gap on fixed finger present in adult males; movable finger of adult males highly curved; number of inner denticles (*ID*) of chelal movable finger, 11–13 (12); hemispermatophore subtype *1a*.

Distribution. **Turkey**: Antalya Province, Kaş District, Hıdırellez Cave. See maps in Figures 3 and 25.

Etymology. Species name is a patronym honoring Dr. Yusuf Kumlutaş, a Turkish herpetologist and discoverer of the *Protoiurus* population of the Hıdırellez Cave.

MALE. The following description is based on the holotype male from the Hıdırellez Cave, Kaş District, Antalya Province, Turkey. Measurements of the holotype and three paratype specimens are presented in Table 1. See Figures 11–12 for a dorsal and ventral view of the male holotype and paratype female.

COLORATION. Basic color of carapace a dark brown with posterior margins a lighter orange-brown; tergites orange-brown; pedipalps dark brown; metasoma, telson, and legs orange-brown; chelicerae and sternites brown; genital operculum, basal piece, and pectines orange. Patterns essentially absent.

CARAPACE (Fig. 13). Anterior edge with a conspicuous median indentation, approximately ten irregularly placed setae visible; entire surface covered with medium sized granules, the most prominent on the interocular area. Mediolateral ocular carinae well-developed and granulated, extending to the lateral eyes; there are three lateral eyes, the posterior eye the smallest. Median eyes and tubercle of medium size, positioned anterior of middle with the following length and width ratios: 0.365 (anterior edge to medium tubercle middle / carapace length) and 0.151 (width of median tubercle including eyes / width of carapace at that point).

MESOSOMA (Figs. 17–18). Tergites I–VII densely populated with small granules; tergite VII lateral carinae crenulated, median carinae crenulated basally. Sternites III–VII smooth and lustrous; VII with weak lateral carinae, formed by two or three granules, median carinae essentially obsolete (Fig. 17). Stigmata (Fig. 18) are medium in size and slit-like in shape, angled 35° in an anterointernal direction.

METASOMA (Fig. 14). Segment I wider than long. Segments I–IV: dorsal and dorsolateral carinae serrated; dorsal carinae with 9/8, 9/7, 9/10, and 9/8 serrated spines (left/right carina); dorsal (I–IV) and dorsolateral (I–III) carinae do not terminate with an enlarged spine; lateral carinae crenulated on I, crenulate on posterior two-thirds of II; irregular, weak to obsolete on segment III and obsolete on IV; ventrolateral carinae granulated on I, weakly granulated on II, and crenulated on III and IV; ventromedian carinae smooth to weakly granulated on I–II, and granulated to crenulated on III–IV. Dorsolateral carinae of segment IV terminate at articulation condyle. Segment V: dorsolateral carinae serrated; lateral carinae irregularly granulated for one-half of posterior aspect; ventrolateral and single ventromedian carinae serrated; ventromedian carina not bifurcated, terminating in

Figure 11: Dorsal and ventral views of *Protoiurus kumlutasi* **sp. nov.**, holotype male, Hıdırellez Cave interior, Kaş District, Antalya Province, Turkey.

Figure 12: Dorsal and ventral views of *Protoiurus kumlutasi* **sp. nov.**, paratype female, Hıdırellez Cave entrance, Kaş District, Antalya Province, Turkey.

straight line. Anal arch with 14 small serrated granules. Intercarinal areas of segments I–V essentially smooth except for dorsal aspect which has dense minute granulation. Segments I–V with numerous setae on ventral, lateral and dorsal aspects.

TELSON (Fig. 14). Vesicle elongated, with highly curved aculeus. Vesicle essentially without granules; ventral surface densely covered with elongated curved setae; dorsal surface irregularly scattered with short setae; base of aculeus with setation ventrally and dorsally. Vesicular tabs each with four small sharp spines.

PECTINES (Fig. 21, paratype female Fig. 21). Well-developed segments exhibiting length / width ratio 2.400 (length taken at anterior lamellae / width at widest point including teeth). Sclerite construction complex, three anterior lamellae and five middle lamella; fulcra of medium development. Teeth number 11/12. Sensory areas developed along most of tooth inner length on all teeth, including basal tooth. Scattered setae found on anterior lamellae and distal pectinal tooth. Basal piece large, with well-developed indentation along anterior edge, length / width ratio 0.509.

GENITAL OPERCULUM (Fig. 21). Sclerites triangular, longer than wide, separated for entire length. Genital papillae visible between sclerites but do not extend beyond genital operculum posterior edge (see discussion on female below).

STERNUM (Fig. 21). Type 2, posterior emargination present, well-defined convex lateral lobes, apex visible but not conspicuous; anterior portion of genital opercu-

