Morphology of the larvae of three species of *Arrenurus* (Acari: Parasitengona: Arrenuridae)

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Abstract

Morphology of the larval stages of *Arrenurus sinuator* (O. F. Müller, 1776), *Arrenurus bifidicodulus* Piersig, 1897, and *Arrenurus perforatus* George, 1881 is described. Particular attention is paid to the characters differing between the three species. Larvae of the three species differ in the size and shape of the dorsal plate, although the proportions of their length and width are the same. Distinct differences appear between the proportions in the length of the lateral margins of the epimers. In *A. sinuator* and *A. perforatus* the shape of the anal plates is very similar, the only difference being a small process on the posterior margin of the plate. In *A. bifidicodulus* the shape of the anal plate is slightly different owing to the truncated anterior margin. The structure of the pedipalps also differs. The PIII1 setae are always bipectinate but they are distinctly thicker in *A. sinuator* and *A. perforatus*. In *A. sinuator* PV4 and PV5 setae are bipectinate, in *A. perforatus* PV3, PV4 and PV5 setae are pectinate, and in *A. bifidicodulus* the PV3 seta is pectinate. Distinct differences also occur in the feathering of legs. Above all, in *A. perforatus* on the tarsus of leg pair III one more seta was observed and marked as IIITa8. The present description of the larval *A. sinuator* is compared to that given by Stechmann (1977) and the description of the larval *A. bifidicodulus* is compared to that given by Cichocka (1980).

Keywords: Acari, Arrenurus bifidicodulus, Arrenurus perforatus, Arrenurus sinuator, larvae, morphology, water mites

Introduction

Currently, in studies on water mites numerous scientists have been interested in the morphology of larval stages on account of the possibility of investigating relations between them and their hosts. Knowledge of these relationships can be useful in studying the distribution and dispersion of water mites, controlling the abundance of individual populations and mechanisms of evolution.

A basic aim of such studies is to describe the morphology of larvae of individual species, and larvae of the genus *Arrenurus* Duges are known to a particularly insufficient degree. Inadequate descriptions can be found in the works by Koenike (1908), Lundblad (1927, 1930), Münchberg (1936), and Sparing (1959). In recent years such studies have been
conducted by Stechmann (1977), Cichocka (1980), Vajnštejn (1980), and Böttger and Martin (2003). The most detailed drawings and descriptions have been given by Imamura and Mitchell (1967), Vajnštejn (1980), Smith (1990), Smith and Cook (1991), and Zawal (forthcoming). Some inaccuracies are encountered in the descriptions of *A. sinuator* (O. F. Müll.) and *A. bifidicodulus* Piers. in Stechmann (1977) and Cichocka (1980).

The aim of this paper is to present detailed descriptions of *A. sinuator*, *A. bifidicodulus*, and *A. perforatus* with a particular consideration to differing features, and also to compare the first two species with the earlier descriptions of Stechmann (1977) and Cichocka (1980).

**Materials and methods**

The descriptions are based on larvae hatched from eggs laid by females caught in the field. Until egg laying, each female was kept in a separate 100 cm$^3$ container filled with 20–24°C water and subsequently fixed in Wilson’s liquid. The eggs were kept, until hatching, under identical conditions. The larvae, 48 h post-hatch, were mounted by embedding them in the Four liquid; the 48 h period was necessary for the larvae to become fully sclerotized.

Larval morphologies of *A. sinuator*, *A. bifidicodulus*, and *A. perforatus* were described based on larvae hatched from eggs laid by a single female of each of the species, the females having been caught in species-specific habitats (a mid-ploughfield pool among reed-maces in the case of *A. sinuator* collected on 10 May 1999, a mid-forest pool among sedges in the case of *A. bifidicodulus* collected on 1 May 1999, and mesotrophic lake Miedwie among elodeids in the case of *A. perforatus* collected on 15 July 2001). The mounts (*A. sinuator*, nos 182, 182a, 182b, 182c; *A. bifidicodulus*, nos 29, 29a, 29b, 29c; *A. perforatus*, nos 1M, 1Ma) are stored at the Department of Invertebrate Zoology and Limnology, University of Szczecin, Poland. Figure 1 shows the appearance of the ventral side and pedipalp of *A. sinuator*, Figure 2 shows the appearance of the ventral side and pedipalp of *A. bifidicodulus*, and Figure 3 shows the appearance of the ventral side of *A. perforatus*.

