Ann. Limnol. - Int. J. Lim. 2007, 43 (3), 199-206

Morphology of the larvae of *Arrenurus biscissus* (O. F. Müller), 1776; *A. pugionifer* Piersig, 1897 and *A. bisulcicodulus* George, 1881 (Acari: Parasitengona: Arrenuridae)

A. Zawal

Department of Invertebrate Zoology & Limnology, University of Szczecin, 71-415 Szczecin, Wąska 13, Poland. E-mail: zawal@univ.szczecin.pl

The morphology of the larval stages of *Arrenurus biscissus, A. pugionifer* and *A. bisulcicodulus* is described. The three species belong to the subgenus *Micruracarus* and share several characters. The larvae of the three species differ in the shape of the dorsal plate, shape of the excretory pore plate, ratio between length of coxal plate median margins, and the numbers of pectinating setae on fifth palpal segment (PV). The larva of *A. biscissus* is very similar to the closely related *A. sinuator*. Larvae of *A. pugionifer* and *A. bisulcicodulus* resemble other *Micruracarus* species (*A. bifidicodulus, A. inexploratus, A. integrator*).

Keywords: Hydrachnidia, *Micruracarus*, water mites, larvae, morphology

Introduction

As in other higher taxa of water mites, also the subgeneric classification within *Arrenurus* is based on adults. Cook (1974) suggests that the *Arrenurus* subgeneric classification is artificial. Larval characters could prove useful in helping to solve these problems. A study of this kind begins with descriptions of the larval morphology of as many species as possible. Descriptions of the larvae of several species within the genus can be found in papers of Koenike (1908), Lundblad (1927, 1930), Münchberg (1936), Sparing (1959), Imamura and Mitchell (1967), Prasad and Cook (1972), Stechmann (1977), Smith I. M. (1978), Vainstain (1980), Cichocka (1980), Tuzovsky (1987), Smith B. P. (1990), Smith and Cook (1991), Martin 2000, Böttger and Martin (2003) and Zawal (2006a, b, c, d, e, 2007).

The present paper is aimed at describing *A. biscissus, A. pugionifer* and *A. bisulcicodulus*, which belong to the subgenus *Micruracarus*, and highlights the characters that allow us to differentiate between the three species; and compare those characters with the earlier descriptions of other *Arrenurus* species.

Materials and methods

The descriptions are based on larvae hatched from eggs laid by females caught in the field in several sites located in Poland (see below). Until egg laying, each female was held in a separate 100 cm^3 container filled with 20-24°C water and subsequently fixed in Wilson's liquid (Zawal 2006c). The eggs were held until hatching, under identical conditions. 48 h after hatching larvae were mounted in Hoyer's medium; the 48 h period being necessary for the larvae to became fully sclerotised.

Larval morphology of *A. biscissus, A. pugionifer* and *A. bisulcicodulus* was described based on larvae hatched from eggs laid by a single female of each of the species. The habitat characteristics of the collecting sites and sampling data as follows: *A. biscissus:* small lake with sandy bottom in Poznań, 15 May 2004, *A. pugionifer:* lake with muddy bottom in an alder-forest near Zgnitek, Międzychód district, 16 May 2004, *A. bisulcicodulus:* lowland peatbog Krępskie Bagno near Krępsko, among sedges, Goleniów district, 2 May 2003). The mounts (*A. biscissus:* Nos 136E, 136Ea; *A. pugionifer:* Nos 52E, 52Ea; *A. bisulcicodulus:* Nos 822, 822a) are stored at the Department of Invertebrate Zoology and Limnology, University of Szczecin. Larval body parts were measured on the progeny of three females of *A. biscissus*, one female of *A. pugionifer*, and 10 females of *A. bisulcicodulus*. The females were collected from various habitats, in order to document a relatively wide range of individual variability.

Drawings were prepared with a drawing attachment to a Nikon ECLIPSE80i microscope. It is very difficult to adequately represent the arrangement of the secon-

Article available at http://www.limnology-journal.org or http://dx.doi.org/10.1051/limn:2007014

dary setae as they are frequently barely visible. For this reason, those setae bearing secondary ones were drawn as they were spotted, at least in one mount. Consequently, all the setae drawn appear to bear secondary setae, as they in fact do. On the other hand, the lack of secondary setae on smooth primary ones could have been caused by overlooking them on a mounted specimen. The setal terminology follows Prasad and Cook (1972), with modification by Zawal (2006a). The metric characters are reported with their ranges, mean values, and standard deviations. The leg segments were measured from their distal margins. In this paper the following abbreviation are used: Cp – coxal plate, Exp – excretory pore, Expp – excretory pore plate.

