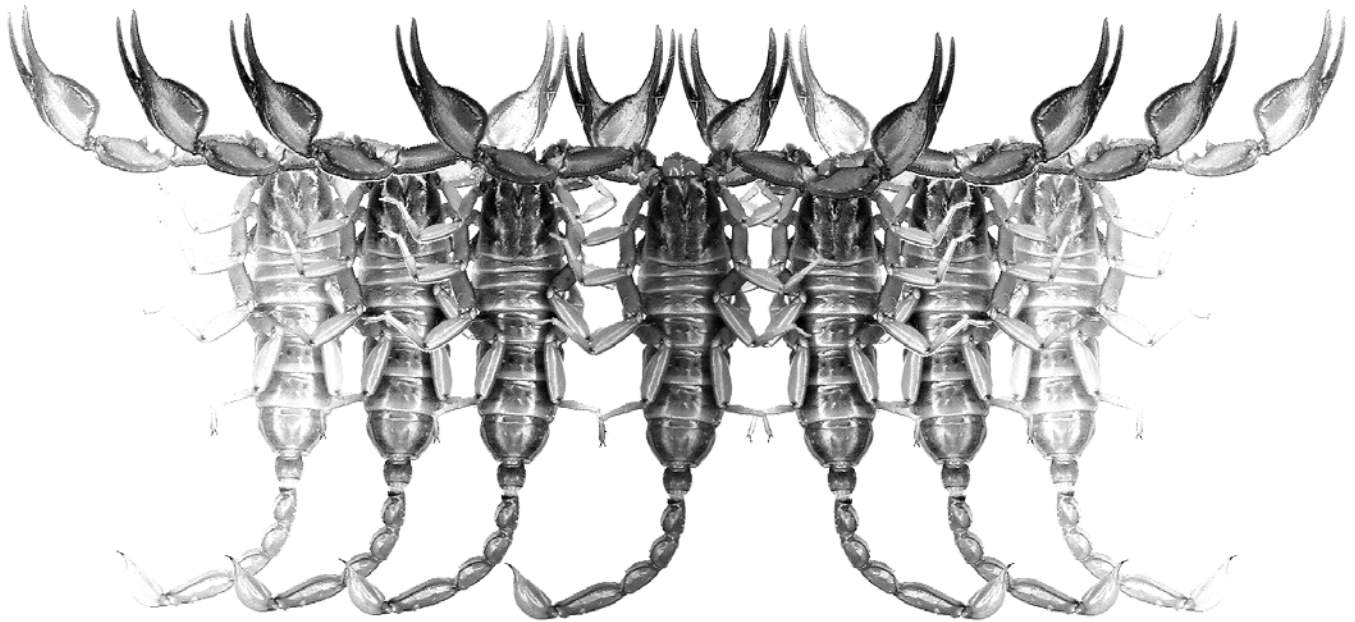


Euscorpilus

Occasional Publications in Scorpiology



**A New *Vaejovis* from the Mogollon Highlands of
Northern Arizona (Scorpiones: Vaejoidea)**

Richard F. Ayrey

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A new *Vaejovis* from the Mogollon Highlands of northern Arizona (Scorpiones: Vaejovidae)

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Summary

A new scorpion species, *Vaejovis halli* sp. nov., is described. This relatively small, brown new species is found on Mount Ord in the Mazatzal Mountains along the Mogollon Rim of northern Arizona. The new species appears most similar to *V. vorhiesi* Stahnke and *V. deboerae* Ayrey. The most distinguishing characteristic of this new species is the number of inner denticles (ID) found on the pedipalp fingers with six on the movable finger and usually five on the fixed finger, which more closely correlates with *Vaejovis* species from the mountains of southern Arizona rather than those geographically closer in northern Arizona.

Introduction

Recent work by myself (Ayrey, 2009 and Ayrey & Soleglad, 2011) and my colleagues (Soleglad, 1973; Graham, 2007; Hughes, 2011; and Sissom et al. 2012) suggest that what was once considered a single widespread species, *V. vorhiesi* (Stahnke, 1940), actually constitutes an astoundingly diverse assemblage of cryptic species. These scorpions, the *Vaejovis* “*vorhiesi*” group, also known as “sky island” *Vaejovis* (Graham, 2007), all inhabit similar habitats, generally high elevation (2000 m or above) forests dominated by Ponderosa Pine. Herein, I describe another new species in the “*vorhiesi*” group that was first discovered by my colleague, Darrel Crump, and reported to me by James Hall, during one of our numerous surveys of Mount Ord, a sky island in the Mogollon Highlands of northern Arizona. This discovery brings the total number of “*vorhiesi*” group scorpions, in Arizona, to ten.

Initially, these species were placed in the “*mexicanus*” group of *Vaejovis* but it is now clear that the original definition of the “*mexicanus*” group (Soleglad, 1973) must be redefined based solely on *V. mexicanus*, the type species of the genus (Ayrey & Soleglad, 2011: 1–2). The “*vorhiesi*” group, as originally referred to by Soleglad & Fet (2008: 46), is a more appropriate informal designation for the sky island species of Arizona.

