# *Euscorpius*

Occasional Publications in Scorpiology
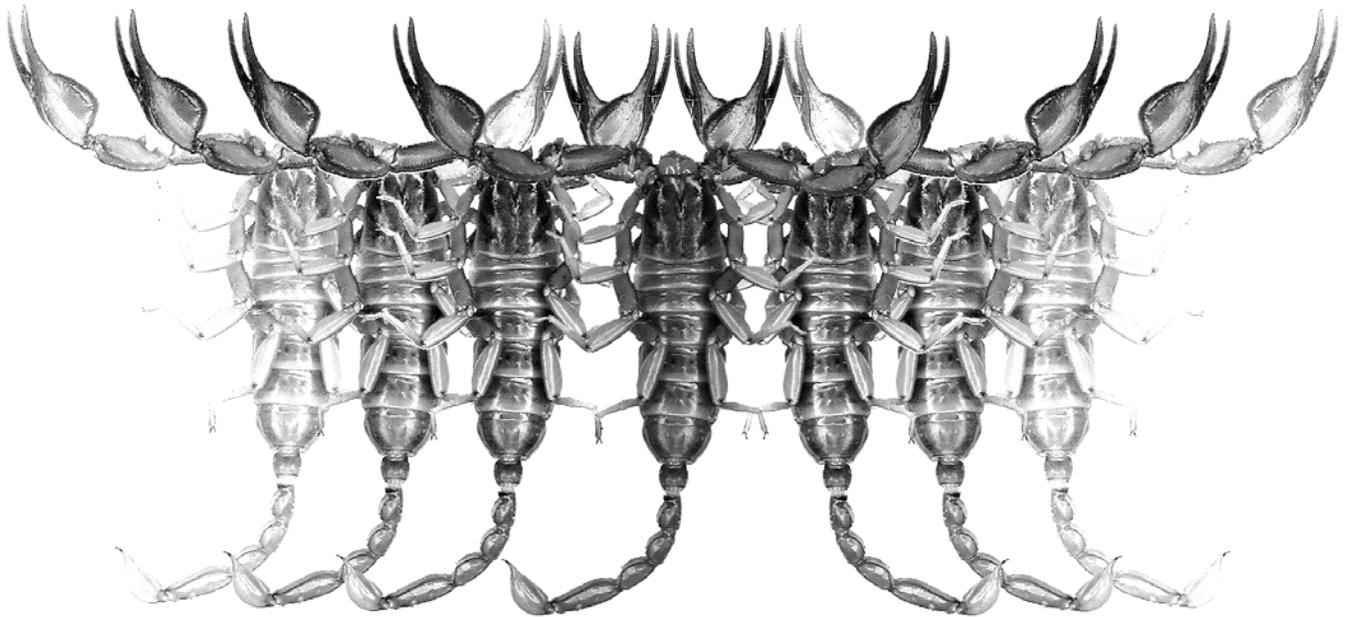
Etudes on Iurids, V. Further Revision of *Iurus* Thorell, 1876
(Scorpiones: Iuridae), with a Description of a New Genus
and Two New Species

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

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Summary

Iurus populations from the Aegean area are studied, including the Greek islands of Crete, Karpathos, Kythira, Rhodes, and Samos. A new genus, *Protoiurus* **gen. nov.**, and two new species, *Protoiurus rhodiensis* **sp. nov.** and *P. stathiae* **sp. nov.**, are described. The two genera, *Iurus* and *Protoiurus*, are diagnosed by their hemispermatophore structure; a cladistic analysis based on this structure is presented. Genus *Iurus* Thorell, 1876 includes three species: *I. dekanum*, *I. dufoureius*, and *I. kinzelbachi*; genus *Protoiurus* includes five species: *P. asiaticus* **comb. nov.**, *P. kadleci* **comb. nov.**, *P. kraepelini* **comb. nov.**, *P. rhodiensis* **sp. nov.,** and *P. stathiae* **sp. nov.** The type specimen of *Chaerilomma dekanum* Roewer, 1943 has been studied and determined to be a valid species *Iurus dekanum* (Roewer, 1943) representing the population from Crete. New diagnoses for subfamilies Calchinae (genus *Calchas*) and Iurinae (genera *Iurus* and *Protoiurus*) are provided as well as keys to the species of *Iurus* and *Protoiurus*.

Introduction

This study is a continuation of our recent *Iurus* revision (Kovařík et al., 2010) where over 300 specimens were examined culminating in the description of two new species, resurrection of one species from synonymy, and the description of neotypes for two existing species; in total, five species were established in *Iurus*. In this offering, over 90 additional specimens of *Iurus* were examined, primarily from the Greek islands in the Aegean Sea, in particular, the islands of Crete, Karpathos, Kythira, Rhodes, and Samos. Based on this continued work, three additional species were identified, each isolated on Rhodes, Karpathos, and Crete. The type specimen of *Chaerilomma dekanum* Roewer, 1943 was studied and determined to be a valid species representing the population from Crete, *Iurus dekanum* (Roewer, 1943).

Based on this study, we were able to finally ascertain the overall phylogenetic framework of the genus *Iurus* and consequently were able to divide its eight species into two genera, *Iurus* and *Protoiurus* **gen. nov**. The generic breakdown is based on the structure of the hemispermatophore where over 40 individual structures were examined across all species. In most cases multiple specimens from multiple geographic locations were used in this analysis. Cladistic analysis of the hemispermatophore structure was conducted and its results are compared to those of a pilot DNA study by Parmakelis et al. (2006). It is shown that the two independent analyses endorse the establishment of the two genera defined herein.

New diagnoses of the iurid subfamilies Calchinae and Iurinae are provided as well as detailed phylogenetic keys to the two genera and eight species of Iurinae. In addition to the detailed cladistic analysis, we provide new data on the chelal movable finger lobe development now based on over 270 samples. This is discussed under the individual new species descriptions as well as summarized in Appendix B. Detailed descriptions and illustrations of two new species, *Protoiurus rhodiensis* **sp. nov.**, and *Protoiurus stathiae* **sp. nov**., as well as *Iurus dekanum*, are provided.

List and distribution of species

Iurus dekanum (Roewer, 1943), **stat. nov.** (**Greece**, Crete)

Iurus dufoureius (Brullé, 1832) (**Greece**, Peloponnese, Kythira Island)

Iurus kinzelbachi Kovařík, Fet, Soleglad & Yağmur, 2010 (**Turkey**, Aydın and Izmir Provinces; **Greece**, Samos Island)

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

Protoiurus kadleci **(**Kovařík, Fet, Soleglad & Yağmur, 2010), **comb. nov.** (**Turkey**, Antalya, and Mersin Provinces)

Protoiurus kraepelini (von Ubisch, 1922), **comb. nov.** (**Turkey**, Antalya, Isparta, Konya, Karaman, Mersin, and Muğla Provinces; **Greece**, Megisti Island)

Protoiurus rhodiensis Soleglad, Fet, Kovařík & Yağmur, **sp. nov.** (**Greece**, Rhodes Island)

Protoiurus stathiae Soleglad, Fet, Kovařík & Yağmur, **sp. nov.** (**Greece**, Karpathos Island)

Methods and Material

Abbreviations

The four-letter institutional abbreviations listed below and used throughout are after Arnett et al. (1993), or introduced here to accommodate other collections: FKCP, personal collection of František Kovařík, Prague, Czech Republic; MRSN, Museo Regionale di Scienze Naturali di Torino, Turin, Italy; MTAS, Museum of the Turkish Society of Arachnology, Ankara, Turkey; NHMC, Natural History Museum of Crete, University of Crete, Heraklion, Crete, Greece; NHMW, Naturhistorisches Museum Wien, Vienna, Austria; NMNHS, National Museum of Natural History, Sofia, Bulgaria; SMFD, Senckenberg Museum, Frankfurt, Germany; ZMHB, Museum für Naturkunde der Humboldt-Universität zu Berlin, Berlin, Germany.

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), and in Kovařík et al. (2010). 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). Trichobothrial nomenclature

and hypothesized homologies are those described and illustrated in Vachon (1974). Techniques using maximized morphometric ratios follow those described in Fet & Soleglad (2002: 5), and further established in Soleglad & Fet (2008: 57–69) and Kovařík et al. (2010: appendix C).

Cladistic analysis and map generation software packages

Software package PAUP* Version 4 (Beta) (Swofford, 1998) was used for Maximum Parsimony (MP) analysis of character codings producing results of tree searches, consensus trees, and bootstrap and jackknife resampling sequences. TreeView (Win 32) Version 1.5.2 (Page, 1998) and Winclada Version 0.9.3 (Nixon, 1999) were used, in part, to generate the resulting PAUP* cladograms showing clade support and distribution of all characters and their states as augmented with the Metafile Companion editor, Version 1.11 (Companion Software, Inc.). Maps were generated from Earth Explorer 6.1, with positional and altitude data compiled through Google Maps.

Material Examined

We examined a total of 91 specimens of *Iurus* (28 specimens) and *Protoiurus* (63 specimens), primarily from the Aegean area. The type series data are presented here, and repeated under the three species descriptions. We also reexamined additional material from Kovařík et al. (2010) which are *not* included in the list below.

Iurus dekanum (Roewer, 1943) [19 specimens]

Greece: *Crete*: 1 ♂ (**holotype**), "Dekan: Anamalai" [incorrect label!], SMF 8893/235 (SMFD). *Chania Region*: Anopoli, 1300 m, 22 July 2006, 1 ♂, leg. M. Chatzaki (NHMC 81.1.5.35); Lefka Ori Mts., 1200 m, 6 July 1991, 1 ♂, leg. P. Lymberakis (NHMC 81.1.5.14), 5 October 1991, 1 ♀, leg. P. Lymberakis (NHMC 81.1.5.28). *Heraklion Region*: Koudouma Monastery, Matala, 26 May 1996, 1 ♂ (NHMC.81.1.5.33), leg. G. Tsiourlis, 21 July 1996 (NHMC 81.1.5.32), 1 ♂, leg. G. Tsiourlis; Lentas, pitfall traps, 15 April 1999–8 June 1999, 1 ♀, leg. M. Papadimitrakis (NHMC 81.1.5.8). *Lasithi Region*: Katharo Plateau, 7 May 1998, 1 ♂, leg. M. E. Braunwalder (NHMC 81.1.5.22); Krasi, 2 June 2000, 1 ♀, leg. Kouroupis (NHMC 81.1.5.16); Kroustas, pitfall traps, 25 May 1999–23 July 1999 (FC 864), 1 ♂, leg. M. Papadimitrakis (NHMC 81.1.5.29), 23 September 1999–1 December 1999 (FC 1010), 1 ♂, leg. M. Papadimitrakis (NHMC 81.1.5.12); Neapoli, May 2004, 1 ♀, leg. Fordakos (NHMC 81.1.5.18); Pachia Ammos, pitfall traps, 16 March 2008–20 May 2008, 1 ♀, leg. D. Kaltsas

(NHMC 81.1.5.21); Prina-Messeleri, pitfall traps, 4 May 1999–23 July 1999 (FC 861), 1 ♂ (NHMC 81.1.5.10), 1 ♀ (NHMC 81.1.5.13), leg. M. Papadimitrakis; no locality, 1 ♀ (ZMB 8071). *Rethymno Region*: Agios Mamas, pitfall traps, 22 April 1999–22 July 1999, 1 ♀, leg. M. Nikolakakis (NHMC 81.1.5.11); Lochria, 1500 m, 27 July 2006, 1 ♂, leg. M. Chatzaki (NHMC 81.1.5.36); Melisoudaki, Mylopotamos, 15 August 2001, 1 ♂, leg. I. Stathi (NHMC 81.1.5.4).

Iurus dufoureius (Brullé, 1832) [6 specimens]

Greece: *Kythira*: Agia Sofia Cave, Mylopotamos, 25 August 2001, 1 ♂, leg. I. Stathi (NHMC 81.1.5.3), 20 September 2002, 1 ♀, leg. Megalokonomos (NHMC 81.1.5.17). *Peloponnese*: Kastorio, Lakonia Region, Taigetos Mts., 24 May 2010, 2 ♂, leg. J. Hromádka & L. Černý (FKCP); Taigetos Mts., April 1901, 1 ♀, leg. F. Werner (NHMW 1624), 10–11 June 1937, 1 ♀, leg. F. Werner (NHMW 1625).

Iurus kinzelbachi Kovařík, Fet, Soleglad et Yağmur, 2010 [3 specimens]

Greece: *Samos*: Manolates, Valley of Nightingales, 4 June 1987, 1 ♀, leg. E. Kritscher (NHMW 15931); Marathokampos, 18 June 1932, 1 ♂, leg. F. Werner (NHMW 2063); Agios Nikolaos, 3 km W Karlovasi, 27 June 2003, 1 ♀, leg. V. Vignoli (FKCP).

Protoiurus kadleci (Kovařík, Fet, Soleglad et Yağmur, 2010), comb. nov. [1 specimen]

Turkey: *Antalya Province*, Alanya, İncekum Cave (18 m), 31 August 2011, 1 ♂, leg. E. A. Yağmur (MTAS).

Protoiurus rhodiensis sp. nov. [40 specimens]

Greece: *Rhodes*: W of Kolymbia, 14–19 June 2010, 2 ♂, 4 ♀ (♂ **holotype, 5 paratypes**), leg. F. Kovařík (FKCP); Agios Isidoros, [650 m, April-May] 1913, 6 ♂, 11 ♀, leg. E. Festa (MRSN Sc. 305, ex. 755) [data in brackets from Borelli, 1913: 2]; Laerma, 1 May 1963, 1 ♂, leg. O. Paget, E. Kritscher & K. Bilek (NHMW 1638); 1 km before Lindos, 10 December 1996, 1 ♂, leg. M. Nikolakakis (NHMC 81.1.5.19, FC 181); Lindos, 16 February 1959, 1 ♀, leg. O. Paget & E. Kritscher (NHMW 1631); Lindos (in town), 7 May 1963, 2 ♂, leg. O. Paget, E. Kritscher & K. Bilek (NHMW 1635); 27 April 1963, 1 ♀, leg. O. Paget & E. Kritscher (NHMW 1636); Lindos, old harbor, 27 April 1963, 2 ♀, leg. O. Paget, E. Kritscher & K. Bilek (NHMW 1637); Moni Artamiti, 3 January 2000, 1 ♂, leg. M. Mylonas (NHMC 81.1.5.20, FC

1032); Mountain Attaviros Profitis Ilias, May 1935, 1 ♀, leg. Hermer (NHMW 1629); Tsambika Monastery, 200 m, 13 May 1963, 1 ♀, leg. O. Paget, E. Kritscher & K. Bilek (NHMW 1639); Rhodes City, Temple of Apollo, 1 April 1959, 1 ♀, leg. O. Paget & E. Kritscher (NHMW), 4 April 1959, 1 ♂, leg. O. Paget & E. Kritscher (NHMW 1633), 29 April 1963, 1 ♀, leg. O. Paget & E. Kritscher (NHMW 1634), 2 October 1977, 1 ♀, leg. E. Kritscher (NHMW 15929); Rhodini, coastal caves, 22 October 1977, 1 ♂, leg. E. Kritscher (NHMW 15930); no exact locality, 1 ♂ (ZMHB 8069).

Protoiurus stathiae sp. nov. [21 specimens]

Greece: *Karpathos*: Karpathos Town, forest in SE, 10 April 1978, 4 ♂, 3 ♀ (♂ **holotype, 6 paratypes**), leg. E. Kritscher (NHMW 15928), 5 October 1977, 3 ♀, leg. E. Kritscher (NHMW 15922), 13 October 1977, 1 ♂, leg. E. Kritscher (NHMW 15925), 15 October 1977, 2 ♀, leg. E. Kritscher (NHMW 15926); forest in SE, under stone, 15 October 1978, 1 ♀, leg. E. Kritscher (NHMW 15921); Menetes, Mountain Olympos, Profitis Ilias, 6 October 1977, 1 ♀, leg. E. Kritscher (NHMW 15923); Agia Kyriaki Monastery, 8 October 1977, 1 ♂, 1 ♀, leg. E. Kritscher (NHMW 15924); Othos, 6 April 1978, 1 ♀, leg. E. Kritscher (NHMW 15927); Pigadia, 15–20 June 1935, 1 ♀, leg. O. v. Wettstein (NHMW 2064), 16 February 2011, 1 ♀, leg. D. Poursanidis (NHMC 81.1.5.34); near Pigadia, 15-20 June 1935, 1 ♀, leg. O. v. Wettstein (NHMW 1627).

Protoiurus sp. [1 specimen]

Greece: *Kasos*: Stylokamara Cave (NMNHS 96), 1 ♂, 6 May 1984, leg. P. Beron.

Character Analysis

We introduce new and/or enhanced character analysis in this paper which complements the analysis presented in Kovařík et al. (2010). In particular the importance and use of the hemispermatophore is discussed in detail where we have doubled the number of species considered. It is shown that the hemispermatophore structure provides information above the species level. Considerations involving the chelal movable finger lobe, which plays an important role in species differentiation, are enhanced where "linear fit lines" and "normalized ratio data" are considered. More than 270 samples have been compiled spanning all eight species. Number of chelal movable finger inner denticles (*ID*), morphometric ratio analysis, and pectinal tooth count tabulation also contribute to the diagnosis of species.
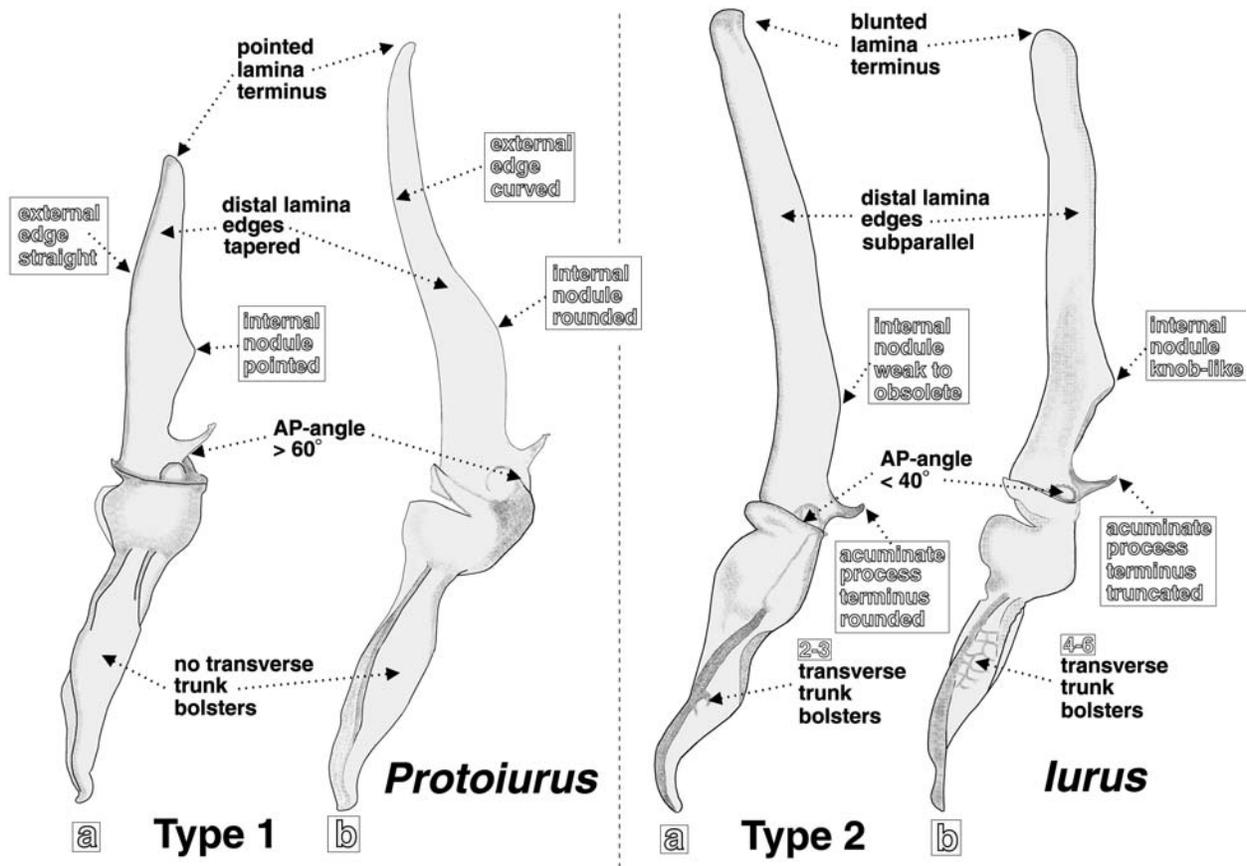
Figure 1: Diagrammatic illustrations of two hemispermatophore types (and subtypes, *a* and *b*) that are diagnostic of genera *Protoiurus* and *Iurus*. Perspective is that of a right hemispermatophore, dorsal view. Characteristics distinguishing types are denoted with black letters, subtypes denoted with *blocked* grey letters. See Table 1 for distribution of these characteristics across the eight species of these two genera and two diagnostic morphometric ratios which further distinguish the hemispermatophore types. AP = acuminate process.

Hemispermatophore

After analyzing the material for this Aegean island study, and in conjunction with the large specimen set studied in a previous paper (Kovařík et al., 2010), we came to the conclusion that the hemispermatophore provides the most important diagnostic character set for these scorpions. This observation became quite apparent when it was clar that the hemispermatophore provided consistent phylogenetic information above the species level, the only structure investigated so far to do so. Below, we highlight the basic structural differences in the hemispermatophore correlating them with the genus-level taxonomy presented in this paper. Cladistic analysis based on the hemispermatophore structure is presented demonstrating further support for the phylogenetic partitioning of these interesting scorpions. Finally, we compare our phylogeny with that from a pilot DNA study published by Parmakelis et al. (2006) where we show that their study essentially agrees in all major clades presented in this paper.

Key structures. We have divided the hemispermatophore structure into two types (*1* and *2*), each type representing a separate genus. Each type is further divided into two subtypes (*a* and *b*) which also correspond to clades below the genus level. (These designations do not imply any general classification of hemispermatophores, but are used here specifically for *Protoiurus* and *Iurus*.) The two hemispermatophore types can be distinguished by the shape and length of the lamina, the angle the acuminate process forms with the dorsal trough edge, and the types of bolsters found on the trunk, thus involving all three basic components of a hemispermatophore (see Figure 1). For type *1* hemi-spermatophores (*Protoiurus* **gen. nov.**), the lamina's distal half edges are tapered, terminating into a point. The lamina is relatively short to medium, 0.9 to 1.2 times longer than the trunk, and the distal lamina is 1.5 to 3.1 times longer than the basal lamina. In contrast, for type *2* hemispermatophores (*Iurus*), the lamina's distal half edges are subparallel, ending in a blunted terminus. The lamina is relatively elongate, 1.4 to 1.7 times longer
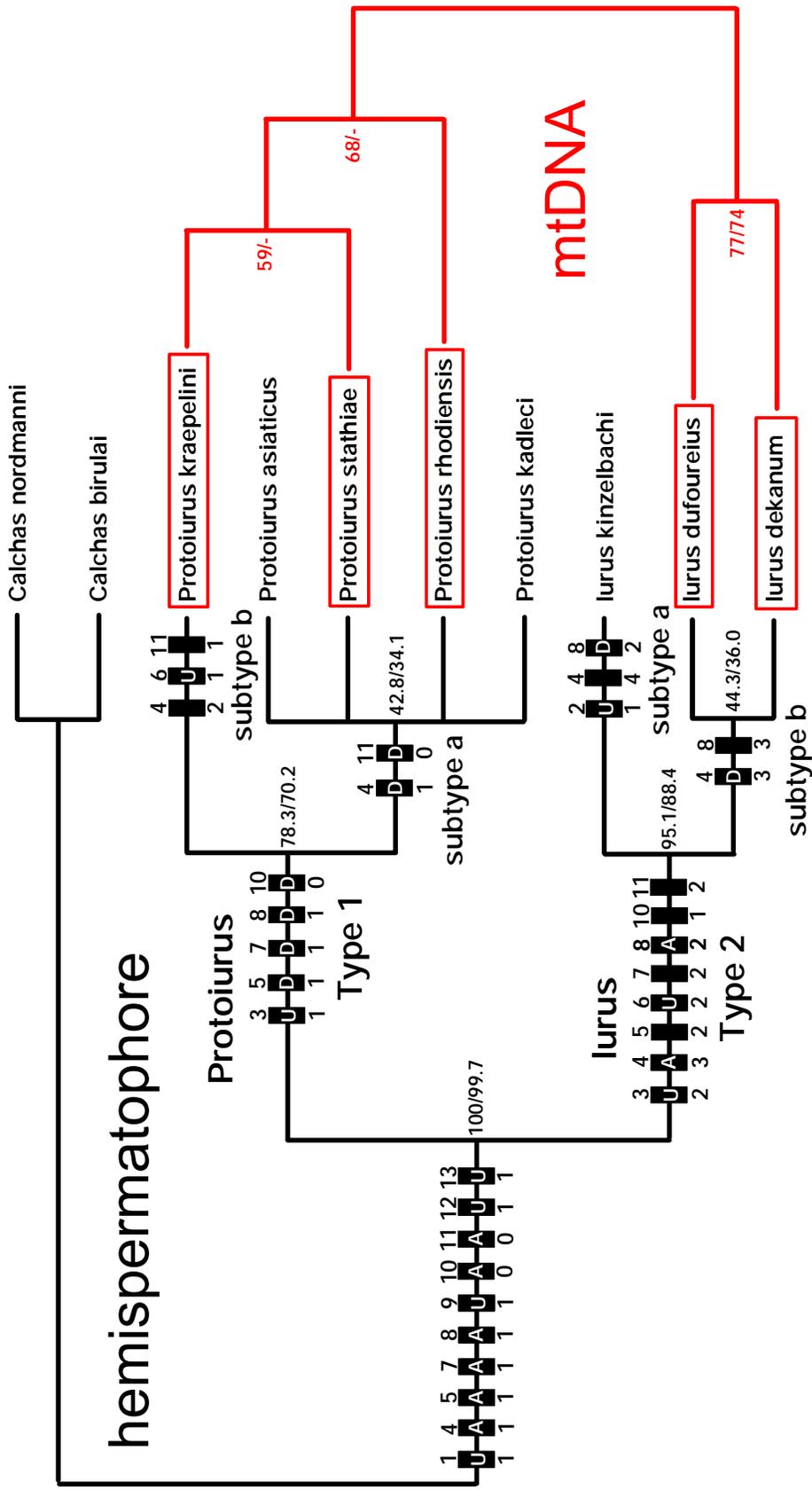
Figure 2: Phylogenetic analysis of genera *Protoiurus* and *Iurus* based on morphology and molecular results. **Left.** Cladogram (semi-strict consensus of four MPTs) showing the phylogeny of genera based on thirteen characters modeling the hemispermatophore structure (resulting in two types and four subtypes). Length/CI/RI/G-Fit = 28/1.0/1.0/-12.0. Character distribution represented by black rectangles, character number on top and state number on bottom. Characters marked with "U" are distributed unambiguously, "A" based on accelerated (ACCTRAN) distribution, "D" based on delayed (DELTRAN) distribution, and no markings indicate consistently distributed for both accelerated and delayed sequences. Numbers at nodes represent the mean of five bootstrap and jackknife sequences (1000 pseudoreplicates per sequence), respectively. *Calchas* species form the outgroup and are assumed to be plesiomorphic for all characters. See Appendix A for character descriptions and character state data matrix. **Right.** Red clades and nodes represent results from Parmakelis et al. (2006: fig. 2) molecular mtDNA pilot study, where five of the eight species were included. Tree is based on Bayesian inference (50% majority rule consensus) and numbers at nodes represent bootstrap support (1000 pseudoreplicates) for neighbor joining and maximum parsimony, respectively. In their study the scorpionoid *Nebo hierichonticus* was used as an outgroup.

Figure 3: Hemispermatophore examples of *Protoiurus* and *Iurus* species.

than the trunk; the distal lamina is 3 to 5 times longer than the basal lamina. For type *1* hemispermatophores, the angle formed by the acuminate process with the dorsal trough edge is large, exceeding 60 degrees. In contrast, for type *2* hemispermatophores, this angle is small, less than 40 degrees. Finally, type *1* hemispermatophores lack transverse bolsters on the trunk, whereas in type *2* transverse bolsters are present.

Each hemispermatophore type is further divided into two subtypes. For type *1*, subtype *1a* is defined by the internal nodule conspicuously developed, terminus pointed, the external edge of the lamina straight, and the lamina distal length / basal length ratio 1.5 to 1.8. This subtype is found in *Protoiurus asiaticus*, *P. kadleci*, *P. rhodiensis*, and *P. stathiae*. Subtype *1b* is defined by a widely rounded internal nodule, the external edge of the lamina curved, and the lamina distal length / basal length ratio 2.2 to 3.1. Subtype *1b* is found in *Protoiurus kraepelini*. Note, we have detected some variability in the proportions of subtype *1b* hemispermatophores, and assume this is due to the relatively large geographic range of *P. kraepelini*, the largest for any species in these two genera. For type *2*, subtype *2a* is defined by a weakly rounded to obsolete internal nodule, a rounded acuminate process terminus, and two to three transverse trunk bolsters, lacking the delicate interconnecting vertical bolsters. This subtype is found in *Iurus kinzelbachi*. Subtype *2b* is defined by a conspicuously developed internal nodule with a knoblike terminus, an acuminate process terminus that is truncated, and four to six transverse bolsters with delicate interconnecting vertical bolsters. This subtype is found in *Iurus dufoureius* and *I. dekanum*.

Table 1 provides important statistics on this structure for these species based on 44 samples and the map in Fig. 4 shows the localities of specimens whose hemispermatophores were examined. Figure 3 shows the hemispermatophore of all eight species of *Iurus* and *Protoiurus*. And, to report a noteworthy event, we (E.Y.) recently collected a large *P. kadleci* male, from which we were successful in obtaining hemispermatophores, the first reported for this species (illustrated in Fig. 3). Additional information on this important male, collected in a cave, will be reported in another paper (Yağmur et al., in progress).