Results

Arrenurus biscissus

The oval dorsal plate is widest in the middle of its length and distinctly narrows in the posterior and the anterior parts. The anterior margin is almost straight and the posterior margin is rounded. The anterior-lateral incisions are very small, almost invisible, with obtuse angles, and reach to about one-fifth of the plate width and one-seventh of its length. The Lpl seta is tripartite; the remaining setae smooth (Fig. 1B).

Median margins of the CpI are distinctly the longest, followed by CpII and CpIII (Fig.1A). The ratios of CpI/CpII/CpIII are 3.9/2.3/1 respectively (Table 1). All seatae on the coxal plates are bipectinate (Fig. 1A). The distance C1-CpI median margin reaches to about ¾ the C4-CxpIII median margin. The C1-C2 distance is long (Table 1, Fig. 1A).

The Expp is pentangonal-shaped with a characteristic process on the posterior part which includes the Exp. The Exp is situated distintly posterior to the middle of the shield and posterior to the E2 setae (Table 1, Fig. 1C).

In shape and sizes pedipalps resemble those of other *Arrenurus* species. The PIII1 seta is thick and bipectinate. The PV4 and PV5 setae are bipectinate, the PV4 seta long and thin and PV5 thicker and shorter (Fig. 1D).

The first segment of the chelicerae has the form of an elongated and slightly curved cylinder with margins parallel to each other (Fig. 1E).

The proportions of the segments are more or less the same on each leg. The distinctly shortest trochanter constitutes about 2/3 of the length of the femur, the genu is slightly shorter than the femur, the tibia is 1.5 times longer and the tarsus twice as long (Table 2).

The IGe3, ITi3, IIGe3, IIGe4 IITi3, IIIGe3, IIIGe4, IIITi3 and IIITi4 setae are thick and bipectinate. The ITi8 seta is long and thin; IITi10 is pectinate and lies near the centre of the tibia (Fig. 1F, G, H).

Arrenurus pugionifer

The dorsal plate is oval, widest in the middle of its length and narrowing distinctly to the front; the posterior margin is pointed. The anterior-lateral incisions are visible but rather small, their angles almost straight, reach about one-sixth of the length and one-third of the width of the plate. The Lpl seta is tripartite, the remaining setae are smooth and thin (Fig. 2B).

The CpII median margin is the shortest. The ratio of CpI/CpII/CpIII median margins is 2.1/1/1.6 (Table 1), respectively. All setae on the coxal plates and the V3 setae are bipectinate (Fig. 2). The distance C1-CpI median margin reaches about 2/3 the distance C4-CpIII median margin. The C1-C2 distance is rather short (Table 1, Fig. 2A).

The Expp is almost rounded, slightly wider than long, with the anterior margin slightly convex and posterior one pointed, with a characteristic process below. The Exp is situated posterior to the centre of the plate and beneath the E2 setae (Fig. 2C).

The PIII1 seta is bipectinate, and the PV5 is pectinate (Fig. 2D).

The first segment of the chelicerae is elongated with slightly bent margins parallel to each other (Fig. 2E).

The segments of the limbs are slightly shorter than in *A. biscisus*, however the proportions are similar (Table 2). The IITi8 seta is thick, short and bipectinate, the IITi10 seta is short and pectinate and lies near the centre of tibia, the IIITi10 is bipectinate and lies posterior to the centre of the tibia (Fig. 2F, G, H).

Arrenurus bisulcicodulus

The dorsal plate is egg-shaped, widest at mid-length with the anterior margin slightly curved and the posterior one rounded. The anterior-lateral incisions are fairly small with slightly obtuse angles, reaching about one-sixth of the length of the plate and one-quarter of its width. The Lpl setae are tripartite and the remaining ones smooth (Fig. 3B).

The CpI median margins are the longest, followed by CpIII; the shortest are those of the CpII. The ratio of CpI/CpII/CpIII is 2.1/1/1.3 respectively (Table 1). All the setae on the coxal plates are smooth (Fig. 3). The distance C1-CpI median margin reaches about 2/3 the distance C4-CpIII median margin. The C1-C2 distance is fairly short (Table 1, Fig. 3A).

