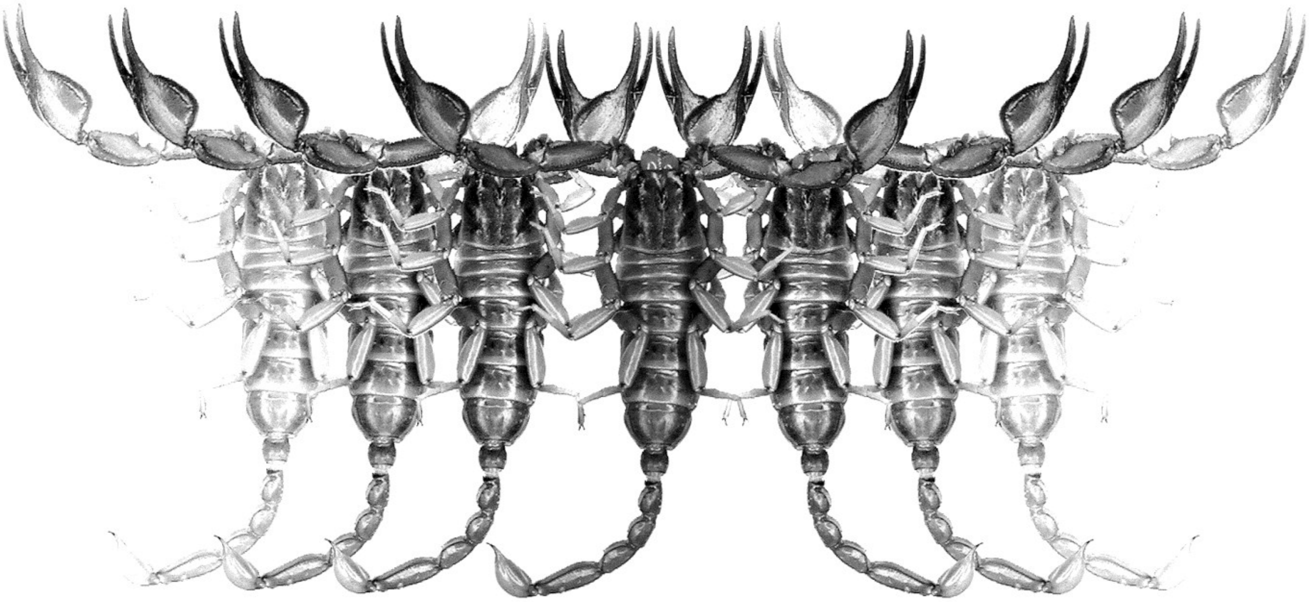
Euscorpius

Occasional Publications in Scorpiology



Observations on Growth and Maturation of a Male *Alloscorpiops wongpromi* (Scorpiones: Euscorpiidae)

František Kovařík, Michael E. Soleglad, Graeme Lowe,
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EDITOR: Victor Fet, Marshall University, ‘fet@marshall.edu’
ASSOCIATE EDITOR: Michael E. Soleglad, ‘soleglad@znet.com’

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Euscorpius — Occasional Publications in Scorpiology. 2015, No. 206

Observations on growth and maturation of a male *Alloscorpiops wongpromi* (Scorpiones: Euscorpiidae)

František Kovařík [1, 4], Michael E. Soleglad [2], Graeme Lowe [3],
Jana Plíškova [4] & František Šťáhlavský [4]

[1] P.O. Box 27, CZ - 145 01 Praha 45, Czech Republic; www.scorpio.cz
[2] 32255 Safflower St., Winchester, California 92596, USA; email: soleglad@znet.com
[3] Monell Chemical Senses Center, 3500 Market St., Philadelphia, Pennsylvania 19104-3308, USA
[4] Department of Zoology, Charles University, Viničná 7, CZ-128 44 Praha 2, Czech Republic

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Summary

An adult male of *Alloscorpiops wongpromi* Kovařík et al., 2013 was raised from birth, and its five exuviae (instars 2 through 6) were compared to the resulting adult. This adult was contrasted with the original holotype male specimen, which was determined to be only a subadult after the fifth ecdysis. The hemispermatophore of *A. wongpromi* is illustrated and described here for the first time. In addition to morphological analysis we also describe the karyotype of *Alloscorpiops wongpromi* (2n=95). Based on comparative analysis of pectinal tooth counts, it is determined that the holotype of *A. troglodytes* Lourenço & Pham (2015) represents a juvenile.

Introduction

We examined an adult male *Alloscorpiops wongpromi* Kovařík et al., 2013 (Euscorpiidae: Scorpiopinae: Scorpiopini) that was raised from a juvenile, the offspring of a paratype female from the original type series (see fig. 22 in Kovařík, Soleglad & Košulič, 2013: 9) collected from the Khong Chiam District, Thailand on 10 November 2012. After close examination and comparison with the male holotype described in Kovařík, Soleglad & Košulič (2013), it was determined that the holotype was only a subadult after the fifth ecdysis. This was based on morphological differences in the pedipalp chela and additional comparisons with a sixth instar exuvia originating from the adult male.

In this study we provide additional structural information about *A. wongpromi* based on the adult male, in particular the hemispermatophore. Also of interest, we compare morphometrics and make selected ratio comparisons between six exuviae and the resulting adult male. In Table 1 we present chronological data of the ecdysis process of the male involving the last five exuviae; it took this male over two years to reach full maturity.

We also describe the karyotype of the analyzed male. The number and morphology of the chromosomes seem to be characteristic at least for some scorpion species (see Schneider et al., 2015). However, no data was previously available on the karyotypes of the genus *Alloscorpiops*. In addition, the karyotypes were described only in two species of *Euscorpiops* for the subfamily Scorpiopinae (Kovařík et al., 2013, 2015).

The species *Alloscorpiops troglodytes* Lourenço et Pham (2015) is discussed, and it is strongly suggested that the holotype is only an immature specimen. Mistakes in the reported trichobothrial pattern are also documented.

Material Examined

Alloscorpiops wongpromi Kovařík, Soleglad et Košulič, 2013
Thailand, Ubon Ratchathani Province, Khong Chiam District, 15°17'48.97"N 105°28'20.04"E, dry dipterocarp forest, rock wall around trail, 10.XI.2012, 2 subadult ♂ (holotype and paratype), 4 adult ♀ (allotype and paratypes), leg. O. Košulič, 17 "juveniles" (see fig 22 in Kovařík et al, 2013: 9), from which a male (Figs. 1–6) and a female are adults (Table 1) bred by F. Kovařík. Laos, Champasak Province, Pak Sé District, Phou Salao Mountain near Pakse City, dry dipterocarp forest, 15°05'11.37"N 105°48'28.46"E, 15.XI.2012, 1 subadult ♂ (paratype), leg. O. Košulič. Most of the specimens are in the personal collection of František Kovařík, Prague, Czech Republic, a female paratype is in the private collection of Jana Plíšková, Czech Republic.

Discussion

The dorsal and ventral views of the adult male *Alloscorpiops wongpromi* (originally designated a para-

Figure 1: *Alloscorpiops wongpromi,* adult male paratype. **Top.** Dorsal and ventral views. **Bottom.** Alive, one week after the sixth ecdysis.

Figure 2: *Alloscorpiops wongpromi,* adult male paratype. **Left.** Carapace and terga I–III. **Right.** Sternopectinal area (note, a portion of the genital operculum and sternum are damaged).

Ecdyses Chronological Data for *Alloscorpiops wongprongi*						
Ecdyses	**first**	**second**	**third**	**fourth**	**fifth**	**sixth**
Date*	**26 Apr 2013**	**18 Aug 2013**	**30 Mar 2014**	**10 Sep 2014**	**7 Feb 2015**	**5 Jun 2015**
Male	5	119	342	506	656	774
Female	5	182	379	511	695	805
Unknown	5	144	304	451	675	-
Days (average)	5	148.33	341.67	489.33	675.33	789.50
Instar duration (mean ± SD)	5 ± 0	143.33 ± 31.72	193.33 ± 31.66	147.67 ± 16.01	186.00 ± 37.04	114.00 ± 5.66

Table 1: Ecdyses data for three juvenile *Alloscropiops wongprongi*. Chronological data are presented in number of days. Original litter was born on 21 April 2013 and included 19 juveniles. * refers to male only.

type) and a photo of the specimen alive after the sixth ecdysis are shown in Figure 1, and close-ups of the carapace and the sternopectinal area are provided in Figure 2. Based on the comparison of six exuviae with the resulting adult male and the holotype male designated in Kovařík, Soleglad & Košulič (2013: 4), it was concluded that the holotype is only a subadult and probably represents the sixth ecdysis since it closely compares morphometrically to the sixth exuvia examined in this study.