Cladistic analysis. We conducted a cladistic analysis based on the hemispermatophore structure of *Iurus* and *Protoiurus* using two species of genus *Calchas* as the outgroup. The hemispermatophore structure was modeled with 13 characters (see Appendix A for definition of these characters and their states and the character state data matrix). Figure 2 shows the resulting cladogram based on the semi-strict consensus of four MPTs. Of the 13 characters, 12 were informative and accounted for zero homoplasy (i.e., CI = 1.0). Character-2, state=1 (acuminate process terminus rounded), is

autapomorphic for *I. kinzelbachi*. It is assumed in this analysis that *Calchas* is plesiomorphic for all characters. All characters are distributed on the cladogram showing both accelerated (ACCTRAN) and delayed (DELTRAN) distribution as well as consistent distribution for both accelerated and delayed, and unambiguous distribution. All characters are unordered except for character-3, the acuminate process / dorsal trough angle. Only two characters utilized the "inapplicable state" (i.e., "-"), assigned to the *Calchas* outgroup for the morphometric ratios. We believe morphometrics are considerably localized and therefore do not apply to taxa of higher orders. *Iurus* is supported by two unambiguous, four consistent, and two accelerated characters; *Protoiurus* is supported with one unambiguous character and four based on delayed distribution (i.e., potential synapomorphies). We exercised both bootstrap and jackknife sequences to establish "robustness" of the result, where on the cladogram we show the mean of five sequences of 1000 pseudoreplicates per algorithm. Across the two algorithms, *Iurus* is supported by 88 to 95 % of the pseudoreplicates and *Protoiurus*, by 70 to 78 %. In this analysis, both hemispermatophore types are correlated with genera specified in this paper as well as the species breakdown for subtypes.

Comparison to molecular data. It is noteworthy to point out that the separation of our two genera based on hemispermatophore morphology is supported by a pilot DNA study of *Iurus* (now *Iurus* and *Protoiurus*) conducted by Parmakelis et al. (2006: fig 2). Their result was based on 441 aligned 16S rRNA mtDNA base pairs. Parmakelis et al. (2006) used 19 *Iurus* and *Protoiurus* samples plus *Nebo hierichonticus* (Scorpionidae: Diplocentrinae) as the outgroup. Seven populations of these two genera were included, which we identify currently as five species: *Iurus dufoureius* (the Peloponnese and Kythira Island), *I. dekanum* (Crete), *Protoiurus stathiae* (Karpathos Island), *P. rhodiensis* (Rhodes Island), and *P. kraepelini* (Megisti Island and mainland Turkey (Alanya)). The topology derived by Parmakelis et al. (2006) is shown in our cladogram presented in Figure 2. Besides the absence of three additional species from their molecular analysis (i.e., *Iurus kinzelbachi*, *Protoiurus asiaticus*, and *P. kadleci*), two differences in the results are present. In the cladogram of Parmakelis et al. (2006), *P. stathiae* from Karpathos shows a closer affinity to *P. kraepelini* than it does to *P. rhodiensis*. This is also shown in their pairwise genetic distance table (table 2) with a difference of 3.7–4.2 % versus 4.9. This result is interesting since, geographically, the Rhodes population is much closer to Turkey than Karpathos, thus from a biogeographic perspective the DNA result seems counterintuitive. In our species level discussion presented elsewhere in this paper, we also note low-level structure similarities supporting the result of Parmakelis et al. (2006). However, based on our cladistic analysis of

	Protoiurus					Iurus		
	P. asiaticus (4/5)	**P. rhodiensis** (2/4)	**P. stathiae** (3/6)	**P. kadleci** (1/2)	**P. kraepelini** (7/9)	**I. kinzelbachi** (2/3)	**I. dufoureius** (3/6)	**I. dekanum** (5/9)
Type	1a	1a	1a	1a	1b	2a	2b	2b
Distal Lamina Edges	Tapered	Tapered	Tapered	Tapered	Tapered	Subparallel	Subparallel	Subparallel
Lamina Terminus	Pointed	Pointed	Pointed	Pointed	Pointed	Rounded	Rounded	Rounded
Acuminate Process Angle/DT*	65°	67°	65°	68°	64.5°	37.5°	37°	38°
Transverse Bolsters	Absent	Absent	Absent	Absent	Absent	2–3, lacking interconnecting vertical bolsters	4–6, with interconnecting vertical bolsters	4–6, with interconnecting vertical bolsters
Acuminate Process Terminus	Truncated	Truncated	Truncated	Truncated	Truncated	Rounded	Truncated	Truncated
External Edge of Lamina	Straight	Straight	Straight	Straight	Curved	Curved	Curved	Curved
Internal Nodule	Conspicuously developed, terminus pointed	Conspicuously developed, terminus pointed	Conspicuously developed, terminus pointed	Conspicuously developed, terminus pointed	Widely rounded	Weakly rounded to obsolete	Conspicuously developed, terminus knoblike	Conspicuously developed, terminus knoblike
Lam_L/Trunk_L	0.884–0.965 (0.921) [5]	0.966–0.981 (0.974) [3]	0.965–1.037 (0.994) [3]	0.886–0.888 (0.887) [2]	0.984–1.221 (1.133) [5]	1.513–1.571 (1.546) [3]	1.338–1.499 (1.392) [4]	1.658–1.798 (1.698) [4]
Lam_DL/Lam_BL	1.614–1.802 (1.729) [4]	1.524–1.720 (1.664) [4]	1.435–1.558 (1.488) [3]	1.614–1.781 (1.698) [2]	2.159–3.074 (2.451) [5]	4.313–5.107 (4.710) [2]	2.934–3.400 (3.156) [5]	2.790–4.116 (3.442) [8]
Hemi_L (mm)	10.90–13.15 (11.86) [5]	11.77–12.09 (11.93) [2]	10.80–12.41 (11.61) [2]	13.93–14.79 (14.36) [2]	10.00–12.75 (11.20) [3]	12.95–13.15 (13.02) [3]	11.20–12.31 (11.87) [3]	11.33–12.95 (12.182) [4]

Table 1: Diagnostic characteristics of the hemispermatophore in *Iurus* and *Protoiurus* species divided into two types and subtypes. Number pairs below species name are "number of specimens/number of hemispermatophores" examined, a total of 44 hemispermatophores from 27 specimens. Lam_L = lamina length, Lam_DL = lamina distal length, Lam_BL = lamina basal length, Trunk_L = trunk length, Hemi_L = hemispermatophore length (mm). See Fig. 1 for further definition of terms. Minimum–maximum (mean) [number of samples]. * Angle formed by a line extending from the AP terminus through the center of the seminal receptacle to a line extending along the dorsal trough.
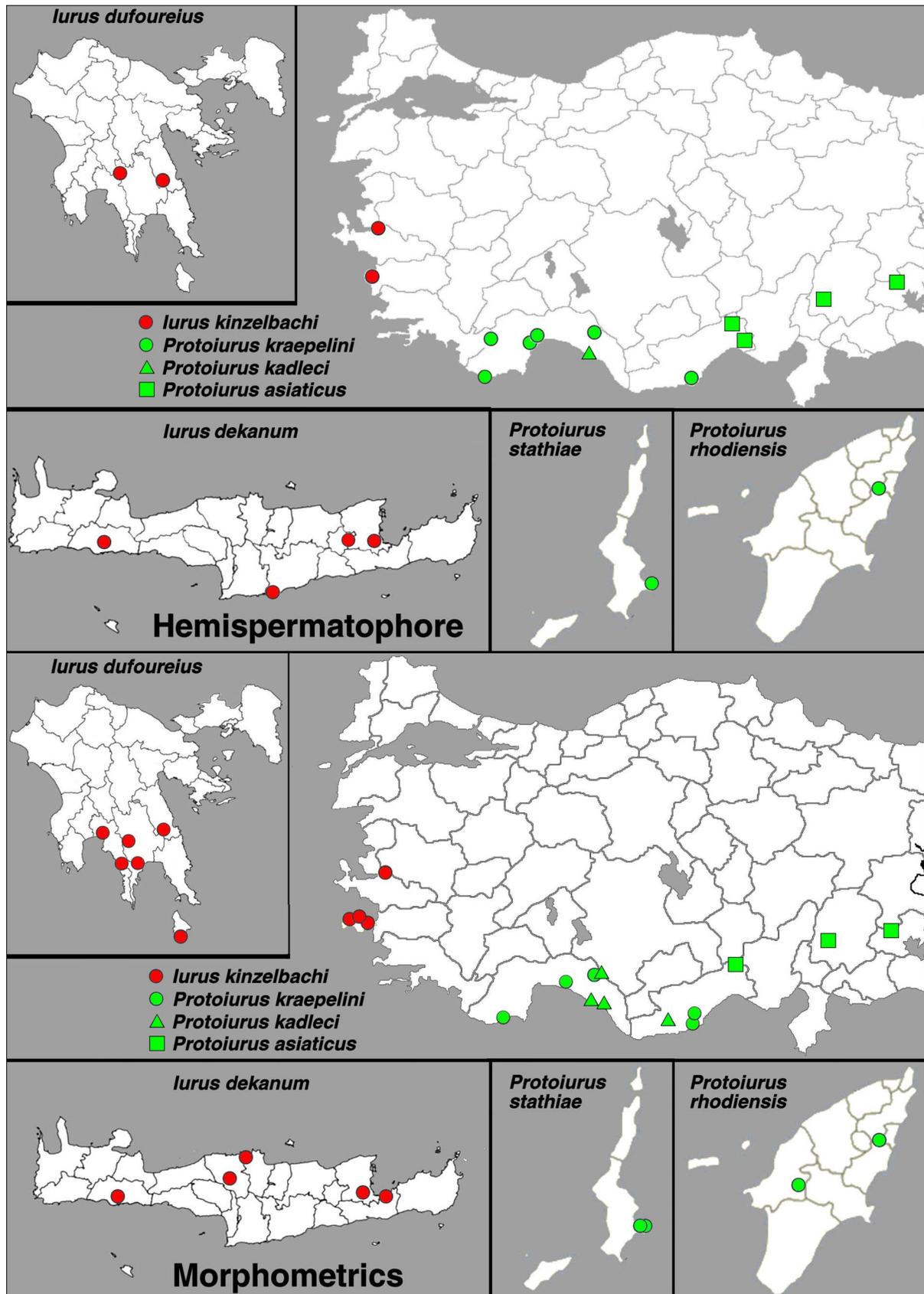
Figure 4: Maps showing geographic distribution of *Iurus* and *Protoiurus* specimens whose hemispermatophores were examined (top) and morphometrics were tabulated (bottom).

the hemispermatophore, we consider *P. kraepelini* to be derived from the primary stock represented by type *1a* hemispermatophores, which includes both Greek species *P. stathiae* and *P. rhodiensis*, as well as Turkish species *P. kadleci* and *P. asiaticus*, the latter considered to be the basal species of this assemblage. The second difference between the two studies is minor: the Parmakelis et al. (2006) study considers the Kythira population to be more closely related to the Crete population, not the Peloponnese, whereas, based on the study of low-level structures, we consider Kythira population to be *I. dufoureius*. See our section on species differences where all these issues are discussed in detail.

Pedipalp chela morphology

We have compiled statistics on the chelal movable finger (MF) lobe from over 270 specimens, spanning all eight species of *Iurus* and *Protoiurus*. This is a continuation of the analysis presented in Kovařík et al. (2010) where it was shown that the MF lobe becomes larger and moves more distally on the finger as the specimen matures. It was also demonstrated that the relative placement, shape, and size of the lobe per development stage is species-dependent. Also, differences in lobe placement and the presence or absence of a fixed finger proximal gap is different per development stage and across genders. We demonstrated that the movable finger lobe during individual development does move distally down the finger, based on comparisons of the lobe's placement with respect to the number of outer denticles (*OD*) occurring distally of the lobe.

In this study, we introduce the term "signature" to represent all the information we have accumulated from the chelal movable finger lobe during all stages of a species/gender development. In our 2010 paper, we represented these data in a single scatter chart based on over 200 samples spanning all known species (five at that time). With the advent of yet more material and more species, it is not practical to show these data in a single figure, which would carry too much information, difficult if not impossible to differentiate. In addition, we employed new information: "linear fit lines", "slope", and "normalized ratio data". Therefore, each species' "signature" is presented in a single chart; where if applicable, two species can be combined into a single chart for relevant comparisons, as we do, for example, with *Iurus dufoureius* and *I. dekanum*, and *Protoiurus stathiae* and *P. rhodiensis*; see individual species descriptions.

Linear fit lines and their slope. "Linear fit lines" graph presents "linear average" of all the plots for each gender and is based on least squares regression. In theory, besides presenting a "linear average", these lines will "predict" where new plots will occur anywhere on the chart. Also, by looking at the algebraic slope of each

line (male vs. female), one can determine which gender's lobe migrates distally at the highest rate as the specimen matures. Normally we see that the slope is larger (i.e., points "higher" in the chart) in the females, implying that lobe does not move as far distally on the finger as in the male when the specimen matures (i.e., the slope for the male is smaller). This observation is true in all eight species (see Table 2).

Normalized ratio data. By dividing the carapace length by the MF lobe ratio, we effectively make the MF lobe ratio independent of the specimen's development. This technique is somewhat effective: the gross results seem to reflect what we see in the charts, but we only use the standard error range and mean as indicators. All normalized ratios per species are presented in Table 2. The larger the normalized ratio value, the more basally the movable finger lobe is positioned. It is interesting to point out that across both genders for the top and bottom four species we see the same partitioning of the highest and lowest ratio values, thus indicating consistency at a species level. Across the eight species we see that *I. dekanum* has the highest value for both genders implying the most basal MF lobe, and likewise, *P. kadleci* has the lowest ratio value for both genders, thus having the most distal MF lobe.

Finally, the MF lobe signature includes diagrams of the lateral view of the chelal fingers for both adult males and females, thus showing typical morphology for adults such as the shape of the chelal fingers, the development of the lobe, its position on the finger, the presence/absence of a fixed finger proximal gap, curvature of the movable finger, etc. Appendix B includes "signatures" of all eight species including the breakout of specimens from the islands of Kythira (*I. dufoureius*) and Samos (*I. kinzelbachi*).

Finger dentition. The exact count of denticles in the chelal fingers is difficult to determine in adults. This is caused by the modification occurring in the denticle rows during the development of the movable finger lobe and the proximal gap of the fixed finger. Also, *Iurus* and *Protoiurus* have 14–17 *MD* rows that are oblique and highly imbricated, further making the identification of individual denticles difficult. Therefore, most of the specimens studied were juveniles and subadults, where the lobe and gap if present are modest. More than 260 samples are included (both movable fingers were tabulated), Table 3 shows the result.

It is interesting to point out that the species with the most *ID*s on the movable finger all belong to the genus *Iurus*, *I. dufoureius* exhibiting the highest numbers, exceeding the species with the lowest number, *Protoiurus kadleci*, by 35.8 %. Also it is curious that the number of *ID*s increases geographically from central Turkey (i.e., *Protoiurus asiaticus*, *P. kraepelini*, and *P. kadleci*) westward through Crete and the Peloponnese. Even the most western *Protoiurus* species, *P. stathiae*

	Male		Female	
	Normalized Ratio	**Slope of Linear Fit (Rank)**	**Normalized Ratio**	**Slope of Linear Fit (Rank)**
I. dekanum	23.607–27.615 (25.401) [9]	21.1 (3)	25.617–31.108 (28.362) [8]	29.1 (5)
*I. dufoureius**	22.290–26.265 (24.420) [11]	35.0 (1)	20.390–28.151 (24.354) [16]	49.3 (1)
I. rhodiensis	21.213–25.652 (23.433) [12]	24.3 (2)	21.288–27.877 (24.583) [20]	40.7 (2)
*I. kinzelbachi***	22.089–23.833 (22.961) [12]	20.2 (4)	25.493–29.532 (28.037) [20]	28.3 (6)
I. asiaticus	21.571–24.060 (22.815) [10]	14.9 (7)	22.377–25.695 (24.036) [10]	22.9 (7)
I. stathiae	20.728–22.291 (21.509) [6]	16.0 (6)	20.430–24.770 (22.600) [14]	39.1 (3)
I. kraepelini	19.229–23.163 (21.196) [56]	17.8 (5)	21.649–25.324 (23.487) [65]	38.2 (4)
I. kadleci	19.417–22.858 (21.138) [5]	-	19.192–21.138 (20.165) [2]	-

Table 2: Normalized chelal movable finger lobe ratio data. Carapace length / MF lobe ratio and slope of the linear fit lines. Normalized ratio data is ordered from largest to smallest means (males). Standard error range (mean) [number of samples]. * includes male and female from Kythira Island. ** includes two females from Samos Island.

	Number of IDs	**MVD %**
I. dufoureius	14–16 (14.933) (±0.521) [30] (14.413–15.454)	> 0.1, 6.9, 9.8, 11.7, 14.0, 18.8, 28.7, 35.8
I. dekanum	13–15 (14.833) (±0.577) [12] (14.256–15.411)	> - 6.0, 9.1, 11.0, 13.2, 18.0, 27.9, 34.8
I. kinzelbachi	13–15 (13.966) (±0.325) [29] (13.640–14.291)	> - - 2.7, 4.5, 6.6, 11.1, 20.4, 27.0
Samos pop.	13–14 (13.600) (±0.548) [5] (13.052–14.148)	> - - - 1.8, 3.8, 8.2, 17.2, 23.6
P. stathiae	13–14 (13.364) (±0.492) [22] (12.871–13.856)	> - - - - 2.0, 6.3, 15.2, 21.5
P. rhodiensis	12–14 (13.101) (±0.622) [69] (12.480–13.723)	> - - - - - 4.2, 12.9, 19.1
P. kraepelini	11–14 (12.568) (±0.691) [88] (11.877–13.260)	> - - - - - - 8.3, 14.3
P. asiaticus	11–12 (11.600) (±0.516) [10] (11.084–12.116)	> - - - - - - - 5.5
P. kadleci	11–11 (11.000) (±0.000) [2] (11.000–11.000)	-

Table 3: Statistical data showing number of inner denticles (*ID*) of the chelal movable finger in genera *Iurus* and *Protoiurus*. Samos Island population (*I. kinzelbachi*) is broken out for comparison. Mean Value Differences (MVD) percentages contrast largest *ID* counts with smaller counts. Data based on 267 samples. Statistical data group = minimum–maximum (mean) (standard deviation) [number of samples] (standard error range).

found on Karpathos, has the highest number of *ID*s in the genus, exceeding the MVD of the species with the lowest numbers (*P. asiaticus* and *P. kadleci*) by 15–22 %.

Morphometric analysis

Kovařík et al. (2010: appendix C) provided a complete morphometric ratio analysis of 31 sets of measurements of *Protoiurus* and *Iurus* specimens (all referred to as *Iurus*). All possible morphometric ratio combinations were analyzed for both genders. A key for adult male and female was provided for all five species based entirely on selected morphometric ratios. Of these measurement sets, 21 were presented in tables. In this contribution, 23 new measurements sets are provided and a complete morphometric ratio analysis is provided for the three species described, across all eight species for both genders. Although generic breakdown between *Iurus* and *Protoiurus* is based on the structure of the hemispermatophore, morphometric ratios are used at

species level for taxa such as *Iurus dufoureius* and *I. dekanum* and all species of *Protoiurus* (see Appendix C for a complete morphometric analysis of the three species described in this paper).

Pectinal tooth statistics

Over 700 samples of pectinal tooth counts have been tabulated for *Iurus* and *Protoiurus*. In Fig. 5 we see that the tooth count ranges across the species are essentially consistent across both genders. In general, the species of *Iurus* have lower pectinal tooth counts than species in *Protoiurus*, the Crete species *I. dekanum* having statistically the lowest number, 8–11 (9.78) for males and 7–10 (8.93) for females. In contrast, *Protoiurus kraepelini* and *P. stathiae* have the highest number of pectinal teeth, 10–16 (12.63) for males, 10–14 (11.48) for females and 11–15 (12.93) for males, 10–14 (11.03) for females, respectively. *P. rhodiensis* has the lowest tooth count for its genus, 10–14 (11.28) for males and 8–12 (9.48) for females.
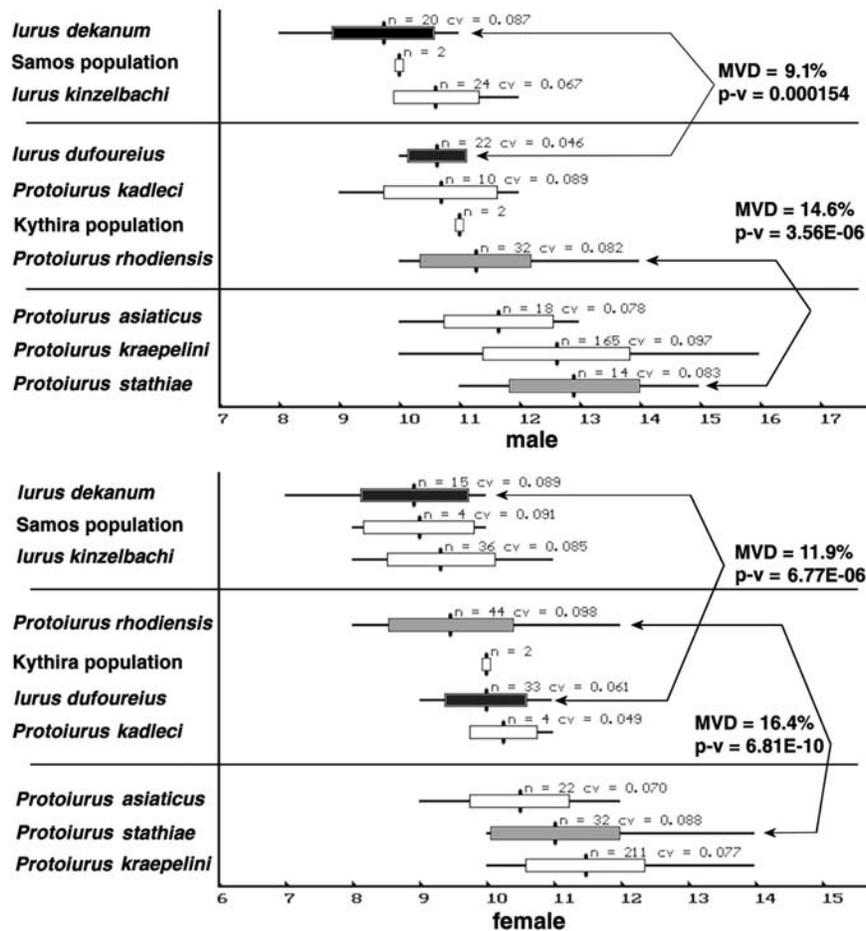
Figure 5: Pectinal tooth count statistics of eight species of *Protoiurus* and *Iurus*. Populations from the islands of Kythira (*I. dufoureius*) and Samos (*I. kinzelbachi*) are separated from their species for comparison with the main populations. This data is based on 309 male and 403 female samples. The male and female histograms are partitioned into three sections from the lowest counts to the highest. Each male and female partition contains the same species/populations thus showing overall consistency across genders. Two population sets are shaded, black for *Iurus dekanum* and *I. dufoureius*, and grey for *Protoiurus rhodiensis* and *P. stathiae*. These species pairs are compared in the text due to their close relationships. In these histograms the mean value difference (MVD) percentages and ANOVA *p*-values are shown.

Systematics

Diagnoses of subfamilies Calchinae and Iurinae and genera *Iurus* and *Protoiurus* are provided in this section. Phylogenetic keys are provided for both genera. Subfamilies Calchinae and Iurinae have been reestablished due to the recognition of two genera in the latter.

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 Calchinae Birula, 1917

Diagnosis. Tibial spurs present on legs III–IV; leg tarsus ventral surface with irregularly populated spinules on juveniles, reduced considerably on adults concentrated only on tarsus base. Femoral trichobothrium *d* located on dorsal surface; *e* located considerably distal of *d*; chelal trichobothrium *db* positioned at fixed finger base; *Db* located dorsally of external (*E*) carina, distal of *Eb* series; patellar trichobothrium *i* located on dorsal sur-

face, adjacent to *DI* carina. Prepectinal plate present in female. Stigma small, oval in shape. Large ventral accessory (*va*) denticle of cheliceral movable finger located at finger base; conspicuous serrula present. Hemi-spermatophore lamellar internal base with triangular protuberance; trunk without bolsters. Chelal finger median denticle (*MD*) groups number 6–8; inner denticles (*ID*) 5–7; movable finger of adult males without lobe. Patellar dorsal (*DPS*) and ventral (*VPS*) spurs doubled but weakly developed.

Type Genus. *Calchas* Birula, 1899.

Composition. This subfamily contains one genus *Calchas* and three species:

Calchas nordmanni Birula, 1899 (type species)
C. birulai Fet, Soleglad et Kovařík, 2009
C. gruberi Fet, Soleglad et Kovařík, 2009

Notes. Calchinae was established by Birula (1917a: 102; 1917b: 55, 143) as a monotypic subfamily of Chactidae, to indicate a separate position of *Calchas* Birula, 1899, a very unusual scorpion genus that at this time was never compared, or considered related, to *Iurus* Thorell, 1876 (then placed in Vaejovidae). The genus remained largely

unstudied (see Fet et al., 2009, for a detailed historical review) until Vachon (1971) first demonstrated its affinity to *Iurus*. When Francke & Soleglad (1981) re-established Iuridae as a family, with two subfamilies (Iurinae and Caraboctoninae), they moved *Calchas* to Iurinae. Subfamily Calchinae was listed as a synonym of Iurinae by Fet & Braunwalder (2000) and Sissom & Fet (2000), and as a synonym of Iuridae by Soleglad & Fet (2003b) Here, we bring it back from synonymy.

Subfamily Iurinae Thorell, 1876

Diagnosis. Tibial spurs absent on legs III–IV; leg tarsus ventral surface with single row of densely populated spinule clusters, terminating in an enlarged pair of distal clusters. Femoral trichobothrium *d* located on external surface; *e* located slightly distal of *d*; chelal tricho-bothrium *db* positioned at fixed finger midpoint; *Db* located ventrally of external (*E*) carina, in line with *Eb* series; patellar trichobothrium *i* located on internal surface, adjacent to *DI* carina. Prepectinal plate absent in female. Stigma medium to long, slit-like in shape. Large conspicuous ventral accessory (*va*) denticle of cheliceral movable finger located at finger midpoint; vestigial serr-ula present on juveniles and subadults, essentially absent in adults. Hemispermatophore lamellar internal base lacking triangular protuberance; trunk with sclerotized bolsters. Chelal finger median denticle (*MD*) groups number 14–16; inner denticles (*ID*) 11–16; movable finger of adult males with conspicuous lobe or lobes. Patellar dorsal (*DPS*) and ventral (*VPS*) spurs strongly developed and conspicuously doubled.

Type Genus. *Iurus* Thorell, 1876.

Composition. This subfamily contains the following two genera:

> *Iurus* Thorell, 1876
> *Protoiurus* **gen. nov.**

Note. Soleglad & Fet (2003b) elevated subfamily Cara-boctoninae to family level, while remaining family Iuridae accommodated *Iurus* and *Calchas*; therefore, subfamily Iurinae was unnecessary**.** Now, as we describe the third genus of Iuridae, *Protoiurus* **gen. nov.,** we reintroduce both Iurinae and Calchinae.

Key to genera of Iurinae

1 – Hemispermatophore type *2* (see diagnosis) …..……. ………………………………….……. ***Iurus* Thorell, 1876**
■ – Hemispermatophore type *1* (see diagnosis) ………. ………………………………...……. ***Protoiurus* gen. nov.**

Genus *Iurus* Thorell, 1876

Iurus Thorell, 1876: 11; type species by original designation *Iurus granulatus* (C. L. Koch, 1837) [= *Iurus dufoureius* (Brullé, 1832)].

Synonyms:
Chaerilomma Roewer, 1943: 237–238; type species by original designation *Chaerilomma dekanum* Roew-er, 1943 [= *Iurus dekanum* (Roewer, 1943). Synon-ymized by Vachon (1966a).

References (selected):
    Iurus: Thorell, 1877: 193 (in part); Pavesi, 1878: 360 (in part); Simon, 1879: 115; Kraepelin, 1899: 178 (in part); Werner, 1902: 605 (in part); Borelli, 1913: 2 (in part); Vachon, 1966a: 453 (in part); Vachon, 1966b: 215 (in part); Stahnke, 1974: 123 (in part); Kinzelbach, 1975: 21 (in part); Francke, 1981: 221 (in part); Francke & Soleglad, 1981: 251 (in part); Kinzelbach, 1982: 58 (in part); Kinzelbach, 1985: map IV (in part); Vachon & Kinzelbach, 1987: 99 (in part); Sissom, 1990: 130 (in part); Kovařík, 1992: 185 (in part); Kritscher, 1993: 381 (in part); Crucitti, 1995a: 1 (in part); Crucitti, 1995b: 91; Crucitti, 1998: 31; Crucitti & Malori, 1998: 133 (in part); Kovařík, 1998: 136 (in part); Kovařík, 1999a: 42 (in part); Crucitti, 1999a: 87 (in part); Crucitti, 1999b: 252; Fet, 2000: 49 (in part); Fet & Braunwalder, 2000: 18 (in part); Sissom & Fet, 2000: 419 (in part); Crucitti & Cicuzza, 2001: 227 (in part); Stathi & Mylonas, 2001: 290 (in part); Kovařík, 2002: 3; Soleglad & Fet, 2003b: 110 (in part); Fet et al., 2004: 18 (in part); Parmakelis et al., 2006: 253 (in part); Koç & Yağmur, 2007: 57; Fet & Soleglad, 2008: 256 (in part); Francke & Prendini, 2008: 218 (in part); Kaltsas et al., 2008: 227 (in part); Kovařík, 2009: 27 (in part); Soleglad et al., 2009: 2 (in part); Yağmur et al., 2009: 154 (in part); Fet, 2010: 8 (in part); Kovařík et al., 2010: 10 (in part); Stockmann & Ythier, 2010: 531 (in part).
    Jurus (incorrect subsequent spelling): Karsch, 1879: 101; Karsch, 1881: 90; Simon, 1884: 351; Kraepelin, 1894: 183 (in part); Birula, 1898: 133 (in part); Birula, 1903: 297 (in part); Penther, 1906: 62; Werner, 1934a: 162; Werner, 1934b: 282; Werner, 1937: 136; Werner, 1938: 172 (in part); Vachon, 1948: 62 (in part); Vachon, 1953: 96 (in part).