Table 1. Dimensions (in µm) of individual body parts

	A. biscissus (n=10)			*A. pugionifer* (n=5)			*A. bisulcicodulus* (n=10)		
	range	mean	standard deviation	range	mean	standard deviation	range	mean	standard deviation
length	258-282	270.0	8.43	250-274	259.8	6.29	220-230	225.0	3.68
width	228-252	237.4	6.74	234-240	237.6	2.46	184-194	188.0	3.27
dorsal plate length	240-280	256.6	13.86	232-250	244.6	5.25	220-224	221.4	1.65
dorsal plate width	220-244	229.6	7.47	220-224	221.2	1.69	168-174	170.8	2.15
CpI medial margin length	94-106	96.2	3.96	75-78	76.3	0.86	62-67	64.9	1.58
CpII medial margin length	57-58	57.4	0.63	36-38	36.9	0.70	31-32	31.4	0.39
CpIII medial margin length	24-26	24.6	0.66	59-62	60.8	1.07	38-42	40.8	1.25
distance: Mp1-Mp1	43-44	43.8	0.39	45-50	46.8	1.47	44-46	44.6	0.66
distance: Lp1-Lp1	64-69	66.9	1.37	57-68	63.8	2.87	54-57	55.4	0.85
distance: Lp2-Lp2	115-118	116.1	0.80	102-105	103.0	1.12	94-97	95.7	0.67
distance: Mp2-Mp2	68-70	69.3	0.94	56-64	60.0	2.10	52-54	53.1	0.86
distance: Mh1-Mp2	57-61	59.3	1.43	63-67	64.6	1.20	43-48	45.7	1.43
distance: Mp1-Lp1	8-11	10.0	0.94	6-10	8.0	0.92	6-7	6.64	0.66
distance: Mp1-Lp2	38-46	42.7	2.21	28-37	31.6	2.42	38-43	39.7	1.60
distance: Mp1-Mp2	68-70	69.2	0.86	69-78	72.0	2.47	70-73	70.7	1.20
distance: Mp2-Mh1	26-45	39.2	5.10	15-22	19.0	1.85	18-27	20.4	2.62
distance between C1 and CpI median margin	28-29	28.3	0.41	22-25	23.8	0.91	20-22	21.6	1.00
distance between C4 and CpIII median margin	41-46	43.1	1.33	30-32	31.8	0.66	30-31	30.4	0.65
distance between C1 and C2	57-62	59.8	1.45	46-52	48.4	1.57	42-45	43.8	0.76
excretory pore plate length	29-33	30.2	1.18	32-36	34.3	1.33	28-30	28.6	0.63
excretory pore plate width	32-36	34.1	1.20	34-38	37.0	1.24	30-31	30.1	0.56
distance between Exp and Expp posterior margin	10-11	10.2	0.63	10-12	10.4	0.84	9-10	10.0	0.57
distance between E1 setae and Expp anterior margin	6-7	6.2	0.51	8-10	8.6	0.54	5-8	6.4	1.07
distance between E2 setae and Expp posterior margin	13-14	13.4	0.63	13-18	15.0	1.35	12-16	13.4	1.20
PI length	10-12	10.7	0.86	8-10	8.6	0.63	10-13	11.6	0.94
PII length	33-36	34.5	0.96	30-32	31.0	0.66	30-34	32.6	1.07
PIII length	35-38	36.9	0.96	27-31	29.4	1.30	29-30	30.0	0.57
length of PIV claw	22-27	24.0	1.41	20-23	21.8	1.07	20-22	21.1	0.67
length of cheliceral segment I	100-110	104.3	2.56	89-94	91.2	2.60	80-86	83.4	1.73
length of PV 8 seta	179-197	191.1	5.75	162-169	165.4	2.20	138-141	138.6	1.12

The width of the oval excretory pore plate is almost equal to its length. The Exp lies posterior to the centre of the plate and beneath E2 setae (Fig. 3C).

The pedipalps resemble those of *A. pugionifer*. The PIII1 seta is smooth. The PV5 seta is pectinate and the PV8 bipectinate (Fig. 3D).

The first segment of the chelicerae has the form of a bent and elongated cylinder (Fig. 3E), slightly narrowing to the front.

The dimensions of the different segments of the legs are slightly shorter than those found in *A. biscisus*, however their mutual proportions are more or less the same (Table 2). The ITi8 is short, IITi10 and IIITi10 are smooth, short and are located about 2/3 of the length of the tibia. On the tarsus of leg pair III, *A. bisulcicodulus* has one seta more than other species of the genus Arrenurus. It is marked as IIITa8 (Fig. 3F, G, H).