	Adult Male Paratype	**Subadult Male Holotype**	**% difference (paratype – holotype)**
Total Length*	63.80	55.00	16.0%
Carapace L	10.80	8.30	30.0%
Carapace W	11.05	8.50	30.0%
Metasoma L*	23.35	17.60	32.7%
Segment I (L/ W : Ratio)	2.90/ 3.60 : 0.806	2.40 / 2.90 : 0.828	20.8%/ 24.1% : –2.7%
Segment II (L/ W : Ratio)	3.40/ 3.05 : 1.115	2.60 / 2.45 : 1.061	30.8%/ 24.5% : +5.1%
Segment III (L/ W : Ratio)	3.85/ 2.90 : 1.328	2.90 / 2.30 : 1.261	32.8%/ 26.1% : +5.3%
Segment IV (L/ W : Ratio)	4.70/ 2.73 : 1.722	3.50 / 2.15 : 1.628	34.3%/ 27.0% : +5.8%
Segment V (L/ W : Ratio)	8.50/ 2.70 : 3.148	6.20 / 2.00 : 3.100	37.1%/ 35.0% : +1.5%
Telson L	10.90	7.30	49.3%
Pedipalp L	40.50	31.15	30%
Pedipalp femur (L/ W : Ratio)	10.60/ 4.30 : 2.465	8.20/2.90 : 2.828	29.3%/ 48.3%: –13.2%
Pedipalp patella (L/ W : Ratio)	9.30/ 4.50 : 2.067	7.20/3.10 : 2.323	29.2%/ 45.2% : -11.0%
Pedipalp chela (L/ W : Ratio)	20.60/ 6.98 : 2.951	15.75/ 4.2 : 3.75	30.8%/ 66.2% : -21.3%
Pedipalp movable finger L	11.30	8.10	39.5%

Table 2: Comparison of morphometrics and selected ratios of captive reared adult male to those of holotype male *Alloscorpiops wongpromi*. Raw measurements (mm) and computed L/W ratios are listed, as well as percentage differences of these quantities for the paratype vs. holotype. Positive differences in all the raw measurements reflect the larger size of the paratype compared to the holotype. Positive (or negative) differences in ratios reflect segments that are more (or less) slender in the paratype compared to the holotype. *Measurement includes telescoping segments of metasoma.

Further observations on *Alloscorpiops wongpromi*. We provide additional information on *A. wongpromi* including morphometrics, description of the hemispermatophore, further information on the chelicerae, trichobothrial patterns, chela structural differences, and comparisons of five exuviae with the resulting adult male specimen.

Morphometrics. Measurements (in mm) and select morphometric ratios of the adult male paratype *A. wongpromi* and subadult holotype male are provided in Table 2 (the holotype measurements are repeated here for convenience in comparison, originally provided in Kovařík, Soleglad & Košulič, 2013: 6–7). In Table 2, simple comparisons are made for each measurement predictably showing an increase in size in the adult male. For the metasoma we see roughly a one-third increase in size for the adult, ranging by segment, 20.8–37.1%, the basal segment showing the least increase and segment V the largest. Similarly, the metasomal segment widths also show the least size increase for segment I and the largest for segment V. The largest size increase between the two male specimens is observed in the pedipalp femur and patella widths (further discussed below) and the telson length. Here we see size increases almost 50 % (i.e., 45.2–49.3 %). The telson exhibited the largest increase in size for the adult male, 49.3 %. Of more interest are potential differences in structural proportions as indicated by the comparison of morphometric ratios. In Table 2 we show ratios (i.e., segment length compared to its width) of the metasoma and pedipalp femur and patella. Interestingly, the metasoma is relatively thinner in the adult, except for segment I. The percentage of differences are small however, spanning only 1.6 to 5.8 %. With the pedipalp segments we definitely see they are stockier in the adult implying morphometric proportional differences in the pedipalp. For the femur and patella, the difference ranged from 12.4 to 14.7 %. Finally in this analysis, we compared all possible morphometric ratio combinations between the two males (a total of 18 morphometrics per specimen, 153 ratio combinations in all). The largest ratio difference in this analysis was the telson length compared to metasomal segment I length, a difference of 23.6 %, the adult paratype with the largest ratio value (3.759).

It is important to note that we detected relatively significant differences in the pedipalpal segment proportions between these two specimens, presumably representing one instar difference. This is discussed below.

Chela morphology. The comparison between the subadult holotype and adult paratype males produced predictable results, especially with size increases. Above, we showed that the pedipalp segments, the femur and patella, exhibited proportional results as well, the two segments being relatively wider in the adult male. In Figure 6, where the adult male is compared to five preceding exuviae, we see a conspicuous set of chela finger lobes present in the adult male. These are missing in the preceding exuvia (number six in Fig. 6) as well as in the holotype male, a subadult; see Kovařík, Soleglad & Košulič (2013: fig. 3).

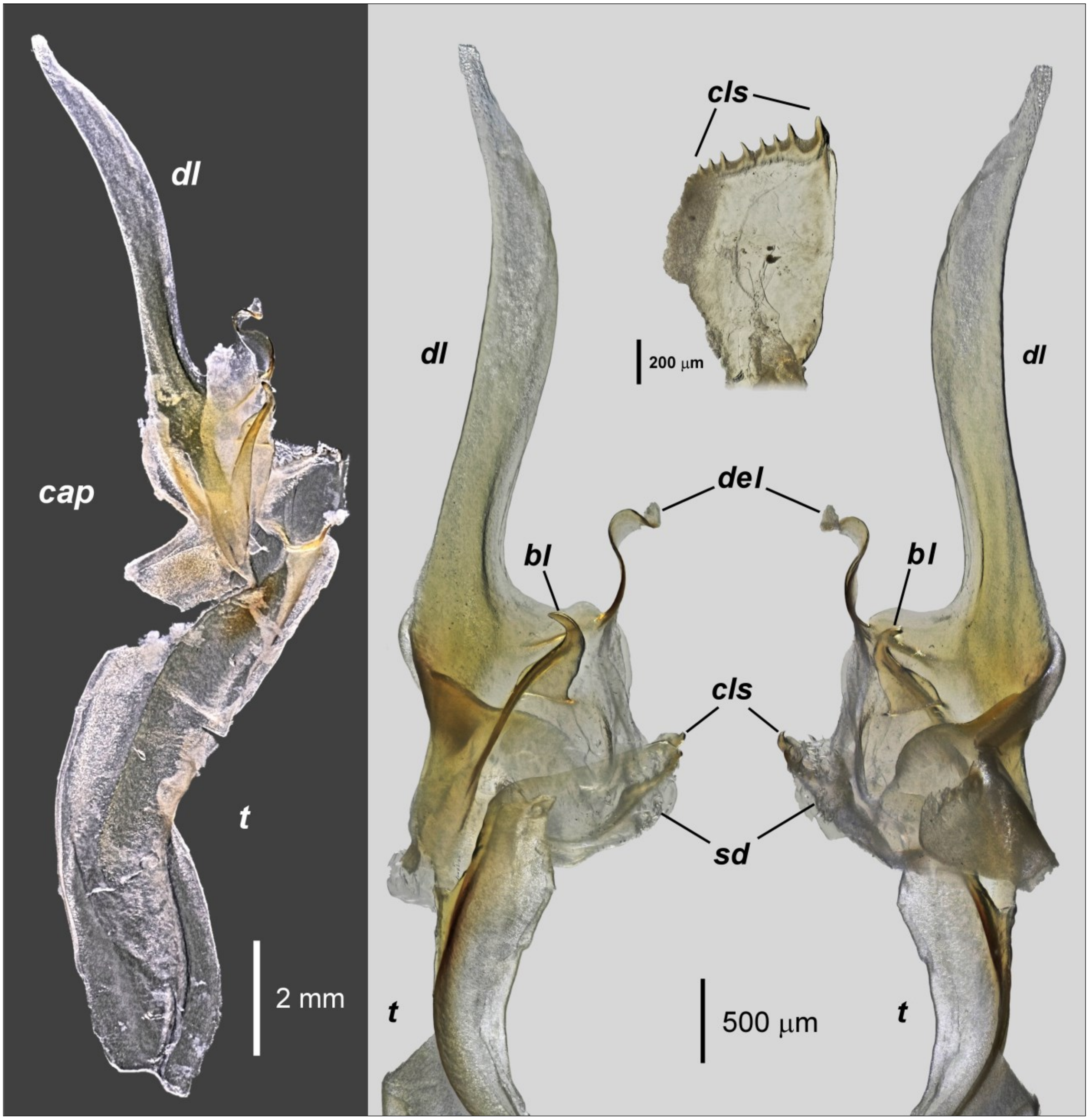

Figure 3: *Alloscorpiops wongpromi* male paratype. **Left.** Right hemispermatophore, dorsal view, showing the entire structure. **Right.** Right hemispermatophore, dorsal and ventral views, trunk terminus not shown. **Upper-Right.** Closeup of a fully developed crown-like structure from the left hemispermatophore. Right hemispermatophore appears to be partially developed in the median area, especially with respect to the lack of heavy sclerotization. However, the *cls* of the left hemispermatophore appears fully developed. *dl* = distal lamina; *del* = distal external lobe; *bl* = basal lobe; *cls* = crown-like structure; *sd* = sperm duct; *t* = trunk. Note, the basal lobe (*bl*), which originates from the dorsal side, is partially visible in the ventral view.