More research needs to be done on how and why this large amount of diversity has occurred in such a small geographic area. Of two other states where “sky

island” scorpion species are found (New Mexico and Sonora, Mexico), each has only two described species.

Materials and Methods

Terminology and conventions

The systematics adhered to in this paper follows the classification as established in Fet & Soleglad (2005) and as modified by Soleglad & Fet (2006), Graham & Soleglad (2007), Fet & Soleglad (2007), Soleglad et al. (2007), and Soleglad & Fet (2008). Measurements are as described in Stahnke (1970), trichobothrial patterns are as in Vachon (1974), and pedipalp finger dentition follows Soleglad & Sissom (2001).

Abbreviations

MES, personal collection of Michael E. Soleglad, Borrego Springs, California, USA; RFA, personal collection of Richard F. Ayrey, Flagstaff, Arizona, USA; USNM, Smithsonian Institution, Washington, DC.

Material

Besides type material listed below under new species description, the following additional specimens were examined:

Arizona: *Vaejovis cashi* Graham, 2007. 6 males, 8 females, Chiricahua Mountains, Cochise Co., (RFA);



Figure 1: *Vaejovis halli* sp. nov. Holotype female in natural habitat.

Vaejovis crumpi Ayrey et Soleglad, 2011. 4 males and 8 females, topotypes, Prescott, Yavapai Co., (RFA); *Vaejovis deboerae* Ayrey, 2009. 6 males, 21 females, topotypes, Santa Catalina Mountains, Pima Co., (RFA); *Vaejovis electrum* Hughes, 2011. 4 males and 8 females, topotypes, Mt Graham, Graham Co., (RFA); *Vaejovis jonesi* Stahnke, 1940. 1 female, topotype, northeast of Flagstaff, Coconino Co., (RFA); *Vaejovis lapidicola* Stahnke, 1940. 1 male, 8 females, topotypes, Flagstaff, Coconino Co., (RFA); *Vaejovis paysonensis* Soleglad, 1973. 2 males, 16 females, Mogollon Rim, Coconino Co. (RFA); *Vaejovis tenuipalpus* Sissom et al., 2012. 2 males, 8 females, Getz Peak, Hualapai Mountains, Mojave Co., (RFA); *Vaejovis vorhiesi* Stahnke, 1940. 2 males, 13 females, topotypes, Miller Canyon, Huachuca Mountains, Cochise Co., (RFA); 4 males, 6 females, Garden Canyon, Huachuca Mountains, Cochise Co., (RFA); 1 male, 2 females, Lutz Canyon, Huachuca Mountains, Cochise Co., (RFA).

New Mexico: *Vaejovis feti* Graham, 2007. 4 males, 3 females, Meadow Creek, Black Mountains, Grant Co., (MES).

Systematics

Order **SCORPIONES** C. L. Koch, 1850
Suborder Neoscorpiones Thorell et Lindström, 1885

Infraorder Orthosterni Pocock, 1911
Parvorder Iurida Soleglad et Fet, 2003
Superfamily Chactoidea Pocock, 1893
Family Vaejovidae Thorell, 1876
Subfamily Vaejovinae Thorell, 1876

Vaejovis halli Ayrey, sp. nov.

Figures 1–11, 13–15; Tables 1–2

Diagnosis. Small (21.5mm) scorpions. Color is brown, lighter on the legs, with underlying mottling on carapace and mesosoma. (see Figure 1). Pedipalp movable finger with six ID denticles and five on the fixed finger. Carapace of female is slightly shorter than the fifth metasomal segment. Pectinal tooth count for females 11.94 [n=16], males 13.81 [n=16]. Ratio of female pectinal tooth count to total length 0.53. Small, spinoid subaculear tubercle. Characters in which *V. halli* differs from the other sky island *Vaejovis* are outlined below.

Type material. Holotype female, Mount Ord, Gila County, Arizona, USA, 11 September 2010 (R. F. Ayrey leg.), specimen #343, deposited in USNM. Two paratype males, Mount Ord, Gila County, Arizona, USA, 11 September 2010 (R.F. Ayrey leg.), specimen numbers 340 and 267 (RFA); two paratype females, Mount Ord, Gila County, Arizona, USA, 2 May 2011 (R.F. Ayrey leg.), specimen numbers 393 and 398 (RFA).



Figures 2–3: *Vaejovis halli*, sp. nov. 2. Holotype female ventral and dorsal views. 3. Paratype male dorsal view.

