Douglas Zeppelini and Kenneth Christiansen - *Arrhopalites* (Collembola: Arrhopalitidae) in U.S. caves with the description of seven new species. *Journal of Cave and Karst Studies, v. 65*, n. 1, p. 36-42.

ARRHOPALITES (COLLEMBOLA: ARRHOPALITIDAE) IN U.S. CAVES WITH THE DESCRIPTION OF SEVEN NEW SPECIES

DOUGLAS ZEPPELINI
Centro de Ciências Exatas e da Natureza. Departamento de Sistemática e Ecologia, Universidade Federal da Paraíba - Campus I. 58059-900, João Pessoa, PB, BRAZIL
KENNETH CHRISTIANSEN
Grinnell College, Box V-3, Grinnell, IA 50112 USA

Seven new species of Arrhopalites *(Collembola: Arrhopalitidae) are described and illustrated. Two species are from Illinois:* A. sapo *and* A. madonnensis*, two from Virginia:* A. sextus *and* A. obtusus*, two from Colorado:* A. incertus *and* A. hubbardi*, and one from Idaho*: A. arca*. The known distribution of cave species of* Arrhopalites *in North America is discussed and both collection efficiency and regional differences are shown to play a role in the number of species known.*

This is a second paper dealing with the genus *Arrhopalites* in U.S. caves (see Christiansen & Bellinger 1996). The genus *Arrhopalites*, Börner 1906, is cosmopolitan, with ~100 described species. Although 28 of these species are known from North America the cave fauna of *Arrhopalites* in this region remains poorly known. In this work we describe 7 new cave species: 4 from the speciose areas of Indiana, Illinois, and Virginia and 3 from the little collected region of the eastern Rocky Mountains.

SPECIES	STATE
arca	Idaho (ID)
incertus	Colorado (CO)
hubbardi	Colorado
madonnensis	Illinois (IL)
obtusus	Virginia (VA)
sapo	Illinois
sextus	Virginia

We use the system of Nayrolles (1991) for the apical sensory organ of the third antennal segment and that of Lawrence (1979) for the anal valve chaetotaxy. We describe the chaetotaxy of head, dens, and furcula following Christiansen (1966) and Christiansen and Bellinger (1998). In all cases, we found these systems to be the easiest to use and with the most general application. For details concerning the abbreviations used herein, see Christiansen & Bellinger (1996 or 1998).

Arrhopalites incertus new species (Fig. 1 A-J)

Description: Body sparsely clothed, posterior setae (Fig. 1C-b) 1.5 times longer than anterior setae (Fig. 1C-a). Antennal ratios as shown in Table 2. Antennal segment 4 (Ant. IV) divided into 4 distinctly ringed subsegments (Fig. 1A); longest setae ~1.8X the width of segment; apex with a capitate sense rod. Antennal segment 3 (Ant. III) slightly swollen basally; apical sense organ (Fig. 1B) with 2 parallel sense rods in a single shallow pit; seta Aai rod-like & blunt; seta Api slender with filamentous apex, Ape cylindrical & acuminate; Ae, Ap, & Ai normal (Ap with a slightly swollen base). Eyes 1+1. Cephalic A3, M4, & L & IL series spine-like, M5 absent (Fig. 1I). Metatrochanteral

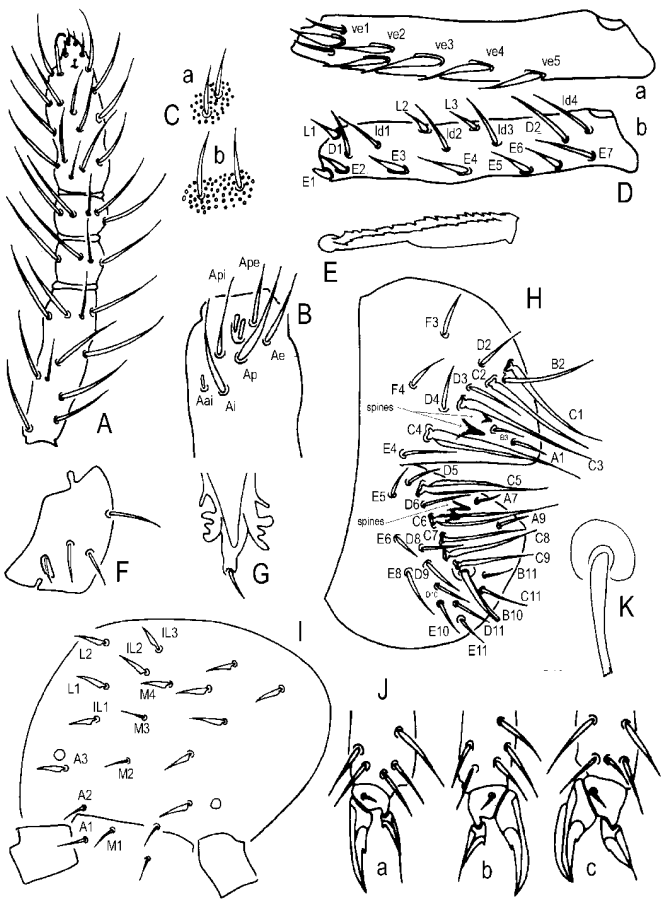

Figure 1. *Arrhopalites incertus* n. sp. A, 4th antennal segment; B, apical sense organ of 3rd antennal segment; C, body setae, a. anterior, b. posterior; D, chaetotaxy of dens, a. ventral surface, b. dorsal surface; E, mucro; F, metatrochanteral organ; G, tenaculum; H, anal valve chaetotaxy; I, posterior cephalic chaetotaxy; J, foot complex, a. 1st leg, b. 2nd leg, c. 3rd leg; K, female subanal appendage.

organ (seta D2) elongate (Fig. 1F). All ungues with inner tooth, 3rd unguis with a slight tunica (figs. 1 J-a-c). All unguiculi with corner tooth & short apical filament, not exceeding apex of unguis (Fig. J a-c). Tenaculum with one seta on anterior unpaired lobe (Fig. 1G). Dens with 7 dorsal E setae, E1 strongly spine like, E2 & E3 spine like; L1, L2 & L3 spine like, L4 absent; D1, D2, Id1, Id2, id3, & Id4 present (Fig. 1D-b); 5 ventral rows of heavy setae (3,2,1,1,1) present (Fig. 1 D-a), median ve1 strongly spinelike. Mucro narrow, gutter-like, both edges serrate (Fig. 1E). 2+2 cuticular spines on each side of the anal valve with setae C4-C6 lamellate, C1, C2, C3, & C8 swollen basally, C7 slender, as shown in figure 1H. Female subanal appendage rod like, somewhat flattened on apical half with truncate apex (Fig. 1K). Body length of the adult female Holotype 0.44 mm, head 0.24 mm.

