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AYYALONIA DIMENTMANI N. G., N. SP. (AYYALONIINI N. TRIB., CHTHONIIDAE, PSEUDOSCORPIONES) FROM A CAVE IN ISRAEL

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Abstract — A new eyeless troglobitic pseudoscorpion, *Ayyalonia dimentmani* n. g., n. sp., is described from inside karstic voids in Israel that form a completely isolated, old underground ecosystem with living populations of blind pseudoscorpions, crustaceans, collembolans, thysanurans and mites. The scorpions, of which only empty carcasses have been found may represent extinct derives or recently dead specimens belonging to an unknown population existing somewhere in the Ayyalon underground spaces.

The pseudoscorpions analysed prove to differ from all other pseudoscorpions and are placed in a new tribe, new genus, and a new species. The possibility is suggested that the subterranean false scorpions are relicts of an old circumtropical pattern of distribution (either of early Miocene or late Mesozoic age and origin) that differs from the present Mediterranean location of Israel.

Key words: Troglobite pseudoscorpion, Chthoniidae, Ayyaloniini, new genus, new species, *Ayyalonia dimentmani*, karst fauna, Ayyalon Cave, Israel, Middle East, eastern Mediterranean

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ISRAELI FRAME

The most heavily populated part of Israel is the narrow coastal belt, which runs for some 117 miles from north to south, bordering the Mediterranean. The low plain is composed of a variety of soils and is nowhere more than 350 feet in elevation. It is famous for its white sand dunes bordering the sea and red sands farther to the east. Farther inland is a strip of heavy, fertile soil that was once swamp. This land in some places is only about 12 miles wide from the sea to the frontier with Jordan. The coastal plain broadens north of Haifa into the Zebulun Valley and south of Tel Aviv into the Plain of Iudaea.

Beyond the plain and running parallel with the coast is an area of higher ground with mountains averaging 2000 feet in altitude. They stretch 200 miles north to south from Lebanon to the Sinai. The slope of the coastal side of the ranges is comparatively gentle, but farther inland they become more rugged and more dissected by valleys and peaks. To the south, in the arid Negev, the mountains attain dramatic proportions with spectacular coloring and deep rifts and faults.

In the north, a spur of high ground runs toward Haifa on the coast and forms the southern boundary of the Jezreel Valley. This valley is the largest of the breaks in the predominantly high ground. From the coast to the Jordan Valley, the rift is some 30 miles long and around 12 miles wide at most.

Also in the north, around Nazareth, are further outcroppings of high ground, where the stratification is more confused, the contours are varied, and the high peaks around Safad combine with valleys and plateaus. The mountains are higher in this region than anywhere else in Israel.

The Jordan Rift Valley is the most spectacular feature of the Israeli topography; although much of the river runs through Jordanian territory, it is an important aspect of the Israel's relief. Running from the Sea of Galilee through the Dead Sea to the Gulf of Aqaba, it forms an abrupt and spectacular ter-

mination of the high ground previously described, which lies to its west. Within a space of a few miles, the terrain drops from several thousand feet above sea level to the Dead Sea, which, at 1286 feet below sea level, is the lowest spot on the earth's surface. The Jordan River, famous since ancient times, meanders through the bottom of this natural valley for much of its length. Apart from the Jordan, the only other rivers of any importance are the Yarkon (16 miles in Israeli territory), the Kishon (eight miles in Israeli territory) and the Yarmuk (five and a half miles in Israeli territory).

Israel has a wide variety of climatic conditions, which can be roughly correlated with the following geographical areas: the coastal plain, the central highlands, the Negev, and the Jordan valley. The coastal plain has a dry, subtropical climate with warm summers and mild winters with sporadic rainfall. The central highlands are warm and dry in the summer and cold and wet in the winter. The Negev is dry and hot in the summer and dry and cool in the winter. The Jordan Valley is dry and hot in the summer and mild in the winter. Generally speaking, the coastal strips are more susceptible to influence from the Mediterranean than are other areas.