<i>Vaejovis halli</i> , sp. nov.					
	Male paratype	Male paratype	Female holotype	Female paratype	Female paratype
Total length	22.06	20.32	22.05	23.43	21.87
Carapace length	2.72	2.49	2.90	3.18	3.04
Mesosoma length	7.16	5.54	7.21	7.12	6.24
Metasoma length	9.56	9.69	9.34	10.17	9.68
Segment I length/width	1.32/1.76	1.41/1.59	1.31/1.70	1.40/1.99	1.32/1.82
Segment II length/width	1.48/1.50	1.47/1.52	1.41/1.62	1.56/1.97	1.49/1.71
Segment III length/width	1.56/1.47	1.64/1.49	1.53/1.56	1.72/1.83	1.60/1.60
Segment IV length/width	2.19/1.38	2.21/1.39	2.12/1.41	2.28/1.79	2.21/1.59
Segment V length/width	3.01/1.38	2.96/1.44	2.97/1.41	3.21/1.79	3.06/1.53
Telson length	2.62	2.60	2.60	2.96	2.91
Vesicle length	1.75	1.62	1.68	1.90	1.81
width/depth	0.81/0.83	0.79/0.75	0.98/0.83	1.13/0.86	0.98/0.84
Aculeus length	0.87	0.98	0.92	1.06	1.10
Pedipalp length	8.80	8.70	9.24	10.24	9.58
Femur length/width	2.32/0.69	2.21/0.69	2.20/0.66	2.52/0.89	2.36/0.71
Patella length/width	2.55/0.78	2.62/0.76	2.76/0.76	3.01/1.04	2.86/0.84
Chela length	3.93	3.87	4.28	4.68	4.36
Palm length	1.71	1.78	1.87	2.13	1.82
width/depth	0.81/0.80	0.78/0.78	0.94/0.93	1.08/1.08	0.91/0.91
Fixed finger length	1.96	2.03	2.12	2.13	2.33
Movable finger length	2.31	2.32	2.41	2.54	2.66
Pectines teeth	14-14	14-14	12-12	13-13	11-11

Table 1: Morphometrics (mm) of *Vaejovis halli*, sp. nov., Mt. Ord, Gila Co., Arizona, USA.

Etymology. This species was named in honor of James Hall for his help in finding the scorpions.

Distribution. Known only from the type locality, Mount Ord, Gila County, Arizona, USA.

Description. Based on holotype female, see Figure 2 for dorsal and ventral views.

Color. Color is brown, lighter on the legs. Underlying dark brown mottling found on the carapace and mesosoma, faint on the legs and pedipalps.

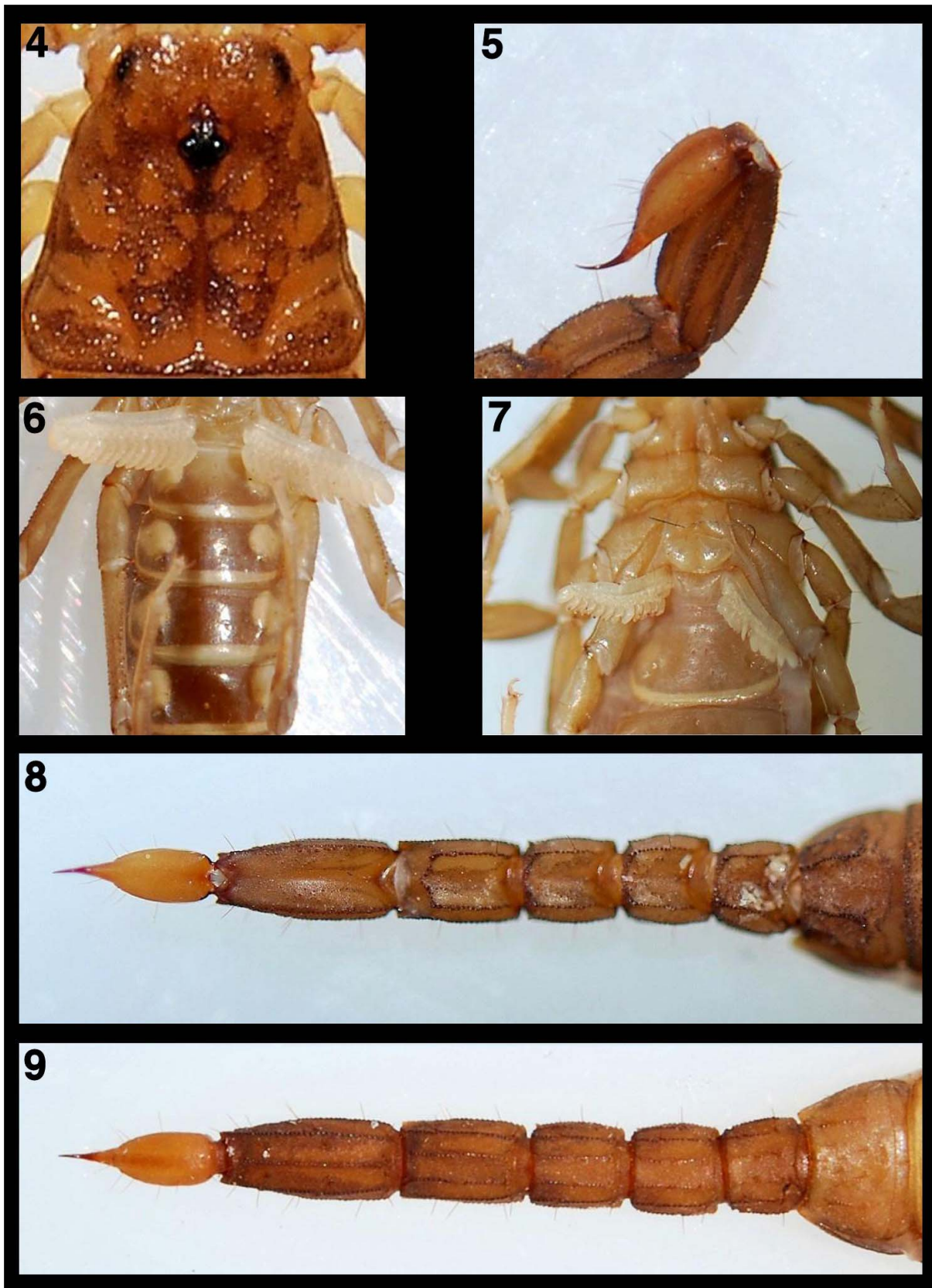
Carapace (Fig. 4). Anterior margin of carapace moderately emarginated, posterior margin straight. Carapace moderately granular. Three lateral eyes on each side. Median furrow moderate and traverses entire length of carapace. Ratio of median eyes location from anterior edge/carapace length 0.32; carapace length/width at median eyes 1.31. Carapace is only slightly shorter than metasomal segment V.