Holotype: female, USA, CO, El Paso Co. Manitou Cave. 3- VIII -1996. on old wood, D. Hubbard Coll., locality 7990. Paratypes: 3 females on the same slide with Holotype. Biogeographic zone 7b.

Derivatio nominis: *Arrhopalites incertus* n. sp. was named after the difficulties in determining its precise position in the phylogeny (Zeppelini 2001) of the *A. coecus* group.

Remarks: *Arrhopalites incertus* is a typical *A. coecus* group species, with a E7 seta present & spine like medial Ve1 seta on the dens. It is easily separated from other members of the group by the subdivision of Ant IV into 4 ringed subsegments. It is also characterized by the single seta on the Tenaculum & the shape of the female subanal appendage.

The species most similar to *A. incertus* are specimens from AK, Poland, & Russia identified as *A. coecus*. These specimens differ from *A. incertus* by possessing anal valve seta D7 (absent in *incertus*), having valve setae C8-9 lamellate & the absence of the E7 on the dorsal surface of dens in *A. coecus* (present in *incertus*). In addition, incertus has ANT IV subsegments & a slight swelling at the base of the ANT III while *caecus* has 5 subsegments & no basal swelling.

Table 1. Arrhopalites in Nearctic caves (our records).

States	# of cave samples	# with Arrhopalites	%	# of species	# of troglobite species
Alabama	113	9	8	2	0
Arizona	18	1	6	1	0
Arkansas	74	34	46	2	1
California	154	0	0	0	0
Colorado	45	4	9	3	2
Georgia	32	0	0	0	0
Idaho	8	2	25	2	2
Iowa	62	12	19	5	2
Indiana	228	61	27	9	4
Illinois	85	19	22	8	5
Kentucky	176	21	12	4	2
Maryland	27	8	3	2	0
Missouri	407	82	20	4	1
N. Carolina	36	3	8	1	0
Ohio	32	0	0	0	0
Oregon & Washington	18	2	20	1	0
Tennessee	110	10	9	2	0
Texas	557	15	3	2	1
W. Virginia	101	7	7	3	1
Virginia	249	84	34	18	12

Arrhopalites hubbardi new species (Fig. 2 A-L)

Description: Body sparsely clothed, posterior setae (Fig. 2D-b) 1.5 times longer than anterior setae (Fig. 2D-a). Antennal ratios as shown in Table 2. Ant. IV, divided into 7 subsegments (Fig. 2A); longest setae 3X the width of segment; Ant. IV apex with a capitate sense rod (arrow in Fig. 2B). Ant. III with a clear, prominent basal papilla (Fig. 2C) ; sense organ (Fig. 2C) with 2 parallel sense rods in a single shallow pit; seta Aai rod-like; seta Api & Ape slender, the latter with a filamentous apex; Ae, Ap, & Ai normal. 1+1 clear & 1+1 vestigial eyes. No cephalic spines, M5 present (Fig. 2J). Metatrochanteral organ elongate (Fig. 2G). All ungues with inner tooth, without tunica (Figs. 2K a-c). All unguiculi with corner tooth, 1st unguiculus with a long apical filament, exceeding the unguis tip, 2nd & 3rd unguiculi with short apical filament,

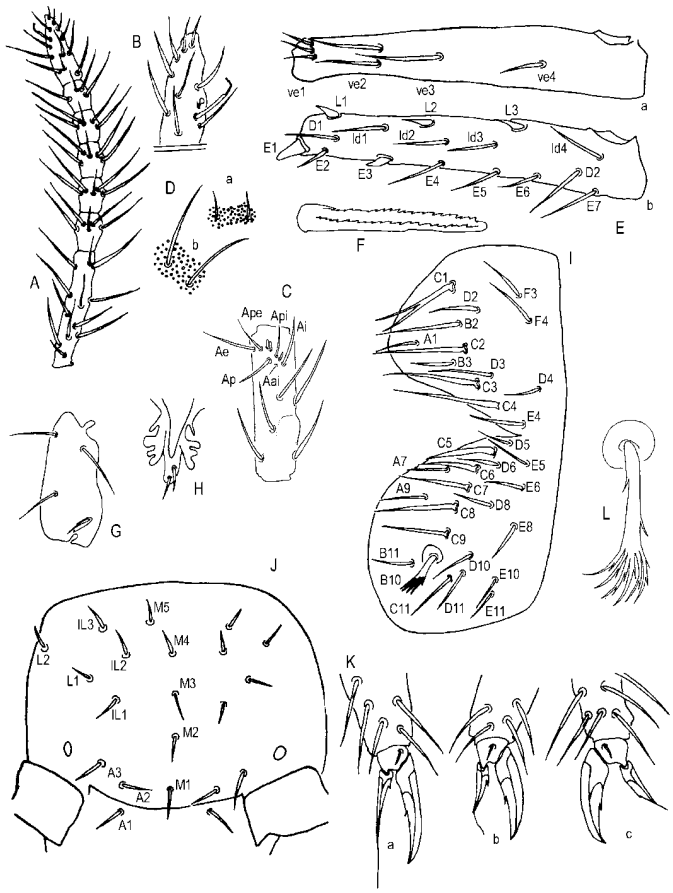

Figure 2. *Arrhopalites hubbardi* n. sp. A, 4th antennal segment; B, apex of 4th antennal segment; C, 3rd antennal segment; D, body setae, a. anterior, b. posterior; E, chaetotaxy of dens, a. ventral surface, b. dorsal surface; F, mucro; G, metatrochanteral organ; H, tenaculum; I, anal valve chaetotaxy; J, posterior cephalic chaetotaxy; K, foot complex, a. 1st leg, b. 2nd leg, c. 3rd leg; L, female subanal appendage.