Hemispermatophore. Figure 3 shows the right hemispermatophore of the mature male *Alloscorpiops wongpromi*, extracted 24 days after its final ecdysis, imaged under low power with dark field illumination. This is the first illustrated hemispermatophore from the genus *Alloscorpiops*. A broad trunk (*t*), capsule complex (*cap*), and narrow distal lamina (*dl*) are identifiable. Also in Fig. 3 are magnified dorsal and ventral views of the capsule complex. The capsule is translucent, weakly sclerotized and flaccid, suggesting that this hemispermatophore was incompletely developed. Nevertheless, we can identify the same structures that have been observed in other hemispermatophores of tribe Scorpiopini: a basal lobe (*bl*) arising from the dorsal side, a

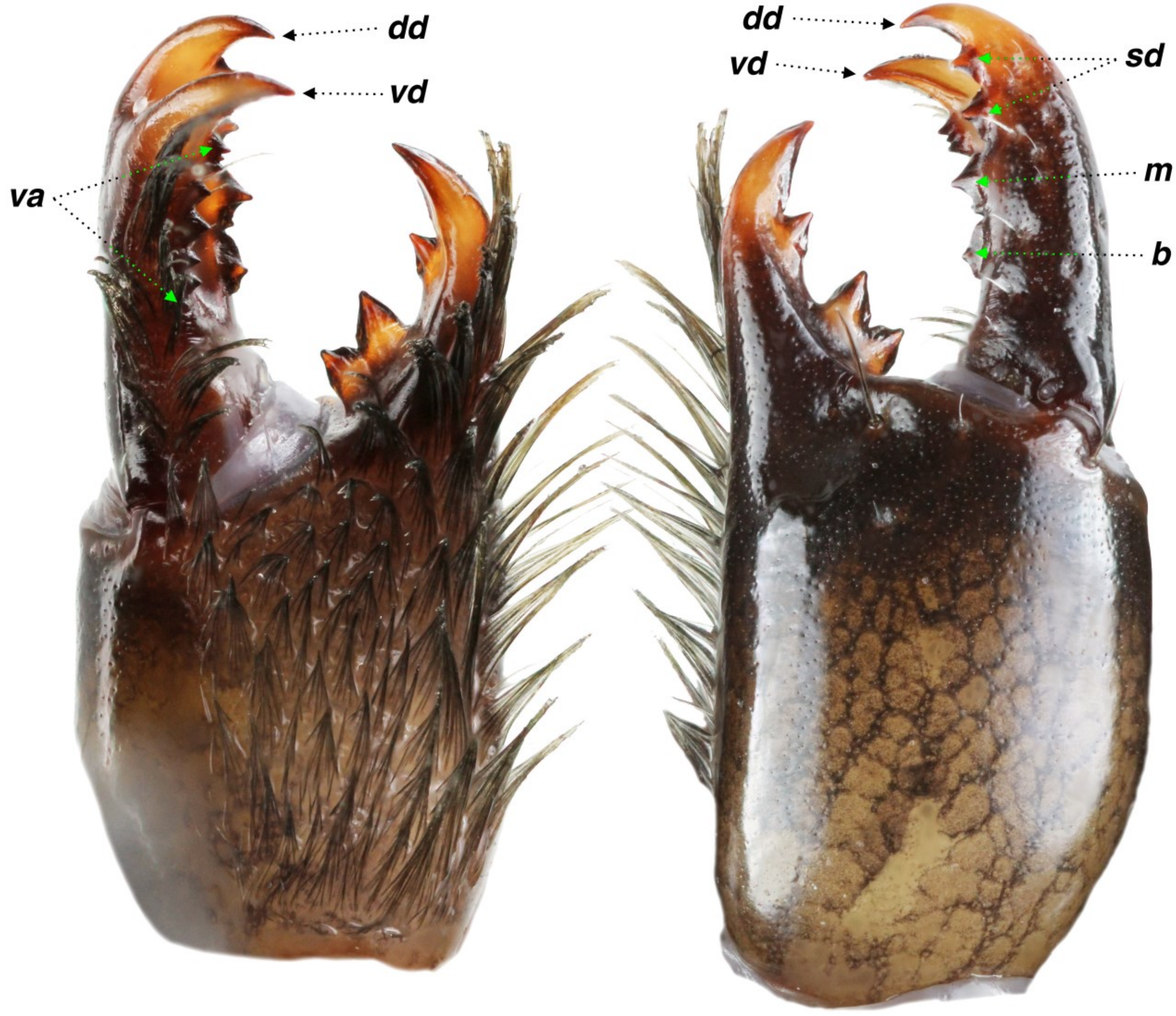

Figure 4: *Alloscorpiops wongpromi,* adult male paratype. Left chelicera (reversed), ventral and dorsal views. *sd* = subdistal denticles; *m* = median denticle; *b* = basal denticle; *dd* = dorsal distal denticle; *vd* = ventral distal denticle; *va* = ventral accessory denticles. Characteristic of the subfamily Scorpiopinae are the extended dorsal distal denticle (*dd*), two large and highly separated subdistal denticles (*sd*), and 6–7 irregularly sized ventral accessory denticles (*va*) distributed on the ventral edge.

distal external lobe (*del*) arising from the posteromedial side at the base of the distal lamina, and a multi-dentate crown-like structure (*cls*) and associated "sperm duct" (*sd*) along the anteromedial side. A higher magnification view of the crown-like structure dissected from the fragmented left hemispermatophore reveals a series of 8 tines of progressively increasing size.

In its overall shape and anatomical features, the hemispermatophore of *A. wongpromi* compares well with those previously reported from several other members of tribe Scorpiopini: *Euscorpiops montanus* Karsch, 1879 (Stockwell, 1989: figs. 206–207), *Euscorpiops puerensis* Di, Wu, Cao, Xiao et Li, 2010, (Di & al., 2010: figs. 25–26), *Parascorpiops montanus* Banks, 1928 (Soleglad & Sissom, 2001: figs. 124, 127), *Neoscorpiops tenuicauda* (Pocock, 1894) (Soleglad & Sissom, 2001: figs. 125, 128), *Scorpiops lhasa* Di et Zhu, 2009 (Di & Zhu, 2009: Figs. 31–33). All are rather elongate structures with a broader trunk and a narrower, curved distal lamina that has little or no basal constriction and tapers towards its apex. There is no truncal flexure and a dorsal trough is not well developed. Similar, presumably homologous structures of the capsule are discernible. However, in *P. montanus*, a dentate crown-like structure seems to be either not well developed or obscured in the illustration, and dentition is shown on what appears to be the distal external lobe. In *S. lhasa*, a distinct basal lobe was not clearly shown. There may also be minor differences in the sizes or shapes of basal or distal external lobes. The taxonomic significance of these differences requires further study, since only single examples of hemispermatophores or