Larval body parts were measured on the progeny of ten females each of *A. sinuator* and *A. bifidicodulus*, and three females of *A. perforatus*. The females were collected from various habitats, for which reason a relatively wide range of individual variability could be covered.

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Figure 1. Female of *Arrenurus sinuator*. (A) Ventral side; (B) pedipalp.
Drawings were prepared with a drawing attachment to a Nikon ECLIPSE80i microscope, all the details being carefully traced. It is very difficult to render adequately the arrangement of the secondary setae as they are frequently hardly 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 seta notation follows that of Prasad and Cook (1972) with modification by Zawal (forthcoming) consisting, in addition, the number of legs in front of the signature of seta.

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

**Arrenurus sinuator**

The elliptical dorsal plate is widest in the middle of its length and distinctly narrows in the posterior and the anterior parts. 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. On the dorsal plate all setae are fairly thin; the Lpl seta is tripartite; the remaining setae smooth (Figure 4B1).

Lateral margins of the first pair of epimers are distinctly the longest, followed by epimers of pair II and the shortest epimers of pair III (Figure 1). Their ratios are 4/2 and 2/5, respectively (Table I). All the setae on the epimers are bipectinate (Figure 4A).

The anal plate is rhomboidal with a characteristic process below (it is sometimes hidden) and a hollow in the front part. The anal aperture is situated distinctly posteriorly to the middle of the shield and posteriorly to the E2 setae (Figure 4C; Table I).

The shape and size of the pedipalps (Figure 4D) resemble those in other *Arrenurus* species. The PIII1 seta is thicker than in other species and bipectinate. The PV1 seta is a solenoid, PV2 is short and smooth, PV3 long and smooth, and PV6 short and thick. The PV4 and PV5 setae are bipectinate from about one-third of their length, the PV4 seta being long and thin and PV5 thicker and shorter. The PV7 seta is characteristically bent (fan-shaped) and pectinate, PV8 is very long and bipectinate as in other species of *Arrenurus* (Imamura and Mitchel 1967; Zawal forthcoming).

The first segment of the chelicerae has the form of an elongated and curved cylinder with margins parallel to each other (Figure 4E).

The proportions of segments are more or less the same on each limb. The decidedly shortest trochanter constitutes about two-thirds 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 II). The tibia of all the limbs are distinctly convex on the ventral side (Figure 4F, G, H1).

The same number of setae is found on each segment and the number of solenoids is similar to that in *Arrenurus cuspidator* (O. F. Müll.) and *A. maculator* (O. F. Müll.) (Zawal forthcoming). The IFe4, IGe2, IGe3, ITi3, ITi7, IIFe4, IIGe2, IIGe3, IIGe4, IITi7, IITi8, IIIFe4, IIIGe2, IIIGe4, IITi4, IITi7, and IITi8 setae are thick and bipectinate. The IITi8 seta is long and thin; IITi10 is pectinate and lies near the centre of the tibia. Setae ITrl, IITrl, IITi10, IITrl, IITi10, and IITa13 are pectinate while IFe7, IIFe7, and IIIFe7 are bipectinate. Setae IGe5, ITi9, IITi9, IITi11, IIGe5, IITi9, and IITi11 show long and thinned feathering (Figure 4F, G, H) like that found in *A. cuspidator* and *A. maculator* (Zawal forthcoming).

**Arrenurus bifidicodulus**

The dorsal plate is elliptical, widest in the middle of its length and distinctly narrowing to the front; the posterior margin is rounded. Anterior-lateral incisions are wide with obtuse angles and reach about one-quarter of the length and one-third of the width of the plate. The Lpl seta is tripartite, the remaining setae are smooth and thin (Figure 5B).