Distribution. GREECE: mainland: Peloponnese; is-lands: Crete, Fourni, Gavdos, Kythira, Samos. TUR-KEY: Aydın and İzmir Provinces. See general map in Fig. 6.
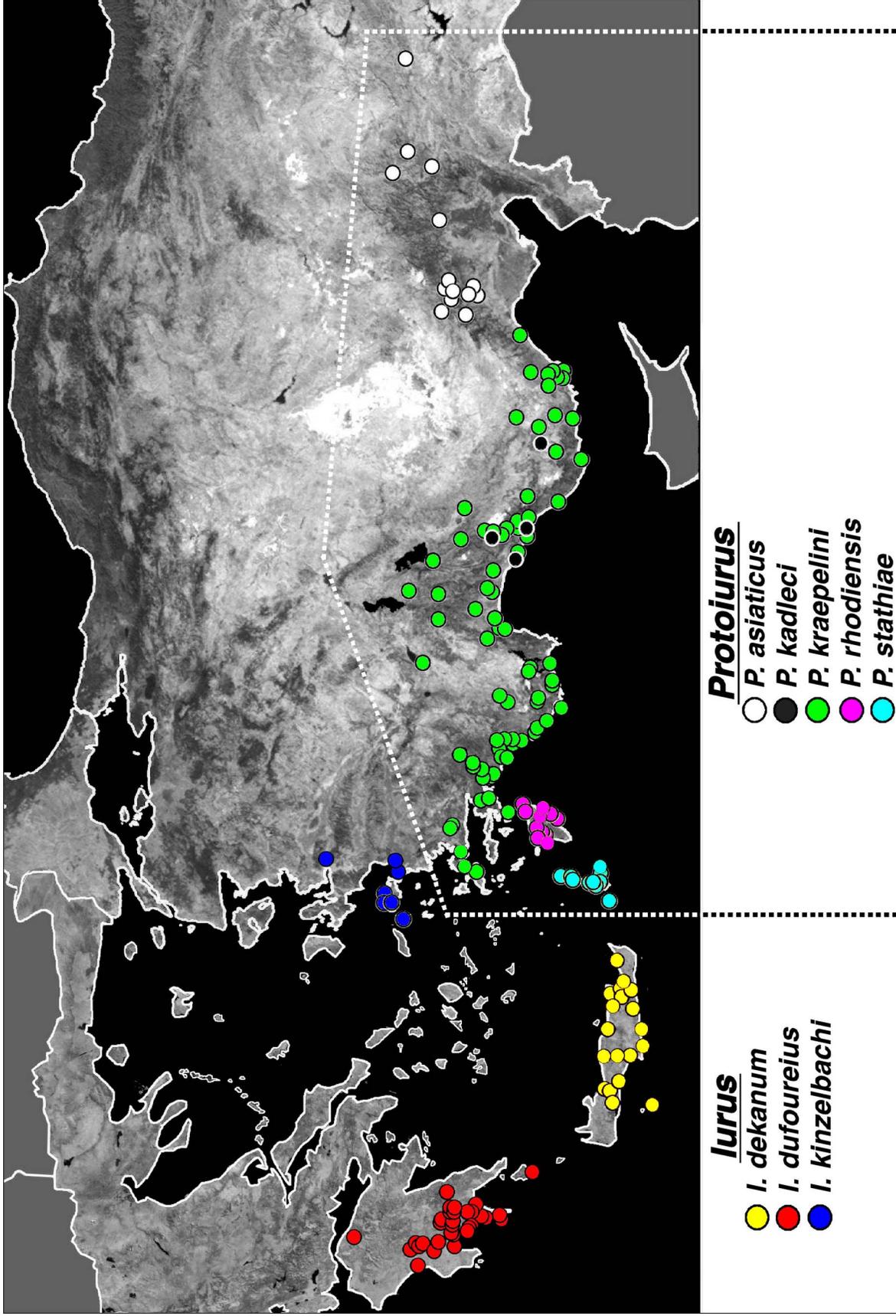
Figure 6: Map of Greece and Turkey showing distribution of genera *Iurus* (left side of map) and *Protoiurus* (right side of map).

Type Species. *Iurus dufoureius* (Brullé, 1832)

Composition. This genus contains the following three species:

> *Iurus dekanum* (Roewer, 1943)
> *I. dufoureius* (Brullé, 1832)
> *I. kinzelbachi* Kovařík, Fet, Soleglad et Yağmur, 2010

Diagnosis. Hemispermatophore type *2*: lamina elongate, 1.3 to 1.8 times longer than trunk; distal lamina edges subparallel ending in a blunted terminus; distal lamina 3 to 5 times longer than basal lamina; acuminate process angle with dorsal trough less than 40 degrees; transverse bolsters present on trunk. Chelal movable finger lobe situated basally of finger midpoint in adults; number of inner denticles (*ID*) on chelal movable finger 13–16 (14.461). Pectinal tooth count range (based on the mean of three species) 9.75–10.67 for males and 8.93–10.00 for females.

Phylogenetic key to species of *Iurus*

1 – Hemispermatophore (type *2b*) internal nodule conspicuously developed, terminus knoblike; acuminate process terminus truncated; transverse trunk bolsters number 4 to 6 and connected with delicate vertical bolsters; proximal gap on chelal fixed finger absent in mature males ……………………………………..…… **2**
■ – Hemispermatophore (type *2a*) internal nodule weakly rounded to obsolete; acuminate process terminus rounded; transverse trunk bolsters number 2 to 3 and lack interconnecting delicate vertical bolsters; proximal gap on chelal fixed finger present in mature males. Turkey: Aydın and İzmir Provinces; Greece: Samos Island ………………………..……………………….
*Iurus kinzelbachi* **Kovařík, Fet, Soleglad et Yağmur, 2010**

2 – Chelal movable finger lobe on adult female weakly developed; telson length / telson width 3.15 to 3.35 (3.23) for males, 3.10 to 3.45 (3.26) for females; telson width / metasomal segment V width 1.05 to 1.10 (1.06) for males, 1.05 to 1.15 (1.09) for females; chelal fixed finger length / chelal depth 1.40 to 1.45 (1.42) for males, 1.50 to 1.70 (1.59) for females. Greece: Peloponnese, Kythira Island …….…… *Iurus dufoureius* **(Brullé, 1832)**
■ – Chelal movable finger lobe on adult female strongly developed; telson length / telson width 2.85 to 2.95 (2.89) for males, 2.85 to 3.05 (2.94) for females; telson width / metasomal segment V width 1.10 to 1.30 (1.22) for males, 1.15 to 1.40 (1.27) for females; chelal fixed finger length / chelal depth 1.60 to 1.70 (1.64) for males, 1.40 to 1.45 (1.44) for females; distribution. Greece: Crete …………….………*Iurus dekanum* **(Roewer, 1943)**

Discussion. The three species of *Iurus* have a disjunct distribution, with *I. kinzelbachi* found in extreme west-central Turkey (Aydın and İzmir Provinces) and the Greek island of Samos, as the proposed basal species (see map in Fig. 6). These three species have the highest number of inner denticles (*ID*) of the movable finger in subfamily Iurinae, 13–16 (14–15), and lowest number of pectinal teeth, counts ranging 8–11 (9–10) for males, 7–11 (9) for females (see Tab. 3 and Fig. 5). Except for the adult male of *I. kinzelbachi*, these species lack a proximal gap on the chelal fixed finger. The movable finger lobe is proximal of the finger midpoint in all adult males and females. *I. kinzelbachi* is distinctly separated from the Peloponnese and Crete species by its hemispermatophore structure and the presence of unique vestigial neobothriotaxy on the pedipalp chelae and patellae. We suggest that the presence of transverse bolsters on the trunk of the hemispermatophore in this genus (lacking in *Protoiurus*) may be due to the elongated lamina, providing additional support for the trunk during the insemination process. Based on the limited hemispermatophore material of *I. kinzelbachi*, we see that the number and development of transverse bolsters is less than in the other two species. In *I. dufoureius* and *I. dekanum* the primary transverse bolsters, which number four to six, are interconnected by a delicate vertical bolster forming a subtle web-like pattern (see Fig. 3).

During the analysis of *I. dekanum* from Crete, we discovered small secondary ventral accessory (*va*) denticles occurring on some cheliceral movable fingers (see examples in Figs. 7–16). These denticles were located in two areas of the ventral edge, at the base of the large *va* denticle, and on the distal half of the *va* denticle. After examining 19 specimens of *I. dekanum* we found this curious denticle on 13 chelicerae, a 35 % occurrence (37 chelicerae were examined). Of these 13 occurrences, five were medium to well-developed and eight were smaller, granule-like in appearance. Interestingly, this secondary *va* denticle was also found on the right chelicera of the male holotype (see Fig. 26). We examined *I. dufoureius* (eight specimens, fifteen chelicerae) and found two occurrences (both from Kythira) and *I. kinzelbachi* (nine specimens, 18 chelicerae) and found nine occurrence(s). Only *I. kinzelbachi* exhibited the distal *sva* denticle. Thirty-two specimens of *Protoiurus* were examined (60 chelicerae in total) and no secondary *va* was detected. Based on this data, we tentatively assume this character is only found in *Iurus* species. However, since these secondary *va* denticles occurs in less than fifty-percent of specimens, if found, usually on one chelicera (only five specimens had this denticle on both chelicerae), and their degree of development is variable, we consider them vestigial, thus declare them here as vestigial secondary ventral accessory (*v-sva*) denticles. Vestigial neobothriotaxy is
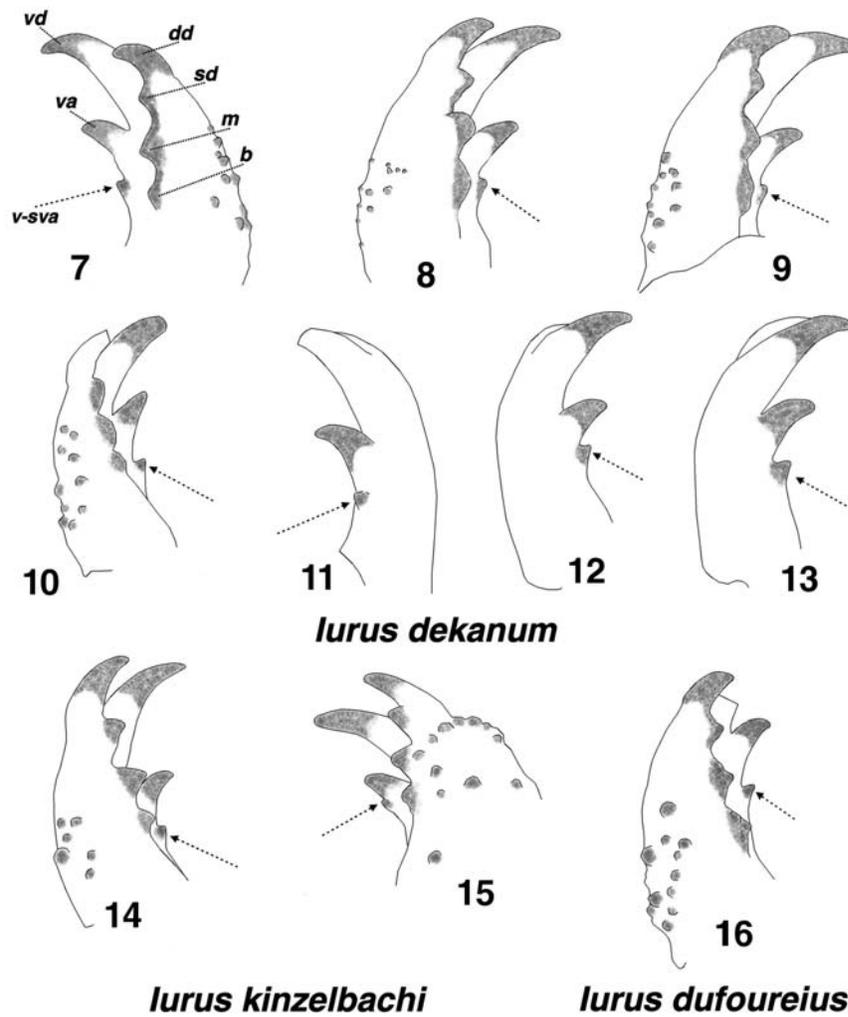
Figures 7–16: Examples of the vestigial secondary ventral accessory (*v-sva*) denticles on the cheliceral movable finger in genus *Iurus*. Statistical data in table follows Figures. **7–13.** *Iurus dekanum*. **7.** Adult male, Koudouma Monastery, Crete. **8.** Subadult female, Lefka Ori Mountains, Crete. **9.** Adult male, Katharo Plateau, Lasithi Region, Crete. **10.** Adult male, Anopoli, Chania Region, Crete. **11.** Adult female, Prina-Messeleri, Lasithi Region, Crete. **12.** Male holotype, Crete. **13.** Adult female, Pachia Ammos, Lasithi Region, Crete. **14–15.** *Iurus kinzelbachi*. **14.** Adult female, Dilek Peninsula National Park, Aydın Province, Turkey. **15.** Adult female, Valley of Nightingales, Manolates, Samos. **16.** *Iurus dufoureius*. Adult male, Agia Sofia Cave, Kythira. Cheliceral dentition: *dd* = dorsal distal, *sd* = subdistal, *m* = median, *b* = basal, *vd* = ventral distal, *va* = ventral accessory, *v-sva* = vestigial secondary ventral accessory. Arrow points to *v-sva*.

	Number of Specimens	Number of Chelicerae	Basal		Distal		*va* % Chelicerae
			Small	Medium	Small	Medium	
Iurus dekanum	19	37	8	5			35.1
Iurus dufoureius	8	15	1	1			13.3
Iurus kinzelbachi	9	18	2		1	6	50.0
Iurus	36	70	11	6	1	6	34.3
Protoiurus asiaticus	2	3					
Protoiurus kadleci	2	4					
Protoiurus kraepelini	12	24					
Protoiurus rhodiensis	9	16					
Protoiurus stathiae	7	13					
Protoiurus	32	60					

also found in this subfamily, unprecedented in Recent scorpions.

Genus *Protoiurus* Soleglad, Fet, Kovařík et Yağmur, gen. nov.

Type Species. *Protoiurus asiaticus* (Birula, 1903) [= *Iurus dufoureius asiaticus* Birula, 1903], designated here.

References (selected):

Iurus: Thorell, 1877: 193 (in part); Pavesi, 1878: 360 (in part); Kraepelin, 1899: 178 (in part); Borelli, 1913: 2 (in part); Caporiacco, 1928: 240; Menozzi, 1941: 234; Roewer, 1943: 235; Caporiacco, 1948: 27; Vachon, 1951: 342; Gruber, 1963: 308; Gruber, 1966: 424; Vachon, 1966a: 453 (in part); Vachon, 1966b: 215 (in part); Stahnke, 1974: 114 (in part); Kinzelbach,

1975: 21 (in part); Francke, 1981: 221 (in part); Francke & Soleglad, 1981: 251 (in part); Kinzelbach, 1982: 58 (in part); Kinzelbach, 1985: map IV (in part); Vachon & Kinzelbach, 1987: 99 (in part); Sissom, 1990: 130 (in part); Kritscher, 1993: 381 (in part); Crucitti, 1995a: 1 (in part); Crucitti & Malori, 1998: 133 (in part); Kovařík, 1998: 136 (in part); Crucitti, 1999a: 87 (in part); Kovařík, 1999a: 42 (in part); Fet, 2000: 49 (in part); Fet & Braunwalder, 2000: 18 (in part); Sissom & Fet, 2000: 419 (in part); Crucitti & Cicuzza, 2001: 227 (in part); Stathi & Mylonas, 2001: 290 (in part); Soleglad & Fet, 2003b: 110 (in part); Fet et al., 2004: 18 (in part); Kovařík & Whitman, 2005: 113; Parmakelis et al., 2006: 253 (in part); Fet & Soleglad, 2008: 256 (in part); Francke & Prendini, 2008: 218 (in part); Kaltsas et al., 2008: 227 (in part); Kovařík, 2009: 27 (in part); Soleglad et al., 2009: 2 (in part); Yağmur et al., 2009: 154 (in part); Fet, 2010: 8 (in part); Kovařík et al., 2010: 10 (in part); Stockmann & Ythier, 2010: 531 (in part).

Jurus (incorrect subsequent spelling): Kraepelin, 1894: 183 (in part); Birula, 1898: 133 (in part); Werner, 1902: 605 (in part); Birula, 1903: 297 (in part); von Ubisch, 1922: 503; Werner, 1934a: 162 (in part); Werner, 1934b: 282 (in part); Werner, 1936a: 192 (in part); Werner, 1936b: 17; Werner, 1938: 172 (in part); Vachon, 1947a: 162; Vachon, 1947b: 2; Vachon, 1948: 62 (in part); Vachon, 1951: 343; Vachon, 1953: 96 (in part).

Distribution. GREECE: islands: Karpathos, Kasos, Megisti, Rhodes, Saria. TURKEY: Adana, Adıyaman, Antalya, Isparta, Kahramanmaraş, Karaman, Konya, Mersin, Muğla, and Niğde Provinces. See general map in Fig. 6.

Etymology. The generic name is derived from the Ancient Greek πρωτο- (*proto-*), combination form of πρῶτος (*protos*, "first", "ancestral"), and *Iurus*, indicates a more primitive genus based on its presumed plesiomorphic position within Iurinae.

Type Species. *Protoiurus asiaticus* (Birula, 1903)

Composition. This genus contains the following five species:

> *Protoiurus asiaticus* (Birula, 1903), **comb. nov.**
> *P. kadleci (*Kovařík, Fet, Soleglad et Yağmur, 2010), **comb. nov.**
> *P. kraepelini* (von Ubisch, 1922), **comb. nov.**
> *P. rhodiensis* **sp. nov.**
> *P. stathiae* **sp. nov.**

Notes. Species found on the Aegean islands of Kasos (Fet, 2000) and Saria (Kinzelbach, 1982), judging from their geographic position close to Karpathos, probably belong to *Protoiurus stathiae*. A single Kasos specimen available for our study was a juvenile, and could not be confidently classified. We did not examine Saria specimens. Records from Kos and Leros (Kinzelbach, 1975) are not confirmed.

Diagnosis. Hemispermatophore type *1*: lamina short to medium, 0.9 to 1.2 times longer than trunk; distal lamina edges tapered, ending in a pointed terminus; distal lamina 1.4 to 3.1 times longer than basal lamina; acuminate process angle with dorsal trough greater than 60 degrees; transverse bolters absent on trunk. Chelal movable finger lobe situated at or distal of finger midpoint in adult males; number of inner denticles (*ID*) on chelal movable finger 11–14 (12.785). Pectinal tooth count range (based on the means of five species) 10.70–12.93 for males and 9.48–11.48 for females.

Phylogenetic key to species of *Protoiurus*

1 – Hemispermatophore (type *1a*) internal nodule conspicuously developed, terminus pointed; external edge of lamina straight; lamina distal length / basal length 1.4 to 1.8 (1.68); chelal palm of mature male not highly vaulted; movable finger curve subtle, 19 to 22 degrees ………………………………………………… **2**

■ – Hemispermatophore (type *1b*) internal nodule widely rounded; external edge of lamina curved; lamina distal length / basal length 2.2 to 3.1 (2.45); chelal palm of mature male highly vaulted; movable finger curve abrupt, 30 degrees or more. Widespread in southern Turkey: Antalya, Isparta, Konya, Karaman, Mersin, and Muğla Provinces; Greece: Megisti Island …………. ……….…… *Protoiurus kraepelini* **(von Ubisch, 1922)**

2 – Chelal movable finger of mature males with one lobe; fixed finger of mature females without proximal gap; metasoma stocky, segment I wider than long in male and female, segment V L/W 2.68 to 3.34 in males, 2.71 to 3.13 in females ………………………….…… **3**

■ – Chelal movable finger of mature males with two distinct lobes; fixed finger of mature females with conspicuous proximal gap; metasoma thin, all segments longer than wide in male and female, segment V L/W 3.76 to 4.24 in males, 3.87 in females. Turkey: Antalya and Mersin Provinces …………………… *Protoiurus kadleci* **(Kovařík, Fet, Soleglad et Yağmur, 2010)**

3 – Chelal fingers are relatively short, movable finger length / palm width = 1.75 to 1.99 in males, 1.90 to 2.08 in females; fixed finger length / palm width = 1.31 to 1.77 in males, 1.48 to 1.63 in females; chelal carinae dark reddish in color, in strong contrast to lighter palm …………………………………………………..….. **4**

■ – Chelal fingers are elongate, movable finger length / palm width = 2.26 to 2.33 (2.28) in males, 2.39 to 2.41 (2.40) in females; fixed finger length / palm width = 1.76 to 1.82 (1.79) in males, 1.63 to 1.91 (1.81) in females; chelal carinae color not noticeably darker than palm. South-central and eastern Turkey: Adana, Adıyaman, Kahramanmaraş, Mersin, and Niğde Provinces ……………..…… ***Protoiurus asiaticus* (Birula, 1903)**

4 – Chelal movable finger lobe in adult males situated on distal half of finger; proximal gap on fixed finger prominent in adult males; chelal palm quite robust, chela length / palm width = 2.86 to 3.15 (2.99) in males, 3.01 to 3.35 (3.19) in females; chela length / palm depth = 2.28 to 2.48 (2.40) in males, 2.52 to 2.76 (2.67) in females; pectinal tooth count standard error range 12–14 (12.93) for males and 10–12 (11.03) for females. Greece: Karpathos Island .. ***Protoiurus stathiae* sp. nov.**
■ – Chelal movable finger lobe in adult males situated on proximal half of finger; proximal gap on fixed finger very weak in adult males; chelal palm less robust, chela length / palm width = 3.14 to 3.63 (3.40) in males, 3.45 to 3.58 (3.53) in females; chela length / palm depth = 2.76 to 3.45 (3.01) in males, 2.88 to 2.99 (2.92) in females; pectinal tooth count standard error range 10–12 (11.28) for males and 9–10 (9.48) for females. Greece, Rhodes Island ………… ***Protoiurus rhodiensis* sp. nov.**

Discussion. The five species of *Protoiurus* form four disjunct geographic ranges, including Greek islands of Karpathos (*P. stathiae*) and Rhodes (*P. rhodiensis*), and two in Turkey, the southwest to south-central area (*P. kraepelini* and *P. kadleci*), and the south-central to eastern area (*P. asiaticus*). The latter two are separated by the higher elevations of the Taurus Mountains (see map in Fig. 6). *P. kraepelini* exhibits the largest range of all species, including those of *Iurus*, spanning the provinces from Muğla to Mersin, whereas *P. kadleci* has the smallest range, which is somewhat spotty in Antalya (two localities from caves) and Mersin Provinces. These five species exhibit the lowest number of inner denticles (*ID*) of the movable finger in subfamily Iurinae, 11–14 (11–13), and the highest number of pectinal teeth counts ranging 10–16 (11–13) in males and 8–14 (9.5–11.5) in females (see Tab. 3 and Fig. 5). The three species of *Protoiurus* from Turkey have distally positioned movable finger lobes in large adults for both genders, with *P. kraepelini* and *P. kadleci* the most exaggerated. A distally placed lobe is also found in sexually mature *P. stathiae* males, while females of *P. stathiae* and both genders of *P. rhodiensis* have the lobe positioned basally of the finger midpoint in adults. A proximal gap on the fixed finger is present in all adult males of *Protoiurus*, from a very subtle gap in *P. rhodiensis* to exaggerated gaps in *P. kadleci* and *P. kraepelini*. *Protoiurus kadleci* is the most unusual among Iurinae in these characters: its

sexually mature females as well as males have a conspicuous proximal gap and the movable finger is armed with a secondary lobe at the base of the finger. Although neobothriotaxy has been reported in four species of Iurinae (see Soleglad et al., 2009; Kovařík et al., 2010: appendix B), only two, *Iurus kinzelbachi* (discussed elsewhere) and some populations of *Protoiurus kraepelini*, show any sort of consistency to be of taxonomic significance. Some populations of *P. kraepelini* from Antalya and Konya Provinces exhibit accessory trichobothria on the chelal inner surface (type 1, 55 instances) and on the external aspect of the palm (type 5, 73 instances). Based on new material analyzed since Kovařík et al. (2010), we have encountered additional cases of type 5 neobothriotaxy from Antalya and Konya Provinces. However, all cases of neobothriotaxy in subfamily Iurinae can be considered vestigial due to its overall inconsistency across pedipalps within a specimen as well as across specimens from the same population, which is unprecedented in scorpions.

Species Descriptions

Iurus dekanum (Roewer, 1943)
(Figs. 18–26, 28–42; Tables 4–6)

Chaerilomma dekanum Roewer, 1943: 238–240, pl. 6, fig. 11, 11a–e.

REFERENCES:
Scorpius gibbus (nec *Buthus gibbosus* Brullé, 1832; incorrect subsequent speling and misidentification): Lucas, 1853: 527; Raulin, 1869: 672.
Jurus dufoureius (incorrect subsequent spelling): Birula, 1898: 135 (in part); Penther, 1906: 62–64; Werner, 1934a: 162 (in part); Werner, 1934b: 282 (in part); Werner, 1937: 136 (in part); Werner, 1938: 172 (in part); Vachon, 1948: 62 (in part); Vachon, 1953: 96 (in part).
Iurus dufoureius: Kraepelin, 1899: 179 (in part); Werner, 1902: 605 (in part); Stahnke, 1974: 123 (in part); Kinzelbach, 1975: 21 (in part); Francke, 1981: 221 (in part); Kinzelbach, 1985: map IV (in part); Kritscher, 1993: 383 (in part); Crucitti, 1995a: 1–2, fig. 1 (in part); Crucitti & Malori, 1998: 133 (in part); Kovařík, 1998: 136 (in part); Crucitti, 1999b: 252 (in part); Stathi & Mylonas, 2001: 290 (in part); Kovařík, 2002: 3; Fet et al., 2004: 18 (in part), figs. 7, 8, 39, 40, 44; Parmakelis et al., 2006: 253 (in part); Soleglad et al., 2009: 2 (in part); Fet, 2010: 8 (in part); Kovařík et al., 2010: 60, 187 (in part), figs. 31 (in part), 100; Stockmann & Ythier, 2010: 531 (in part).
Jurus dufourejus (incorrect subsequent spelling): Birula, 1903: 297–298 (in part).
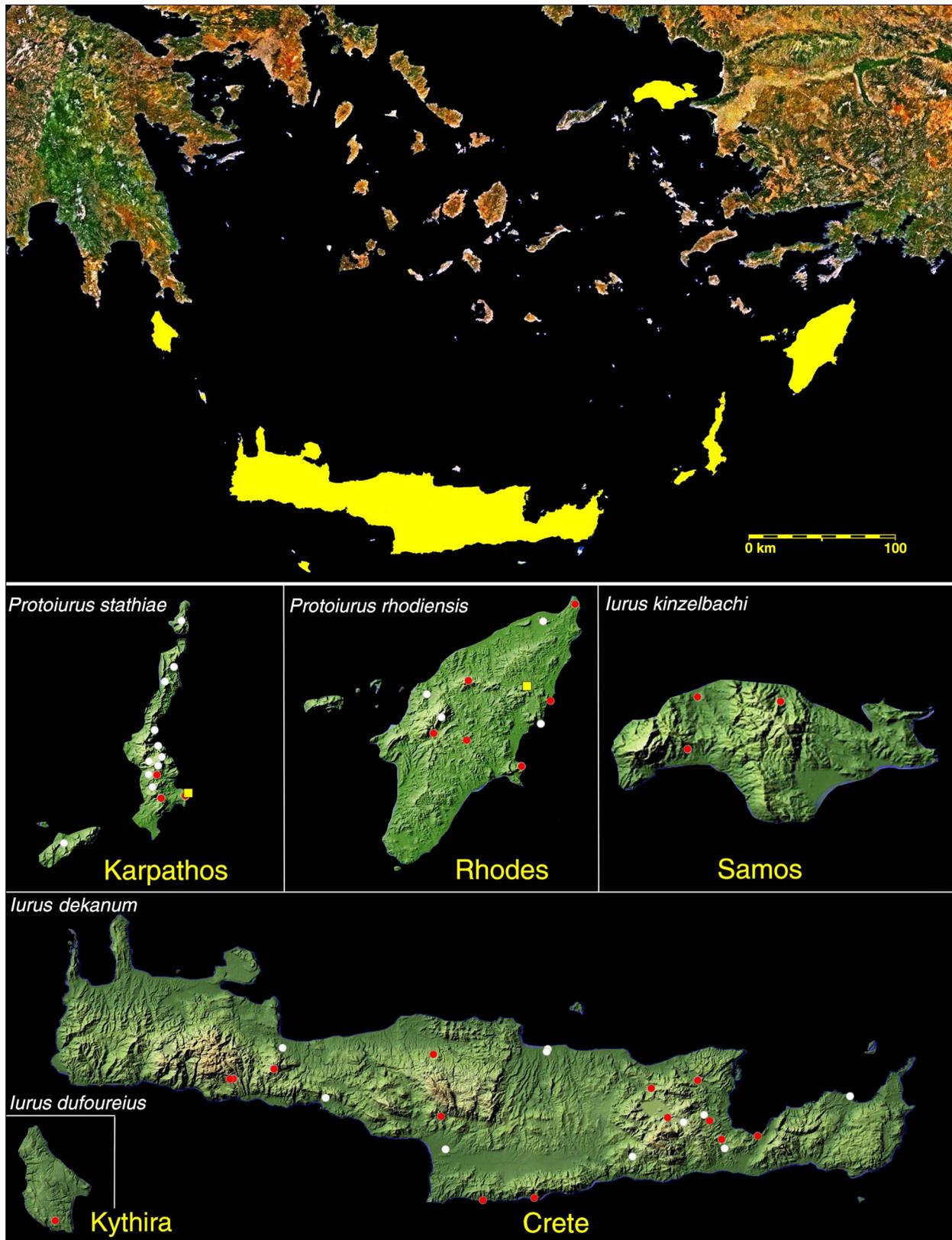
Figure 17: Map of Greek islands (bottom) showing distribution of *Iurus* and *Protoiurus* specimens reported and/or examined in this study. White icons represent reported localities in literature and red icons represent specimens examined. Yellow rectangle indicates *type localities* of the two new species *Protoiurus rhodiensis* and *P. stathiae*. General area of the Aegean area shown on top, the five islands of interest are colored yellow.

