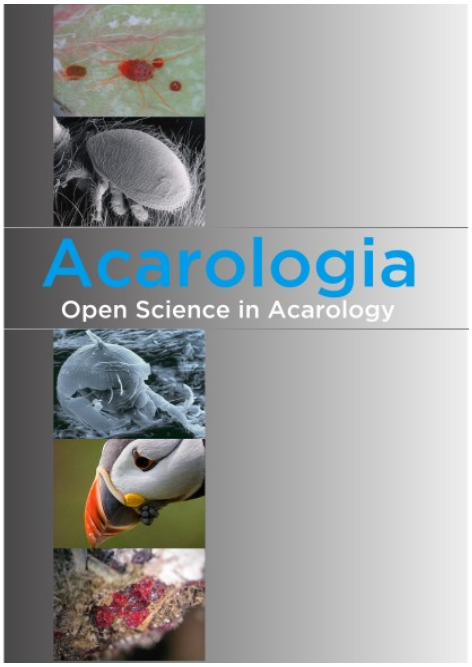

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MORPHOLOGY OF THE LARVAL STAGES OF *ARRENURUS CRASSICAUDATUS* KRAMER, 1875 *A. INEXPLORATUS* VIETS, 1930 AND *A. INTEGRATOR* (O. F. MÜLLER, 1776)

BY A. ZAWAL [1]

(Accepted February 2006)

WATER MITES
HYDRACHNIDIA
MICRARRENURUS
MICRURACARUS

SUMMARY: Larval stage of *A. crassicaudatus* is redescribed and larval stage of *A. inexploratus* and *A. integrator* are described for the first time. A particular attention is paid to the different characters of the three species. The present description of larval *A. crassicaudatus* is compared to that given by STECHMANN (1977). Differences between the three species concern the in shape of the dorsal plate and excretory pore plate, ratio of the length of the median margins of the coxal plates and the distance of *Mp1-Mp1*.

ZUSAMMENFASSUNG: Die vorliegende Arbeit beinhaltet die Beschreibung der Larven von *A. inexploratus* und *A. integrator.* Verglichen wurden die Larven untereinander sowie die Beschreibung von *A. crassicaudatus* mit derjenigen von STECHMANN (1977). Morphologische Unterschiede zwischen den beschriebenen Arten betreffen die Gestalt der Dorsal- und Excretoryplatte, die Verhältnisse zwischen den medialen Längen der Coxalplatten sowie das Vorhandensein oder Fehlen einer Fiederung bestimmter Borsten und *Mp1-Mp1* Entfernung.

INTRODUCTION

Knowledge about water mites is based mainly on adults and can be substantially increased, both in taxonomic, biological, and ecological aspects, by intensifying research on larval stages. Such research is particularly important for resolving the distribution and dispersal of various species, and in population size control.

Water mites have three active stages: larva, deutonymph and adults. The deutonymph and adults are predators, whereas the larva is parasitic in most species (GLEDHILL 1985). In *Arrenurus* Dugès, the initial period of attachment by the larva to its larval host (phoretic period) is followed by a parasitic stage on adult odonates (BÖTTGER 1976).

A study of this kind begins with descriptions of the larval morphology of each species. Our knowledge of larval *Arrenurus* is particularly poor. Very inadequate descriptions of several species of the genus can be found in papers of KOENIKE (1908), LUNDBLAD (1927, 1930), MÜNCHBERG (1936), and SPARING (1959). The best descriptions can be found in papers of IMAMURA & MITCHELL (1967), PRASAD & COOK (1972), SMITH I. M. (1978), VAINSTEIN (1980), CICHOCKA (1980), SMITH B. P. (1990), TUZOVSKY (1987), MARTIN (2000), SMITH *et al.* (2001), BÖTTGER & MARTIN (2003) and ZAWAL (2006a, b, c, d, e).