The ratios of the lateral margins of the epimers of pairs I, II, and III are 2.4/1/1.3 (Table II), respectively. C2 and C3 setae are feathered on both sides and fairly thick while C1 and C4 setae are feathered on one side (Figure 5A).
Figure 4. Morphology of the larva of *Arrenurus simuator*. (A) Ventral side; (B) dorsal side; (C) anal plate; (D) pedipalp; (E) chelicera; (F) leg I; (G) leg II; (H) leg III.
Table I. Dimensions (µm) of individual body parts.

|                      | Arrenurus perforatus | Arrenurus simuator | Arrenurus bifidicodulus | Arrenurus bifidicodulus |
|----------------------|----------------------|--------------------|-------------------------|--------------------------|
|                      | Range    | Mean  | SD    | Range    | Mean  | SD    | Range    | Range |
| Length               | 254–276  | 265.6 | 7.59  | 240–258  | 247.2 | 4.64  | 194–208  | 198.8  | 4.24  |
| Width                | 210–222  | 216.6 | 3.41  | 200–220  | 211.6 | 7.29  | 150–188  | 170.2  | 12.59 |
| Dorsal plate length  | 240–268  | 252.4 | 8.98  | 236–244  | 239.2 | 3.43  | 180–200  | 190.2  | 5.69  |
|                      | 192–208  | 200.4 | 4.60  | 190–200  | 196.0 | 3.27  | 136–158  | 148.8  | 7.38  |
| Pair I epimere length| 96–102   | 98.2  | 2.36  | 86–96    | 90.8  | 2.90  | 67–72    | 68.5   | 1.47  |
|                      | 61–66    | 63.0  | 1.59  | 53–60    | 56.6  | 2.50  | 31–34    | 32.5   | 0.94  |
| Pair III epimere length| 30–37 | 33.2  | 2.24  | 21–25    | 22.7  | 1.14  | 35–40    | 37.0   | 1.45  |
| Distances            |          |       |       |          |       |       |          |       |
| Mp1–Mp1              | 38–45    | 41.4  | 2.61  | 42–50    | 45.0  | 2.64  | 31–37    | 33.4   | 1.85  |
| Lp1–Lp1              | 50–58    | 61.2  | 2.40  | 56–61    | 59.9  | 2.11  | 40–46    | 43.0   | 2.17  |
| Lp2–Lp2              | 92–106   | 55.1  | 5.52  | 104–111  | 107.8 | 1.92  | 78–83    | 81.0   | 1.73  |
| Mp2–Mp2              | 58–64    | 99.9  | 1.47  | 58–64    | 61.4  | 1.92  | 41–46    | 43.1   | 1.48  |
| Mh1–Mp2              | 51–57    | 53.7  | 1.86  | 54–61    | 57.4  | 2.36  | 46–50    | 46.9   | 1.32  |
|                      | 9–13     | 11.0  | 1.45  | 8–10     | 9.4   | 0.74  | 7–10     | 8.2    | 0.91  |
|                      | 48–63    | 56.1  | 4.82  | 38–45    | 39.9  | 2.63  | 36–40    | 37.5   | 1.22  |
|                      | 68–78    | 72.9  | 3.21  | 66–72    | 68.8  | 1.96  | 56–62    | 59.1   | 2.34  |
|                      | 37–42    | 39.0  | 1.72  | 27–38    | 32.2  | 3.29  | 18–22    | 18.2   | 1.46  |
|                      | 30–34    | 32.0  | 1.57  | 26–28    | 27.3  | 0.59  | 17–20    | 18.2   | 0.91  |
|                      | 42–45    | 43.0  | 0.92  | 37–40    | 38.2  | 1.13  | 29–34    | 31.1   | 2.01  |
|                      | 25–29    | 27.0  | 1.20  | 27–30    | 28.6  | 0.93  | 20–25    | 23.4   | 1.86  |
|                      | 34–38    | 36.0  | 1.40  | 32–34    | 33.3  | 0.77  | 22–28    | 24.9   | 2.28  |
|                      | 10–14    | 12.0  | 1.05  | 6–10     | 8.2   | 1.12  | 6–10     | 8.1    | 1.16  |
|                      | 3–6      | 4.0   | 0.75  | 4–7      | 6.1   | 0.86  | 9–10     | 5.6    | 0.59  |
|                      | 14–16    | 14.0  | 0.70  | 11–14    | 12.6  | 0.76  | 5–7      | 9.7    | 0.84  |
|                      | 11–16    | 14.0  | 1.36  | 10–13    | 11.4  | 0.91  | 8–10     | 8.6    | 0.66  |