Mesosoma. Tergites moderately granular with vestigial median carina on Tergites I–VI. Tergite VII with weak median carina on anterior third and strong dorsal lateral and lateral suprmedian granular carinae. Sternites III–VI finely granular and without carinae. Sternite VII with granular ventral lateral carinae on middle third. Pre-sternites smooth. Spiracles ovoid with median side rotated 35 degrees from posterior sternite margin. Sternites with variable number of microsetae.

Sternum (Figs. 6, 7). Sternum is type 2.

Genital Operculum (Figs. 6, 7). Sclerites separated on posterior one-fifth.

Pectines (Figs. 6, 7). Pectinal tooth counts 11–13 (11.94) (± 0.66) [$n=16$] for females and 13–15 (13.81) (± 0.57) [$n=16$] for males. All pectinal teeth have extero-distal angling with large sensorial areas. Middle lamellae 7/7. Fulcra are present. Each fulcra with one to three central setae.



Figures 4-9: *Vaejovis halli*, sp. nov. 4, 5, 7-9, holotype female. 4. Carapace. 5. Telson. 6. Paratype male, pectines and sternites; 7. Pectines and sternites. 8, 9. Metasoma and telson, dorsal and ventral views.

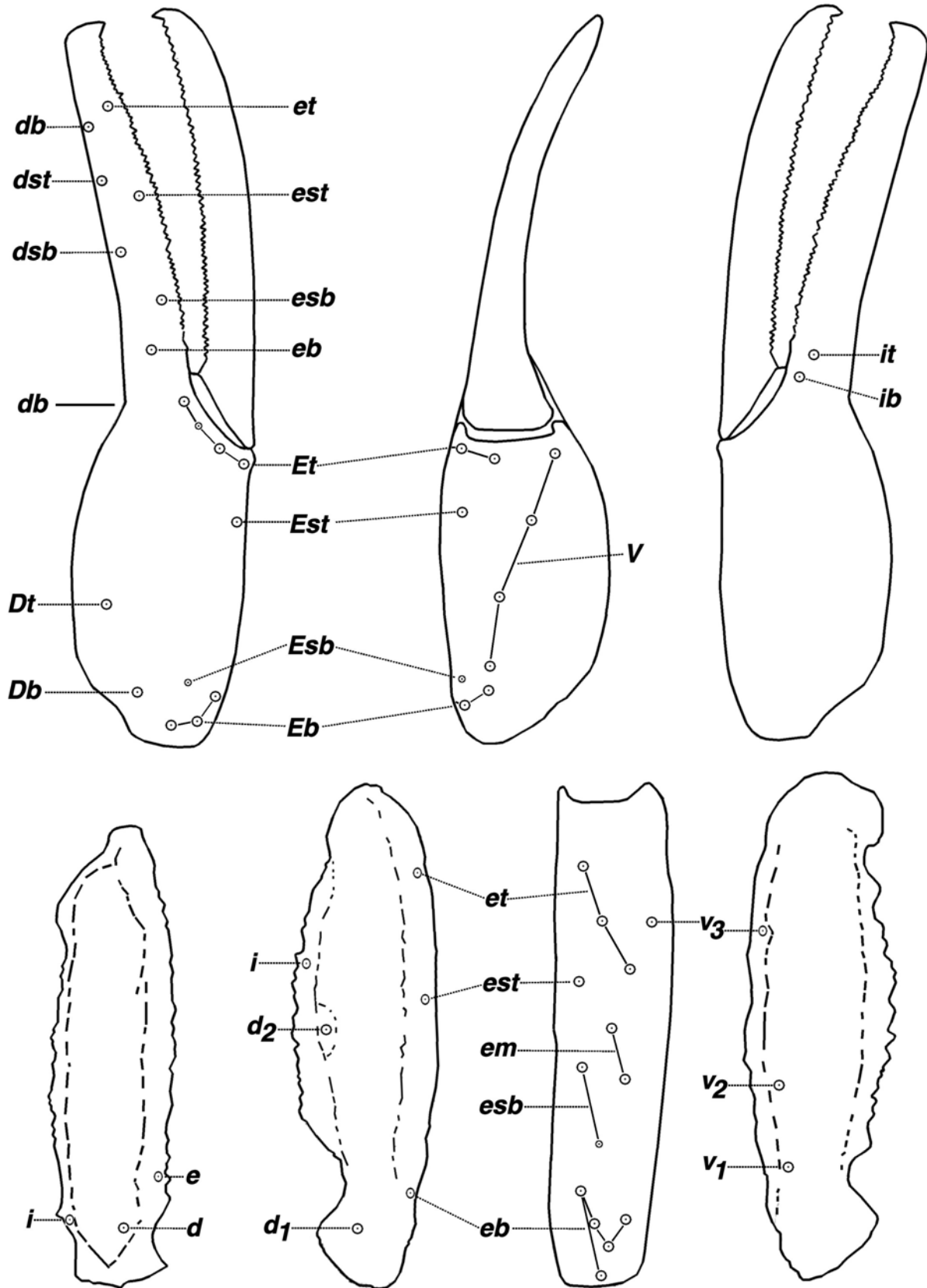


Figure 10: *Vaejovis halli*, sp. nov. Female holotype trichobothrial pattern.



Figure 11: *Vaejovis halli*, sp. nov., male paratype. Right hemispermaphore (submerged in alcohol). **Left.** Dorsal view showing the short bifurcated lamellar hook emanating from the dorsal trough and the distal lamellar crest. **Top Right.** Close-up of lamellar hook. **Bottom Right.** Mating plug, dorsal view, showing the slightly sclerotized smooth barb (from left hemispermaphore, reversed in image).

Metasoma (Figs. 8, 9). Carapace of female is only slightly shorter than the fifth metasomal segment. Ratio of segment I length/width 0.77; of segment II length/width 0.87; of segment III length/width 1.05; of segment IV length/width 1.50; of segment V length/width 2.11. Segments I–IV: dorsolateral carinae strong and granular with distal denticle of I–IV enlarged and spinoid. Lateral supramedian carinae I–IV strong and granular with enlarged spinoid distal denticle. Lateral inframedian carinae moderately granular on segment I, posterior 4/5 of II, 4/5 of III, and weak on 2/5 of IV. Ventrolateral carinae I weak and granular; on II–III moderate, granular; on IV strong, granular. Ventral submedian carinae weak on segment I, weak to moderate on II, moderate, granular on III and IV. Dorsal and lateral intercarinal spaces very finely granular. Segment I–IV ventral submedian setae 3/3. Segment V: Dorsolateral carinae moderate, distally crenulate, basally granular. Lateromedian carinae weak and granular on basal 3/5, obsolete on distal 2/5. Ventrolateral and ventromedian carinae strong. Intercarinal spaces finely granular. Segment V ventrolateral setae 4/4.