not exceeding apex of unguis (Fig.2K b-c). Tenaculum with 2 setae on anterior unpaired lobe (Fig. 2H). Dens with 7 dorsal E setae, E1 & E3 strongly spine-like, other E setae normal; L1, L2, & L3 spine like, L4 absent; D1, D2, Id1, Id2, Id3, & Id4 present (Fig. 2E-b); 4 ventral rows of setae (3,2,1,1) present (Fig. 2E-a). Mucro narrow, gutter-like, both edges serrate (Fig. 2F). No cuticular spines on anal valve; C1 bifurcate, chaetotaxy as in Figure 2I. Female subanal appendage palmate (Fig. 2L). Body length of the adult female Holotype 0.44mm, head 0.28mm.

Holotype: female, USA, CO, Garfield Co. Glenwood Caverns. 9– VI I - 1999. D. Hubbard coll, locality 9452. 2 paratypes CO, Garfield Co. Glenwood Caverns, Fairy cave 15 IV 2000, Steinmann coll 9655. Biogeographic zone 7b

Derivatio nominis: This species is named after David Hubbard, whose collecting has been instrumental for this work.

Remarks: One specimen appears to have only 1 + 1 eye but the others have a clear vestige of a 2nd eye present. This species is closely related to *A. clarus*, *A. hirtus,* & *A. habei* &, all of which, circumanal seta C1 forked. It can be distinguished from all these by the anal valve chaetotaxy, the strong basal papilla on the 3rd antennal segment & 4th antennal segment subsegmentation. The features separating the species of this group are shown in Table 3

Table 2. Antennal and Cephalic diagonal measurements in mm

A. incertus

A1	0.0255	0.01785	0.01785	0.0204
A2	0.06375	0.04845	0.04845	0.051
A3	0.08925	0.06375	0.0765	0.0765
A4	0.1785	0.1224	0.1275	0.14025
CD	0.19125	0.153	0.153	0.17085

A. hubbardi

A1	0.03825	0.051	0.04335
A2	0.0765	0.102	0.08925
A3	0.1326	0.1632	0.1479
A4	0.32385	0.408	0.3366
CD	0.255	0.36975	0.306

A. arca

A1	0.0255	0.0459	0.0255	--------	0.04335
A2	0.0816	0.102	0.0765	--------	0.102
A3	0.14025	0.16575	0.11475	--------	0.16575
A4	0.408	0.4743	0.357	0.408	0.47685
CD	0.24225	0.255	0.204	0.21675	0.255

A. sapo

A1	0.03825	0.0459	0.0306	0.03825	0.03825	0.04335	0.04335	0.0255
A2	0.0714	0.0765	0.06375	0.0765	0.0765	0.0867	0.06885	0.06375
A3	0.13005	0.14025	0.11475	0.1224	0.1224	0.14535	0.11475	0.102
A4	0.31365	0.357	0.255	0.3315	0.31875	0.3927	0.3009	0.26265
CD	0.255	0.2805	0.24225	0.2805	0.255	0.34425	0.255	0.2244

A. sapo

A1	0.04335	0.03825	0.0306
A2	0.0663	0.102	0.06885
A3	0.14025	0.1428	0.1071
A4	0.3825	0.36975	0.2805
CD	0.29325	0.3315	0.2295

A. sextus

A1	0.0765	0.0561	0.0765	0.0765	0.08925	0.07905	0.06375	0.03825
A2	0.1428	0.1428	0.1683	0.1428	0.1785	0.16575	0.14025	0.08925
A3	0.255	0.255	0.34425	0.2856	0.306	0.31365	0.255	0.14025
A4	0.49725	0.612	0.82875	0.663	0.77775	0.72675	0.62475	0.41565
CD	0.36975	0.39525	0.4335	0.459	0.4845	0.459	0.42075	0.255

A. sextus

A1	0.0765	0.0561	0.0561
A2	0.1785	0.14025	0.11475
A3	0.3468	0.255	0.24225
A4	0.7905	0.6375	0.5355
CD	0.47175	0.408	0.357

A. obtusus

A1	0.051	0.04845	0.05355	0.051	0.03825	0.0459	0.051
A2	0.0969	0.09435	0.09435	0.0969	0.0765	0.1173	0.10965
A3	0.1938	0.19125	0.19635	0.21675	0.153	0.22695	0.2142
A4	0.4335	0.44625	0.4386	0.51765	0.3825	0.49725	0.47685
CD	0.306	0.31875	0.31875	0.3315	0.255	0.34425	0.3825

A. madonnensis

A1	0.02805	0.03315	0.0306
A2	0.07395	0.0765	0.0765
A3	0.11475	0.1173	0.10455
A4	0.306	0.255	0.2856
CD	0.255	0.255	0.24225

Arrhopalites arca new species (Fig. 3 A-K)