Table 2. Dimensions (in µm) of leg segments

		trochanter			femur			genu			tibia			tarsus		
		range	mean	standard deviation	range	mean	standard deviation	range	mean	standard deviation	range	mean	standard deviation	range	mean	standard deviation
A. biscissus (n=10)	I	24-26	24.8	0.84	44-50	45.7	1.86	46-52	48.0	1.92	73-80	75.0	2.29	86-99	88.5	4.20
	II	31-32	31.8	0.34	48-54	51.6	1.57	49-50	49.8	0.63	78-84	80.5	1.78	100-112	106.3	3.78
	III	48-49	48.2	0.41	48-49	48.5	0.41	48-51	49.9	1.14	74-82	77.5	2.21	104-114	108.4	2.48
A. pugionifer (n=5)	I	24-26	24.7	0.70	40-43	42.0	1.42	40-42	40.6	0.63	58-60	59.4	0.66	74-76	75.0	0.63
	II	27-29	27.8	0.51	42-44	42.7	0.77	40-42	40.4	0.57	59-62	60.7	0.88	80-84	82.1	1.20
	III	34-38	35.8	1.30	40-42	41.0	0.83	39-41	40.1	0.45	60-62	61.0	0.63	80-85	84.2	2.03
A. bisulcicodulus (n=10)	I	22-27	25.4	1.31	40-42	40.5	0.67	35-37	36.1	0.59	50-53	51.4	0.98	68-69	68.5	0.41
	II	26-29	28.0	0.75	41-42	41.4	0.34	36-37	36.6	0.39	53-55	53.9	0.77	71-76	73.8	1.64
	III	35-36	35.7	0.41	40-42	40.6	0.63	37-38	37.4	0.39	54-56	55.2	0.84	75-76	75.9	0.41

Discussion

Larvae of the species belonging to the subgenus *Micruracarus* have at least three pectinate setae on PV (Zawal 2006b). The characters differentiating the species described include: the number of pectinate setae on PV, the shape of the dorsal and excretory pore plates; and the proportions of CpI/CpII/CpIII. *A. biscissus* shows four pectinate setae (PV4, PV5, PV7 and PV8), three pectinate setae each occurring in *A. pugionifer* and *A. bisulcicodulus* (PV5, PV7 and PV8). The *A. biscissus* larva is very similar to that of *A. sinuator* in shape of dorsal plate, CpI/CpII/CpIII ratio, in shape of chelicera, in the size and pectinating of the PIII1, PV4 and PV5 setae, and in the size and setation of legs; which characters differ them from other *Arrenurus* species (Zawal 2006b). *A. biscissus* larva differs from *A. sinuator* in having a more rounded posterior margin to the dorsal plate, in the shape of Exp which is rhomboid with a small process on the posterior margin in *A. sinuator* and pentagonal with a much larger process in *A. biscissus*, and in the PV4 and PV5 setae, which are pectinate along the entire length in *A. biscisus*, while in *A. sinuator* they begin to be pectinate at 1/3 of their length from the base. The *A. biscissus* larvae are slightly larger than those of *A. sinuator*. However, because all the dimensions are proportionally larger and the number of *A. biscisus* larvae obtained from the culture was relatively low, the existence of smaller *A. biscissus* larvae cannot be ruled out. Imagines of the two species are very similar also, which evidences their close affinity.

Larvae of *A. pugionifer* and *A. bisulcicodulus* reseamble in particular characters to different *Arrenurus* species. Therefore we are can not to show the most similar species. In their proportions of CpI/CpII/CpIII and presence secondary setae on the three PV setae, the *A. pugionifer* and *A. bisulcicodulus* larvae resemble the larvae of three other species (*A. bifidicodulus, A. inexploratus, A. integrator*) of the sub-genus *Micruracarus* (other species of *Micruracarus* have more then three PV setae pectinate) (Zawal 2006b, 2007).

Dorsal plates and excretory pore plates in the *Micruracarus* larvae have differ shape in different species (Zawal 2006b) and cannot be used as a diagnostic character of subgenus *Micruracarus*. The dorsal plate of *A. pugionifer* is similar to that of *A. stecki*, a species representing the sub-genus *Truncaturus* (Zawal 2006e), while the dorsal plate of *A. bisulcicodulus* resembles those of the species (*A. tricuspidator, A. claviger*) belonging to the sub-genus *Arrenurus* s. str. (Zawal 2006d, c). The Expp of *A. bisulcicodulus* resembles than in *A. inexploratus* (Zawal 2007), while the Expp of *A. pugionifer* is similar to that in *A. sinuator* (Zawal 2006b).

