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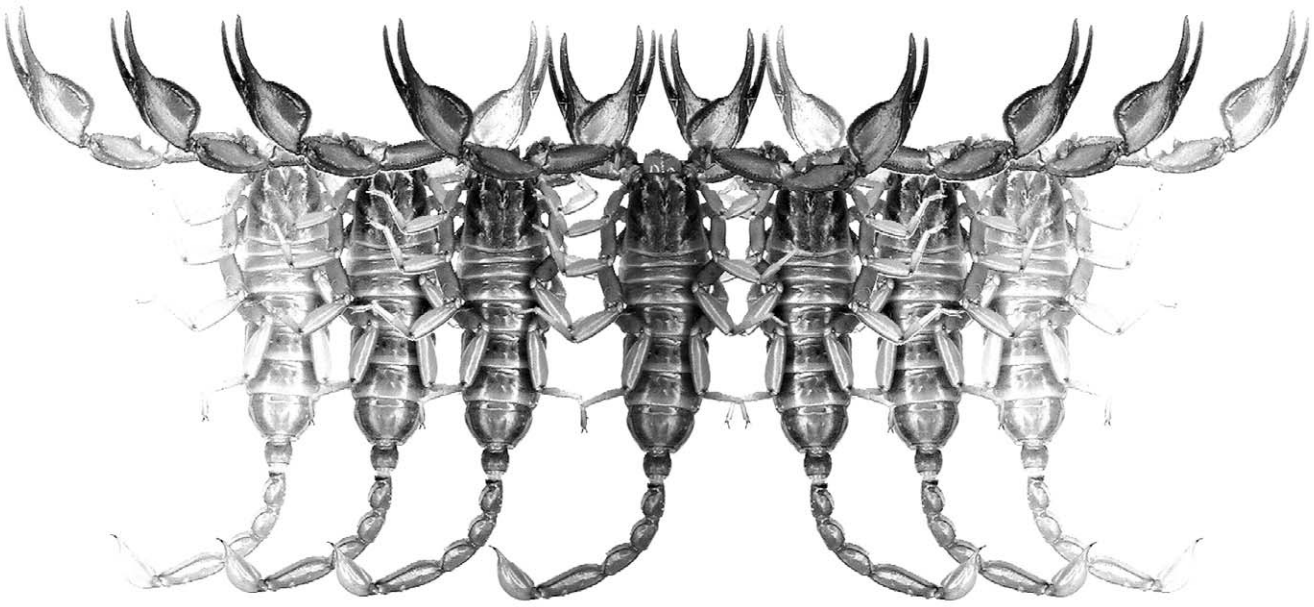

The Second Record of a Relict *Akrav israchanani* Levy, 2007 (Scorpiones: Akravidae) from Levana Cave, Israel

Victor Fet, Michael E. Soleglad, Sergei L. Zonstein, Israel Naaman, Shlomi Lubaton, Boaz Langford & Amos Frumkin

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The second record of a relict *Akrav israchanani* Levy, 2007 (Scorpiones: Akravidae) from Levana Cave, Israel

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Summary

We report the remnants of five new scorpion specimens discovered dead in Levana Cave in Israel in December 2015. We confirm that they belong to the relict scorpion *Akrav israchanani* Levy, 2007 (Akravidae), famously described from the neighboring Ayyalon Cave, also from dead specimens. The details of morphology of the new specimens are given; they match completely the characters of *A. israchanani* redescribed by Fet, Soleglad & Zonstein (2011). This second record indicates a wider distribution of this unique cave scorpion, which, however, is extinct in both caves. There is still no evidence that live populations of this species exist.

Introduction

A relict, blind scorpion *Akrav israchanani* was described from Ayyalon Cave in central Israel by Gershom Levy (2007) and placed in a separate monotypic chactoid family Akravidae Levy, 2007. All scorpions found in this cave (20 specimens) were dead, represented by exoskeletons but extremely well preserved, and fluorescent under UV light. Time and cause of death are unknown; there is no evidence of fossilization.