Description: Body sparsely clothed, posterior setae (Fig. 3C-b) 1.5 times longer than anterior setae (Fig. 3C-a). Antennal ratios as shown in Table 2. Ant. IV divided into 7 subsegments (Fig. 3A); longest setae 3X the width of segment; Ant. IV apex with a capitate sense rod. Ant. III without basal swelling; sense organ (Fig. 3B) with 2 parallel sense rods in a single shallow pit; seta Aai club-shaped & blunt; setae Api & Ape slender with filamentous apex; Ae, Ap, & Ai normal. 1+1 eyes & a circular smooth area behind each eye. No cephalic spines, M5 absent (Fig. 3I). Metatrochanteral organ (seta D2) elongate (Fig. 3F). 1st unguis slender, without inner tooth, 2nd & 3rd ungues with inner tooth & tunica absent (Figs. 3J a-c). All unguiculi with corner tooth, 1st & 2nd unguiculi with a long apical filament, exceeding the unguis tip, 3rd unguiculus with short apical filament, not exceeding apex of unguis (Fig. 3J a-c). Tenaculum with 2 setae on anterior unpaired lobe (Fig. 3G). Dens with 7 dorsal E setae, E1 & E3 strongly spine like, other E setae normal; L1, L2, & L3 spine like, L4 absent; D1, D2, Id1, Id2, Id3, & Id4 present (Fig. 3D-a); 4 ventral rows of setae (3,2,1,1) present (Fig. 3D-b). Mucro narrow, gutter-like, both edges serrate (Fig. 3E). No cuticular spines on anal valve; seta C1 bifurcate, chaetotaxy as in Figure 3H. Female subanal appendage palmate (Fig. 3K). Body length of the adult female Holotype 0.88 mm, head 0.38 mm.

Derivatio nominis: Latin arcus = arch, after the type locality cave.

Holotype: female, USA, ID, Lincoln Co. Little Arch Cave, 16- VII- 1999. D. Hubbard coll. locality 9453,. Paratypes: 5 female & 2 males, same data as Holotype.

Other localities: ID, Lincoln Co. Tee Cave, 16 – VII-1999 D. Hubbard Coll. Locality 9451. Biogeographic zones 8 & 7B

Remarks: This species is very similar to *A. hubbardi* n. sp.; however it lacks the strong 3rd antennal segment basal papilla seen on *A. hubbardi*. This species can also be differentiated from *A. hubbardi* by lacking the M5 seta on the posterior part of head, by the presence of D9 seta on the anal valve & the shape of the female subanal appendages not branched at its shaft.

Arrhopalites sapo new species (Fig. 4 A-K)

Description: Body sparsely clothed, posterior setae (Fig. 4D-b) 1.5 times longer than anterior setae (Fig. 4D-a). Antennal ratios as shown in Table 2. Ant. IV, divided into 5 subsegments (Fig. 4A); longest setae 2X the width of segment; Ant. IV apex with a very small capitate sense rod. Ant. III without basal swelling; sense organ with 2 parallel sense rods in a single shallow pit; seta Aai rod-like & acuminate; seta Api & Ape slender & filamentous ; Ae, Ap, & Ai normal. 1+1 eyes. No cephalic spines, M5 absent (Fig. 4J). Metatrochanteral organ elongate (Fig. 4G). All ungues elongate, with inner tooth near base, no tunica (figs.4Ka-c). 1st & 2nd unguiculi with small corner tooth (Fig. 4K-a&K-b) , 3rd smooth (Fig.4K-c), long apical filament on 1st unguiculus, exceeding the unguis tip, 2nd & 3rd unguiculi with short apical filament, not exceeding apex of unguis. Tenaculum with 2 setae on anterior unpaired lobe (Fig. 4H). Dens with 7 dorsal E setae, E1 strongly spine-like, other E setae long & acuminate; L1, L2, & L3 not spine like but L1 is slightly swollen basally, L4 absent; D1, D2, Id1, Id2, Id3, & Id4 present (Fig. 4E-b); 4 ventral rows of setae (3,2,1,1) present (Fig. 4E-a). Mucro narrow, gutter-like, both edges serrate (Fig. 3F). No cuticular spines on anal valve; C1-C6 spiny or finely denticulate, chaetotaxy as in Figure 4I. Female subanal appendage spatulate with edges of distal 3rd serrate . Body length of the adult female Holotype 0.72 mm, head 0.4 mm.

Holotype: female, USA, Illinois, Monroe Co. Frog cave, locality 9462. paratypes 1 male, 2 females & one juvenile on the same slide as the Holotype. 4 VII 1999. J. Lewis coll.

Other localities: IL, Monroe Co. Rose hole cave, 5 – VII-1999 locality 9464. Pautler cave, 6-VI-1999 locality 9465. Jacobs Cave, 8-XI I -1998 locality 9466. All J. Lewis coll. Biogeographic zone 7a

Derivatio nominis: From Portuguese sapo = frog, after type locality cave.

Remarks: Arrhopalites sapo n. sp. is easy to recognize

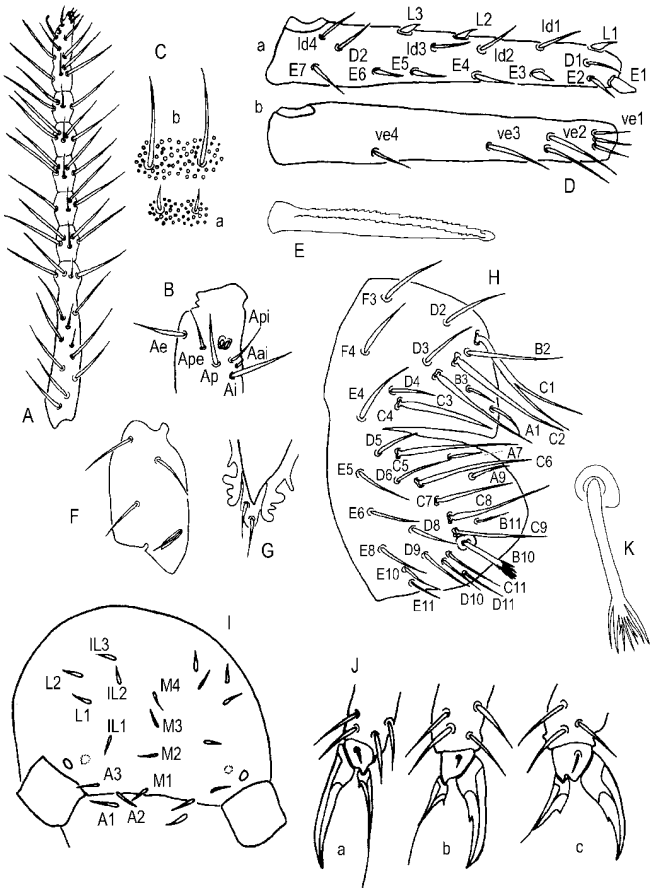

Figure 3. ***Arrhopalites arca*** **n. sp. A, 4th antennal segment; B, apical sense organ of 3rd antennal segment; C, body setae, a. anterior, b. posterior; D, chaetotaxy of dens, a. dorsal surface, b. ventral surface; E, mucro; F, metatrochanteral organ; G, tenaculum; H, anal valve chaetotaxy; I, posterior cephalic chaetotaxy; J, foot complex, a. 1st leg, b. 2nd leg, c. 3rd leg; K, female subanal appendage.**