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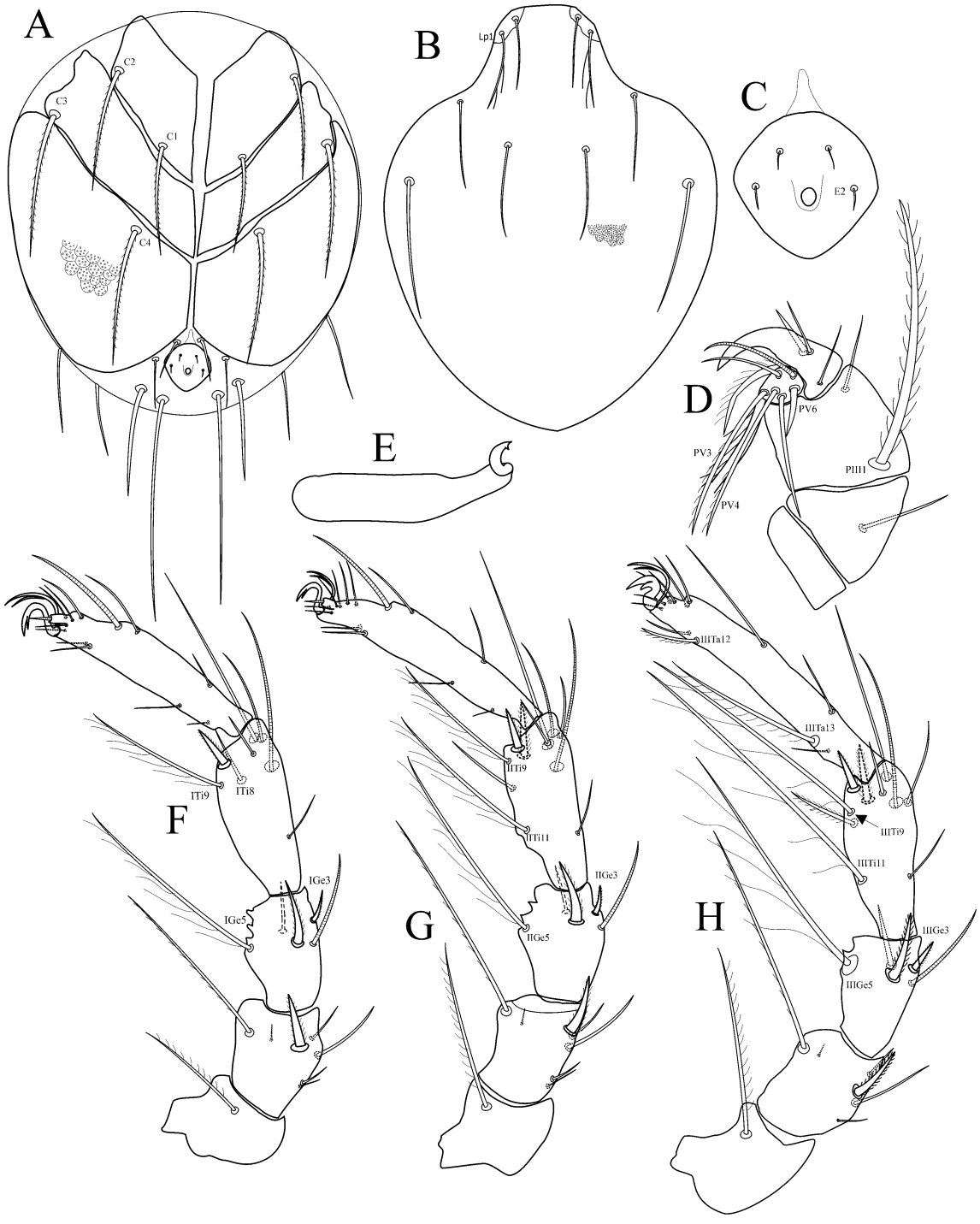

FIG. 1. *Arrenurus crassicaudatus* Larva A. — Ventral side. B. — Dorsal plate. C. — Excretory pore plate. D. — Pedipalp. E. — Chelicera. F. — Leg I. G. — Leg II. H. — Leg III.

The present paper is aimed at describing *Arrenurus crassicaudatus*, *A. inexploratus*, *A. integrator* and to highlight the characters that allow us to differentiate between the three species. It is also intended to compare those characters with the earlier description of *A. crassicaudatus*, published by Stechmann (1977).

Materials and methods

The descriptions are based on larvae hatched from eggs laid by females caught in the field. The females were identified using keys (Viets (1936) and Sokolov (1940)), in the case of *A. crassicaudatus* the description by Cassagne-Méjan (1966), and in the case of *A. inexploratus* the description of Smith & Hammen (1990) was used. The female of *A. integrator* was identified by the very short fourth palpal segment. Before egg laying, each female was kept in a separate 100 cm^3 container filled with 20-24°C water without any feeding and subsequently fixed in Wilson's liquid (Zawal 2006d). Females of *A. crassicaudatus* lay 2-51 eggs, which hatch in 7.6 days on average (Włodarczyk & Zawal 2004). Females of *A. inexploratus* and *A. integrator* lay 5-9 and 5-18 eggs respectively, which hatch in 12.0 and 8.0 days on average respectively (Daszkiewicz & Zawal 2004). The eggs were kept, until hatching, under identical conditions. The larvae, 48h post hatch, were mounted by embedding them in Hoyer's medium; the 48h period was necessary for the larvae to became fully sclerotised.