Fet, Soleglad & Zonstein (2011) revised Levy's specimens describing and illustrating many morphological characters in detail. In particular, the monotypy of Akravidae was challenged and affinities to the New World family Typhlochactidae was demonstrated. A combination of scorpion's ecological adaptations and trophic chains of the Ayyalon Cave implied that this scorpion might have survived on aquatic (crustacean) prey. All of specimens were originally collected as dried, dead skins (not exuvia); no live scorpions have been found. For much more detail, see Fet, Soleglad & Zonstein (2011).

In December 2015, five new dead specimens were discovered in a separate cave, located very close (350 m) to the Ayyalon Cave. We studied these remnants and conclude that they belong to the same species. This second record shows that the population of *Akrav israchanani* was not limited to Ayyalon Cave. There is still no evidence that live scorpions of this species exist.

The Levana Cave and its Scorpions

Levana Cave is located 350 m ENE of Ayyalon Cave, sharing a similar setting: Turonian B'ina Formation, within the Ayyalon salinity anomaly of Yarkon-Taninim aquifer, at the watertable and above it. Levana Cave was breached by Nesher quarry in 2015 (Frumkin & Naaman, 2015).

Levana Cave is 493 m long (Fig. 1). Its major passage is 140 m long generally sloping to SW towards the watertable, meeting it at several points. Its common width is between 2–15 m, and height is commonly between 1–10 m. The present watertable of the Yarkon-Taninim aquifer appears at several points in the cave, and the water depths reaches 2 m (Fig. 2). The water is partly covered by a bacterial mat serving as the base of the chemoautotrophic ecosystem (Por et al., 2016). In addition to the main passage, the NE part of the cave is a 3-dimensional maze of narrow passages and shafts. The