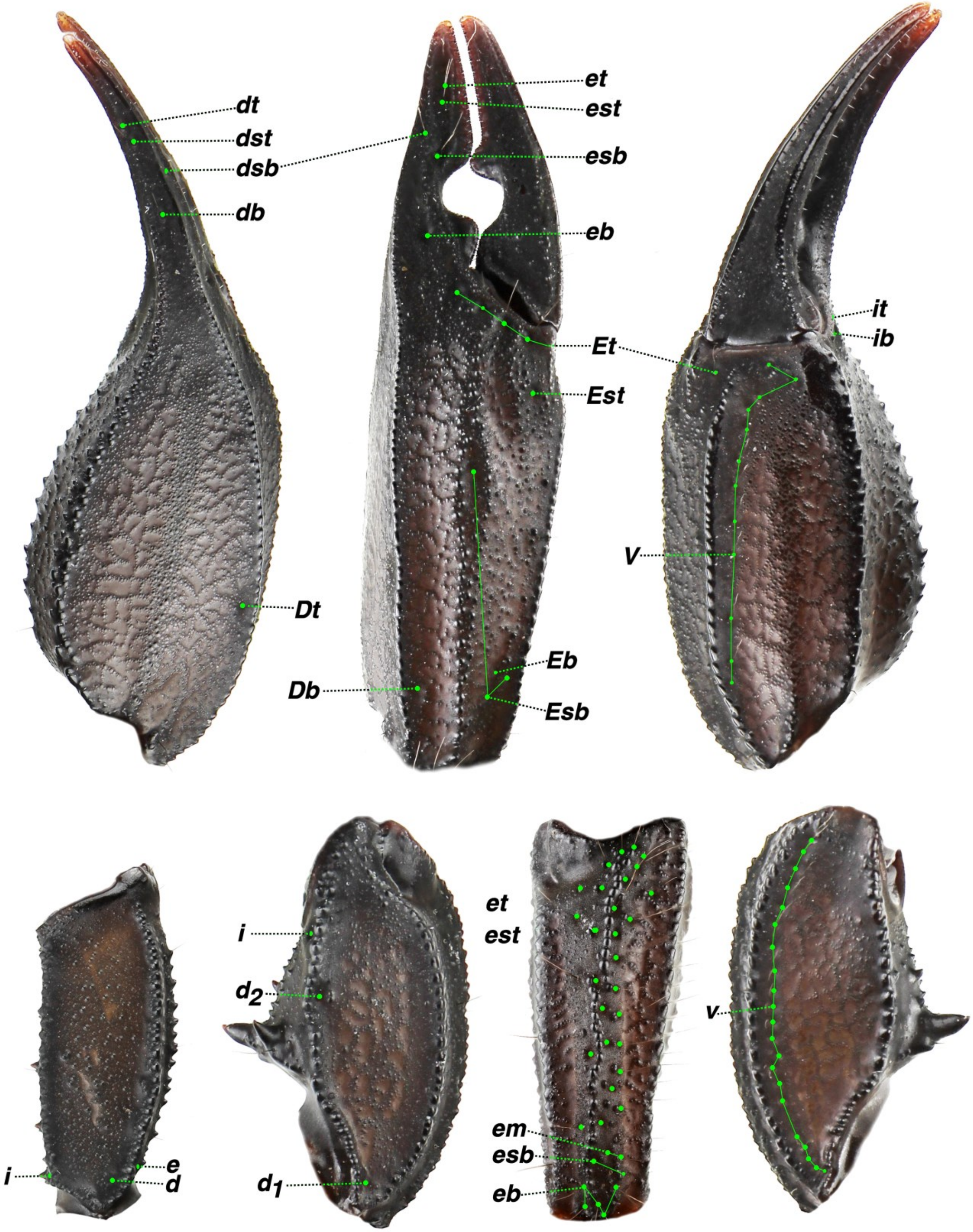

Figure 5: *Alloscorpiops wongpromi,* trichobothrial pattern, adult male paratype. Note, patellar series *et* and *est* are not specifically identified due to a large number of accessory trichobothria. See further discussion in body of text.

Y	*a* (Proportional Coefficient)	*b* (exponent)	Correlation Coefficient for log-log Regression
Total L	16.5181	1.0343 ± 0.0440	0.9964
Carapace L	2.9360	1.0254 ± 0.0155	0.9995
Carapace W	2.9527	1.0183 ± 0.0311	0.9981
Pedipalp femur L	2.7318	1.0339 ± 0.0171	0.9994
Pedipalp femur W	1.0351	1.0924 ± 0.0164	0.9996
Pedipalp patella L	2.5817	0.9812 ± 0.0173	0.9994
Pedipalp patella W	1.1211	1.0665 ± 0.0314	0.9983
Pedipalp chela L	5.6442	0.9869 ± 0.0245	0.9988
Pedipalp palm L	3.0523	1.0526 ± 0.0310	0.9983
Pedipalp chela W	1.2502	1.2669 ± 0.0663	0.9946
Metasoma V L	1.9493	1.0766 ± 0.0344	0.9980

Table 3: Allometric scaling parameters for growth of carapace, pedipalp segments and metasoma V, plotted against metasoma I width. Values were derived by linear least squares regression of log-log plots, using the equation: log Y = log *a* + *b*. log X (where X = metasoma I W). The proportional coefficient (*a*) measures the size of the structure relative to metasoma I W. The exponent (*b*) measures the allometric growth rate relative to metasoma I W. Exponents highlighted in gray have values signficantly larger than *b* = 1 (case of isometric growth), indicating allometric expansion of the segment relative to metasoma I W. Correlation coefficients measure the goodness of fit.

their line drawings are available for comparison, and the hemispermatophore of *A. wongpromi* may itself not be fully developed. In *Troglocormus willis* Francke, 1981, a member of Scorpiopinae placed in a different tribe (Troglocormini) the distal lamina is also narrow, curved and apically tapered (Soleglad & Sissom, 2001: Fig. 123). However, the capsule complex bears rather different lobes or processes, and a spiculate sperm duct and crown-like structure were not depicted. Note that, due to the lack of hemispermatophore material, Soleglad & Sissom (2001: Appendix, Characters 76–82) suppressed these characters in their cladistic analysis of the family Euscorpiidae.

Chelicerae. The unique chelicerae of *Alloscorpiops wongpromi* are consistent with that exhibited by other species/genera in subfamily Scorpiopinae (see Figure 4): the extended distal denticle (*dd*) of the dorsal edge of the movable finger, approaching the length of its ventral counterpart (v*d*). In addition, the two large somewhat widely spaced subdistal denticles (*sd*) and the irregularly sized ventral accessory (*va*) denticles found distributed for most of the ventral edge are consistent with this subfamily. See Soleglad & Sissom (2001: figs. 136–138, 143–147, 207) for other examples of these characteristics spanning several genera. Also, it is important to note that Soleglad & Sissom (2001: fig. 211) in their cladistic analysis demonstrated that two of these characters were unambiguous synapomorphies for subfamily Scorpiopinae: character 5 (state =2), the widely spread *va* denticles on the movable finger (on the other genera, either absent, or present only on the distal half of the finger); and character 6 (state = 2), the distal denticles of the dorsal (*dd*) and ventral (*vd*) edges are adjacent, forming a deep V-shaped notch.

Trichobothria. In Figure 5 the trichobothrial pattern of the adult male is shown, exhibiting 12 ventral trichobothria on the chela (as compared to 11–12 in the holotype), 21 on the ventral surface of the patella (as compared to 21–22 in the holotype), and a total of 36 trichobothria on the external surface of the patella (as compared to 33–37 in the holotype). Of particular interest, note that we did not specifically identify trichobothria in the *et* or *est* series of the patella. This was due, in part, to the large number of accessory trichobothria found on this surface. However, series *eb*, *esb*, and *em* are identified and they do not contain accessory trichobothria. We need to point out, this is consistent with Vachon's (1980: figs. 8, 15, 23, 31, 38) original designations for the four scorpiopine genera *Scorpiops* Peters, 1861, *Neoscorpiops* Vachon, 1980, *Alloscorpiops* Vachon, 1980, and *Euscorpiops* Vachon, 1980. It is important to note that in genera *Parascorpiops* Banks, 1928, *Scorpiops*, and *Neoscorpiops* the neobothriotaxy is quite limited, found only on the mid-to-distal aspects of the patellar extern. Therefore, Vachon was able to hypothetically isolate the nine orthobothriotaxic trichobothria of these three series. This hypothesis is also supported by the Type C "landmark" petite trichobothrium *esb*$_2$, which is even visible in the highly neobothriotaxic genus *Dasyscorpiops* Vachon, 1974 (see Vachon, 1974: fig. 142). These three series, and their somewhat *proximal location* on the patella, made it straightforward to identify them on the more neobothriotaxic genera such as *Neoscorpiops* and *Alloscorpiops*. In line with this proposed homology, we also see that the Mexican genus *Troglocormus* Francke, 1981 has no accessory trichobothria in the *eb*, *esb*, and *em* series and they are similarly located proximally on the

