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Description of *Alpheus cedrici* sp. n., a strikingly coloured snapping shrimp (Crustacea, Decapoda, Alpheidae) from Ascension Island, central Atlantic Ocean

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Abstract

Alpheus cedrici **sp. n.** is described based on two specimens collected under rocks while scuba diving off the coast of Ascension Island, central Atlantic Ocean. The new species belongs to the *Alpheus macrocheles* (Hailstone, 1835) species complex and appears to be most closely related to the eastern–central Atlantic *A. macrocheles*, the western Atlantic *A. amblyonyx* Chace, 1972, and the eastern Pacific *A. bellimanus* Lockington, 1877 and *A. rectus* Kim & Abele, 1988. However, it differs from all these species by a combination of morphological characters and by a diagnostic and striking colour pattern.

Keywords

Caridea, Alpheidae, new species, *Alpheus*, Ascension Island, Atlantic Ocean

Introduction

The current knowledge of the alpheid shrimp fauna of the isolated central Atlantic islands St. Helena and Ascension is mainly based on two accounts, Chace (1966) for St. Helena and Manning and Chace (1990) for Ascension. Chace (1966) reported only three alpheid species from St. Helena, viz. *Alpheus macrocheles* (Hailstone, 1835), *Synalpheus fritzmuelleri* Coutière, 1909, and *Metalpheus paragracilis* (Coutiere, 1897). Manning and Chace (1990) reported the same three alpheids from Ascension Island, and in addition *Alpheus bouvieri* A. Milne Edwards, 1878, *A. crockeri* (Armstrong, 1941) [with some doubts], *A. dentipes* Guérin, 1832, *A. holthuisi* Ribeiro, 1964, *A. paracrinitus* Miers, 1881, *Automate dolichognatha* De Man, 1888, *Metalpheus rostratipes* (Pocock, 1890), *Parabetaeus hummelincki* (Schmitt, 1936) [as *Neoalpheopsis euryone* (De Man, 1910)], *Salmoneus setosus* Manning & Chace, 1990, and *S. teres* Manning & Chace, 1990, resulting in a total of 13 species of Alpheidae known to occur in the Central Atlantic Ocean south of Equator. Most alpheid specimens reported in Chace (1966) and Manning and Chace (1990) were collected in intertidal and shallow subtidal habitats, in tide pools, under rocks, in crevices of rocks and conglomerates of coralline algae, or in buoy fouling.

In April 2008, while scuba diving in English Bay, Ascension Island, one of us (SDG) collected two strikingly coloured snapping shrimps, by flipping rocks at a depth range of 10–15 m. A closer examination of these specimens revealed that they belong to a hitherto unnamed species of *Alpheus* Fabricius, 1798. This species is herewith described as new. Type material is deposited in the collections of the Oxford University Museum of Natural History, Oxford, the United Kingdom (OUMNH.ZC). Abbreviations used in the text: cl, carapace length (measured from the tip of the rostrum to the posterior margin of the carapace); Mxp, maxilliped; P, pereiopod; CA, central Atlantic; EA, eastern Atlantic; WA, western Atlantic; EP eastern Pacific.

Systematics

Family Alpheidae Rafinesque, 1815
Genus *Alpheus* Fabricius, 1798

Alpheus cedrici sp. n.

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http://species-id.net/wiki/Alpheus_cedrici
Figs 1–3

Material examined. Holotype: male, cl 10.1 mm, OUMNH.ZC.2008-11-0017, Ascension Island, west side of English Bay, 07°53.675'S, 014°22.999'W, depth 10 m, under rocks, leg S. & H. De Grave, 16.04.2008. Paratype: ovigerous female, cl 11.8 mm, OUMNH.ZC.2008-11-0018, Ascension Island, west side of English Bay, 07°53.675'S 014°22.999'W, depth 15 m, under rocks, leg. S. & H. De Grave, 17.04.2008.

Comparative material examined. *Alpheus macrocheles* (Hailstone, 1835): 1 male, cl 9.0 mm, OUMNH.ZC.2003-36-0002, Madeira, Canico, depth 20 m, leg. P. Wirtz, 02.11.2003. *Alpheus amblyonyx* Chace, 1972: 1 male, cl 5.6 mm, OUMNH.ZC.2011-03-0070, Panama, Isla Grande, in coral rubble, 1–1.5 m, leg. A. Anker, 09.12.2006.

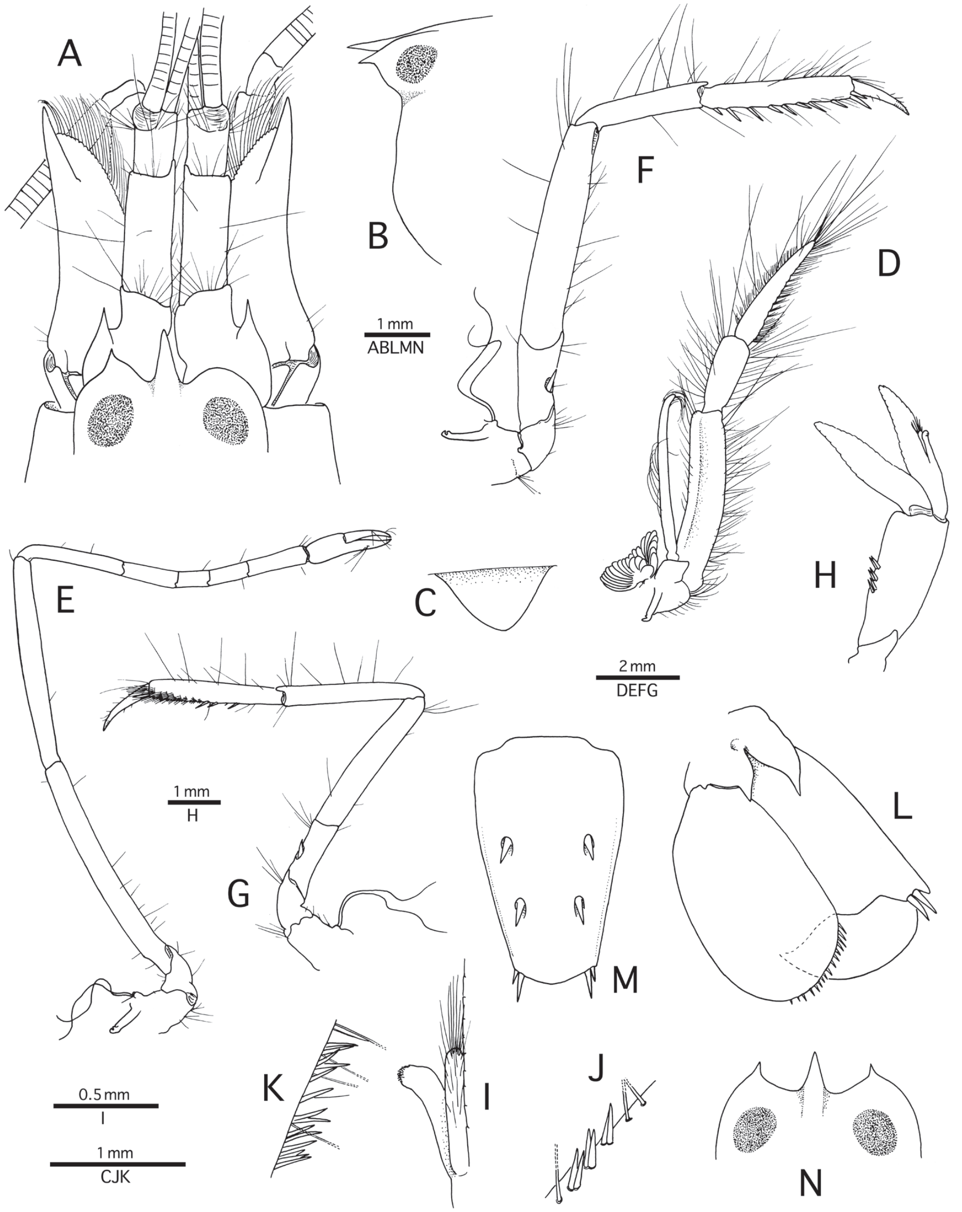

Figure 1. *Alpheus cedrici* sp. n. **A–M** holotype, male from Ascension Island (OUMNH.ZC. 2008-11-0017); **N** paratype, female, same locality (OUMNH.ZC. 2008-11-0018). **A** frontal region, dorsal **B** anterior carapace, lateral **C** tooth of ventromesial carina of first article of antennular peduncle, lateral **D** third maxilliped, lateral **E** second pereiopod, lateral **F** third pereiopod, lateral **G** fifth pereiopod, lateral **H** second pleopod, lateral **I** same, appendix masculina and appendix interna, mesial **J** same, detail of spiniform setae on protopod, lateral **K** third pleopod, detail of spiniform setae on protopod, mesial **L** uropod, dorsal **M** telson, dorsal **N** anterior carapace, dorsal.

Diagnosis. Frontal margin of carapace with rostrum slightly flattened dorsally, tapering distally, with acute tip, much longer than wide, reaching half-length of first article of antennular peduncle; rostral carina not distinct; orbital teeth in marginal position, small, acute distally, shorter than rostrum; margin between orbital teeth and rostrum broadly V-shaped; rostro-orbital process present; pterygostomial angle rounded; antennular peduncle with stylocerite not reaching distal margin of first article, with acute tip; second article about 2.5 times as long as wide; antenna with basicerite terminating in sharp distoventral tooth; carpocerite slightly exceeding both scaphocerite and antennular peduncle; scaphocerite with well-developed blade, shallowly concave lateral margin and large, stout distolateral tooth, latter reaching far beyond distal margin of blade; male minor cheliped with ventromesial margin of merus ending in small, acute distomesial tooth, and with minute spiniform setae; palm strongly compressed, with sculpture on both lateral and mesial surfaces, consisting of low crests ending in sharp teeth distally; lateroventral surface with distinct, rounded shoulder; pollex shallowly excavated on cutting edge; dactylus somewhat flattened and twisted laterally, not conspicuously broadened, only slightly convex dorsally; male and female major chelipeds similar in shape and in proportions; ventromesial surface of ischium with small spiniform seta; ventromesial margin of merus straight, ending in stout, sharp distomesial tooth, and with small, widely spaced spiniform setae; palm somewhat compressed, with strong sculpture on lateral and mesial surfaces, consisting of low crests ending in sharp teeth distally; lateroventral surface with rounded, smooth, non-projecting shoulder adjacent to deep notch, latter continuing transversely to shallow groove on mesial surface; dorsal margin with subcylindrical elevation ending in large adhesive disk distally; distomesial surface with transversally deeply notched crest ending in sharp tooth; pollex shorter than dactylus, somewhat twisted and shallowly depressed laterally, cutting edge bluntly projecting laterally; dactylus flattened, twisted laterally, convex dorsally, bulbous distally, plunger reduced to broad, low tooth; second pereiopod with five-articulated carpus, ratio of articles approximately equal to 4 : 2 : 1 : 1.5 : 2; third and fourth pereiopods similar; ischium armed with spiniform seta on ventrolateral surface; merus about five times as long as wide, without distoventral tooth; propodus with about eight spiniform setae along ventral margin and additional pair of spiniform setae close to propodo-dactylar articulation; dactylus about 0.4 length of propodus, simple, conical, faintly curved, with acute tip; pleopods with protopods furnished with spiniform setae on lateral margin, some inserted in pairs; male second pleopod with appendix masculina subequal in length to appendix interna, not reaching distal margin of endopod; uropodal exopod with sinuous diaeresis and small distolateral spiniform seta; uropodal endopod with row of small spiniform setae along distolateral margin; telson subrectangular, tapering posteriorly, about twice as long as wide at base; dorsal surface with two pairs of strong spiniform setae, first pair anterior to telson mid-length, second pair at about 0.7 telson length; posterior margin broadly convex, with two pairs of posterolateral spiniform setae, mesial about twice as long as lateral; anal tubercles well developed; gill–exopod formula typical for genus.

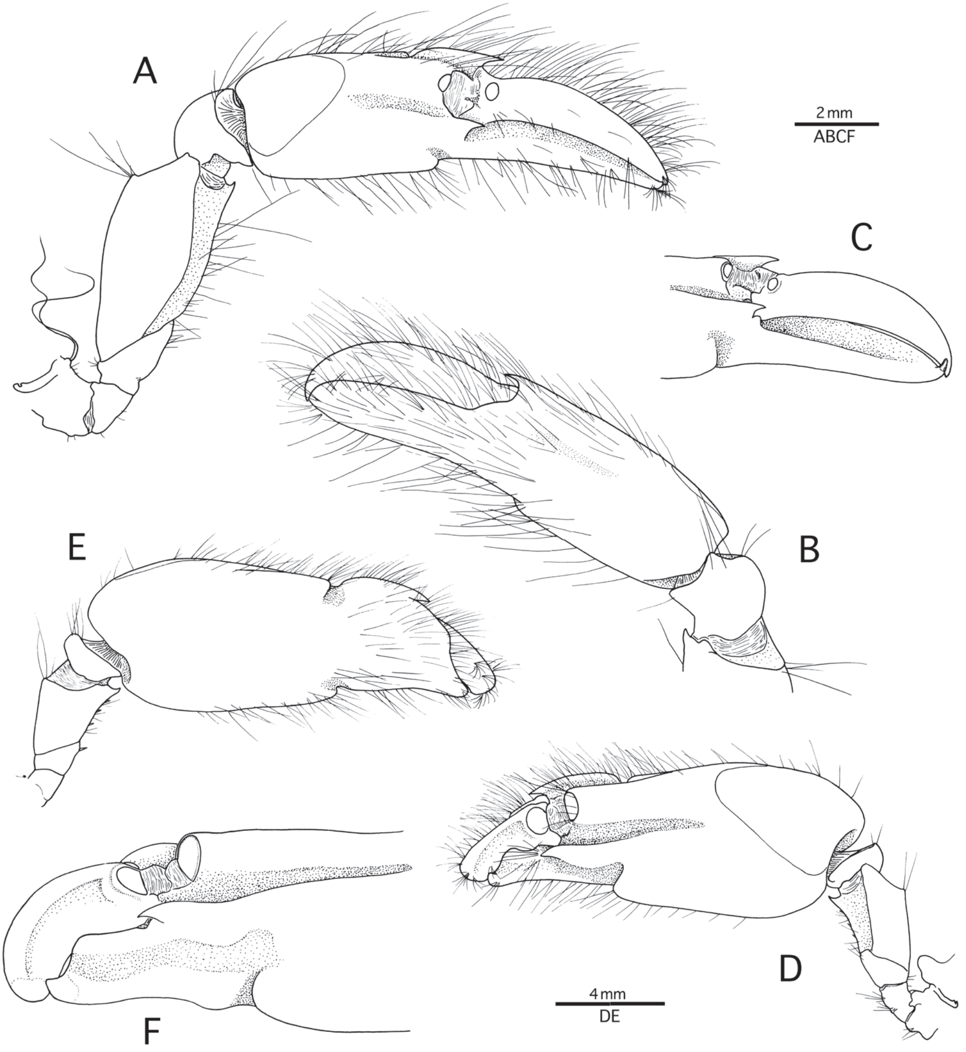

Figure 2. *Alpheus cedrici* sp. n. Holotype, male from Ascension Island (OUMNH.ZC. 2008-11-0017). **A** minor (right) cheliped, lateral **B** minor (right) chela and carpus, mesial **C** same, distal palm and fingers, lateral, setae omitted **D** major (left) cheliped, lateral **E** major (right) cheliped, mesial **F** same, distal palm and fingers, lateral, setae omitted.

Description. Body stout, laterally not compressed. Carapace glabrous; frontal margin with well-developed rostrum and orbital teeth; rostrum slightly flattened dorsally, tapering distally, with acute tip, much longer than wide; lateral margins without setae; tip reaching half-length of first article of antennular peduncle; rostral carina not distinct; orbital teeth in marginal position, relatively small, acute distally, shorter than rostrum (note: right orbital hood atypical, i.e. without tooth in male); margin between orbital teeth and rostrum broadly V-shaped; orbital hoods moderately swollen, enclosing eyes from all sides (Fig. 1A, B); rostro-orbital process present. Pterygostomial angle rounded, not protruding anteriorly (Fig. 1B); cardiac notch deep. Abdominal somites with posteroventral margins broadly rounded, fifth slightly more angular; sixth somite without articulated flap, bluntly projecting posteriorly.

Eyes with well-developed corneas; anteromesial margin bluntly protruding. Ocellar beak projecting, acute, visible in lateral view. Epistomial sclerites not acutely projecting.

Antennule with moderately slender peduncle; stylocerite not reaching distal margin of first article, with acute tip; ventromesial carina with large, subtriangular tooth as illustrated (Fig. 1C); second article much longer than dorsally visible portion of first article, about 2.5 times as long as wide (Fig. 1A); lateral flagellum with groups of aesthetascs starting from 12th article. Antenna with basicerite terminating in sharp distoventral tooth; carpocerite slightly exceeding both scaphocerite and antennular peduncle; scaphocerite with shallowly concave lateral margin and large, stout distolateral tooth, latter reaching far beyond distal margin of blade (Fig. 1A).

Mouthparts (not dissected) not specific in external view. Third maxilliped rather slender; coxa with lateral plate somewhat truncate distally; exopod long, overreaching distal margin of antepenultimate article; antepenultimate article somewhat flattened, ventral margin densely setose; penultimate article no more than three times as long as greatest width, distally slightly widening, very setose; ultimate article slender, tapering distally, with rows of serrulate setae and long, simple setae, tip unarmed (Fig. 1D).

Male minor cheliped with short, stout ischium; merus broad, subtriangular in cross-section; ventrolateral margin smooth; ventromesial margin straight, ending in small, acute distomesial tooth, and with four minute spiniform setae roughly equidistantly spaced along 0.6–0.7 of merus margin, and with tips falling just short of margin (therefore invisible in lateral view); distodorsal angle blunt; carpus rounded, cup-shaped; chela strongly compressed, with palm sculptured distally; lateral surface with low crest starting at about mid-length of palm and ending in a sharp distolateral tooth; ventral margin with blunt, non-protruding shoulder and adjacent deep notch, latter continuing transversely forming a shallow depression on mesial surface; dorsal margin with subcylindrical elevation ending distally in small adhesive disk; distomesial surface with crest ending in stout sharp tooth; fingers as long as palm; pollex shallowly excavated on cutting edge; dactylus somewhat flattened and twisted laterally, slightly convex dorsally, proximally with small adhesive disk (Fig. 2A–C). Female minor cheliped unknown (missing in the paratype).

Male major cheliped with short, stout ischium, ventromesial surface with small spiniform seta; merus stout, short, broad, subtriangular in cross-section; ventrolateral margin smooth; ventromesial margin straight, ending in stout, sharp distomesial tooth, and with small, widely spaced spiniform setae; dorsal margin ending bluntly distally; carpus very short, cup-shaped; chela somewhat compressed; palm strongly sculptured; lateral surface with low crest starting at about 0.6 length of palm and ending in sharp distolateral tooth; ventral margin with rounded, smooth, non-projecting shoulder adjacent to deep notch, latter continuing transversely to shallow groove on mesial surface; dorsal margin with subcylindrical elevation ending in large adhesive disk dis-

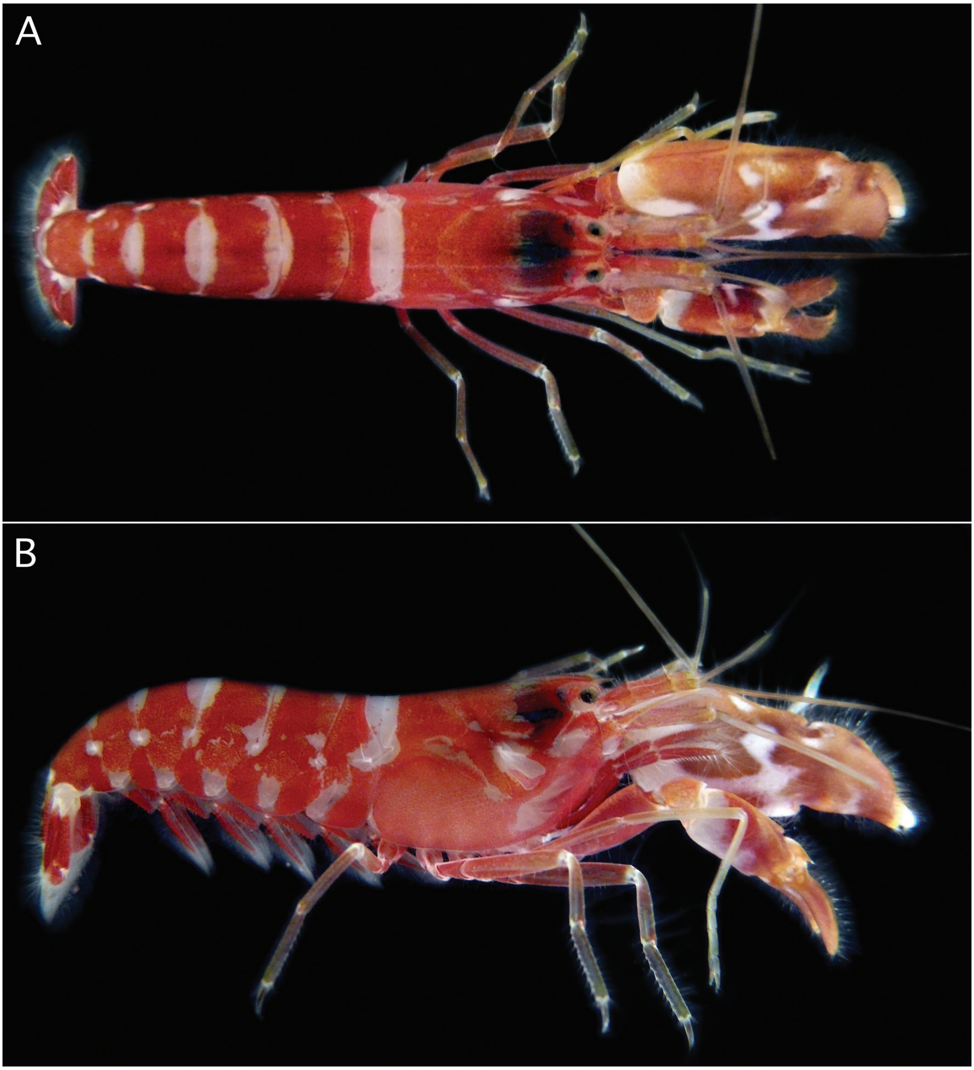

Figure 3. *Alpheus cedrici* sp. n. Holotype, male from Ascension Island (OUMNH.ZC. 2008-11-0017). **A** dorsal view **B** lateral view (photographs by S. De Grave).

tally; distomesial surface with transversally deeply notched crest ending in sharp tooth; pollex shorter than dactylus, somewhat twisted and shallowly depressed laterally, cutting edge bluntly projecting laterally; dactylus flattened, twisted laterally, convex dorsally, bulbous distally, plunger reduced to broad, low tooth (Fig. 2D–F). Female major cheliped generally similar in shape and proportions to male major cheliped.