Larval morphologies of *A. crassicaudatus*, *A. inexploratus* and *A. integrator* are described (figures and descriptions) based on larvae hatched from eggs laid by a single female of each species The mounts (*A. crassicaudatus*: N° 171 – female, 171a — larva; *A. inexploratus*: N° 95 – female, 95a – larva; *A. integrator*: N° 265 – female, 265a – larva) are stored at the Department of Invertebrate Zoology and Limnology, University of Szczecin, 71-415 Szczecin, ul. Wąska 13. Body parts were measured on the progeny of 10 females of the three species (N=10). Females were collected from various freshwater reservoirs and various habitats, so that a relatively wide range of intraspecific variability could be detected.

Drawings were prepared with a drawing attachment to a Nikon ECLIPSE 80i microscope, all the details being carefully traced. It is very difficult to adequately show the arrangement of the secondary setae, as they are frequently barely visible. For this reason, those setae bearing secondary ones were drawn as they were spotted. 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 names are those used by Prasad & Cook (1972) with a modification involving placing, before the leg seta symbol, a Roman numeral, denoting the leg pair in question (Zawal 2006a).

The metric characters are reported with their ranges, mean values, and standard deviations. The leg segments were measured from their distal margins.

Abbreviation: ***Cp*** – coxal plate, ***Exp*** – excretory pore, ***Expp*** – excretory pore plate.

Arrenurus crassicaudatus Kramer, 1875 (Fig. 1 A-H)

The dorsal plate is egg-shaped, widest in the middle of its length and distinctly narrowing to the front and the back. Anterior-lateral indents are wide with obtuse angles and reach about 1/4 of length and 1/3 of width of the plate. The ***Lpl*** seta is tripartite, the remaining setae are smooth (Fig. 1). The distance ***Mp1-Mp1*** is the shortest of the three species and shorter then ***Mp2-Mp2*** (Table 1, Fig. 1B).

The median margins of ***CpII*** and ***CpIII*** are about the same length, median margins of ***CpI*** is almost twice as long (Table 1). All the setae on the coxal plates are bipectinate (Fig. 1). Distance between ***C1-CpI*** median margin reaches about 2/3 distance between ***C4-CpIII*** median margin. The ***C1-C2*** distance is quite long (Table 1, Fig. 1A).

The shape of the excretory pore plate is rhomboidal with rounded anterior margin, its width and length are almost equal. The excretory pore lies in the middle of the shield and at the same level as the ***E2*** setae (Fig. 1C).

Pedipalps are typical. The ***PIIII*** seta is fairly thick and bipectinate. The ***PV3*** and ***PV4*** setae are pectinate in the posterior part, the ***PV6*** seta is short and thick (Fig. 1D).