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Table I. (Continued)

|                  | Arrenurus perforatus | Arrenurus sinuator | Arrenurus bifidicodulus | Arrenurus simuator (Stechmann 1977) | Arrenurus bifidicodulus (Cichocka 1980) |
|------------------|----------------------|-------------------|-------------------------|-------------------------------------|----------------------------------------|
|                  | Range | Mean  | SD    | Range | Mean  | SD    | Range | Mean  | SD    | Range | Range |
| PII length       | 32–37 | 34.0  | 1.55  | 26–29 | 27.3  | 0.88  | 24–28 | 25.4  | 1.25  | –     | 19–26 |
| PIII length      | 33–36 | 34.0  | 0.83  | 27–30 | 28.6  | 0.93  | 24–28 | 25.0  | 1.31  | –     | 31–36 |
| Length of PIV claw | 29–37 | 32.0  | 2.27  | 21–24 | 22.8  | 1.32  | 22–25 | 23.7  | 0.67  | –     | 20–23 |
| Length of cheliceral segment I | 115–120 | 117.5 | 1.48  | 88–92 | 89.7  | 1.38  | 70–83 | 79.4  | 4.08  | –     | 78–83 |
| Length of PV8 seta | 220–228 | 223.6 | 2.17  | 186–193 | 187.7 | 2.33  | 142–154 | 148.2 | 3.11  | –     | 150–156 |

aStechmann (1977) reported the Mh1–Mh1 distance; the value given here was obtained by calculating [(Mh1–Mh1) – (Mp2–Mp2)]/2. bStechmann (1977) reported the

Table II. Dimensions (μm) of leg segments.

|                | Trochanter | Femur | Genu | Tibia | Tarsus |
|----------------|------------|-------|------|-------|--------|
|                | Range | Mean | SD    | Range | Mean | SD    | Range | Mean | SD    | Range | Mean | SD    |
| A. perforatus  |       |      |       |       |       |       |       |       |       |       |       |       |
| I              | 27–32 | 30   | 1.86  | 45–51 | 48   | 1.78  | 46–51 | 48   | 1.68  | 69–75 | 72   | 1.74  |
| II             | 30–35 | 32   | 1.79  | 46–52 | 48   | 2.02  | 46–50 | 48   | 0.88  | 69–76 | 72   | 2.04  |
| III            | 28–38 | 33   | 3.58  | 46–50 | 48   | 1.46  | 42–45 | 44   | 0.67  | 67–74 | 70   | 1.86  |
| A. sinuator    |       |      |       |       |       |       |       |       |       |       |       |       |
| I              | 20–24 | 21.8 | 1.41  | 40–45 | 42.2 | 1.43  | 42–48 | 45.0 | 2.17  | 62–68 | 65.6 | 1.60  |
| II             | 22–30 | 25.2 | 2.90  | 40–46 | 44.2 | 1.73  | 40–48 | 44.1 | 2.78  | 62–68 | 64.7 | 2.08  |
| III            | 27–37 | 32.2 | 3.11  | 42–47 | 44.5 | 1.52  | 40–44 | 41.6 | 1.31  | 61–68 | 63.5 | 2.27  |
| A. bifidicodulus |      |      |       |       |       |       |       |       |       |       |       |       |
| I              | 19–24 | 20.6 | 1.46  | 30–34 | 32.2 | 1.51  | 30–34 | 31.4 | 1.31  | 46–52 | 48.6 | 1.69  |
| II             | 20–24 | 22.5 | 1.75  | 30–33 | 31.3 | 0.88  | 31–34 | 32.2 | 0.74  | 44–50 | 46.9 | 2.33  |
| III            | 22–26 | 24.0 | 1.13  | 30–34 | 32.3 | 1.26  | 30–34 | 31.8 | 0.83  | 44–50 | 46.6 | 2.32  |
| A. bifidicodulus |      |      |       |       |       |       |       |       |       |       |       |       |
| (Cichocka 1980) | I     | 26–31 | –     | 33–39 | –     | –     | 31–33 | –     | –     | 52–57 | –     | –     |
| II             | 20–28 | –     | –     | 31–39 | –     | –     | 28–36 | –     | –     | 49–56 | –     | –     |
| III            | 23–28 | –     | –     | 31–39 | –     | –     | 31–36 | –     | –     | 49–59 | –     | –     |
The anal plate is pentagonal-shaped with right upper angles and the front margin slightly convex; its width slightly exceeds its length. The anal foramen is situated posterior to the centre of the plate and beneath E2 setae (Figure 5C).