Second pereiopod elongate, slender; ischium slightly longer than merus; carpus with five articles with ratio approximately equal to 4 : 2 : 1 : 1.5 : 2; chela simple, fingers with scarce tufts of setae (Fig. 1E). Third and fourth pereiopods generally similar, moderately slender; third pereiopod with ischium armed with spiniform seta on ventrolateral surface; merus about five times as long as wide, without distoventral tooth; carpus more slender and about half as long as merus; propodus longer than carpus, with eight or so robust spiniform setae along ventral margin and one pair of longer spiniform setae adjacent to dactylus; dactylus about 0.4 length of propodus, simple, conical, faintly curved, with acute tip (Fig. 1F). Fifth pereiopod much more slender than third and fourth pereiopods; merus only slightly longer than carpus; ischium with spiniform seta; propodus with some spiniform setae along ventral margin and well-developed setal brush distolaterally (Fig. 1G).

Pleopods with protopods furnished with spiniform setae on lateral margin, some inserted in pairs (Fig. 1H, J, K), first pleopod with small endopod furnished with setae, male second pleopod with appendix masculina subequal in length to appendix interna, not reaching distal margin of endopod, furnished with numerous stiff setae (Fig. 1I); female second pleopod with appendix interna only. Uropod with lateral lobe of protopod ending in large, acute tooth; diaeresis sinuous, with blunt tooth adjacent to one (occasionally two) stout distolateral spiniform seta(e); endopod with row of small spiniform setae along distolateral margin (Fig. 1L).

Telson subrectangular, tapering towards posterior margin, about twice as long as wide at base; lateral margins slightly convex; dorsal surface with two pairs of strong spiniform setae inserted at some distance from lateral margin, first pair anterior to telson mid-length, second pair at about 0.7 telson length; posterior margin about 0.6 length of anterior margin, broadly convex, with two pairs of posterolateral spiniform setae, mesial about twice as long as lateral (Fig. 1M); anal tubercles well developed.

Gill–exopod formula typical for *Alpheus*: five pleurobranchs (above P1–5), one arthrobranch (Mxp3), two lobe-shaped epipods (Mxp1–2), five mastigobranchs (Mxp3, P1–4), five setobranchs (P1–5); three exopods (Mxp1–3).

Size. *Alpheus cedrici* sp. n. is a medium-sized species of *Alpheus*, with 10.1 mm cl for the male, and 11.8 mm for the ovigerous female.

Colour. Body ground colour bright red or red–orange; carapace mostly red with transverse white band along posterior margin and several colourless or whitish areas on flanks; abdomen mostly red with transverse, more or less oval-shaped, white bands, latter mainly dorsal and not extending to ventral margins of pleura, additional colourless or whitish patches present near ventral margin of each pleuron; major chelae orange–brown marbled with pale yellow on mesial side, and with a distinct, somewhat zigzag-shaped, transverse, white band on palm, extending ventrally and posteriorly; dactylus pale brown with white tip; minor chela similar to major chela, orange–brown with transverse white bands on palm, a broader, more diffuse distal band, and smaller, well-delimited, V-shaped, proximal band; second to fifth pereiopods pale reddish to yellowish, with white articulations; pleopods red; uropods and telson mostly red except for white uropodal protopods and most proximal portion of telson (Fig. 3).

Etymology. Named after our friend and colleague, Dr. Cedric d'Udekem d'Acoz, in recognition of his important contribution to the taxonomy of caridean shrimp and other decapods, particularly in the Atlantic Ocean.

Habitat. Both specimens were collected by lifting large, shallowly buried rocks on a fine sandy substrate at depths between 10 and 15 m, where the marginal boulder talus meets the sand. Other decapods obtained in the same habitat were the alpheids *Automate* cf. *dolichognatha*, *Alpheus holthuisi*, *Metalpheus paragracilis*, and the axiid *Axiopsis* cf. *serratifrons* (A. Milne-Edwards, 1873).

Type locality. English Bay, Ascension Island, central Atlantic Ocean.

Distribution. Central Atlantic Ocean: currently known only from the type locality.

Remarks. *Alpheus cedrici* sp. n. belongs to the monophyletic *Alpheus macrocheles* species group, which is comprised of about 30 species worldwide, all sharing a unique sculpture of the major chela (e.g. Coutière 1905; De Man 1911; Crosnier and Forest 1966; Banner 1953; Banner and Banner 1982; Kim and Abele 1988). Within the *A. macrocheles* species group, *A. cedrici* sp. n. belongs to the *A. macrocheles* species complex, characterised by the presence of acuminate orbital teeth on the frontal margin of the carapace; the major cheliped bearing a well-developed ventral notch and a dorsomesial notch or constriction; and the third and fourth pereiopods (P3–4) with unarmed meri and simple or minutely biunguiculate (not conspicuously biunguiculate) dactyli. The majority of species in the *A. macrocheles* complex are found in the Atlantic Ocean: *A. macrocheles* (EA, CA), *A. platydactylus* Coutière, 1897 (EA), *A. amblyonyx* Chace 1972 (WA), *A. lentiginosus* Anker & Nizinski, 2011 (WA), *A. puapeba* Christoffersen, 1979 (WA), *A. pouang* Christoffersen, 1979 (WA), and *A. cedrici* sp. n. (CA). Two species are distributed in the eastern Pacific: *A. bellimanus* Lockington, 1877 (EP), and *A. rectus* Kim & Abele, 1988 (EP). Finally, only one Indo-West Pacific species presents the above combination of characters: *A. albatrossae* (Banner, 1953). All these species are contrasted and compared with the new species below, in order of geographical proximity.

Alpheus macrocheles is a well-known, mostly shallow-water species (0–50 m, exceptionally to 185 m), ranging in the eastern Atlantic from the British Isles and Mediterranean Sea south to Gabon, and extending to the Central Atlantic islands of Ascension and St. Helena (Holthuis 1951; Crosnier and Forest 1966; Chace 1966; Manning and Chace 1990). *Alpheus cedrici* sp. n. can be separated from *A. macrocheles* by the presence of a row of spiniform setae on the protopods of the pleopods (absent in *A. macrocheles*); the scaphocerite with a better developed blade (cf. Fig. 1A and Crosnier and Forest 1966, fig. 2a); and the male minor chela being more slender and with the dactylus less expanded and less arched dorsally (cf. Figs. 2A–C and Crosnier and Forest 1966, fig. 2c). The two species also differ in their colour patterns: the white bands and patches on the abdomen of *A. cedrici* sp. n. are contrasting with the mostly uniform deep-red to bright or pale orange abdomen of *A. macrocheles* (Fig. 4A, B). All records of *A. macrocheles* from the western Atlantic, e.g. records from Brazil (Ramos-Porto 1979; Guterres et al. 2005), have to be treated with some caution as they may refer to *A. amblyonyx* or other species of the *A. macrocheles* complex.

Alpheus platydactylus is a poorly known deep-water species (50–600 m) restricted to the northeastern Atlantic (Mediterranean Sea to the Azores and Cape Verde). *Alpheus cedrici* sp. n. can be easily distinguished from *A. platydactylus* by the much stout-

Figure 4. Colour patterns of some species of the *Alpheus macrocheles* (Hailstone, 1835) complex. **A** *Alpheus macrocheles* from Cadaques, Mediterranean coast of Spain **B** *Alpheus macrocheles* from Madeira **C** *Alpheus amblyonyx* Chace, 1972 from Guadeloupe **D** *Alpheus amblyonyx* from Isla Grande, Panama **E** *Alpheus bellimanus* Lockington, 1877 from Santa Barbara, California **F** *Alpheus bellimanus* from Galapagos **G** *Alpheus* sp. ? *rectus* Kim & Abele, 1988, from the Gulf of California. Photographic credits: A, Josep Lluis Peralta; B, Peter Wirtz; C, Frédéric Fasquel; D, Arthur Anker; E, Gregory Jensen; F, Todd Zimmerman (courtesy of Cleveland Hickman); G, Alex Kerstitch (from Kerstitch 1988, courtesy of A. Kerstitch).

er, shorter antennular peduncles; the broader scaphocerite; the smooth ventral margin of the major chela palm (vs. rugose in *A. platydactylus*); the stouter minor chela, with the relatively shorter fingers; and the less slender second pereiopod (cf. Figs. 1, 2 and Crosnier and Forest 1966, fig. 2e–h).

Alpheus amblyonyx, a species widespread in the western Atlantic from the Gulf of Mexico to Brazil (Chace 1972; Christoffersen 1998), is generally very similar to *A. macrocheles*. Chace (1972) separated *A. amblyonyx* from *A. macrocheles* mainly on the basis of four characters: (1) the more prominent rostrum; (2) the transverse notch on the mesiodorsal surface of the major chela palm broader and less sharply defined; (3) the major chela dactylus more strikingly bulbous distally; and (4) the minor chela dactylus without a high dorsal crest. With the exception of the last feature, *A. cedrici* sp. n. can be separated from *A. amblyonyx* using the same criteria as from *A. macrocheles* (see above). The colour pattern of *A. amblyonyx* (Fig. 4C, D) is much more similar to the colour pattern of *A. macrocheles* (Fig. 4A, B) than to that of *A. cedrici*. sp. n. (Fig. 3).

Alpheus pouang and *A. puapeba* are two deep-water species presently known only from the southwestern Atlantic, off southern Brazil and Uruguay, at depth ranges of 120–268 m and 45–175 m, respectively (Christoffersen 1979, 1998). *Alpheus cedrici* sp. n. can be distinguished from *A. pouang* by the anterior margin of the carapace between the rostrum and the orbital teeth being shallowly and broadly concave (vs. much more deeply incised in *A. pouang*), and the minor chela with a non-protruding ventral shoulder and a distinctly less flattened and dorsally arched dactylus (cf. Figs. 1–2 and Christoffersen 1979, figs. 14–15). The new species differs even more from *A. puapeba*, for example, by the much shorter antennular peduncles and the less elongate, more swollen major chela (cf. Figs. 1–2 and Christoffersen 1979, figs. 16–17). In addition, the pleopodal protopods of both *A. pouang* and *A. puapeba* are not armed with rows of spiniform setae (Christoffersen 1979, figs. 15r, 17d, 18f), as is the case of *A. cedrici* sp. n. (Fig. 1J).

Alpheus lentiginosus is another deep-water western Atlantic species presently known only from the northern Gulf of Mexico, at depths of 336–438 m (Anker and Nizinski 2011). *Alpheus cedrici* sp. n. can be separated from *A. lentiginosus* by the less expanded, dorsally non-arched dactylus of the minor chela; the less slender third to fifth pereiopods, with simple, conical dactyli (vs. with a minute accessory unguis on the flexor margin in *A. lentiginosus*); and the presence of spiniform setae on the pleopodal protopods (absent in *A. lentiginosus*) (cf. Figs 1–2 and Anker and Nizinski 2011, figs. 1–2). The colour patterns of *A. cedrici* sp. n. and *A. lentiginosus* are different as well (cf. Fig. 3 and Anker and Nizinski 2011, fig. 3).

The two eastern Pacific species of the *A. macrocheles* complex, *A. bellimanus* and *A. rectus*, are both morphologically very close to *A. cedrici* sp. n. *Alpheus bellimanus* is a relatively common species with a very wide depth range (0–300 m), and also with a wide geographic range, from California via Mexico, Panama and Galapagos to northern Chile (Kim and Abele 1988). *Alpheus rectus* is a much less common species from moderately deep-water (55–73 m); it is currently known only from the type locality in Panama and one locality in southern Baja California (Kim and Abele 1988). *Alpheus cedrici* sp. n. shares with *A. bellimanus* the presence of spiniform setae on the protopods of pleopods. The two species also have very similar frontal margins of the carapace, antennules and antennae, major chelipeds, and walking legs. However, *A. cedrici* sp. n. can be separated from *A. bellimanus* by the non-protruding ventral shoulder of the male minor chela (vs. protruding in *A. bellimanus*); the less expanded, dorsally non-arched dactylus of the male minor chela (vs. more expanded and dorsally strongly convex in *A. bellimanus*); and the anteriorly rounded tooth on the ventromesial carina of the first article of the antennular peduncle (vs. with a subacute tooth in *A. bellimanus*) (cf. Figs. 1–2 and Kim and Abele 1988, fig. 5). The colour pattern of *A. bellimanus* (Fig. 4E, F) resembles more the uniform colour patterns of *A. macrocheles* (Fig. 4A, B) and *A. amblyonyx* (Fig. 4C, D) than the distinctly banded colour pattern of *A. cedrici* sp. n. (Fig. 3).

The new species from Ascension also differs from *A. rectus*, for example, by the less rectangular general shape of the major chela, with the ventral shoulder of the palm broadly rounded, not protruding anteriorly (vs. bluntly projecting in *A. rectus*); and the anteriorly rounded tooth on the ventromesial carina of the first article of the antennular peduncle (vs. with a small point in *A. rectus*). The colour pattern of *A. rectus* remains unconfirmed. However, a colour photograph of a snapping shrimp erroneously identified as "*Alpheus paracrinitus*" in Kerstitch (1988) matches *A. rectus*, especially in the shape of the major and minor chelipeds. The colour pattern of this individual (*Alpheus* sp. ? *rectus* in Fig. 4G), although characterised by a conspicuous transversal orange-white banding, is different from that of *A. cedrici* sp. n., especially in the clearly banded carapace and the abdominal bands extending ventrally to the pleural margins (cf. Figs. 3, 4G).

All other species of the *A. macrocheles* group present in the western and eastern Atlantic and in the eastern Pacific differ more markedly from *A. cedrici* sp. n. (see Coutière 1910; Armstrong 1940, 1941; Holthuis 1951; Crosnier and Forest 1966; Chace 1972; Wicksten and Méndez 1981; Kim and Abele 1988; Wicksten and McClure 2003; Anker et al. 2008). The shape of the frontal margin of the carapace separates the new species from *A. inca* Wicksten & Méndez, 1981, *A. grahami* Abele, 1975, *A. cylindricus* Kingsley, 1878, *A. vanderbilti* Boone, 1930, *A. clamator* Lockington, 1877, *A. peasei* (Armstrong, 1940), *A. dentipes* Guérin, 1832 and *A. candei* Guérin-Méneville, 1855). The shape of the major cheliped separates the new species from *A. crockeri* (Armstrong, 1941), *A. hortensis* Wicksten & McClure, 2003, *A. grahami*, *A. cylindricus* and *A. vanderbilti*. The shape of the minor cheliped separates the new species from *A. hoonsooi* Kim & Abele, 1988, *A. crockeri*, *A. hortensis*, *A. grahami*, *A. cylindricus* and *A. vanderbilti.* The presence of a distinct distoventral tooth on the merus of the third and fourth pereiopod in *A. hoonsooi*, *A. clamator*, *A. peasei* and *A. dentipes* separates these species from *A. cedrici* sp. n. Finally, the strongly biunguiculate dactylus of the third to fifth pereiopods in *A. clamator*, *A. peasei*, *A. dentipes* and *A. candei* separates these species from *A. cedrici* sp. n.

Alpheus cedrici sp. n. can be separated from the Indo-West Pacific *A. albatrossae* by the presence of a distinct shoulder on the ventrolateral surface of the minor chela palm (absent in *A. albatrossae*); the stouter fingers of the minor chela; and the absence of a small unguis on the dorsal margin of the dactylus of the third to fifth pereiopods (present in *A. albatrossae*) (cf. Figs. 1, 2 and Banner, 1953, fig. 18). None of the other Indo-West Pacific species of the *A. macrocheles* group appears to be closely related to *A. cedrici* sp. n. (e.g. Coutière 1905; De Man 1911; Banner 1953; Kensley 1969; Banner and Banner 1982; Burukovsky 1990).

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RESEARCH ARTICLE

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Review of the Chinese leafhopper genus *Parazyginella* Chou & Zhang (Hemiptera, Cicadellidae, Typhlocybinae, Zyginellini) with description of a new species

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Abstract

The two leafhopper species in the genus *Parazyginella* Chou & Zhang from China are reviewed and illustrated including one new species, *Parazyginella tiani* **sp. n.** which is described. A key to separate males of the two species is provided.

Keywords

Homoptera, Auchenorrhyncha, taxonomy

Introduction

Zyginellini is one of the smaller tribes in the large leafhopper subfamily Typhlocybinae. Members of the subfamily feed on trees, shrubs and herbs and some occur on economic crops including two species of Zyginellini, *Zyginella mali* (Yang) and *Z. minuta* (Yang), which damage apple trees in China. Members of this tribe can be distinguished by their usual bright coloration with distinct patterns and by the hindwing venation with the vannal veins separate apically, with only one transverse vein visible and submarginal vein extended directly to vein CuA, forming one open cell (Fig. 13).

The Oriental Zyginellini genus *Parazyginella* was erected by Chou and Zhang (1985) with *P. lingtianensis* from Guangxi, China as its type species. There have been no further reports of this genus which is recognized by its depressed body form and a dark spot near the apex of the forewing (Figs 1–3). In this paper, we describe a second species, *Parazyginella tiani* sp. n. from Yunnan, China. The type specimens of the new species are deposited in the collections of the Entomological Museum, Northwest A & F University, Yangling, China (NWAFU) and The Natural History Museum, London (BMNH).

Systematics

Parazyginella Chou & Zhang, 1985

http://species-id.net/wiki/Parazyginella

Parazyginella Chou & Zhang, 1985: 295; Zhang 1990: 174.

Type species. *Parazyginella lingtianensis* Chou & Zhang, 1985

Description. Body flattened. Vertex conically produced, middle length nearly equal to width and length of pronotum; coronal suture distinct. Head and pronotum whitish yellow. Scutellum and venter yellow. Forewing with base of 1st and 4th apical cells at same level; 3rd apical cell triangular and with a dark spot; hind margin of brochosome field and veins in apical area of wing touched with dark brown.

Abdominal apodemes elongate, reaching beyond 5th abdominal sternite.

Male pygofer strongly sclerotized, with short, finger-like process caudo-dorsally and few scattered microsetae. Subgenital plates broad at base, distally abruptly tapered to short narrow apex, with few macrosetae basally. Paramere simple, with central part expanded, apical part tapering to acute apex and strongly bent. Connective with short arms and medial lobe present. Aedeagus asymmetrical with basal part strongly sclerotized with short preatrium and large dorsal apodeme, the latter laterally compressed with distal anterior region membranous and distal posterior region strongly curved anteriorly; shaft elongate, with a single elongate apical process on one side; gonopore obscure.

Parazyginella resembles *Zyginella* Löw, but differs in its more greatly developed dorsal apodeme of the aedeagus and male pygofer with a dorsal finger-like process and without long macrosetae (Figs 16, 17).

Distribution. China (Guangxi, Yunnan).

Key to species of *Parazyginella*

1 Head without brown markings. Aedeagal shaft in lateral view similar in width throughout length, process moderately long and slim, lying parallel to shaft (Figs 10, 11) .... ***P. lingtianensis***

– Head with brown markings (Figs 2–4). Aedeagal shaft in lateral view slightly expanded from midlength to near apex, process long and stout, directed slightly towards basal apodeme (Figs 21, 22)........................... ***P. tiani* sp. n.**

Parazyginella lingtianensis Chou & Zhang, 1985

http://species-id.net/wiki/Parazyginella_lingtianensis
Figs 1, 5–12

Parazyginella lingtianensis Chou & Zhang, 1985: 295; Zhang 1990: 174

Description. Head and pronotum whitish yellow. Scutellum and venter yellow; vertex and pronotum either side of midline marked with orange (Figs 1, 5); 3rd apical cell of forewing with dark elliptical spot (Figs 1, 12).

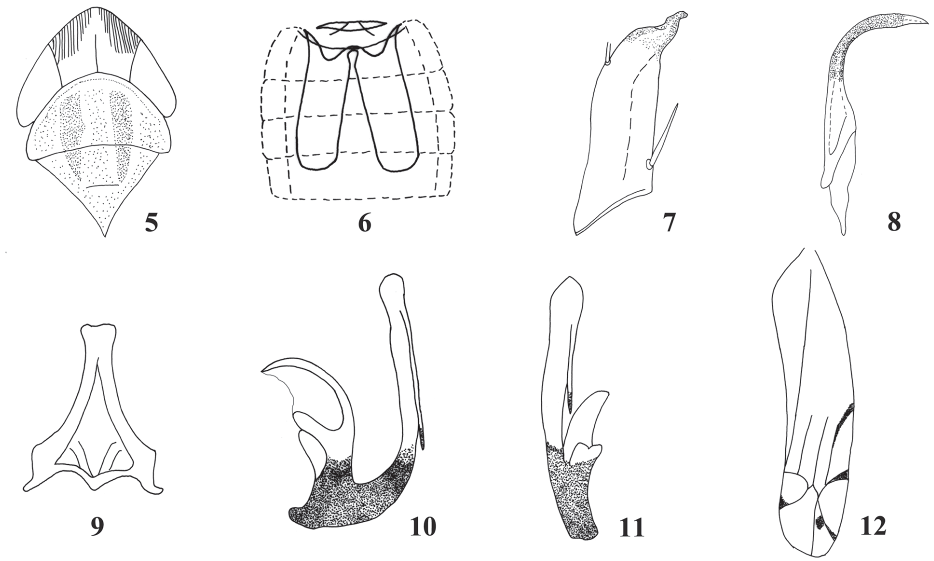
Abdominal apodemes reaching middle part of 6th abdominal sternite (Fig. 6).

Subgenital plates with one macroseta near base, apex beak-like (Fig. 7). Paramere slightly expanded subapically (Fig. 8). Aedeagal shaft in lateral view similar in width throughout length, process moderately long and slim, lying parallel to shaft (Figs 10, 11).

Body length. Male 3.00 mm (including wing).

Material examined. *Holotype*, male, China: Guangxi Prov., Lingchuan, Lingtian, 5 June 1984, coll. Lu Xiaolin, lamp (NWAFU).

Figures 1–4. 1 *Parazyginella lingtianensis*, dorsal habitus **2–4** *Parazyginella tiani* sp. n. **2** dorsal habitus **3** lateral habitus **4** face.



Figures 5–12. *Parazyginella lingtianensis* (after Chou and Zhang 1985) **5** Head, dorsal view **6** Abdominal apodeme **7** Subgenital plate **8** Paramere **9** Connective **10** Aedeagus, lateral view **11** Aedeagus, posterior view **12** Forewing.

Distribution. China (Guangxi).

Remarks. The male genitalia of the unique type could not be found. Therefore the pygofer (originally not figured) could not be examined and compared to the new species. Also, the original figure of the aedeagus (shown here, Fig. 10) did not show the membranous area of the basal apodeme shown in our new species. We conclude that this area was probably overlooked and add a line to the figure to show its approximate position.

Parazyginella tiani sp. n.