The recent (2006) discovery of the Ayyalon Cave in Israel revealed a peculiar underground ecosystem. The completely isolated subterranean space is located in a quarry deep below the surface that precludes the permeability of water or organic matter from the outside. This space comprises galleries of winding passages and a large chamber with warm brackish groundwater having high H_2S levels (Frumkin and Gvirtzman, 2006). The closed subterranean ecosystem depends basically on biomass production by chemoautotrophic sulfide-oxidizing bacteria that are found there in great masses (Por and Dimentman, 2006; Dimentman et al., 2006). The troglobites discovered include populations of various species of blind crustaceans, collembolans, thysanurans, pseudoscorpions, and scorpions. No live scorpions have as yet been detected, only their empty carcasses. These desiccated but not fossilized cuticular remains retaining their bright fluorescence under UV light were found firmly attached to rocks at various levels corresponding to the levels attained by the rise and fall of the underground water inside the voids.

Named the Ayyalon Cave, this landform is actually an accidental opening in a deep limestone quarry near Ramla in the inland plain of Israel, 24 kilometers from the Mediterranean coast. Excavating down to over 100 m, the quarry reached the level of the groundwater. This groundwater is the Yargon-Tanninim Aquifer, the second most important freshwater source in the country. The aquifer is impacted by saline and warm water upsurgences, the so-called Ayyalon Saline Anomaly (Frumkin and Gvirtzman, 2006). An accidentally opened and accessed system of karstic ducts in the quarry led to a cavity with a small pool in which fresh groundwater mixes with this saline water intrusion. The cave and its afferent karstic ducts are situated in a Turonian limestone, overlain by tens of meters of an aquaclude of Senonian chalk. The saline waters are brackish, over 1300 mg/L, warm (up to 30^0C), and rich in H_2S. Dissolved oxygen is present in the first meter down or so, after which the conditions become anaerobic down to the bottom at 4 m. Rich mats of sulfide oxidizing bacteria of the *Beggiatoa* type, float in the water and cover the receding shores of the pool.

The crustacean fauna observed till now consists of immense populations of *Tethysbaena*, the cyclopoids *Fierscyclops* n. sp. and *Metacyclops* sp. (D. Defaye, personal communications), and hundreds of large *Typhlocaris* prawns (Tsurnamal, 2007). Ciliate and amoeboid protozoans also accompany the bacterial growths (Ch. Dimentman, personal communications). The bacterial films are obviously the sole food basis of this system, completely isolated for long geological periods from the distant outer world. Indeed, the gut of *Tethysbaena* specimens was gorged with bacterial cells. Among several terrestrial taxa found in the cave, the scorpion *Akrav israchanani* Levy, 2007, which belongs to a new family of scorpions, stands out (Levy, 2007). This must be a very old biome, possibly coeval with sunlit terrestrial biomes. Since bacterial chemolithotrophy is ancestral in Earth's history and pre-dates photolithotrophy, it is reasonable to assume that the animal invasion of this underground milieu started back in

the Mesozoic, though the presence of dissolved oxygen in the continental groundwater was mandatory for the existence of this metazoan fauna.

The stygobionts are thus not accidental relics or living fossils. Despite its old age (Por, 2007), the colonization of Ophel and other chemotrophic subterranean environments has been, and still is an active process (Rouch and Danielopol, 1987). As in epigean continental biomes, adaptation of new marine and aquatic taxa to the subterranean biome is an ongoing process.

Several taxa of stygobitic crustaceans are represented in both open marine and subterranean waters, for example the Cirolanidae (Isopoda), which are evidently younger additions to Ophel. Cases of locally-originated relictual biotas also exist, as in any other continental biomes. Iliffe and Botosaneanu (2006) consider that the remarkable diversity of 11 endemic genera and 42 endemic species of the stygobitic Cirolanidae found in the peri-Caribbean and Mexican Realm resulted from the fragmentation of a Cretaceous original stock.