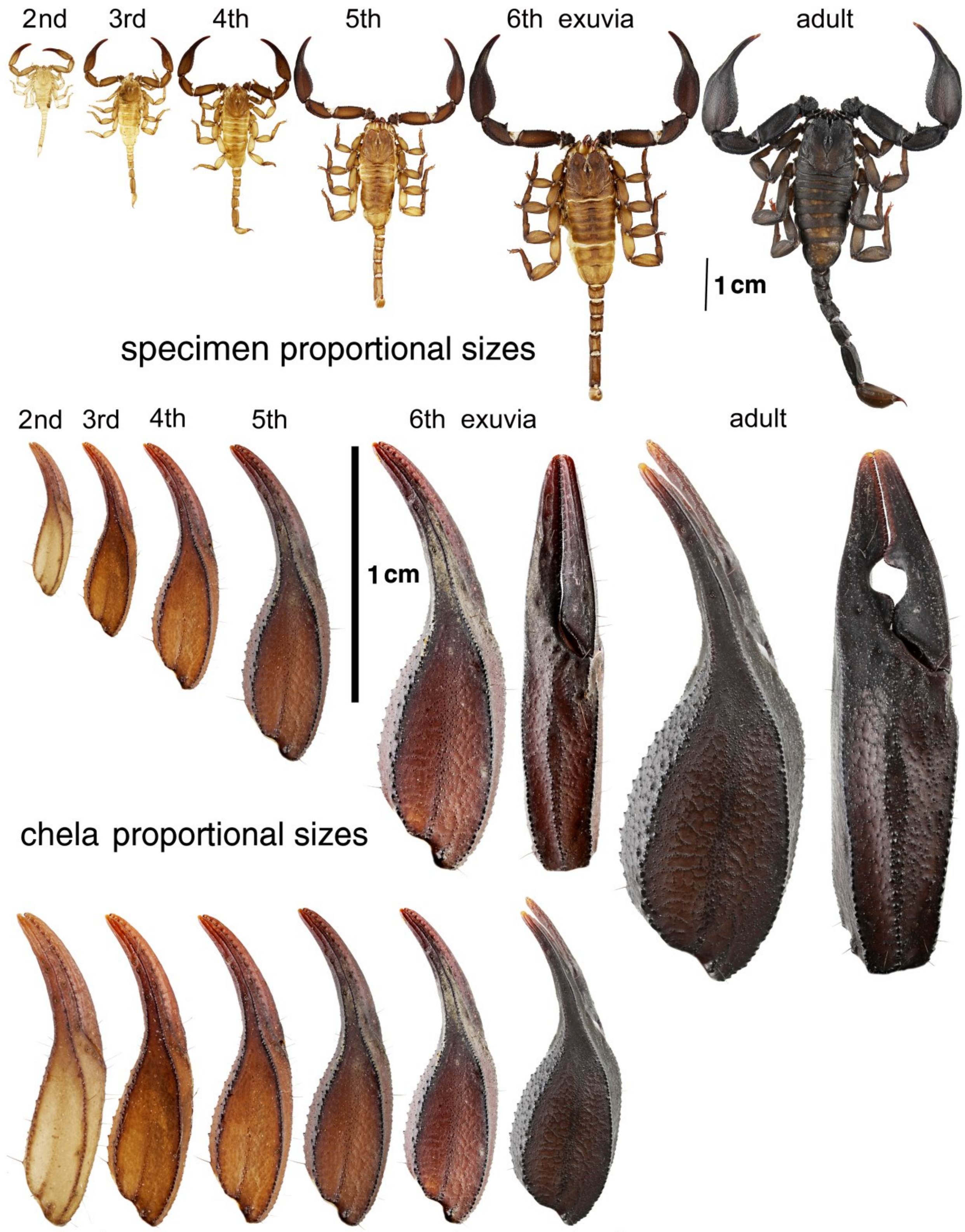

Figure 6: *Alloscorpiops wongpromi,* comparison of the adult male and its five exuvias. **Top.** Proportional dorsal view of specimen with a 1-cm scale bar. **Middle.** Right chela, showing proportional size with a 1-cm scale bar. **Bottom.** Right chela, dorsal view, adjusted to be the same size. Note the proportionally increasing chelal palm width and the conspicuous finger lobes in the adult.

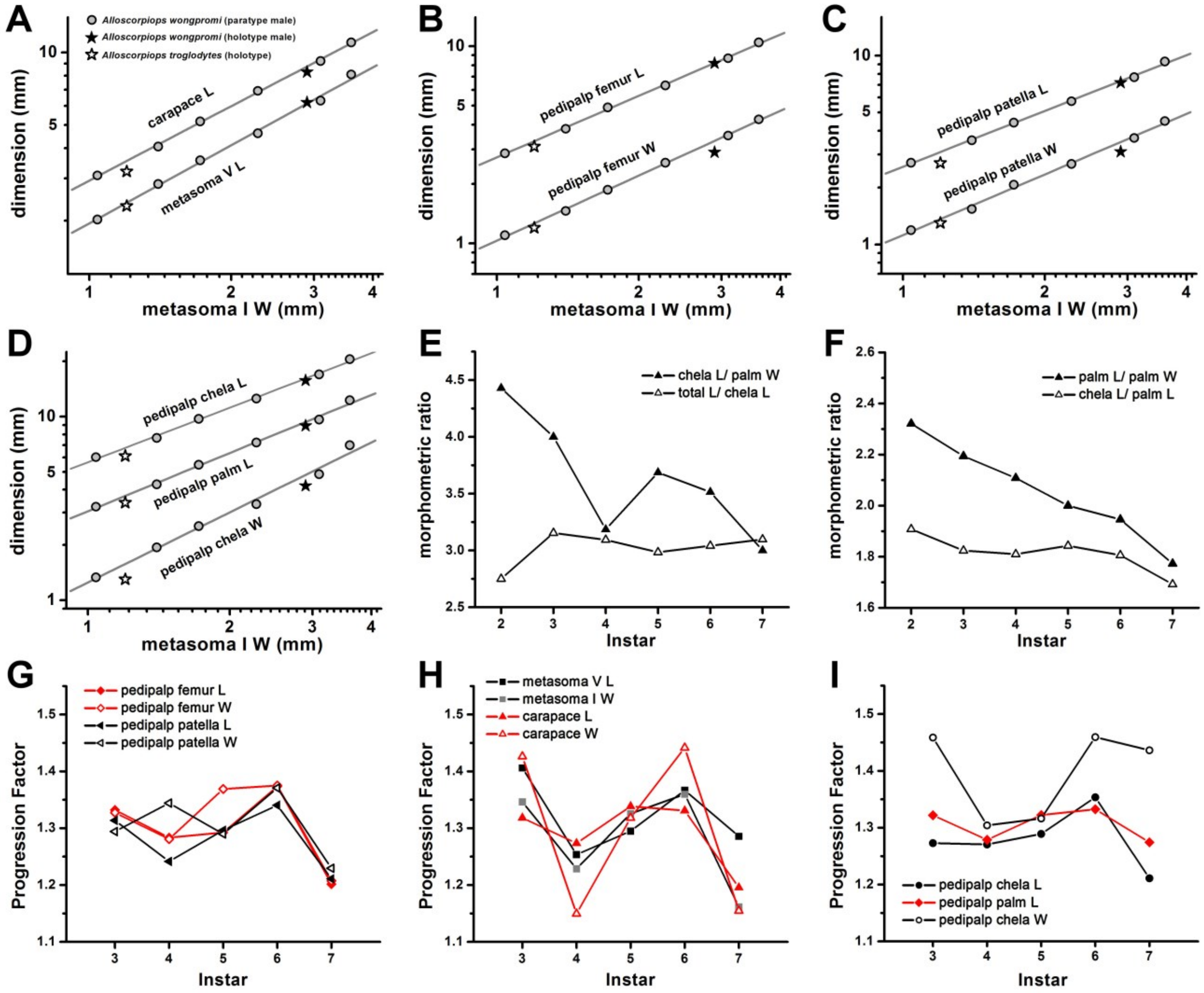

Figure 7: Allometric and ratiometric analyses of the growth in male *Alloscorpiops wongpromi*, based on five exuviae and adult male paratype **A–D.** Double logarithmic plots of dimensional scaling of selected segments vs. metasoma I W. **A.** Carapace L, metasoma V L. **B.** Pedipalp femur L, W. **C.** Pedipalp patella L, W. **D.** Pedipalp chela L, palm L, W. *Gray filled circles*: measurements of exuviae and adult male paratype. *Gray lines*: last squares linear regression fits to gray filled circles, using the allometric equation: log Y = log *a* + *b*.log X. *Filled stars*: measurements of holotype male plotted for comparison. *Open stars*: measurements of holotype 'male' of *Alloscorpiops troglodytes* plotted for comparison. **E–F.** Scatter plots showing variation of selected morphometric ratios with instar number. **E.** Pedipalp chela L/ palm W and Total body L/ pedipalp chela L. **F.** Pedipalp palm L/ W and pedipalp chela L/ palm L. **G–I.** Scatter plots showing variation of instar progression factors with instar number. **G.** Pedipalp femur and patella L, W. **H.** Metasoma I W, metasoma V L, and Carapace L, W. **I.** Pedipalp chela L, and palm L, W.

patella, providing additional support for its inclusion in this subfamily. See Soleglad & Sissom (2001: figs. 100–105) for diagrammatic examples of six of the seven genera comprising subfamily Scorpiopinae. Also of importance, in Soleglad & Sissom's (2001: fig. 211) cladistic analysis, characters 61 (state = 0) and 62 (state = 1), which deal with the number and position of trichobothria in the *em* series, are synapomorphies for subfamily Scorpiopinae, thus further suggesting their importance in the taxonomy of the family Euscorpiidae.