Larvae of all the species described in this work show one character typical for larvae of the subgenus *Micruracarus* (at least three PV setae are pennate). From other points of view the *A. biscissus* larva is very

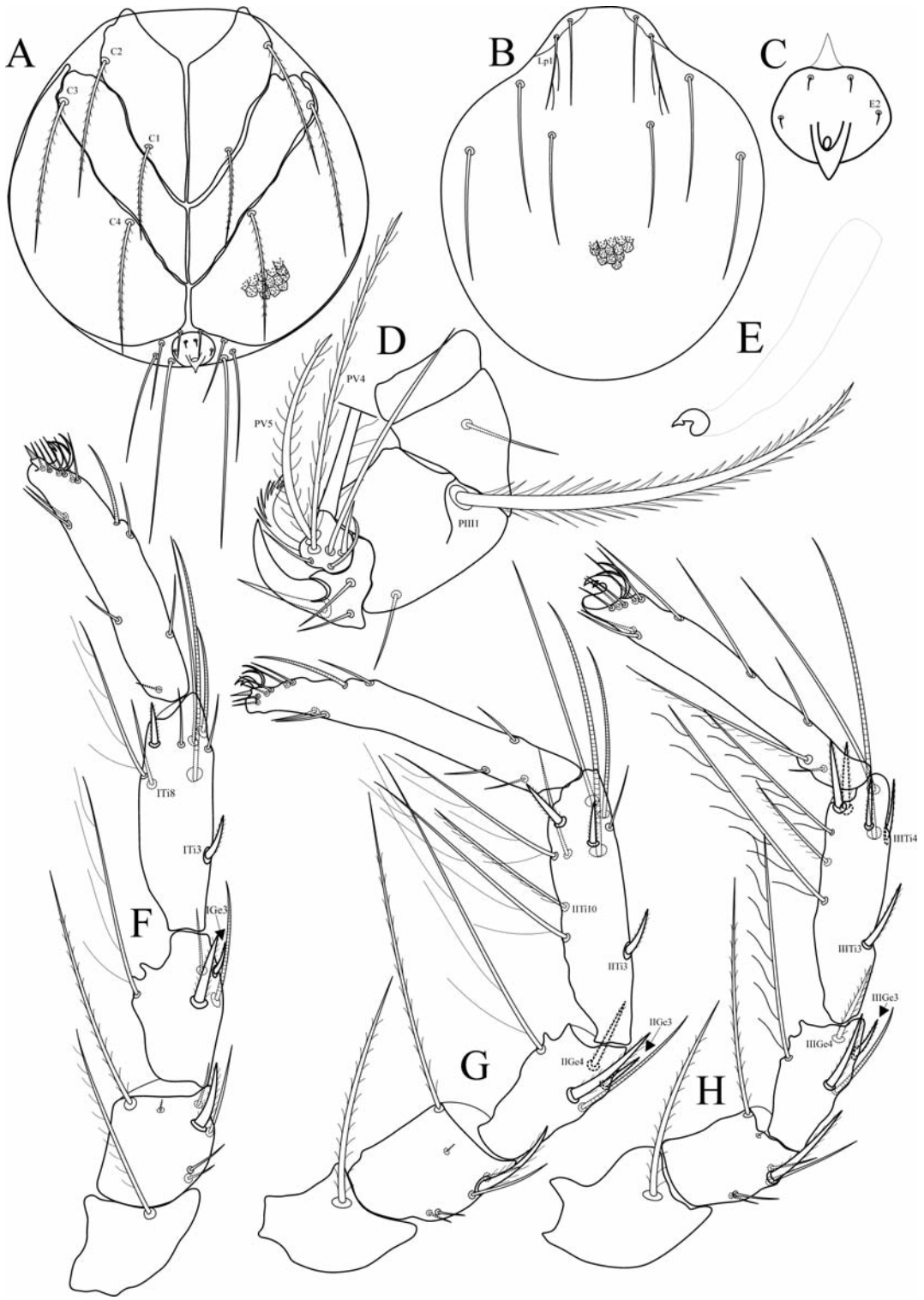

Fig. 1. Morphology of the larva of *Arrenurus biscissus*: A – ventral side, B – dorsal plate, C – excretory pore plate, D – pedipalp, E – chelicera, F – leg I, G – leg II, H – leg III.