Telson (Figs. 5, 8, 9). Smooth with four pairs of large setae on the ventral surface, three large setae along both lateral edges of the vesicle and numerous smaller setae. Small, spinoid subaculear tubercle present.

Chelicerae. Dorsal edge of movable cheliceral finger with two subdistal (sd) denticles. Ventral edge is smooth, with well developed serrula on distal half.

Pedipalp (Fig. 10). Trichobothrial pattern: orthobothriotaxic type C (see Figure 10). Trichobothria *ib* and *it* at base of fixed finger. Pedipalp ratios: chela length/width 4.55; femur length/width 3.33; patella length/width 3.63; fixed finger length/carapace length 0.73. **Chela.** Carinae moderate. Fixed finger median denticles (MD) aligned and divided into six subrows by five outer (OD) denticles and usually five ID denticles. Movable finger with six subrows, five OD denticles and six ID denticles. **Femur.** Carinae moderate. **Patella.** Carinae strong, internal surface with very large granules on the *DPSc* carina.



Figure 12: *Vaejovis halli* sp. nov. female, on Mt. Ord at night near potential prey.



Figure 13: *Vaejovis halli* sp. nov. female with first instar juveniles.



Figure 14: *Vaejovis halli* sp. nov. habitat.

Hemispermatothore (Fig. 11, paratype male). Both left and right hemispermatothores were extracted from a paratype male and both had a sclerotized mating plug. The right hemispermatothore is 3.45 mm in length and its lamina 1.94 mm. The hemispermatothore is lightly sclerotized particularly in the trough area. On the dorsal surface a subtle distal crest is present on the inner distal aspect of the lamella. The lamellar hook, which is highly sclerotized and widely bifurcated, is quite short, emanating entirely from the dorsal trough. The shortness of the lamellar hook is also indicated by comparing its length to the lamellar length, a ratio value of 0.274. A medium truncal flexure is visible on the external aspect of the trunk/lamina juncture. A very small slightly sclerotized mating plug was located on the ventro-internal surface, just below the ventral trough, embedded in the soft material of the trunk. Its stock is somewhat thick and the barb's ventral edge is *smooth*. Its base is wide and irregularly shaped (partially visible in Fig. 11).