Recently, Lourenço & Pham (2015) described *Alloscorpiops troglodytes* from a cave in Vietnam. In their paper they discussed and illustrated the trichobothrial pattern of this species (see their figs. 7–13) as well as providing a key to the species of *Alloscorpiops* based entirely on the number of trichobothria (see pp. 80–81). Although the authors state this species has three *Esb* trichobothria on the chela palm, we see in their fig. 7 two *additional basal trichobothria* straddling the digital carina. These are shown in addition to other standard basal trichobothria Eb_1, Eb_2, *Esb*, and *Db* (note, Eb_3 is located distal to the palm midpoint, characteristic of this genus). We suspect that these non-existent "trichobothria" were probably illustrated in error when macrosetae were confused with trichobothria. In their key, Lourenço & Pham (2015)

		Instar 2	Instar 3	Instar 4	Instar 5	Instar 6	Instar 7
PF	Metasoma V L	–	1.406	1.254	1.295	1.367	1.286
	Metasoma I L	–	1.346	1.229	1.326	1.360	1.161
	Carapace L	–	1.318	1.273	1.339	1.331	1.195
	Carapace W	–	1.426	1.150	1.318	1.442	1.155
	Pedipalp femur L	–	1.332	1.284	1.292	1.373	1.202
	Pedipalp femur W	–	1.327	1.281	1.369	1.375	1.207
	Pedipalp patella L	–	1.314	1.242	1.296	1.340	1.211
	Pedipalp patella W	–	1.294	1.344	1.290	1.371	1.230
	Pedipalp chela L	–	1.273	1.271	1.289	1.354	1.211
	Pedipalp palm L	–	1.322	1.279	1.322	1.332	1.274
	Pedipalp chela W	–	1.459	1.304	1.316	1.460	1.436
Ratio	Total L/ Pedipalp chela L	2.750	3.154	3.093	2.984	3.041	3.097
	Pedipalp chela L/ Palm L	1.908	1.824	1.810	1.843	1.806	1.692
	Pedipalp chela L/ Palm W	4.429	4.000	3.815	3.686	3.514	3.000
	Pedipalp palm L/ Palm W	2.321	2.194	2.108	2.000	1.946	1.773

Table 4: Growth progression factors (PF) and pedipalp chela morphometric ratios for six instars of male *Alloscorpiops wongpromi*, derived from measurements of 5 exuviae and the adult of the captive reared male. PF values for structures of an instar were computed as ratios of measurements for that instar to those of the previous instar.

continue recognizing the proposed subgenus *Laoscorpiops* Lourenço, 2013. This subgenus was synonymized by Kovařík, Soleglad & Košulič (2013: 1–2) due to a complete misunderstanding of the assignment of homologous trichobothria in the *Eb* series by Vachon (1974), the primary reason Lourenço used for defining the subgenus.

Ontogeny. In Table 1 we record the chronology of ecdyses for three individual *A. wongpromi* reared in captivity: the paratype adult male, and two others from the same litter (one female, the other of indeterminate sex as it only reached the 6th instar). Duration of the first instar for all three was 5 days, which is at the shorter end of the range for all scorpions (1–28 days; Polis & Sissom, 1990). Later instar durations varied considerably with instar number and individual, ranging from 110 days to 224 days. Duration of instar 3 was consistently longer than that of instars 2 and 4 for all individuals, as shown by their mean values. The mean age to maturity (for the male and female) was ca. 789/30 = 24.6 months, which is close to the mean value of 27.7 ± 20.1 months for all scorpions cited by Polis & Sissom, 1990. The number of ecdyses to maturity (n = 6) is also about average for scorpions (typical range 4–8; Francke & Sissom, 1984; Polis & Sissom, 1990).

To analyze growth, we generated double logarithmic plots of the lengths (L) and widths (W) of selected segments of the paratype male and its exuviae (Fig. 7A–D). We took as independent variable X = metasoma I W, which has been suggested to be a sex-neutral proxy measurement of size in some scorpions (Fox & al., 2015). The plots were then fitted to the allometric scaling equation, $Y = a.X^b$, where a is the proportionality coefficient characterizing segment size relative to metasoma I W, and b the exponent describing nonlinear allometric growth, i.e. a power law, or geometric progression of instars (Dyar, 1890). Although we only analyzed data from one individual, we obtained precise linear fits to double logarithmic plots of Y vs. X for dimensions of all measured segments (correlation coefficients > 0.99). Inspection of the derived exponent values reveals greater allometric growth in the widths of the pedipalp femur, patella and chela, as well as chela palm length and metasoma V L (Table 3, gray highlighted panels). This shows that as the animal grows, its pedipalp segments, and especially its chela manus, become stockier, and its metasoma becomes more slender. These trends correlate directly with the morphometric differences between the adult male and the holotype that we discussed above. Indeed, superposing data from the holotype over the allometric plots (filled star symbol) clearly shows its closest biometric proximity to instar 6, confirming its identification as penultimate instar subadult. The allometric expansion of the male pedipalp chela was monophasic, proceeding at a constant rate over the life of the animal. This is perhaps the most common situation for scorpions. It can be contrasted to the markedly diphasic allometry of the male pedipalp chela in the buthid scorpion *Vachoniolus*, which represents an extreme case of sexually dimorphic chela expansion (Lowe, 2010: figs. 28–29). We can also express male chela expansion of *A. wongpromi* in terms of the steep decline with increasing instar number of morphometric ratios: chela L/palm W, and palm L/ palm W (Fig. 7E–F, Table 4 Ratios). On the other hand, the ratio plots of: total body L/ chela L, and chela L/ palm L,

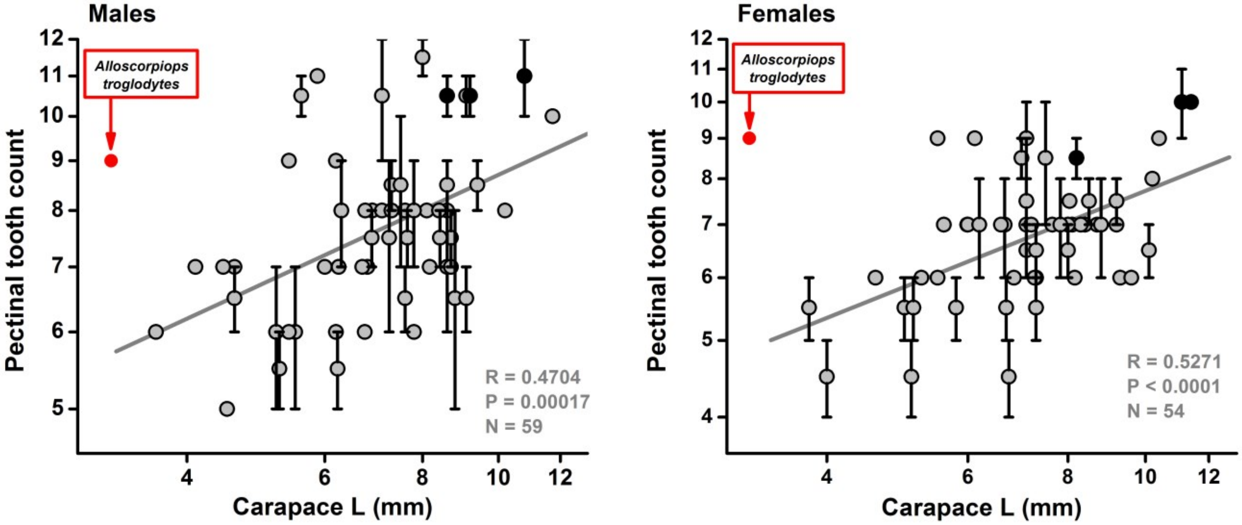

Figure 8: Double logarithmic plots of the scaling of pectinal tooth count with carapace length in presumed adults of all known species belonging to the subfamily Scorpiopinae (Euscorpiidae). **Left.** Males. **Right**. Females. In each plot, gray filled and black circles represent all species except *Alloscorpiops troglodytes*, which is plotted as a red filled circle. Black circles represent other species of *Alloscorpiops*. Gray lines are least squares regression fits to the gray filled and black circles (R = Pearson's correlation coefficient; P = significance level; N = number of points, each representing one species).

did not exhibit such clear reductions and were nearly flat, so relative growth between these segments was nearly isometric (Fig. 7E–F).

Table 4 also presents computed values of the progression factors (PF) for growth of different segments between molts for each instar. Values ranged widely from 1.14 to 1.45, often deviating from theoretical values of 1.26 (Przibram Rule based on mass doubling at each molt). Such deviations have been reported before in many other scorpions (e.g. Brown, 1997; Francke & Sissom, 1984; Lourenço et al., 2003; Lourenço et al., 2008; Lourenço et al., 2010; Rouaud et al., 2000). Plotting progression factors against instar number (Fig. 7G–I) shows that growth rate fluctuated between instars. However, the variable progression factors (averaged over segments) were not correlated with variable instar durations (Table 2), i.e. growth rates were not constant. This could be due variations in the environment or nutrition in the laboratory.

Comparison of male and female exuviae did not reveal any obvious differences from the second to fourth instars (data not shown). This includes the shapes of the chela and pectines. After the fifth exuvia, the shape of the chela is still the same and the dentate margins of the pedipalp fingers in both sexes lack lobes. However, there is a difference in the shape of the pectines which are larger in the subadult male than in the subadult or the adult female, even after the sixth ecdysis (cf. figs. 2, 6, 17 in Kovařík, Soleglad & Košulič, 2013: 9). After the sixth ecdysis, the chela fingers of the female essentially lack lobes (fig. 6 in Kovařík, Soleglad & Košulič, 2013: 3), whereas in contrast, the male fingers exhibit exaggerated lobes (Figs. 5–6).