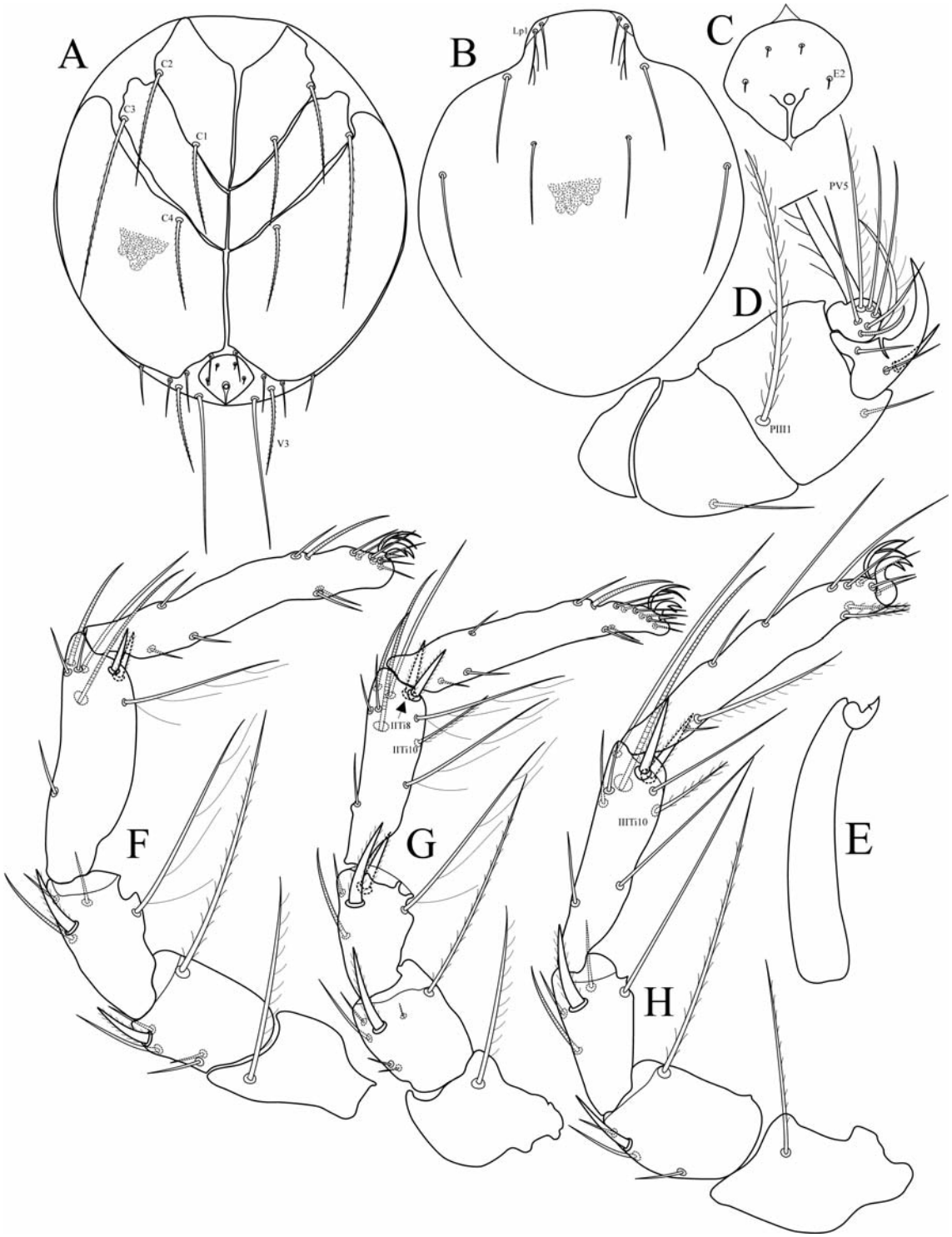

Fig. 2. Morphology of the larva of *Arrenurus pugionifer*: A – ventral side, B – dorsal plate, C – excretory pore plate, D – pedipalp, E – chelicera, F – leg I, G – leg II, H – leg III.