Other current paradigms of speleobiology have to be also re-discussed in light of the existence of the groundwater biome of Ophel. However, this discussion should take place in the more parochial circles of speleologists.

In studing some blind pseudoscorpions from a collection made by Israel Na'aman (under the supervision of Professor Amos Frumkin) in the Ayyalon Cave, we concentrated on a new genus and species from the family Chthoniidae. The sample was represented by four males and four females. These specimens of false scorpions turned out to belong to a new tribe, new genus, and a new species. In the present paper, the new taxon is thoroughly described, diagnosed, and illustrated. In addition, some taxonomic, biogeographical, and evolutionary traits of this new form are briefly discussed.

MATERIAL AND METHODS

The pseudoscorpion specimens studied were mounted in gum chloral medium (Swan's fluid); they are deposited in the collection of the Institute of Zoology, Faculty of Biology, University of Belgrade, 11000 Belgrade, Serbia, and in that of the Department of Evolution, Systematics and Ecology, the Hebrew University, 91905 Jerusalem, Israel.

Setal designations follow Beier (1963).

SYSTEMATIC PART

FAMILY CHTHONIIDAE DADAY, 1888

TRIBE AYYALONIINI ĆURČIĆ, NEW TRIBE

SYNONYM: TROGLOCHTHONIINI CHAMBERLIN, 1962 (PART.) (sensu Judson, 2007).

Diagnosis: Chthoniinae with no epistome or eyes; no chemosensory setae extending along dorsum of chelal palm; only coxae II each with 11 fine elongated coxal spines, middle spines longest, spines with tiny and delicate spinules on either side (distributed along two-thirds of each rod); cheliceral spinneret absent; trichobothria *ib* and *isb* in the proximal finger third; body color: whitish-yellowish; epistome absent; trichobothrium *isb* somewhat more distal than *ib,* both sensitive setae closer to the hand's base than to apex; pedipalpal chelal palm straight dorsolaterally and convex ventrolaterally; abdominal tergites I-III with two setae each, tergites IV-X with four setae each; tactile seta of basitarsus IV on the middle of the podomere; with no thick setae on median side of chelal hand at base of fixed chelal finger; intercoxal tubercle absent; flagellum six-bladed (five distal setae of the same length, the most proximal seta less than half their length), each blade with tiny pinnules; fixed chelal finger heterodentate, movable chelal finger homodentate; apex of pedipalpal coxa with three setae; no additional terminal seta on this podomere; female genital area: sternite II with nine setae arranged in a single row, sternite III with two setae and two suprastigmatic microsetae on either side, sternites IV-X with a row of posterior setae; male genital area: sternite II with 11 setae in the form of a triangle, sternite III with genital opening in the form of an inverted Ω, sternites III-X each with a row of posterior setae; lamina superior reduced or almost invisible. Trichobothriotaxy as in Figs. 3, 5, 7, 8, and 11.

Table 1. Linear measurements (in mm) and morphometric ratios in *Ayyalonia dimentmani* n. g., n. sp. (from Israel). Abbreviations: HF = holotype female, AM = alotype male..