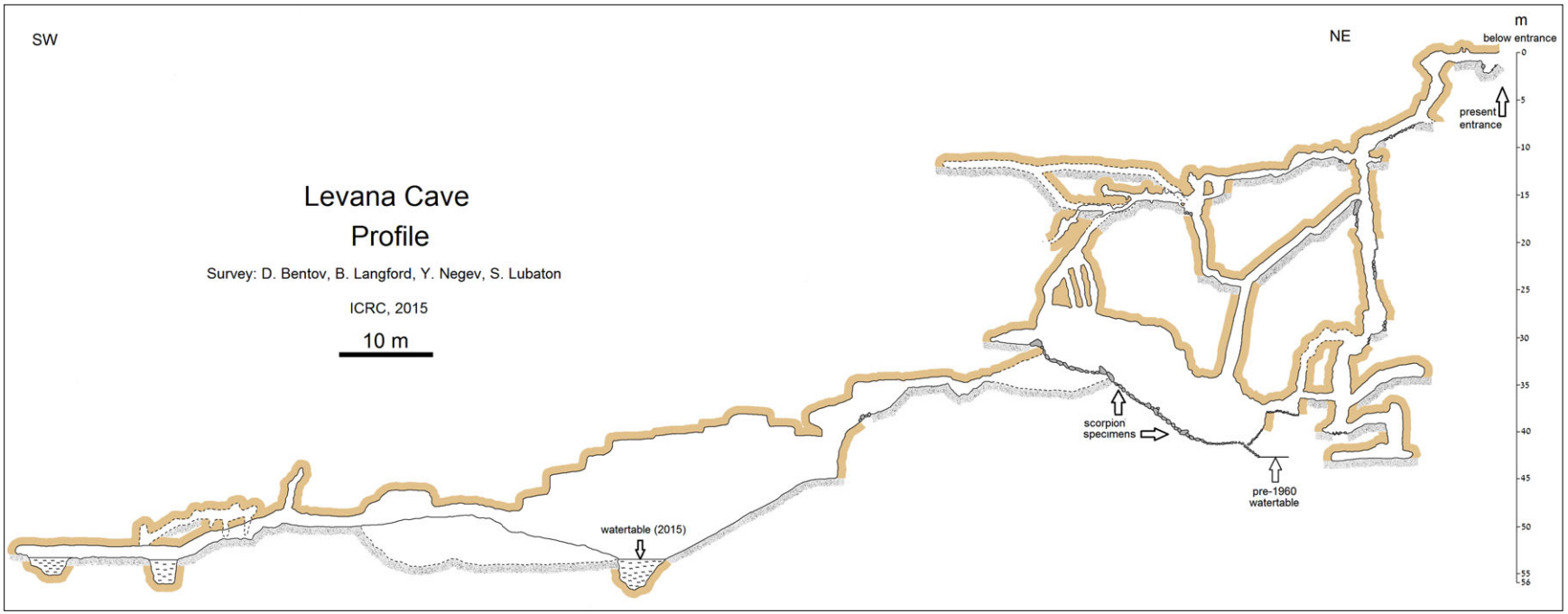

Figure 1: Levana Cave profile with location of scorpion specimens. Surveyed by Israel Cave Research Center, 2015.

Figure 2: Levana Cave. **Top,** The scorpion chamber in Levana Cave. Scorpion specimens were found on and between boulders. **Bottom,** Watertable of Levana Cave in 2015, with bacterial mat serving as the base of the chemoautotrophic ecosystem. Photographs: Amos Frumkin.

presently accessible entrance is located at the upper part of this maze.

The dead scorpion specimens, fluorescent under UV light (Fig. 3), were found in partially articulated condition, on and between dry rocks of a talus slope, within the northern part of the major passage, 26–30 m above sea level (Figs. 1–2). This corresponds to a few meters above the pre-1960 watertable (~24 m asl), before modern pumping has lowered the water level in the aquifer and the cave (Frumkin & Gvirtzman, 2006). The

Figure 3: *Akrav israchanani.* **Top,** Scorpion as found at Levana Cave. **Bottom,** Scorpion as found at Levana Cave, using UV light. Photographs: Boaz Langford.

scorpion specimens previously described from Ayyalon Cave were found at similar levels, corres-ponding to a similar historic watertable. The populations of this species in both caves became extinct probably due to the massive drop of water level in the cave and resulting reduction in primary production at the water surface.

The Nesher quarry is known to cut into several caves of the same type, as exemplified by Ayyalon and Levana caves. However, no physical connections via cave passages of human size were observed between Ayyalon and Levana Caves. The connection between Ayyalon and Levana Caves must have been via smaller passages, inaccessible to humans.

Material & Methods

Three vials deposited at the Hebrew University, Jerusalem, Israel, contain remnants of five scorpion specimens. One contains a single exoskeleton which is partially fragmented; two others contain completely fragmented specimens (most probably, judging from a number of the chelae, each with remnants of two specimens in each of them). Samples are not numbered. Label data (an "umbrella" label for all three samples) is: "Israel Levana Cave 12/17/15 [= 17 Dec. 2015] Coll. Israel Naaman & Shlomi Lubaton."

Photographs were taken by S.Z. at Tel-Aviv University using a Zeiss Discovery V20 stereo-microscope with a Canon PowerShot G9 camera, and prepared using the Helicon ver. 6.3.2Pro (licensed) soft-ware. Measurements (in mm) are given in Table 1.

Akrav israchanani	
First specimen (illustrated)	
Prosoma + mesosoma (measured at 7.5 x)	14.64
Carapace	3.52/3.09
Mesosoma	9.31
Metasoma I	2.17/1.22
Metasoma II	absent
Metasoma III	2.17/1.14
Metasoma IV	2.77/1.08
Metasoma V	3.96/1.07
Telson	3.66
Vesicle	2.68
Aculeus	0.98
Palpal femur	4.18/1.03
Patella	4.32/1.16
Chela	7.92 (8.13) /1.49
Palm	3.47 (3.69)
Movable finger	4.70 (4.35)
Second specimen	
Chela	8.12
Palm	3.33
Movable finger	4.95

Table 1: Measurements (mm) of the best preserved exo-skeletons of *Akrav israchanani* Levy, 2007 from Levana Cave: length/width, left (right)

Character Analysis

Here, we compare the morphology of the specimens recently found in the Levana Cave to the *Akrav israchanani* specimens from the Ayyalon Cave described in detail by Fet, Soleglad & Zonstein (2011). Based on several important diagnostic characters, it is shown here that the specimens from the Levana Cave are indeed the species *Akrav israchanani*.