Figure 18: *Iurus dekanum*, adult male. Katharo Plateau, Lasithi Region, Crete.
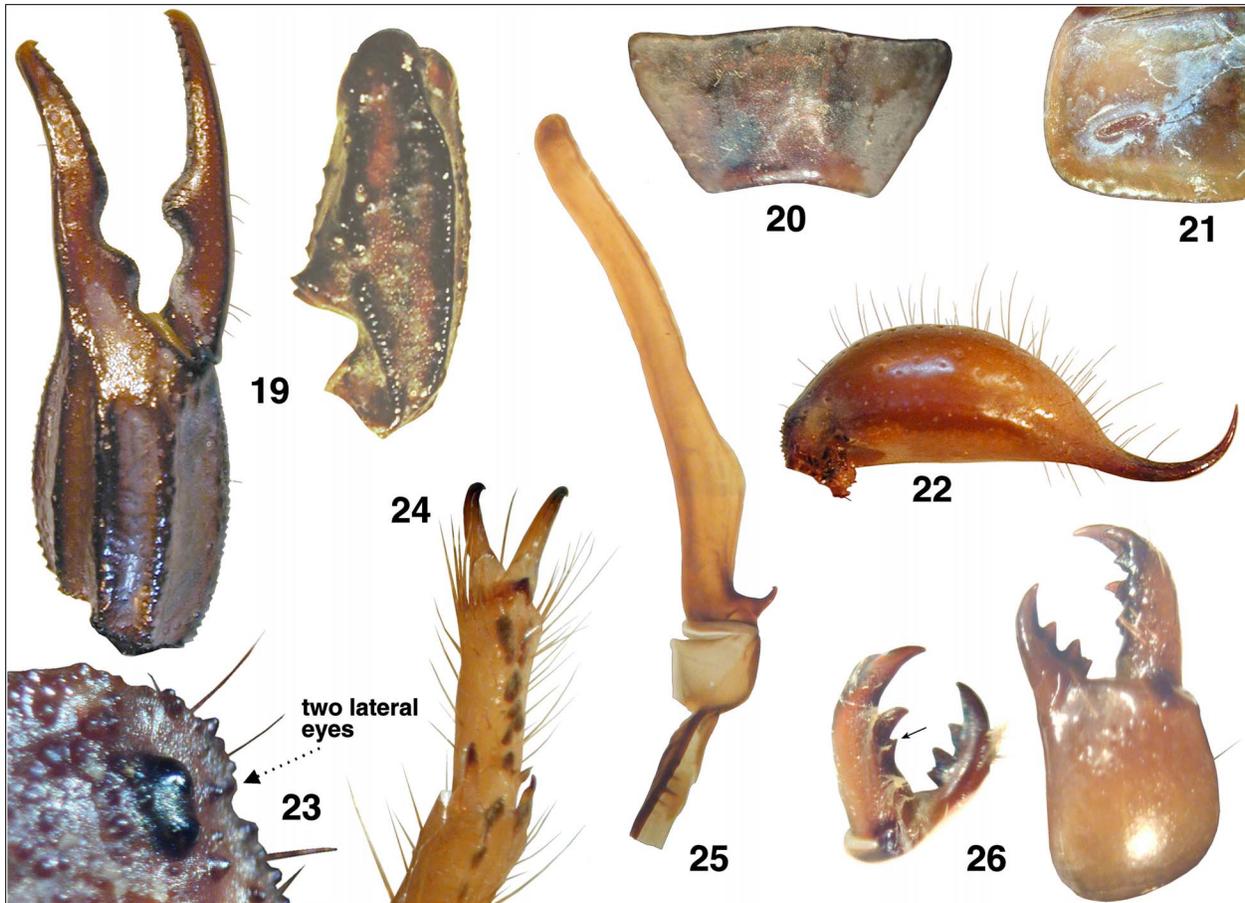
Figure 19–26: *Iurus dekanum*, male holotype, Crete. **19.** Chela and patella, lateral views. **20.** Sternite VII. **21.** Right stigma III. **22.** Telson, lateral view. **23.** Carapace, partial view, showing only two lateral eyes on right anterior corner. **24.** Right leg tarsus II, ventral view. **25.** Right hemispermatophore, dorsal view (trunk terminus missing). **26.** Chelicera, ventral and dorsal views. Note in ventral view the additional smaller secondary *va* denticle located just below normal large *va* (pointed to by *arrow*). This denticle was not found on left chelicera.

Iurus dekanum: Vachon, 1966a: 453–458, figs. 1–6, 13, 15, 17, 19–21.
Iurus dufoureius dufoureius: Sissom & Fet, 2000: 420 (in part); Facheris, 2007a: 1–2 (in part); Facheris, 2007b: 1–2 (in part).

The bizarre case of *Chaerilomma dekanum*

Scorpion genus *Chaerilomma*, with a single species *Chaerilomma dekanum*, was described by C. F. Roewer (1943) from "Dekan, Anamalai" (southern India). Vachon (1966a) synonymized *Chaerilomma* with *Iurus* but recognized *Iurus dekanum* as a valid species from India. However, no Iuridae were ever recorded from India; the eastern limit of the family's range is in northern Iraq (Fet et al., 2009, fig. 38). In fact, it is highly likely that the labels were mixed up, and the Indian label is fallacious. Roewer examined arachnid material from Crete as well as from India collected roughly during the same period. In summer 1926,

Roewer himself together with an Austrian speleologist H. Wichmann, collected in Greece and especially in many localities of Crete from where he published an extensive collection of Opiliones, and also two species of scorpions, *Mesobuthus gibbosus* and *Euscorpius carpathicus* (Roewer, 1928). Approximately at the same time, J. Carl and K. Escher (Muséum d'Histoire naturelle de Genève, Geneva, Switzerland) collected many arachnids during their expedition to South India in winter 1926–27, and Roewer (1929) studied this material as well. Anamalai (or Anaimalai) Hills – which are in fact a mountain range up to 2700 m asl – form the southern part of Western Ghats; Deccan Plateau lies further east. There, Carl and Escher collected many new taxa of Opiliones described by Roewer (1929), including even genus *Anaimalus* (derived from spelling version "Anaimalai"). Roewer (1929) also listed seven common Indian scorpion species, some of them from Attakatti forest in Anaimalai Hills, but did not at that time publish any descriptions of new scorpion taxa.

Figure 27: *Iurus dekanum* (Roewer, 1943), SMFD museum labels. **Lower Left.** Original label of Roewer accompanying the type of *Chaerilomma dekanum*, 1943. **Top.** Vachon's synonymization of *Chaerilomma* to *Iurus*, 1966. **Lower Right.** Identification of *I. dekanum* as *I. dufoureius* by F. Kovařík, [September] 1999, in agreement with Francke (1981). **Upper Right.** Museum identification number 8893.

Roewer, who worked mainly on other arachnid orders, has published only one comprehensive work on scorpions (Roewer, 1943), essentially a checklist of his own collection deposited in SMFD. Roewer (1943) has described not only *Chaerilomma* but also several other new scorpion species from Asia, Africa, and Australia, all from his SMFD collection. Among these taxa, Roewer (1943) described two new species of genuine Indian scorpions (fam. Buthidae) collected by Carl and Escher. These were *Hemiscorpius kraepelini* from Nilgiri Hills, now synonym of *Hottentotta rugiscutis* (see Kovařík, 1999b), and *Orthochirus luteipes* from "Anamalei" (a German spelling version given in 1943 text on p. 210; the text under *Chaerilomma dekanum* on p. 240, and its original SMFD label has "Anamalai"), now synonym of *O. flavescens* (see Kovařík, 2004). Therefore, it appears that Roewer (1929) did not report unidentified scorpions from Carl and Escher's Indian expedition but put these specimens apart for future analysis. He clearly returned to this unidentified material in the 1930s since another specimen from "Anamalei" (*sic*) mentioned by Roewer (1943: 210), a very rare buthid *Stenochirus politus* Pocock (now *Buthoscorpio politus*), has a label "det. 1932" (Kovařík, 2002).

The scorpion list of Roewer (1943) appears to have many misidentifications and wrong locality labels (Kovařík, 2002). Francke (1981: 221) mentioned, after Helversen & Martens (1972) that "Roewer's arachnid collection contains numerous specimens, including type specimens, with erroneous locality data". In particular, Helversen & Martens (1972) reported that ten arachnid taxa allegedly collected by Roewer on Crete in 1926, and described as new species by Beier (1931) (Pseudoscorpiones) and Roewer (1950) (Opiliones) are in fact *not* found on Crete but originate from other areas of Europe, so their labels in Roewer's collection must have been mixed up. "Wrong data are not limited to collections made personally by Roewer" (Helversen & Martens, 1972). We consider it quite likely that a single male of *Iurus*, collected by Roewer or Wichmann on Crete in 1926, got mixed with his Indian material.

A new genus *Chaerilomma* was created by Roewer (1943) in a very superficial way. Vachon (1966a) suggested that Roewer followed the simplistic family key of Werner (1934b: 265) where the couplet 4 led him to choose two lateral eyes (leading to Chactidae) versus three to five (leading to Buthidae and Vaejovidae). Roewer (1943) placed his new genus in family Chactidae, under its erstwhile subfamily Chaerilinae, probably going by geographic proximity; and then he diagnosed "unique" characters of the new genus by contrasting it with *Chaerilus*. As it turns out, the holotype of *I. dekanum* has two lateral eyes only on the right side (see Vachon, 1966a: figs. 19–20, and our Fig. 23). Vachon (1966a) discussed these issues in detail as he compared the type of *Chaerilomma* with a specimen of *Protoiurus asiaticus* (referred to as *Iurus dufoureius*) from Tarsus, Mersin Province of central Turkey. Interestingly, Roewer (1943: 235) also listed, as *Iurus dufoureius*, a specimen of *Protoiurus kraepelini* from Turkey (Ovacık near Fethiye, Muğla Province), but it is clear that he has not compared his *Chaerilomma* to this specimen.

The primary purpose of Vachon (1966a) was to demonstrate that *Chaerilomma* and *Iurus*, then placed in separate families (Chactidae and Vaejovidae, respectively), were extremely similar in all important taxonomic characters: trichobothrial patterns, cheliceral and chelal dentition, leg tarsus armature, etc. Vachon also questioned the general partitioning of families Chactidae and Vaejovidae based solely on the number of lateral eyes, noting important exceptions; also see Soleglad

(1976: 252–253, 299) and Fet & Soleglad (2007: 261) for further discussion on using the number of lateral eyes in scorpion systematics. Vachon (1971; 1974: figs. 212–219) used the same approach to show the weakness of using the eye number for family diagnosis when he emphasized the nearly identical but highly unusual trichobothrial patterns shared by genera *Calchas* and *Iurus*, which, at that time, were placed in different families (Chactidae and Vaejovidae, respectively). While Vachon (1966a) synonymized *Chaerilomma* with *Iurus*, he recognized *Iurus dekanum* as a valid species from India, different from his single *Protoiurus asiaticus* specimen from Turkey. Vachon (1966a) then even speculated on biogeography of *Iurus*, including India in his historical scenarios.

Francke (1981) reexamined the holotype of *I. dekanum*, comparing it to a small series of specimens from Crete and Turkey. Based on the chelal finger lobe morphology and pectinal tooth counts, Francke concluded that *I. dekanum* was too similar to the Crete population and therefore synonymized *I. dekanum* with *I. dufoureius*, a conclusion accepted by all authors until now. Clearly, the Turkish material viewed by Francke was different from *I. dekanum*; in fact, it was composed of two species, *Protoiurus asiaticus* and *P. kraepelini*; see Kovařík et al. (2010: 50) for a detailed discussion of Francke's analysis. Below, we redescribe *Iurus dekanum*, which we consider a separate species of the redefined genus *Iurus*, endemic to the island of Crete.

Type material: Holotype ♂, original label: "Dekan, Anamalai" (Fig. 27), [incorrect label; most likely Crete], SMF 8893/235 (SMFD).

Diagnosis. Medium to large sized species, 75–90 mm. Carapace, mesosoma, pedipalps, and metasoma dark gray to black in overall coloration, legs lighter orange. Pectinal tooth counts lowest in genus, 8–11 (9.75) for males, 7–10 (8.93) for females. Chelal movable finger lobe in adult males located on basal half, lobe ratio 0.40–0.45; proximal gap on fixed finger is absent in adult males; movable finger of adult males essentially straight, not highly curved; movable finger lobe in adult females is well-developed; number of inner denticles (*ID*) of chelal movable finger, 13–15 (14.833); hemispermatophore type *2b*.

Distribution. **Greece**: Crete Island. See map in Fig. 17 and *Material Studied* section above.

MALE. The following description is based on the holotype male presumably from Crete, Greece. Measurements of the holotype plus six other specimens are presented in Tables 4–5. The holotype male is in poor condition: the posterior edges of the carapace are fragmented, the metasoma is detached in three areas, one chela and patella are detached, several legs are detached from the mesosoma, and much of the setation is absent.

COLORATION. Basic color of carapace, mesosoma, pedipalps, and metasoma dark gray to black; legs and telson orange; pedipalp carinae darker, essentially black; genital operculum, basal piece and pectines yellow-tan. Eyes and tubercles black, leg condyles and aculeus tip dark brown.

CARAPACE (Fig. 23, Fig. 30, female). Anterior edge with a conspicuous median indentation; entire surface densely covered with small to medium granules, the largest occurring between the lateral eyes. Mediolateral ocular carinae well-developed and granulated, extending to the lateral eyes; there are three lateral eyes on the left side and two on the right, the most posterior eye missing. Median eyes and tubercle of medium size, positioned anterior of middle with the following length and width ratios: 0.352 (anterior edge to medium tubercle middle / carapace length) and 0.152 (width of median tubercle including eyes / width of carapace at that point).

MESOSOMA (Figs. 20–21, Figs. 32, 35, female). Tergites I–VII covered with minute granules; tergite VII carinae obsolete due to dense granulation. Sternites III–VII smooth and lustrous; VII with crenulated lateral carinae and smooth median carinae (Fig. 20). Stigmata (Fig. 21) are medium in size and slit-like in shape, angled 35° in an anterointernal direction.

METASOMA (Fig. 34, female). Segment I wider than long. Segments I–IV: dorsal carinae serrated; dorsolateral carinae crenulated; dorsal carinae with 11/11, 13/12, 12/13, and 12/12 spines (left/right carina); dorsal (I–IV) and dorsolateral (I–III) carinae do not terminate with an enlarged spine; lateral carinae crenulated on I, crenulated on posterior one-sixth of II; obsolete on segments III–IV; ventrolateral carinae smooth to rough on I–II, and crenulated on III–IV; ventromedian carinae smooth on I, smooth to granulated on II, and crenulated on III–IV. Dorsolateral carinae of segment IV terminate at articulation condyle. Segment V: dorsolateral carinae serrated; lateral carinae crenulated for two-thirds of posterior aspect; ventrolateral and single ventromedian carinae serrated; ventromedian carina not bifurcated, terminating in straight line. Anal arch with 16 small serrated granules. Intercarinal areas of segments I–V essentially smooth.

TELSON (Fig. 22, Fig. 34, female). Vesicle elongated, with highly curved aculeus. Vesicle essentially void of granules; ventral surface with elongated curved setae; dorsal surface irregularly scattered with short to medium
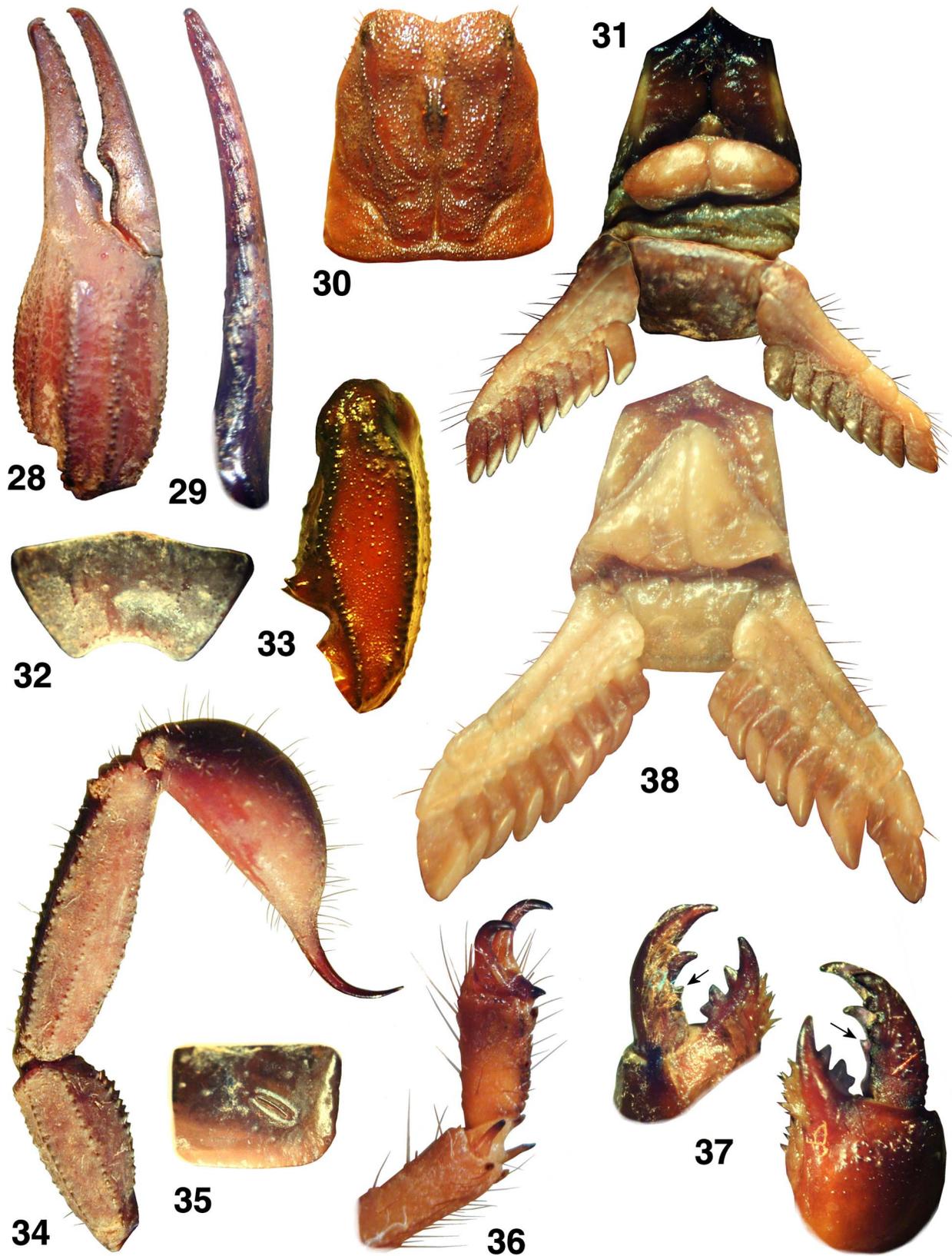
Figures 28–38: *Iurus dekanum*. **28–37.** Female, Pachia Ammos, Lasithi Region, Crete. **38.** Male, Lochria, Rethymno Region, Crete. **28.** Chela, lateral view. **29.** Chelal movable finger dentition. **30.** Carapace. **31.** Sternopectinal area. **32.** Sternite VII. **33.** Patella, dorsal view. **34.** Metasomal segments IV–V and telson, lateral view. **35.** Right stigma III. **36.** Right leg III tarsus, lateroventral view. **37.** Chelicera, ventral and dorsal views. *Arrow* points to vestigial secondary ventral accessory denticle. **38.** Sternopectinal area.
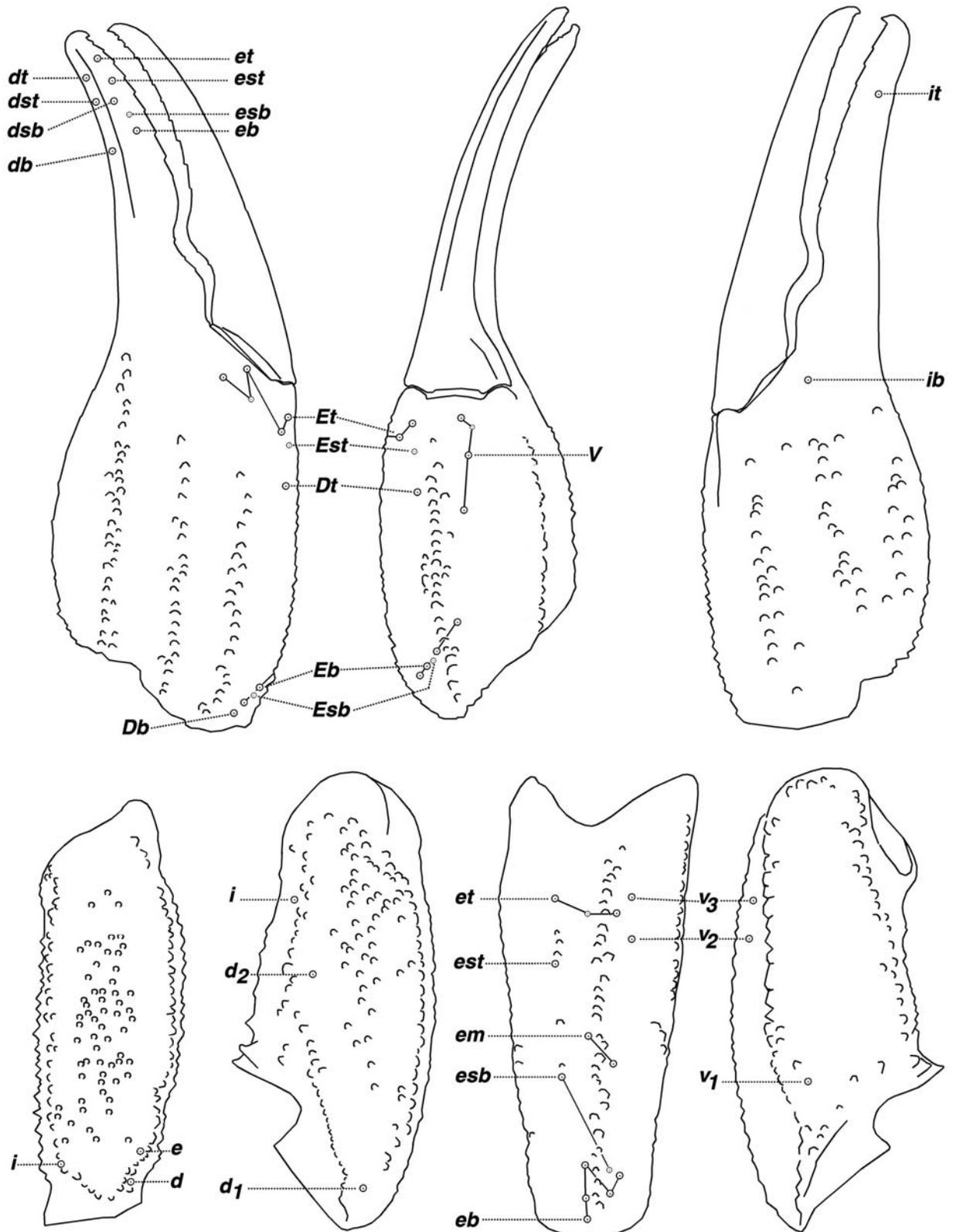
Figure 39: *Iurus dekanum*. Female, Pachia Ammos, Lasithi Region, Crete. Trichobothrial pattern.
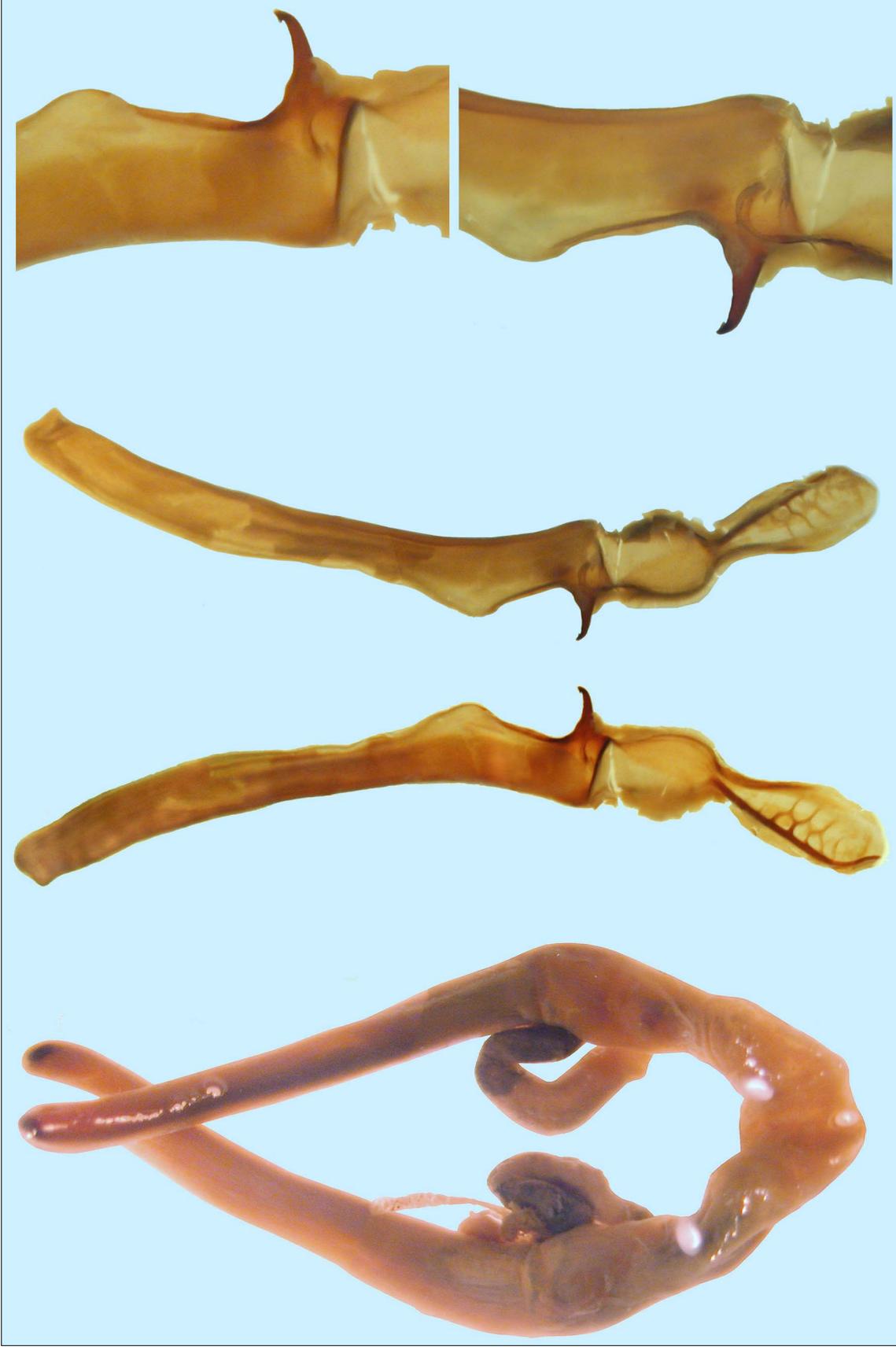
Figure 40: Hemispermatophore (submerged in alcohol) of *Iurus dekanum*. **Left.** Katharo Plateau, Lasithi Region, Crete. Connected hemispermatophores encased in membranous sack showing attachment of the paraxial organ and severed vas deferens (on left side only). Note, from a scorpion internal perspective, the view is from the ventral surface (i.e., the external edges of the hemispermatophores are shown). **Center.** Kroustas, Lasithi Region, Crete. Right hemispermatophore, dorsal and ventral views. Note that the distal tip of the trunk is missing. **Right.** Closeup of the median area, dorsal, and ventral views, showing the knob-like internal nodule, acuminate process with truncated terminus, and seminal receptacle.

		Iurus dekanum				
	Crete ***	Pachia Ammos Lasithiou, Crete	Agios Mamas Rethymnou, Crete	Kroustas Lasithiou, Crete	Lefka Ori Mountains, Crete	Katharo Plateau Lasithiou, Crete
	Male Holotype	Female	Female	Male	Male	Male
Total length	69.60	89.25	84.90	77.65	68.75*	77.50
Carapace length	9.80	13.15	12.30	11.10	10.80	11.85
Mesosoma length	20.30	28.20	25.40	23.35	19.00*	20.30
Metasoma length	28.15	34.30	34.35	31.20	28.40	32.95
Segment I length/width	3.45/4.45	4.55/5.45	4.30/5.40	4.00/4.65	3.60/4.30	4.10/5.00
Segment II length/width	4.30/3.80	5.35/4.80	5.30/4.55	4.70/4.20	4.40/3.75	4.95/4.45
Segment III length/width	4.75/3.55	5.85/4.30	5.70/4.20	5.30/3.90	4.90/3.55	5.40/4.10
Segment IV length/width	5.60/3.25	6.90/3.90	7.05/3.65	6.40/3.60	5.80/3.20	6.65/3.80
Segment V length/width	10.05/3.15	11.65/3.35	12.00/3.65	10.80/3.35	9.70/3.25	11.85/3.40
Telson length	11.35	13.60	12.85	12.00	10.55	12.40
Vesicle length	7.80	8.95	9.15	8.20	7.55	8.65
width/depth	4.00/3.30	4.80/4.05	4.25/3.55	4.20/3.45	3.60/3.25	4.20/3.45
Aculeus length	3.55	4.65	3.70	3.80	3.00	3.75
Pedipalp length	40.80	51.60	46.30	45.80	39.50	45.80
Femur length/width	10.25/3.35	13.15/4.45	12.20/4.20	11.75/3.55	10.15/3.35	11.85/3.90
Patella length/width*	9.60/3.70	12.40/4.25	11.25/4.30	11.20/3.85	9.70/3.35	11.10/3.80
DPS height**	1.50	1.60	1.85	1.50	1.60	1.60
Chela length	20.95	26.05	22.85	22.85	19.65	22.85
Palm length	9.20	11.85	11.00	10.70	8.75	11.00
width/depth	5.40/6.65	6.65/8.55	6.45/8.00	6.15/7.10	5.15/6.45	6.20/7.60
Fixed finger length	10.70	12.25	11.70	12.10	10.35	x
Movable finger length	12.50	15.30	13.50	13.20	11.70	14.55
Sternum Length/width	2.15/2.65	3.35/3.25	3.35/2.90	2.15/3.00	2.50/2.15	2.35/3.10
Pectines teeth	10-9	8-9	9-9	10-9	10-10	x-x
middle lamellae	4-3+	2-2+	3+-3	4-4	4-4	x-x

Table 4: Morphometrics (mm) of *Iurus dekanum*. * Patella width is widest distance between the dorsointernal and externo-medial carinae. ** DPS height is from tip of spines to dorsointernal carina centered. *** Note, actual holotype locality is unknown. The specimen was originally defined as *Chaerilomma dekanum* by Roewer (1943) and given the erroneous locality of Anamalai Hills, India.

length setae; base of aculeus with setation ventrally and dorsally. Vesicular tabs with one small pointed spine.

PECTINES (Figs. 31, 38). Well-developed segments exhibiting length / width ratio 2.2 (length taken at anterior lamellae / width at widest point including teeth). Sclerite construction complex, with three anterior lamellae and four/three middle lamella; fulcra of medium development. Teeth number 10/9. 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, anterior edge lacking indentation, length / width ratio 0.6.

GENITAL OPERCULUM (Figs. 31, 38). Sclerites triangular, longer than wide, separated for entire length, genital papillae not visible externally but present behind sclerites (see discussion on female below).

STERNUM (Figs. 31, 38). Type 2, posterior emargination present, well-defined convex lateral lobes, apex visible but not conspicuous.