	A. crassicaudatus (Stechmann 1977) (n=5)	A. crassicaudatus (n=10)			A. inexploratus (n=10)			A. integrator (n=10)		
	range	range	mean	standard deviation	range	mean	standard deviation	range	mean	standard deviation
length	-	210-222	217.6	3.98	234-254	241.4	6.47	220-236	228.8	4.92
width	-	166-180	173.8	3.82	198-216	205.2	4.64	190-206	195.8	4.57
dorsal plate length	204-208	196-208	202.6	3.27	216-242	230.4	8.21	208-224	216.6	4.99
dorsal plate width	149-165	156-174	165.4	6.26	186-200	192.6	3.78	180-188	185.0	3.16
CpI medial margin length	59-62	63-67	65.8	1.30	71-76	73.5	1.43	66-73	69.8	2.07
CpII medial margin length	31-35	36-40	38.1	1.20	34-38	36.4	1.15	32-37	34.5	1.62
CpIII medial margin length	35-36	34-39	36.8	1.55	50-54	51.8	1.84	44-51	48.3	2.24
distance: Mp1-Mp1	30-32	30-33	31.6	0.86	35-38	36.6	0.91	38-42	40.2	1.41
distance: Lp1-Lp1	43-45	42-46	44.0	1.46	48-56	51.8	2.38	49-56	53.0	2.29
distance: Lp2-Lp2	76-85	78-85	82.2	1.88	90-96	93.0	2.26	84-102	89.0	4.97
distance: Mp2-Mp2	38-42	39-44	41.3	1.52	50-58	54.4	2.20	50-61	54.0	3.14
distance: Mh1-Mp2	45-53*	44-50	46.6	1.56	56-62	58.8	1.86	50-59	54.6	2.63
distance: Mp1-Lp1	-	7-9	8.1	0.45	7-10	8.3	0.77	6-10	6.8	1.37
distance: Mp1-Lp2	-	37-45	40.7	2.81	34-41	37.4	2.38	26-34	30.0	2.54
distance: Mp1-Mp2	55-57	58-62	60.2	1.41	66-76	71.2	3.29	64-74	67.3	2.71
distance: Mp2-Mh1	31-41**	18-22	19.8	1.30	22-30	26.4	2.13	24-29	27.0	1.92
distance between C1 and CpI median margin	17-19	18-21	19.0	0.85	19-22	21.0	1.05	19-21	19.9	0.59
distance between C4 and CpIII median margin	-	29-31	29.8	0.74	26-32	29.5	2.31	26-30	28.6	1.25
distance between C1 and C2	52-55	44-51	47.6	2.07	52-54	53.4	0.90	50-53	51.4	0.93
excretory pore plate length	-	24-27	25.8	1.00	28-32	29.8	1.30	30-34	31.9	0.88
excretory pore plate width	-	24-27	25.8	0.93	35-38	36.6	0.91	32-37	34.1	1.32
distance between Exp and Expp posterior margin	-	11-14	12.3	0.86	7-9	8.4	0.57	7-9	8.0	0.53
distance between E1 setae and Expp anterior margin	-	4-7	6.1	0.86	4-9	7.8	1.50	10-13	11.8	0.74
distance between E2 setae and Expp posterior margin	-	10-13	12.0	1.07	13-16	14.5	1.03	4-9	7.1	1.58
PI length	-	9-10	9.6	0.53	11-14	12.4	0.78	8-9	8.2	0.39
PII length	-	22-27	24.3	1.65	22-26	24.4	1.08	24-26	25.6	0.84
PIII length	-	22-26	24.4	1.08	24-27	25.2	1.15	25-26	25.5	0.59
length of PIV claw	-	18-22	19.7	1.01	20-23	21.4	1.00	20-22	20.8	0.53
length of cheliceral segment I	-	78-83	79.5	1.89	82-90	85.8	2.35	78-82	80.5	1.20
length of PV 8 seta	-	135-139	137.0	1.35	144-162	151.5	4.88	148-156	153.0	2.33

* Stechmann (1977) reported the Mh1-Mh1distance; the value given here was obtained by calculating [(Mh1-Mh1) — (Mp2-Mp2)]/2
** Stechmann (1977) reported the Mp1-Mh1 distance; the value given here was obtained by calculating (Mp1-Mh1) — (Mp1-Mp2)

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

The first segment of the chelicerae is bottle-shaped distinctly narrowing to the front with margins parallel to each other (FIG. 1E).

The segments on each leg have more or less the same proportions. The clearly shortest trochanter constitutes about 2/3 of the femur and genu which are of the same length; the tibia is 1.5 times longer and the tarsus twice as long (TABLE 2). The ***ITi8*** seta is thin, the ***IGe3***, ***IIGe3***, ***IIIGe3*** setae are short, thick and bipectinate, and the ***IIITa12*** and ***IIITa13*** setae are pectinate (FIG. 1F, G, H).

Material examined: progeny from ten females collected from a pool in a ploughed field near Trzebień, Dolice district, Poland, 53°17'N, 15°27'E, among reed-marshes, 10 May 1999.