Pedipalps are similar to those in *A. sinuator*. The PIII1 seta is bipectinate, thinner than in *A. sinuator*; PV3 seta is pectinate and the PV6 seta is short and thick (Figure 5D).

The first segment of chelicerae is elongated, slightly shorter than in *A. sinuator*, with slightly bent margins parallel to each other (Figure 5E).

Figure 5. Morphology of the larva of *Arrenurus bifidicodulus*. (A) Ventral side; (B) dorsal side; (C) anal plate; (D) pedipalp; (E) chelicera; (F) leg I; (G) leg II; (H) leg III.
The segments of the limbs are slightly shorter than in *A. sinuator*, however the proportions are fairly similar (Table II). The IGe3, ITi3, IIGe3, IIGe4, IITi3, IITi6, IITi7, IIIGe4, IIITi3, and IIITi4 setae are smooth and fairly thin. The IITi8 seta is relatively thick and short while the IIITi10 seta is smooth and lies near the centre of the tibia (Figure 5F, G, H).

*Arrenurus perforatus*

The dorsal plate is egg-shaped, widest at mid-length, and distinctly narrowing anteriorly and posteriorly. The anterior-lateral incisions are fairly small with 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 (Figure 6B).

The lateral margins of the first pair of epimers are the longest, followed by the epimeres of pair II; the shortest are these of the epimeres of pair III. Their ratio is 3/2/1, respectively (Table I). All the setae on epimeres are bipectinate while setae V3 are pectinate (Figure 6A).

The width of the rhomboidal anal plate distinctly exceeds its length. The anal foramen lies slightly posterior to its centre and beneath E2 setae (Figure 6C).

The pedipalps resemble those of *A. sinuator*. The PIII1 seta is thick and bipectinate. The PV3, PV4, and PV5 setae are pectinate and the PV8 seta is distinctly longer than in the other two species (Table I; Figure 6D).

The first segment of the chelicerae has the form of a bent and elongated cylinder (Figure 6E), slightly narrowing to the front; it is distinctly longer than in the other two species (Table I).

The dimensions of the different segments of the legs slightly exceed those found in *A. sinuator*, however, their mutual proportions are more or less the same (Table II). The ITi8 is distinctly shorter than in the other two species; ITi5 is bipectinate, IIITa11, IIITa12 and IIITa14 setae are fairly large and pectinate. The IITi10 seta is smooth and lies near the centre of the tibia. On the tarsus of leg pair III *A. perforatus* has one seta more than other species of the genus *Arrenurus*. It was marked as IIITa8 (Figure 6F, G, H).