Character/species/sex	HF	AM
Body		
Length (1)	1.68	1.58
Cephalothorax		
Length (2)	0.61	0.62
Breadth (2a)	0.45	0.40
Ratio 2/2a	1.355	1.55
Abdomen		
Length	1.07	0.96
Chelicerae		
Length (3)	0.46	0.46
Breadth (4)	0.20	0.20
Length of movable finger (5)	0.24	0.23
Ratio 3/5	1.92	2.00
Ratio 3/4	2.30	2.30
Pedipalps		
Length with coxa (6)	3.13	2.895
Ratio 6/1	1.86	1.83
Length of coxa	0.50	0.48
Length of trochanter	0.275	0.20
Length of femur (7)	0.805	0.73
Breadth of femur (8)	0.13	0.12
Ratio 7/8	6.19	7.66
Ratio 7/2	1.32	1.18
Length of patella (tibia) (9)	0.35	0.315
Breadth of patella (tibia) (10)	0.14	0.13
Ratio 9/10	2.50	2.42
Length of chela (11)	1.20	1.17
Breadth of chela (12)	0.16	0.16
Ratio 11/12	7.50	7.31
Length of chelal palm (13)	0.45	0.44
Ratio 13/12	2.81	2.75
Length of chelal finger (14)	0.75	0.72
Ratio 14/13	1.67	1.64
Leg IV		
Total length	2.765	2.64
Length of coxa	0.22	0.26
Length of trochanter (15)	0.24	0.22
Breadth of trochanter (16)	0.13	0.13
Ratio 15/16	1.85	1.69
Length of femur + patella (17)	0.825	0.77
Breadth of femur + patella (18)	0.21	0.21
Ratio 17/18	3.93	3.67
Length of tibia (19)	0.56	0.53
Breadth of tibia (20)	0.08	0.09
Ratio 19/20	7.00	5.89
Length of metatarsus (21)	0.24	0.22
Breadth of metatarsus (22)	0.06	0.06
Ratio 21/22	4.00	3.67
Length of tarsus (23)	0.68	0.64
Breadth of tarsus (24)	0.04	0.04
Ratio 23/24	17.00	16.00
TS ratio - tibia IV	0.36	0.38
TS ratio - metatarsus IV	0.48	0.50
TS ratio - tarsus IV	0.33	0.43

Type genus: *Ayyalonia*, new genus.

Other included genera: None.

AYYALONIA ĆURČIĆ, NEW GENUS

Etymology: After the Ayyalon Cave in Israel, its type locality.

Diagnosis: Chthoniinae with no epistome and eyes; no chemosensory setae extending along dorsum of chelal palm; only coxae II with 11 elongated spines, each spine with tiny and delicate pinnules on either side; cheliceral spinneret absent; tergites I-III with two setae each (one on either side), tergites IV-X with four posterior setae each; basitarsus IV tactile seta on the middle of the podomere; flagellum six-bladed; no thick setae on median side of chelal hand at base of fixed chelal fingers; intercoxal tubercle absent; fixed chelal finger heterodentate distally, movable finger homodentate; dorsolateral tubercle (tooth) present; apex of pedipalpal coxa I with three setae; female genital area: sternite II with nine setae arranged in a single row (anterior to the genital operculum); male genital area: sternite II with 11 setae in form of a triangle, sternite III with genital opening in form of an inverted Ω. Trichobothriotaxy as in Figs. 3, 5, 7, 8, and 11.

Type species: *Ayyalonia dimentmani* Ćurčić, new species.

Other included species: None.