Although we do not have complete specimens from the Levana Cave, more than enough structures are available, illustrated and described herein, to demonstrate that these specimens are *Akrav israchanani*.

Overall Coloration. In the Levana Cave specimens (Figs. 3–4) overall coloration is a light pale-gray, with reddish chelal fingers. In constrast, in the Ayyalon Cave specimens (Fet, Soleglad & Zonstein, 2011: fig. 4)) overall coloration is a light yellowish-brown, with reddish chelal fingers.

Carapace. The carapace of the Levana Cave specimens (Fig. 5) is elongate with a width, deep anterior indentation. The carapace is missing both median and lateral eyes, i.e. scorpions are completely blind. Its surface is rough but essentially devoid of carinae. This descripton matches the specimens from the Ayyalon Cave described by Fet, Soleglad & Zonstein (2011: figs. 4–5).

Chelicerae. Structure of the chelicerae of *A. israchanani* described by Fet, Soleglad & Zonstein (2011: 36; figs. 5, 32) from the Ayyalon Cave is unique, and typical of many of the chelicerae found in subfamily Typhlochactinae: single subdistal (*sd*) denticle on the movable finger dorsal edge, distal denticles (*dd*) of the dorsal and ventral edges of the movable finger are unequal in size, the ventral much longer, and the median (*m*) and basal (*b*) denticles of the fixed finger do not form a bicuspid. In the Levana Cave specimens (Fig. 6) only the movable finger is partially visible. However, from this we can see that it has a single *sd* and the ventral *dd* is longer than the dorsal *dd*, matching the description of these denticles as presented above for the Ayyalon Cave specimens.

Telson. The telson of *A. israchanani* is quite distinct with is large bulbous vesicle and short, highly curved aculeus (Fet, Soleglad & Zonstein, 2011: fig. 10).

Figure 4: *Akrav israchanani,* Levana Cave, Israel. Ventral view showing sternocoxal area and sternites.

Figure 5: *Akrav israchanani*, Levana Cave, Israel. Carapace and chelicerae.

In the Levana Cave specimens (Fig. 7), the telson has the same shape.

Leg Tarsus. In Fet, Soleglad & Zonstein (2011: figs. 11, 30) the leg tarsus is shown. In particular we see three important diagnostic characters for *A. israchanani*: the retrolateral pedal spur is missing, only the prolateral spur is present; the median ventral aspect of the tarsus lacks a spinule row; and the ventral surface of the tarsus is aligned with two subparallel rows of elongate setae.

Figure 6: *Akrav israchanani*, Levana Cave, Israel. Chelicerae, dorsal and ventral views.

Figure 7: *Akrav israchanani*, Levana Cave, Israel. Telson, lateral view, leg tarsus, interolateral view, and left pecten.

The Levana Cave specimens (Fig. 7) comply with these three diagnostic characters, from an external lateral view.

Pectines. All specimens, from both the Ayyalon Cave (Fet, Soleglad & Zonstein, 2011: figs. 6–8, 22, 31; tabs. 2–3) and Levana Cave (Fig. 7), have pectines with