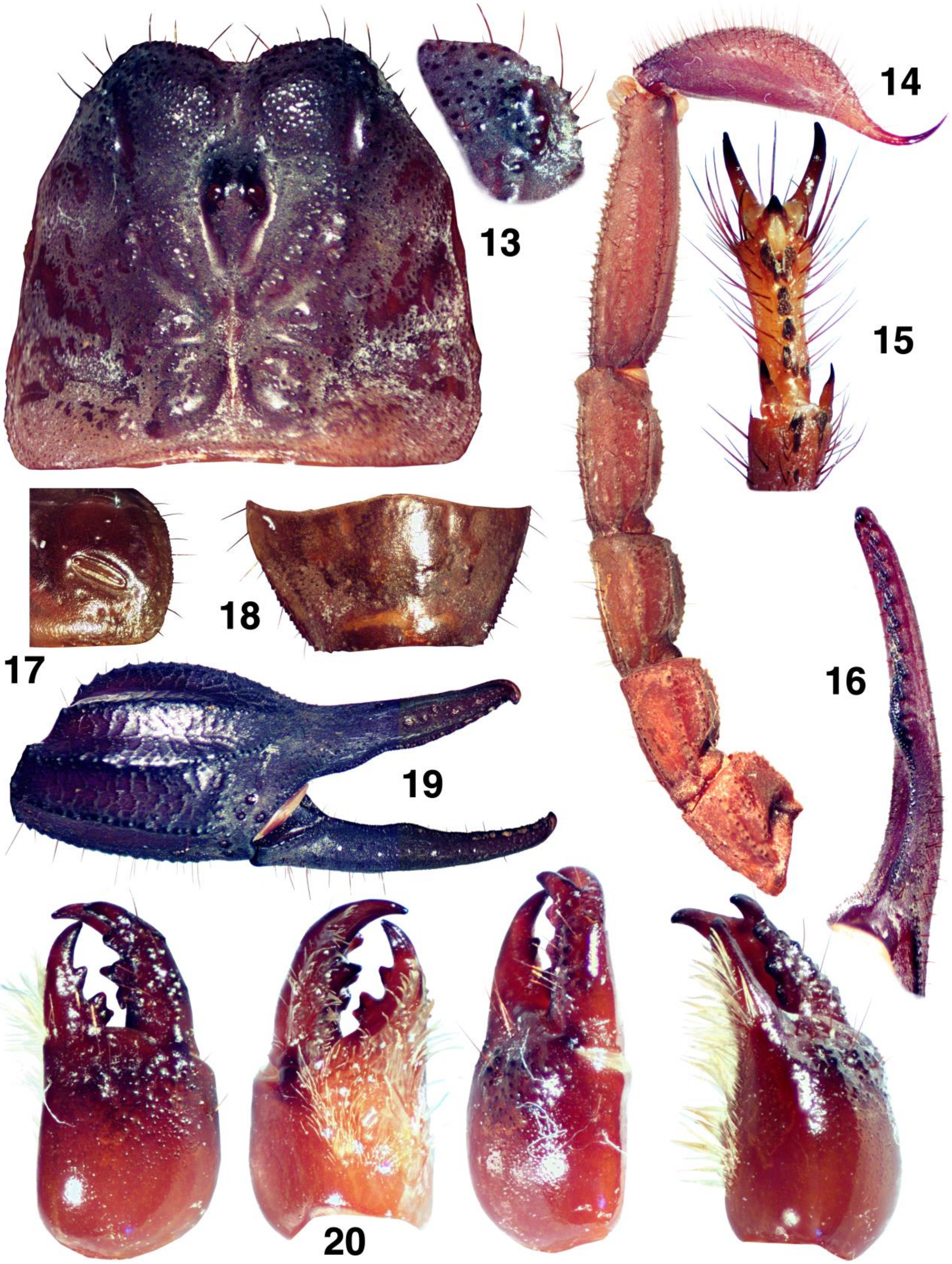
	Protoiurus kumlutasi				***Protoiurus kraepelini***
	Hıdırellez Cave, Antalya Province, Turkey				**Kaş Town, Antalya Province, Turkey**
	Male Holotype	**Male Paratype**	**Male Paratype**	**Female Paratype**	**Male**
Total length	84.20	89.15	83.55	82.40	77.35
Carapace length	11.60	12.65	11.10	11.20	10.70
Mesosoma length	27.95	30.50	34.30	30.50	26.65
Metasoma length	31.95	33.00	27.05	28.90	29.00
Segment I length/width	4.00/4.60	4.30/5.10	3.50/4.60	3.80/4.60	3.70/5.00
Segment II length/width	4.70/4.20	5.00/4.70	4.00/4.20	4.30/4.15	4.40/4.30
Segment III length/width	5.35/4.15	5.50/4.55	4.40/4.00	4.70/4.00	4.75/4.00
Segment IV length/width	6.50/3.45	6.70/3.90	5.55/3.55	5.90/3.60	5.65/3.60
Segment V length/width	11.40/3.20	11.50/3.65	9.60/3.25	10.20/3.50	10.50/3.35
Telson length	12.70	13.00	11.10	11.80	11.00***
Vesicle length	9.00	9.50	7.90	8.00	7.70
width/depth	3.50/3.20	3.70/3.30	3.20/2.80	3.20/2.90	3.30/3.15
Aculeus length	3.70	3.50	3.20	3.80	3.30***
Pedipalp length	44.55	45.90	41.25	42.30	39.60
Femur length/width	11.60/3.95	11.50/4.20	10.40/4.05	10.80/3.85	9.80/3.75
Patella length/width*	10.50/4.00	10.70/4.50	9.90/4.05	9.90/4.10	9.50/3.00
DPS height**	1.00	1.10	1.20	1.00	0.85
Chela length	22.45	23.70	20.95	21.60	20.30
Palm length	10.20	11.20	10.00	10.00	9.70
width/depth	6.35/9.05	7.00/10.95	5.90/8.00	6.05/8.30	6.20/8.70
Fixed finger length	10.25	11.00	9.90	9.50	9.50
Movable finger length	14.25	15.25	13.15	13.65	12.80
Sternum length/width	2.80/2.80	3.00/2.70	2.50/2.40	3.25/3.35	2.50/2.05
Pectines teeth	11-12	11-12	10-11	12-11	x-12
middle lamellae	5-5	6-5+	5-5	6-5+	x-4

Table 1: Morphometrics (mm) of *Protoiurus kumlutasi* **sp. nov**. and *P. kraepelini*. * Patella width is widest distance between the dorsointernal and externomedial carinae. ** DPS height is from tip of spines to dorsointernal carina centered. *** An estimate, aculeus malformed.

lum situated proximally between lateral lobes; sclerite length and width the same (see discussion on female below).

CHELICERAE (paratype male, Fig. 20). Movable finger dorsal edge with one large subdistal (*sd*) denticle; ventral edge with one large pigmented accessory denticle at finger midpoint, lacking the vestigial secondary *va* denticle found in some *Iurus* specimens; ventral edge serrula not visible. Ventral distal denticle (*vd*) slightly longer than dorsal (*dd*). Fixed finger with four denticles, median (*m*) and basal (*b*) denticles conjoined on common trunk; no ventral accessory denticles present.

PEDIPALPS (Figs. 16, 22, paratype female Fig. 19). Well-developed chelae, with relatively long fingers, heavily carinated, and conspicuous scalloping on chelal fingers: well-developed lobe on movable finger, positioned distal of midpoint in ratio 0.604; proximal gap on fixed finger is strong. **Femur:** Dorsointernal, dorsoexternal and ventrointernal carinae serrated, ventroexternal rounded and granulated. Dorsal surface widely populated with medium to strong granules, ventral sur-



Figures 13–**20:** *Protoiurus kumlutasi* **sp. nov.**, Hıdırellez Cave, Kaş District, Antalya Province, Turkey. **13–18.** Male holotype. **13.** Carapace and lateral eyes. **14.** Metasoma and telson, lateral view. **15.** Right leg III tarsus, ventral view. **16.** Movable finger dentition. **17.** Right third stigma. **18.** Sternite VII. **19.** Female paratype, chela, external view. **20.** Male paratype, chelicera, dorsal, ventral, exterodorsal, and interodorsal views.