CHELICERAE (Figs. 26, Fig. 37, female). Movable finger dorsal edge with one large subdistal (*sd*) denticle; ventral edge with one large pigmented accessory denticle at finger midpoint and a much smaller vestigial secondary *va* denticle, marked with an arrow in the
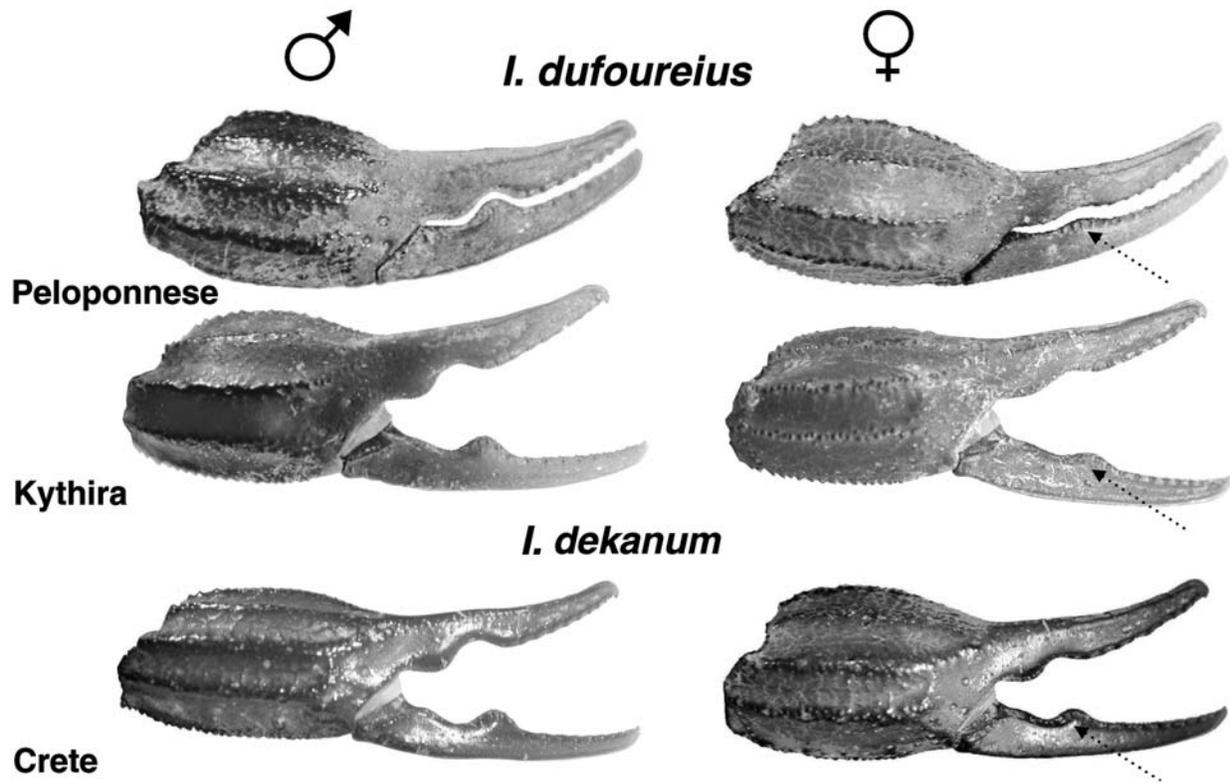
Figure 41: Comparison of movable finger lobe development in species *Iurus dufoureius* and *I. dekanum*. **Top.** *Iurus dufoureius*. Male (carapace length = 10.8 mm), Gythio, Peloponnese, Greece. Female neotype (carapace length = 12.20 mm), Nedontas River, Peloponnese, Greece. **Middle.** *Iurus dufoureius*. Cave Agia Sofia, Mylopotamos, Kythira Island. Male (carapace length = 10.70 mm). Female (carapace length = 11.35 mm). **Bottom.** *Iurus dekanum*. Male (carapace length = 11.10 mm), Kroustas, Lasithi Region, Crete. Female (carapace length = 11.85 mm), Crete, Greece (ZMB). Arrows point to the movable finger lobe showing different developments in adult females between the three populations: *I. dufoureius* from the Peloponnese, very weakly developed; from Kythira, moderately developed; and *I. dekanum*, strongly developed.

Figure. This denticle was not present on the other chelicera. 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 (Fig. 1, Figs. 28, 29, 33, 39, female). Well-developed chelae, heavily carinated, conspicuous scalloping on chelal fingers: well-developed lobe on movable finger, positioned proximal of midpoint in ratio 0.414; proximal gap absent on fixed finger. **Femur:** Dorsointernal and ventrointernal carinae serrated, dorsoexternal and ventroexternal crenulated. Dorsal surface scattered with minute granules and ventral surface with slight granulation, internal surface with line of 21 granules and external surface with line of 17 granules. **Patella:** Dorsointernal carina granulated, ventrointernal carina serrated, dorsoexternal and ventroexternal crenulated, and exteromedian carina strong and crenulated, a second carina found medially irregularly granulated. Dorsal and ventral surfaces with slight granulation;

external surface with serrated exteromedian carina; internal surface smooth with well-developed, doubled DPS and VPS. **Chelal carinae:** Complies to the "8-carinae configuration". Digital (*D1*) carina strong, irregularly granulated; dorsosecondary (*D3*) irregularly granulated; dorsomarginal (*D4*) rounded, granulated; dorsointernal (*D5*) weak, rounded, irregularly serrated; ventroexternal (*V1*) strong and irregularly crenulated; ventrointernal (*V3*) rounded and irregularly granulated, continuous to internal condyle; external (*E*) strong irregularly granulated; internal (*I*) rounded, weakly granulated. **Chelal finger dentition (Fig. 29, female):** Median denticle (*MD*) row groups oblique and highly imbricated, 13/13 on the fixed and movable fingers; 12/12 *ID*s on fixed finger and 16/16 *ID*s on movable finger; 11/11 *OD*s on fixed finger (to proximal gap) and 14/13 *OD*s on movable finger. No accessory denticles present. **Trichobothrial patterns (Fig. 39, female):** Type C, orthobothriotaxic.

LEGS (Fig. 24, Fig. 36, female). Both pedal spurs present on all legs, lacking spinelets; tibial spurs absent.

	I. dufoureius			*I. dekanum*	*I. kinzelbachi*	
	Kalivia Sochas, Peloponnese, Greece	Cave Agia Sofia Mylopotamou, Kythira Island, Greece		Crete, Greece	Nikolaos, Samos Island, Greece	Monolates, Valley of Nightingales, Samos Island, Greece
	Female	Male	Female	Female	Female	Female
Total length	82.15	-	83.35	72.85	84.50	84.55
Carapace length	10.80	-	11.35	11.85	12.15	11.75
Mesosoma length	27.95	20.85	27.95	17.80	27.45	27.95
Metasoma length	30.75	31.00	31.55	31.10	31.40	31.90
Segment I length/width	3.85/5.05	4.00/4.75	3.90/4.85	4.00/4.75	4.15/5.20	4.05/4.95
Segment II length/width	4.85/4.20	4.85/4.00	4.95/4.25	4.75/4.20	4.80/4.45	4.80/4.20
Segment III length/width	5.35/3.90	5.25/3.70	5.35/3.80	5.20/4.00	5.20/4.10	5.35/3.80
Segment IV length/width	6.10/3.55	6.30/3.35	6.35/3.30	6.35/3.60	6.15/3.85	6.50/3.55
Segment V length/width	10.60/3.40	10.60/3.35	11.00/3.25	10.80/3.35	11.10/3.35	11.20/3.10
Telson length	12.65	11.35	12.50	12.10	13.50	12.95
Vesicle length	8.65	7.55	8.65	8.00	9.30	8.75
width/depth	3.90/3.30	3.45/3.25	3.55/2.95	4.10/3.80	4.00/3.35	3.55/3.20
Aculeus length	4.00	3.80	3.85	4.10	4.20	4.20
Pedipalp length	40.90	40.60	44.00	44.95	48.10	46.80
Femur length/width	10.45/3.85	9.95/3.65	10.70/3.80	11.35/4.00	12.00/3.90	11.75/3.55
Patella length/width*	10.15/3.90	9.70/3.90	10.45/4.00	10.80/4.30	11.20/4.30	10.90/4.10
DPS height**	1.45	1.30	1.70	1.50	1.50	1.30
Chela length	20.30	20.95	22.85	22.80	24.90	24.15
Palm length	9.30	9.70	10.00	10.25	11.50	10.90
width/depth	5.35/6.70	5.80/7.10	6.05/7.45	6.25/7.85	7.00/8.65	5.90/7.35
Fixed finger length	11.00	10.05	11.45	11.10	12.40	11.55
Movable finger length	13.45	12.50	14.05	13.80	15.60	14.45
Sternum length/width	2.80/2.85	-/-	2.90/3.25	2.40/2.70	3.30/3.25	3.25/2.90
Pectines teeth	11-11	11-11	10-10	9-7	10-9	9-8
middle lamellae	4+-4	2+-2+	3+-2+	4-4	2-2	3-2

Table 5: Morphometrics (mm) of additional *Iurus*. * Patella width is widest distance between the dorsointernal and externomedial carinae. ** DPS height is from tip of spines to dorsointernal carina centered.

Tarsus with conspicuous spinule clusters in single row on ventral surface (numbering 7-6-6-8 for legs I–IV, respectively), terminating distally with a pair of enlarged spinule clusters. Unguicular spine (dactyl) well-developed and pointed. Basitarsus with external and internal rows of spinule clusters.

HEMISPERMATOPHORE (Figs. 25, 40). Hemispermatophore is type *2b*: Distal lamina is elongated with subparallel sides, terminus blunted; internal nodule is conspicuously developed and knob-like; transverse trunk bolsters are present; acuminate process terminus is truncated. Specific ratio values for the holotype left hemispermatophore, which is 12.41 mm in length, are lamina length / trunk length = 1.675 and lamina distal length / lamina basal length = 3.201.

Male and female variability (Figs. 41, 43). As seen in Figure 41 and unusual in *Iurus*, the adult female exhibits a well-developed movable finger lobe, essentially as well developed as in the male. Neither gender has a proximal gap. The position of the lobe is more basal on the female for comparable development stages, carapace length / MF lobe ratio shows 11.6 % difference (see Fig. 43 and Tab. 6). For adult comparisons, we have the following ranges, 0.393–0.441 (0.409) [4] for the female, and 0.414–0.447 (0.436) [3] for the male. There is no significant sexual dimorphism in morphometrics. Though the male has a slightly thinner metasoma, the MVDs (L/W) only ranged from 0.2 to 3.4 %. The chelal length as compared to its width and depth, we see 1.9 % and 5.8 % difference, respectively (i.e., the male dominating slightly). For the telson length as compared to its width and depth, 1.4 % and 1.5 % difference. Pectinal

Figure 42: *Iurus dekanum*, adult female. Crete (after Kovařík et al., 2010: fig. 100).

tooth counts in males exceed those of females by approximately 0.82 teeth, male 8–11 (9.75) [20], female 7–10 (8.93) [15] (see histograms in Fig. 5). The genital operculum of the male is dramatically different from that in the female (Figs. 31, 38). 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 18 and 42 show dorsal views of both male and female specimens.
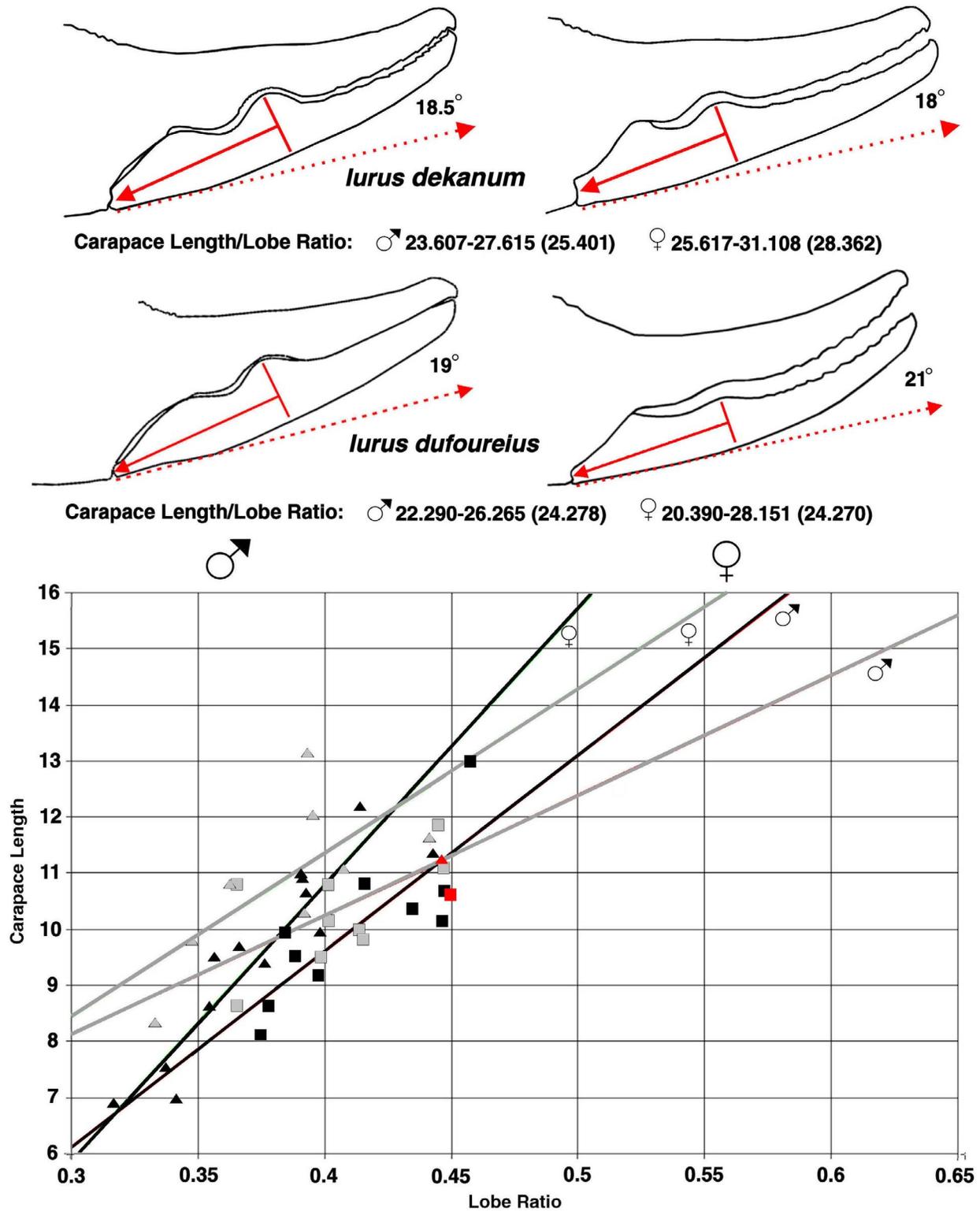
Figure 43: Comparison of movable finger lobe *signatures* for species *Iurus dufoureius* (black, 25 samples) and *I. dekanun* (grey, 17 samples). Red icons indicate Kythira Island specimens. Note the lobe position, basal, is essentially the same in the two species, but is more pronounced in *I. dekanum*, especially in the female. The lines depict linear fit by least squares regression. Lobe ratio = distance from external condyle to lobe center / movable finger length. Squares = males, triangles = females.

Statistical Comparisons of *Iurus dekanum*, *Iurus dufoureius*, and Kythira Population			
Carapace Length/ MF_Lobe Ratio	MVD $\quad$ 4.6%, 6.2% $\quad$ 1.5% ♂ *I. dekanum* (25.401)[9] > *I. dufoureius* (24.278)[10] > *Kythira* (23.918)[1]		
	MVD $\quad$ 10.7%, 16.9% $\quad$ 5.6% ♀ *I. dekanum* (28.362)[8] > *Kythira* (25.621)[1] > *I. dufoureius* (24.270)[15]		
Pectinal Tooth Counts	MVD $\quad$ 9.1%, 12.8% $\quad$ 3.4% ♂ *I. dekanum* (9.75)[20] < *I. dufoureius* (10.64)[22] < *Kythira* (11.00)[2]		
	MVD $\quad$ 12.0%, 12.0% $\quad$ 0% ♀ *I. dekanum* (8.93)[15] < *I. dufoureius* (10.00)[33] = *Kythira* (10.00)[2]		
Telson_W/Telson_L	MVD $\quad$ 11.7%, 13.8% $\quad$ 1.8% ♂ *I. dekanum* (0.346)[4] > *I. dufoureius* (0.309)[3] > *Kythira* (0.304)[1]		
	MVD $\quad$ 11.0%, 20.1% $\quad$ 8.2% ♀ *I. dekanum* (0.341)[3] > *I. dufoureius* (0.307)[3] > *Kythira* (0.284)[1]		
Telson_W/Meta-V_W	MVD $\quad$ 15.1%, 18.2% $\quad$ 2.7% ♂ *I. dekanum* (1.217)[4] > *I. dufoureius* (1.057)[3] > *Kythira* (1.030)[1]		
	MVD $\quad$ 16.8%, 16.7% $\quad$ 0.2% ♀ *I. dekanum* (1.274)[3] > *I. dufoureius* (1.091)[3] < *Kythira* (1.092)[1]		

Table 6: Diagnostic differences between *Iurus dekanum*, *I. dufoureius*, and the Kythira island population. (Mean) [number of samples]. MVD = mean value difference. Refer to Figs. 5 and 43 for more information.

Discussion

Iurus dekanum from Crete is closely related to *I. dufoureius* (the Peloponnese) and the population from the island of Kythira. Two of these populations share the same hemispermatophore type (*2b*) (Kythira not known). They all have a basal movable finger lobe and lack a proximal gap on the fixed finger. These characters uniquely define this clade of scorpion populations, the **Peloponnese + Kythira + Crete** clade. The closest relative to these scorpions is the distant species *I. kinzelbachi* from extreme west Turkey and the island of Samos (hemispermatophore type *2a*). All of these species, including *I. kinzelbachi*, also exhibit the lowest number of pectinal teeth and the highest number of inner denticles (*ID*) on the chelal movable finger. Diagnostic differences separating *I. dekanum* from *I. dufoureius* and the taxonomic placement of the Kythira population depend upon the development of the movable finger lobe, pectinal tooth counts, and morphometric analysis. It must be stressed here, however, that we have examined *only* a single adult male and female from the island of Kythira, so therefore its statistical range is not known.

Movable finger lobe. The development of the movable finger lobe of an adult female Kythira specimen is *intermediate* between *I. dufoureius*, which has the weakest lobe, and *I. dekanum* where the lobe is quite well developed (see Fig. 41 for comparisons). With respect to the carapace length/MF_lobe ratio, we have the following comparisons as presented in Table 6. The lobe ratio is larger by 4.6 to 10.7 % across genders, implying that the movable finger lobe is more basal in *I. dekanum*. In addition, *I. dufoureius* lobe is also more basal than in the Kythira population (thus the ratio is larger) but by smaller MVD, 1.5 to 5.6%. For both genders we see that the Kythira population is closer to *I. dufoureius* than *I. dekanum*. Also in the composite signature chart for *I. dufoureius* and *I. dekanum* (Fig. 43), we see the two plots for Kythira, male and female, are closer to comparable *I. dufoureius* plots, though all plots are similar indicating a basal movable finger lobe characteristic of the genus.

Pectinal tooth counts. The lowest number of pectinal teeth is found in genus *Iurus*. However, we can measure statistical differences between *I. dufoureius* and *I. dekanum*, as shown in Table 6. Figure 5 shows the pectinal tooth count statistics for all species of *Iurus* and *Protoiurus* where we see the tight clustering of *I. dufoureius* with the Kythira population. Statistically (i.e., as shown with variance analysis) *I. dekanum* and *I. dufoureius* are well separated in both genders with respect to pectinal tooth counts, although the overlap of the standard error range is 46.4 % and 28.1 % for the male and female, respectively. In contrast, Kythira pop-

ulation is within the standard error range of *I. dufoureius* and outside the absolute range of *I. dekanum*.

Morphometric analysis. We compared all morphometric ratios across three adult males and females of *I. dufoureius* and *I. dekanum* as well as the two specimens from the island of Kythira. When *I. dekanum* was compared to the other seven species of *Iurus* and *Protoiurus*, exercising all possible morphometrics, the telson width and depth dominated most ratios, scoring 19.7 to 23.6 (out of 25 comparisons). See Appendix C for a complete analysis of *I. dekanum* morphometrics. The telson length, however, dominated in few ratios, scoring only 6.6 to 7.7. This clearly implies that the telson of *I. dekanum* is relatively stocky, short with a wide and deep vesicle. With respect to these three populations we isolated two morphometric ratios that provide 11.0 to 16.8 % MVD between *I. dufoureius* and *I. dekanum*, telson width/telson length and telson width/metasomal segment V width. See Table 6 for the relevant data. Taking into consideration the major morphometric differences between *I. dufoureius* and *I. dekanum*, we can readily see that the Kythira population is much closer to *I. dufoureius* in both ratios for both genders, exhibiting 13.8 to 20.1 % MVDs from *I. dekanum* across both ratios.

In conclusion, we consider the well-developed movable finger lobe seen in adult *I. dekanum*, unprecedented in genera *Iurus* and *Protoiurus* (with the sole exception of *P. kadleci*), as the major diagnostic character separating it from *I. dufoureius* where lobe in the female is quite weak (Fig. 41). The morphometric ratio differences are the second most important criterion distinguishing these two species. And in all cases, including the pectinal tooth counts, the Kythira population is closer to *I. dufoureius*, thus giving us a reason for assigning it to this species (again, however, based on only two specimens from Kythira).

Protoiurus rhodiensis Soleglad, Fet, Kovařík et Yağmur, sp. nov.
(Figs. 44–63, 65–67; Tables 7–8)

REFERENCES:
Iurus granulatus: Thorell, 1877: 193 (in part).
Iurus gibbosus (nec *Buthus gibbosus* Brullé, 1832; misidentification): Pavesi, 1878: 360 (in part).
Jurus dufourejus (incorrect subsequent spelling): Birula, 1903: 297 (in part).
Iurus dufoureius: Borelli, 1913: 2 (in part); Caporiacco, 1928: 240; Werner, 1936b: 17; Menozzi, 1941: 234 (in part); Caporiacco, 1948: 27; Gruber, 1963: 308 (in part); Gruber, 1966: 424; Kinzelbach, 1975: 21 (in part); Kinzelbach, 1982: 58 (in part); Kinzelbach, 1985: map IV (in part); Fet, 2000: 49 (in part); Stathi & Mylonas, 2001: 290 (in part); Kovařík & Whitman, 2005: 113; Soleglad et al., 2009: 2 (in part).

Jurus (incorrect subsequent spelling) *dufoureius*: Werner, 1934a: 162 (in part); Werner, 1938: 172 (in part); Vachon, 1953: 96 (in part).
Iurus asiaticus: Francke, 1981: 221 (in part); Vachon & Kinzelbach, 1987: 99, 102, fig. 6 (in part); Crucitti, 1995a: 2, fig. 1 (in part); Crucitti & Malori, 1998: 133 (in part).
Iurus dufoureius asiaticus: Kritscher, 1993: 383 (in part); Sissom & Fet, 2000: 419 (in part); Parmakelis et al., 2006: 253 (in part); Facheris, 2007a: 1–2 (in part); Facheris, 2007b: 1–2 (in part).
Iurus sp.: Fet, 2010: 8; Kovařík et al., 2010: 4–5, 189, figs. 49, 94, 102, 103

Note. Francke (1981: 222) suggested that, since Thorell (1877: 193–195) placed under *Iurus granulatus* a female from Greece as well as a male from Rhodes, this makes *Buthus granulatus* C. L. Koch, 1837 an available senior synonym of *Iurus asiaticus* Birula, 1903 (now *Protoiurus*). This is, however, incorrect, since Koch's original name was clearly given to a Peloponnese population. Therefore *Buthus granulatus* C. L. Koch, 1837 is a junior synonym of *Iurus dufoureius* (Brullé, 1832), as synonymized by Karsch (1879); the Rhodes specimen of Thorell is not name-bearing.

Type material: Holotype ♂ **Greece**, Rhodes Island, W. of Kolymbia, 36°15'50.5"N, 28°05'39.0"E, 107 m a.s.l., 14–19.VI.2010, leg. F. Kovařík (FKCP); paratypes, same as holotype, 1 ♂ 7 ♀ 1 im. ♀ (FKCP).

Diagnosis. Medium sized species, 85 mm. Orange-brown carapace and mesosoma, legs, metasoma, and pedipalps lighter orange to yellow, pedipalp carinae dark reddish-brown, distinctly contrasted with palm. Pectinal tooth counts average for genus, 10–14 (11.28) males, 8–12 (9.48) females. Chelal movable finger lobe in adult males located on basal half, lobe ratio 0.44–0.49; a subtle weak proximal gap on fixed finger present in adult males; movable finger of adult males essentially straight, not highly curved; number of inner denticles (*ID*) of chelal movable finger, 12–14 (13); hemispermatophore type *1a*.

Distribution. **Greece**: Rhodes Island. See map in Fig. 17 and *Material Studied* section above.

Etymology. The new species is named after its area of provenance and endemism, the Rhodes Island.

MALE. The following description is based on holotype male from Kolymbia, Rhodes Island, Greece. Measurements of the holotype plus five other specimens are presented in Table 7. See Figure 44 for a dorsal and ventral view of the male holotype.

Figure 44: *Protoiurus rhodiensis*, **sp. nov.**, male holotype, Kolymbia, Rhodes Island, Greece. Dorsal and ventral views.

COLORATION. Basic color of carapace and mesosoma orange-brown; femur and patella of pedipalp, metasoma and telson light orange; chela dark orange and legs yellow; cheliceral fingers and distal aspect of palm brown, proximal aspect of palm yellowish; pedipalp carinae reddish-brown distinctly contrasted with palm; metasomal carinae light orange; sternites orange-brown; genital operculum, basal piece and pectines yellow-tan. Eyes and tubercles black, leg condyles and aculeus tip dark brown. Carapace median area darkish brown,
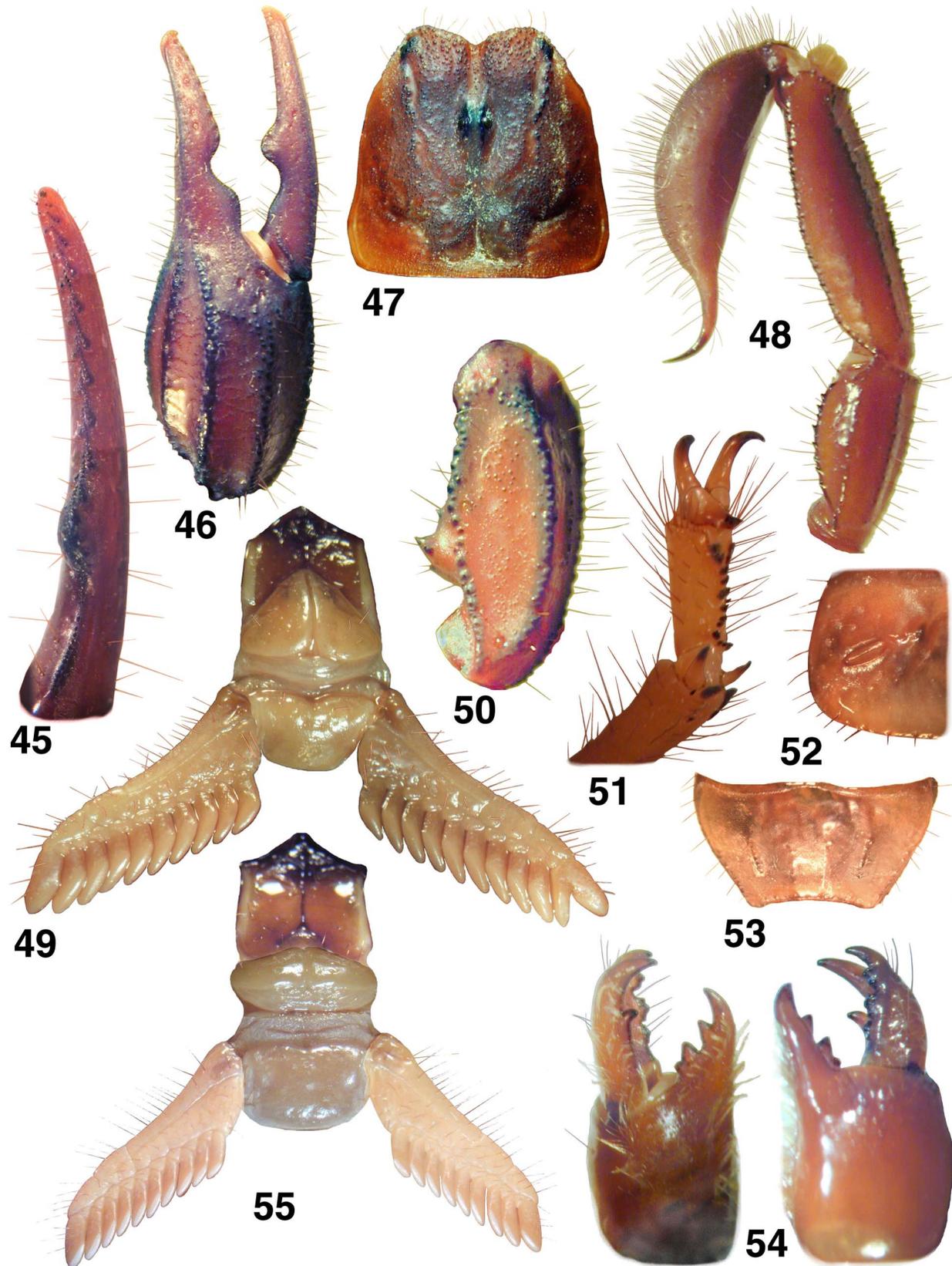
Figures 45–55: *Protoiurus rhodiensis*, **sp. nov.,** Kolymbia, Rhodes Island, Greece. **45–54** Male paratype. **55.** Female paratype. **45.** Chelal movable finger dentition. **46.** Chela, lateral view. **47.** Carapace. **48.** Metasomal segments IV–V and telson, lateral view. **49.** Sternopectinal area. **50.** Patella, dorsal view. **51.** Right leg III tarsus, lateroventral view. **52.** Right stigma III. **53.** Sternite VII. **54.** Chelicera, ventral and dorsal views. **55.** Sternopectinal area.

mediolateral ocular carinae dark brown, lateral edges yellow.

CARAPACE (Fig. 47). Anterior edge with a conspicuous median indentation, approximately 12 irregularly placed setae visible; entire surface densely covered with small to medium granules. 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: 0.393 (anterior edge to medium tubercle middle / carapace length) and 0.149 (width of median tubercle including eyes / width of carapace at that point).

MESOSOMA (Figs. 52–53). Tergites I–VII rough in appearance, posterior half densely populated with minute granules; tergite VII surface covered with granules, lateral carinae granulated, median carinae only visible basally. Sternites III–VII smooth and lustrous; VII with crenulated lateral carinae and smooth to crenulated median carinae (Fig. 53). Stigmata (Fig. 52) are medium in size and slit-like in shape, angled 45° in an anterointernal direction.