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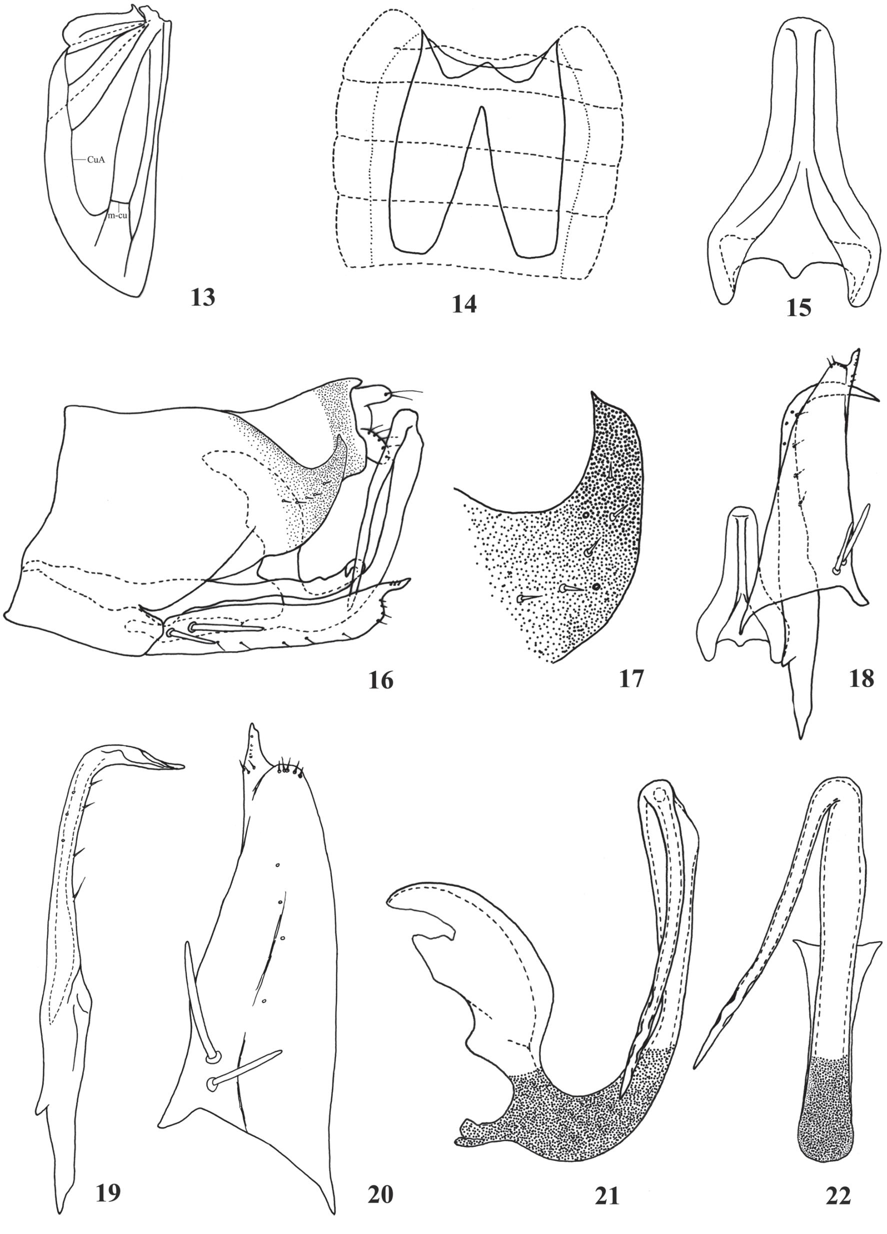
http://species-id.net/wiki/Parazyginella_tiani
Figs 2–4, 13–22

Description. Head and pronotum whitish yellow; scutellum and venter yellow; vertex with disc and apex dark brown, orange laterally; face sordid white, with a dark brown patch above antennae; dorsum of abdomen stramineus. Forewing with dark spot in 3rd apical cell (Figs 2, 3).

Abdominal apodemes nearly reaching end of 6th abdominal sternite (Fig. 14).

Male pygofer with short, sclerotized, sickle-like process caudo-dorsally (Figs 16, 17). Subgenital plates with two macrosetae near base, apex digitate with few microsetae (Figs 18, 20). Paramere subapically with row of fine setae on outer margin and row of



Figures 13–22. *Parazyginella tiani* sp. n. **13** Hindwing **14** Abdominal apodeme **15** Connective **16** Genital capsule, lateral view **17** Apical part of male pygofer **18** Paramere, connective, subgenital plate, ventral view **19** Paramere **20** Subgenital plate **21** Aedeagus, lateral view **22** Aedeagus, posterior view.

sensory pits on inner margin; with curved apical part with sinuate ridge (Figs 18, 19). Aedeagal shaft in lateral view slightly expanded from midlength to near apex, process long and stout, directed slightly towards basal apodeme, apex ornamented (Figs 21, 22).

Body length. 2.95–2.98 mm (including wing).

Material examined. *Holotype*, male, China: Yunnan Province, Sanchahe, 7 June 1991, coll. Tian Rungang (NWAFU). *Paratypes*, two males, seven females, same data as holotype (NWAFU, BMNH).

Distribution. China (Yunnan).

Remarks. The new species resembles *P. lingtianensis* but differs in having brown markings on the vertex (compare Figs 1 and 2) and different shaped aedeagus as noted in the key.

Etymology. The new species is named after the collector's family name in gratitude.

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RESEARCH ARTICLE

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Review of *Dicrotendipes* Kieffer from China (Diptera, Chironomidae)

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Abstract

The genus *Dicrotendipes* Kieffer from China, including 8 species, is reviewed. Two new species, *D. nudus* **sp. n.** and *D. saetanumerosus* **sp. n.** are described and the male imagines are illustrated; the record of *D. fusconotatus* (Kieffer) is the first for China. A key to the males of *Dicrotendipes* in China is given.

Keywords

Chironomidae, *Dicrotendipes*, new species, key, China

Introduction

The genus *Dicrotendipes* was erected by Kieffer in 1913, with *Dicrotendipes septemmaculatus* (Becker, 1908) as type species. Adults of *Dicrotendipes* have been considered as pests due to large emergences (Frommer and Rauch 1971; Epler 1988), and have been implicated in allergic reactions in humans in Africa (Cranston et al. 1983). The immature stages are found in both lentic and lotic habitats, but are generally more prevalent in lentic situation. So far, there are 102 species recorded around the word.

In this paper, the Chinese material of *Dicrotendipes* is reviewed. Two new species are described, and a key to the Chinese species of *Dicrotendipes* is presented.

Materials and methods

The morphological nomenclature follows Saether (1980). The material examined was mounted on slides, following the procedure outlined by Saether (1969). Measurements are given as ranges followed by the mean, when three or more specimens are measured, followed by the number of specimens measured (n) in parentheses. Specimens are deposited in the College of Life Science, Nankai University, China and College of Life Science, Taizhou University, China.

Abbreviations of parts measured are as follows:

TL	Total length, Length of abdomen + length of thorax; Abdomen is measured from the concave anteriomedian margin of segment I to the apex of the gonostylus; the thorax is measured from the posterior margin of the postnotum to the anterior apex of the scutum in lateral view.
WL	Wing length, measured from arculus to apex of wing.
Pfe	Length of profemur.
AR	Antennal ration, length of 11th / length of flagellomeres 1–10.
L: 5th/3rd	Length of the 5th Palpomere / length of the 3rd Palpomere.
Ftu	Length of frontal tubercle.
VR	Venarum ration, length of Cubitus (Cu) / length of Media (M).
BV	Length of (femur + tibia + ta_1) / length of (ta_2 + ta_3 + ta_4 + ta_5)
LR	Leg ration, length of ta1 / length of tibia.
SV	Length of (femur + tibia) / length of ta_1.
HR	Hypopygium ration, length of gonocoxite / length of gonostylus.
HV	Hypopygium value, total length / length of gonostylus times ten.
P_1	Fore leg.
P_2	Mid leg.
P_3	Hind leg.
fe	femur.
ti	tibia.
ta_1…ta_n	$tarsus_1$…$tarsus_n$.
B	Brachiolum.
R	Radius.
R_1	Radius 1 vein.
R_{4+5}	Radius 4+5 vein.

Taxonomy

Dicrotendipes flexus **(Johannsen, 1932)**
http://species-id.net/wiki/Dicrotendipes_flexus

Chironomus (*Limnochironomus*) *flexus* Johannsen, 1932: 530.

Limnochironomus flexus: Lenz 1937: 6.
Dicrotendipes flexus: Hashimoto et al. 1981: 14; Epler 1988: 128; Wang et al. 1990: 29; Wang 2000: 643.

Specimens examined. China, Hubei: 5♂♂, Wuhan City, Donghu Lake, 30°35.06'N, 114°22.42'E, 22.iv.1977, Wang SD sweeping method; Guangdong: 2♂♂, Fengkai County, Heishiding Nature Conservation Area, 23°29.14'N, 111°50.54'E, 18.iv.1988, Wang XH, light trap; Shandong: 1 ♂, Yantai City, Kunyu Mountain, 37°23.53'N, 121°36.42'E, 24.viii.1987, Wang XH, sweeping method.

Remarks. *D. flexus* (Johannsen) closely resembles *D. nervosus* (Staeger) in the structure of hypopygium, but can be separated by the apparently disjunct distributions and fewer setae on R and R_1, (21–26 in *D. flexus*, more than 35 in *D. nervosus*). All examined Chinese specimens comply with the description of Johannsen (1932) and Hashimoto et al. (1981).

Distribution. China (Hubei, Guangdong and Shandong Province); Australia; Japan; Indonesia.

Dicrotendipes fusconotatus (Kieffer, 1922)

http://species-id.net/wiki/Dicrotendipes_fusconotatus

Calochironomus fusconotatus Kieffer, 1922: 68.
Calochironomus grisseonotatus Kieffer, 1922: 69.
Dicrotendipes forkficula Kieffer, 1925: 298.
Dicrotendipes nilicola Kieffer, 1925: 300.
Chironomus (*Dicrotendipes*) *fusconotatus*: Freeman 1957: 362.
Dicrotendipes fusconotatus: Contreras-Lichtenberg 1986: 717.

Specimens examined. China, Jiangxi: 5♂♂, Yongxiu County, Nanji Town, 28°56.42'N, 116°21.37'E, 12.vi.2004, Yan CC, light trap.

Remarks. Chinese specimens mainly agree with the description of Freeman (1957), but vary in the coloration of the abdomen: the abdomen of the Chinese species is black; while in Freeman (1957), the abdomen is light green and the median of each abdominal tergite black.

Distribution. China (Jiangxi Province); Belgium; Congo; Egypt; Israel; Kenya; Sudan; Zaire.

Dicrotendipes nervosus (Staeger, 1839)

http://species-id.net/wiki/Dicrotendipes_nervosus

Chironomus nervosus Staeger, 1839: 567.
Tendipes (*Dicrotendipes*) *nervosus*: Dendy and Sublette 1959: 514.
Chironomus (*Dicrotendipes*) *nervosus*: Sublette 1964: 126.

Dicrotendipes nervosus: Epler 1988: 63; Wang et al. 1990: 29; Wang 2000: 643.

Specimens examined. China, Jiangxi: 7♂♂, Yongxiu County, Nanji Town, 28°56.42'N, 116°21.37'E, 12.vi.2004, Yan CC, light trap; Ningxia: 3♂♂, Yinchuan City, 38°29.23'N, 106°13.19'E, Wang XH, light trap; Shandong: 2♂♂, Zaozhuang City, Baodugu Mountain, 34°59.11'N, 117°43.07'E, 28.v.1994, Wei MC, sweeping method; Tianjin: 6♂♂, Yuqiao Reservoir, 40°02.35'N, 117°27.01'E, 17.x.1987, Wang XH, light trap; Zhejiang: 1♂, Quzhou City, Yunxi village, 29°01.15'N, 118°56.51'E, 20.iv.2011, Lin XL, sweeping method.

Distribution. China (Jiangxi, Shandong, Zhejiang Province, Ningxia Hui Autonomous Region and Tianjin City); Brazil; Britain; Canada; Denmark; Germany; Japan; Netherlands; Korea; Sweden; Russia; USA.

***Dicrotendipes nudus* sp. n.**

urn:lsid:zoobank.org:act:C0444659-611D-4DAB-BDD3-1AD246E9978F
http://species-id.net/wiki/Dicrotendipes_nudus
Figs 1–5

Diagnosis. R_1 and R_{4+5} without seta; tergite IX without median seta; anal point with basal peduncle and bulbous ventral extension, 6–9 dorsal basal setae and 6 lateral setae.

Description. Male imago (n = 18)

TL 2.65–3.20, 2.95 mm. WL 1.65–2.00, 1.82 mm. TL/WL 1.58–1.94, 1.72. WL/Pfe 2.14–2.43, 2.31.

Coloration. Head, thorax and abdominal tergite VI–IX brown, abdominal tergite I–V pale yellow; legs yellowish-brown.

Head. AR 1.85–2.12, 2.02. Temporal setae 10–16, 13. Clypeus with 12–19, 16 setae. Tentorium 100–163, 146 µm long, 20–35, 28 µm wide. Palpomere lengths (in µm): 34–42, 35; 43–55, 48; 40-45; 108–130, 121; 130–148, 138; 163–215, 179. L: $5^{th}/3^{rd}$ 1.35–1.67, 1.58. Frontal tubercle 10.20–17.50, 14.20 µm long, 5.00–7.50, 6.20 µm wide.

Wing (Fig.1). Wing transparent, without markings. VR 1.11–1.16, 1.13. B 1–3, 2 setae; R with 7–11, 9 setae; R_1 and R_{4+5} without seta. Squama with 4–6, 5 setae.

Thorax. Dorsocentrals 8–11, 10; acrostichals 4–5, 4; prealars 3–4, 4. Scutellum with 4–9, 7 setae.

Legs. Fore tibia with rounded scale lacking spur. Spurs on mid tibiae 23–25, 24 µm and 18–25,20 µm long, including combs 26–32, 30 µm and 26–32, 30 µm long; spurs on hind tibia 22–32, 26 µm and 18–20,19 µm long including combs 24–28, 26 µm and 22–25, 23 µm long. Width at apex of front tibia 53–58, 55 µm, of mid tibia 50–55, 53 µm, of hind tibia 55–65, 59 µm. Lengths (in µm) and proportions of legs in Table1.

Hypopygium (Figs 2–5). Anal point 40–60, 50 µm long, with basal peduncle and bulbous ventral extension, 6–9 dorsal basal setae and 6 lateral setae. Tergite IX without

Table 1. Lengths (in μm) and proportions of legs of *Dicrotendipes* nudus sp. n.

	P_1	P_2	P_3
fe	710–850, 788	670–790, 752	770–870, 818
ti	560–640, 600	570–710, 638	800–940, 870
ta_1	890–1050, 991	310–380, 338	490–560, 528
ta_2	380–460, 428	180–220, 197	260–300, 278
ta_3	310–380, 353	110–140, 127	210–240, 218
ta_4	240–300, 280	70–80, 77	110–130, 123
ta_5	130–150, 143	71–83, 77	90–100, 95
LR	1.59–1.75, 1.65	0.52–0.55, 0.53	0.59–0.64, 0.61
BV	1.89–2.04, 1.96	3.45–4.87, 3.84	3.06–3.19, 3.11
SV	1.32–1.43, 1.37	4.03–4.17, 4.11	3.08–3.29, 3.20

median setae; laterosternite IX with 3–4, 3 setae. Phallapodeme 95–103, 97 μm long; transverse sternapodeme 40–50, 45 μm long, laterally narrowed, medially broad, inverted U-shaped. Gonocoxite 142–165, 156 μm long. Superior volsella 83–92, 85 μm long, 23–27, 25 μm wide; digitiform with short ventral extension; with numerous micro setae and 3–4 short apical setae (Figs4–5). Inferior volsella 128–155, 142 μm long; elongate, apex bulbiform, with 6–9, 8 apical setae in 2 rows. Gonostylus 150–195, 172 μm long; slightly curved medially, with 5–7, 6 apical setae along inner margin. HR 0.73–1.17, 0.82; HV 1.82–1.88, 1.85.

Type materials. Holotype: 1♂, China, Hebei: Chicheng County, 40°54.16'N, 115°54.08'E, 21.vii.2001, Guo YH, light trap. Paratypes (17): Hebei: 2♂♂, Chicheng County, 40°54.16'N, 115°54.08'E, 21.vii.2001, Guo YH, light trap; Xinjiang: 5♂♂, Hebahe County, 48°04.30'N, 86°24.47'E, 15.vii.2002, Tang HQ, light trap; Zhejiang: 3♂♂, Ningbo City, 29°48.36'N, 121°34.53'E, 10.v.2010, Qi X, sweeping method; 1♂, Sanmen County, 29°05.55'N, 121°23.45'E, 28.vii.2010, Lin XL, sweeping method; 6♂♂, Tiantai County, Huading Mountain, 29°14.51'N, 121°06.31'E,13.iv.2011, Lin XL, light trap.

Etymology. The species name is from Latin, *nudus*, meaning bare, referring to R_1 and R_{4+5} without seta, which is unique within the genus.

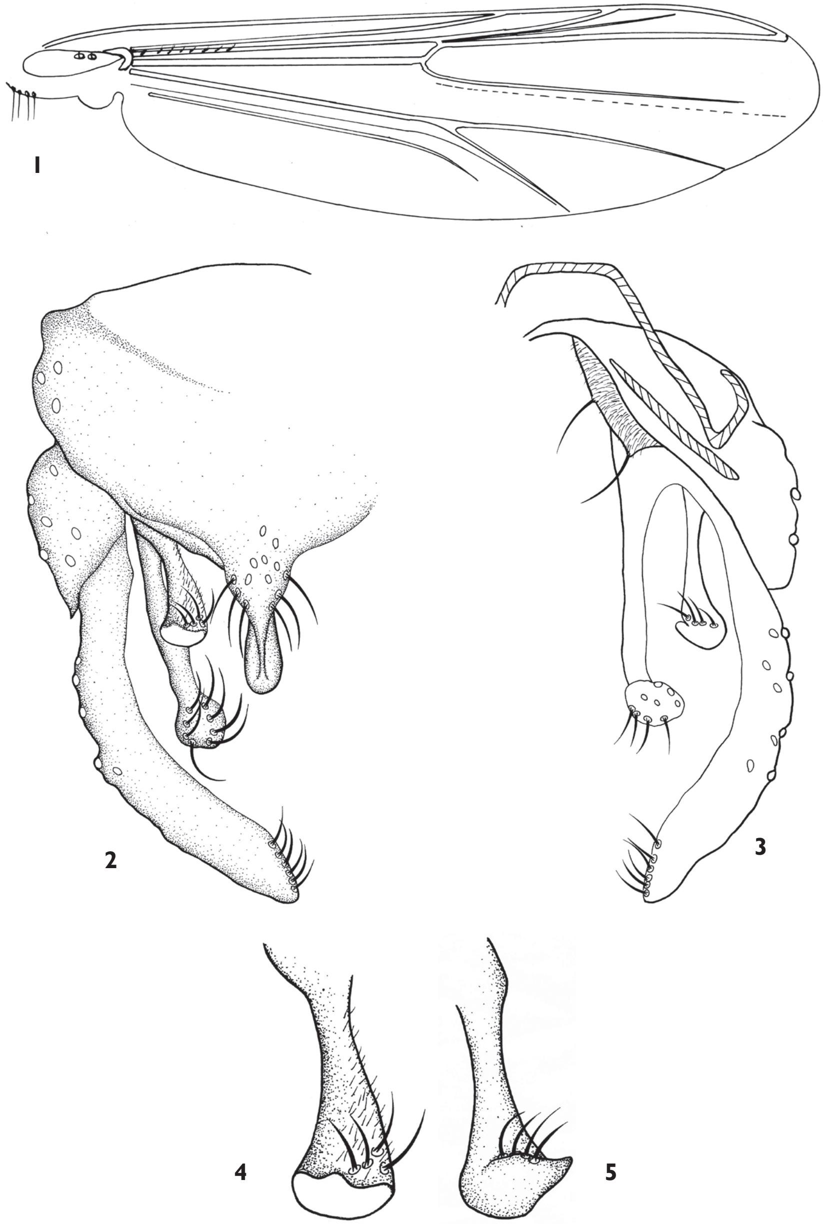
Remarks. *D. nudus* closely resembles *D. nervosus*, but can be separated by R_1 and R_{4+5} of *D. nudus* without seta; while in *D. nervosus*, R_1 with 11–20, 15 setae, R_{4+5} with17–28, 22 setae.

Distribution. The species is known from Hebei, Zhejiang Province and Xinjiang Uygur Autonomous Region of China.

Dicrotendipes pelochloris (Kieffer, 1912)

http://species-id.net/wiki/Dicrotendipes_pelochloris

Tendipes pelochloris Kieffer, 1912: 39; Kieffer 1916: 113.
Limnochironomus niveicauda Kieffer, 1921: 585.



Figures 1–5. *Dicrotendipes nudus* sp. n., male **1** wing **2** hypopygium (dorsal view) **3** hypopygium (ventral view) **4–5** superior volsella.

Chironomus (*Limnochironomus*) *niveicauda*: Johannsen 1932: 528.
Dicrotendipes niveicauda: Sublette and Sublette 1973: 404; Hashimoto et al. 1981: 13.
Chironomus inferior Johannsen, 1932: 534.
Cladotendipes inferior: Lenz 1937: 7.
Dicrotendipes inferior: Sublette and Sublette 1973: 403.
Chironomus (*Dicrotendipes*) *wirthi* Freeman, 1961: 692.
Dicrotendipes pelochloris: Epler 1988: 134; Wang et al. 1990: 28; Wang 2000: 644.

Specimens examined. China, Hainan: 2♂♂, Xinglong County, Huaqiao Farm, 18°43.27'N, 110°14.42'E, 21.v.1985, Wang XH, light trap; Hebei: 1♂, Qinhuangdao City, 39°55.53'N, 119°36.19'E, 4.vi.1985, Li HH, sweeping method; 3♂♂, Chicheng County, 40°54.16'N, 115°54.08'E, 21.vii.2001, Guo YH, light trap; Jiangxi: 2♂♂, Yongxiu County, Nanji Town, 28°56.42'N, 116°21.37'E, 12.vi.2004, Yan CC, light trap; Fujian: 11♂♂, Shanghang County, 25°02.32'N, 116°26.12'E, 6.v.1993, Wang XH, light trap; 2♂♂, Longyan City, 25°07.14'N, 117°02.20'E, 25.ix.2002, Liu Z, light trap; Guangxi: 4♂, Leye County, 24°47.30'N, 106°33.47'E, 24.vii.2004, Yu X, light trap; Guizhou: 2♂♂, Guiyang City, Huaxi, 26°24.32'N, 106°38.58'E, 23.vii.1995, Bu WJ, sweeping method; Taiwan: 2♂♂, Taibei City, 25°08.33'N, 121°36.57'E, 21.vii.2003, Wang XH, light trap.

Remarks. The Chinese specimens mainly agree with the description by Epler (1988). According to Epler (1988), there was some variation in the coloration of the wing in *D. pelochloris*, from hyaline to dusky brown, or with diffuse brown cloud along R_1, R_{4+5}, M, Cu and An. The wings of Chinese specimens are hyaline, without markings. The Chinese specimens are smaller than the specimens described in Epler (1988). Some measured differences between the Chinese specimens and the specimens described by Epler (1988) are shown in Table 2.

Distribution. China (Hainan, Hebei, Fujian, Guizhou, Jiangxi, Taiwan Province and Guangxi Zhuang Autonomous Region); Australia; India; Indonesia; Japan; Pakistan; Philippines; South Korea.