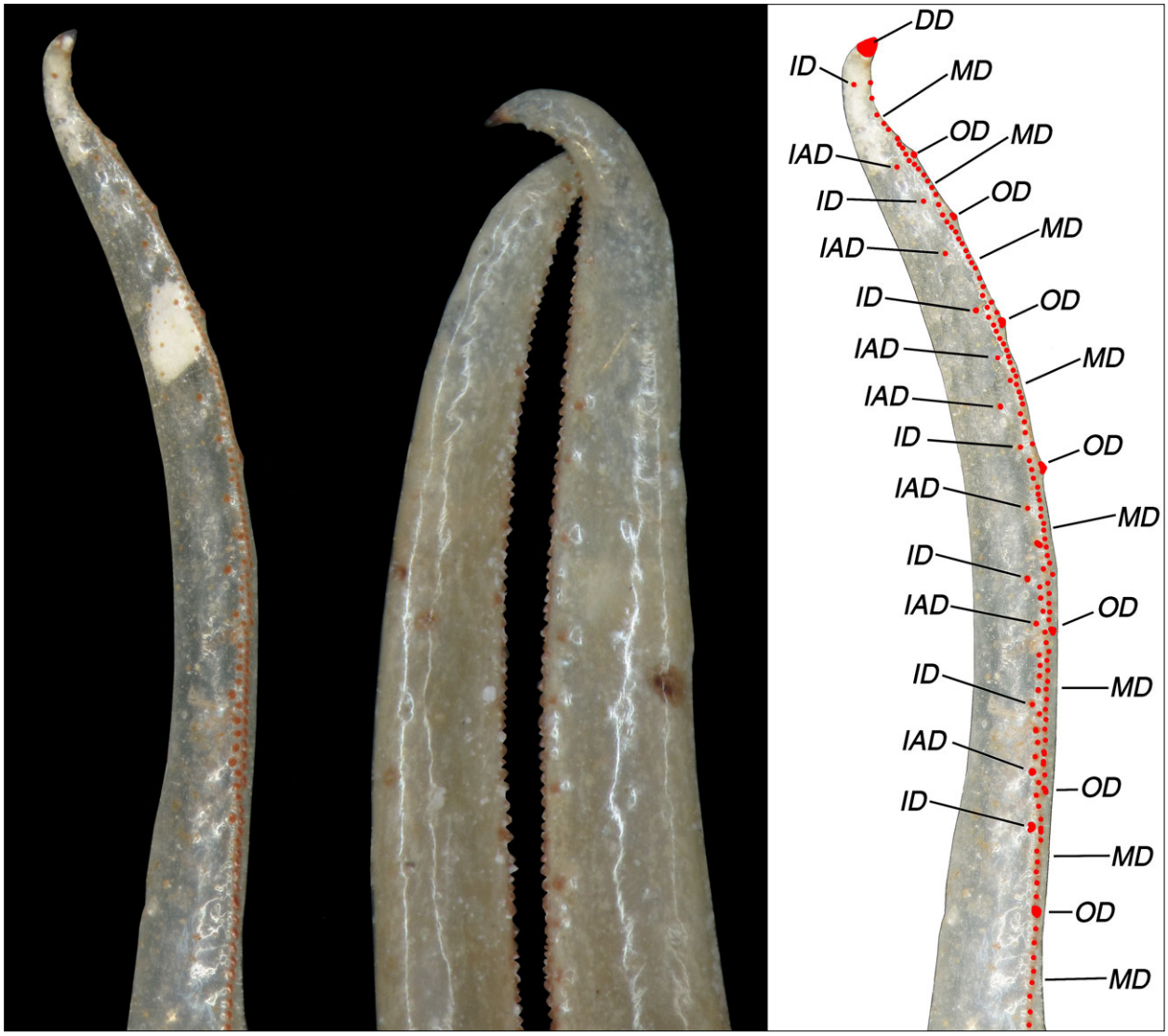

Figure 8: *Akrav israchanani*, Levana Cave, Israel. Pedipalp chela fingers. **Left.** Left chela fixed finger, internal view, and distal half of right chela fixed and movable fingers, internal view. **Right.** Diagrammatic view of the fixed finger, internal view, identifying key denticles including the diagnostic inner accessory denticles (*IAD*) denticles. *DD*, distal denticle, *MD*, median denticle row, *OD*, outer denticle, *ID*, inner denticle, and *IAD*, inner accessory denticle.

five teeth. The pectines in both populations have two anterior lamellae and a large basal triangular middle lamella.