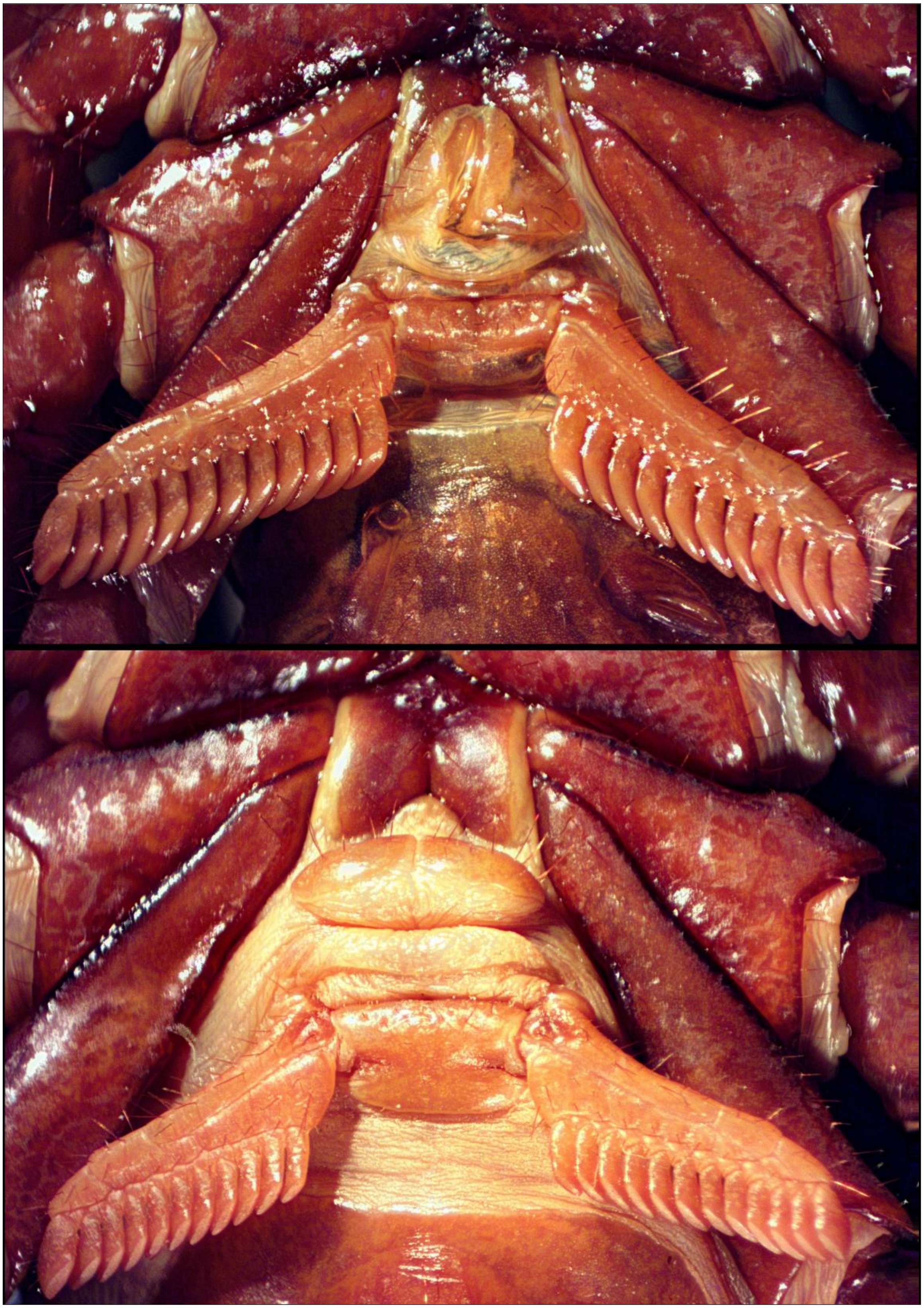


Figure 21: Sternopectinal area of *Protoiurus kumlutasi* **sp. nov.**, Hıdırellez Cave, Kaş District, Antalya Province, Turkey. **Top.** Male holotype. **Bottom.** Female paratype.

Figure 22: Trichobothrial pattern of *Protoiurus kumlutasi* **sp. nov.**, male holotype. Hıdırellez Cave interior, Kaş District, Antalya Province, Turkey.

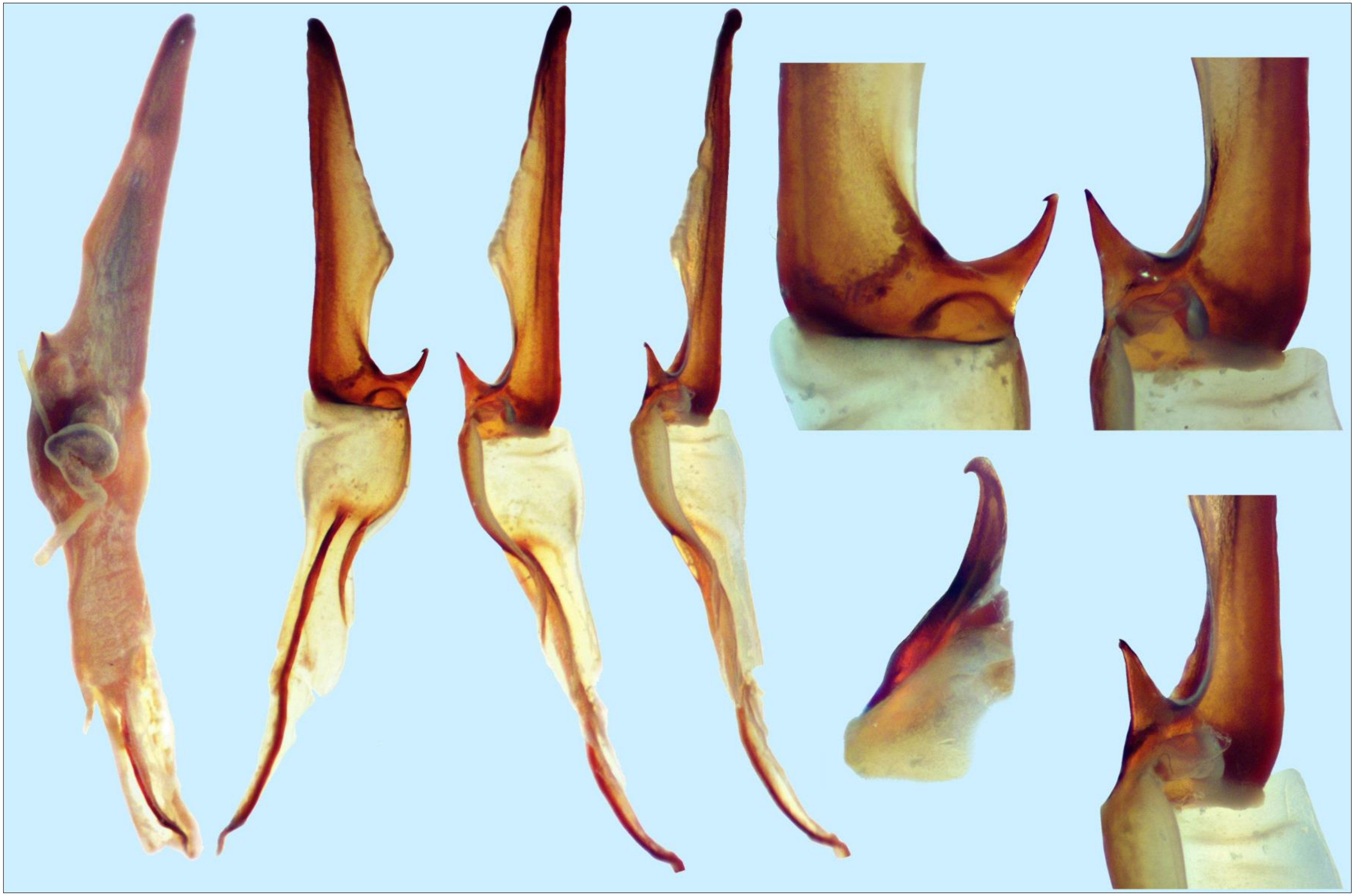


Figure 23: Left hemispermatophore (reversed, submerged in alcohol) of *Protoiurus kumlutasi* **sp. nov.**, holotype male, Hıdırellez Cave interior, Kaş District, Antalya Province, Turkey. **Left.** Complete structure, ventral view still encased in paraxial organ (severed vas deferens connected to seminal vesicle is visible), dorsal, ventral, and interoventral views. **Right.** Closeup of median area, dorsal, ventral, interoventral views, and internal view showing a further closeup of the curved acuminate process terminus.