Legs. Ventral surface of tarsomere II with single median row of spinules terminating distally with one spinule pair.

Variability. Variability of fixed finger ID denticle count was noted in *V. halli* as well as several other species of

Vaejovis. For *V. halli* the counts were 6 (n=2) and 5 (n=18), for *V. vorhiesi* 6 (n=2) and 5 (n=10), for *V. cashi* 6 (n=2) and 5 (n=10), for *V. feti* 6 (n=4) and 5 (n=8), for *V. deboerae* 6 (n=6) and 5 (n=6).

Reproduction. Several females were kept alive in the laboratory in order to observe them giving birth and to count the number of first instar juveniles (see Figure 13). All four females gave birth in the first week of August, 2011. The juvenile count was 20.50 (n=4). The first instar orientation on the mother's back was non-random, as is seen with many other species of *Vaejovis* (Hjelle, 1974). They were facing anteriorly with the prosoma down and the metasoma raised over the prosoma of the juvenile immediately posterior to them.

Type Locality Description. The type specimens were found, using a blacklight at night, on Mount Ord, Gila County, Arizona (33°55.606'N, 111°24.343'W) at an elevation of 1780 m asl. The vegetation type is mesic Ponderosa pine and mixed evergreen oak woodland (see Fig. 14). No other scorpions were found sympatrically with *V. halli* during seven field trips to Mt. Ord.

Comparison of Species

Map in Fig. 15 shows the type localities of the eleven currently described species of *Vaejovis* from

Morphometric Ratio	Species	Statistical Range min-max (mean) (\pm SDEV) [N] {STD-ERROR Range}	MVD %
<i>V. fети</i>			
FixF_L/Che_W: ♂ ♂ ♀ ♀	<i>V. halli</i> :	2.42–2.60 (2.511) (\pm 0.129) [002] {2.38–2.64}	> 53.0 %
	<i>V. fети</i> :	1.61–1.67 (1.641) (\pm 0.046) [002] {1.59–1.69}	
	<i>V. halli</i> :	1.97–2.56 (2.263) (\pm 0.294) [003] {1.97–2.56}	> 22.8 %
	<i>V. fети</i> :	1.80–1.94 (1.843) (\pm 0.080) [003] {1.76–1.92}	
FixF_L/Che_D: ♂ ♂ ♀ ♀	<i>V. halli</i> :	2.45–2.60 (2.526) (\pm 0.108) [002] {2.42–2.63}	> 41.0 %
	<i>V. fети</i> :	1.77–1.81 (1.792) (\pm 0.031) [002] {1.76–1.82}	
	<i>V. halli</i> :	1.97–2.56 (2.271) (\pm 0.294) [003] {1.98–2.56}	> 18.5 %
	<i>V. fети</i> :	1.86–2.02 (1.916) (\pm 0.088) [003] {1.83–2.00}	
<i>V. vorhiesi</i>			
Che_D/Che_L: ♂ ♂ ♀ ♀	<i>V. halli</i> :	0.20–0.20 (0.203) (\pm 0.001) [002] {0.20–0.20}	> 18.0 %
	<i>V. vorhiesi</i> :	0.16–0.18 (0.172) (\pm 0.016) [002] {0.16–0.19}	
	<i>V. halli</i> :	0.21–0.23 (0.219) (\pm 0.011) [003] {0.21–0.23}	> 21.3 %
	<i>V. vorhiesi</i> :	0.17–0.19 (0.180) (\pm 0.007) [003] {0.17–0.19}	
<i>V. cashi</i>			
FixF_L/Che_W: ♂ ♂ ♀ ♀	<i>V. halli</i> :	2.42–2.60 (2.511) (\pm 0.129) [002] {2.38–2.64}	> 34.4 %
	<i>V. cashi</i> :	1.75–1.99 (1.868) (\pm 0.167) [002] {1.70–2.04}	
	<i>V. halli</i> :	1.97–2.56 (2.263) (\pm 0.294) [003] {1.97–2.56}	> 12.5 %
	<i>V. cashi</i> :	1.82–2.24 (2.011) (\pm 0.212) [003] {1.80–2.22}	
<i>V. electrum</i>			
FixF_L/Che_W: ♂ ♂ ♀ ♀	<i>V. halli</i> :	2.42–2.60 (2.511) (\pm 0.129) [002] {2.38–2.64}	> 19.2 %
	<i>V. electrum</i> :	1.95–2.26 (2.106) (\pm 0.220) [002] {1.89–2.33}	
	<i>V. halli</i> :	1.97–2.56 (2.263) (\pm 0.294) [003] {1.97–2.56}	> 14.8 %
	<i>V. electrum</i> :	1.92–2.02 (1.971) (\pm 0.051) [003] {1.92–2.02}	
Palm_L/Che_W: ♂ ♂ ♀ ♀	<i>V. halli</i> :	2.11–2.28 (2.197) (\pm 0.121) [002] {2.08–2.32}	> 28.5 %
	<i>V. electrum</i> :	1.59–1.83 (1.710) (\pm 0.163) [002] {1.55–1.87}	
	<i>V. halli</i> :	1.97–2.00 (1.987) (\pm 0.014) [003] {1.97–2.00}	> 16.9 %
	<i>V. electrum</i> :	1.61–1.76 (1.699) (\pm 0.077) [003] {1.62–1.78}	