Discussion

The morphology of *Arrenurus sinuator* larvae was previously described by Stechmann (1977). The shapes of the dorsal plate and the epimeres agree with the descriptions given in the present paper. An exception is the feathering of setae on the epimeres (it is difficult to discern it even using very precise optical equipment) and the three-part structure of the Lpl seta (Figure 4B). The drawings of limbs presented by Stechmann (1977) are imprecise, however, most details agree with the picture observed in the present work. There are differences in respect of setae IGe5, ITi9, IIGe5, IITi9, IITi11, IIIGe5, IIITi8, and IIITi10 whose characteristic feature is long and thinned feathering (Figure 4F, G, H). The same shape setae is observed in these setae in *A. bifidicodulus, A. perforatus, A. cuspidator*, and *A. maculator* (Zawal forthcoming), indicating that this is probably a common characteristic (plesiomorphy) of all species of the genus *Arrenurus*. In this species the dimensions of the bodies of larvae quoted in the present paper and those given by Stechmann (1977) distinctly differ (Table I), suggesting a great variability in larvae of this species, however, the proportions of the different body parts are the same.

The *A. bifidicodulus* larva has been previously described by Cichocka (1980). The shapes of the dorsal plate, epimeres, anal plate, and chelicerae described by the above author agree
Figure 6. Morphology of the larva of Arrenurus perforatus. (A) Ventral side; (B) dorsal side; (C) anal plate; (D) pedipalp; (E) chelicera; (F) leg I; (G) leg II; (H) leg III.
with that given in the present paper while differences appear in the three-part structure of Lpl setae and in the feathering of setae on the epimers (Figure 5A). However, distinct differences are noted in the setae of the pedipals. The PIII1 seta which is described as very small by Cichocka (1980) is actually much greater and bipectinate. Cichocka (1980) claims the occurrence of six setae (no solenoid PV1 and no PV3 seta pectinate), while their real number is eight (Figure 5D). Most dimensions of the different body parts determined by Cichocka (1980) agree with those given in the present paper (Tables I, II).

Larvae of the three species described differ in their size: the smallest are A. bifidicodulus larvae, followed by A. sinuator and A. perforatus (Table I). They also differ in the size and shape of the dorsal plate, however, the proportions of their length and width are the same. The smallest dorsal plate characterized by the greatest anterior-lateral incisions is found in A. bifidicodulus. In respect of size it is followed by the dorsal plate of A. sinuator, however, the latter shows the smallest, hardly visible, anterior-lateral incisions. The greatest dorsal plate, characterized by medium-sized anterior-lateral incisions, is that of A. perforatus (Table I; Figures 4B, 5B, 6B).

Distinct differences appear between the proportions in the length of lateral margins of the epimers. In A. sinuator and A. perforatus the epimers of pair I are characterized by the longest lateral margin, followed by the epimers of pair II and finally by the epimers of pair III, however, much greater differences in proportions are observed in A. sinuator. In A. bifidicodulus the longest lateral margin is that of the first pair of epimers, followed by the epimers of pair III and finally by the epimers of pair II (Table I; Figures 4A, 5A, 6A).

In A. sinuator and A. perforatus the shape of the anal plates is very similar, the only difference being a small process on the posterior margin of the plate (Figures 4C, 6C). In A. bifidicodulus the shape of the anal plate is slightly different owing to its pentagonal shape (Figure 5C).

In all three species the shape of the first segment of the chelicerae is very much alike (Figures 4E, 5E, 6E), however, its size is different. The longest one is noted in A. perforatus, followed by A. sinuator, the shortest being found in A. bifidicodulus (Table I).

The structure of the pedipalps also differs (Figures 4D, 5D, 6D). The PIII1 setae are always bipectinate but they are distinctly thicker in A. sinuator and A. perforatus. In A. sinuator PV4 and PV5 setae are bipectinate, in A. perforatus PV3, PV4, and PV5 setae are pectinate, and in A. bifidicodulus the PV3 seta is pectinate. The longest PV8 seta is found in A. perforatus, followed by A. sinuator and by A. bifidicodulus (Table I).

Distinct differences also occur in the feathering of legs. Above all, in A. perforatus on the tarsus of leg pair III one more seta was observed and marked as IIIIta8 (Figure 6H).

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