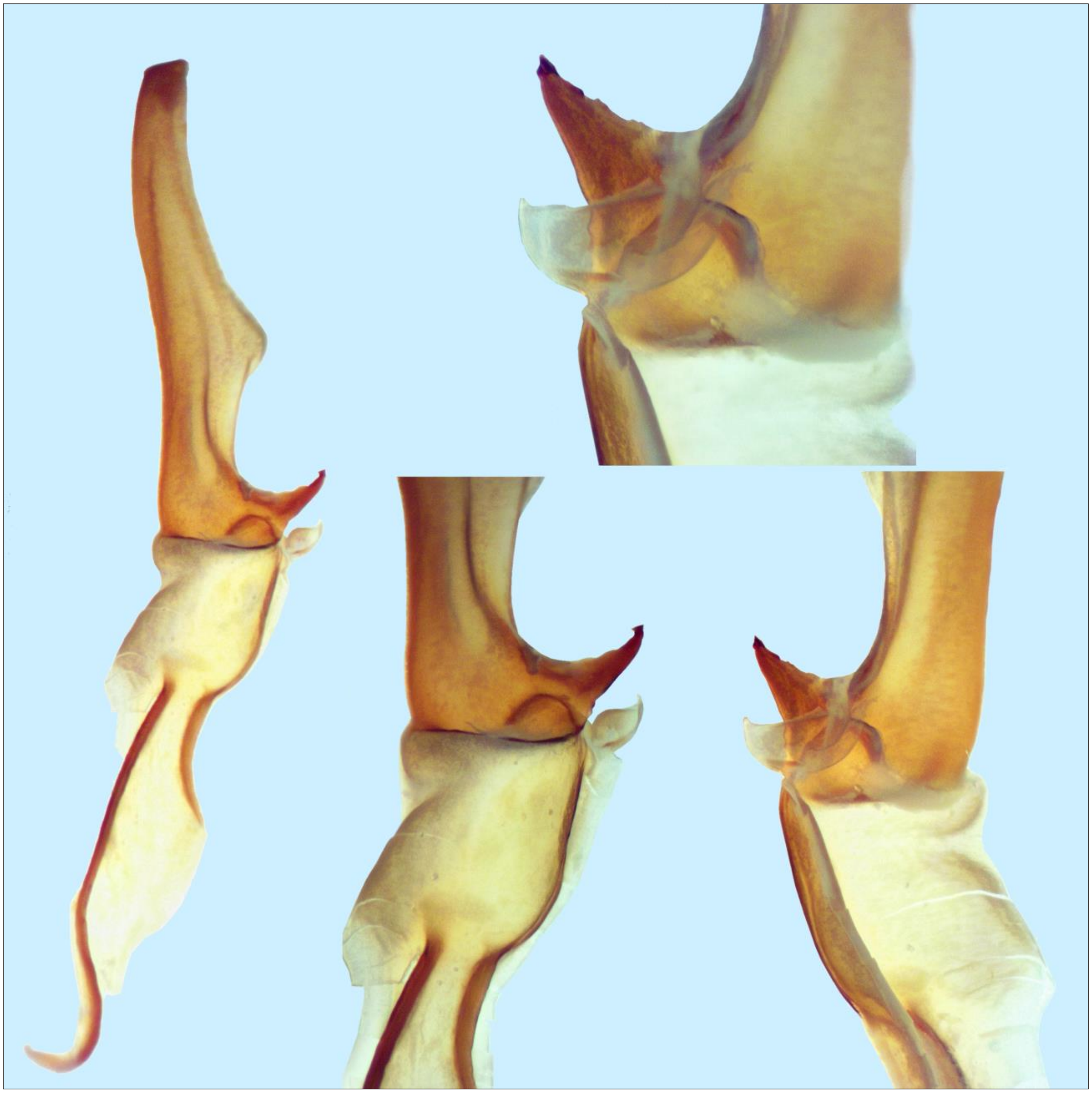


Figure 24: Right hemispermatophore (submerged in alcohol) of *Protoiurus kumlutasi* **sp. nov.**, paratype male, Hıdırellez Cave entrance, Kaş District, Antalya Province, Turkey. **Left.** Complete structure, dorsal view. Note the lamina terminus is folded onto the ventral surface. **Bottom-Right.** Closeup of median area, dorsal and ventral views showing the paraxial organ sleeve. **Upper-Right.** Further closeup of median area of ventral view, showing further details of the paraxial organ sleeve.

face with minute granules, internal surface with irregular line of 7–8 sharp granules, and external surface with line of 14–16 sharp granules. **Patella:** Dorsointernal and ventrointernal carinae serrated, dorsoexternal and ventroexternal granulated to crenulated, and exteromedian carina strong and crenulated, a second weak carina found medially with small granules. Dorsal surface widely populated with medium to strong granules medially; ventral surface marbled with minute granules; external surface rough in texture; internal surface smooth with well-developed, doubled DPS and VPS. **Chelal carinae:** Complies with the “8-carinae configuration”. Digital (*D1*) carina medium to strong with blunted flat granulation; dorsosecondary (*D3*) rounded and smooth; dorsomarginal (*D4*) rounded with scattered granules; dorsointernal (*D5*) irregularly serrated; ventroexternal (*V1*) strong and granulated, terminating at external condyle of movable finger; ventrointernal (*V3*)

		Chela_Length/Telson_Depth	MVD %	Chela_Length/Telson_Width	MVD %
♂	**P. kumlutasi**	7.02–7.48 (7.227) (±0.236) [3]: {6.99–7.46} → 0.033	12.2	6.41–6.55 (6.456) (±0.079) [3]: {6.38–6.53} → 0.012	10.3
	P. kraepelini	5.81–6.80 (6.443) (±0.450) [4]: {5.99–6.89} → 0.070	-	5.24–6.15 (5.854) (±0.415) [4]: {5.44–6.27} → 0.071	-
♀	**P. kumlutasi**	7.45–7.45 (7.448) (±0.000) [1]: {7.45–7.45} → 0.000	13.2	6.75–6.75 (6.750) (±0.000) [1]: {6.75–6.75} → 0.000	18.3
	P. kraepelini	6.42–6.64 (6.578) (±0.107) [4]: {6.47–6.68} → 0.016	-	5.51–5.99 (5.707) (±0.202) [4]: {5.50–5.91} → 0.035	-

Table 2: Morphometric ratio comparisons between adult *Protoiurus kumlutasi* **sp. nov.** and *P. kraepelini*. The pedipalp chelal length is compared to the telson vesicle depth and width for both genders. In all four comparison sets, involving a total of 12 samples (4 *P. kumlutasi* and 8 *P. kraepelini*), *P. kumlutasi*, as indicated by larger ratio values, demonstrating a more slender telson vesicle and a longer chela. All ratio comparisons show absolute range separation. The mean value difference (MVD) percentages ranged from 10.3 to 18.3, larger in the female for both ratios. Statistical data group: minimum–maximum (mean) (±standard deviation) [number of samples]: {standard deviation range} → coefficient of variability.

widely rounded, essentially smooth except for scatter flat granules, continuous to internal condyle; external (*E*) strong with large flat granules, internal (*I*) irregularly serrated. **Chelal finger dentition (Fig. 16):** Median denticle (*MD*) row groups oblique and highly imbricated; 10/10 *ID*s to socket beginning on fixed finger and 12/12 *ID*s on movable finger; 9/9 *OD*s on fixed finger (to gap) and 10/10 *OD*s on movable finger. No accessory denticles present. **Trichobothrial patterns (Fig. 22):** Type C, orthobothriotaxic.

LEGS (Fig. 15). Both pedal spurs present on all legs, lacking spinelets; tibial spurs absent. Tarsus with conspicuous spinule clusters in single row on ventral surface (numbering 8-7-7-9 for legs I–IV, respectively), terminating distally with a pair of enlarged spinule clusters. Unguicular spine well-developed and pointed. Basitarsus with external and internal rows of spinule clusters as follows: 15/4 - 16/2 - 2/4 - 2/1 for legs I–IV, respectively.