Table 2: Pedipalp chelal morphometric ratio comparisons of *Vaejovis halli*, sp. nov. with other select Arizona *Vaejovis* species. MVD = mean value difference. FixF_L = fixed finger length, Che_D = chela depth; Che_L = chela length, Che_W = chela width, Palm_L = palm length.

Arizona and western New Mexico. Comparisons of *V. halli* to each of these species are provided below. Much of the morphometric comparisons discussed below are also shown in Table 2.

Vaejovis jonesi, *V. lapidicola*, *V. paysonensis*, *V. crumpi* and *V. bigelowi*: These species all usually exhibit seven inner denticles (ID) on the chela movable finger, commonly found in genus *Vaejovis*, not the reduced number six which is found on the “sky island” species of southern Arizona and *V. halli*.

Vaejovis tenuipalpus: This species has 6 ID denticles on both the fixed and movable fingers while *V. halli* has 5 ID denticles on the fixed finger. Female FF

L/ Carapace L 0.81–0.89 (Sissom et al., 2012) versus 0.67–0.77 for *V. halli* and female Chela L/W 5.00–5.39 (Sissom et al., 2012) versus 4.33–4.79.

Vaejovis vorhiesi: In *V. halli*, the depth of the chela dominates in the ratio calculations, when compared to *V. vorhiesi*. MVD ranges 18% to 21.3 % and separation is present, this is the only case, of the species examined, that the chela is not thinner in *V. halli* (see Table 2.). Carapace of female *V. halli* is slightly shorter than metasomal segment V, while in *V. vorhiesi* it is often longer than segment V. Female pectinal tooth counts for *V. halli* are 11.94 [n=16] versus 12.87 (n=339) (Hughes, 2011), male counts 13.81 [n=16] versus 14.99(n=104)