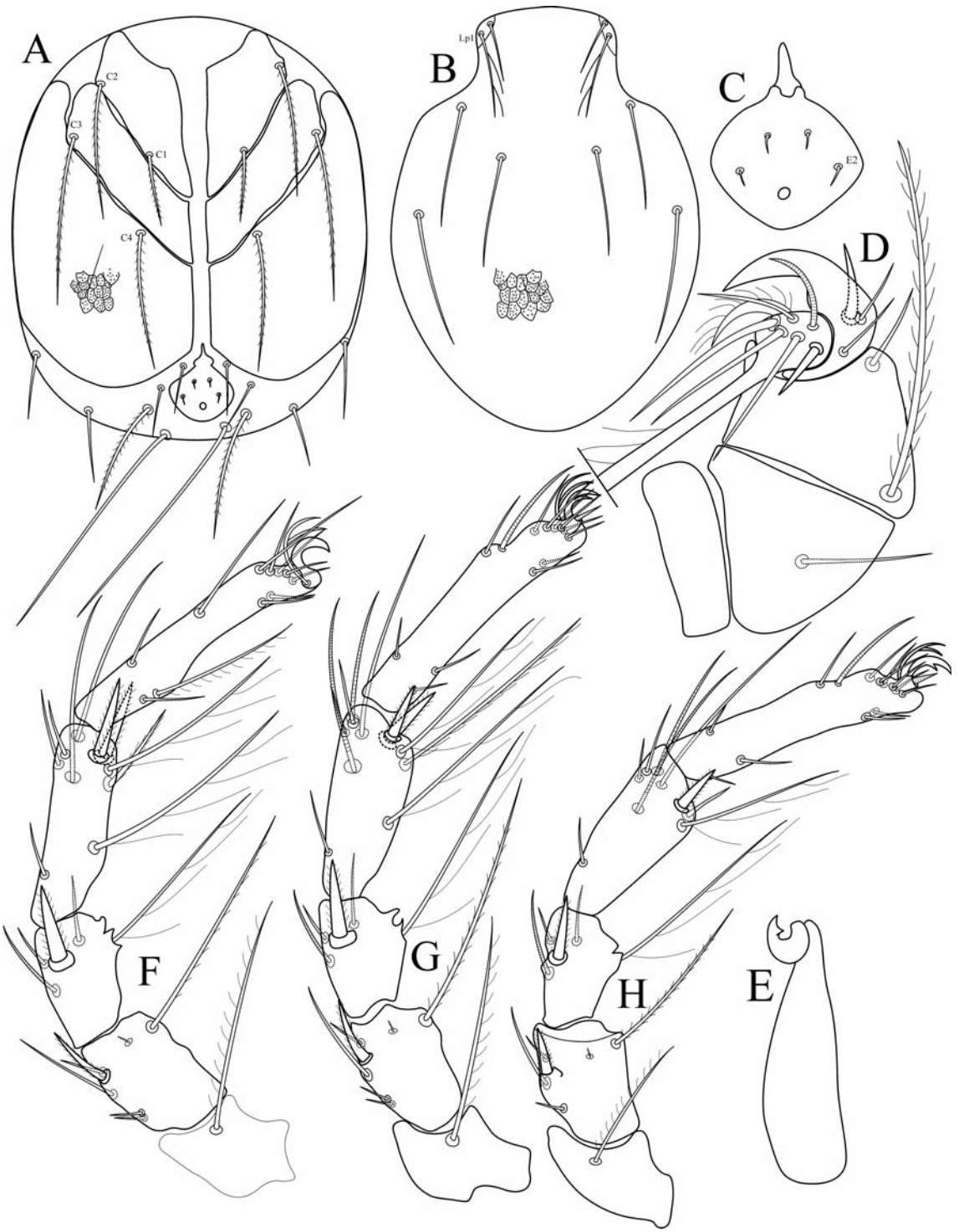

Fig. 3. Morphology of the larva of *Arrenurus bisulcicodulus*: A – ventral side, B – dorsal plate, C – excretory pore plate, D – pedipalp, E – chelicera, F – leg I, G – leg II, H – leg III.

similar to that of the very closely related *A. sinuator*, while larvae of *A. pugionifer* and *A. bisulcicodulus* resemble to those of other subgenera (*Truncaturus* and *Arrenurus* s. str.). It seems that the analysis of larval morphology could serve as a starting point for phylogenetic conclusions, but these, however, would have to be based on analysis of larvae of a higher number of species representing the genus *Arrenurus*. Further studies with more species from all subgenera are need in order to test if the characters investigated here are useful for definition of species-groups and subgenera in *Arrenurus*.

Acknowledgements

I thank E. Biesiadka, University of Warmia and Mazury for consultation, and R. A. Baker, University of Leeds for corrections to the text. Financial support was provided by the Committee for Scientific Research in 2004-2007 years, research grant no. 2P04C10527.

References

Böttger K. & Martin P. 2003. – On the morphfology and parasitism of *Arrenurus globator* (O.F. Müller, 1776) (Hydrachnidia, Acari) a water mite with an unusually extensive host spectrum. *Acarologia*, 43, 49-57.