Chelal Fingers and Dentition. Fet, Soleglad & Zonstein (2011: figs. 18, 20–21, 27–28) discussed in detail the unusual chelal fingers found in *A. israchanani*. The fingers are long and thin with the terminus of the fixed finger highly curved, extending beyond the distal tip of the movable finger and curving inward crossing the terminus of the movable finger. Two inner denticles (*ID*) are located on the curvature of the distal aspect of the fixed finger. The median denticle (*MD*) rows are oblique and significantly imbricated, numbering seven to nine rows. Of particular importance diagnostically, both fingers exhibit inner accessory (*IAD*) denticles. Fet, Soleglad & Zonstein (2011: 43: fig. 33) consider this arrangement of denticles on the two fingers very important in distinguishing *Akrav* from the "*Typhlochactas* clade" of chactoid scorpions found in Mexican caves, its closest relative. The specimens from the Levana Cave (Fig. 8) match the Ayyalon Cave specimens in all details discussed above.

Trichobothrial Patterns. The trichobothrial pattern of *Akrav israchanani* conforms to the Type C pattern and is orthobothriotaxic. However, Fet, Soleglad & Zonstein (2011: 34–37; figs. 12–17, 29) listed several

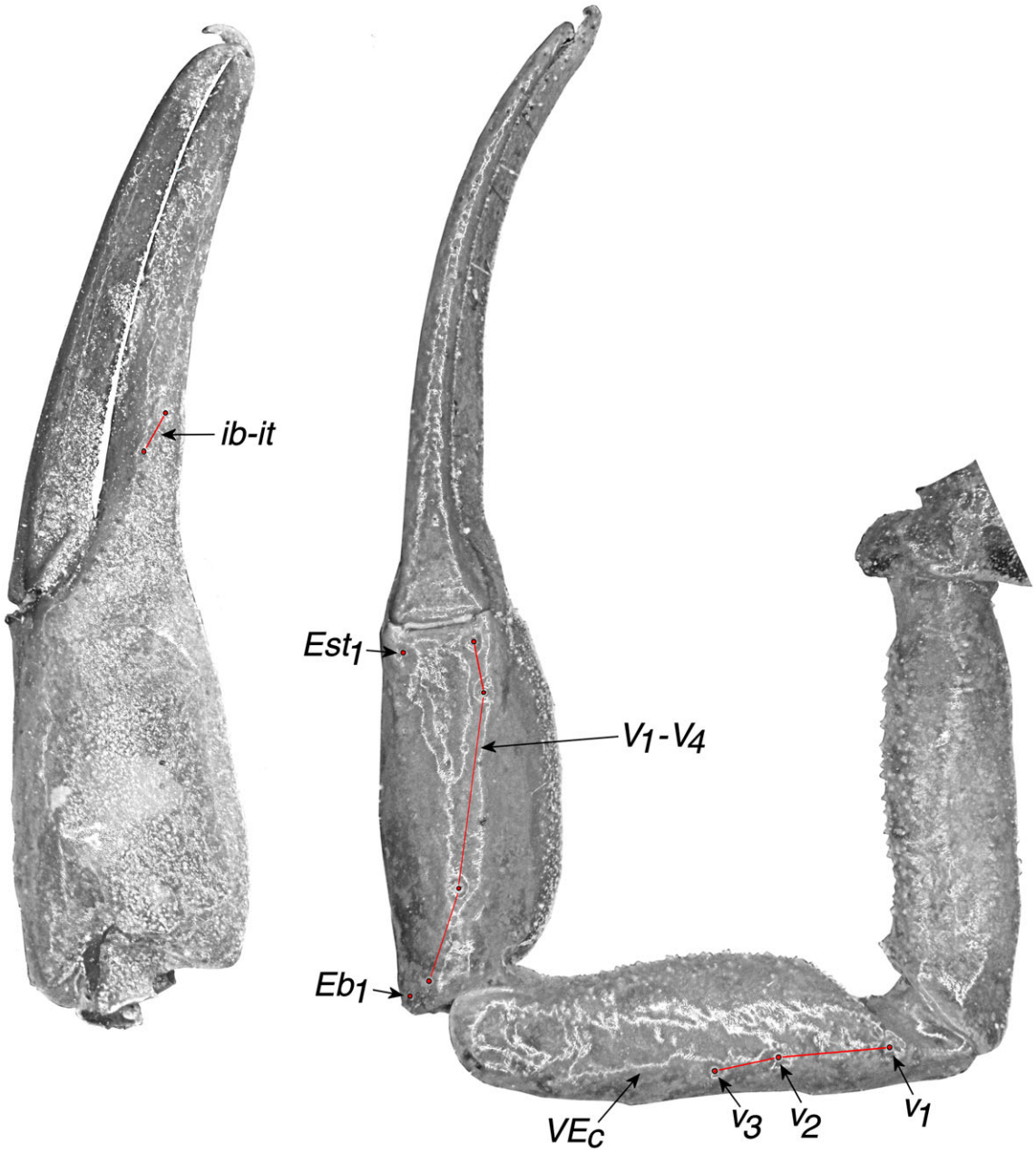

Figure 9: *Akrav israchanani*, Levana Cave, Israel. Right chela, internal view, showing trichobothrial series *ib–it*. Left pedipalp (reversed), ventral view showing the chelal trichobothria V_1–V_4, Est_1, and Eb_1, and the patellar series v_1–v_3 as they are aligned with the ventroexternal carina (*VEc*).

diagnostic characters for *Akrav* that involved specific locations of trichobothria and the presence of additional petite trichobothria (i.e., other than the three defined for Type C; i.e., chelal Et_4, *Esb*, and patellar esb_2): femur (three trichobothria): trichobothrium *e* is located on the dorsal surface, not the external surface. Patella (19 trichobothria): on the dorsal surface trichobothrium *i* is located on the dorsal surface (not in its ususal position, the internal surface); on the ventral surface trichobothria v_3 is located on the ventral surface, v_2 on the ventroexternal (VE_c) carina, and v_3 on