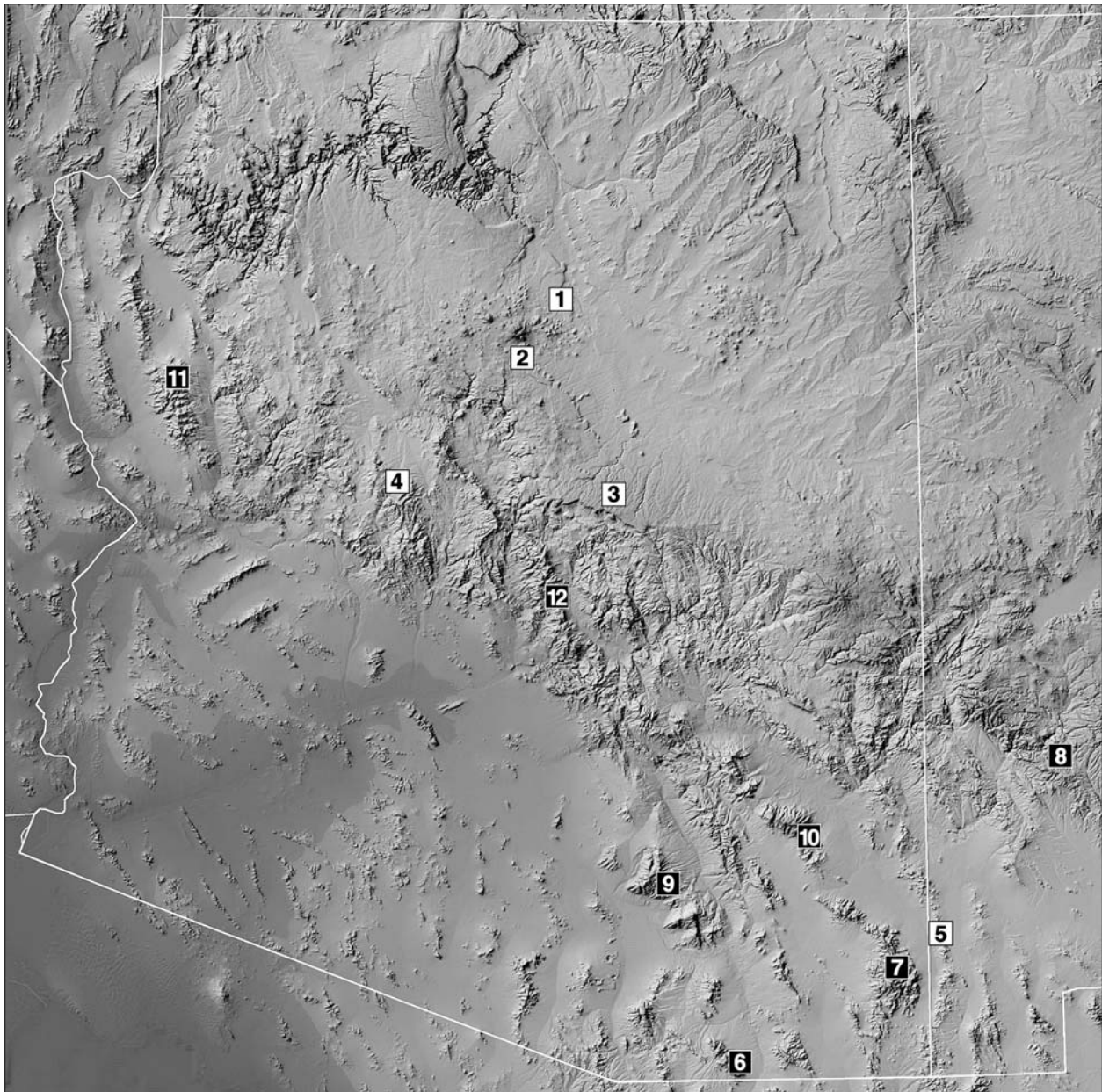


Figure 15: Map of Arizona and extreme western New Mexico showing the *type locality* of the twelve *Vaejovis* species discussed in this paper, including new species *Vaejovis halli*. Localities are divided into those species exhibiting seven inner denticles (*ID*) on the chelal movable finger (white rectangles with black lettering) and those with primarily six *ID* denticles (black rectangles with white lettering). **Seven *IDs*:** 1 = *V. jonesi*, 2 = *V. lapidicola*, 3 = *V. paysonensis*, 4 = *V. crumpi*, 5 = *V. bigelowi*. **Six *IDs*:** 6 = *V. vorhiesi*, 7 = *V. cashi*, 8 = *V. feti*, 9 = *V. deboerae*, 10 = *V. electrum*, 11 = *V. tenuipalpus*, and 12 = *V. halli*, *sp. nov.*

(Hughes, 2011) for *V. vorhiesi*. *V. halli* is also widely allopatric with *V. vorhiesi*.

***Vaejovis cashi*:** The first three metasomal segments in *V. halli* are thinner than in *V. cashi*, especially in the male: 17.1 to 22.3 MVD, male; 7.8 to 15.5 MVD, female. The chelal palm is also thinner, showing a 12.5% to 34.4 % MVD difference, there is significant ratio overlap in the female (see Table 2.) *V. halli* can be separated from *V. cashi* by having a single, relatively

small subaculear tubercle versus the frequent multiple subaculear tubercles of the latter (Hughes, 2011). Female pectinal tooth counts for *V. halli* *sp. nov.* are 11.94 [n=16] versus 10.98 (n=337) (Hughes, 2011), male counts 13.81 [n=16] versus 13.07(n=319)(Hughes, 2011) for *V. cashi*. *V. halli* is also widely allopatric with *V. cashi*.

***Vaejovis feti*:** Thinner chela in *V. halli* than in *V. feti*, shown by both the palm width and depth, MVD

ranges from 18.5% to 53 %, and standard error separation exhibited in two of the three ratios (see Table 2.). Female pectinal tooth counts for *V. halli* sp. nov. are 11.94 [n=16] versus 10.00 [n=6], male counts 13.81 [n=16] versus 11.00 [n=6] for *V. feti*. *V. halli* is also widely allopatric with *V. feti*.

***Vaejovis deboerae*:** *V. halli* can be separated from *V. deboerae* by size with female *V. deboerae* 41% larger than female *V. halli* and female *V. deboerae* carapace length being 36% longer. A similar but less dramatic size difference is seen in the males. *V. halli* can also be separated from *V. deboerae* by the lack of a “whitish patch” on the male sternite V (see Fig. 7); the relatively small subaculear tubercle versus the well developed subaculear tubercle of the latter. *V. halli* is also widely allopatric with *V. deboerae*.

***Vaejovis electrum*:** As in other cases above, the chela of *V. halli* is thinner than in *V. electrum* when the palm width is compared to the fixed finger length and the palm length. We see 14.8% to 28.5 % MVD, with three out of four showing separation of the standard error range (see Table 2.). *V. halli* can be separated from *V. electrum* by having a relatively small subaculear tubercle versus the well developed and frequently multiple subaculear tubercle of the latter (Hughes, 2011). Female pectinal tooth counts for *V. halli* sp. nov. are 11.94 [16] versus 11.75 (96) (Hughes, 2011), male counts 13.81 [16] versus 13.11(36) (Hughes, 2011) for *V. electrum*. *V. halli* is also widely allopatric with *V. electrum*.

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