METASOMA (Fig. 48). Segment I wider than long. Segments I–IV: dorsal and dorsolateral carinae serrated; dorsal carinae with 11/10, 8/8, 11/11, and 9/9 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, irregularly present on posterior one-third of II; obsolete on segments III–IV; ventrolateral carinae smooth to granulated on I and granulated on II–IV; ventromedian carinae smooth to granulated on I–II, and granulated on III–IV. Dorsolateral carinae of segment IV terminate at articulation condyle. Segment V: dorsolateral carinae serrated; lateral carinae irregularly granulated for two-thirds of posterior aspect; ventrolateral and single ventromedian carinae serrated; ventromedian carina not bifurcated, terminating in straight line. Anal arch with 15 small serrated granules. Intercarinal areas of segments I–V essentially smooth. Segments I–V with numerous long setae on ventral, lateral and dorsal aspects.

TELSON (Fig. 48). Vesicle elongated, with highly curved aculeus. Vesicle essentially void of granules; ventral surface densely covered with elongated curved setae; dorsal surface irregularly scattered with short to medium length setae; base of aculeus with setation ventrally and dorsally. Vesicular tabs smooth.

PECTINES (Fig. 49, Fig. 55, paratype female). Well-developed segments exhibiting length / width ratio 2.325 (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 11/10 (note: distal two teeth of left pecten are fused basally, intervening fulcrum missing). 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 0.625.

GENITAL OPERCULUM (Fig. 49). 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. 49). Type 2, posterior emargination present, well-defined convex lateral lobes, apex visible but not conspicuous; anterior portion of genital operculum situated proximally between lateral lobes; sclerite length and width the same; sclerite slightly tapers anteriorly, posterior-width / anterior-width ratio 1.051 (see discussion on female below).

CHELICERAE (Fig. 54). Movable finger dorsal edge with one large subdistal (*sd*) denticle; ventral edge with one large pigmented accessory denticle at finger midpoint; 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. 45, 46, 56). Well-developed chelae, with short fingers, heavily carinated, conspicuous scalloping on chelal fingers: well-developed lobe on movable finger, positioned proximal of midpoint in ratio 0.49; proximal gap weak, subtly present on fixed finger. **Femur:** Dorsointernal, dorsoexternal and ventrointernal carinae serrated, ventroexternal rounded and granulated. Dorsal and ventral surfaces with minute granules medially, internal surface with 15 serrated granules and external surface smooth. **Patella:** Dorsointernal and ventrointernal carinae serrated, dorsoexternal and ventroexternal crenulated, and exteromedian carina strong and crenulated, a second carina found medially with ten granules. Dorsal and ventral surfaces with minute granules medially; external surface with serrated exteromedian carina; internal surface smooth with well-developed, doubled DPS and VPS. **Chelal carinae:** Complies with the "8-carinae configuration". Digital (*D1*) carina strong, lustrous, and granulated; dorsosecondary (*D3*) granulated in low profile; dorsomarginal (*D4*) rounded, heavily granulated; dorsointernal (*D5*) weak with medially placed serrated granules; ventro-
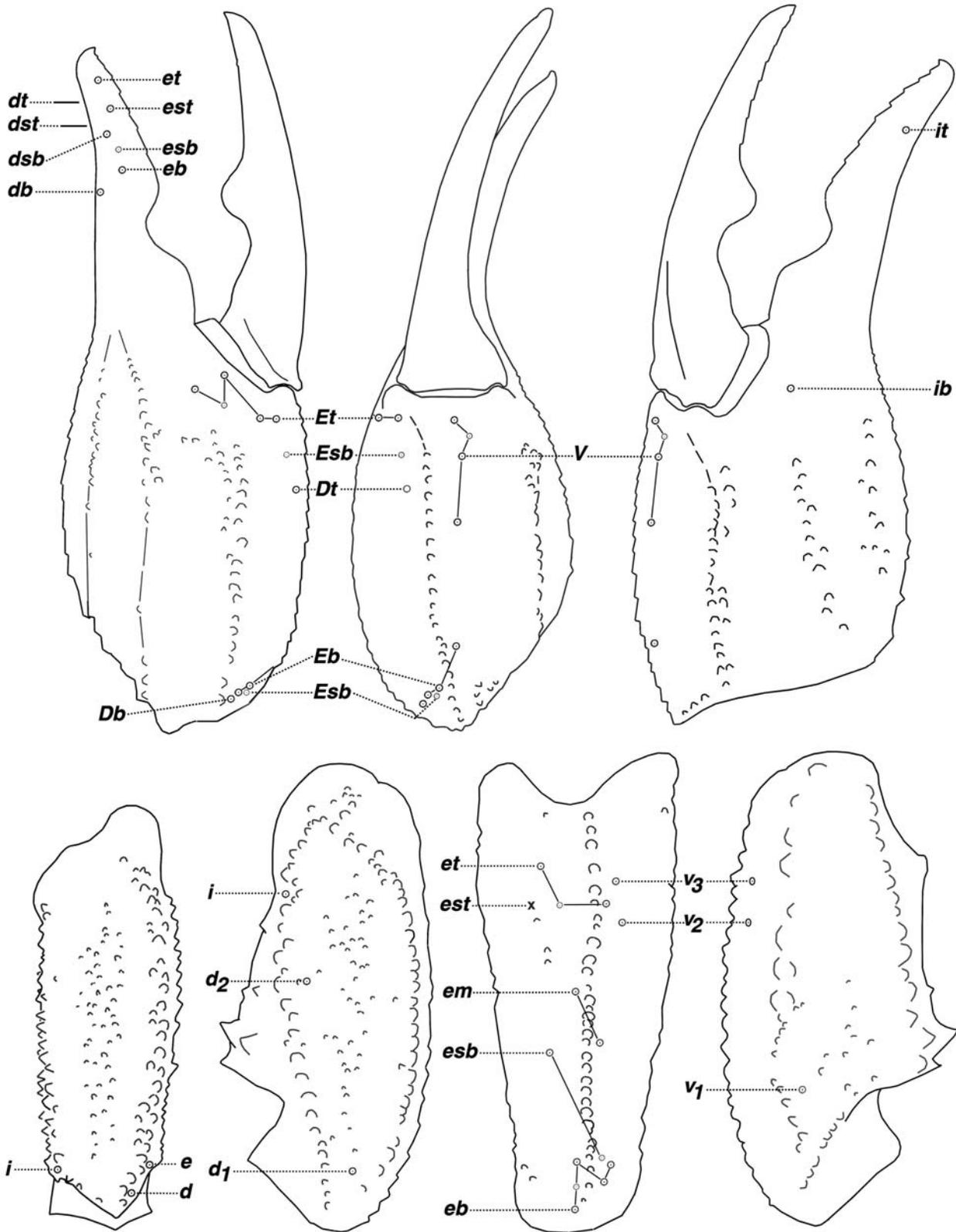
Figure 56: *Protoiurus rhodiensis*, **sp. nov.,** male holotype, Kolymbia, Rhodes Island, Greece. Trichobothrial pattern. Note, patellar trichobothrium *est* is missing on the right patella but a depression is present that marks its presumed position (x).
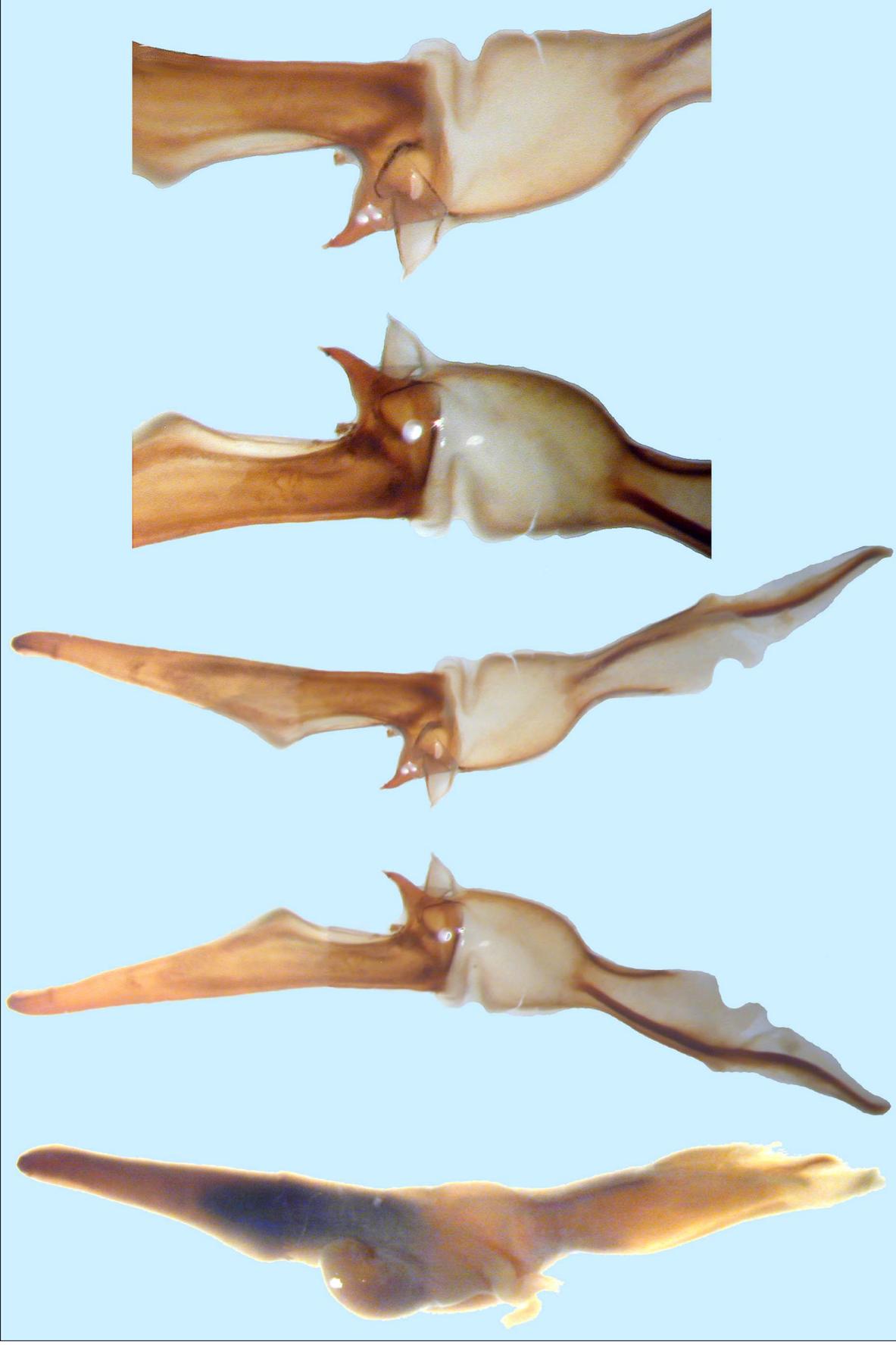
Figuer 57: Hemispermatophore (submerged in alcohol) of *Protoiurus rhodiensis*, **sp. nov.**, male holotype, Kolymbia, Rhodes Island, Greece. **Left.** Ventral view of right hemispermatophore still encased in membraneous sack with attached paraxial organ seminal vesicle. **Middle.** Right hemispermatophore, dorsal and ventral views. **Right.** Closeup of the median area, dorsal, and ventral views, showing the well developed internal nodule, acuminate process with truncated terminus, seminal receptacle, and paraxial organ sleeve (the latter two fully in view on ventral side).

		Protoiurus rhodiensis				
		Kolymbia, Rhodes Island, Greece				Agphios Isidoros, Rhodes Island, Greece	Rhodes Island, Greece (ZMB)
	Male Holotype	Male Paratype	Female Paratype	Female Paratype	Female	Male
Total length	78.30	74.15	84.95	79.60	83.05	72.80
Carapace length	11.00	10.60	12.00	10.90	12.95	10.70
Mesosoma length	25.40	22.85	31.50	30.50	25.40	22.85
Metasoma length	29.90	28.95	29.45	27.30	31.55	27.80
Segment I length/width	3.95/4.80	3.85/4.20	4.00/4.55	3.55/4.30	4.30/4.90	3.65/4.25
Segment II length/width	4.55/4.30	4.55/3.90	4.55/4.25	4.10/3.95	4.85/4.45	4.30/3.85
Segment III length/width	5.15/4.00	4.85/3.70	4.95/3.90	4.65/3.65	5.15/4.10	4.75/3.60
Segment IV length/width	6.10/3.45	5.90/3.30	5.95/3.55	5.65/3.35	6.35/3.70	5.60/3.25
Segment V length/width	10.15/3.40	9.80/3.15	10.00/3.45	9.35/3.15	10.90/3.55	9.50/3.00
Telson length	12.00	11.75	12.00	10.90 ***	13.15	11.45
Vesicle length	8.65	8.30	8.40	8.10	9.20	8.00
width/depth	3.80/3.25	3.55/2.90	3.65/3.15	3.45/3.00	4.00/3.35	3.45/3.10
Aculeus length	3.35	3.45	3.60	2.80 ***	3.95	3.45
Pedipalp length	41.55	40.75	43.75	41.45	47.55	40.37
Femur length/width	10.35/3.55	9.95/3.45	10.80/4.00	10.45/3.65	12.15/4.45	10.25/3.35
Patella length/width*	10.15/3.25	9.95/3.15	10.80/3.35	10.05/3.15	11.25/3.55	9.80/3.85
DPS height**	1.70	1.60	1.60	1.60	1.40	1.20
Chela length	21.05	20.85	22.15	20.95	24.15	20.32
Palm length	10.90	9.80	10.90	9.95	11.85	10.00
width/depth	6.70/8.10	6.10/7.45	6.25/7.65	5.85/7.00	7.00/8.40	5.60/7.35
Fixed finger length	9.60	9.70	9.70	9.55	10.90	9.90
Movable finger length	12.50	12.15	12.95	11.85	13.95	11.10
Sternum length/width	2.60/2.60	2.80/2.60	3.25/3.20	3.00/2.75	3.25/3.00	2.15/2.35
Pectines teeth	11-10	11-11	9-10	8-9	9-x	11-11
middle lamellae	5-5	4+-4+	2-2	2-3	2+-x	1-1++

Table 7: Morphometrics (mm) of *Protoiurus rhodiensis*, **sp. nov**. * Patella width is widest distance between the dorsointernal and externomedial carinae. ** DPS height is from tip of spines to dorsointernal carina centered. *** Aculeus tip broken, length extrapolated.

external (*V1*) strong and serrated, terminating at external condyle of movable finger; ventrointernal (*V3*) rounded, lustrous, and granulated, continuous to internal condyle; external (*E*) strong, serrated; internal (*I*) irregularly serrated. **Chelal finger dentition (Fig. 45):** Median denticle (*MD*) row groups oblique and highly imbricated, 11 on the fixed finger (to gap) and 13 on movable finger; 11/11 *ID*s to socket beginning on fixed finger and 13/13 *ID*s on movable finger; 9/10 *OD*s on fixed finger (to gap) and 13/13 *OD*s on movable finger. No accessory denticles present. **Trichobothrial patterns (Fig. 56):** Type C, orthobothriotaxic.

LEGS (Fig. 51). Both pedal spurs present on all legs, lacking spinelets; tibial spurs absent. Tarsus with conspicuous spinule clusters in single row on ventral surface (numbering 8-7-9-8 for legs I–IV, respectively),

terminating distally with a pair of enlarged spinule clusters. Unguicular spine (dactyl) well-developed and pointed. Basitarsus with external and internal rows of spinule clusters as follows: 20/7 - 14/3 - 4/3 - 3/3 for legs I–IV, respectively

HEMISPERMATOPHORE (Fig. 57). Hemispermatophore is type *1a*: Distal lamina is tapered and pointed; 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: lamina length / trunk length = 0.966–0.981 (0.974) and lamina distal length / lamina basal length = 1.699–1.710 (1.705). Hemispermatophore length of holotype male is 11.77 mm.
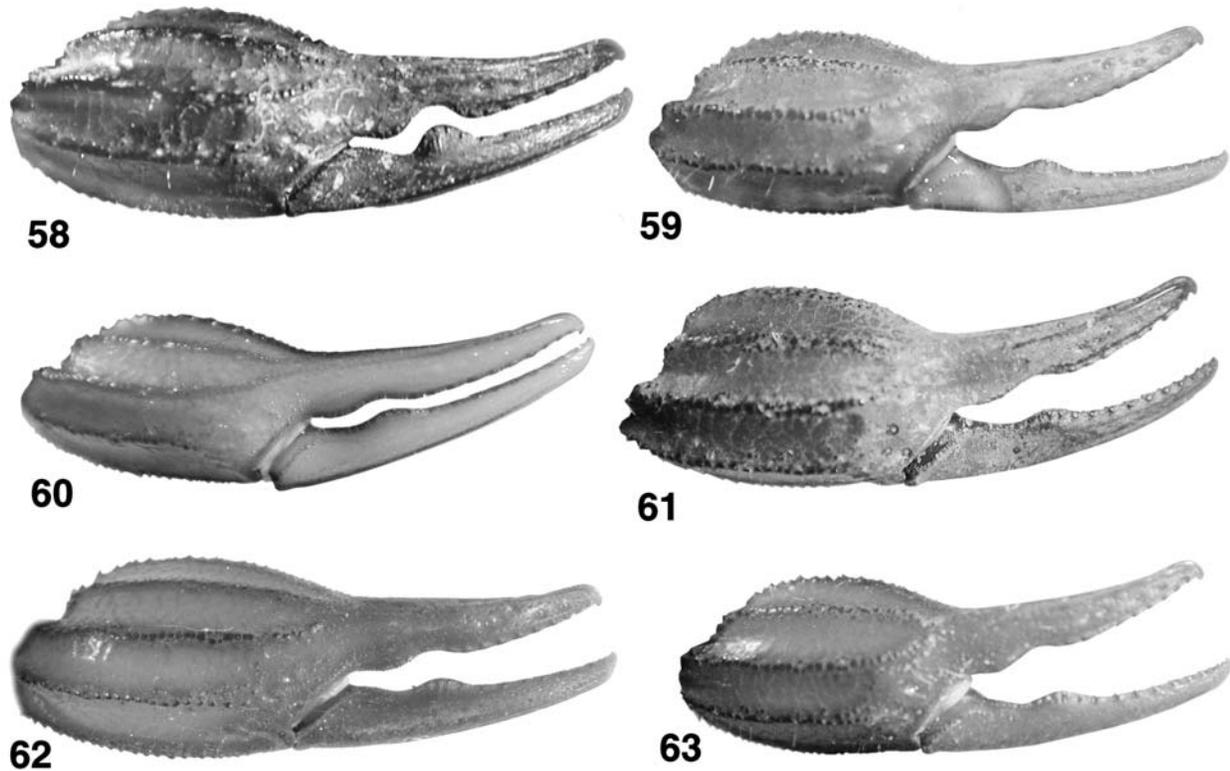
Figures 58–63: *Protoiurus rhodiensis*, **sp. nov.**, chela, lateral view. **58.** Adult male paratype (carapace length = 10.60 mm), Kolymbia, Rhodes Island, Greece. **59.** Subadult male (carapace length = 10.05 mm), Aghios Isidoros, Rhodes Island, Greece. **60.** Subadult male (carapace length = 9.70 mm), Lindos, Rhodes Island, Greece. **61.** Adult female (carapace length = 12.95 mm), Agphios Isidoros, Rhodes Island, Greece. **62.** Adult female paratype, Kolymbia, Rhodes Island, Greece. **63.** Subadult female paratype (carapace length = 9.95 mm), Kolymbia, Rhodes Island, Greece.

Male and female variability (Figs. 58–64). As seen in Figures 58–63, the adult female does not exhibit a proximal gap and the movable finger lobe is not as developed as in the male. In sexually mature males, a slight proximal gap is visible. The position of the lobe is slightly more basal on the female for comparable development stages, carapace length length/MF lobe ratio only showing a 4.9 % difference (see Fig. 64). There is no significant sexual dimorphism in morphometrics. Though the male has a slightly thinner metasoma, the MVDs (L/W) only ranged from 0.6 to 4.5 %. Pectinal tooth counts in males exceed those of females by approximately 1.8 teeth, male 10–14 (11.28) [32], female 8–12 (9.48) [44] (see histograms in Fig. 5). The genital operculum of the male is dramatically different from that in the female (Figs. 49, 55). 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 44, 65–67 show dorsal and ventral views of both male and female specimens, the map of distribution for this species, live specimens, and photographs of its type locality.

Discussion

Protoiurus rhodiensis, which is isolated on the island of Rhodes, appears to be the most closely related to *P. stathiae* from the island of Karpathos and less so to *P. asiaticus* from central Turkey. The hemispermatophore (type 1a) of these three species are identical in all aspects, based on 15 samples (see Table 1). *P. kadleci*, whose hemispermatophore is also type *1a*, is quite different from *P. rhodiensis* with its very thin metasoma and exaggerated movable finger lobe configuration. *P. rhodiensis* is the only species in *Protoiurus* whose movable finger lobe is basal of the finger midpoint on both male and female adults. The movable finger lobe ratio for adults whose carapace lengths are 10 mm or greater range 0.396–0.487 [5] for males (carapace 10.05–11.00) and 0.380–0.446 [10] for females (carapace 10.05–12.95). In comparison, *P. stathiae* ranges 0.453–0.532 [5] for males (carapace 10.25–11.1) and

Figure 64: Comparison of movable finger lobe *signatures* for species *Protoiurus stathiae* **sp. nov.** (black, 20 samples) and *P. rhodiensis* **sp. nov.** (grey, 32 samples). Note the lobe is more distal (as also shown by the smaller carapace length / lobe ratio values) and the proximal gap more pronounced in *P. stathiae*. The lines depict linear fit by least squares regression. Lobe ratio = distance from external condyle to lobe center / movable finger length. Squares = males, triangles = females.

Statistical Comparisons of *Protoiurus rhodiensis*, *P. stathiae*, and *P. asiaticus*		
Carapace Length/ MF_Lobe Ratio	MVD 2.7%, 8.9% 6.1% ♂ *P. rhodiensis* (23.433)[12] > *P. asiaticus* (22.815)[10] > *P. stathiae* (21.509)[6]	
	MVD 2.3%, 8.8% 6.4% ♀ *P. rhodiensis* (24.583)[20] > *P. asiaticus* (24.036)[10] > *P. stathiae* (22.600)[14]	
Pectinal Tooth Counts	MVD 3.5%, 14.6% 10.8% ♂ *P. rhodiensis* (11.28)[32] < *P. asiaticus* (11.67)[18] < *P. stathiae* (12.93)[14]	
	MVD 10.8%, 16.4% 5.0% ♀ *P. rhodiensis* (9.48)[44] < *P. asiaticus* (10.50)[22] < *P. stathiae* (11.03)[32]	
MF_L/Palm_W	MVD 17.3%, 20.5% 2.7% ♂ *P. asiaticus* (2.283)[3] > *P. rhodiensis* (1.947)[3] > *P. stathiae* (1.895)[3]	
	MVD 18.3%, 22.5% 3.6% ♀ *P. asiaticus* (2.401)[3] > *P. rhodiensis* (2.030)[3] > *P. stathiae* (1.960)[3]	
FF_L/Palm_W	MVD 12.3%, 24.8% 11.2% ♂ *P. asiaticus* (1.793)[3] > *P. rhodiensis* (1.597)[3] > *P. stathiae* (1.437)[3]	
	MVD 14.6%, 17.8% 2.8% ♀ *P. asiaticus* (1.811)[3] > *P. rhodiensis* (1.581)[3] > *P. stathiae* (1.537)[3]	
Chela_L/Palm_W	MVD 14.8%, 30.3% 13.6% ♂ *P. asiaticus* (3.898)[3] > *P. rhodiensis* (3.396)[3] > *P. stathiae* (2.991)[3]	
	MVD 8.2%, 19.5% 10.4% ♀ *P. asiaticus* (3.813)[3] > *P. rhodiensis* (3.525)[3] > *P. stathiae* (3.192)[3]	
Chela_L/Palm_D	MVD 0%, 25.1% 25.1% ♂ *P. asiaticus* (3.006)[3] > *P. rhodiensis* (3.005)[3] > *P. stathiae* (2.403)[3]	
	MVD 4.8%, 9.4% 14.6% ♀ *P. asiaticus* (3.060)[3] > *P. rhodiensis* (2.921)[3] > *P. stathiae* (2.669)[3]	
Metasomal Segments I–V (L/W)	♂ *P. rhodiensis* > *P. stathiae*: MVD 8.2–11.8 %	
	♀ *P. rhodiensis* > *P. stathiae*: MVD 5.6–13.7 %	

Table 8: Diagnostic differences between *Protoiurus rhodiensis*, **sp. nov.**, *P. stathiae*, and *P. asiaticus*. (Mean) [number of samples]. MVD = mean value difference. Refer to Figs. 5 and 64 for more information.

0.467–0.487 [7] for females (carapace 10.8–12.65). Consistent with the basal movable finger lobe, the proximal gap found in sexually mature *P. rhodiensis* males is the least developed in *Protoiurus*, only visible on the largest males. In *P. stathiae*, the gap is much more prominent: see comparisons in composite signatures of these two species in Fig. 64. Finally, the normalized lobe ratios between these two species, involving 52 samples, shows *P. rhodiensis* with the largest ratio, thus implying a more basal lobe (see Fig. 64). *P. rhodiensis* along with *P. kadleci* have the lowest pectinal tooth counts in *Protoiurus* (see Fig. 5). With respect to *P. stathiae*, who has the highest number of pectinal teeth in the subfamily along with *P. kraepelini*, we see considerable statistical differences between it and *P. rhodiensis*, 14 to 16 % MVD.

Table 8 summarizes statistical comparisons of *P. rhodiensis*, *P. stathiae*, and *P. asiaticus* for the data discussed above as well as prominent morphometric differences. These data present important morphometric differences between the three species as stated in the key to *Protoiurus*. In Table 8 the morphometric ratio analysis is broken into two groups, ratios that distinguish *P. asiaticus* from the other two island species, and ratios that distinguish *P. rhodiensis* from *P. stathiae*. *P. asiaticus* has relatively longer chelal fingers as compared to the two island species. Therefore, ratios that compare the finger lengths to the chelal width demonstrate significant ratio differences as presented in Table 8, 17 to 23 % MVD differences for the movable finger (including both genders) and 12 to 25 % MVD differences for the fixed finger. Incidentally, the two ratios

Figure 65: *Protoiurus rhodiensis*, **sp. nov.**, female paratype, Kolymbia, Rhodes Island, Greece. Dorsal and ventral views.

between *P. asiaticus* and the two island species exhibit standard error separation. Three morphometric ratio sets demonstrate significance statistical differences between *P. rhodiensis* and *P. stathiae*, the chelal length as compared to its width and depth and the proportions of the five metasomal segments. Though both species have somewhat stocky pedipalp chelae, it is more robust in *P. stathiae*. The MVD differences for both ratios range from 14 to 25 % for males and 10 to 15 % for females.

Again, for both ratios we have standard error separation. *P. stathiae* has the most robust metasoma in the entire subfamily, even more stocky than that seen in *P. kraepelini*. The metasoma in *P. rhodiensis* is also somewhat robust, but not as exaggerated as seen in *P. stathiae*. All metasomal segments of *P. rhodiensis* are more slender than in *P. stathiae* (i.e., length compared to width), exhibiting a 8.2–11.8 % and 5.6–13.7 % MVD for male and female, respectively.
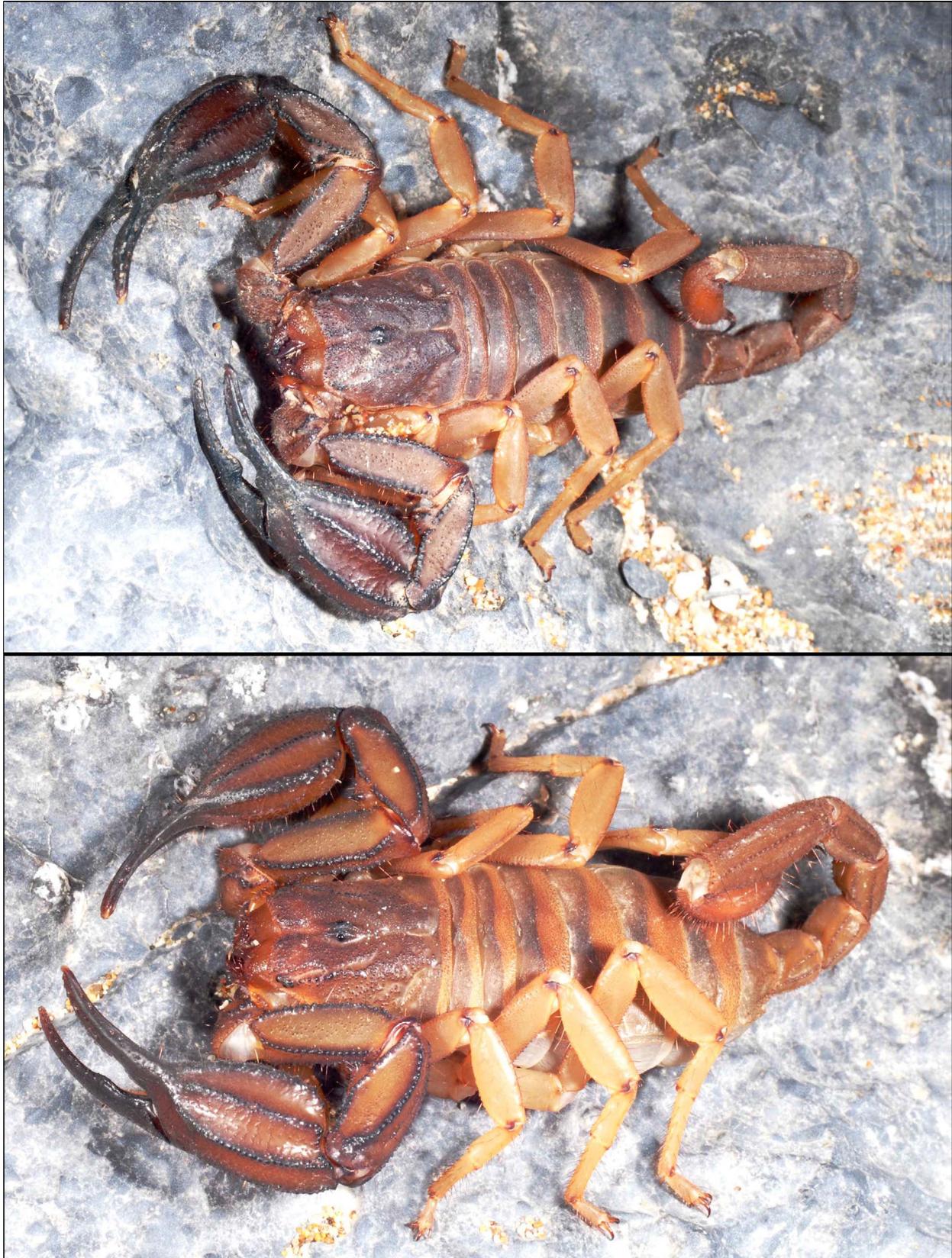
Figure 66: Photographs of live adult *Protoiurus rhodiensis*, **sp. nov.**, Kolymbia, Rhodes Island, Greece. Male (top) and female (bottom).