Table 2. Differences between the specimens of China and of Epler (1988)

	Chinese specimens	Description of Epler (1988)
TL	2.68–4.25, 3.55 mm	3.74–4.40, 4.01 mm
WL	1.38–2.43, 1.82 mm	1.73–2.28, 1.96 mm
Ftu	13–33, 19 μm	16–26, 20 μm
AR	1.91–2.44, 2.17	1.95–2.27, 2.09
VR	1.05–1.14, 1.10	0.81–0.92, 0.85
LR_1	1.58–1.84, 1.73	1.66–2.07, 1.86
BV_1	1.71–2.75, 1.87	1.78–1.98, 1.89
BV_2	3.66–4.27, 3.89	4.06–4.74, 4.22
SV_2	3.72–4.17, 3.97	3.98–4.38,4.17

Dicrotendipes saetanumerosus sp. n.

urn:lsid:zoobank.org:act:B8666895-7A48-41E0-8799-8B236E7FDDAD
http://species-id.net/wiki/Dicrotendipes_saetanumerosus
Figs 6–8

Diagnosis. Tergite IX with more than 30 median setae; anal point broad, bare; superior volsella pediform, with 11–16 lateral setae.

Description. Male imago (n = 7)

TL 3.65–4.30, 3.82 mm. WL 1.80–2.30, 2.10 mm. TL/WL 1.87–2.03, 1.93. WL/Pfe 1.86–2.04, 1.96.

Coloration. Head, thorax and abdominal tergite VII–IX brown, abdominal tergite I–VI pale yellow; legs yellowish-brown.

Head. AR 2.38–2.55, 2.40. Temporal setae 19–22, 20. Clypeus with 16–20, 17 setae. Tentorium 120–155, 136 µm long, 26–35, 30 µm wide. Palpomere lengths (in µm): 32–53, 45; 58–68, 62; 155–185, 167; 165–195, 172; 235–260, 241. L: 5th/3 rd 1.41–1.52, 1.46. Frontal tubercle 7.50–15.00, 10.00 µm long, 5.00–6.50, 5.52 µm wide.

Wing (Fig.6). Wing transparent, without markings. VR 1.05–1.06, 1.05. B 2–3, 2 setae; R with17–20, 18 setae; R_1 with 12–16, 14 setae; R_{4+5} with 17–19, 18. Squama with 4–9, 6 setae.

Thorax. Dorsocentrals 8–11, 10; acrostichals 9–16, 12; prealars 4–5, 4. Scutellum with 8–11, 9 setae.

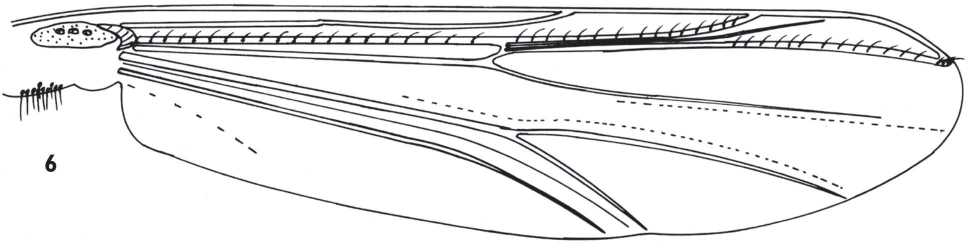
Legs. Fore tibia with rounded scale lacking spur. Spurs on mid tibiae 23–28, 26 µm and 25–30, 26 µm long, including combs 20–23, 21 µm and 15–18, 16 µm long; spurs on hind tibia 23–28, 26 µm and 25–30, 27 µm long including combs 20–23, 21 µm and 15–18, 16 µm long. Width at apex of front tibia 58–68, 60 µm, of mid tibia 58–73, 63 µm, of hind tibia 63–85, 70 µm. Lengths (in µm) and proportions of legs in Table 3.

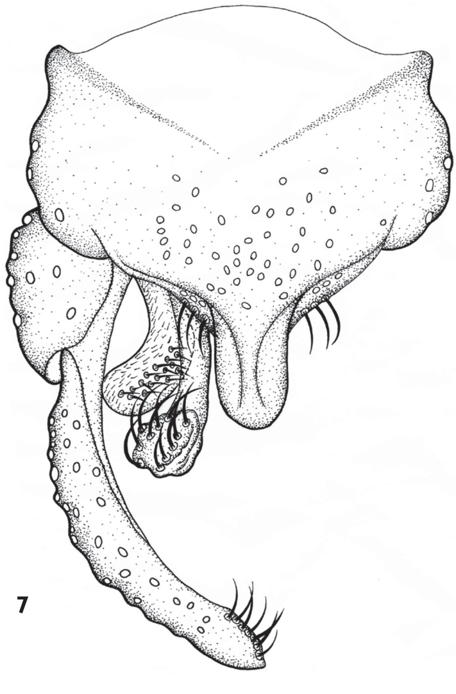
Hypopygium (Figs 7–8). Anal point 40–50, 45 µm long, broad, bare. Tergite IX with more than 30 median setae; laterosternite IX with 2–4, 3 setae. Phallapodeme 90–115, 97 µm long; transverse sternapodeme 40–50, 45 µm long, laterally narrowed, medially broad, inverted U-shaped. Gonocoxite 165–230, 180 µm long. Superior volsella 68–77, 70 µm long, 38–68, 50 µm wide; pediform, with 11–16 lateral setae. Inferior volsella 138–163, 142 µm long; elongate, apex bulbiform, with 9–12, 10 apical setae in 2 rows. Gonostylus 180–195, 186 µm long; slightly curved medially, with 5–7, 6 apical setae along inner margin. HR 0.80–0.90, 0.82; HV 1.83–2.05, 1.87.

Type materials. Holotype: 1♂, China, Shandong: Taian City, Tai Moutain 36°11.37'N, 117°08.13'E, 25.v.1994, Wang XH, light trap. Paratypes (8): Shandong: 1♂, Taian City, Tai Moutain, 36°11.37'N, 117°08.13'E, 25.v.1994, Wang XH, light trap; Hubei: 2♂♂, Shiyan City, Wudang Mountain, 32°30.22'N, 111°05.09'E, 16.vii.1997, Wang BX, light trap; Zhejiang: 5♂♂, Kaihua County, 29°05.57'N, 118°23.19'E, 13.iv.2011, Lin XL, light trap.

Table 3. Lengths (in µm) and proportions of legs of *Dicrotendipes saetanumerosus* sp. n.

	P_1	P_2	P_3
fe	970–1125, 1010	840–990, 890	950–1125, 1000
ti	750–780, 760	710–840, 750	970–1150, 1000
ta_1	1400–1600, 1500	390–470, 432	620–750, 674
ta_2	650–680, 660	220–270, 240	310–390, 350
ta_3	525–580, 550	150–180, 160	260–310, 280
ta_4	450–500, 470	90–120, 110	150–190, 170
ta_5	225–270, 240	70–90, 80	90–120, 115
LR	1.87–1.96, 1.92	0.55–0.58, 0.56	0.64–0.72, 0.66
BV	1.73–1.78, 1.76	3.48–3.66, 3.54	3.00–3.29, 3.14
SV	1.76–1.95, 1.83	2.47–2.76, 2.55	4.15–5.01, 4.26


6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8

Figures 6–8. *Dicrotendipes saetanumerosus* sp. n., male **6** wing **7** hypopygium (dorsal view) **8** hypopygium (ventral view).

Etymology. The species name is from Latin, *saeta*, meaning setae, *numerosus*, meaning numerous, referring to the tergite IX of the species with more than 30 setae, which is unique within the genus.

Remarks. *D. saetanumerosus* sp. n. closely resembles *D. tamaviridis* Sasa, 1981 in the structure of hypopygium, but the new species *D. saetanumerosus* can be separated from *D. tamaviridis* on the basis of following points: (1) the anal point of *D. saetanumerosus* sp. n. is broad and not expanded apically, but the anal point of *D. tamaviridis* is slender and expanded apically; and (2) the tergite IX in *D. saetanumerosus* sp. n. has more than 30 median setae, while *D. tamaviridis* has no median setae and 8–9 setae in the base of anal point.

Distribution. The species is known from Hubei, Shandong and Zhejiang Province of China.

***Dicrotendipes septemmaculatus* (Becker, 1908)**

http://species-id.net/wiki/Dicrotendipes_septemmaculatus

Chironomus septemmaculatus Becker, 1908: 77.

Dicrotendipes pictipennis Kieffer, 1913: 23; Freeman 1955: 22.

Dicrotendipes formosanus Kieffer, 1916: 115; Hashimoto 1981: 12.

Dicrotendipes formosanus var *frontalis* Kieffer, 1916: 116.

Dicrotendipes frontalis: Sublette and Sublette 1973: 403.

Dicrotendipes speciosus Kieffer, 1924: 256; Kieffer 1925: 299.

Dicrotendipes quatuordecimpunctatum (Goetghebuer, 1936): Contreras-Lichtenberg 1986: 710.

Dicrotendipes septemmaculatus: Epler 1988: 42; Wang et al. 1990: 28; Harrison 1993: 363; Spies and Saether 2004: 41.

Specimens examined. China, Hebei: 3♂♂, Qinhuangdao City, 39°55.53'N, 119°36.19'E, 4.vi.1985, Li HH, sweeping method; Guizhou: 2♂♂, Guiyang City, Huaxi, 26°24.32'N, 106°38.58'E, 23.vii.1995, Bu WJ, sweeping method; 1♂, Libo County, Maolan Town, 25°17.21'N, 108°04.28'E, 28.vii.1995, Bu WJ, sweeping method; Shandong: 1♂, Taian City, Tai Moutain, 36°11.37'N, 117°08.13'E, 25.v.1994, Wang XH, light trap; Taiwan: 3♂♂, Taibei City, 25°08.33'N, 121°36.57'E, 21.vii.2003, Wang XH, light trap; Yunnan: 1♂, Wuding County, Shishan Moutain, 25°31.58'N, 102°22.32'E, 8.vii.1986, Wang XH, sweeping method; 1♂, Eryuan County, 26°19.56'N, 100°02.03'E, 18.vii.1986, Wang XH, light trap; 2♂♂, Kunming City, 25°04.09'N, 102°42.14'E, Bu WJ, sweeping method; 2♂♂, Dali City, Yinqiao Town, 25°45.16'N, 100°07.31'E, 22.v.1996, Wang XH, sweeping method.

Remarks. The wing spots are variable in *D. septemmaculatus*. They may be absent in teneral specimens, and the pair of spots in cell r_{4+5} is sometimes combined into one spot. The Chinese specimens have one spot in cell r_{4+5}.

Distribution. China (Hubei, Guizhou, Shandong, Taiwan and Yunnan Province); Algeria; Australia; Burma; Egypt; Bangladesh; India; Indonesia; Japan; Lebanon; Namibia; Nigeria; South Africa; Spain; Sundan; Uganda; Zimbabwe; Zaire.

Dicrotendipes tamaviridis Sasa, 1981

http://species-id.net/wiki/Dicrotendipes_tamaviridis

Dicrotendipes tamaviridis Sasa, 1981: 99; Niitsuma 1995: 444; Wang 2000: 644.

Specimens examined. China, Hubei: 3♂♂, Shiyan City, Wudang Mountain, 32°30.22'N, 111°05.09'E, 16.vii.1997, Wang BX, light trap; Gansu: 1♂, Dingxi City, Min County, 34°26.34'N, 104°02.20'E, 16.v.1993, Yang ZC, light trap; Shaanxi: 1♂, Liuba County, 33°37.16'N, 106°55.12'E, 2.vii.1994, Bu WJ, light trap; Zhejiang: 6♂♂, Kaihua County, 29°05.57'N, 118°23.19'E, 13.iv.2011, Lin XL, light trap.

Remarks. Sasa (1981) described this species based on material from Japan and Niitsuma (1995) described the pupae, larvae and adults. Chinese specimens agree with the adult description of Niitsuma (1995). Some measured differences between the Chinese specimens and the specimens described by Niitsuma (1995) are shown in Table 4.

Distribution. China (Hubei, Gansu, Shaanxi and Zhejiang Province); Japan.

Table 4. Differences between the specimens of China and of Japan

	Chinese specimens	Japanese specimens
TL	2.94–3.60 mm	2.5–3.3 mm
Ftu	7.5–10 µm	3–10 µm
AR	1.85–2.21	1.9–2.3
VR	1.12–1.14	0.81–0.92, 0.85

Key to males of the genus *Dicrotendipes* in China

1 R_{4+5} without setae .... ***D. nudus* sp. n.**

– R_{4+5} with setae **2**

2 Small, membranous, triangular flap-like appendages present near base of anal point........ ***D. fusconotatus* (Kieffer)**

– Base of anal point without appendages **3**

3 Inferior volsella deeply bifid apically .... ***D. septemmaculatus* (Becker)**

– Inferior volsella with simple apex or apex bulbiform **4**

4 Tergite IX with median setae........ **5**

– Tergite IX without median setae **6**

5 Anal point sharply reflexed ventrad; tergite IX with 6–14 setae........ ***D. pelochloris* (Kieffer)**

– Anal point not sharply reflexed ventrad; tergite IX with more than 30 setae.. .... ***D. saetanumerosus* sp. n.**

6 Wing with more than 35 setae on R & R_1 .... ***D. nervosus* (Staeger)**

– Wing with less than 30 setae on R & R_1 7

7 Superior volsella with 3 short setae; cylindrical, curving outward; apex bare, expanded .... ***D. flexus* (Johannsen)**

– Superior volsella with 9–10 short setae; pediform, apex not expanded .... ***D. tamaviridis* Sasa**

Acknowledgements

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A review of the North American genus *Epimartyria* (Lepidoptera, Micropterigidae) with a discussion of the larval plastron

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Abstract

The indigenous North American micropterigid genus *Epimartyria* Walsingham,1898 is revised. Three species are recognized, including *E. auricrinella* Walsingham, 1898 which occurs widely over much of the northeastern United States and Canada, a new species, *E. bimaculella* Davis & Landry from northwestern United States and Canada, and *E. pardella* (Walsingham, 1880) from northern California to northern Oregon. The larva of *E. auricrinella* is described in detail, supplemented with illustrations of the external structure of the larval integument. The larval plastron is described and illustrated for *Epimartyria*, and this is compared with the plastrons of *Neomicropteryx* Issiki, 1931 and *Micropterix* Hübner, 1825. COI barcode sequences show that the three species are genetically distinct, congruent with morphological differences. Marked haplotype divergence within some *E. auricrinella* populations appears to be unrelated to morphology, geography or phenology.

Keywords

Distribution, DNA barcodes, genital morphology, larval morphology, plastron

Introduction

The archaic moth family Micropterigidae constitutes the only member of the suborder Zeugloptera and is one of three extant families whose adults are partially characterized as possessing articulated mandibles and in having never developed a coilable proboscis (Kristensen 1998). The oldest fossil remains of Micropterigidae are known from lower Cretaceous Lebanese amber of ~ 140 mya (Whalley 1977, 1978). Approximately 21 genera and 160 species of Micropterigidae are now known, with more than 100 additional species recognized but not described (Nieukerken et al. 2011). The family is widely distributed , with no records yet reported from Amazonia, or equatorial Africa. However, the recent discovery of two undescribed genera from lowland (and montane) Costa Rica indicates that the family can also occur in more equatorial, tropical rainforests.

Micropterigidae typically occur in humid habitats where their larvae frequently feed on foliose liverworts or possibly on fungi within rotten logs or soil (Gibbs (2010). Heath (1976) reported larvae of *Micropterix* Hübner, 1825 at depths down to 10 cm. in loose soil. Occasionally fresh as well as decaying angiosperm leaves may be consumed by larval *Micropterix*. Lorenz (1961) reared larvae of *Micropterix calthella* (Linnaeus, 1761) on decayed plant detritus as well as upon fresh leaves of *Veronica agrestis* L. Carter and Dugdale (1982) found that successful rearing of two species of British *Micropterix* was dependent upon a supply of fresh, photosynthetic angiosperm tissue, particularly chickweed (*Stellaria media* (L.). The number of larval instars is known to vary between 3 in *Epimartyria* (Tuskes and Smith, 1894) and 4 in *Micropterix* (Klausnitzer et al, 2002), *Kurokopteryx* Hashimoto, 2006 and *Neomicropteryx* Issiki, 1931, (Hashimoto 2006). Adult Micropterigidae are known to feed on plant pollen from a broad range of angiosperm families (Zeller-Lukashort et al. 2007). Members of the southwestern Pacific *Sabatinca* group have also been reported feeding on fern spores (Kristensen 1998, Gibbs 2010). Adults of a few new species of Micropterigidae have been recently discovered in Costa Rica feeding on fern spores (Wagner and Davis in prep.).

Major portions of the larval integument of *Epimartyria auricrinella* have been found to be densely covered with minute, irregularly shaped micropapillae (Davis 1987). Because the minute size and distribution of these cuticular structures closely resemble those of other insects known to inhabit aquatic or occasionally flooded habitats, it is believed that portions of the integument of *Epimartyria* may also serve in assisting respiration as has been demonstrated in those species (Thorpe 1950, Hinton 1969, 1976). These specializations are discussed further under the larval morphology of *E. auricrinella.*

Five monophyletic lineages have been determined within the Micropterigidae based on analysis using the 16S rRNA gene (Kobayashi et al. 2000, Gibbs et al. 2004). *Epimartyria* is a member of the northern hemisphere group which is represented by five genera in Japan: *Issikiomartyria* Hashimoto, 2006, *Kurokopteryx*, *Neomicropteryx*, *Palaeomicroides* Issiki, 1931, and *Paramartyria* Issiki, 1931, with a single genus each known from Vietnam (*Vietomartyria* Hashimoto & Mey, 2000), and North America (*Epimartyria*) (Gibbs 2010).

Material

Specimens examined in this study are deposited in the following institutions:

BMNH	The Natural History Museum (formerly the British Museum (Natural History), London, United Kingdom.
BIO	Biodiversity Institute of Ontario, University of Guelph, Ontario, Canada.
CZC	Collection of Christof Zeller-Lukashort, Thalgau, Austria.
CNC	Canadian National Collection of Insects, Arachnids and Nematodes, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.
ONPS	Olympic National Park Service Collection, Port Angeles, Washington, USA.
UCB	Essig Museum of Entomology, University of California, Berkeley, California, USA.
USNM	Collections of the former United States National Museum, now deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.
WSDAC	Washington State Department of Agriculture Collection, Olympia, Washington, USA.

Methods

Specimen preparation

Genitalic dissections were cleared by heating in hot 10% KOH for ~ 30 minutes, and subsequently cleaned and stained with either 2% chlorazol black E or mercurochrome solutions. All genitalic illustrations were drawn from dissections temporarily stored in glycerine, which were later permanently embedded in Canada balsam or Euparal. Genitalic terminology follows Klots (1970) and Kristensen (1984b). Samples of alcohol-preserved larvae and pupae were gently washed in 409 ® detergent, then dried in a critical point drier, sputter coated with 20–25 gold palladium 60:40 alloy, and photographed with an Amray 1810 scanning electron microscope.

Molecular analysis

DNA barcodes were produced at the Canadian Centre for DNA barcoding at the Biodiversity Institute of Ontario, University of Guelph following standard protocols (Hebert et al. 2003; Floyd et al. 2009). 1–2 legs were removed from adult moths for DNA extraction. All Voucher data, images, sequences, and trace files are publicly available on the Barcode of Life Database (BOLD) (Ratnasingham and Hebert 2007). Sequences were also deposited in GenBank. Sample IDs, Barcode IDs, and GenBank Accession numbers are listed in Appendix 1. Neighbour-Joining (NJ) trees for all barcode data were constructed using the quicktree algorithm (Howe et al. 2002) and under the Kimura two-parameter (K2P) model of base substitution (Kimura 1980). Genetic distances were estimated with MEGA 5.05 (Tamura et al. 2011) using the K2P model. Maximum parsimony (MP) analyses was performed with PAUP* 4.0d100 (Swofford 2003) on selected sequences representing distinct haplotypes. Only full-length barcode sequences without ambiguous sites were analyzed. Heuristic searches for MP analysis were carried out with all positions equally weighted and under the tree bisection-reconnection (TBR) swapping algorithm with 100 random addition sequences. Bootstrapping of 1000 replicates was conducted under the parsimony criterion with the default setting starting with a random seed and the TBR branch-swapping algorithm. Bremer support values were calculated using Treerot v.3 (Sorenson and Franzosa 2007). Haplotype diagrams were constructed in TCS 1.21, with a 95% confidence limit for parsimony (Templeton et al. 1995). Shorter sequences or those with ambiguous bases were excluded from the haplotype analysis.

Systematic account

Epimartyria Walsingham

http://species-id.net/wiki/Epimartyria

Epimartyria Walsingham, 1898: 161.– Kearfott in Smith 1903: 125.– Dyar 1903: 581.– Meyrick 1912: 3.– Forbes 1923: 63.– McDunnough 1939: 2.– Davis 1983: 5; 1987: 341.– Kristensen 1984b: 97.– Nye and Fletcher 1991: 113.– Poole 1996: 716.– Hashimoto 2006: 98.
Micropteryx Hübner.– Forbes 1923:64 (subgenus *Epimartyria* Walsingham).

Type species. *Micropteryx pardella* Walsingham, by original designation.

Diagnosis. *Epimartyria* appears closely allied to the Asian genus *Paramartyria* as suggested by the similar elongate process arising from the inner base of the male valvae (Fig. 78) and by similar larval chaetotaxy (Hashimoto 2006). More significantly, close affinities of these two northern genera were also indicated from the molecular study initiated by Kobayashi et al. (2000) and Gibbs et al. (2004), based on the 16S rRNA gene. At least one species of the Asian genus *Vietomartyria*, *V. nankushana* Hirowatari & Hashimoto (Hirowatari et al. 2009), also posseses a similar basal process on the valva, as pointed out by one reviewer. The forelegs of *Vietomartyria* also lack an epiphysis as do two species of *Epimartyria. Epimartyria* differs from all other micropterigid genera in possessing a deeply divided phallus, and from *Paramartyria* in particular by possessing a pair of lateral projections near the apical one third of the distal phallus and in having tergum X divided into dorsal and ventral processes (Hashimoto 2006). Hashimoto (2006) also mentioned the presence of an epiphysis in *Paramartyria* as one feature that distinguishes the latter from *Epimartyria.* Two of the three species of *Epimartyria* lack an epiphysis, but an epiphysis is present in *E. pardella* (Fig. 17).

Adult. *Head* (Figs 13–15): Vestiture entirely hairy, scales erect and piliform with acute apices. Antenna (Figs 18–20) 0.75–0.9× length of forewing, slightly longer in male; pedicel enlarged, ~ 1.5× length of first flagellomere; flagellum moniliform, with 46–58 flagellomeres in male, 38–47 in female; flagellomeres mostly sparsely covered with long, piliform scales which exceed the length of their supporting flagellomere; basal 2–3 flagellomeres in male and 5–7 in female covered dorsally with moderately broad scales; a pair of large ascoid sensilla, opposite one another, with ~ 11–16 elongate, curved, sensory branches (Fig. 18) on each flagellomere; a single irregularly shaped and often bilobed multiporus sensillum placodeum (Faucheux 1997) arising between the ascoid sensillae from a shallow pit near the ventral anterior margin of the flagellomere. Compound eyes reduced, interocular index (Davis 1975) ~ 0.35–0.37; interfacetal setae absent. Ocelli present, base moderately elevated. Labrum approximately pentagonal, length ~ 2× that of clypeus. Mandible elongate triangular in form; distal edge truncate. Maxillary palpus elongate, 5-segmented, with main flexions between segments 1 and 2 and between 3 and 4; length ratio from basal segment 1: 1:2.7:2.7:0.9. Labial palpus short, total length ~ equal to that of basal segment of maxillary palpus; 2- segmented; sensory pit (organ vom Rath) present distally on apical segment enclosing numerous sensillae; apices of most sensillae terminating in a cluster of ~ 2- 5 minute acute lobes (Figs 21–22). Proximal prelabial sclerite slender, crescentiform; distal prelabial sclerite broadly triangular. Occipital sulcus incomplete but distinct laterally.