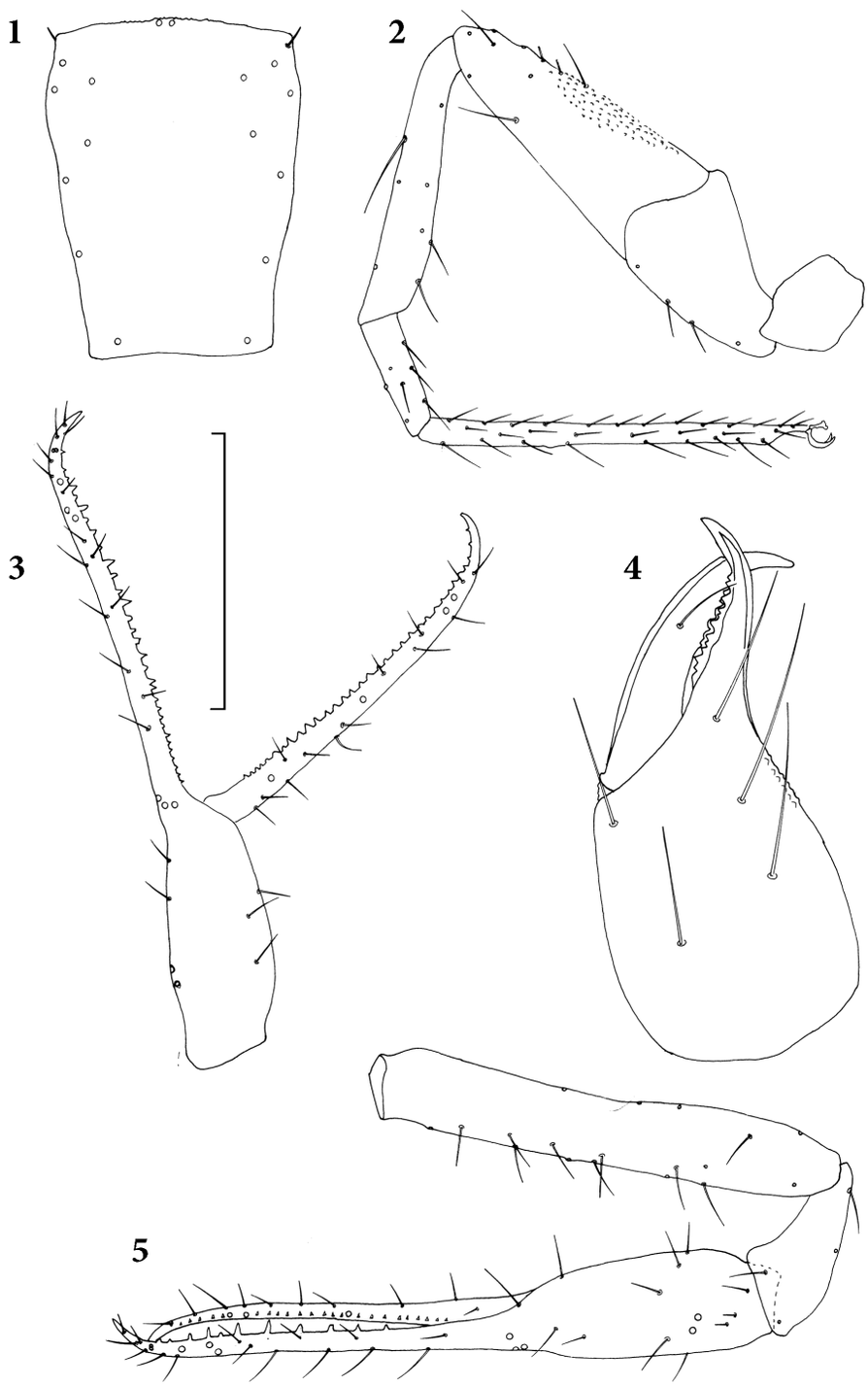
AYYALONIA DIMENTMANI, NEW SPECIES
(Figs. 1-17; Table 1)

Etymology: After Dr. Chanan Dimentman, a noted Israeli naturalist.