Remarks on the sexual maturity of types in *Alloscorpiops*. Our conclusion that the holotype male of *A. wongpromi* was not an adult leads us to consider whether this might also be an issue for other closely related species. Of particular interest is *A. troglodytes* Lourenço et Pham, 2015, a species based on a single specimen collected from a cave in Vietnam, and presumed to male. This species apparently stands apart from other known members of the genus due to its exceptionally small size (total length 20.9 mm), pale yellow coloration, and weak carination and granulation of the integument. All other species are much larger, dark, and well-carinated and granulated. In addition, the pedipalp chela of *A. troglodytes* is quite slender compared to other known males of *Alloscorpiops*. The species was characterized as "remarkable", and perhaps the pale color, smooth features, slender chelae and diminutive size were interpreted as troglobitic adaptations. However, these characters are also typical of juvenile scorpions in their very early instars, a fact that we have directly verified in the genus *Alloscorpiops* by rearing juveniles from birth (see Fig. 6, exuviae 2 and 3). When measurements of *A. troglodytes* are plotted over allometric growth curves for the paratype male *A. wongpromi*, its data points (Fig. 7A–D, open stars) mostly fall near the fitted lines between exuviae 2 and 3 of the latter species. Thus, we hypothesized that the *A. troglodytes* type may actually represent a juvenile, probably second or third instar. To test this hypothesis, we compared the pectinal tooth count (PTC) of *A. troglodytes* with the PTCs recorded for all other known members of subfamily Scorpiopinae. It has long been known that within many groups of related scorpions, the

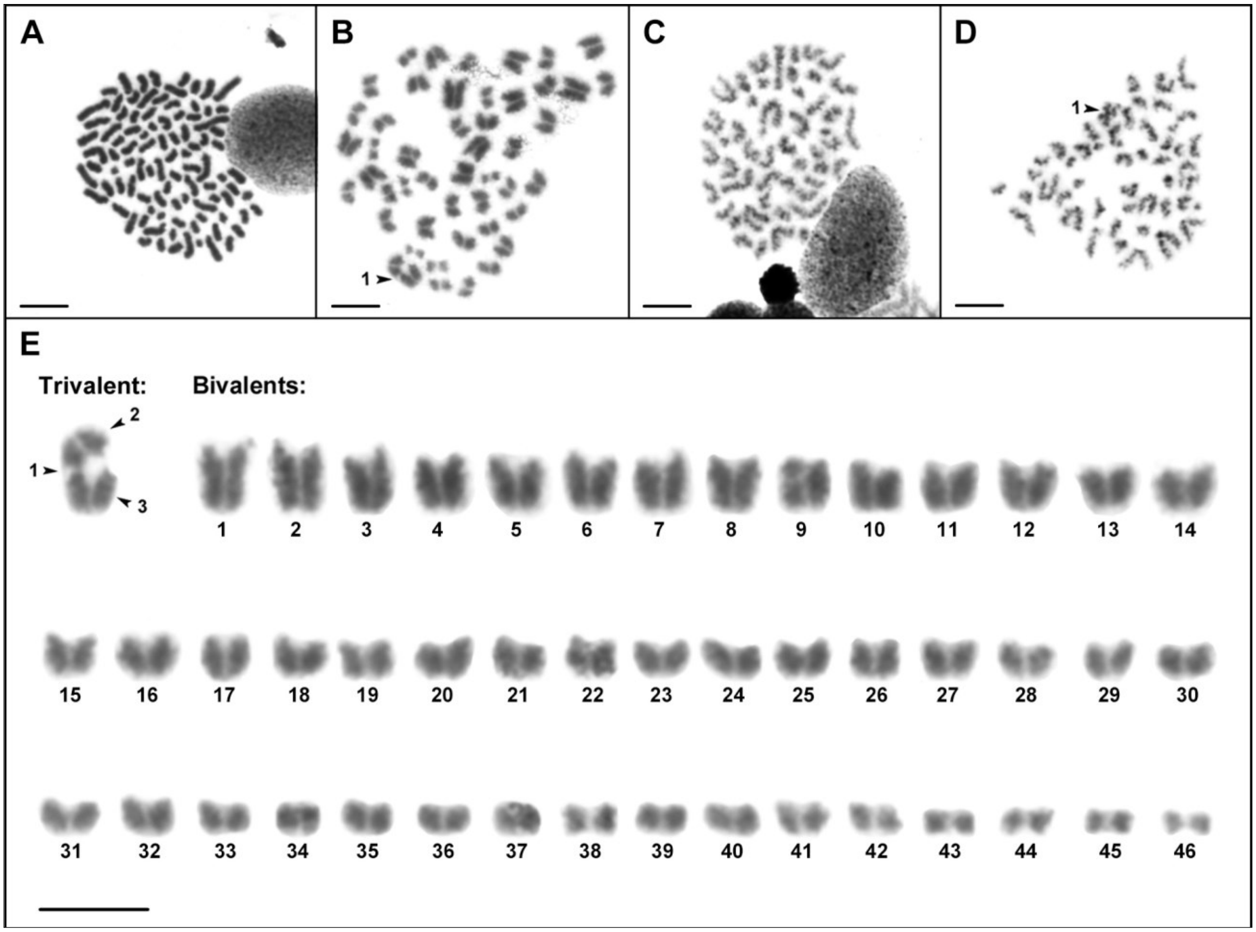

Figure 9: The chromosomes of *Alloscorpiops wongpromi*, A) Spermatogonial metaphase (2n=95); B) metaphase I, arrowhead shows large metacentric chromosome within trivalent; C) metaphase II (n=48), the cell with only acrocentrics; D) metaphase II (n=47), arrowhead shows large metacentric chromosome from trivalent; E) karyogram of analysed adult male. Bar = 10µm.

PTC scales with body size such that pectines of larger species tend to have higher numbers of teeth (Soleglad, 1973; Soleglad & Fet, 2003). In this context, the PTC for *A. troglodytes* (9/ 9) seemed anomalously large for such a small species (ca. 21 mm long), being comparable to the PTC of the much larger *A. wongpromi* (9–11 in females, 10–12 in males) whose adults are ca. 64 mm long. To visualize this, we constructed double logarithmic plots of PTC vs. carapace length for all male Scorpiopinae (Fig. 8, left panel). In this plot, *A. troglodytes* is a conspicuous outlier (red filled circle) that violates the PTC scaling principle. We further noticed that the pectines of *A. troglodytes* are structurally more similar to those of female scorpions, than those of males. The combs are small and spaced well apart, with teeth that are short relative to the pectinal width. To allow for this possibility, we also compared PTCs of *A. troglodytes* and all female Scorpiopinae (Fig. 8, right panel). On the PTC vs. carapace L plot for females, we see that *A. troglodytes* is even more distant from the main regression line of all other species. Our analysis therefore supports the conclusion that *A. troglodytes* is indeed based on a juvenile, not an adult specimen, and may also be female rather than male. In the key of Lourenço & Pham (2015), *A. troglodytes* is distinguished from other species by having one fewer trichobothrium in the large series of accessory trichobothria on the pedipalp chela and patella. The taxonomic significance of this small difference is unclear because *Alloscorpiops* species are known only from limited material from a few collection sites, so interpopulation and geographic variation in accessory trichobothrial counts is not quantified. In our opinion, the true identity of *A. troglodytes* remains to be determined.

Karyotype: We analysed the adult male of *Alloscorpiops wongpromi* using standard cytogenetic methods (see Kovařík et al., 2015). The diploid set is composed of 95 chromosomes (Figs. 9-A, B) which exhibit typical monocentric organization (Figs. 9-C, D). Bivalents gradually decrease in size from 2.24 % to 0.42 % of the relative diploid set length (DSL) and they are acrocentric (Fig. 9-E). However in several of the smallest chromosomes the primary constriction is not clearly visible and thus we cannot confirm exactly the morphology of these chromosomes. The odd number of chromosomes in the diploid set is caused by existence of one trivalent (Figs. 9-B, E) that is present in all observed postpachytene and metaphase I. This distinct trivalent is composed of one large metacentric chromosome (No. 1) and two smaller acrocentric chromosomes (No. 2 and 3). According to the size and morphology of the chromosomes within the trivalent, this untypical chromosomal structure is probably caused by the heterozygous centric fusion or fission. We observed only two types of cells with metaphases II. One type of cell (n=48) contains only acrocentrics (Fig. 9-C) and the other one (n=47) has large metacentric chromosome (Fig. 9-D). This type of separation provides production of balanced gametes in this individual. The heterozygous centric fusion or fission was also observed in *Euscorpiops orioni* Kovařík et al., 2015 from the same subfamily (Kovařík et al., 2015). The Robertsonian translocations seem to be an important mechanism in the differentiation of karyotypes of this group of scorpions.

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Appendix A

This appendix presents raw measurements of five exuviae, an adult, and the holotype male of *Alloscorpiops wongpromi* (Table A1). Table A2 presents pectinal tooth count data and the carapace length extracted from published literature presumably representing all species in subfamily Scorpiopinae.

	exuvia 2	**exuvia 3**	**exuvia 4**	**exuvia 5**	**exuvia 6**	**instar 7 (adult)**	**holotype ♂**
Metasoma I W	1.04	1.40	1.72	2.28	3.10	3.60	2.90
Metasoma V L	2.02	2.84	3.56	4.61	6.30	8.10	6.20
Carapace L	3.08	4.06	5.17	6.92	9.21	11.01	8.30
Carapace W	3.05	4.35	5.00	6.59	9.50	10.97	8.50
Pedipalp femur L	2.86	3.81	4.89	6.32	8.68	10.43	8.20
Pedipalp femur W	1.10	1.46	1.87	2.56	3.52	4.25	2.90
Pedipalp patella L	2.71	3.56	4.42	5.73	7.68	9.30	7.20
Pedipalp patella W	1.19	1.54	2.07	2.67	3.66	4.50	3.10
Pedipalp chela L	6.01	7.65	9.72	12.53	16.96	20.54	15.75
Pedipalp palm L	3.23	4.27	5.46	7.22	9.62	12.26	8.92
Pedipalp palm W	1.33	1.94	2.53	3.33	4.86	6.98	4.20

Table A1: Raw measurements of lengths (L) and widths (W) of analyzed segments of 5 exuviae and adult instar of captive reared male and holotype male of *A. wongpromi*.