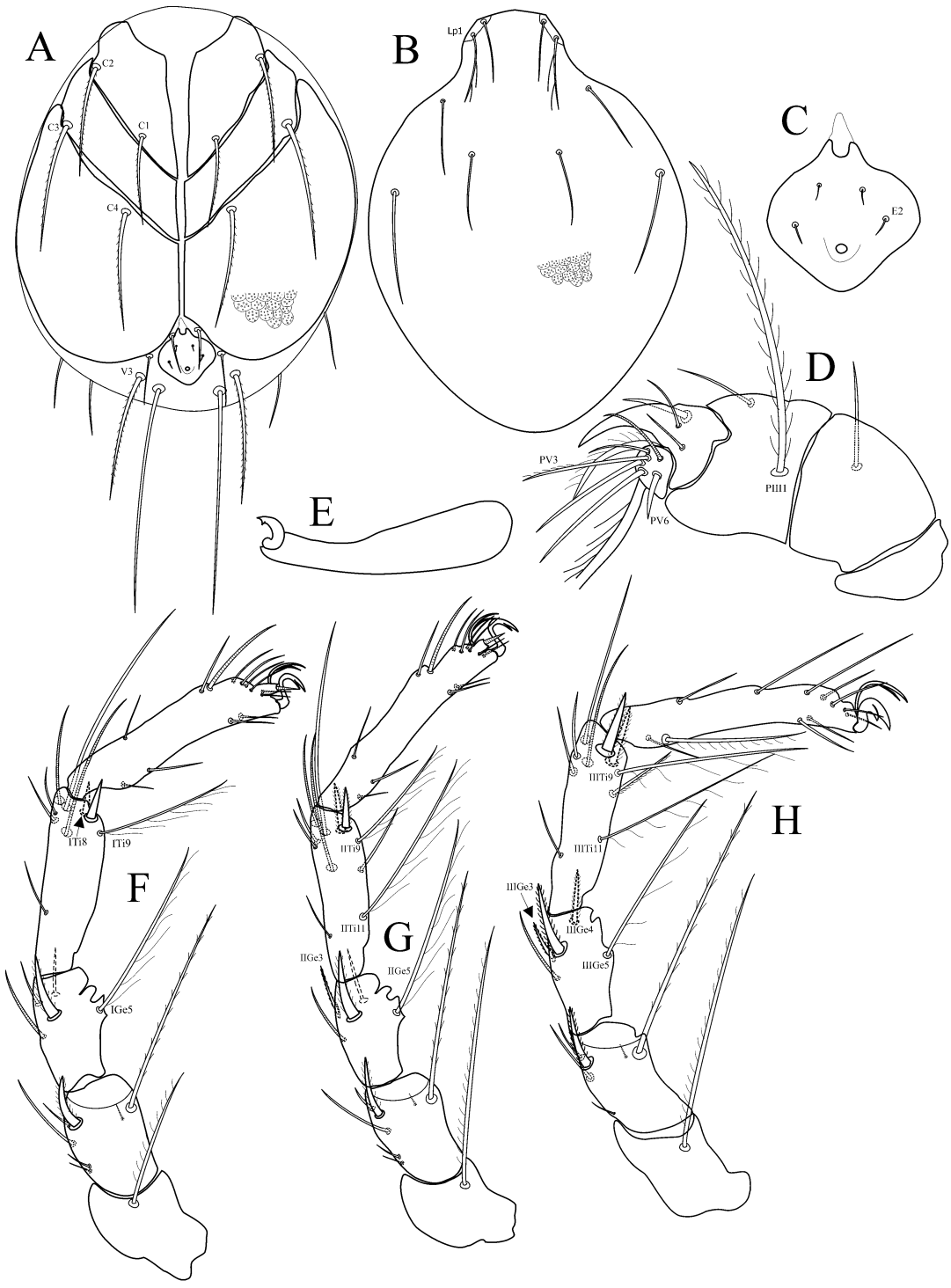

FIG. 2. *Arrenurus inexploratus* Larva A. — Ventral side. B. — Dorsal plate. C. — Excretory pore plate. D. — Pedipalp. E. — Chelicera. F. — Leg I. G. — Leg II. H. — Leg III.

Arrenurus inexploratus Viets, 1930
(Fig. 2 A-H)

The dorsal plate is egg-shaped, with the widest part in mid-length and distinctly narrowing in the anterior and posterior part. Front-lateral indents are very small, with slightly obtuse angles, and reach to about 1/6 of the plate length. The ***Lpl*** seta is tripartite; the remaining setae are smooth and thin (Fig. 2B). Distance ***Mp1-Mp1*** is the shorter than in *A. integrator* and longer than in *A. crassicaudatus*, and shorter than ***Mp2-Mp2*** (Table 1, Fig. 2B).

The ratios of the median margins of ***CpI/CpII/CpIII*** are 2/1/1.5, respectively (Table 1). The ***C2*** and ***V3*** setae are bipectinate, and the ***C1, C3*** and ***C4*** setae are pectinate. The distance between the ***C1-CpI*** median margin reach about 2/3 distance between ***C4-CpIII*** median margin. The ***C1-C2*** distance is long (Table 1, Fig. 2A).