the external surface close to VE_c; on the external surface we find 13 trichobothria plus v_3. Of particular interest the esb_1–esb_2 series slants distally, where esb_2 is distal of esb_1. Chela (26 trichobothria): in addition to petite trichobothria Et_4 and *Esb*, three additional trichobothria are also petite: Eb_3, *db*, and *dsb*. On the internal surface trichobothria *ib–it* are located basally, but not close to the articular

membrane of the movable finger. On the ventral surface trichbothria V_1–V_2 are distributed over the entire length of the chelal palm, where V_1 and V_2 are positioned quite close to each other, the distance between V_2 and V_3 is more than three times the distance between V_1 and V_2. The juncture of V_1–V_2–V_3 is straight, not angling towards the internal edge. On the external/dorsal surfaces *Db* is located quite basally whereas *Dt* is positioned distally on the palm/fixed finger juncture; the *db–dt* and *eb–et* series are positioned well on the fixed finger. For the Levana Cave specimens only three trichobothria series are determinable, the chelal *ib–it* and V_1–V_4 series and the patellar v_1–v_3 series (Fig. 9). In all cases, these three series matched the descriptions presented above for the Ayyalon Cave specimens.

Conclusions

We detected no important structural differences between the specimens found in the Levana Cave and those described in detail by Fet, Soleglad & Zonstein (2011) from the neighboring Ayyalon Cave. We conclude that the dead Levana Cave specimens indeed belong to the same relict chactoid species, *Akrav israchanani*. No live specimens have been found in either cave.

Acknowledgments

The study of *Akrav israchanani* would not have been possible without an enthusiastic help and attention of many Israeli zoologists and speleologists. We are especially grateful Dr. Ariel Chipman (Department of Evolution, Ecology and Behaviour, Hebrew University, Jerusalem, Israel) who allowed us (V.F. and S.Z.) to study, in 2010 and 2011, the unique *Akrav* specimens from the Ayyalon Cave described by Gershom Levy in 2007, and kept in the Hebrew University collection.

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