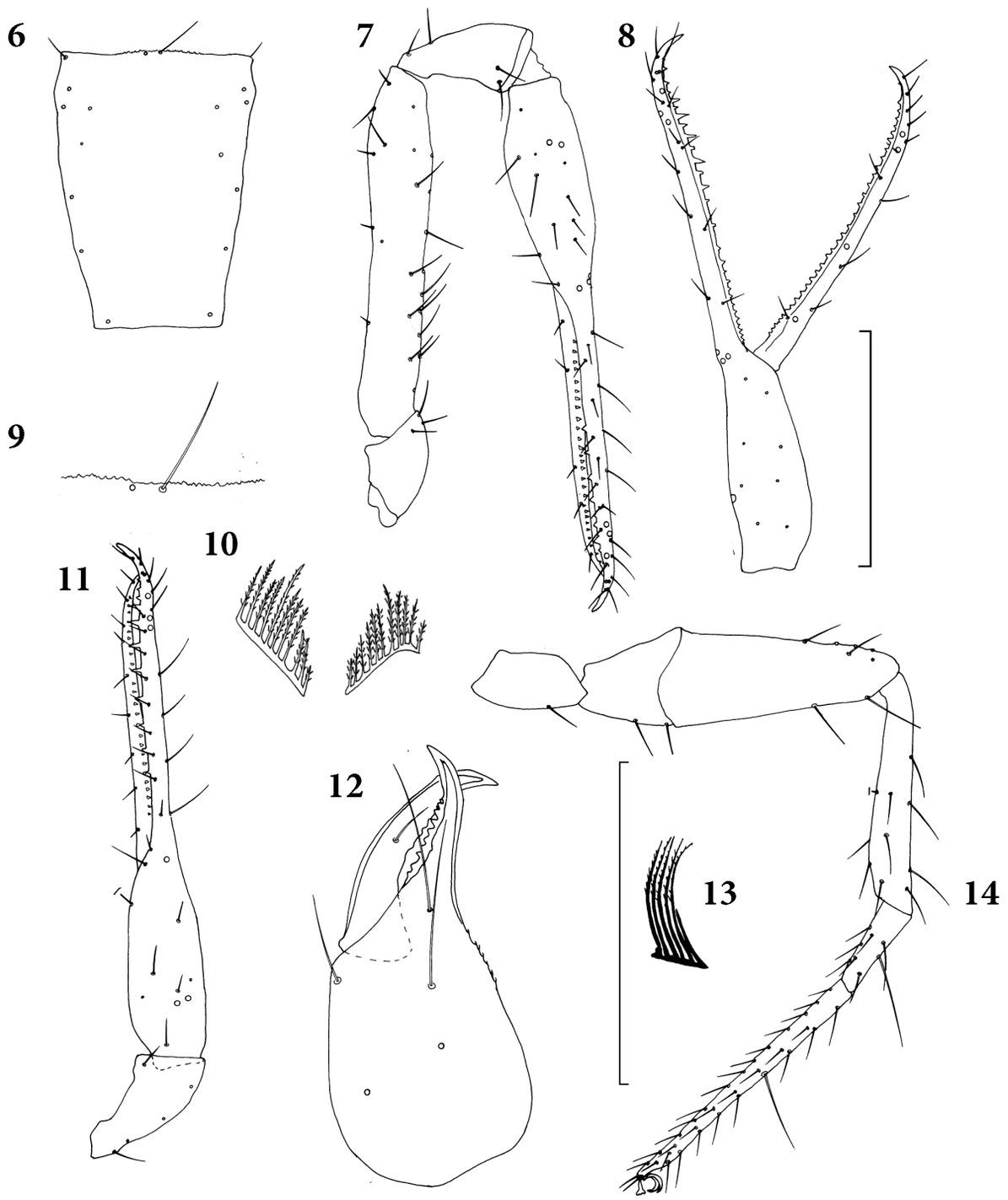
Material examined: Holotype female, three paratype females, allotype male, and three paratype males, from the Ayyalon Cave System, near Jerusalem, Israel, collected on June 2006 by Israel Na'aman.

Diagnosis: Troglobitic species with no epistome and eyes and with elongate appendages; tergites I-III with two setae each; pedipalpal chela 7.50 (female) to 7.31 times (male) longer than broad.

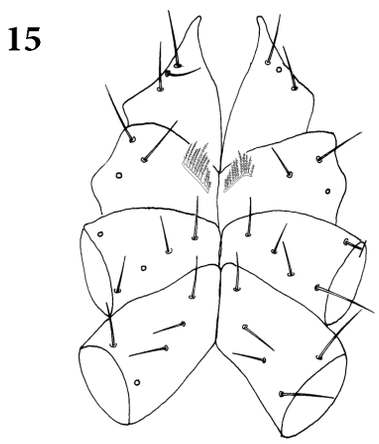
Description: Cavernicolous species, with no eyes