HEMISPERMATOPHORE (Fig. 23, paratype male, 24). Hemispermatophore conforms to subtype *1a*: distal lamina is tapered and pointed, external edge essentially straight; internal nodule is conspicuously developed and pointed; transverse trunk bolsters are absent; acuminate process terminus is truncated. Specific ratio values for this species are the following based on two specimens, both hemispermatophores (i.e., n = 4): lamina length / trunk length = 0.874–0.952 (0.913) and lamina distal length / lamina basal length = 1.576–1.667 (1.606). Length of holotype male hemispermatophores 11.65 mm (left) and 11.85 mm (right).

Sexual dimorphism. The adult female does not exhibit a proximal gap on the chelal fixed finger and the movable finger lobe is relatively weak. In sexually mature males, a conspicuous proximal gap is visible and the movable finger lobe is well developed (see Fig. 27). Based on the material available, the lobe on the female is slightly basal of the finger midpoint on adults, whereas in the male, the lobe is distal of the midpoint. There is no significant sexual dimorphism present in morphometrics (based on one sexually mature female and three males). Though the male has a slightly thinner metasoma, the MVDs (L/W) only ranged from 0.0 to 10.6 %. Pectinal tooth counts in males exceed those of females by approximately one tooth, male 10–14 (11.79) [29] and female 9–12 (10.73) [15] (see histograms in Fig. 26). The genital operculum of the male is different from that in the female (Fig. 19). The sclerites, subtriangular in shape, are as long as or longer than wide in the male, whereas in the female the sclerites are short and wide, more than twice as wide as long. Whereas the sclerites are fused medially in the female, they are separated along their entire length in the male, exposing significantly developed genital papillae. The enlarged genital operculum of the male extends distally between the lateral lobes of the sternum partially obscuring its proximal region. Figures 11–12, 1–2, 3 and 25 show dorsal and ventral views of both male and female specimens, photographs of its type locality, live specimens, and the maps of distribution for this species.

Discussion

Protoiurus kumlutasi **sp. nov.** is known from the type locality, the Hıdırellez Cave, found in the extreme southwest coastal area of Antalya Province, Turkey (see maps in Figs. 3 and 25). Specimens have been collected inside the cave (18 specimens, including the holotype male) as well as outside at the cave entrance (five specimens).

Morphologically, *P. kumlutasi* resembles the widespread species *P. kraepelini*, most notably in the characteristic pedipalp chela with the exaggerated finger lobes, proximal gaps, and highly curved movable fingers that are exhibited in sexually mature males. These spe-

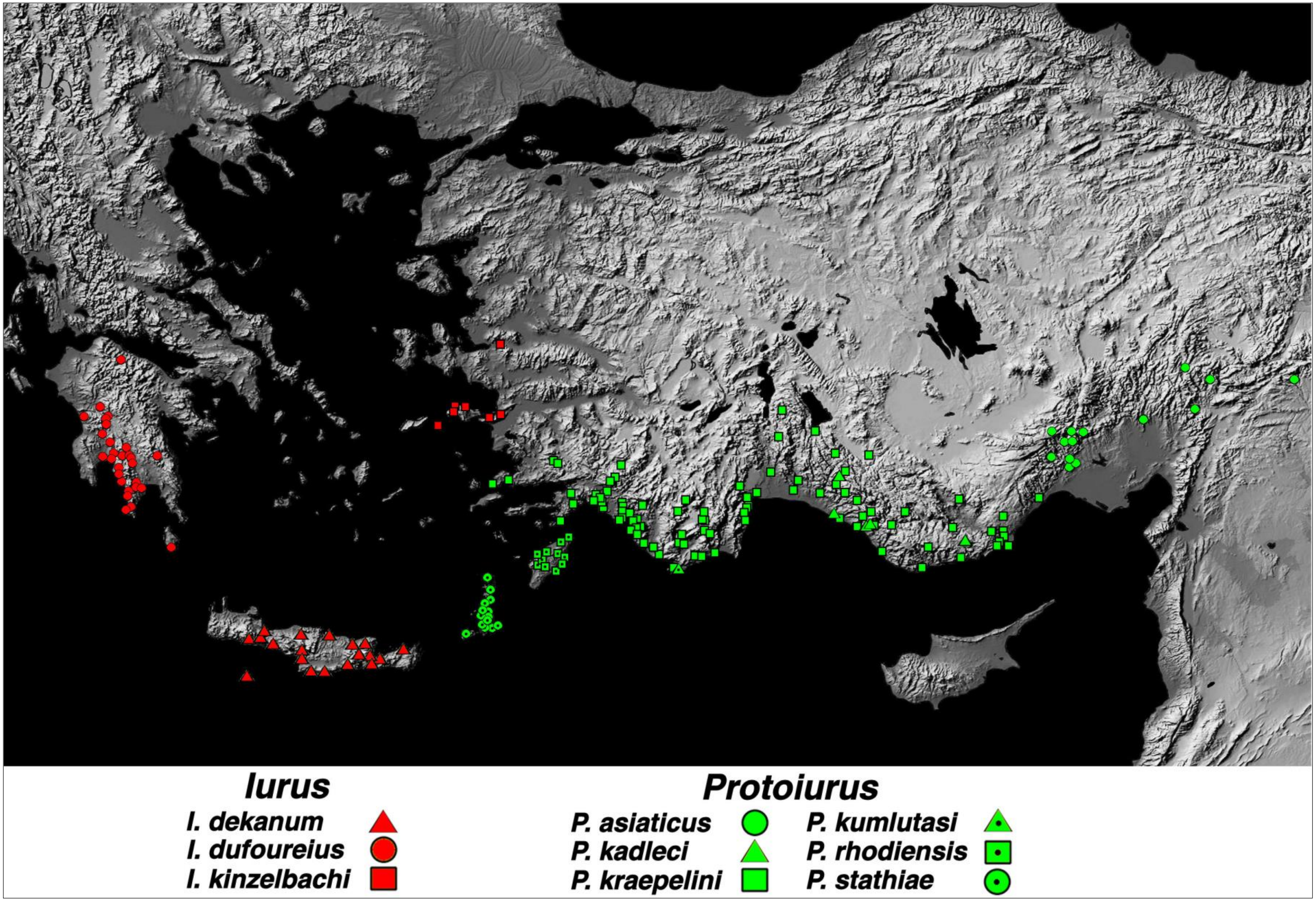


Figure 25: Map showing geographic distribution of *Iurus* (red) and *Protoiurus* (green) specimens examined and/or reported in literature, including new species *Protoiurus kumlutasi*.