Cichocka M. 1980. – Opis larwy *Arrenurus bifidicodulus* Piersig, 1897 (Hydrachnellae, Acari). *Przegl. Zool.*, 24, 309-315. [in Polish with English summary]

Cook D.R. 1974. – Water mite genera and subgenera. *Mem. Am. ent. Inst.*, 21, 1–860.

Imamura T. & Mitchell R. 1967. – The water mites parasitic on the damselfly, *Cercion hierglyphicum* Brauer. I. Systematics and life history. *Annot. Zool. Japan.*, 40, 28–36.

Koenike F. 1908. – Beitrag zur Kenntnis der Hydrachniden. *Abh. naturw. Ver., Bremen*, 19, 245–250.

Lundblad O. 1927. – Die Hydracarinen Schwedens. I. Beitrag zur Systematik, Embryologie, Ökologie und Verbreitungsgeschichte der schwedischen. *Arten. Zool. Bidrag*, 11, 185–540.

Lundblad O. 1930. – Hydracarina. *Zoology of the Faroes Copenhagen*, 2, 1–65.

Martin P. 2000. – Larval morphology and host-parasite associations of some stream living water mites (Hydrachnidia, Acari). *Arch. Hydrobiol.*, suppl., 121(3-4), 269-320.

Münchberg P. 1936. – Zur Morphologie der *Arrenurus*- und *Georgella*-Larven nebst -Nymphen, mit besonderer Berücksichtigung der Libellenparasiten. *Arch. Naturg. N. F.*, 5, 93–115.

Prasad V. & Cook. D.R. 1972. – The taxonomy of water mite larvae. *Mem. Am. ent. Inst.*, 18, 1–326

Smith B.P. 1990. – Description of larval *Arrenurus bartonensis* Cook, *Arrenurus birgei* Marshall, *Arrenurus neobirgei* Cook, and *Arrenurus rotundus* Marshall (Acari: Hydrachnidia; Arrenuridae). *Can. Ent.*, 122, 77–91.

Smith I.M. 1978. – Descriptions and observations on host associations of some larval Arrenuroidea (Prostigmata: Parasitengona), with comments on phylogeny in the superfamily. *Can. Ent.*, 110, 957–1001.

Smith I.M. & Cook D.R. 1991. – Water mites. In: Thorp, J. H. & Covich, A. P. (eds) *Ecology and Classification of North American Freshwater Invertebrates* (New York: Academic Press), 523-592.

Sparing J. 1959. – Die Larven der *Hydrachnellae*, ihre parasitische Entwicklung und ihre Systematik. *Parasit. Schr. reiche*, 10, 1–168.

Tuzovsky P.V. 1987. – *Morphologia i postembrionalnoie raswitie wodianych klieščiej*. Nauka, Moscow, 172 p. [in Russian]

Vainstein B.A. 1980. – *Opriedielitiel ličinok wodianych klieščiej*. Nauka, Leningrad, 238 p. [in Russian]

Zawal A. 2006a. – Morphology of larval stages of *Arrenurus cuspidator* (O. F. Müller, 1776), and *A. maculator* (O. F. Müller, 1776) (Acari: Hydrachnidia). *Zootaxa*, 1194, 57-68.

Zawal A. 2006b. – Morphology of the larvae of three species of *Arrenurus* (Acari: Parasitengona: Arrenuridae). *Jour. Nat. Hist.*, 40 (1-2), 89-100.

Zawal A. 2006c. – Larval morphology of *Arrenurus cuspidifer* Piersig, *A. claviger* Koenike, and *A. latus* Barrois & Moniez (Acari: Hydrachnidia). *Zootaxa*, 1276, 55-68.

Zawal A. 2006d. – Morphology of the larval stages of *Arrenurus bicuspidator* Berlese, 1885; *A. tricuspidator* (O. F. Müller), 1776 and *A. tetracyphus* Piersig, 1894. *Acarina*, 14 (1), 89-96.

Zawal A. 2006e. – Morphology of the larvae of *Arrenurus nodosus* Koenike, 1896; *A. knauthei* Koenike,1895 and *A. stecki* Koenike, 1894 (Acari: Parasitengona: Arrenuridae). *Ann. Limnol. -Int. J. Lim.*, 42 (3), 197-204.

Zawal A. 2007. – Morphology of larval stages of *Arrenurus crassicaudatus* Kramer, 1875; *A. inexploratus* Viets, 1930 and *A. integrator* (O. F. Müller), 1776. *Acarologia*. (in press).