Species	Sex	Carapace L	PTC min	PTC max	PTC mid
Alloscorpiops anthracinus (Simon, 1887)	M	9.20	10	11	10.5
Alloscorpiops calmonti Lourenço, 2013	F	11.40	10	10	10
Alloscorpiops citadelle Kovařík, 2013	M	8.60	10	11	10.5
	F	8.20	8	9	8.5
Alloscorpiops troglodytes Lourenco et Pham, 2015	M	3.20	9	9	9
Alloscorpiops wongpromi Kovařík, Soleglad et Kosulic, 2013	M	10.80	10	12	11
	F	11.10	9	11	10
Dasyscorpiops grandjeani Vachon, 1974	F	7.00	8	9	8.5
Euscorpiops alexandreanneorum Lourenço, 2013	M	6.00	7	7	7
Euscorpiops artemisae Kovařík et al, 2015	M	7.10	8	8	8
Euscorpiops asthenurus Pocock, 1900	M	5.50	5	7	6
	F	7.30	6	6	6
Euscorpiops beccaloniae Kovařík, 2005	M	9.40	8	9	8.5
Euscorpiops bhutanensis (Tikader et Bastawade, 1983)	M	6.25	7	7	7
Euscorpiops binghamii Pocock, 1893	M	7.80	7	9	8
	F	7.10	6	9	7.5
Euscorpiops cavernicola Lourenço et Pham, 2013	M	6.80	7	7	7
	F	7.10	7	7	7
Euscorpiops dakrong Lourenço et Pham, 2014	M	4.10	7	7	7
	F	3.80	5	6	5.5
Euscorpiops kaftani (Kovařík, 1993)	F	5.50	6	6	6
Euscorpiops kamengensis Bastawade, 2006	F	6.75	4	5	4.5
Euscorpiops karschi Qi, Zhu et Lourenço, 2005	M	6.9	8	8	8
	F	7.65	7	7	7
Euscorpiops kubani Kovařík, 2004	M	7.60	8	8	8
	F	7.10	6	7	6.5
Euscorpiops longimanus (Pocock, 1893)	M	7.30	8	9	8.5
	F	8.70	7	7	7
Euscorpiops montanus Karsch, 1879	M	8.60	8	8	8
	F	8.40	7	7	7
Euscorpiops neradi Kovařík, Plíšková et Šťáhlavský, 2013	M	3.65	6	6	6

	F	4.00	4	5	4.5
Euscorpiops novaki Kovařík, 2005	M	8.10	8	8	8
Euscorpiops orioni Kovařík et al, 2015	M	8.60	8	9	8.5
	F	8.50	7	8	7.5
Euscorpiops puerensis Di, Wu, Cao, Xiao et Li, 2010	M	8.7	7	8	7.5
	F	9.2	7	8	7.5
Euscorpiops problematicus Kovařík, 2000	M	7.10	8	8	8
	F	8.10	7	7	7
Euscorpiops sejnai Kovařík, 2000	M	6.20	6	6	6
Euscorpiops shidian Qi, Zhu & Lourenço, 2005	M	7.65	7	8	7.5
	F	8.04	7	8	7.5
Euscorpiops thaomischorum Kovařík, 2012	M	7.80	7	9	8
	F	8.80	6	8	7
Euscorpiops vachoni Qi, Zhu et Lourenço, 2005	M	8.42	7	8	7.5
	F	5.99	7	7	7
Euscorpiops validus Di, Cao, Wu et Li, 2010	M	8.6	6	8	7
	F	9.3	6	6	6
Euscorpiops xui Sun & Zhu, 2010	M	8.40	8	8	8
	F	9.20	7	7	7
Euscorpiops yangi Zhu, Zhang et Lourenço, 2007	M	6.8	7	7	7
	F	7.3	5	6	5.5
Neoscorpiops deccanensis (Tikader et Bastawade, 1977)	F	7.30	6	7	6.5
Neoscorpiops maharashtraensis Mirza et al., 2014	M	8.17	7	7	7
	F	6.67	6	8	7
Neoscorpiops satarensis (Pocock, 1900)	M	6.70	7	7	7
	F	8.00	6	7	6.5
Neoscorpiops tenuicauda (Pocock, 1894)	M	7.60	6	7	6.5
Parascorpiops montanus Banks, 1928	M	6.75	6	6	6
	F	6.85	6	6	6
Scorpiops afghanus Lourenço et Qi, 2006	F	5.8	5	6	5.5
Scorpiops atomatus Qi, Zhu et Lourenço, 2005	M	5.87	11	11	11
	F	6.12	9	9	9
Scorpiops bhutanensis Tikader et Bastawade, 1983	M	6.25	7	7	7
Scorpiops braunwalderi Kovařík, 2000	M	5.40	6	6	6
Scorpiops dastychi Kovařík, 2000	M	5.20	5	7	6
	F	5.00	5	6	5.5
Scorpiops demisi Kovařík, 2005	F	6.00	7	7	7
Scorpiops dentidactylus Lourenço et Pham, 2015	M	4.60	7	7	7
Scorpiops farkaci Kovařík, 1993	M	4.45	7	7	7
	F	4.60	6	6	6
Scorpiops feti Kovařík, 2000	M	7.30	8	8	8
	F	7.20	7	7	7
Scorpiops hardwickii (Gervais, 1843)	M	4.60	6	7	6.5
	F	6.7	5	6	5.5
Scorpiops sp. (*hardwickii* "complex") Di et al., 2011	M	7.25	6	9	7.5
	F	7.83	6	8	7
Scorpiops ingens Yin, Zhang, Pan, Li et Di, 2015	M	8.70	7	7	7
	F	9.60	6	6	6
Scorpiops irenae Kovařík, 1994	F	7.30	5	6	5.5
Scorpiops jendeki Kovařík, 1994	M	4.50	5	5	5
	F	5.10	4	5	4.5
Scorpiops kraepelini Lourenço, 1998	M	5.40	9	9	9
	F	5.60	7	7	7
Scorpiops langxian Qi, Zhu et Lourenço, 2005	M	6.76	8	8	8
	F	7.27	6	6	6
Scorpiops leptochirus Pocock, 1893	M	6.30	7	9	8
	F	6.60	7	7	7
Scorpiops lhasa Di & Zhu, 2009	M	5.6	10	11	10.5
	F	5.5	9	9	9
Scorpiops lindbergi (Vachon, 1980)	M	5.40	9	9	9
	F	5.40	6	8	7
Scorpiops luridus Qi, Zhu et Lourenço, 2005	M	11.73	10	10	10
	F	10.20	8	8	8

Scorpiops margerisonae Kovařík, 2000	M	7.10	9	12	10.5
	F	7.10	8	10	9
Scorpiops pachmarhicus Bastawade, 1992	F	5.25	6	6	6
Scorpiops pakistanus Kovařík et Ahmed, 2009	M	10.20	8	8	8
	F	10.10	6	7	6.5
Scorpiops petersii Pocock, 1893	M	8.80	5	8	6.5
	F	8.30	7	7	7
Scorpiops pococki Qi, Zhu et Lourenço, 2005	M	6.89	7	8	7.5
	F	8.16	6	6	6
Scorpiops pseudomontanus Kovařík et Ahmed, 2009	M	9.10	6	7	6.5
	F	8.00	7	7	7
Scorpiops rohtangensis Mani, 1959	M	5.25	5	6	5.5
Scorpiops spitiensis Zambre, Sanap et Mirza, 2014	M	6.23	5	6	5.5
	F	5.13	5	6	5.5
Scorpiops tibetanus Hirst, 1911	M	7.50	7	10	8.5
	F	7.50	7	10	8.5
Scorpiops zubairahmedi Kovařík, 2009	M	7.80	6	6	6
Troglocormus ciego Francke, 1982	M	8.00	11	12	11.5
Troglocormus willis Francke, 1982	M	9.10	10	11	10.5
	F	10.40	9	9	9

Table A2: Data compiled from published literature on carapace length (mm) and pectinal tooth count (PTC) ranges (PTC min = minimum, PTC max = maximum) in males (M) and females (F) of presumed adults of all known species of the euscorpiiid subfamily Scorpiopinae. PTC mid = midpoint value (obtained by averaging the minimum and maximum values). In some cases, two adult carapace lengths were available and the mean value was computed.