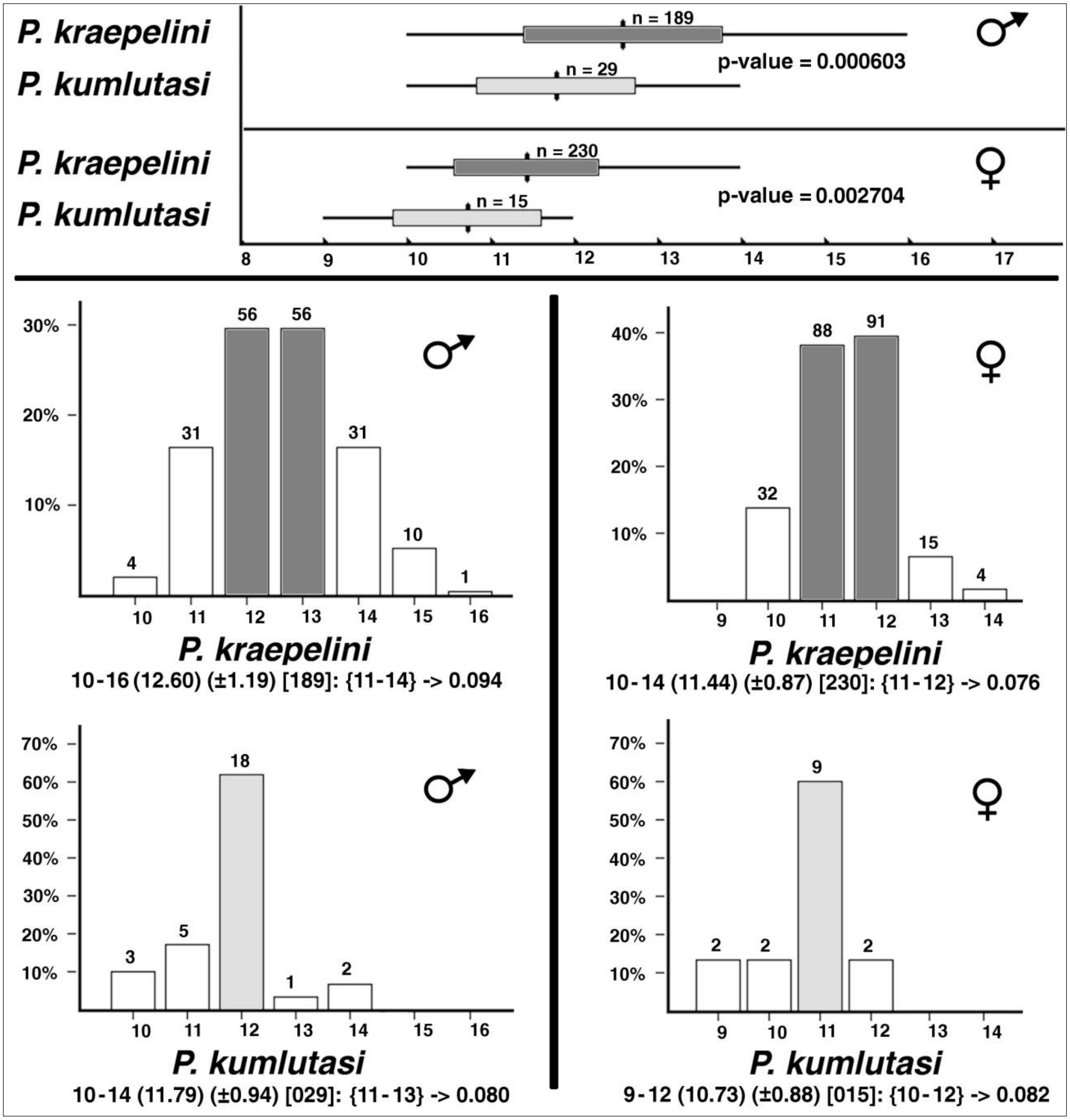


Figure 26: Pectinal tooth count comparisons of *Protoiurus kumlutasi* **sp. nov.**, 44 samples, and *P. kraepelini*, 419 samples. **Top.** In the horizontal bar histograms the thin line represents the minimum and maximum range, the wide rectangle represents the plus-minus standard deviation range, and the verticle bar is the mean. ANOVA *p-value* is shown for each gender. **Bottom.** In the vertical bar histograms individual counts and their percentage of occurrence are shown, and the mode is indicated by the darker bars. Statistical data group: minimum–maximum (mean) (±standard deviation) [number of samples]: {standard deviation range} → coefficient of variability.

cies are also sympatric (as discussed above, we examined a sexually mature male *P. kraepelini* from Kaş Town, less than 3 km from the Hıdırellez Cave). Other *Protoiurus* species are not found in close proximity to *P. kumlutasi*; the closest, *P. rhodiensis* on the Rhodes Island, roughly 140 km from the Hıdırellez Cave across the sea. *Protoiurus kadleci* is also found in the Antalya Province (sympatric with *P. kraepelini*) but its range lies 200 km away from the Hıdırellez Cave; the farthest species, *P. asiaticus*, is about 400 km away (Fig. 25).

Of particular interest, *Protoiurus kumlutasi* does not exhibit any troglomorphic characteristics (see compar-

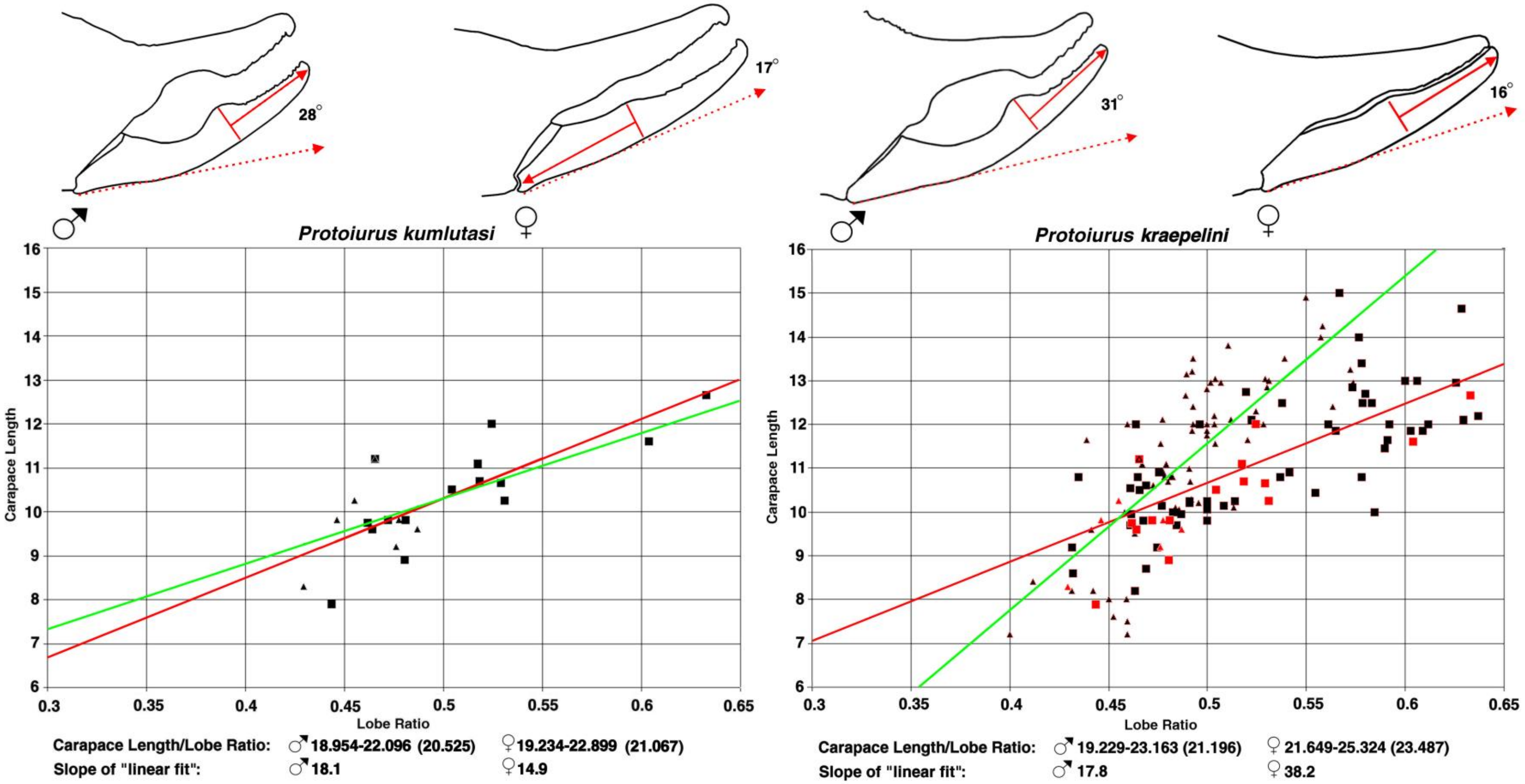


Figure 27: Movable finger lobe signatures. **Left.** *Protoiurus kumlutasi* **sp. nov. Right.** *Protoiurus kraepelini*, black icons, compared with *P. kumlutasi*, red icons. Squares = males, triangles = females.The lines depict linear fit by least squares regression, red for males and green for females. Lobe ratio = distance from external condyle to lobe center / movable finger length.