Figure 67: Collection locality of *Protoiurus rhodiensis*, **sp. nov.**, Kolymbia, Rhodes Island, Greece.

***Protoiurus stathiae* Soleglad, Fet, Kovařík, et Yağmur, sp. nov.**
(Figs. 68–88; Table 9)

REFERENCES:
Iurus dufoureius: Werner, 1936b: 17; Menozzi, 1941: 234 (in part); Kinzelbach, 1966: 12; Kinzelbach, 1975: 21 (in part); Kinzelbach, 1982: 58 (in part); Kinzelbach, 1985: map IV (in part); Fet, 2000: 49 (in part?; Kasos); Stathi & Mylonas, 2001: 290 (in part); Soleglad et al., 2009: 2 (in part).
Jurus (incorrect subsequent spelling) *dufoureius*: Werner, 1938: 172 (in part); Vachon, 1948: 62 (in part); Vachon, 1953: 96 (in part).
Iurus asiaticus: Francke, 1981: 221 (in part); Vachon & Kinzelbach, 1987: 99, 102, fig. 6 (in part); Crucitti, 1995a: 2, fig. 1 (in part); Crucitti & Malori, 1998: 133 (in part).
Iurus dufoureius asiaticus: Kritscher, 1993: 382–383 (in part); Sissom & Fet, 2000: 419 (in part); Parmakelis et al., 2006: 253 (in part); Facheris, 2007a: 1–2 (in part); Facheris, 2007b: 1–2 (in part).
Iurus sp.: Fet, 2010: 8; Kovařík et al., 2010: 4–5, 189, figs. 48, 95.

Type material: Holotype ♂ **Greece**, Karpathos, Karpathos Town, forest in SE (35.50 ºN, 27.2333 ºE), 10 April 1978, leg. E. Kritscher (NHMW 15928); paratypes, same label as holotype, 3 ♂ 3 ♀ (NHMW 15928).

Diagnosis. Medium sized species, 75–85 mm. Orange-brown carapace and mesosoma, legs, metasoma, and pedipalps lighter orange to yellow, pedipalp carinae dark reddish-brown, distinctly contrasted with palm. Pectinal tooth counts large for genus, 11–15 (12.93) in males, 10–14 (11.03) in females. Chelal movable finger lobe in adult males located on distal half, lobe ratio 0.52–0.53; a well-developed proximal gap on fixed finger present in adult males; movable finger of adult males essentially straight, not highly curved; number of inner denticles (*ID*) of chelal movable finger, 13–14 (13.4); hemispermatophore type *1a*. Dominant morphometrics refer to chelal movable and fixed finger lengths.

Distribution. **Greece**: Karpathos Island; ?Kasos Island, ?Saria Island. See map in Fig. 17 and *Material Studied* section above.

Etymology. We are honored to name this new species after our wonderful colleague, the Greek scorpiologist Dr. Iasmi Stathi (Natural History Museum of Crete, University of Crete, Heraklion, Crete, Greece).

Figure 68: *Protoiurus stathiae*, **sp. nov.**, male holotype, Karpathos Town, Karpathos Island, Greece. Dorsal and ventral views.

MALE. The following description is based on holotype male from Karpathos Town, Karpathos Island, Greece. Measurements of the holotype plus five other specimens are presented in Table 9. See Figure 68 for a dorsal and ventral view of the male holotype.

COLORATION. Basic color of carapace and mesosoma orange-brown; femur and patella of pedipalp, metasoma and telson light orange; chela dark orange and legs yellow; pedipalp carinae reddish-brown; metasomal carinae light orange; sternites brown; genital operculum, basal piece and pectines yellow-tan. Eyes and tubercles black, leg condyles and aculeus tip dark brown.

CARAPACE (Fig. 71). Anterior edge with a conspicuous median indentation, approximately eleven irregularly placed setae visible; entire surface densely covered with small to medium granules, the largest occurring between the lateral eyes. 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, postion-
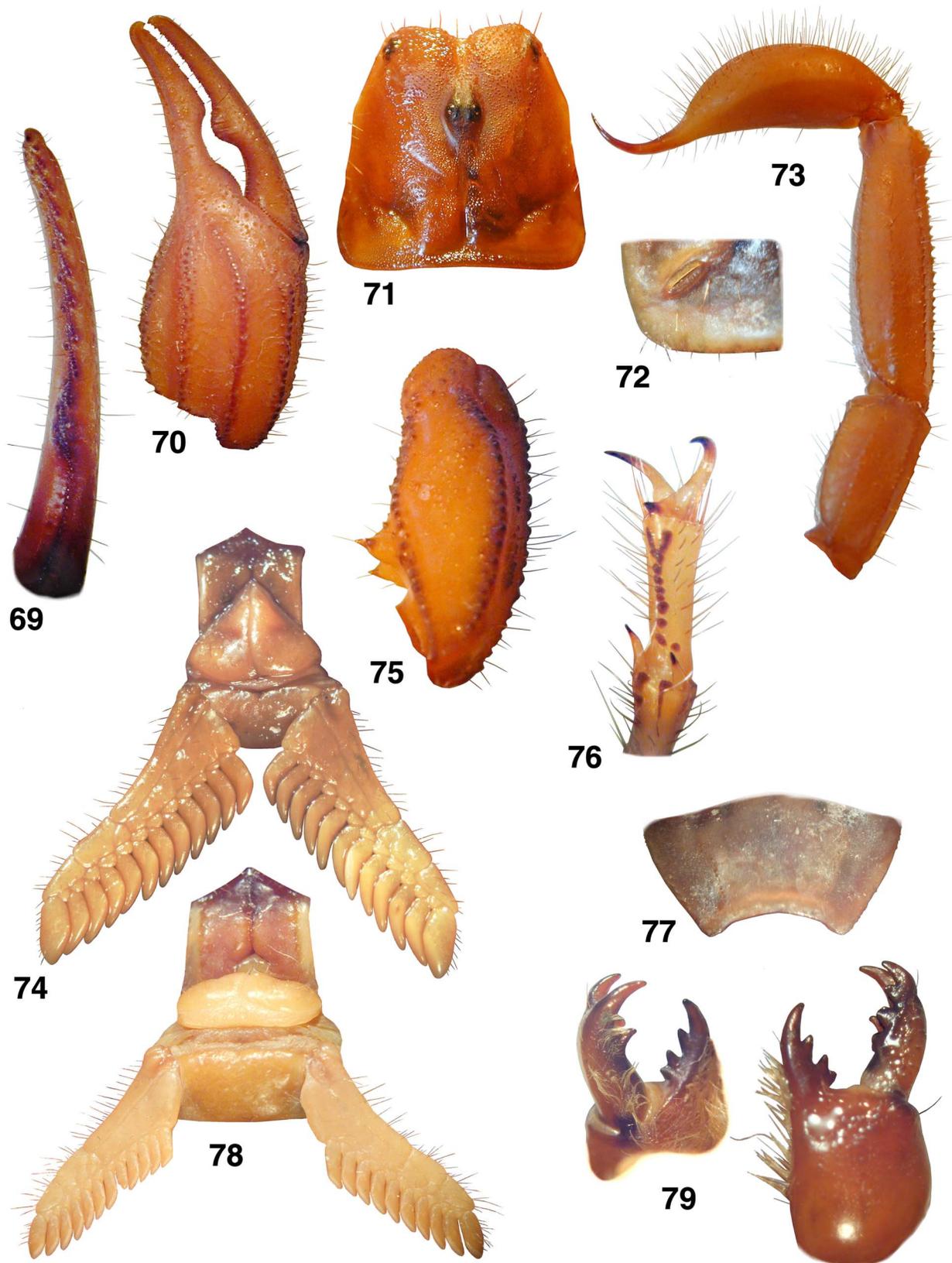
Figures 69–79: *Protoiurus stathiae*, **sp. nov**., Karpathos Town, Karpathos Island, Greece. **69–77.** Male holotype. **78–79.** Female. **69.** Chelal movable finger dentition. **70.** Chela, lateral view. **71.** Carapace. **72.** Right stigma III. **73.** Metasomal segments IV–V and telson, lateral view. **74.** Sternopectinal area. **75.** Patella, dorsal view. **76.** Left leg IV tarsus, lateroventral view. **77.** Sternite VII. **78.** Sternopectinal area. **79.** Chelicera, ventral and dorsal views.
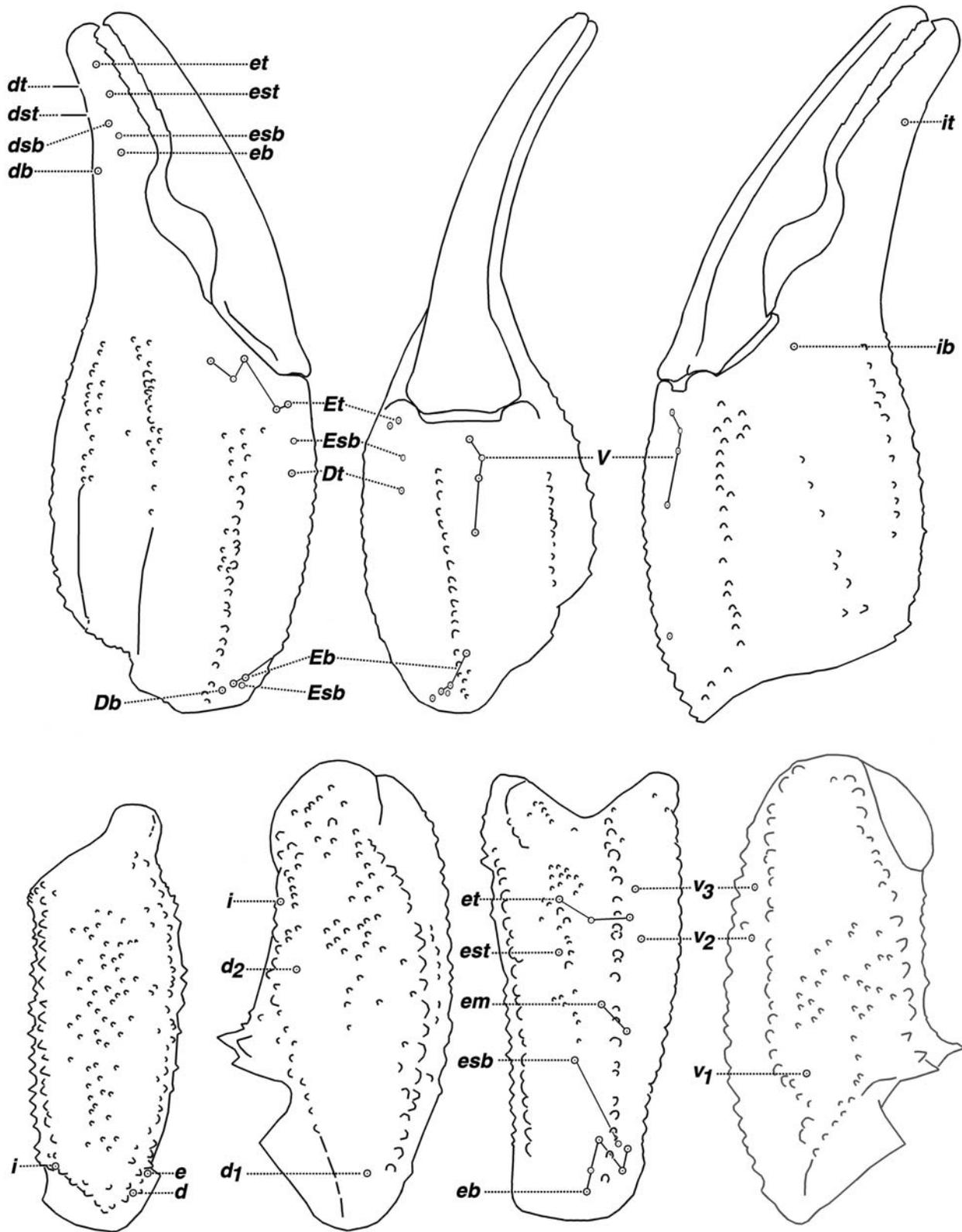
Figure 80: *Protoiurus stathiae*, **sp. nov.,** male holotype, Karpathos Town, Karpathos Island, Greece. Trichobothrial pattern.
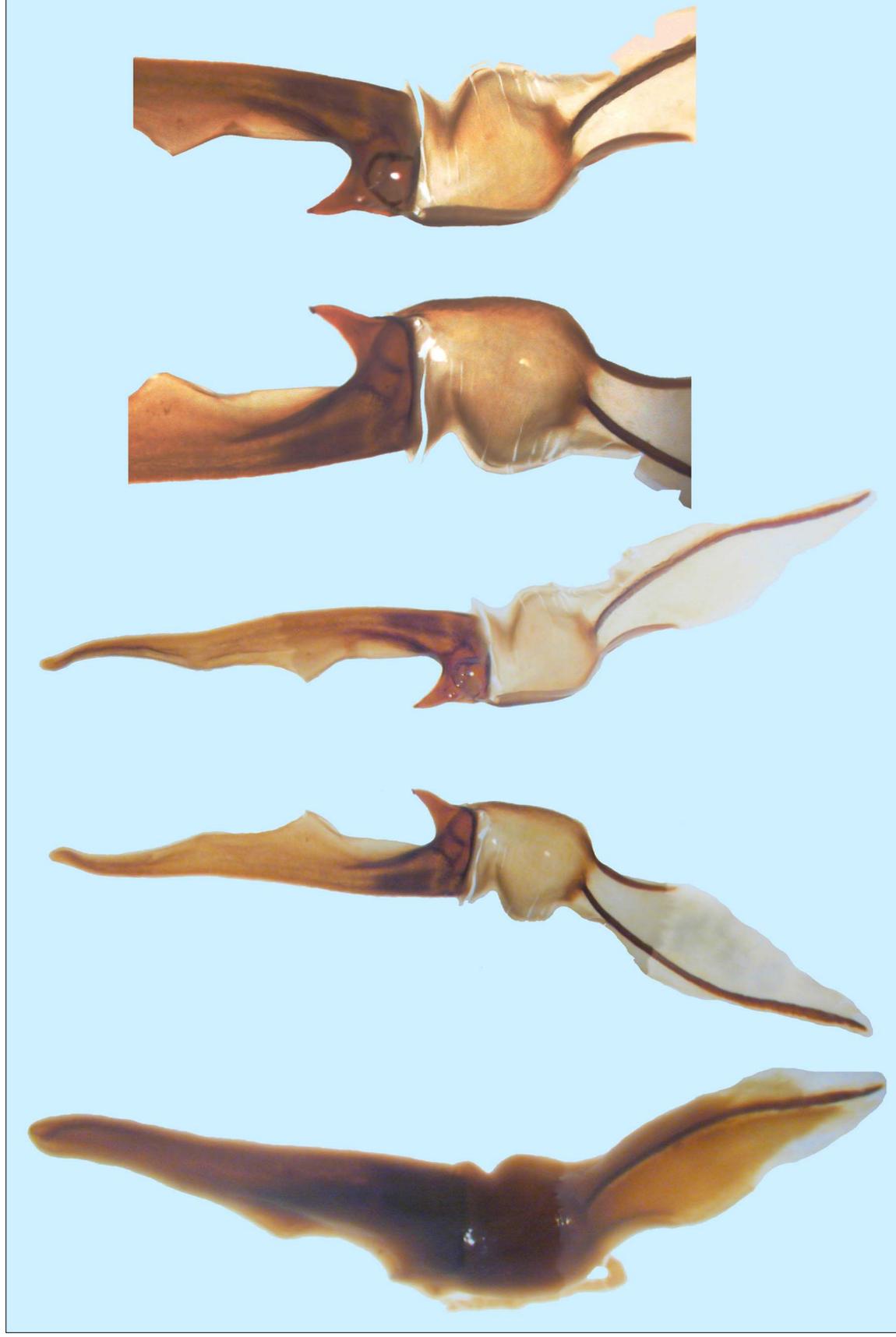
Figure 81: Left hemispermatophore (reversed, submerged in alcohol) of *Protoiurus stathiae*, **sp. nov.**, male paratype, Karpathos Town, Karpathos Island, Greece. **Left.** Ventral view, showing hemispermatophore still encased in membraneous sack with attached paraxial organ seminal vesicle and severed *vas deferens*. **Middle.** Dorsal and ventral views. **Right.** Closeup of the median area, dorsal, and ventral views, showing the well developed internal nodule, accuminate process with truncated terminus, and seminal receptacle.

	Protoiurus stathiae					
	Karpathos Town, Karpathos Island, Greece					Mt. Kiryaki, Karpathos Island, Greece
	Male Holotype	Male Paratype	Male Paratype	Female Paratype	Female Paratype	Female
Total length	69.35	73.55	70.55	78.60	82.80	75.90
Carapace length	11.10	10.60	11.10	12.65	12.20	11.35
Mesosoma length	16.50	23.90	21.60	22.85	30.50	27.95
Metasoma length	29.60	27.60	26.75	30.35	27.95	26.00
Segment I length/width	3.90/4.85	3.65/4.65	3.65/4.75	4.05/5.20	3.55/4.85	3.50/4.60
Segment II length/width	4.55/4.35	4.25/4.15	4.10/4.25	4.75/4.70	4.20/4.30	4.00/4.10
Segment III length/width	4.90/4.10	4.55/3.85	4.45/3.95	5.05/4.35	4.65/3.85	4.30/3.80
Segment IV length/width	6.00/3.65	5.55/3.35	5.30/3.50	6.05/3.90	5.60/3.50	5.30/3.40
Segment V length/width	10.25/3.50	9.60/3.25	9.25/3.45	10.45/3.85	9.95/3.35	8.90/3.20
Telson length	12.15	11.45	11.10	12.75	12.15	10.60
Vesicle length	8.50	8.10	8.10	8.75	8.65	7.10
width/depth	4.00/3.25	3.80/3.15	-/-	4.00/3.25	3.85/3.20	3.30/2.70
Aculeus length	3.65	3.35	3.00	4.00	3.50	3.50
Pedipalp length	41.15	40.45	38.65	45.80	44.15	39.95
Femur length/width	10.60/3.70	10.00/3.55	9.60/3.65	11.25/4.20	11.10/4.05	10.45/4.10
Patella length/width*	10.25/3.75	9.95/3.80	9.35/3.90	10.40/4.55	10.45/4.05	9.95/4.10
DPS height**	1.50	1.35	1.40	1.35	1.40	1.30
Chela length	20.30	20.50	19.70	24.15	22.60	19.55
Palm length	10.45	10.05	9.30	11.35	10.80	10.05
width/depth	6.85/8.30	6.50/8.25	6.90/8.65	7.50/8.85	6.75/8.20	6.50/7.75
Fixed finger length	10.05	9.95	9.05	11.10	10.80	9.95
Movable finger length	13.50	12.75	12.10	14.25	14.05	12.35
Sternum Length/width	2.60/2.65	-/-	2.60/2.50	3.50/2.80	3.25/2.90	3.25/2.55
Pectines teeth	12-12	14-14	11-12	10-10	11-11	10-10
middle lamellae	5-5	5-6	5-5	3+-4	3+-2+	4-4

Table 9: Morphometrics (mm) of *Protoiurus stathiae*, **sp. nov**. * Patella width is widest distance between the dorsointernal and externomedial carinae. ** DPS height is from tip of spines to dorsointernal carina centered.

ed anterior of middle with the following length and width ratios: 0.354 (anterior edge to medium tubercle middle / carapace length) and 0.169 (width of median tubercle including eyes / width of carapace at that point).

MESOSOMA (Figs. 72, 77). Tergites I–VII rough in appearance; tergite VII lateral and median carinae irregularly crenulated. Sternites III–VII smooth and lustrous; VII with crenulated lateral carinae and smooth median carinae (Fig. 77). Stigmata (Fig. 72) are medium in size and slit-like in shape, angled 45° in an anterointernal direction.

METASOMA (Fig. 73). Segment I wider than long. Segments I–IV: dorsal carinae crenulated on I–II, serrated on III–IV; dorsolateral carinae crenulated; dorsal carinae with 11/8, 12/11, 11/10, and 12/10 spines (left/right carina); dorsal (I–IV) and dorsolateral (I–III)

carinae do not terminate with an enlarged spine; lateral carinae irregularly granulated on I, granulated on posterior one-third of II; obsolete on segments III–IV; ventrolateral carinae smooth on I, irregularly granulated on II, and crenulated on III–IV; ventromedian carinae smooth on I–II, irregularly granulated on III, and crenulated on IV. Dorsolateral carinae of segment IV terminate at articulation condyle. Segment V: dorsolateral carinae serrated; lateral carinae irregularly granulated for two-thirds of posterior aspect; ventrolateral and single ventromedian carinae serrated; ventromedian carina not bifurcated, terminating in straight line. Anal arch with 14 small serrated granules. Intercarinal areas of segments I–V essentially smooth with scattered granulation on ventral surface of segment V. Segments I–V with scattered setae on ventral, lateral and dorsal aspects, heaviest on segment V.
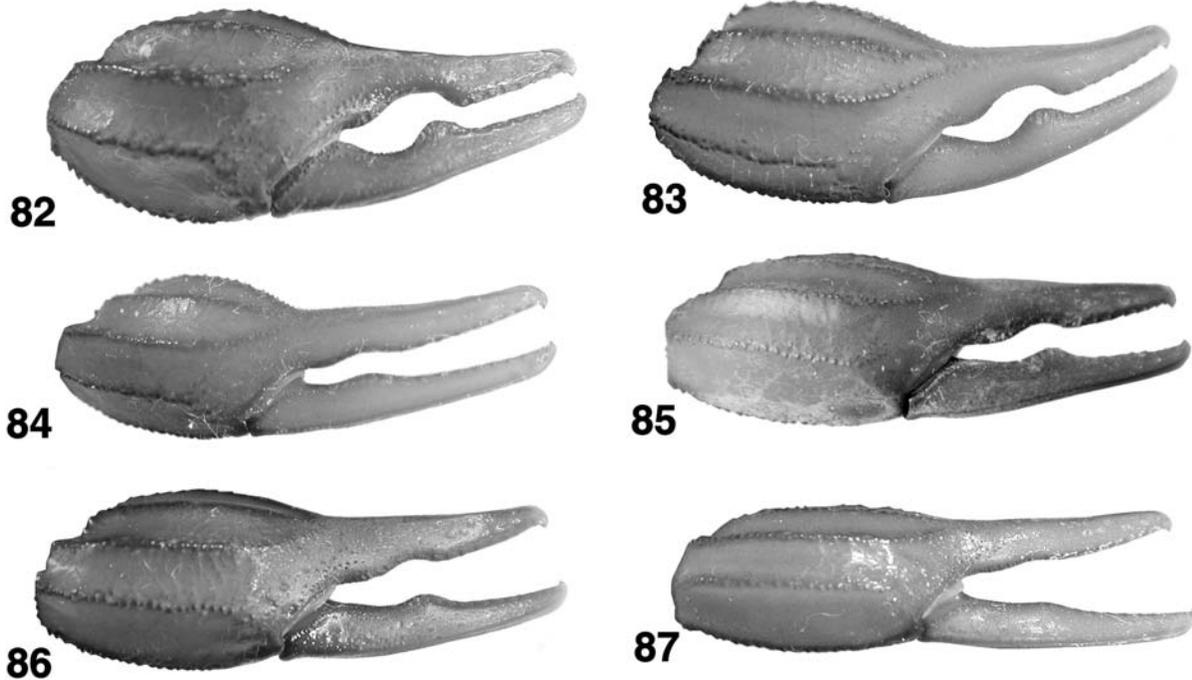
Figures 82–87: *Protoiurus stathiae*, **sp. nov.**, chela, lateral view. **82.** Adult male paratype (carapace length = 11.10 mm), Karpathos Town, Karpathos, Greece. **83.** Adult male paratype (carapace length = 10.60 mm), Karpathos Town, Karpathos, Greece. **84.** Subadult male (carapace length = 8.80 mm), Karpathos Town, Karpathos, Greece. **85.** Adult female paratype (carapace length = 12.65 mm), Karpathos Town, Karpathos, Greece. **86.** Adult female, Mt. Kiryaki, Karpathos, Greece (carapace length = 11.35 mm). **87.** Subadult female (carapace length = 8.30 mm), Karpathos Town, Karpathos, Greece.

TELSON (Fig. 73). Vesicle elongated, with highly curved aculeus. Vesicle essentially void of granules; ventral surface densely covered with elongated curved setae; dorsal surface irregularly scattered with short to medium length setae; base of aculeus with setation ventrally and dorsally. Vesicular tabs with 5–6 small pointed spines.

PECTINES (Fig. 74, Fig. 78, paratype female). Well-developed segments exhibiting length / width ratio 2.297 (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 12/12. 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 0.495.

GENITAL OPERCULUM (Fig. 74). Sclerites triangular, longer than wide, separated for entire length. Genital papillae present but hidden behind sclerites (see discussion on female below).

STERNUM (Fig. 74). Type 2, posterior emargination present, well-defined convex lateral lobes, apex visible but not conspicuous; anterior portion of genital oper-

culum situated proximally between lateral lobes; sclerite length and width approximately the same.

CHELICERAE (Fig. 79, paratype female). Movable finger dorsal edge with one large subdistal (*sd*) denticle; ventral edge with one large pigmented accessory denticle at finger midpoint; 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. 69, 70, 80). Well-developed chelae, with short fingers, heavily carinated, conspicuous scalloping on chelal fingers: well-developed lobe on movable finger, positioned distal of midpoint in ratio 0.52; proximal gap well-developed on fixed finger. **Femur:** Dorsointernal, dorsoexternal and ventrointernal carinae serrated, ventroexternal irregularly granulated. Dorsal surface covered with minute granules and ventral surface with granules medially, internal surface with line of 20 granules and external surface with line of 16 granules. **Patella:** Dorsointernal and ventrointernal carinae serrated, dorsoexternal and ventroexternal crenulated, and exteromedian carina strong and serrated, a second carina found medially irregularly granulated. Dorsal and ventral surfaces with minute granules med-

Figure 88: *Protoiurus stathiae*, **sp. nov.**, female paratype, Karpathos Town, Karpathos, Greece. Dorsal and ventral views.

ially; external surface with serrated exteromedian carina; internal surface smooth with well-developed, doubled DPS and VPS. **Chelal carinae:** Complies with the "8-carinae configuration". Digital (*D1*) carina strong, lustrous, and closely granulated; dorsosecondary (*D3*) irregularly granulated, connected to *D1* laterally with granules; dorsomarginal (*D4*) rounded, heavily granulated; dorsointernal (*D5*) weak with medially placed serrated granules; ventroexternal (*V1*) strong and crenulated; ventrointernal (*V3*) rounded and granulated, continuous to internal condyle; external (*E*) strong, crenulated; internal (*I*) rounded, irregularly serrated. **Chelal finger dentition (Fig. 69):** Median denticle (*MD*) row groups oblique and highly imbricated, 11/11 on the fixed finger (to gap) and 13/14 on movable finger; 10/10 *ID*s to socket beginning on fixed finger and 13/13 *ID*s on movable finger; 9/9 *OD*s on fixed finger

(to gap) and 12/13 *OD*s on movable finger. No accessory denticles present. **Trichobothrial patterns (Fig. 80):** Type C, orthobothriotaxic.

LEGS (Fig. 76). Both pedal spurs present on all legs, lacking spinelets; tibial spurs absent. Tarsus with conspicuous spinule clusters in single row on ventral surface (numbering 7-7-8-9 for legs I–IV, respectively), terminating distally with a pair of enlarged spinule clusters. Unguicular spine (dactyl) well-developed and pointed. Basitarsus with external and internal rows of spinule clusters as follows: 16/8 - 12/3 - 3/2 - 2/3 for legs I–IV, respectively

HEMISPERMATOPHORE (Fig. 81). Hemispermatophore is type *1a*: Distal lamina is tapered and pointed; internal nodule is conspicuously developed and pointed; trans-

verse trunk bolsters are absent; acuminate process terminus is truncated. Specific ratio values for this species are the following based on two specimens: lamina length / trunk length = 0.965–1.037 (1.001) and lamina distal length / lamina basal length = 1.471–1.558 (1.515). Hemispermatophore length of holotype male is 10.795mm.

Male and female variability (Figs. 82–87). As seen in Figures 82–87, the adult female does not exhibit a proximal gap and the movable finger lobe is not as developed as in the male. In sexually mature males, a sizable proximal gap is visible. The position of the lobe is slightly more basal on the female for comparable developmental stages, carapace length / MF lobe ratio only showing a 5.1 % difference (see Fig. 64). For adult comparisons, the female lobe is slightly proximal of midpoint whereas the male is distal, as shown in the following ranges, 0.474–0.487 (0.481) [5] for the female, and 0.516–0.532 (0.523) [3] for the male. There is no significant sexual dimorphism in morphometrics. Though the male has a slightly thinner metasoma, the MVDs (L/W) only ranged from 0.1 to 3.8 %. The chelal length as compared to its width and depth, we see 6.7 % and 11.1 % difference, respectively. Pectinal tooth counts in males exceed those of females by approximately 1.9 teeth, male 11–15 (12.93) [14], female 10–14 (11.03) [14] (see histograms in Fig. 5). The genital operculum of the male is dramatically different from that in the female (Figs. 74, 78). 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 68 and 88 show dorsal and ventral views of both male and female specimens.

Discussion

Protoiurus stathiae is most closely related to *P. rhodiensis* and *P. asiaticus* than to the other two species of *Protoiurus*. This is discussed in detailed under the *P. rhodiensis* discussion where these three species are contrasted (also see Table 8). *P. stathiae* and *P. rhodiensis* can be separated by their pectinal tooth counts, with *P. stathiae* having the higher number exhibiting 14.6 % and 16.4 % MVD for males and females, respectively. The chelae are more robust in *P. stathiae*, the chelal length when compared to its width and depth demonstrated 10.4 % to 25.1 % MVD across the two genders. Finally, the metasomal segments are more stocky in *P. stathiae* than in *P. rhodiensis* exhibiting

8.2–11.8 % MVD and 5.6–13.7 % MVD for males and females, respectively.