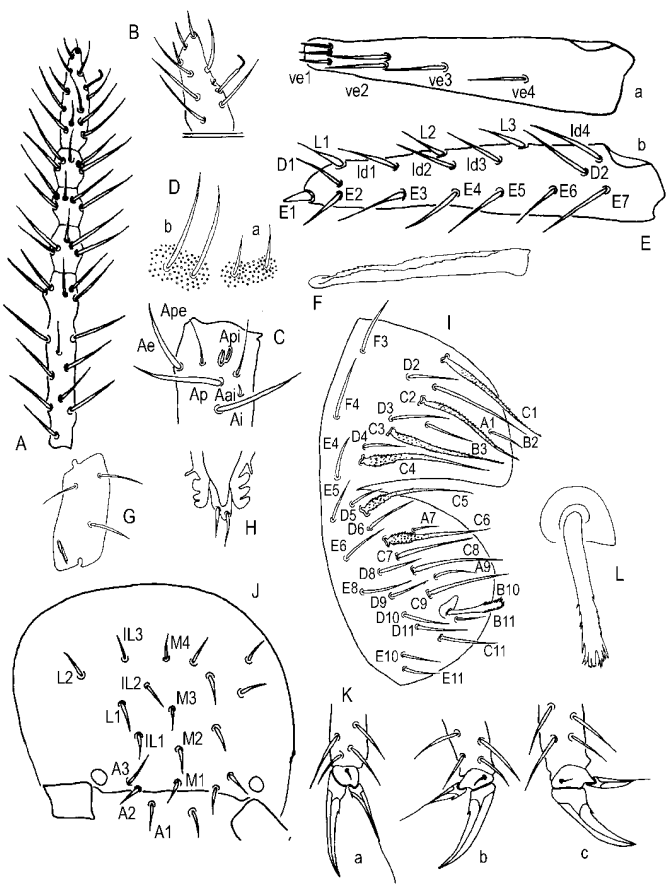

Figure 4. ***Arrhopalites sapo*** **n. sp. A, 4th antennal segment; B, apex of 4th antennal segment; C, apical sense organ of 3rd antennal segment; D, body setae, a. anterior, b. posterior; E, chaetotaxy of dens, a. ventral surface, b. dorsal surface; F, mucro; G, metatrochanteral organ; H, tenaculum; I, anal valve chaetotaxy; J, posterior cephalic chaetotaxy; K, foot complex, a. 1st leg, b. 2nd leg, c. 3rd leg.**

Table 3. Characteristrics of the clarus group of Arrhopalites.

	Species			
CHARACTER	*hubbardi*	*clarus*	*hirtus*	*habei*
Anal valve seta D7	absent	present	present	present
Anal valve seta D9	absent	present	present	present
Seta E7 of dens	present	present	absent	present
Subegments ANT IV	7divided	7divided	6divided	7divided
Apical ANT III seta Api	normal	normal	normal	rod like
Apical ANT III seta Ape	normal	normal	normal	Rod like
Ant III basal swelling	present	absent	absent	absent
cephalic seta M5	present	present	present	absent
Female subanal appendage	Palmate, short branches in its shaft	Rod like	Palmate, smooth shaft	flattened and fringed

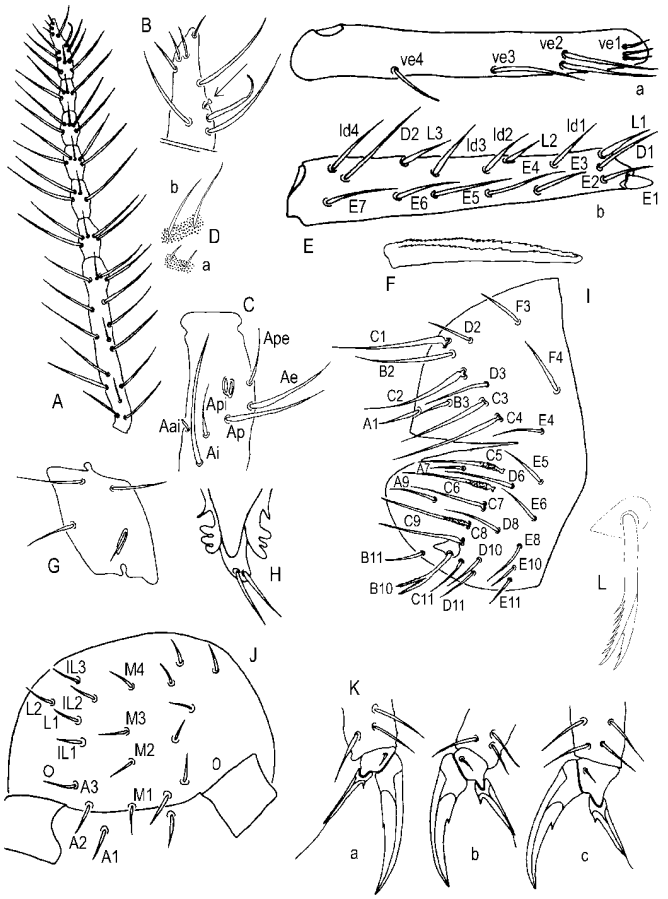

Figure 5. *Arrhopalites sextus* n. sp. A, 4th antennal segment; B, apex of 4th antennal segment; C, apical sense organ of 3rd antennal segment; D, body setae, a. anterior, b. posterior; E, chaetotaxy of dens, a. ventral surface, b. dorsal surface; F, mucro; G, metatrochanteral organ; H, tenaculum; I, anal valve chaetotaxy; J, posterior cephalic chaetotaxy; K, foot complex, a. 1st leg, b. 2nd leg, c. 3rd leg; L, female subanal appendage.