The shape of the excretory pore plate is rhomboidal. Its width slightly exceeds its length (Table 1). The excretory pore lies below the centre of the plate and beneath the ***E2*** setae (Fig. 2C).

The pedipalps are typical. The ***PIII1*** seta is fairly thick and bipectinate. The ***PV3*** seta is pectinate, the ***PV6*** is fairly long and thick (Fig. 2D). The first segment of the chelicerae is elongated, curved and narrowing in the posterior part, with margins parallel to each other (Fig. 2E).

The segments on every leg have more or less the same proportions. The clearly shortest trochanter constitutes about 2/3 of the femur and genu which are of the same length; the tibia is lightly longer (ratio 1/1.3) and the tarsus 1.5 times longer (Table 2). The ***ITi8*** seta is smooth and fairly thick and short, the ***IIGe3***, ***IIIGe3*** and ***IIIGe4*** setae are fairly thick and bipectinate (Fig. 2F, G, H).

Material examined: progeny from a single female collected from a lowland bog, near Moskorzyn, Dolice district, Poland, 53°17'N, 15°27'E, among reed-marshes, 1 May 1999.

Arrenurus integrator (O. F. Müller), 1776
(Fig. 3 A-H)

The elliptical dorsal plate is widest in the middle of its length, however in 1/3 its length the width is similar. Front-lateral indents are fairly small with slightly obtuse angles, and reach to about 1/4 of the plate width and 1/5 of its length. The setae on the dorsal plate are thin, the ***Lpl*** seta tripartite and the remaining setae are smooth (Fig. 3). Distance ***Mp1-Mp1*** is the longest of the three species and shorter then ***Mp2-Mp2*** (Table 1, Fig. 3B).

The ratios of the lateral margins of coxal plates I, II and III are 2/1/1.4, respectively (Table 1). The ***C2*** setae are bipectinate, the remaining ones on epimeres are pectinate. The distance between the ***C1-CpI*** median margin reach about 2/3 distance between ***C4-CpIII*** median margin. The ***C1-C2*** distance is long (Table 1, Fig. 3A).

The shape of the excretory pore plate is rhomboidal, its width and length are almost equal. The excretory pore lies widely below the centre of the plate and beneath the ***E2*** setae. The distance between the ***E1 setae and anterior margin is longer than in the other*** *Arrenurus* species (Fig. 3C).

The pedipalps are typical. The ***PIII1*** seta is bipectinate. The ***PV3*** seta is pectinate, the ***PV6*** is fairly long and thin (Fig. 3D). The first segment of the chelicerae is bottle-shaped with one margin lightly depressed and the other lightly convex (Fig. 3E).

The proportions of the segments are more or less the same on each limb. The clearly shortest trochanter constitutes about 2/3 of the femur and genu which are of the same length; the tibia is lightly longer (ratio 1/1.4) and the tarsus two times longer (Table 2). The ***ITi7*** and ***ITi8*** setae are smooth and thin, the ***IIGe3*** and ***IIIGe3*** setae are thin and smooth (Fig. 3F, G, H).

Material examined: progeny from a single female collected from a small lake near Karsk, Nowogard district, Poland, 53°41'N, 15°07'E, among reed-marshes, 7 July 1999.

Discussion

The larvae of *Arrenurus inexploratus* and *A. integrator* were hitherto undescribed. The larva of *Arrenurus crassicaudatus* was described by Stechmann (1977). However, his drawings and descriptions provide little detail and are inadequate, hence they are difficult to use for identification and comparisons. Only the drawing of the dorsal plate is sufficiently clear and