Thorax: Scales of mesonotum broad, appressed. Metanotum mostly naked except for a few long, piliform scales. Tegulae rather sparsely covered with long piliform scales. Forewing length: 4.2–5.5 mm; forewing (Fig. 16) with humeral vein present; Sc deeply bifurcate; R simple; Sc-R crossvein present near fork of Sc; Rs with 4 veins; Rs3–4 fused to ~ basal 1/3; accessory cell present; M with 3 branches; 1A and 2A fused over distal half; 3A extending across base of moderately small jugal lobe. Wing scale morphology of the primitive, generally non-glossatan type (Kristensen and Simonsen 2003) consisting of fused dorsal and ventral surfaces (without internal chambers), and with a herringbone pattern formed by oblique-longitudinal crests overlying a dense layer of transverse microribs (Figs 28–31). Hindwing venation similar to forewing except with Sc and R fused; 1A and 2A completely fused; anal crossvein connecting to CuP near distal 2/3; scales over distal third of hindwing dark fuscous and nearly as broad and iridescent as in forewing; scales gradually becoming more slender, gray, and without iridescence over basal 2/3. Legs (Fig. 17) with tibial spur pattern of 0–0-4; a short epiphysis ~ 1/3 the length of tibia arising slightly beyond its midlength present in *E. pardella*; epiphysis absent in *E. auricrinella* and *bimaculella*; pretarsus (Figs 24–27) consisting of a pair of strongly curved claws; a lateral pair of pad-like pulvilli densely covered with long spinose setae; a median arolium with apical surface densely lined with minute grooves (Fig. 27); pseudempodial seta (Fig. 25) with longitudinal grooves.

Abdomen: Cuticle dark brown, sparsely covered with long, piliform scales. A pair of glands present, opening on sternum V in both sexes (Philpott 1925); glands similar to those present in *Paleomicroides*, *Paramartyria*, and *Neomicropteryx* in not protruding and possessing a narrow slit-like opening within a smooth, hyaline area (Kristensen 1984a).

Male genitalia: Tergum X (uncus) ~ half the median ventral length of IX; apex deeply divided nearly half its length into two broad lobes. Sternum X (venter X) variously bilobed, with or without short lateral lobes. Segment IX a completely sclerotized ring, with dorsal median length ~ 1/6 of ventral length. Sternum IX (vinculum) a broad plate with subparallel lateral margins; anterior end as broad or broader than caudal end. Valva with a subacute to rounded apex; base of valva with a long digitate process from mesal surface. Medial plate (juxta) with a slender stalk-like base gradually expanding anteriorly to a small, flat, oval plate. Distal phallus divided into two slender branches ~ half the total length of phallus; shorter dorsal branch of phallus terminating in gonopore (phallotreme) with thickened radial folds; a pair of minute, acute spines present laterally near distal third of dorsal branch; apex of longer ventral branch densely covered with numerous minute flattened scutate processes with rounded apices directed basad; phallobase moderately inflated, as long as or slightly longer than divided branches.

Female genitalia: Abdominal segment IX a complete ring with mid dorsal length ~ 0.5–0.6× the mid ventral length. Segment X consisting of a pair of lateral, setose plates; cloaca ending terminally; X often telescoped into IX and VIII in repose. Apophyses absent. Genital chamber with thickened walls surrounding a variably shaped slerite; caudal end of sclerite furcate. Ductus spermatheca with a moderately enlarged, spindle-shaped reservoir (utriculus) located at varying distances along ductus. Corpus bursae gradually enlarging anteriorly, membranous, with four tridentaform signa equally spaced around middle of corpus bursae; enlarged bases of signa projecting externally beyond wall of corpus bursae, with spinose branches projecting internally.

Remarks. For many years John Heath, formerly employed at the Experimental Research Station at Monks Wood in England, pursued research on the family Micropterigidae, resulting in about 20 papers on this group (Emmet 1987). Heath had partially completed a revision of the genus *Epimartyria*, but this was never published. We had not viewed a copy of this manuscript until our publication was in review. In his manuscript, Heath recognized an additional new species from New Jersey, based on specimens collected at Essex County Park by W. D. Kearfott. Our studies found no morphological justification for this species.

Because this is the first taxonomic revision of *Epimartyria*, there remain some gaps in our knowledge about their biology which cannot be answered with available material and evidence.

Key to species of *Epimartyria*

1 Forewing without spots, uniformly dark fuscous with coppery to purplish luster (Fig. 1) .... ***auricrinella***

– Forewing with pale yellowish spots **2**

2 Forewing with 2 pale yellowish spots (Fig. 2); foretibia with epiphysis absent; caudal apex of male sternum X (gnathos) deeply divided, with apex of lobes acute (Fig. 82).. ***bimaculella***

– Forewing with 4 pale yellowish spots (Fig. 3); foretibia with epiphysis present; caudal apex of male sternum X not deeply divided, with short, triangular, caudal lobes (Fig. 89) .... ***pardella***

Epimartyria auricrinella Walsingham

http://species-id.net/wiki/Epimartyria_auricrinella
Figs 1, 4–5, 10, 18–32, 33–59, 74–80

Epimartyria auricrinella Walsingham, 1898: 162.– Kearfott in Smith 1903: 125.– Dyar 1903: 581.– Meyrick 1912: 6.– McDunnough 1939: 110.– Davis 1983: 5; 1987: 341.– Poole 1996: 716.– Djernaes 2011: 3.– Hashimoto 2006: 43.
Micropteryx Epimartyria auricrinella Walsingham.– Forbes 1923:64.

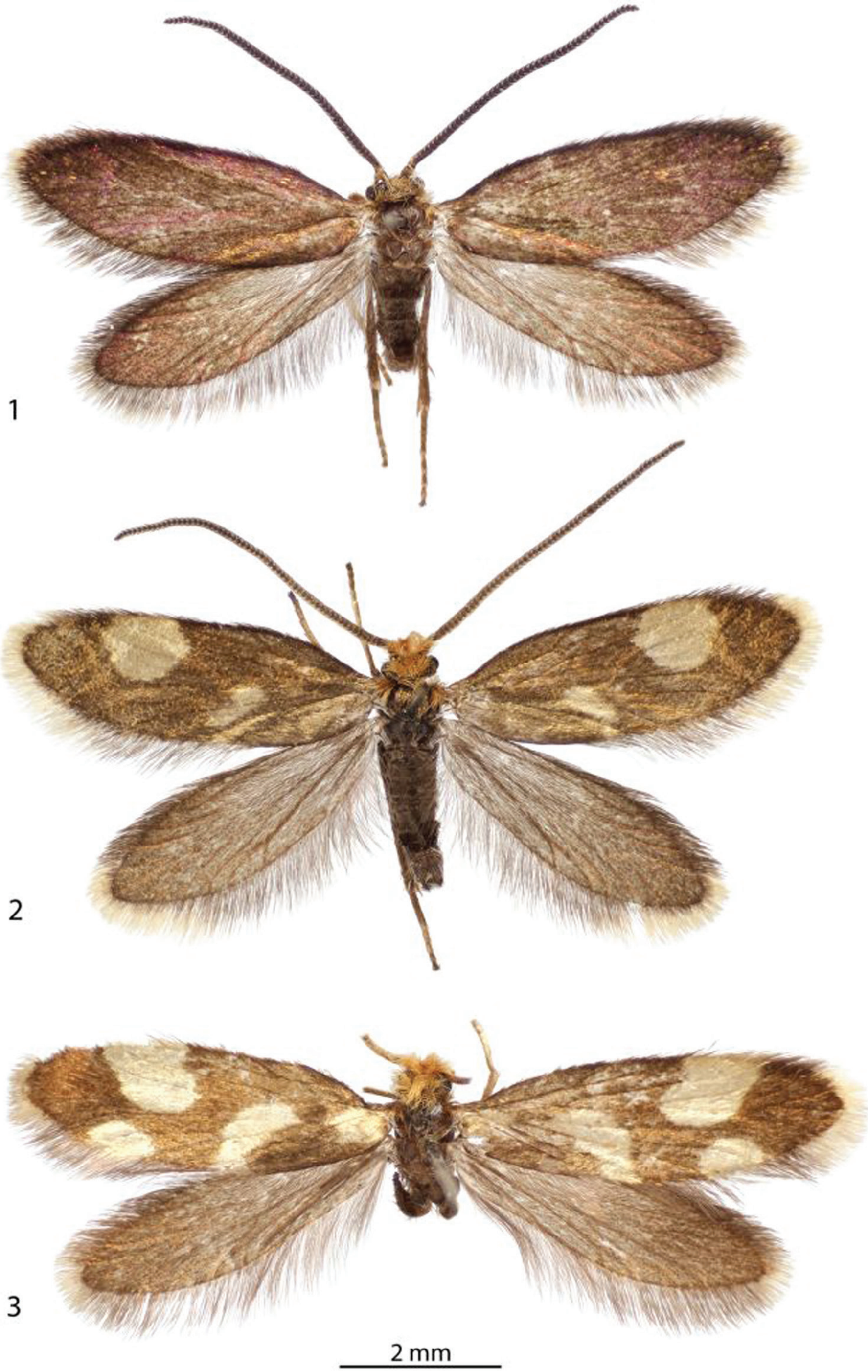
Diagnosis. Adult *E. auricrinella* are easily distinguished from those of the other members of *Epimartyria* in possessing uniformly dark fuscous forewings without the yellowish spots present in those species.

Adult (Figs 1, 4–5)**.** *Head*: Vestiture light orange brown. Antenna with vestiture of scape and pedicel concolorous with head; scales of flagellum dark brown to fuscous. Labial palpus cream.

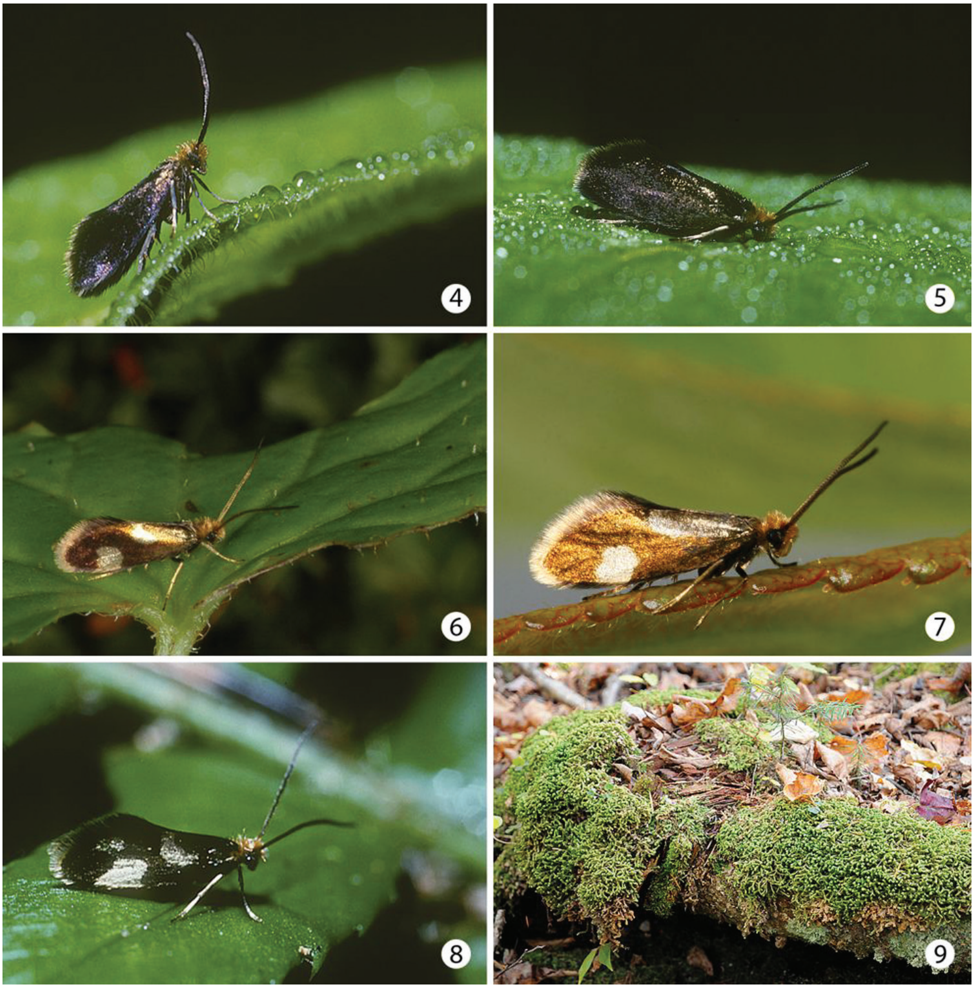
Thorax: Dark fuscous with coppery to purplish luster. Tegula concolorous with head. Forewing dark fuscous with coppery or golden to purplish luster dorsally, less iridescent ventrally; fringe paler, more gray. Forewing length: 4.2–5.6 mm. Hindwing with scales over distal third nearly as broad, dark fuscous and iridescent as in forewing; scales gradually becoming more slender, more gray, and less iridescent over basal 2/3; fringe gray. Legs medium to dark brown dorsally, light brown ventrally and at apices of tarsomeres; epiphysis absent.

Abdomen: Piliform scales uniformly brown dorsally and ventrally. Paired glands of sternum 5 with muscle for opening glands originating on anterior edge of sternum 6 and inserted into each gland duct just inside aperature; gland reservoir slightly larger and more ovoid in female, but surrounding layer of secretory cells better developed and 2–3× thicker in female (Djernaes 2011, Djernaes and Sperling 2011).

Male genitalia (Figs 74–78): Caudal lobes of tergum X broadly rounded. Caudal apex of sternum X deeply divided, with apex of lobes acute, recurved; a pair of short, lateral lobes present near base. Valvae moderately long, ventral length nearly half the maximum length of segment IX; apex subacute and bearing a short, slender, recurved spine; a short, triangular, rounded process arising midway from mesal surface; elongate basal process ~ 4/5 the length of valva; distal margin of valva variable within populations from slightly concave to convex (Figs 78a-d). Dorsal branch of phallus cylindrical and smooth.



Figures 1–3. Adults**. 1** ♂, *Epimartyria auricrinella*, (4.9 mm) Canada: Quebec **2** ♂, *Epimartyria bimaculella* (5.5 mm) Holotype, Canada: British Columbia **3** ♀, *Epimartyria pardella* (5.5 mm) USA: California. (Forewing length in parentheses).



Figures 4–9. Adults and habitat. **4–5** *Epimartyria auricrinella*, at Lac Brûlé, Québec, 30 Jun 1997, ca 0700 hrs. on dewy *Solidago* leaf **6–7** *Epimartyria bimaculella* **6** at Washington, Olympic National Park, Hoh Rainforest Road, 22 Jun 2010 (photo by Zeller-Lukashort) **7** at British Columbia, Vancouver area, Belcarra, 24 May 2009, ca 1000 hrs (photo by Holden) **8** *Epimartyria pardella*, California, Redwood National Park, Gold Bluffs State Beach, Fern Canyon **9** Habitat, clump of the liverwort *Bazzania trilobata* at Lac Brûlé, Québec in which larvae of *E. auricrinella* were found.

Female genitalia (Figs 79–80): As described for genus. Caudal end of genital sclerite moderately furcate as in *E. bimaculella*; length of furcations ~ 0.2 that of relatively shorter, undivided base.

Larva (Figs 33–59). Mature larva up to 5 mm in length. Body approximately hexagonal in cross section; color generally brown, lighter brown ventrally. Integument over dorsal half of body with a honeycomb-like surface of raised ridges (Figs 52, 58); integument of ventral half densely covered with micropapillae (Fig. 56) with an exten-

Figures 10–11. Habitats of *Epimartyria* **10** Swampy forest at Lac Brûlé, Quebec where larvae and numerous adults of *E. auricrinella* were collected **11** Douglas fir forest where adults of *E. bimaculella* were observed swarming around the ferns (photo by Zeller-Lukashort).

sive plastron surface laterally (Fig. 52). Primary setae longitudinally ribbed, moderately slender, long, clavate.

Head: Prognathous and capable of being retracted into prothorax. Antenna elongate, slender, 3- segmented, arising posterior of clypeal margin and dorsal to stemmata;

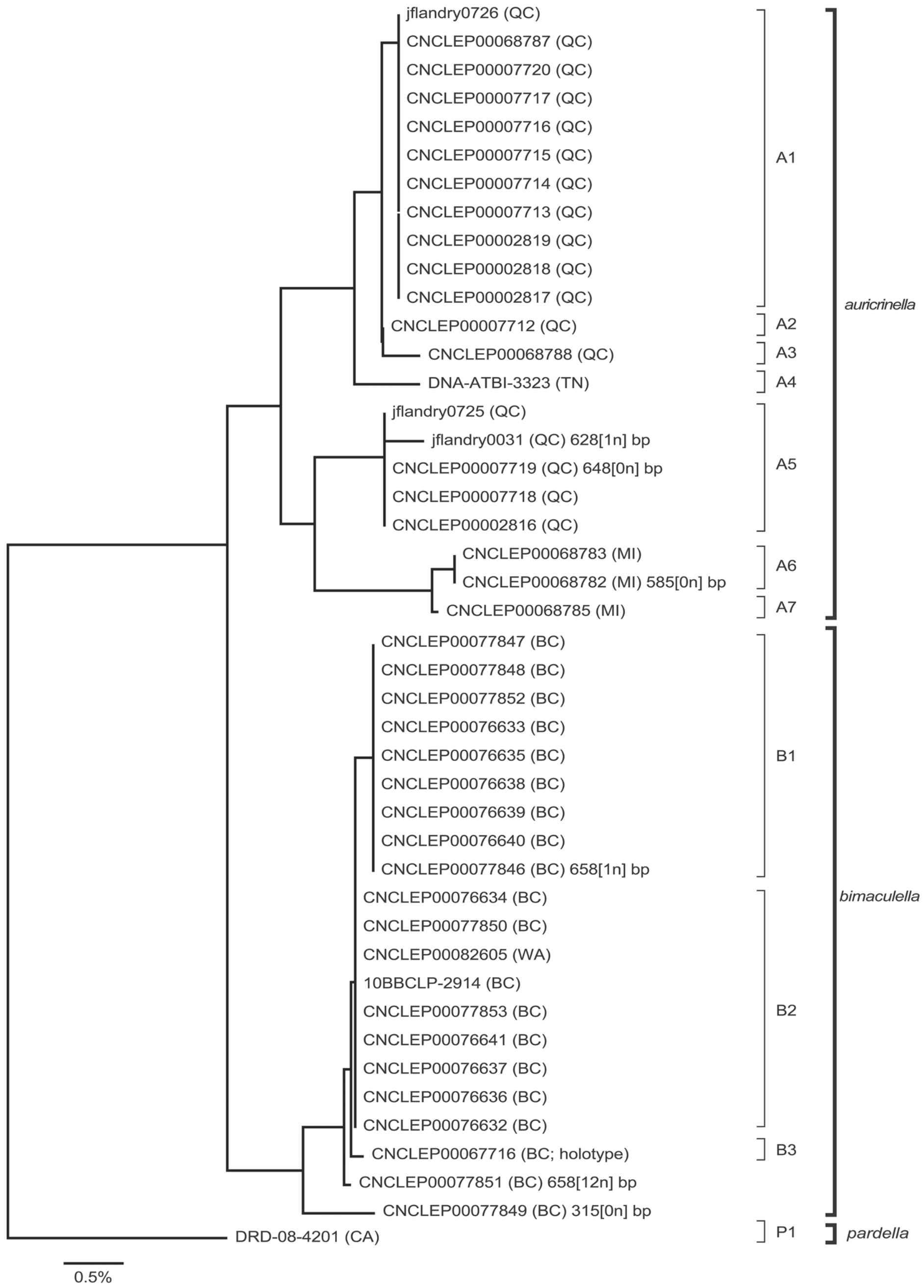


Figure 12a. Neighbour-joining tree of genetic distances (K2P model) for cytochrome c oxidase I (COI) in species of *Epimartyria* (total = 44 specimens). End-branch labels are specimen Sample IDs followed by the geographic area in parentheses: BC = British Columbia; CA = California; MI = Michigan; QC = Quebec; TN = Tennessee; WA = Washington. Sequence lengths are 658bp unless otherwise indicated (xn in square brackets indicates the number of ambiguous positions). Distinct haplotypes are designated by a capital letter and digit.

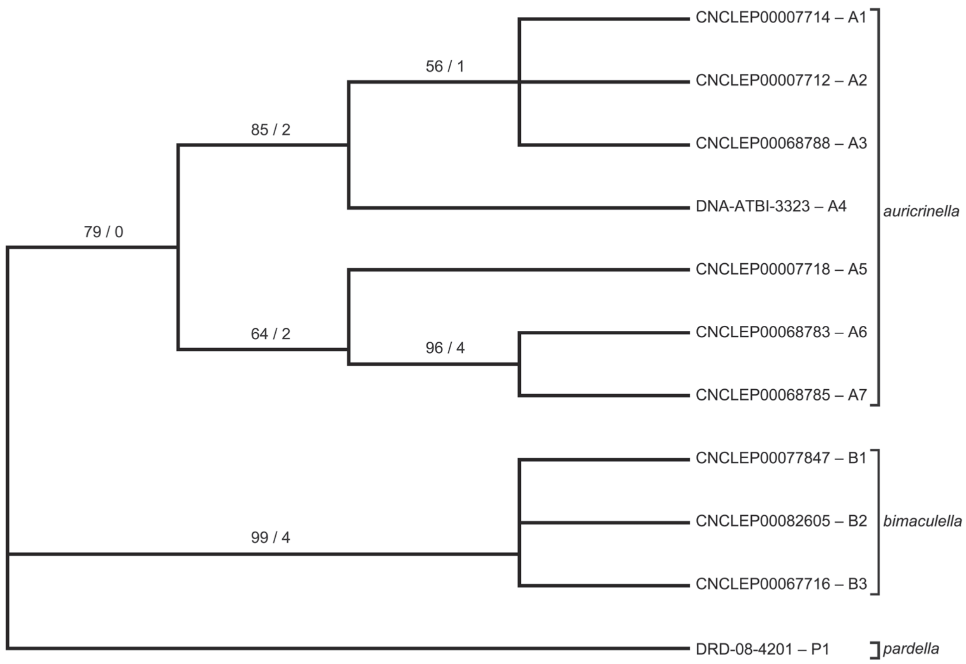


Figure 12b. Strict consensus tree of three most parsimonious trees (length = 65, CI = 0.877, RI = 0.857) based on 11 unique DNA barcode haplotypes in species of *Epimartyria*. End-branch alphanumeric labels are specimen SampleIDs with haplotype designations (A1, A2, etc.). Numbers above branches are bootstrap values (1000 replicates) / Bremer support values.