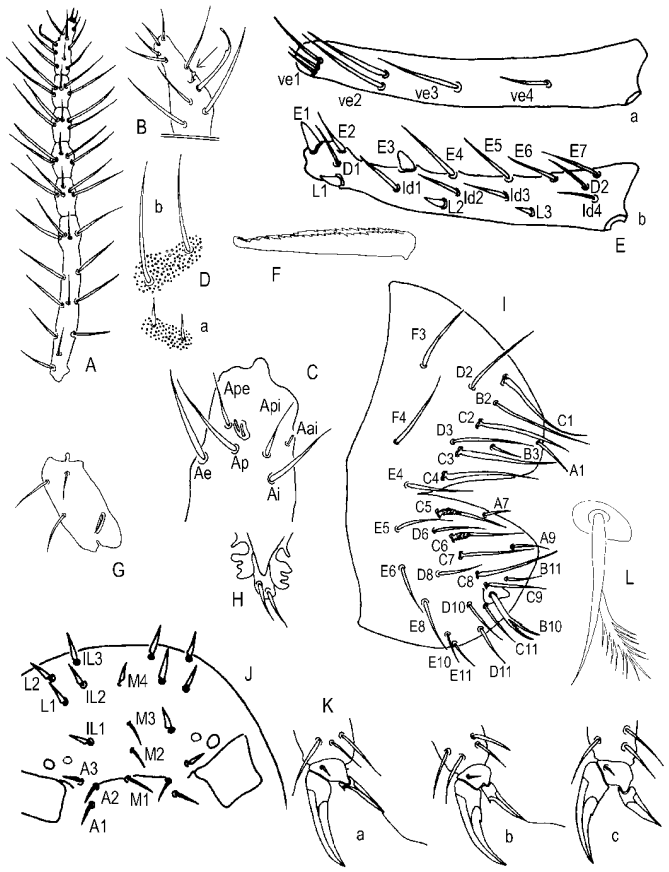

Figure 6. *Arrhopalites obtusus* n. sp. A, 4th antennal segment; B, apex of 4th antennal segment; C, apical sense organ of 3rd antennal segment; D, body setae, a. anterior, b. posterior; E, chaetotaxy of dens, a. ventral surface, b. dorsal surface; F, mucro; G, metatrochanteral organ; H, tenaculum; I, anal valve chaetotaxy; J, posterior cephalic chaetotaxy; K, foot complex, a. fmrst leg, b. 2nd leg, c. 3rd leg; L, female subanal appendage.

based on its subanal appendage the spiny setae on C series of anal valve & the basal inner ungual teeth. It is closely related to *A. commorus* but differs from it by lacking the basal papilla on antennal segment III & in the 4th antennal segment subsegmentation as well as the denticulate anal valve setae.

Arrhopalites sextus new species (Fig. 5 A-L)

Description: Body sparsely clothed, posterior setae (Fig. 5D-b) 1.5 times longer than anterior setae (Fig. 5D-a). Antennal ratios as shown in Table 2. Ant. IV, divided into 7 subsegments (Fig. 5A); longest setae 3.6X the width of segment; Ant. IV apex with a capitate sense rod. Ant. III without basal swelling; sense organ with 2 parallel sense rods in a single shallow pit; setae Aai rod like & pointed; setae Api & Ape slender with filamentous apex; Ae, Ap, & Ai normal (Fig. 5C). 1+1 eyes. No cephalic spines, M5 absent (Fig. 5J). Metatrochanteral organ (seta D2) elongate (Fig. 5G). All ungues elongate, with inner tooth, no tunica (Figs. K a-c). All unguiculi with corner tooth, long apical filament on 1st unguiculus, as long as the unguis tip, 2nd & 3rd unguiculi with shorter apical filament, not exceeding apex of unguis. Tenaculum with 2 setae on anterior unpaired lobe (Fig. 5H). Dens with 7 dorsal E setae, E1 strongly spine like, other E setae normal; L1, L2, & L3 not spine like but L1 is swollen basally, L4 absent; D1, D2, Id1, Id2, Id3, & Id4 present (Fig. 5 E-b); 4 ventral rows of setae (3,2,1,1) present (Fig. 5E-a). Mucro narrow, gutter-like, both edges serrate (Fig. 5F). No cuticular spines on anal valve; C5, C6, & C8 fine denticulate, chaetotaxy as in Figure 5I. Female subanal appendage forked & serrate along the distal half (Fig. 5L). Body length of the adult female Holotype 1.2 mm, head 0.52 mm.

Holotype: female, USA, VA, Wythe Co. Sam Six Cave. 25-XI-1998. On water surface, D. Hubbard coll. Locality 9951. Paratypes: same data as Holotype, 3 females. Biogeographic zone 7a

Derivatio nominis: Latin sextus = sixth, after the type locality – Sam Six cave.

Remarks: Arrhopalites sextus n. sp. shares the peculiar denticulate C series setae on the anal valves with *A. commorus* & *A. sapo* n. sp. It differs from them in the forked female subanal appendages, the 7-4th antennal segment subsegments, anal valve chaetotaxy & structure of the unguiculi.