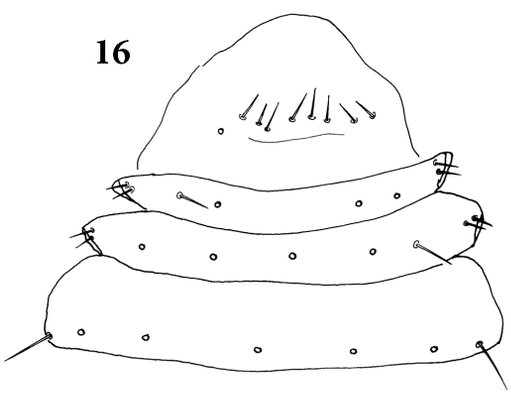


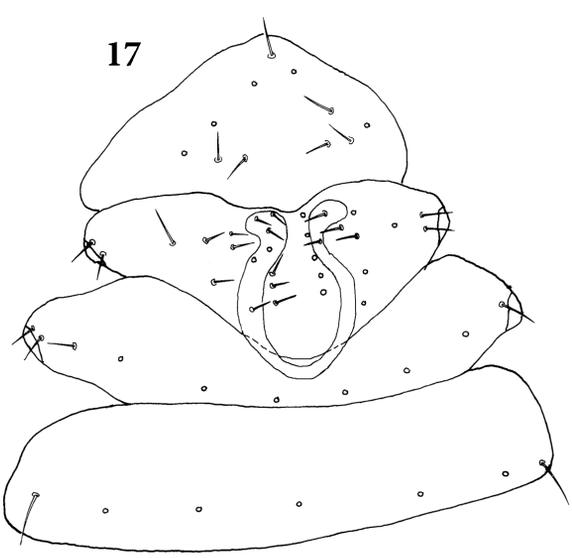
Figs. 1-5. *Ayyalonia dimentmani* n. g., n. sp. from Israel. Holotype female: 1 – carapace, 2 – leg IV, 3 – pedipalpal chela (lateral view), 4 – chelicera, 5 – pedipalp. Scale = 0.25 mm (Fig. 4) and 0.50 mm (Figs. 1-3 and 5).



Figs. 6-14. *Ayyalonia dimentmani* n. g., n. sp. from Israel. Allotype male: 6 – carapace, 7 – pedipalp, 8 – pedipalpal chela (lateral view), 9 – epistome, 10 – coxal spines, 11 – pedipalpal chela and patella (dorsal view), 12 – chelicera, 13 – flagellum, 14 – leg IV. Scales: 0.25 mm (Figs. 9, 10, 12, 13) and 0.50 mm (Figs. 6-8, 11 and 14).







Figs. 15-17. *Ayyalonia dimentmani* n. g., n. sp., from Israel: 15 – coxae I-IV, allotype male; 16 – genital area, holotype female; 17 – genital area, allotype male.

or eyespots (Figs. 1, 6). Carapax trapezoid, constricted posteriorly, much longer than wide (Table 1). Anterior carapacal margin straight, with some tiny points, epistome absent; this margin thick and clearly visible (Fig. 9). Carapacal setation: 4 + 6 + 4 + 2 + 2 = 18 setae (in both female and male). Only two anterior and median setae on either side of the epistome, close to each other (Figs. 1, 6). Preocular microsetae absent. Suture anterior to posterior carapacal setal row absent.

Tergal chaetotaxy: 2-2-2-4-4-4-4-4-4-4. Female genital area (Fig. 16): sternite II with a transverse row of nine setae (anterior to the female operculum), sternite III with four setae (two on each sclerite side) and two suprastigmatic microsetae on either side, sternite IV with five posterior setae and two small setae along each of the stigma. Sternites V-X with 7-7-7-6-7-7 setae. Anal papilla with two pairs of setae. Male genital area as in Fig. 17. Coxae I-IV: anterior process of coxa I long: I - three, II - three, III - five, IV - five setae; intercoxal tubercle absent (Fig. 15). Coxae II each with 11 long spines, with delicate pinnules on either side, arranged in an arc, distal (middle) ones longer, spines pinnate for about two thirds of their length.