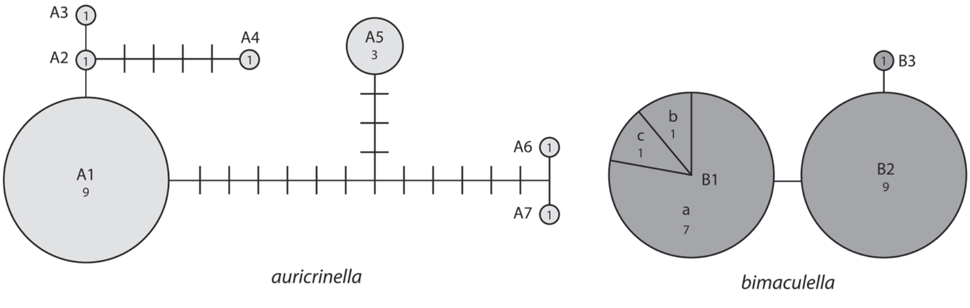
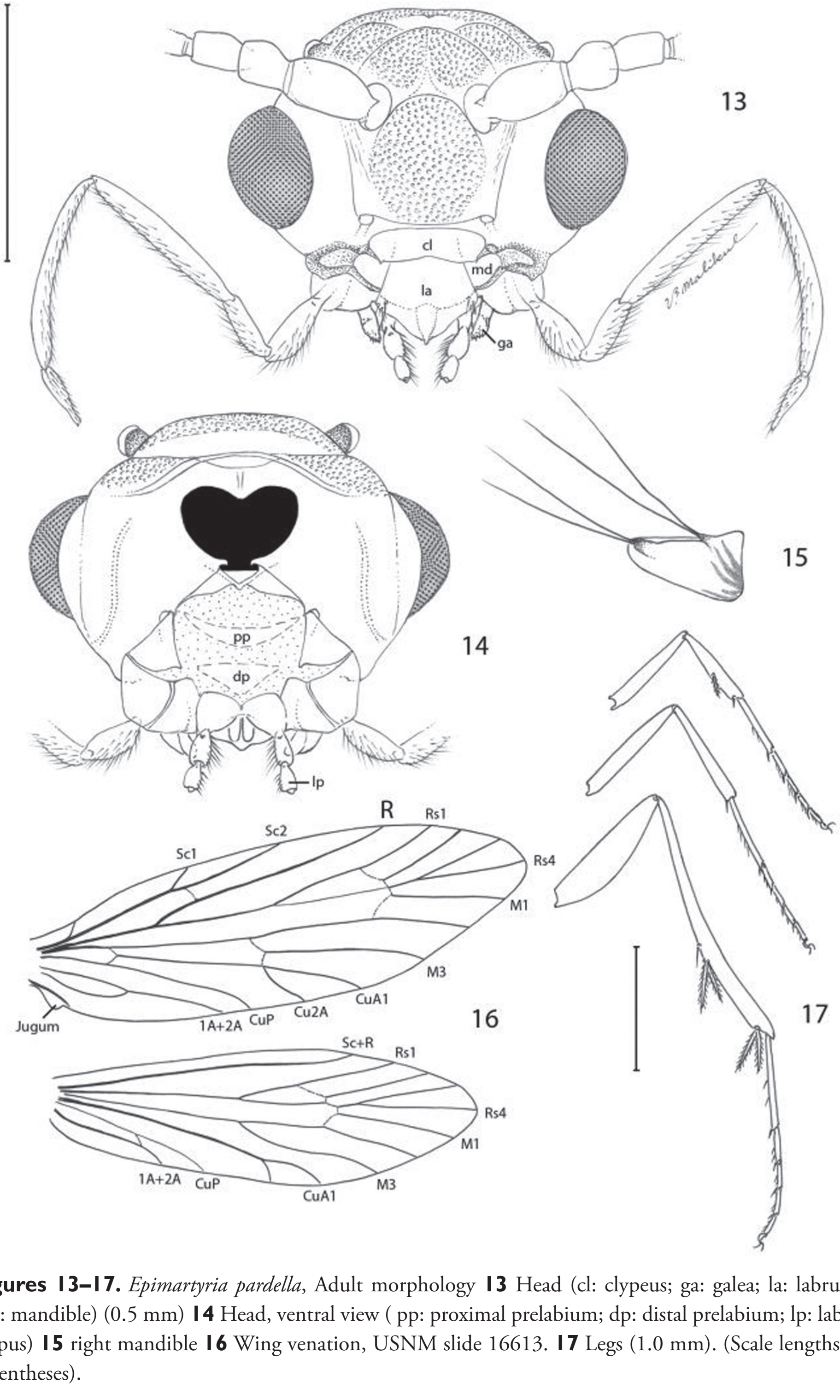
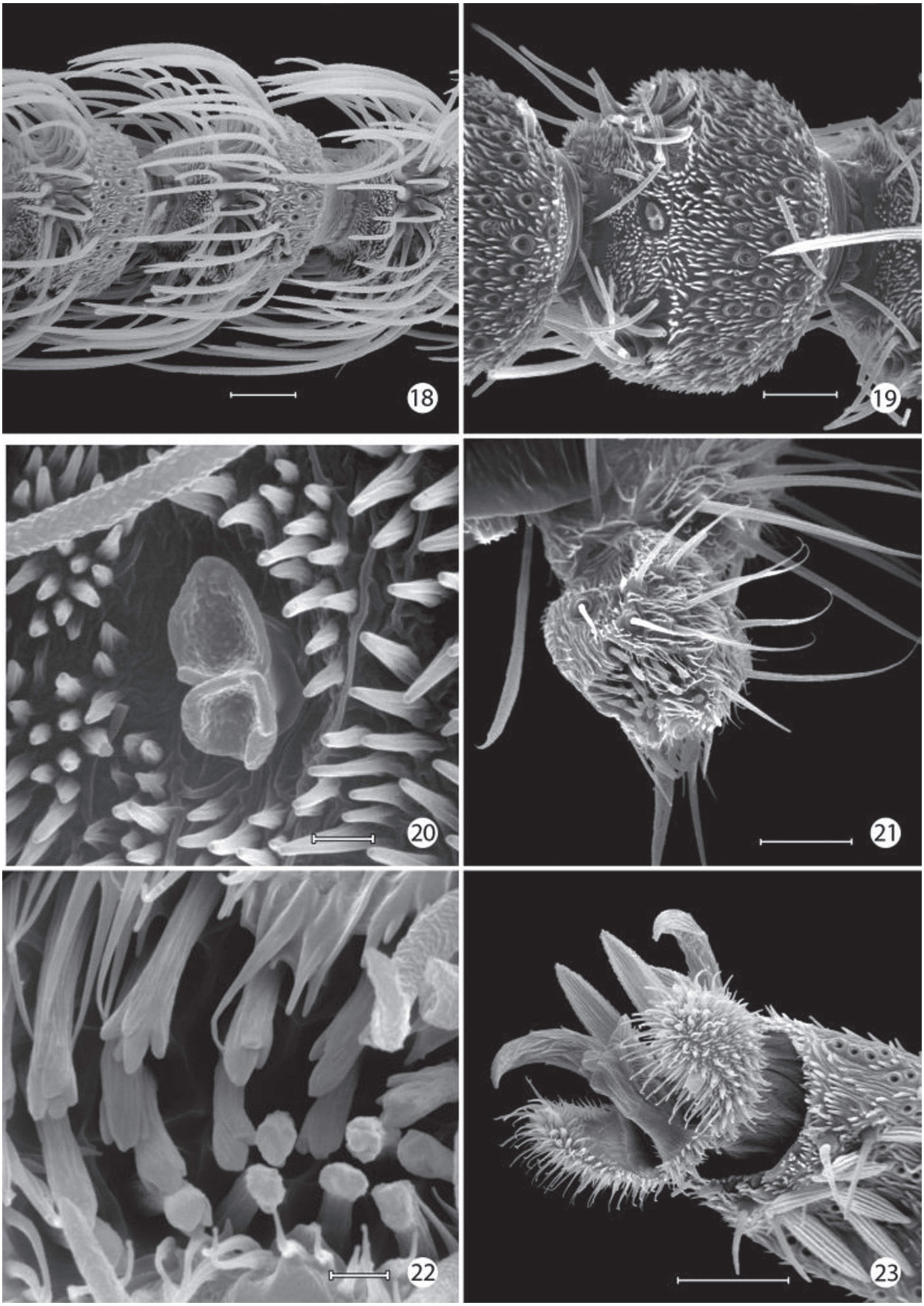


Figure 12c. Haplotype network for 10 distinct haplotypes detected in two species of *Epimartyria* (7 for *E. auricrinella*, 4 for *E. bimaculella*). Circles are labelled with the haplotype name (capital letter), and the number of specimens per haplotype; lower case letters refer to localities indicated on the distribution map (Fig. 32). The single sequence of *E. pardella*, which separated out, is not shown.

second segment the longest, ~ 2× the length of basal segment; all antennal segments without sensory setae except for elongate terminal spinose seta. Five stemmata present, arranged in a tight circle. Adfrontal sutures vestigial, not extending to vertex; adfrontal ridges similarly undeveloped. Ecdysial lines externally indistinct. Tubular spinneret absent; external opening of labial salivary gland circular, relatively large, diameter ~



Figures 13–17. *Epimartyria pardella*, Adult morphology **13** Head (cl: clypeus; ga: galea; la: labrum; md: mandible) (0.5 mm) **14** Head, ventral view (pp: proximal prelabium; dp: distal prelabium; lp: labial palpus) **15** right mandible **16** Wing venation, USNM slide 16613. **17** Legs (1.0 mm). (Scale lengths in parentheses).



Figures 18–23. *Epimartyria auricrinella*, Adult morphology **18** Flagellomeres with ascoid sensilla (20 µm) **19** Flagellomere with multiporus sensillum placodeum (20 µm) **20** Detail of multiporus sensillum placodeum in Fig. 19 (2 µm) **21** Apical segment of labial palpus with distal organ vom Rath (20 µm). **22** Sensilla of organ vom Rath (2 µm) **23** Mesothorcic pretarsus (20 µm). (Scale lengths in parentheses).

equal to length of second segment of labial palpus. Cranial setae reduced in length and number and concentrated over anterior third of head; stemmatal setae absent; a single medial (M) seta arising midway between antennae, without homology in other Lepidoptera but possibly homologous to campaniform sensillum in Trichoptera larva (Kristensen 1998). Labrum with 6 pairs of primary setae and numerous spines along anterior margin; seta La 1 arising distad of anterior margin of labrum (Fig. 38). Mandible generally triangular in form with 3 acute cusps, the basal-most cusp the most reduced. Maxillary palpi relatively well developed, 3–segmented, with apical sensillae as in Fig. 46. Labial palpi reduced, 3 - segmented with minute apical segment bearing a long sensillum (Fig. 47). Intersegmental membrane between head and thorax covered with flattened, multidentate, scutate outgrowths (Figs 41–42).

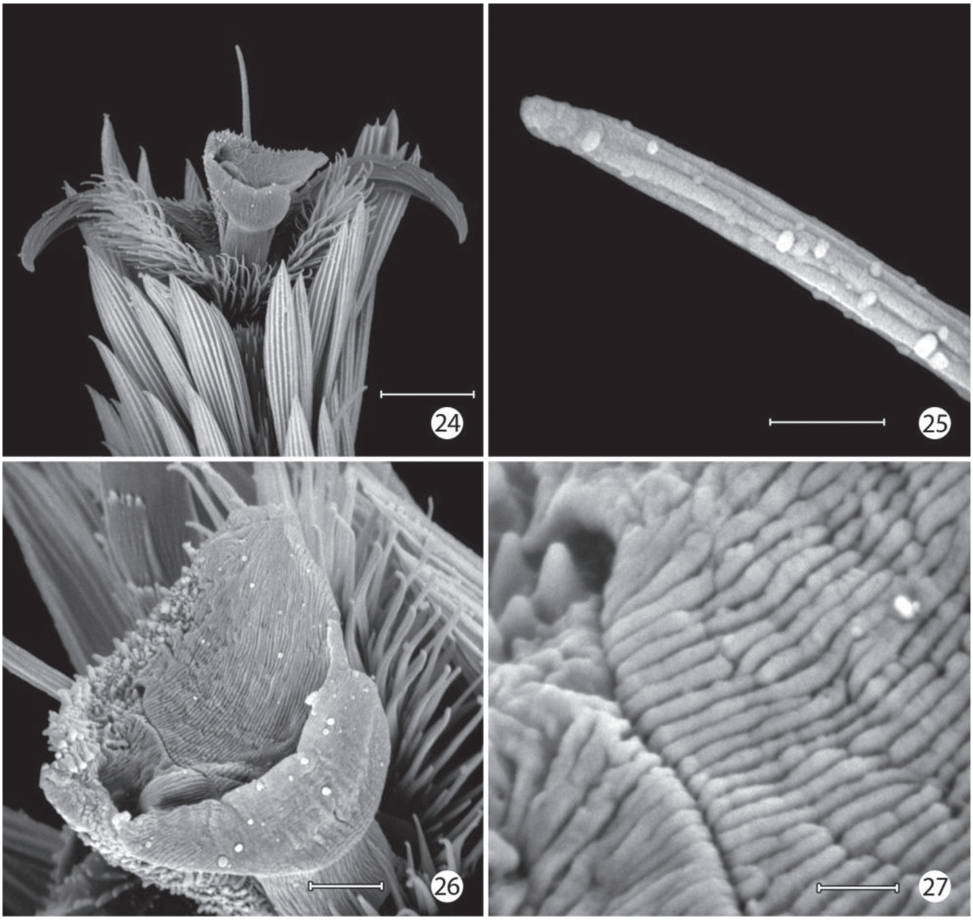
Thorax: Prothorax with 7 primary tactile setae and 4 peg-like microsetae, the latter located along anterior margin of prothorax near the head- prothoracic fold; XD1 and XD2 greatly reduced to peg-like microsetae along dorso-anterior margin of prothorax below D2; L1 posterior to XD1; L2 below L1 and anterior to spiracle. MV1 and MV2 short, peg-like, below SV2 and closer to anterior margin of prothorax; MV2 about 2 × length of MV1. Subdorsal setae absent on all body segments. Meso- and metathorax with 5 primary setae and one microseta (SV2); L1 and 2 well developed and equal in size. Legs with 3 well defined segments and large pretarsal segment; 4- segmented including reduced coxa; pretarsal claw curved, elongate, ~ 1/3 the length of remainder of leg; axial spine at base of claw well developed; femur and trochanter fused, as well as tibia and tarsus; coxa with a bilobed and possibly eversible tactile vesicle located posterior-mesally near base of femur (Figs 48–49);

Abdomen: Segments 1–8 with 4 primary setae and 2 peg-like (L2) to spherical microseta (SV2); segment 9 with only D1 and L1; segment 10 with 2 microsetae, possibly representing D1 and L1. Spiracles peripneustic, located anteriorly in intersegmental fold on segments 1–8; spiracle raised to form a small dome with walls subdivided into ~ 10–12 fimbriated bands. Abdominal segments 1- 8 with short, fleshy, nonmuscular prolegs with rounded apices (Fig. 50); crochets absent in all genera of Micropterigidae,

Larval hosts. Hepaticophyta**:** Lepidoziaceae: *Bazzania trilobata* (L.) S. Gray.

Pupa. Unknown.

Biology (Figs 9–10). The species occurs in shaded locations, in wet swampy woods, boggy ditches, or creek sides where leafy (moss-like) liverworts, the probable larval host, grow. Such habitats can be periodically or seasonally flooded. Larvae possess a plastron which indicates the capacity to live for short periods in a subaquatic environment or, at least in a habitat that is water-saturated. Adults are diurnal and are best obtained by gently sweeping the understory or clumps of liverworts (Landry and Landry 1992). They can be seen perched on low foliage during the day and can be active even in early morning after sunrise (Figs 1–2). Mating was observed in the afternoon between 1200–1700H (JFL pers. obs.). Larvae obtained (by JFL) by placing in a Berlese funnel clumps of the liverwort *Bazzania trilobata* collected on 3 September 2000 at Lac Brûlé (Quebec) yielded larvae of two different size classes (3.4 mm vs 1.8 mm overall body length). This supports the previous observations by Davis (1987)

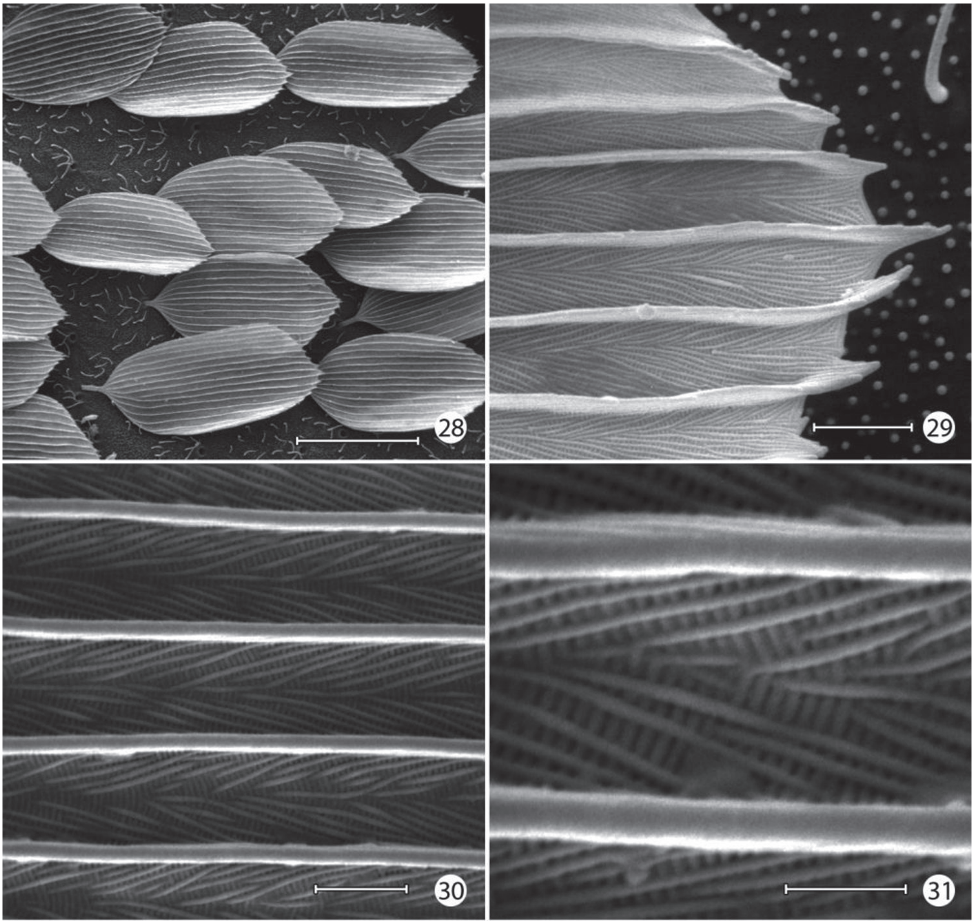


Figures 24–27. *Epimartyria auricrinella*, Adult morphology **24** Mesothorcic pretarsus (20 µm) **25** Detail of pseudempodium of pretarsus (2 µm) **26** Arolium (5 µm) **27** Detail of surface of arolium (1 µm). (Scale lengths in parentheses).

that larval development probably spans over two years, at least in the northern part of the range, although adults emerge every year. One larva was found on the tip of a liverwort leaflet at the same locality in early October when the air temperature was around 5°C. Adults generally begin to emerge in mid May in the southern part of their range (Georgia, North Carolina) with April 30 being the earliest date recorded (from southern Maryland near Washington, DC). Further north the flight period is gradually delayed, with adults in northern New York and all of Canada active during the summer between mid-June and mid-July.

Holotype. ♂**,** USA**:** North Carolina, 1884, H. K. Morrison, Type No. 35325, slide BM 8947 (BMNH).

Material examined. CANADA: NOVA SCOTIA: Baddeck: 1 ♂, 23 Jun 1936; 1 ♂, 30 Jun 1936, T.N. Freeman, specimens # CNCLEP00077282–00077283, slide



Figures 28–31. *Epimartyria auricrinella*, Forewing scale structure **28** Dorsal forewing scales from discal cell (40 μm) **29** Apical margin of scale in Fig. 28 (2 μm) **30** detail of Fig. 29 (2 μm) **31** Detail of Fig. 30 (1 μm). (Scale lengths in parentheses).

MIC1825 (CNC); Parrsboro: 1 (abdomen missing), 12 Jul 1944, J. McDunnough, (CNC). ONTARIO: Ottawa: 4 ♂, 19 Jun 1906, C.H. Young, slide USNM 16615 (USNM, CNC); 5 ♂, 20 Jun 1906, C.H. Young, slide USNM 34372, specimens # CNCLEP00077266–00077268, CNC slide MIC1822 (CNC, USNM); 1 ♂, 27 Jun 1906, slide USNM 98008 (USNM); 1 ♂, 12 Jun 1946, G.S. Walley, specimen # CNCLEP00077269 (CNC). Black Lake, N of Burgess Township: 1 ♂, 22 Jun 1974; 2 ♂, 1 ♀, 14 Jun 1975, J.A. Downes, specimens # CNCLEP00077277–00077280 (CNC). Moosonee: 1 ♀, 18 Jul 1934, G.S. Walley, specimen # CNCLEP00077288 (CNC). Orillia: 3 ♂, 26 Jun 1926; 1 ♂, 3 ♀, 2 Jul 1926, C.H. Curran, specimens # CNCLEP00077276–00077270–00077276, CNC slide MIC1823 (CNC). Thunder Bay: 1 ♀, Jul 1945, H. S. Parish. QUEBEC: Havre-Saint-Pierre: 4 ex., 3–17 Jul 2010, malaise trap, C. Bélanger. Gaspé Peninsula: Mont Albert: 2 ♂, 1 ♀, 18 July 1940, A.