Parmakelis et al. (2006), considered the population from Rhodes to be more distant from the Megisti and Alanya populations (i.e., *P. kraepelini*) than the population from Karpathos, a Greek island further removed from the Turkey mainland than Rhodes. This was demonstrated in their DNA study being supported by genetic distance as well as by phylogenetic analysis. The result, on the surface, seems counterintuitive due to the incongruities in biogeography, also discussed in detail by Parmakelis et al. (2006). They proposed that the speciation occurred when the Aegean-Anatolian area was a solid landmass, thus not being dictated by later island/mainland connections. In our cladistic analysis, based solely on the hemispermatophore morphology, these two island species, along with *P. kadleci* and *P. asiaticus*, group together showing separation from *P. kraepelini*, which exhibits a different subtype. However, when considering the other species-level characters such as movable finger lobe morphology, number of inner denticles (*ID*), pectinal tooth counts, i.e. structures not considered in the cladistic analysis, we see a stronger affinity of *P. stathiae* to *P. kraepelini* than to *P. rhodiensis*. As discussed under *P. rhodiensis*, both these island species show stronger separation from the eastern species *P. asiaticus*, based primarily on morphometric considerations. In addition, the slenderness of *P. kadleci* and its exaggerated movable finger lobe configuration make it quite distinct and easily separable from *P. stathiae*. Besides the difference in hemispermatophore morphology (two different subtypes), *P. kraepelini* has very exaggerated chelae in adult males, being highly vaulted and a strongly curved movable finger. Other low-level characters between these two species, however, show similarities: the pectinal tooth counts are the highest found in the subfamily, slightly larger than that exhibited in *P. asiaticus*; and the metasomal segments I–IV of adult males are the stockiest in the subfamily.

Biogeographic Notes

Our recent revisionary work (Kovařík et al., 2010, and the present paper) has expanded the former "monotypic species *Iurus dufoureius*" into two genera and eight species. At the same time, our phylogenetic interpretation of these taxa largely agrees with a pilot DNA analysis by Parmakelis et al. (2006). We demonstrate now a distinct separation into two genera, *Iurus* and *Protoiurus*, which follow exactly western and eastern clades first identified by Parmakelis et al. (2006) who addressed these clades as two traditional "subspecies of *I. dufoureius*" (i.e., *I. dufoureius dufoureius* and *I. d. asiaticus*) but noted their more ancient origin than suggested by former authors (Vachon, 1953;

Francke & Soleglad, 1981). Geographic ranges of these two clades follow a common vicariant pattern for the Aegean-Anatolian area, described in a number of phylogenetic studies (see e.g. Poulakakis et al., 2003, 2005; Poulakakis & Sfenthourakis, 2007). Such separation is believed to be due to the formation of the Mid-Aegean Trench (east of Crete and west of Kasos–Karpathos), a major geological feature that, in Miocene, has sundered this region into western and eastern parts. Formation of this trench 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). Our two genera of subfamily Iurinae correspond exactly to this vicariant event, and therefore it is likely that their common ancestor had existed in this area before the trench formation. Range of our new genus *Protoiurus* (Karpathos, Rhodes, and Anatolia), which we consider a more basal taxon, lies entirely eastward from the Mid-Aegean Trench. A more derived *Iurus*, however, is not limited to Peloponnese, Kithyra and Crete but also includes *I. kinzelbachi* from Samos and western Anatolia. The third, most basal genus of Iuridae, *Calchas* Birula, 1899, is found currently only in Anatolia (and its coastal islands of Samos and Megisti). All three existing iurid genera could be seen as derived from the ancient stock that populated the united Agäis landmass in Lower to Middle Miocene (23–12 Mya). The reader should consult Parmakelis et al. (2006) for more detailed relevant biogeographic information and literature references for the Aegean-Anatolian area.

Acknowledgments

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Appendix A
Cladistic Character Definitions and Data Matrix

This appendix presents the cladistic characters which model the hemispermatophore structure of genera *Protoiurus* and *Iurus*. Two *Calchas* species represent the outgroup. The character state data matrix is provided at the end. "-" = inapplicable.

Character-1: Internal protuberance
   0: present
   1: absent

Character-2: Acuminate process terminus.
   0: truncated
   1: rounded

Character-3: Acuminate process/dorsal trough angle (ordered, tree)
   0: ≥ 80 degrees
   1: > 60 degrees
   2: < 40 degrees

Character-4: Internal nodule shape
   0: weakly developed, pointed
   1: conspicuously developed, pointed
   2: widely rounded
   3: conspicuously developed, knob-like
   4: weak to obsolete

Character-5: Distal lamina
   0: short subparallel
   1: tapered
   2: elongate subparallel

Character-6: Lamina external edge
   0: essentially straight
   1: base and terminus curve externally (state-1)
   2: base and terminus curve externally (state-2)

Character-7: Lamina terminus
   0: truncated
   1: pointed
   2: blunted

Character-8: Trunk bolsters
   0: no bolsters
   1: primary and secondary bolsters present
   2: primary, secondary, and 2-3 transverse bolsters present without delicate interconnecting vertical bolsters
   3: primary, secondary, and 4-6 transverse bolsters present with delicate interconnecting vertical bolsters

Character-9: Truncal flexure
   0: present, modestly developed
   1: present, conspicuously developed

Character-10: Lamina length / trunk length
   0: 0.85 – 1.25
   1: 1.35 – 1.65
   (-):

Character-11: Lamina distal length / lamina basal length
    0: 1.5 – 1.8
    1: 2.2 – 3.1
    2: 3.3 – 5.1
    (-):

Character-12: Seminal receptacle
    0: small, slit-like, close to ventral trough edge
    1: semi-circular, removed from ventral trough edge

Character-13: Trunk
    0: membraneous, non-sclerotized
    1: sclerotized

Character-State Data Matrix

```
                          1 111
Character        1234567890 123
C.nordmanni      000000000- -00
C.birulai        000000000- -00
P.asiaticus      1011101110 011
P.stathiae       1011101110 011
P.rhodiensis     1011101110 011
P.kadleci        1011101110 011
P.kraepelini     1012111110 111
I.kinzelbachi    1124222211 211
I.dufoureius     1023222311 211
I.dekanum        1023222311 211
```

Appendix B
Chelal Movable Finger Lobe "Signatures"

This Appendix presents the movable finger lobe "signature" data for all eight species comprising genera *Iurus* and *Protoiurus*, involving over 270 samples. For each "signature" the plot of the movable finger lobe ratio is correlated to the specimen's carapace length (i.e., an indicator of specimen development). A diagram of the lateral view of the chelal fingers is shown for both the adult male and female indicating the position of the movable finger lobe, the presence/absence of a proximal gap on the fixed finger, and the curvature of the movable finger. Red and green lines depict linear fit by least squares regression for males and females, respectively. The slope of these regression lines is provided, a relative indicator of the rate of movement of the lobe as a specimen matures. Males are represented by rectangular icons, female triangular icons. Lobe ratio = distance from external condyle to lobe center / movable finger length. Note, due to the sparseness of samples, *Protoiurus kadleci* is plotted on the *P. kraepelini* chart.

Iurus dufoureius. Signature based on 25 samples (10 males and 15 females). Also included are male and female from Kythira (red icons). The lobe in adults is located on the proximal half of the movable finger, there is no proximal gap on the fixed finger, and the curvature of the movable finger from the external condyle is slight, 19 – 21 degrees. The movable finger lobe in the adult female is quite weak. The carapace_length / lobe_ratio ratio is one of the largest in the genus, implying statistically it has a basal movable finger lobe.

Iurus dekanum. Signature based on 17 samples (nine males and eight females). The lobe in adults is located on the proximal half of the movable finger, there is no proximal gap on the fixed finger, and the curvature of the movable finger from the external condyle is slight, 18–18.5 degrees. Unusual within the genus, however, is the well developed movable finger lobe in the adult female. The carapace_length / lobe_ratio ratio is the largest in the subfamily, implying statistically the most basal movable finger lobe.

Iurus kinzelbachi. Signature based on 33 samples (13 males and 20 females). Also included are three specimens from Samos Island (red icons). The lobe in adults is located on the proximal half of the movable finger, there is a noticeable proximal gap on the fixed finger of the male, and the curvature of the movable finger from the external condyle is slight, 19–22 degrees. The movable finger lobe in the adult female is quite weak. The carapace_length / lobe_ratio ratio is one of the largest in the genus, implying statistically it has a basal movable finger lobe.

Protoiurus kraepelini. Signature based on 121 samples (56 males and 65 females). The lobe in adults is located on the distal half of the movable finger, there is an exaggerated proximal gap on the fixed finger in adult males, though not present in the female, and the curvature of the movable finger from the external condyle is conspicuous in the male, 31 degrees, and modest in the female, 16 degrees. The carapace_length / lobe_ratio ratio is the smallest in the genus (for the male), implying statistically the most distal movable finger lobe.

Protoiurus kadleci. Signature based on 7 samples (five males and two females). The lobe in adults is located on the distal half of the movable finger, there is an exaggerated proximal gap on the fixed finger in *both* adult males and females, and the curvature of the movable finger from the external condyle is slight, 15–18 degrees. Of particular interest, we see a second movable finger lobe (red arrow) at the base of the finger.

Protoiurus rhodiensis. Signature based on 32 samples (12 males and 20 females). The lobe in adults is located on the proximal half of the movable finger, there is a slight proximal gap on the male fixed finger, and the curvature of the movable finger from the external condyle is slight, 18–19 degrees. Note the weak movable finger lobe in the adult female. The carapace_length / lobe_ratio ratio is somewhat large, implying statistically a basal movable finger lobe.

Protoiurus stathiae. Signature based on 20 samples (six males and 14 females). The lobe in adults is located on the distal half of the movable finger in males and the proximal half in females, there is a medium proximal gap on the male fixed finger, and the curvature of the movable finger from the external condyle is slight, 16–21 degrees. Note the modest movable finger lobe in the adult female. The carapace_length / lobe_ratio ratio is somewhat small, implying statistically a more distal movable finger lobe.

Protoiurus asiaticus. Signature based on 20 samples (10 males and 10 females). The lobe in adults is located on the distal half of the movable finger in males and females, there is a medium proximal gap on the male fixed finger, and the curvature of the movable finger from the external condyle is slight, 16–21 degrees. Note the modest movable finger lobe in the adult female. The carapace_length / lobe_ratio ratio is somewhat small, implying statistically a more distal movable finger lobe.
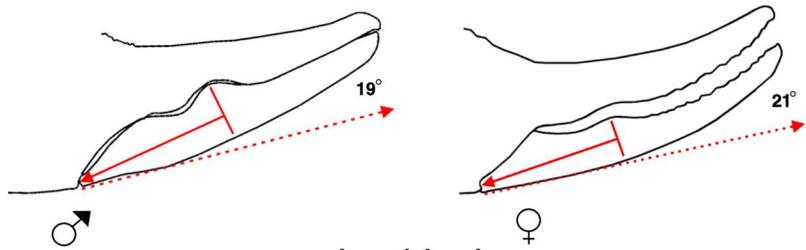
Iurus dufoureius
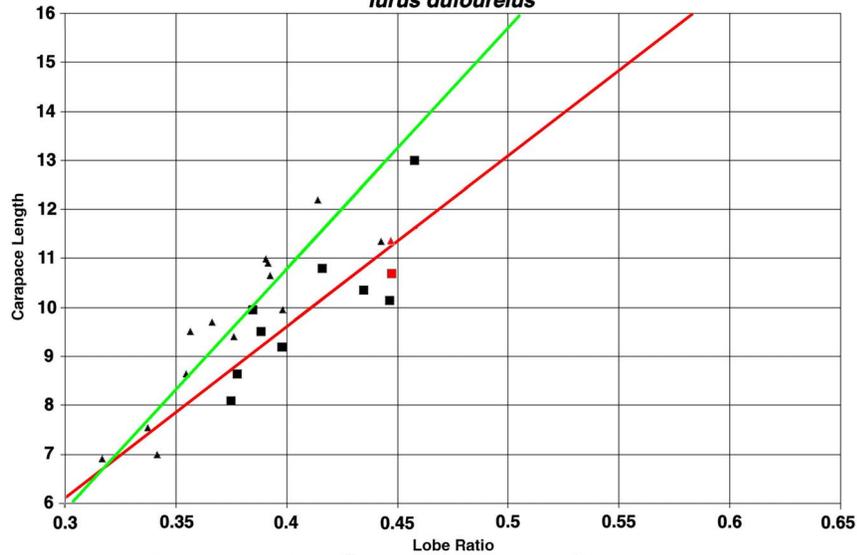
Carapace Length/Lobe Ratio: ♂ 22.290-26.265 (24.278) ♀ 20.390-28.151 (24.270)
Slope of "linear fit": ♂ 35.0 ♀ 49.3
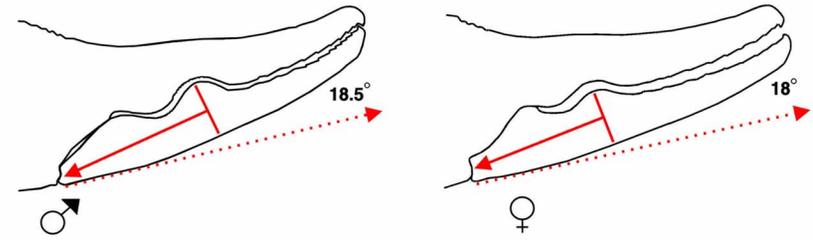
Iurus dekanum
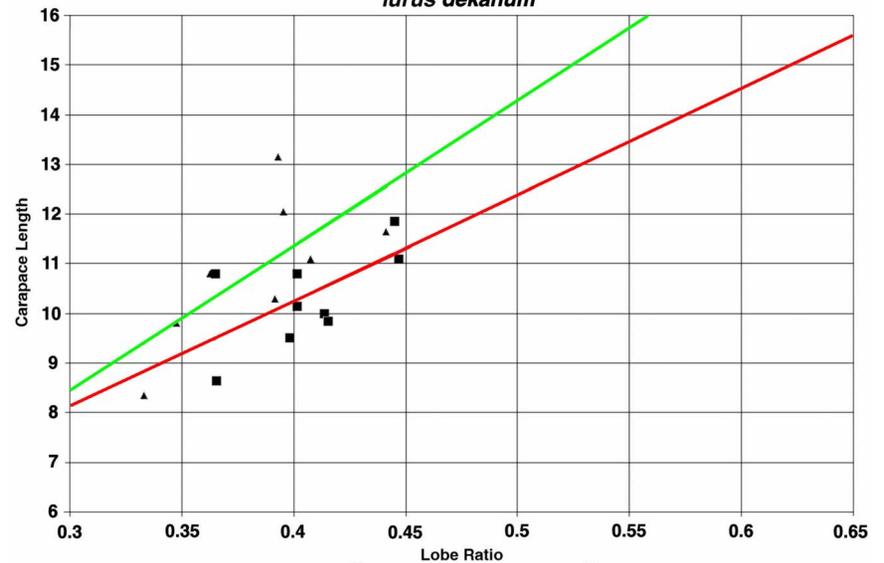
Carapace Length/Lobe Ratio: ♂ 23.607-27.615 (25.401) ♀ 25.617-31.108 (28.362)
Slope of "linear fit": ♂ 21.1 ♀ 29.1

Iurus kinzelbachi

Carapace Length/Lobe Ratio: ♂ 22.089-23.833 (22.961)   ♀ 26.795-29.532 (28.163)
Slope of "linear fit":   ♂ 20.2   ♀ 28.3

Protoiurus kadleci

Protoiurus kraepelini

Carapace Length/Lobe Ratio: ♂ 19.229-23.163 (21.196)   ♀ 21.649-25.324 (23.487)
Slope of "linear fit":   ♂ 17.8   ♀ 38.2

Protoiurus rhodiensis

Carapace Length/Lobe Ratio: ♂ 21.213-25.652 (23.433)   ♀ 21.288-27.877 (24.583)
Slope of "linear fit": ♂ 24.3   ♀ 40.7

Protoiurus stathiae

Carapace Length/Lobe Ratio: ♂ 20.728-22.291 (21.509)   ♀ 20.430-24.770 (22.600)
Slope of "linear fit": ♂ 16.0   ♀ 39.1

Protoiurus asiaticus

Carapace Length/Lobe Ratio: ♂ 21.571-24.060 (22.815)   ♀ 22.377-25.695 (24.036)
Slope of "linear fit":   ♂ 14.9   ♀ 22.9

Appendix C
Morphometric Analysis

    In this study we provide the morphometrics of 24 adult specimens from species *Iurus dufoureius*, *I. dekanum*, *I. kinzelbachi*, *Protoiurus stathiae*, and *P. rhodiensis* (see Tables 4, 5, 7, and 9). This data is comprised of eleven males and thirteen females. These new morphometrics were added to an existing database compiled for the *Iurus* revision presented in Kovařík et al. (2010: appendix C), thus providing a total of 56 sets of measurements representing the eight species of *Iurus* and *Protoiurus*. The morphometrics of the three species described in this paper are compared to each other as well as to the other existing five species for both genders. The approach used in this analysis is discussed in detail in Kovařík et al. (2010: appendix C). We continue comparing all eight species in subfamily Iurinae, even though they span two genera.

    For each species described in this paper, we present two tables: **one**, the summary of major measurements that show dominance (and lack of dominance, which is equally important) in morphometric ratios across the other seven species of *Iurus* and *Protoiurus* where all possible ratios are calculated on a gender basis. In this analysis, the chela, metasoma, and telson are considered, a total of nineteen morphometrics. Each value states the number of ratios the measurement dominated for that species when compared to the other species. Highlighted entries indicate morphometrics used in constructing ratios, *grey* for high dominant and *yellow* for low dominant values. The following abbreviations are used in this table: **st** = *P. stathiae*, **rh** = *P. rhodiensis*, **du** = *I. dufoureius*, **kr** = *P. kraepelini*, **de** = *I. dekanum*, **ki** = *I. kinzelbachi*, **ka** = *P. kadleci*, and **as** = *P. asiaticus*. **ave** = average; **two**, morphometric ratio Mean Value Difference (MVD) percentages are presented of select diagnostic ratios separating the species from the other seven species of *Iurus* and *Protoiurus*.

I. dekanum	Male								Female							
	st	rh	du	kr	ki	ka	as	ave	st	rh	du	kr	ki	ka	as	ave
Chela_W	01	00	12	01	11	21	10	[8.0]	00	01	19	06	16	21	11	[10.6]
Chela_D	00	08	14	00	01	23	00	[6.6]	01	08	25	01	17	20	17	[12.7]
Chela_L	18	15	20	17	06	10	05	[13.0]	12	09	18	14	04	11	04	[10.3]
Palm_L	09	01	23	08	03	22	03	[9.9]	04	00	23	14	04	24	00	[9.6]
MF_L	14	22	18	04	00	08	09	[10.7]	09	15	08	09	00	08	02	[7.3]
FF_L	25	25	25	25	14	12	23	[21.3]	15	23	15	19	00	09	12	[13.3]
MS_I_L	12	04	02	12	06	02	02	[5.7]	18	14	14	18	19	01	15	[14.1]
MS_II_L	16	10	00	17	17	04	13	[11.0]	22	22	03	21	21	01	21	[15.9]
MS_III_L	24	13	03	19	06	03	17	[12.1]	23	20	01	22	19	04	19	[15.4]
MS_IV_L	21	15	01	22	14	05	19	[13.9]	23	17	10	23	22	07	22	[17.7]
MS_V_L	23	20	13	11	10	07	22	[15.1]	19	21	11	12	08	06	23	[15.7]
MS_I_W	05	17	10	13	16	20	18	[14.3]	10	19	02	05	10	21	13	[11.4]
MS_II_W	03	06	06	11	19	18	14	[11.0]	07	09	06	07	08	20	08	[9.3]
MS_III_W	02	05	08	09	20	13	15	[10.3]	08	12	10	08	13	19	13	[11.9]
MS_IV_W	08	14	09	10	22	19	20	[13.1]	06	07	08	03	14	17	10	[9.3]
MS_V_W	04	12	04	20	23	24	21	[15.4]	02	03	00	02	16	15	06	[6.3]
Tel_L	12	04	11	03	03	01	12	[6.6]	13	09	05	04	05	03	15	[7.7]
Tel_W	15	24	20	24	25	25	25	[22.6]	20	24	21	23	25	25	25	[23.3]
Tel_D	18	23	16	17	24	16	24	[19.7]	25	25	21	24	24	22	24	[23.6]

Iurus dekanum (4/3)	Male	Female
Iurus dufoureius (3/3)		
TL/TW	Δ 11.7 %	Δ 11.0 %
TW/5_W	Δ 15.1 %	Δ 16.8 %
Iurus kinzelbachi (3/3)		
TL/TW	Δ 26.9 %	Δ 23.9 %
TL/TD	Δ 16.5 %	Δ 16.5 %
TW/MFL	Δ 30.9 %	Δ 32.4 %
Protoiurus asiaticus (3/3)		
TL/TW	Δ 18.3 %	Δ 16.5 %
TL/TD	Δ 8.3 %	Δ 9.3 %
TW/CD	Δ 27.5 %	Δ 16.4 %
TW/PL	Δ 23.7 %	Δ 26.2 %
Protoiurus kadleci (3/1)		
TL/TW	Δ 50.0 %	Δ 41.8 %
TL/TD	Δ 33.9 %	Δ 28.9 %
Meta (L/W)	Δ 21.1–44.9 %	Δ 13.9–35.0 %
Protoiurus kraepelini (3/4)		
FFL/CD	Δ 47.0 %	Δ 12.3 %
CL/CW	Δ 17.4 %	Δ 7.6 %
CL/CD	Δ 34.3 %	Δ 10.5 %
TL/TW	Δ 17.6 %	Δ 13.9 %
Protoiurus rhodiensis (3/3)		
MFL/PW	Δ 16.6 %	Δ 8.4 %
FFL/PW	Δ 24.4 %	Δ 14.6 %
MFL/PL	Δ 12.7 %	Δ 8.7 %
FFL/PL	Δ 21.5 %	Δ 14.8 %
Protoiurus stathiae (3/3)		
CL/CW	Δ 26.2 %	Δ 16.0 %
CL/CD	Δ 29.2 %	Δ 10.0 %
Meta (L/W)	Δ 4.8–15.5 %	Δ 8.9–18.0 %

Table C1: Morphometric analysis of *Iurus dekanum*. Numbers in parentheses indicate number of males and females used in the calculations, respectively.

Protoiurus rhodiensis	Male								Female							
	de	st	du	kr	ki	ka	as	ave	de	st	du	kr	ki	ka	as	ave
Chela_W	25	01	24	02	24	25	24	[17.9]	23	00	22	17	25	24	24	[19.3]
Chela_D	17	00	17	00	03	23	04	[9.1]	17	01	23	02	20	22	20	[15.0]
Chela_L	10	20	21	17	05	12	03	[12.6]	16	14	16	21	06	12	05	[12.9]
Palm_L	24	21	25	25	16	24	12	[21.0]	25	12	25	25	16	25	07	[19.3]
MF_L	02	03	13	01	00	09	01	[4.1]	09	04	08	04	01	09	01	[5.1]
FF_L	00	12	15	06	01	08	06	[6.9]	02	03	03	09	00	07	00	[3.4]
MS_I_L	21	19	10	24	14	03	08	[14.1]	11	25	11	23	18	01	11	[14.3]
MS_II_L	15	23	01	21	13	02	09	[12.0]	03	18	01	14	11	00	12	[8.4]
MS_III_L	12	25	02	19	06	01	17	[11.7]	05	23	02	15	12	02	10	[9.9]
MS_IV_L	10	24	00	22	09	03	16	[12.0]	07	24	04	18	13	06	19	[13.0]
MS_V_L	05	15	05	02	03	07	14	[7.3]	04	17	06	00	02	04	16	[7.0]
MS_I_W	08	03	06	10	12	20	14	[10.4]	06	02	05	00	04	18	03	[5.4]
MS_II_W	19	06	09	18	19	19	18	[15.4]	15	05	13	05	10	17	07	[10.3]
MS_III_W	20	07	12	19	21	15	23	[16.7]	13	06	14	10	16	20	13	[13.1]
MS_IV_W	11	09	08	12	20	17	19	[13.7]	18	09	15	07	18	18	18	[14.7]
MS_V_W	13	05	03	21	23	22	22	[15.6]	22	07	10	12	23	21	21	[16.6]
Tel_L	21	17	14	05	10	05	20	[13.1]	15	12	12	03	08	05	17	[10.3]
Tel_W	01	03	12	12	25	21	25	[14.1]	01	11	07	11	24	22	25	[14.4]
Tel_D	02	10	07	04	17	12	13	[9.3]	00	18	00	07	14	13	08	[8.6]

Protoiurus rhodiensis (3/3)	Male	Female
Iurus dufoureius (3/3)		
MFL/PL	Δ 16.1 %	Δ 17.6 %
FFL/PL	Δ 14.9 %	Δ 21.0 %
Iurus kinzelbachi (3/3)		
MFL/PW	Δ 26.6 %	Δ 24.0 %
FFL/PW	Δ 24.3 %	Δ 31.0 %
MFL/PL	Δ 18.6 %	Δ 16.2 %
FFL/PL	Δ 16.8 %	Δ 22.7 %
Iurus dekanum (4/3)		
MFL/PW	Δ 16.6 %	Δ 8.4 %
FFL/PW	Δ 24.4 %	Δ 14.6 %
MFL/PL	Δ 12.7 %	Δ 8.7 %
FFL/PL	Δ 21.5 %	Δ 14.8 %
Protoiurus asiaticus (3/3)		
MFL/PW	Δ 17.3 %	Δ 18.3 %
FFL/PW	Δ 12.3 %	Δ 14.6 %
Protoiurus kadleci (3/1)		
MFL/PW	Δ 32.4 %	Δ 31.1 %
FFL/PW	Δ 40.6 %	Δ 37.8 %
MFL/PL	Δ 28.5 %	Δ 33.7 %
FFL/PL	Δ 34.2 %	Δ 40.6 %
Protoiurus kraepelini (3/4)		
MFL/PL	Δ 18.9 %	Δ 16.0 %
CD/PL	Δ 34.2 %	Δ 16.5 %
Protoiurus stathiae (3/3)		
CL/CW	Δ 13.6 %	Δ 10.4 %
CL/CD	Δ 25.1 %	Δ 9.4 %
Meta (L/W)	Δ 8.2–11.8 %	Δ 5.6–13.7 %

Table C2: Morphometric analysis of *Protoiurus rhodiensis* **sp. nov.** Numbers in parentheses indicate number of males and females used in the calculations, respectively.

Protoiurus stathiae	Male								Female							
	de	rh	du	kr	ki	ka	as	ave	de	rh	du	kr	ki	ka	as	ave
Chela_W	24	24	24	20	24	24	25	[23.6]	25	25	25	25	25	25	25	[25.0]
Chela_D	25	25	25	00	22	25	23	[20.7]	24	24	24	17	24	24	24	[23.0]
Chela_L	07	05	14	11	04	10	01	[7.5]	13	10	14	19	10	12	06	[12.0]
Palm_L	15	04	22	17	13	20	10	[14.4]	21	12	23	24	16	23	12	[18.7]
MF_L	11	22	20	03	02	13	12	[11.9]	16	21	15	12	03	10	11	[12.6]
FF_L	00	13	09	06	00	08	03	[5.4]	10	22	10	21	00	08	12	[11.9]
MS_I_L	13	06	05	16	12	02	06	[8.6]	07	00	06	09	13	01	01	[5.3]
MS_II_L	09	02	02	11	10	02	04	[5.7]	03	05	02	05	09	00	06	[4.3]
MS_III_L	01	00	01	05	01	01	06	[2.1]	01	02	00	06	06	02	03	[2.9]
MS_IV_L	02	01	00	10	06	03	08	[4.3]	01	01	03	07	07	05	06	[4.3]
MS_V_L	02	09	04	00	03	07	14	[5.6]	06	08	05	01	01	04	13	[5.4]
MS_I_W	20	22	12	21	15	21	20	[18.7]	15	23	12	08	15	22	16	[15.9]
MS_II_W	22	19	12	22	19	19	19	[18.9]	18	20	19	13	17	19	18	[17.7]
MS_III_W	23	17	18	22	21	16	21	[19.7]	17	19	17	14	18	20	19	[17.7]
MS_IV_W	17	16	10	18	20	18	18	[16.7]	19	16	20	11	19	17	19	[17.3]
MS_V_W	21	20	07	24	23	23	22	[20.0]	23	17	13	15	23	21	21	[19.0]
Tel_L	13	08	07	03	09	04	15	[8.4]	12	11	09	03	10	07	15	[9.6]
Tel_W	10	22	18	25	25	21	24	[20.7]	05	14	07	10	21	18	23	[14.0]
Tel_D	07	15	06	0 9	18	13	17	[12.1]	00	06	01	02	12	12	05	[5.5]

Protoiurus stathiae (3/3)	Male	Female
***Iurus dufoureius* (3/3)**		
CL/CW	Δ 15.6 %	Δ 15.5 %
CL/CD	Δ 19.9 %	Δ 15.1 %
Meta (L/W)	Δ 6.5–18.2 %	Δ 8.3–17.6 %
***Iurus kinzelbachi* (3/3)**		
CL/CW	Δ 28.7 %	Δ 24.1 %
CL/CD	Δ 21.8 %	Δ 18.0 %
Meta (L/W)	Δ 6.9–23.3 %	Δ 3.4–23.3 %
***Iurus dekanum* (4/3)**		
CL/CW	Δ 26.2 %	Δ 16.0 %
CL/CD	Δ 29.2 %	Δ 10.0 %
Meta (L/W)	Δ 4.8–15.5 %	Δ 8.9–18.0 %
***Protoiurus asiaticus* (3/3)**		
CL/CW	Δ 30.3 %	Δ 19.4 %
CL/CD	Δ 25.1 %	Δ 14.7 %
Meta (L/W)	Δ 10.8–14.3 %	Δ 6.6–9.4 %
***Protoiurus kadleci* (3/1)**		
CL/CW	Δ 37.0 %	Δ 31.7 %
CL/CD	Δ 41.6 %	Δ 24.3 %
Meta (L/W)	Δ 33.2–51.8 %	Δ 32.1–47.7 %
***Protoiurus kraepelini* (3/4)**		
CL/CW	Δ 7.4 %	Δ 7.8 %
CL/CD	Δ 3.9 %	Δ 0.5 %
Meta (L/W)	Δ 4.6–16.1	Δ 0.5–12.4 %
TW/CD	Δ 17.0 %	Δ 3.7 %
***Protoiurus rhodiensis* (3/3)**		
CL/CW	Δ 13.6 %	Δ 10.4 %
CL/CD	Δ 25.1 %	Δ 9.4 %
Meta (L/W)	Δ 8.2–11.8 %	Δ 5.6–13.7 %

Table C3: Morphometric analysis of *Protoiurus stathiae*, **sp. nov.** Numbers in parentheses indicate number of males and females used in the calculations, respectively.