Arrhopalites obtusus new species (Fig. 6)

Description: Body sparsely clothed, posterior setae (Fig. 6D-b) 1.5 times longer than anterior setae (Fig. 6D-a). Antennal ratios as shown in Table 2. Ant. IV, divided into 6 subsegments (Fig. 6A); longest setae 2.9X the width of segment; Ant. IV apex with a capitate sense rod. Ant. III without basal swelling; sense organ with 2 parallel sense rods in a single shallow pit; seta Aai club-shaped & blunt; seta Api & Ape slender with filamentous apex; Ae, Ap,

& Ai normal (Fig. 6C). 2+2 eyes but the 2nd eye is reduced to a circular smooth area & is much smaller than each lens-bearing eye. A3, M4, & L & IL series spine-like, M5 absent (Fig. 6J). Metatrochanteral organ elongate (Fig. 6J). 1st unguis without inner tooth, 2nd & 3rd with very weak teeth; No tunica (figs. a-c). 3rd unguiculus without corner tooth, 1st & 2nd with long apical filament, exceeding the unguis tip, 3rd unguiculus without apical filament. Tenaculum with 2 setae on anterior unpaired lobe (Fig. 6H). Dens with 7 dorsal E setae, E1 & E3 strongly spine like, other E setae normal; L1, L2, & L3 spine like, L4 absent; D1, D2, Id1, Id2, Id3, & Id4 present (Fig. 6E-b); 4 ventral rows of setae (3,2,1,1) with the external Ve2 2X the length of the others (Fig. 6E-a). Mucro narrow, gutter-like, both edges serrate (Fig. 6F). No cuticular spines on anal valve; Seta C1 simple, not forked, C5 & C6 finely denticulate (Holotype) or smooth (Paratypes), chaetotaxy as in Figure 6I. Female subanal appendage forked & serrate along one margin in the distal half (Fig. 6L) in Holotype but smooth in paratypes. Body length of the adult female Holotype 0.9 mm, head 0.4 mm.

Holotype: female, USA, VA, Rockingham Co. Bakers cave. 6-XII -1994. D. Hubbard coll. Locality 7801, Paratypes: same data as Holotype, 1 juvenile & 4 specimens from nearby Orebaugh Cave, 2- I- 2002, Hubbard Coll. Locality 9679. Biogeographic zone 7a

Derivatio nominis: Latin obtusus = blunt after the blunt E1 & E3 setae.

Remarks: This species is closely related to *A. jay* (Zeppelini 2001) but can easily distinguished by the unforked C1 seta & heavy spine-like cephalic setae on *A. obtusus*. Despite the denticulate C series setae on some specimens, this species is not related to *A. sextus* n. sp. It lacks setaceous L setae & has thick spine-like E3 seta on the dens. This species was collected both times along with specimens of the *A. pygmaeus* (Zeppelini 2001) group.

Arrhopalites madonnensis new species (Fig. 7 A-L)

Description: Body sparsely clothed, posterior setae (Fig. 7D-b) 1.5 times longer than anterior setae (Fig. 7D-a). Antennal ratios as shown in Table 2. Ant. IV subdivided into 5 subsegments (Fig. 7A); longest setae 2X the width of segment; Ant. IV apex with a capitate sense rod. Ant. III without basal swelling; sense organ (Fig. 7C) with 2 parallel sense rods in a single shallow pit; seta Aai club-shaped & blunt; seta Api short with filamentous apex, Ape short & acuminate; Ae, Ap, & Ai normal. 1+1 eyes. No cephalic spines, M5 absent (Fig. 7J). Metatrochanteral organ elongate (Fig. 7G). All ungues with inner tooth, tunica lacking (Figs. 7K a-c). 3rd unguiculus without corner tooth, 1st & 2nd with long apical filament, exceeding the unguis tip, 3rd unguiculus with a short apical filament. Tenaculum with 2 setae on anterior unpaired lobe (Fig. 7H). Dens with 6 dorsal E setae, E1 & E3 short heavy & strongly spine like as in *A. obtusus*, other E setae normal; L1 & L2 spine like but L3 is not. L4 absent; D1, D2, Id1, Id2, Id3, & Id4 present (Fig. 7E-b); 4 ventral rows of setae (3,2,1,1) present (Fig. 7E-a). Mucro narrow, gutter-like, both edges serrate (Fig. 7F). No cuticular spines on anal valve; setae C1(not bifurcate), C4, C5, & C6 lamellate, chaetotaxy as in Figure 7I. Female subanal appendage palmate (Fig. 7L). Body length of the adult female Holotype 0.54 mm, head 0.33 mm.

Holotype: female, USA, IL, Monroe Co. Madonnaville Cave. 11-XII -1998. J. Lewis. Paratypes: same data as Holotype, 1 female + 1 specimen in alcohol, locality 9961. Biogeographic zone 7a

Derivatio nominis: This species was named after type locality Madonna Ville Cave.

Remarks: This species is related to A. whitesidei & A. sericus (Zeppelini 2001). The two can be separated by their female subanal appendages, acuminate in *A. whitesidei & A. sericus* and palmate in *madonnensis*. It is also similar to *A. pavo* in many respects but differs sharply in the structure of the apical organ of the 3rd antennal segment. In *pavo* Ai is equal to or longer than Ap & Ae & below Aai. In *madonnensis,* Ai is much smaller than Ap & Ae & located on a level with Aai. One specimen has an unusual abnormality on one dens. Dorsal seta L2 is positioned between Id1 & Id2 rather than m outside these & in line with L1 & L3 as is normal.

DISCUSSION

The 28 previously described North American species of *Arrhopalites* are listed, keyed, described and figured in Christiansen and Bellinger (1998). The present work brings