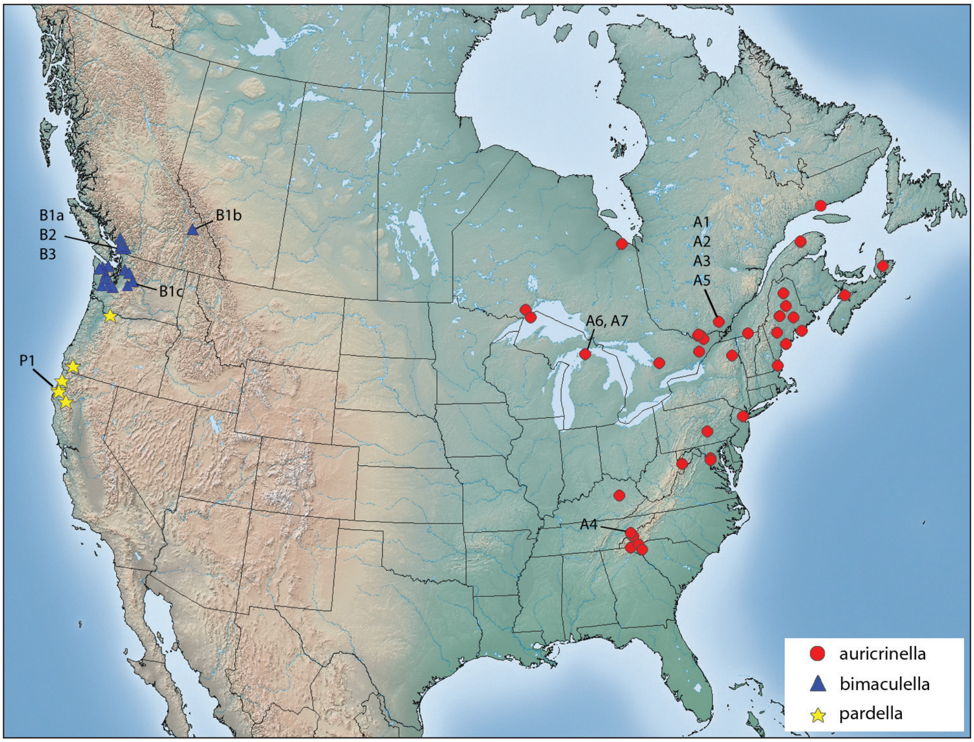
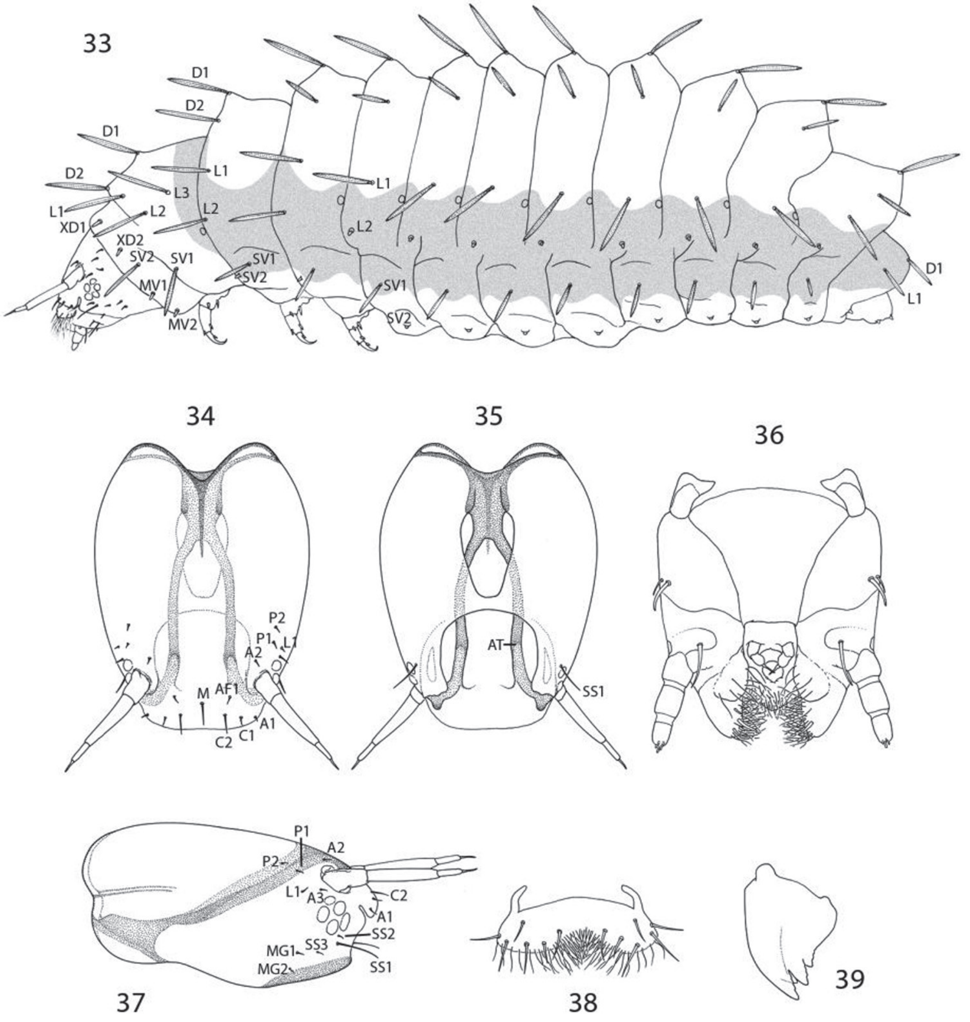


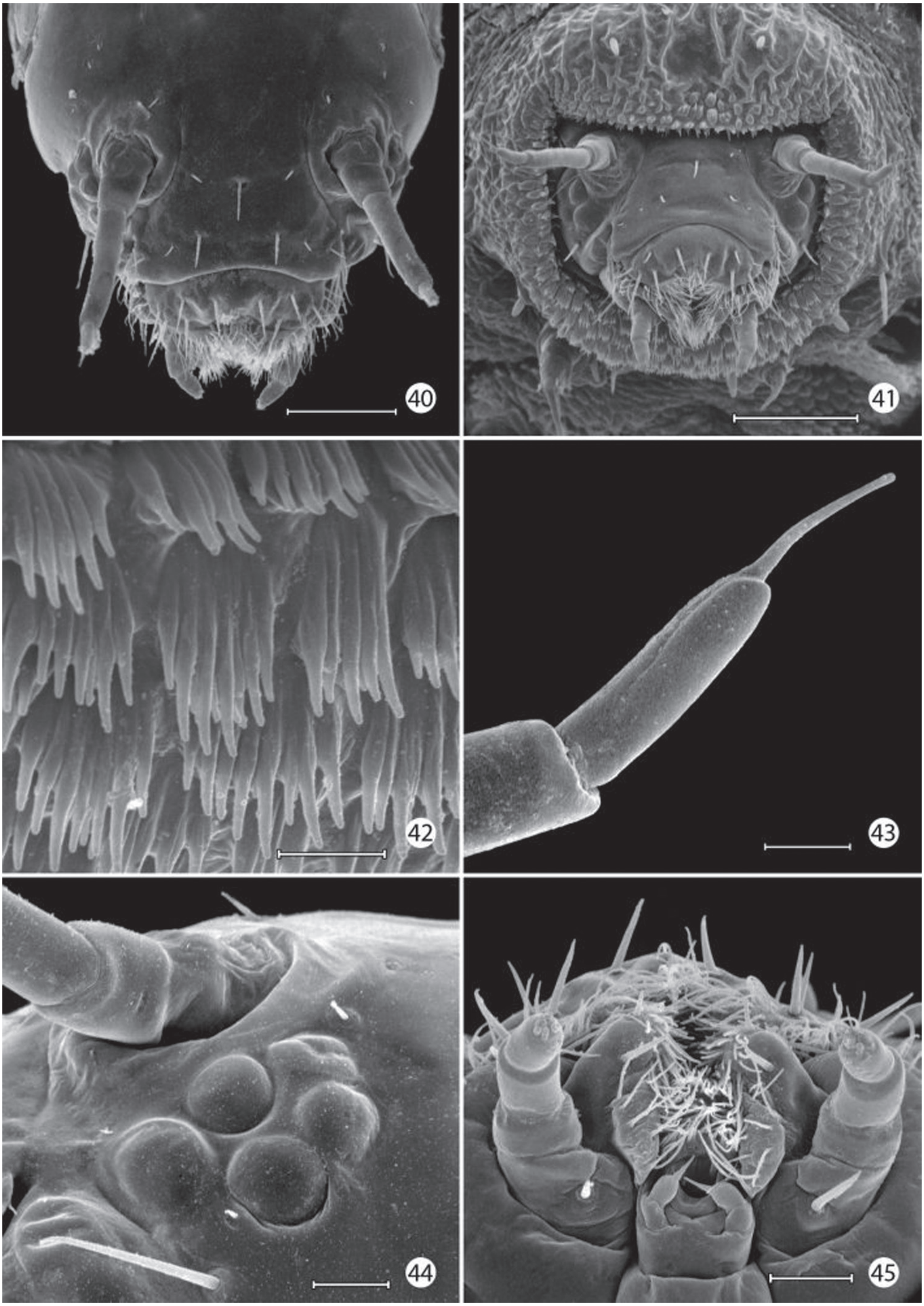
Figure 32. Distribution of *Epimartyria* species. Alphanumeric designations refer to haplotypes shown in the haplotype network of Fig. 12c.

E. Brower, slides USNM 16621, 17501, SEM slide 18394 (USNM); 11 ♂, 1 ♀, 19 Jul 1940, 2♂, 22 Jul 1940; side Mt. Albert: 2 ♂, 2 ♀, wing slide USNM 16157, slides USNM 18396, 18408, 98007, SEM slide 18430, (USNM, CNC). Mansonville: 1 ♂, 18 Jun 1928, W.J. Brown, specimen # CNCLEP00077286, CNC slide MIC1824 (CNC). Ste-Agathe-des-Monts, Lac Brûlé, 46.0903°N, 74.26°W, 370 m: 11 ♂, 6 ♀, 26 Jun 1991, afternoon sweeping in swampy ditch with liverworts and mosses at edge of spruce forest, J.-F. Landry, specimens # CNCLEP00076615–00076631 (CNC); Lac Brûlé, 46.0909°N, 74.2756°W, 370 m: 9 ♂, 3 ♀, 8 Jul 1992, 2 ♂, 16 Jul 1992, day sweeping on shaded liverworts near boggy marsh, J.-F. Landry; specimens # CNCLEP00068799–00068800 (CNC, USNM); Lac Brûlé, 46.0903°N, 74.26°W, 370 m: 3 ♂, 2 ♀, 1 Jul 1993, afternoon sweeping liverworts and mosses, J.-F. Landry, specimens # CNCLEP00067565–00067569 (CNC); Lac Brûlé, 46.0885°N, 74.2789°W, 370 m: 1 ♂, 4 Jul 1993, day sweep in mixed forest, J.-F. Landry, specimen # CNCLEP00076570 (CNC); Lac Brûlé, 46.0909°N, 74.2756°W, 370 m: 4 ♂, 2 ♀, 7 Jul 1993, day sweeping in shaded spruce-birch forest swamp, J.-F. Landry, specimens # CNCLEP00076571–00076576 (CNC); Lac Brûlé, 46.0885°N, 74.2789°W, 370 m: 1 ♂, 9 Jul 1993, at mercury light in mixed forest, J.-F. Landry, specimens # CNCLEP00076577 (CNC); Lac Brûlé, 46.0885°N, 74.2789°W,



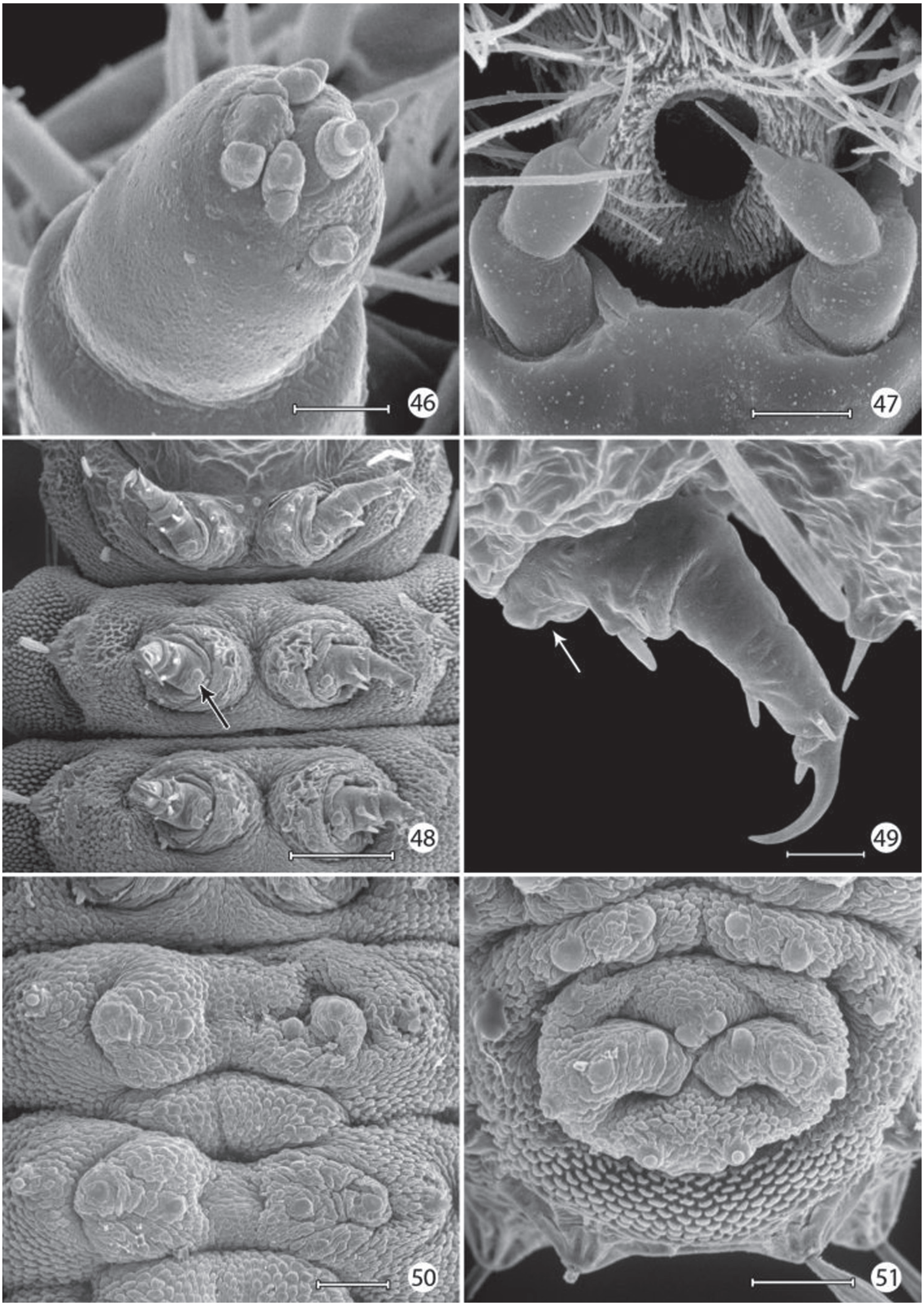
Figures 33–39. *Epimartyria auricrinella*, larval morphology **33** Chaetotaxy; shaded area indicates extent of epidermal plastron **34** Head, dorsal view (M: medial seta) **35** Head, ventral view (AT: anterior arm of tentorium) **36** Ventral view of maxilla and labrum **37** Head, lateral view **38** Labrum, dorsal view **39** Mandible.

370 m: 1 ♂, 1 Jul 1996, sweeping ferns at forest edge in afternoon, J.-F. Landry, specimens # CNCLEP00076577 (CNC); Lac Brûlé, 46.0885°N, 74.2789°W, 370 m: 1 ♂, 30 Jun 1997; 1 ♂, 1 Jul 1997, day sweep in mixed forest, J.-F. Landry, specimen # CNCLEP00076578 (CNC); Lac Brûlé, 46.0812°N, 74.2833°W, 370 m: 2 ♀, 1 Jul 1997, sweep in forest trail ca 18:00H, sunny, J.-F. Landry, specimens # CNCLEP00076580–00076581 (CNC); Lac Brûlé, 46.0919°N, 74.2756°W, 370 m: 13 ♂, 5 ♀, 2 Jul 1997, in swampy wood perched on vegetation 11:30H–12:30H overcast just before thunderstorm, J.-F. Landry, specimens # CNCLEP00076582–00076599



Figures 40–45. *Epimartyria auricrinella*, larval morphology **40** Head, dorsal view (100 µm) **41** head, anterior view (100 µm) **42** Scutate cuticular outgrowths from head-prothoracic fold (of Fig. 41) (10 µm) **43** Apex of antenna (10 µm). **44** Stemmata, 5 total (25 µm) **45** Ventral view of maxilla and labium (20 µm). (Scale lengths in parentheses).

(CNC); Lac Brûlé, 46.0921°N, 74.2756°W, 370 m: 1 ♂, 1 ♀, 2 Jul 2000, afternoon sweeping liverworts and low vegetation in forest swamp, specimens # CNCLEP00067787–00067788, CNC slide MIC5756, DNA barcoded (CNC); 14 ♂, 5 ♀, 8 Jul 2002, day sweeping shaded liverworts near boggy marsh, specimens # CNCLEP00007712–00007720, 00068787–00068788, CNC slides MIC5753, MIC5755, MIC5757, MIC5758, MIC5760, MIC5762, MIC5763, 9 DNA barcoded (CNC); 6 ♂, 29 Jun 2003, in mixed forest swamp day-sweeping herbaceous and shrub vegetation, J.-F. Landry, specimens # CNCLEP00002816–00002821, CNC slide MIC5761, DNA barcoded (CNC); Lac Brûlé, 46.0881°N, 74.2788°W, 370 m: 1 ♂, 1 ♀, 4 Jul 2004, day sweep in forest swamp with liverwort, J.-F. Landry, specimens # CNCLEP00006682–00006683, CNC slide MIC5754, 1 DNA barcoded (CNC). Gatineau Park, Ramsey Lake, Hopkin's Hole, 45.6025°N, 76.1079°W, 245 m: 12 ♂, 3 ♀, 11 Jun 1991, afternoon sweeping in forest swamp, J.-F. Landry, specimens # CNCLEP00076600–00076614 (CNC). Gatineau, Masham Township, 45.68°N, 76.05°W: 1 ♂, 26 Jun 1974; 1 ♀, 30 Jun 1974, D.M. Wood, specimens # CNCLEP00077284–00077285 (CNC). UNITED STATES: GEORGIA: Rabun Co: Chattahochee National Forest, Tate Br. Campground: 1 ♀, 16–17 May 1970, O. S. Flint, Jr. (USNM). KENTUCKY: Powell Co: 1 ♂, 23 Nov 1909, 1 ♂, 25 May 1924 (USNM). MAINE: Aroostook Co: Round Mountain: 1 ♂, 20 Jul 1956. Piscataquis Co: Greenville: 1 ♂, 9 Jul (USNM). Franklin Co: West Farmington: 1 ♂, 29 Jun 1966, A. E. Brower (USNM). Hancock Co: Acadia National Park, Mt. Desert Island: 1 ♂, 30 Jun 1933, (USNM). Penobscot Co: Passadumkeag: 1 ♀, 25 Jun 1938 (USNM). Piscataquis Co: Baxter State Park, Mt. Katahdin, Hunt Trail, 2400 feet: 1 ♂, 17 Jul 1948, bushes by brook, A. E. Brower, slides 16388, wing USNM 29861 (USNM). Sagadahoc Co: Woolwich: 1 ♀, 29 Jun 1965, A. E. Brower, slide USNM 33917 (USNM). MARYLAND: Montgomery Co: Cabin John: 1 ♂, 30 Apr 1921, A. Busck (USNM). MICHIGAN: Keweenaw Co: Isle Royale National Park: 2 ♂, 10 Jul 1957, R. W. Hodges (USNM). Emmet Co: Wilderness State Park, 45.7119°N, 84.9402°W, 180 m: 6 ♂, 30 Jun 1992, 17:00–18:00 hrs sweeping liverworts on banks of shaded stream in oak-pine forest with thuja, J.-F. and B. Landry, specimens # CNCLEP00068781–00068786, CNC slides MIC5752, MIC5764, DNA barcoded (CNC). NEW HAMPSHIRE: Rockingham Co: Hampton: 1 ♂, 6–11–1904, S.A. Shaw (USNM). NEW JERSEY: Essex Co: Essex Co. Park: 1 ♂, 3 Jun 1900, W. D. Kearfott (USNM). Essex Co: 1 ♂, 3 Jun; 7 ♂, 3 ♀, 8 Jun 1907, W. D. Kearfott, slides USNM 18409, 91794, 91795 (USNM). NEW YORK: Essex Co: [Keene]: Table Top Mountain, 3500 feet: 2 ♂, 1 ♀, 21 Jul 1940 (USNM). NORTH CAROLINA: Swain Co: Great Smoky Mountains National Park: Oconaluftee River at Towstring Road: 1 ♂, 11 May 1970, SEM slide USNM 17565 (USNM). Smokemont Campground and nearby: 2 ♀, 11–14 May 1970, slide USNM 33920, head slide 16614 (USNM). Whitewater River at rt. 171: 1 ♂, 18 May 1970, O. S. Flint, Jr. (USNM). PENNSYLVANIA: Dauphin Co: Inglenook: 1 ♀, 30 May 1911 (USNM). SOUTH CAROLINA: Pickens Co: Clemson, Wildcat Creek: 1 ♂, 25 Apr 1968, P. Carlson, J. Morse (USNM). TENNESSEE: Sevier Co: University of Tennessee Field Station, 35.739°N,

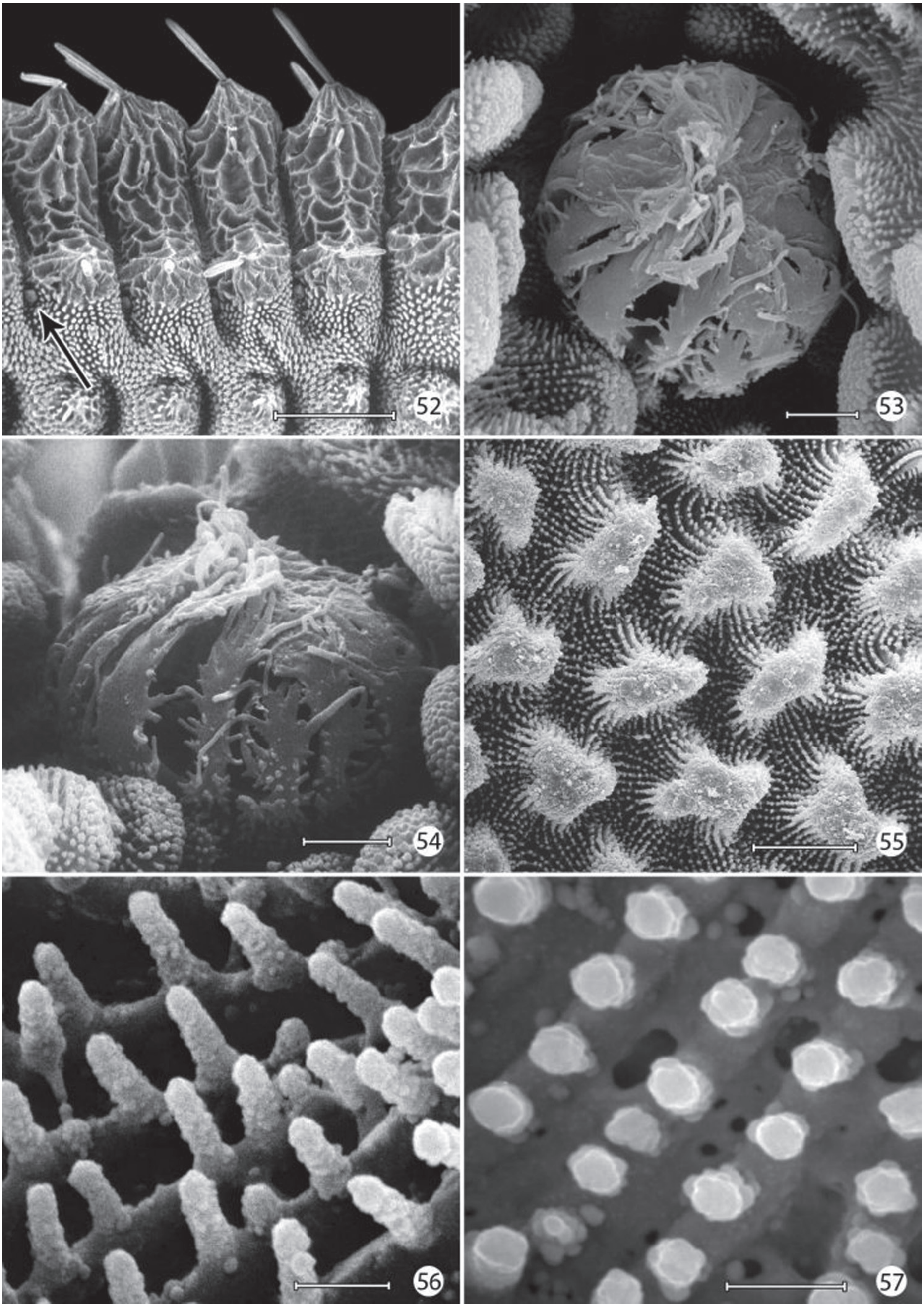


Figures 46–51. *Epimartyria auricrinella*, larval morphology **46** Apical sensilla of maxillary palpus (5 µm) **47** Labial palpi and opening of labial salivary gland (100 µm) **48** Thoracic legs (arrow: tactile vesicle of coxa) (200 µm) **49** Mesothoracic leg (arrow: tactile vesicle of coxa) (25 µm) **50** Abdominal prolegs, segments 1–2 (100 µm) **51** Anal prolegs (100 µm). (Scale lengths in parentheses).