ison of troglobitic species in Fet et al. (2011: tabs. 4, 5) in their redescription of scorpion genus *Akrav*): no reduction in sclerotization, coloration, or attenuation of appendages. Median and lateral eyes are well developed (see Fig. 13), not reduced or missing. Pectines are well developed, no loss of fulcra or anterior lamellae (see Fig. 21). Leg armature and cheliceral dentition are typical for the genus, not exhibiting lost or reduced pedal spurs, or missing denticles (see Figs. 15, 20). The telson vesicle is not inflated, resembling telsons of other *Protoiurus* species. Note that the related *P. kadleci* also has been found in Antalya caves (Dim Cave) as well as outside (Kovařík et al., 2010), and exhibits no troglomorphic features.

Hemispermatophore comparison. The primary character separating *P. kumlutasi* from morphologically close *P. kraepelini* is the hemispermatophore. The hemispermatophore of *P. kumlutasi* exhibits subtype *1a* as originally defined by Soleglad et al. (2012: 4–7, fig. 1) and as further discussed in this paper. In Figure 4, we see that the four hemispermatophores examined from two *P. kumlutasi* specimens are well within the statistical range for the two morphometric ratios used to distinguish subtype *1a* and *1b* (the subtype *1b* being exhibited solely in *P. kraepelini*). Figures 23 and 24 show hemispermatophores of the holotype of *P. kumlutasi* collected inside the Hıdırellez Cave and a paratype from the cave entrance. Both match the subtype *1a* as depicted in Fig. 4. Finally, compare the hemispermatophores of *P. kumlutasi* with those of *P. kraepelini* (Figs. 6–10), representing four separate specimens and localities within Antalya (two of these close to the type locality of *P. kraepelini*), all exhibiting subtype *1b*.

Pectinal teeth comparison. The pectinal tooth counts in *P. kumlutasi* are lower than in *P. kraepelini*, on average slightly less than one tooth for each sex: 10–14 (11.79) as compared to 10–16 (12.60) for males, and 9–12 (10.73) as compared to 10–14 (11.44) for females. Figure 26 shows histograms and statistical data supporting these differences, based on 44 samples of *P. kumlutasi* and 419 samples of *P. kraepelini*. Statistically, ANOVA analysis provided somewhat significantly small p-values for male and female comparisons, 0.000603 and 0.002704, respectively.

Morphometric ratio comparisons. We conducted morphometric analysis on four adult *P. kumlutasi*, three males and one female. These specimens were compared to *P. kraepelini*, four specimens of each sex including the male from Kaş Town, Antalya. Comparisons of the individual metasomal segment lengths to their widths did not show any significant or consistent differences. The largest mean value differences ranged from 1.4 to 6.4 % in the males and 1.3 to 9.6 % in the females, where the largest mean values were inconsistently spread between the two species. Calculating all possible ratios across all structure measurements for both sexes of the two species (i.e., 351 ratios across 27 morphometrics per sex), we isolated dominant morphometrics for each species (i.e., morphometrics that accounted for the largest ratio values). Ratios involving the telson width or depth dominated in almost all ratio comparisons for *P. kraepelini* across both sexes, exhibiting 98 out of a 100 ratio comparisons. This implies that the telson vesicle is relatively more robust in *P. kraepelini* than in *P. kumlutasi*. *P. kumlutasi* dominated for the chelal length in both sexes, exhibiting 39 out of 46 comparisons, thus implying a relatively longer chela than in *P. kraepelini*. Of key importance in this analysis is that both sexes across the two species dominated for the same morphometrics, thus providing a consistent diagnostic character for the species. From these three morphometrics we constructed two ratios, the chelal length compared to the telson width and to the telson depth. The results of these comparisons across both sexes are shown in Table 2. The ratio comparisons of this small dataset did not overlap and their mean value differences (MVD) ranged from 10.3 to 18.3 %. Morphometrics of *P. kumlutasi* and the *P. kraepelini* specimen from Kaş Town are shown in Table 1. Other *P. kraepelini* morphometrics are from Kovařík et al. (2010: tab. 5) and unpublished data.

Chelal finger lobe comparison. In Figure 27 the chelal finger lobe/gap statistical data is shown for *P. kumlutasi* and compared to *P. kraepelini*. Based on the limited number of subadult to adult *P. kumlutasi* females available, we see that the movable finger lobe does not extend to the finger midpoint. The largest female (carapace length = 11.20) exhibits a lobe ratio of 0.465 and a second female (carapace length = 9.80) has a ratio of 0.477. In *P. kraepelini*, we see the female's lobe ratio exceeding 0.500, ranging from carapace lengths 10.00 to 15.00. However, more *P. kumlutasi* adult female material needs to be studied before we can accurately quantify these data. The lobe ratio of the male *P. kumlutasi* is consistent with that shown for *P. kraepelini*, both distal of finger midpoint in adult specimens.

Metasomal dorsal carinae comparison. Kovařík et al (2010: tab. 9) compared the number of spines comprising the dorsal carinae of metasomal segments I–IV across the five species comprising genus *Iurus* at that time (note, some species are now placed in genus *Protoiurus*). In particular this statistic was provided in order to illustrate the large number of spines found in species *P. kadleci*, averaging over twelve. We calculated the number of spines (both left and right carinae) for the 23 specimens of *P. kumlutasi* examined. The average number of the eight carinae per specimen was calculated, yielding 7.50–10.00 (8.391) [23]. In comparison to *P. kraepelini*, 6.00–9.12 (7.807) [62], we see *P. kumlutasi* has a slightly larger average number exhibiting a MVD of 7.48 %.