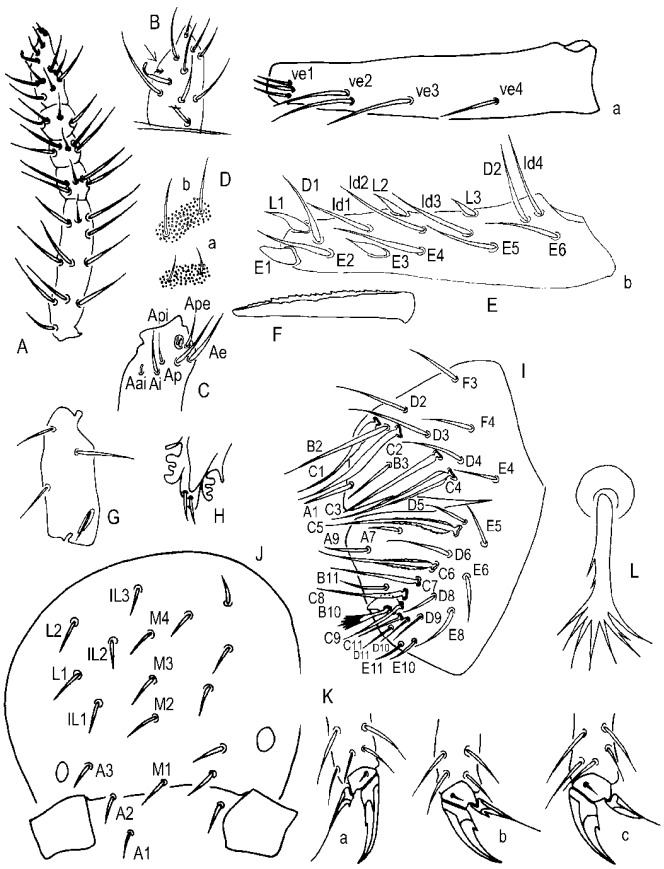

Figure 7. *Arrhopalites madonnensis* n. sp. A, 4th antennal segment; B, apex of 4th antennal segment; C, apical sense organ of 3rd antennal segment; D, body setae, a. anterior, b. posterior; E, chaetotaxy of dens, a. ventral surface, b. dorsal surface; F, mucro; G, metatrochanteral organ; H, tenaculum; I, anal valve chaetotaxy; J, posterior cephalic chaetotaxy; K, foot complex, a. 1st leg, b. 2nd leg, c. 3rd leg; L, female subanal appendage.

this number up to 35 but the fauna is still poorly known. This lack of knowledge almost certainly is partly because of problems collecting specimens of this genus. *Arrhopalites* species frequently are found on the surface film of water and are difficult to collect. It also appears likely that troglobitic species are more difficult to collect than the troglophile forms. The difficulty of collecting this genus is evidenced by the nature of *Arrhopalites* collections from VA. In our records, there are 153 Virginia cave collections made by David Hubbard and 96 made earlier by others. In collections made by those other than Hubbard, 14 (15%) yielded specimens of *Arrhopalites*. These specimens fell into 4 species only one of which was troglobitic. In contrast, 46% of Hubbard's collections yielded *Arrhopalites* with >10 troglobitic species. These data make any judgments about the richness of *Arrhopalites* fauna of any region questionable.

However, it does appear that there are regional differences (Table 1). Thus, in Missouri where we know of 407 collections

of cave Collembola, 82 (20%) of these contain *Arrhopalites* belonging to 4 species only 1 of which is troglobitic. Similarly, in Iowa, where 62 cave collections of Collembola have been made, 12 (19%) contained specimens of *Arrhopalites*. This indicates a very limited *Arrhopalites* fauna. This difference is not primarily collector determined because the Iowa caves were sampled by the junior author who has had great success in collecting this genus, yet in 62 caves with Collembola only 19% yielded specimens of *Arrhopalites*. Further evidence of geographic variation in species diversity is shown by the samples taken by Hubbard from 30 caves in Colorado and Idaho. Only 3 (10%) of these were found to contain *Arrhopalites*. Twenty-two percent of 85 collections of Collembola from Illinois caves yielded 8 species of Arrhopalites. Five of these are troglobites. Indiana has similar ratios of caves yielding Arrhopalites and troglobite species. Table 1 shows a mixture of genuine geographic differences and collector bias with the large percentage of caves with known *Arrhopalites* for Indiana and Illinois probably partly a genuine geographic variation but also influenced by the extensive collections made by Jerry Lewis in these regions. Similarly, while the large difference between Virginia and West Virginia or North Carolina in percentage of caves yielding *Arrhopalites* may to some degree reflect biogeographic features, the primary cause is almost certainly collector bias. On the other hand, the paucity of species in Texas and the West coast is probably mainly the result of biogeographic differences rather than collector bias. The junior author made many of the Texas collections and these did not yield more *Arrhopalites* that those made by other collectors. A better understanding of the geographic distribution of this group must await more extensive and effective collections; however, it is clear that the genus is poorly represented in caves both west of the Mississippi and in the extreme south of the continent. This trend seen in the U.S. is carried on in Mexico where, although 12 species have been recorded, only 3 are found in caves and 2 of these are troglobites.

Acknowledgments

This study was made possible by the collections of a number of speleologists. In addition to David Hubbard and Jerry Lewis, whom we have already mentioned, we would like to thank David Steinmann for his collections. Summer Ventis assisted with the preparation of the manuscript. The research was made possible by a grant to the senior author from the Brazilian CNPq and grants from Grinnell College.

References

Börner, C., 1906, Das System der Collembolen nebst Beschreibung neuer Collembolen des Hamburger Naturhistorischen Museums: Mitteilungen Naturhistorishe Museum Hamburg, v. 23, p. 147-188.

Christiansen, K., 1966, The genus *Arrhopalites* (Collembola, Sminthuridae) in the United States and Canada: International Journal of Speleology, v. 2, p. 43-73.

Christiansen, K., & Bellinger P., 1996, Cave *Arrhopalites* new to Science: Journal Cave & Karst Studies, v. 58, p. 168-180.

Christiansen, K., & Bellinger P., 1998, The Collembola of North America, north of the Rio Grande. A taxonomic analysis: Grinnell College, Grinnell, Iowa. p. 129–1264.

Lawrence, P.N., 1979, The terminology of terminalia and cartography of chaetotaxy in the Collembola, its evolutionary significance and systematic utility: First International Seminar Apterygota, Siena, p. 69-80.

Nayrolles, P., 1991, La chétotaxie antennaire des collemboles symphyplèones: Travaux Laboratoire Ecobioogique, Arthropodes Édaphique Toulouse, v. 6, p.1-94.

Zeppelini, D.F., 2001, Relações filogenéticas no gênero *Arrhopalites* (Collembola: Symphypleona: Arrhopalitidae): Tese de Doutoramento, Universidade de São Paulo, p. 1-183.