Cheliceral palm with five setae (Figs. 4, 12). Palm with moderate granulations ventrolaterally, otherwise smooth. Fixed cheliceral finger with 10 (male) or 12 teeth (female), distal teeth larger than others; movable cheliceral finger with six or seven (male, female) lower teeth. Spinneret absent (Figs. 4, 12). Flagellum with six blades, distal blade not set apart from other blades, the latter tightly grouped and with long undivided pinnules (Fig. 13).

Pedipalp smooth (Figs. 5, 7). Femur 1.18-1.32 times longer than carapace + chelal palm. Dorsal surface with no chemosensory setae. Finger curved in dorsal view. Fixed finger with 31 (female) and 29 teeth (male), out of which seven (female) and eight (male) are microdenticles, distributed in the distal half of this podomere; these teeth are set apart in the distal two thirds of the finger; the remaining teeth are also triangular, but small and almost close-set. Movable chelal finger with 33 (female, male) triangular, small, and somewhat set-apart teeth, only

a few proximal ones smaller and close-set. Fixed chelal finger also with a modified accessory tooth on dorsoaxial face (Figs. 3, 5, and 11).

Apodeme complex of movable finger weakly sclerotized.

Trichobothriotaxy (Figs. 3, and 8): *ib* and *isb* slightly closer to palm base than to *eb* and *esb*; *isb* somewhat distal in relation to *ib*. Sensitive setae *eb*, *esb*, and *ist* grouped at the fixed base. Trichobothria *est*, *et*, and *it* on the top of the fixed finger. Movable chelal finger: seta *sb* somewhat closer to *b* than to *st*, *st*, and *t* in the distal third of the podomere (Figs. 3, 8).

Tibia IV, basitarsus IV, and telotarsus IV each carry a single tactile seta (Figs. 2, 14). A number of small and chitinous points are borne dorsally and laterally on telofemur IV.

Measurements and morphometric ratios are presented in Table 1.

DISCUSSION AND CONCLUSIONS

The state of taxonomic knowledge of the *Ayyalonia* and its eventual phenetically similar forms is much more complicated than it appeared to be at the beginning of the research. Its diversity is much greater and large gaps occur between particular forms (the so-called «*Tyrannochthonius*»– like taxa), suggesting the existence of intermediate species and genera yet to be discovered. The group's geographical distribution is much broader, but very incompletely known. Explanation of resemblances and classification of genera must be delayed until more species are known.

The occurrence of originally tropical *Ayyalonia* in Israel, not being tropical, is thus an exception. But the distribution of the subterranean crustaceans living in the Ayyalon Cave is considered to be a relict of the Miocene circum-tropical Tethys Ocean (Por, 1996) or even older times. It is possible that the existence of the troglobite scorpion and pseudoscorpion deep down in Israel preserve the old constellation and are therefore in line with contemporary worldwide records. On the other hand, these troglobites may represent a detached subterranean fauna of its own, as postulated by Por (pers. com.) and Ćurčić (1988, 1990; Ćurčić et al., 2004).

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AYYALONIA DIMENTMANI N. G., N. SP. (AYYALONIINI N. TRIB., CHTHONIIDAE, PSEUDOSCORPIONES) ИЗ ПЕЋИНЕ У ИЗРАЕЛУ

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У овој студији дијагностификовани су нови род и врста слепих троглобионтних псеудоскорпије, *Ayyalonia* ***dimentmani*** **n. g., n. sp., и то из** старог подземног екосистема пећине Ајалон код Јерусалима, Израел. Ову пећину насељавају још и троглобионтни представници ракова, колембола, тизанура и (?) скорпија. Анализиране псеудоскорпије припадају новом трибусу у оквиру породице Chthoniidae (Ayyaloniini n. trib.) и разликују се од свих познатих родова. Претпоставља се да су ове пећинске псеудоскорпије реликти старе циркум-тропске фауне (из раног миоцена или чак и са краја мезозоика), које се битно разликују од садашње средоземне фауне Израела.