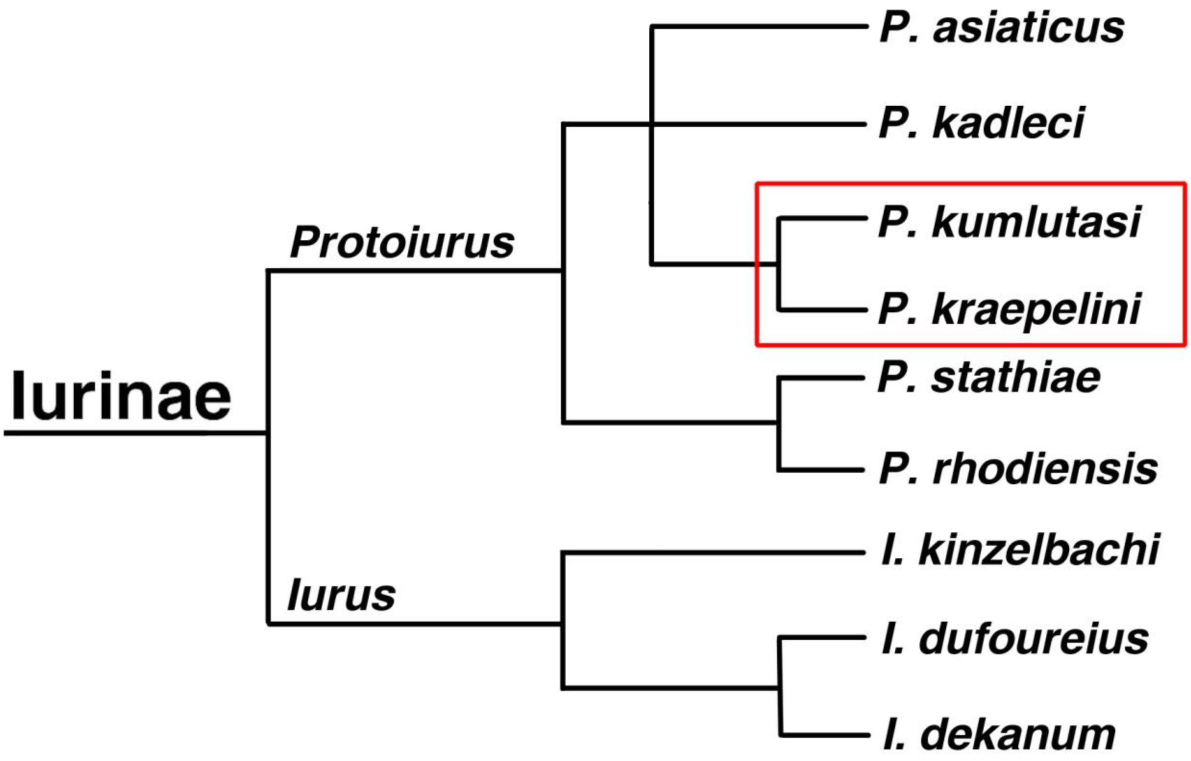


Figure 28: Phylogeny of scorpion subfamily Iurinae based on morphology of the hemispermatophore and the pedipalp chela. Cladogram is based on the original 13 hemispermatophore-based characters presented in Soleglad et al. (2012: fig. 2, app. A), augmented with four characters derived from pedipalp chela morphology. Red rectangle indicates species of interest for this paper.

Biogeography and Phylogeny of *Protoiurus*

Our recent revisionary work on Iuridae (Kovařík et al., 2010; Soleglad et al., 2012; and the present paper) has dramatically expanded the former "monotypic species *Iurus dufoureius*" into two genera and nine species. At the same time, our phylogenetic interpretation of these taxa largely agrees with an early DNA analysis by Parmakelis et al. (2006). We demonstrated an ancient distinct separation into two genera, *Iurus* and *Protoiurus*, which follow exactly western and eastern clades first identified by Parmakelis et al. (2006). These two genus-level clades follow a common vicariant pattern for the Aegean-Anatolian area, due to the formation of the Mid-Aegean Trench (east of Crete and west of Kasos–Karpathos). Formation of this trench, which has sundered this region into western and eastern parts, started at the end of the middle Miocene (12 Mya) and was fully completed during the beginning of the late Miocene (10–9 Mya) (Creutzburg, 1963; Dermitzakis & Papanikolaou, 1981; Dermitzakis, 1990). In many animal groups, the Mid-Aegean Trench serves as an important historical biogeographic boundary (Douris et al., 2007; Poulakakis et al., 2015). Range of the genus *Protoiurus* (Karpathos, Rhodes, and Anatolia), which we consider a more basal taxon than *Iurus* (Soleglad et al., 2012), lies entirely eastward from the Mid-Aegean Trench (MAT). The geographic distribution of sister genera *Protoiurus* and *Iurus* is presented in our map (Fig. 25).

Our current phylogeny of *Protoiurus* (Fig. 28) is based largely on Soleglad et al. (2012: fig. 2, app. A), but was augmented with new data, in particular on pedipalp chela morphology. An obvious hypothesis emerging from this phylogeny (Soleglad et al., 2012: 10) is the ancestral split into two clades reflecting hemispermatophore subtypes in *Protoiurus*: the subtype *1a* (ancestral; present in five species out of six) and the subtype *1b* (derived; present only in *P. kraepelini*). The geographic distribution of the studied hemispermatophore subtypes is given in Fig. 5.

The current distribution of six *Protoiurus* species could be a result of vicariance and dispersal events combined with endemic speciation and isolation. Two Aegean island species (*P. rhodiensis* and *P. stathiae*) follow a common pattern of island speciation in the eastern Aegean Sea. Since Rhodes and Karpathos were joined to Anatolia, ancestral representatives of the *Protoiurus* dispersed to these islands possibly during Messinian and later speciated there after the Aegean Sea refilled by the end of Pliocene (Dermitzakis, 1990). This pattern is not rare and also observed in Orthoptera (*Eupholidoptera*; Çıplak et al., 2010) and snails (Douris et al. 2007).

On the mainland, the easternmost *Protoiurus asiaticus* clade is consistent with well-known patterns of allopatric speciation for Anatolian taxa separated by high mountain ranges. This type of vicariant speciation is well observed in the iurid genera *Calchas* and *Neocalchas* (Yağmur et al., 2013). Two localized southwestern clades, *Protoiurus kadleci* and *P. kumlutasi* **sp. nov.,** appear to reflect local speciation with isolation in southern Anatolian refugia. The Anatolian Peninsula is divided into two main sectors by a well-known biogeographic boundary, the "Anatolian diagonal", which stretches from the north-western corner to the south-eastern border of the Mediterranean Anatolia. The southern part of Anatolia, limited by the Taurus Mountains from the north, is considered an important refugium of biodiversity and center of endemism (Çiplak, 2004, 2008; Kenyeres et al., 2009). The biota of Southwestern Anatolia has been experiencing vicariant speciation events since late Miocene; especially an aridization at 6.8–6.7 Ma, during the Tortonian-Messinian transition appears to have contributed to endemic speciation (Kornilios et al., 2012).

At the same time, *Protoiurus kraepelini* is quite widespread. In fact, spanning over 600 km from the western Muğla to the eastern Mersin (Fig. 25), it is the most widely ranging species of the family Iuridae. This broad distribution, as well as its presence on coastal islands (Megisti) could reflect an extensive recent (Pleistocene interglacial) dispersal of this, ecologically most common, species. Its local sympatry with *P. kadleci* and *P. kumlutasi* serves as a natural test of genetic identity of all three species—much like sympatry of widely ranging *Euscorpius sicanus* and a more localized *E. kinzelbachi* (Euscorpiidae) on Mt. Olympus in Greece (Tropea et al., 2014).

Finally, independently derived, intraspecific geographic variation within the range of *Protoiurus kraepelini* (especially in Antalya) is demonstrated by its many types of neobothriotaxy (Soleglad et al., 2009; Kovařík et al., 2010: 96, table B1), quite rare in the allopatric *P. asiaticus*. Some variation in hemispermatophore structure of *P. kraepelini* (subtype *1b*) was also detected (Soleglad et al., 2012: 7). A more detailed phylogeographic study of *Protoiurus kraepelini* across its wide range is needed, which could recover patterns of cryptic speciation so common in scorpions. New upcoming DNA data on Iuridae (Parmakelis et al., in progress) will further clarify relationships of these amazing East Mediterranean relicts.

Acknowledgments

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