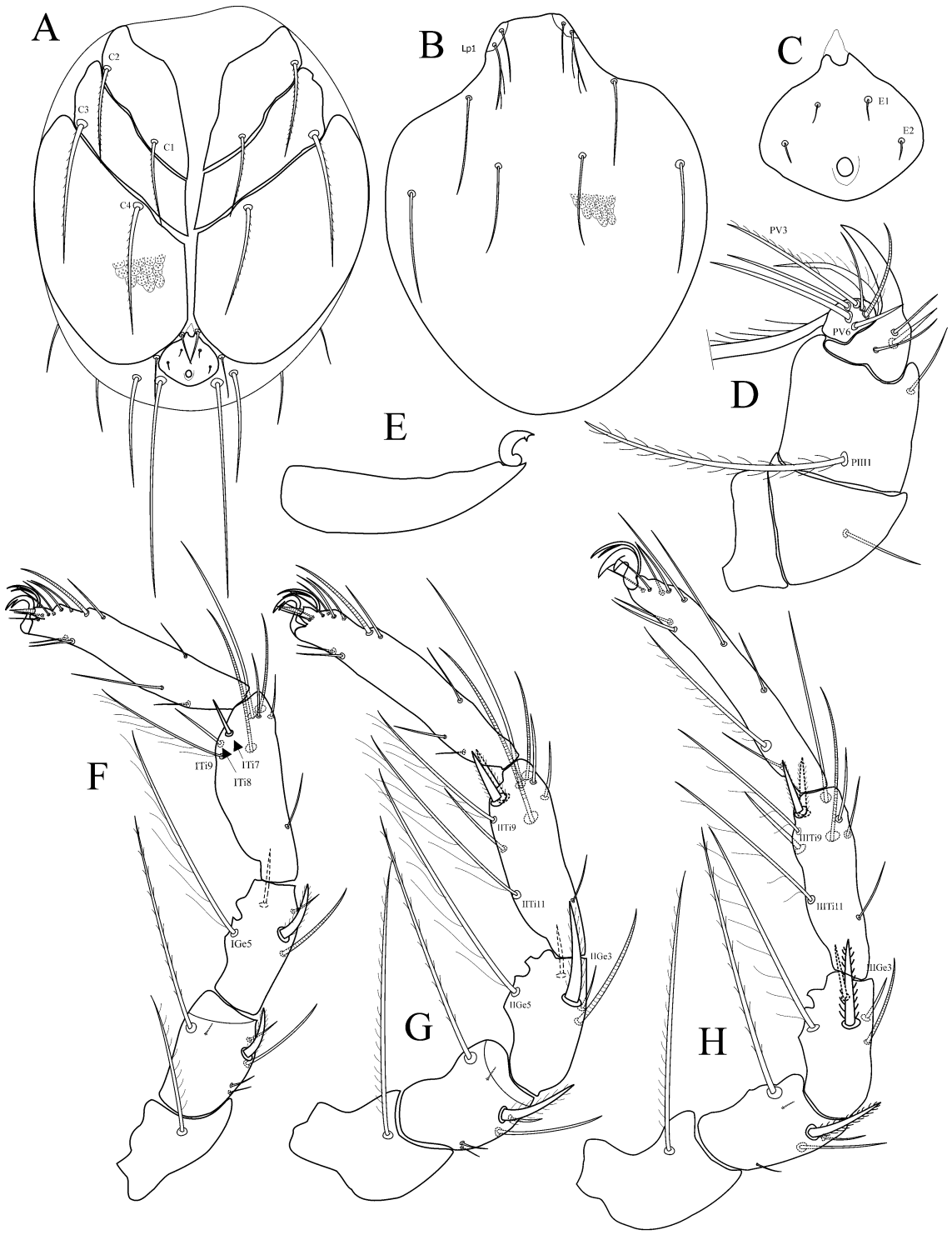

FIG. 3. *Arrenurus integrator* Larva A. — Ventral side. B. — Dorsal plate. C. — Excretory pore plate. D. — Pedipalp. E. — Chelicera. F. — Leg I. G. — Leg II. H. — Leg III.

		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. crassicaudatus (n=10)	I	18-22	20.5	1.78	32-40	36.6	2.52	33-38	36.5	1.47	48-55	51.8	2.00	68-71	69.9	1.37
	II	22-26	24.3	0.94	34-42	37.6	2.38	34-40	37-2	1.57	48-52	49.6	1.60	72-76	74.8	1.47
	III	27-30	28.6	076	35-38	36.6	1.07	35-38	36-0	0.75	46-51	47.3	1.71	72-79	76.1	2.15
A. inexploratus (n=10)	I	24-29	26.2	1.45	37-43	39.8	1.80	38-43	40.4	1.82	50-59	54.0	2.59	62-72	67.2	3.27
	II	24-28	26.5	1.22	38-43	39;8	1.59	36-43	39.0	2.09	48-60	54.2	3.81	67-75	71.4	2.87
	III	27-32	29.9	1.52	36-41	38-8	1.61	37-44	40.5	2.21	51-88	54.3	1.86	69-80	75.4	3.67
A. integrator (n=10)	I	22-28	25.2	1.47	32-40	36.8	2.23	36-41	38.9	1.42	48-56	53.8	2.45	64-78	70.9	5.01
	II	24-32	28.2	2.30	36-40	37.6	1.64	36-43	38.3	3.14	50-54	52.1	1.33	67-78	71.1	3.19
	III	26-34	31.4	2.64	32-40	37.0	2.13	35-38	36.6	1.07	51-56	53.4	2.00	70-74	71.9	1.03

TABLE 2. Dimensions (in μm) of leg segments

similar to that shown in this paper; however, his work does not show the actual tripartity of the ***Lp1*** seta and the secondary setae arranged on the epimeres (FIG. 2A, B). The body dimensions, as reported in this paper and by STECHMANN (1977), are basically in agreement, however, in this work they have bigger range of variability (TABLE 1).

The larvae of the three species described have almost the same size of body but the larva of *A. inexploratus* is minimally larger, followed by *A. integrator* and *A. crassicaudatus* (Table 1). The small but clear differences are in the shape of the dorsal plates, which in *A. inexploratus* is distinctly narrower in the anterior part than in two other species. Front-lateral incisions in *A. inexploratus* and *A. integrator* have a similar size but in *A. crassicaudatus* they are slightly smaller. Distance between ***Mp1-Mp1*** is shortest in *A. crassicaudatus* and longest in *A. integrator* (FIGS. 1B, 2B, 3B).

Median margins of ***CpI*** is the longest in all the described species. The length of the median margins of ***Cp***II and ***CpIII*** in *A. crassicaudatus* are very similar while in the two other species, ***CpIII*** are distinctly longer than ***Cp***II. Proportions between ***C1-CpI*** median margin and ***C4-CpIII*** median margin is similar in the three species (TABLE 1, FIGS. 1A, 2A, 3A).

Setae on the coxal plates of the three species are bipectinate, the only exception is the ***C3*** setae of *A. inexploratus* which is pectinate (FIG. 1A, 2A, 3A). The differences in the arrangement of the secondary setae on the epimeres are not a reliable character as those setae are difficult to detect.

The pedipalps of all the three species are very similar. Differences are in the ***PIII1*** seta, which is thicker in *A. crassicaudatus* than in the two other, and in the ***PV4*** which is pectinate in *A. crassicaudatus* and smooth in two other species (FIG. 1D, 2D, 3D).

The first segment of the chelicerae is larger in *A. inexploratus* than in the two other species (TABLE 1).

The shape and size of the leg segments are similar in all three species, there are some differences in the arrangement of setae (TABLE 2, FIG. 1, 2, 3). The ***ITi8***, ***IGe3***, ***IIGe3***, ***IIIGe3*** setae in *A. inexploratus* are shorter and thicker than in the two other species, and the ***IIITa9*** is pectinate (FIG. 1F, G, H; 2F, G, H; 3F, G, H).

A common feature of the three species is that the ***IGe5***, ***ITi9***, ***IIGe5***, ***IITi9***, ***IITi11***, ***IIIGe5***, ***IIITi8***, and ***IIITi10*** setae bear characteristically long secondary setae, spaced widely apart. Similar, long secondary setae are seen on the setae in *A. bartonensis* Cook, *A. birgei* Marshall, *A. neobirgei* Cook, *A. rotundus* Marschall, *A. cuspidator* Müller, *A. maculator* Müller,

A. sinuator Müller, *A. bifidicodulus* Piersig, *A. perforatus* George, *A. albator* Müller and *A. fimbriatus* Koenike (Smith 1990, Zawal 2006 a, b, c,). Therefore this feature is probably common in all species of *Arrenurus* genus.

The characters discriminating between the larvae of the three species described, similarly to other species of the genus *Arrenurus*, are relatively minor but sufficiently distinct to render the species identifiable.

Another issue is the assignment of individual species to subgenera. *A. inexploratus* and *A. integrator* belong to the subgenus *Micruracarus*, while *A. crassicaudatus* is classified with the subgenus *Micrarrenurus*, separated from the subgenus *Arrenurus* s. str. by Cassagne-Méjean (1966). This subgenus is controversial and regarded as artificial by many authors. Cook (1974) even suggests that the whole subgeneric classification is artificial. As shown by this and other currently conducted studies (Zawal 2006 b, c, e), larvae of the subgenera *Micrarrenurus* and *Micruracarus* are very similar to each other and differ from those of other subgenera in having more than two pectinate setae on the fifth pedipalp segment. The character is absent in all the remaining subgenera and points to a close affinity between the two sub-genera mentioned. To answer the question whether the subgeneric classification in the *Arrenurus* genus is natural or artificial will only be possible after a comprehensive analysis of larval *Arrenurus* morphology has been completed.

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