83.4235°W, 503 m: 1 ♀, 22 May 2005, afternoon sweeping vegetation along forest creek, J.-F. Landry, specimen # CNCLEP00016403, CNC slide MIC5759, DNA barcoded (CNC). VIRGINIA: Falls Church: 1 ?, 1908, A. Busck, wing slide USNM 91787 (USNM). WEST VIRGINIA: Pendleton Co., Smoke Hole State Park, Briggs Run: 3 ♂, 2 ♀, 28 May 1977, [sweeping low vegetation 8–11 AM], D. & M. Davis, slide USNM 20690 (USNM).

Distribution (Fig. 32). *Epimartyria auricrinella* occurs widely over eastern North America, in Canada from Nova Scotia to Ontario, and in the U.S. from Maine to Michigan and south to Tennessee and Georgia.

Remarks on larval morphology. *Chaetotaxy*: Because the larvae of Micropterigidae lack some thoracic and abdominal setae present in higher Lepidoptera, determining the homology of those setae present is subject to uncertainty. Various assumptions have been made as to which setae are present, based in part on their position to longitudinal muscle groups or to various body ridges (Hashimoto 2001, 2006; Gibbs 2010), as well as to the generally accepted chaetotaxy of glossatan Lepidoptera (Hinton 1946, Stehr 1987) which was followed by Davis (1987). Greatest uncertainty persists with the prothoracic chaetotaxy, where the number and relative development of setae can vary between different genera of Micropterigidae. Hashimoto (2001) concluded that the XD (of the prothorax) and the SD groups are absent in Micropterigidae, with the possibility that the two most dorsal of the four pairs of peg-like microsetae along the anterior margin of the prothorax in *Epimartyria* could be vestiges of one or more of these groups. The more ventral of the two microsetae along the anterior margin of the prothorax are believed to represent MV1 and MV2 present in most Lepidoptera, but homology of the dorsal pair is questionable. Because microsetae in this region are not known to occur on the prothorax of other Lepidoptera (Hinton 1946), we have considered the dorsal pair to be homologous to XD1 and XD2 as suggested by Hashimoto (2001). Hinton (1946) briefly discussed the possibility that the XD group in higher Lepidoptera might be homologous to the microsetae of other body segments, but he argued that long tactile setae along the front margin of the prothorax represented instead a special setal group essential for protecting larvae, especially in those species with prognathous, retractable heads. In Micropterigidae it appears as if this protection has been compensated by several of the prothoracic tactile setae being directed strongly forward (Fig. 33). It may also be possible that several proprioreceptor (microscopic) setae homologous to those of higher Lepidoptera do not occur in Micropterigidae, and that all or most of the relatively stout microsetae present may represent greatly reduced tactile setae. Such reductions have occurred with the abdominal L2 and SV2 setae of *Epimartyria* (Fig. 33), D1 and D2 of *Austromartyria* (Gibbs 2010), and D2 of *Agrionympha* (Gibbs and Kristensen 2011). All microsetae of *Epimartyria auricrinella* are similar to the prothoracic microsetae in being relatively stout and greatly reduced it length (Fig. 33). Consequently, in this study we have largely followed the protothoracic chaetotaxy proposed by Hashimoto (2006) for the closely related genera *Paramartyria* and *Neomicropteryx*. The number and distribution of the prothoracic microsetae have not been well studied or illustrated in most genera of Micropterigidae.



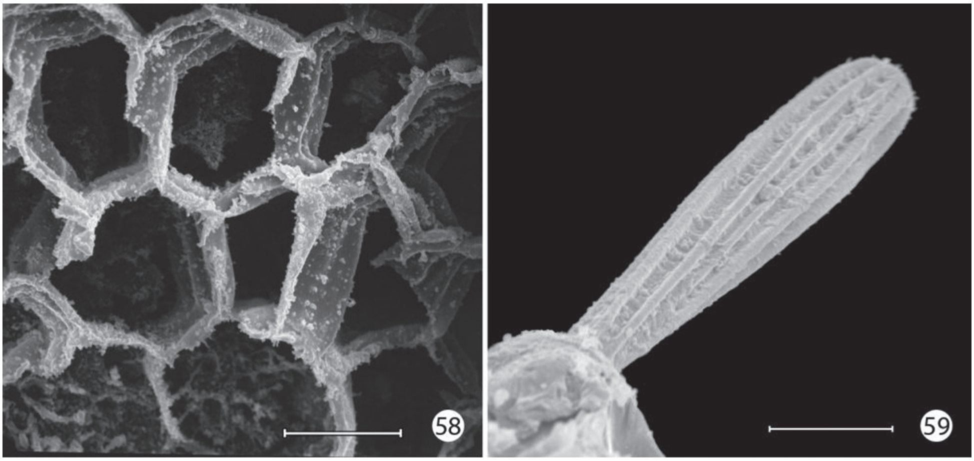
Figures 52–57. *Epimartyria auricrinella*, larval morphology **52** Abdominal segments 1–4, lateral view, showing sculptured epicuticle of dorsal half and plastron region (shaded area) of lower half (arrow indicates spiracle) (200 µm) **53** Spiracle, apical view (5 µm) **54** Spiracle, lateral view (5 µm) **55** Plastron of lateral surface of abdomen with numerous, irregular micropapillae (10 µm) **56** Detail of fig. 55 showing parallel rows of microtubercules extending between micropapillae (1 µm) **57** View looking down on microtubules in fig. 56 showing cuticular openings between rows (1 µm). (Scale lengths in parentheses).

Better resolution of the prothoracic setal homology might become possible as larvae of more genera are discovered and studied.

Prolegs: The larval prolegs of Micropterigidae, which occur on abdominal segments 1–8 and 10, differ in their morphology from those of all other Lepidoptera where crochet- bearing prolegs are typically present only on segments 3–6 and 10. Hinton (1958) also reported muscles to be lacking in micropterigid prolegs, although this probably should be examined further in some genera such as *Micropterix* where the prolegs appear more developed and with more melanized, acute, clawlike apices (Figs 66–68). The anal prolegs of *Micropterix* are also distinct in forming a relatively broad, trilobed sucker (Fig. 66; Zeller-Lukashort et al. 2007).

Integumental specializations: Larvae of Micropterigidae often occur close to the ground in habitats more likely to be subjected to periodic flooding and drying. As an adaptation to such conditions, the larvae have developed an unusual cuticular morphology in the form of a physical gill, or plastron (Thorpe 1950, Davis 1987), which provides extensive air–water interface for gaseous exchange. The aquatic larvae of several species of Crambidae have also developed special gills and plastron cuticles for breathing underwater (Wichard et al. 2002).

An extensive plastron area has been observed in *Epimartyria* (Davis 1987), and similar cuticular structures with various modifications appear in other genera of Micropterigidae examined. The plastron in *Epimartyria auricrinella* extends as a broad band laterally around the body between the level of the lateral (L1) and subventral (SV1) setae and then dorsally over the posterior margin of the prothorax (Fig. 33). The abdominal spiracles are located near the dorsal margin of the band at the extreme anterior edge of the segment (Fig. 52). The surface of the integument within this zone is densely covered with minute, irregularly shaped micropapillae (Figs 52, 55). Radiating out between adjacent micropapillae are dense series of even smaller ridges, aligned ~ 0.4–1.0 µm apart. Each ridge bears a single row of elongate, erect, knobby microtubercules ~ 0.2–0.4 µm in diameter and ~ 0.8–1.2 µm in length (Fig. 56). These minute structures are believed to help form an air film around that portion of the body (when submerged) that excludes water under normal hydrostatic pressure. Minute openings in the epicuticle are visible between the ridges (Fig. 57). These lead internally into an unusually complex, multichambered exocuticle reported by Kristensen (1990, 1998) in the larvae of *Sabatinca* and *Micropterix*. The basal layer of the exocuticle was found in these genera to possess small pores in each chamber which opened into a fluid- filled space between the exo- and endocuticle. Kristensen hypothesized the function of these unique cuticular specializations may be to assist in maintaining a water balance for larvae in a habitat subjected to periodic drying. An extremely thin, extracuticular pellicle covers much of the dorsal, lateral, and part of the ventral larval trunk to which small particles may adhere. The function and origin of the pellicle remain unknown. Immediately beneath the abdominal pellicle of *E. auricrinella* the exocuticle is divided into a series of honeycombed chambers (Fig. 58) resembling the condition Kristensen discovered in the larvae of *Sabatinca* and *Micropterix.*



Figures 58–59. *Epimartyria auricrinella*, larval morphology **58** Honeycombed chambers of abdominal exocuticle with pellicle removed, in dorsal half (dorsal to spiracle) of abdominal segment 4 (10 µm) **59** Abdominal seta D1 showing longitudinal ridges (20 µm). (Scale lengths in parentheses).

The multidentate, scale-like cuticular outgrowths (Figs 41–42) covering the intersegmental membrane between the head and prothorax of *Epimartyria auricrinella* may further assist in a respiratory function. These structures superficially resemble the plastron scales present in certain Coleoptera (Hinton 1969, 1976). The spiracles in *Epimartyria* (Figs 53–54) are also modified to prevent water entry. Each spiracle is raised into a small dome with finely divided, fimbriated walls. The spiracles in later instars of *Neomicropteryx* larvae are also conical with fimbriated walls, but the spiracular walls of the first instar are completely fused (i.e., solid) (Hashimoto 2006) as they are in later instars of *Sabatinca* and *Micropterix* (early instars not examined). Spiracles of the first instar of *Epimartyria* have not been examined but may be similar to those of *Neomicropteryx.*

The larval plastron of *Neomicropteryx nipponensis* Issiki is similar to that of *Epimartyria auricrinella* in possessing a dense zone of minute, irregularly shaped micropapillae interconnected by dense radiations of smaller ridges bearing rows of knobby microtubercules (Figs 60–62). Scutate outgrowths also arise from the intersegmental head-prothoracic membrane (Fig. 63) as in *Epimartyria*. It is likely that larvae of all members of the northern hemisphere group of micropterigid genera proposed by Kobayashi et al. (2000) and Gibbs et al. (2010) have developed similar plastron specializations. In contrast, the external surface of the exocuticle of *Micropterix* (Figs 70–72) possesses a more extensive, regular arrangement of micropapillae, each ~ 10–20 µm in diameter, with ~ 6- 8 relatively stouter, often bifurcate, arm-like ridges radiating from a central disk. The ridges in *Micropterix* do not continue with those of adjacent ridges, but the extremities of each ridge are densely covered with microtubercules. Minute openings of variable size are present in the exocuticle of *Micropterix* (Figs 71–72), similar to those observed in *Epimartyria* and *Neomicropteryx.*

Epimartyria bimaculella sp. n.

urn:lsid:zoobank.org:act:6A40EFD1-BC6D-4DF3-AB1C-D4031870E61D
http://species-id.net/wiki/Epimartyria_bimaculella
Figs 2, 6–7, 11, 32, 81–87

Diagnosis. Adults of *E. bimaculella* most resemble those of *E. pardella* in possessing dark fuscous forewings marked by pale golden spots. A total of two yellowish spots occur in *bimaculella*, with only a single large costal spot present beyond the middle of the forewing. Four spots are present on the forewing of *pardella*, with two of these located across the distal third of the wing on the costal and dorsal margins respectively.

Adult (Figs 2, 6–7). *Head*: Vestiture similar to *E. auricrinella*, light orange brown. Antenna with vestiture of scape and pedicel concolorous with head; scales of flagellum mostly pale golden brown, becoming darker, more fuscous over distal third. Labial palpus cream.

Thorax: Dark fuscous with coppery to purplish luster. Tegula concolorous with head. Forewing mostly dark fuscous with coppery to purplish luster dorsally, marked with two pale yellowish spots; the largest, irregularly oval to rectangular spot extends from the costa approximately halfway across the distal third of wing; a second smaller, more slender spot extends diagonally from about midway along dorsal margin to midway on discal cell; a slight suffusion of pale yellowish scales may be sometimes evident at the base of the forewing, but only seldom does this occur; forewing less iridescent ventrally; fringe pale yellow along termen, fuscous along dorsal margin. Forewing length: 4.6–5.3 mm. Hindwing mostly gray, becoming darker and slightly iridescent toward apex; fringe gray. Legs medium to dark brown dorsally with a slight purplish luster, light brown to cream ventrally; epiphysis absent.

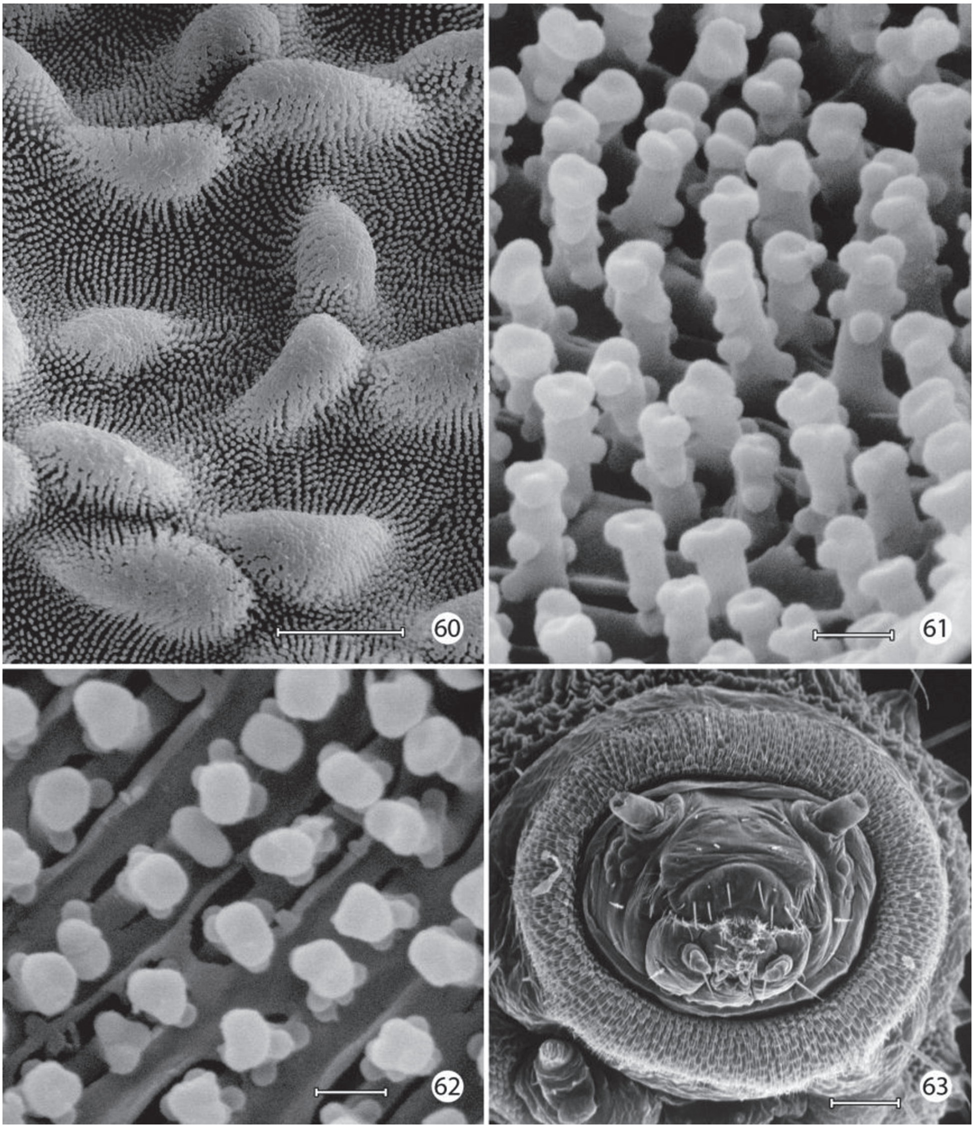
Abdomen: Piliform scales dark brown dorsally, paler brown ventrally.

Male genitalia (Figs 81–85): Tergum X similar to *E. auricrinella*, broadly bilobed. Caudal apex of sternum X deeply divided, with apex of lobes acute, only slightly curved; a pair of short, lateral lobes present near base. Valva moderately long, ventral length ~ half the maximum length of segment IX; apex subacute and bearing a short, slender, recurved spine similar to *E. auricrinella*; a short but broader and more triangular, rounded process arising midway from mesal surface; elongate basal process ~ 4/5 the length of valva; distal margin of valva variable within populations from slightly convex to ~ straight. Dorsal branch of phallus cylindrical and smooth.

Female genitalia (Figs 86–87): As described for genus. Caudal end of genital sclerite moderately furcate as in *E. auricrinella*; length of furcations ~ 0.3 that of moderately long, undivided base.

Larva and pupa. Unknown.

Biology (Figs 6–7, 11)**.** At the type locality, specimens were captured by sweeping low lying vegetation or during diurnal flight along a shaded seepage in a Douglas Fir–Western Red Cedar forest where leafy liverworts grew. Adults were also observed perching on lower parts of plants such as Salmonberry (*Rubus spectabilis* Pursh) no more than approximately 25 metres from the liverwort habitat (D.G. Holden, pers.



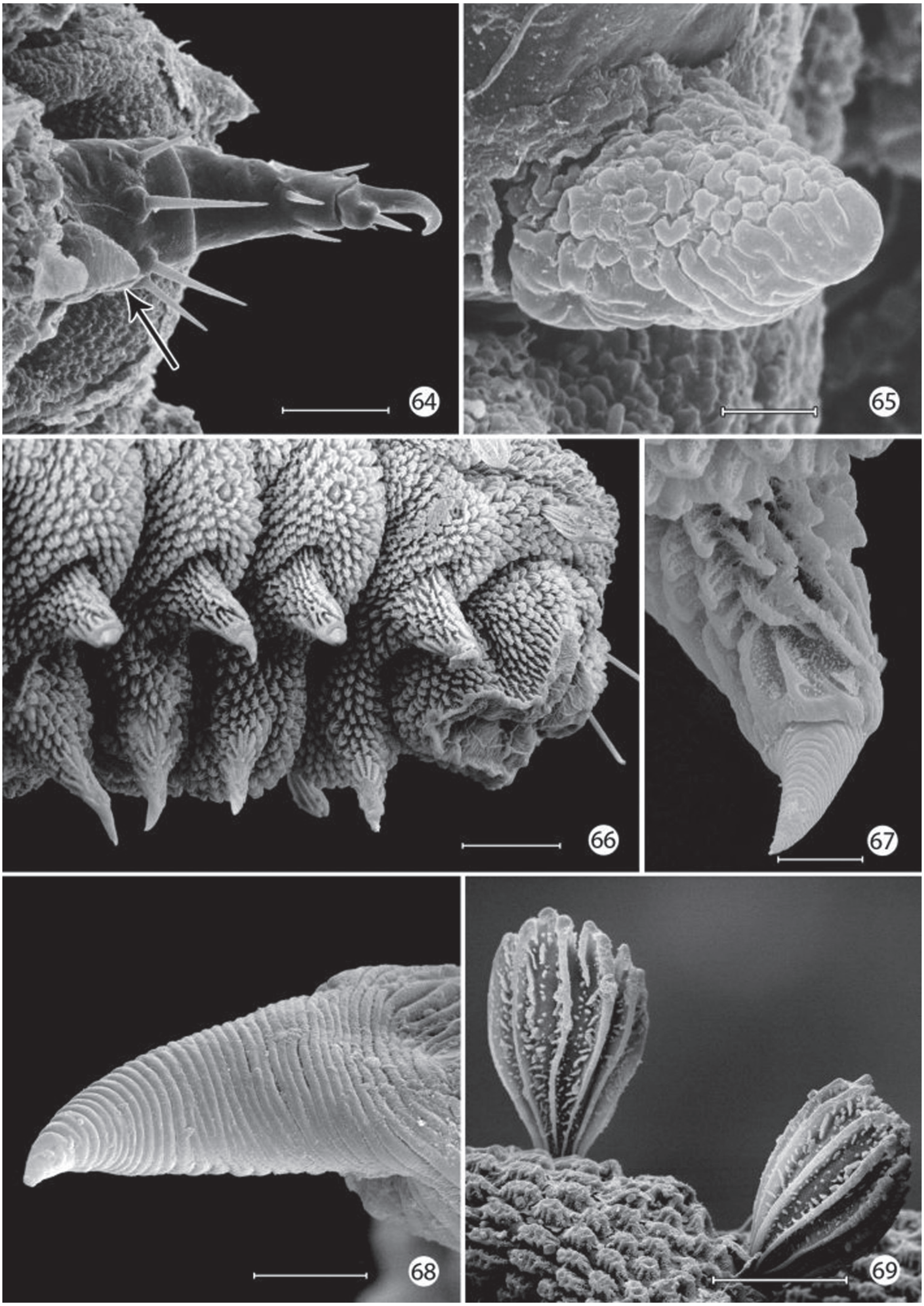
Figures 60–63. *Neomicropteryx nipponensis,* larval morphology **60** Plastron from lateral surface of abdomen with numerous, irregular micropapillae (10 µm) **61** Detail of Fig. 55 showing parallel rows of microtubercules extending between micropapillae (0.5 µm) **62** View looking down on microtubules in fig. 61 showing cuticular openings between rows (0.5 µm) **63** Head, anterior view (100 µm). (Scale lengths in parentheses).

comm.). In different parts of the range, specimens were collected from late April to mid August, with most records in June. Late records (July and August) are from higher elevations.

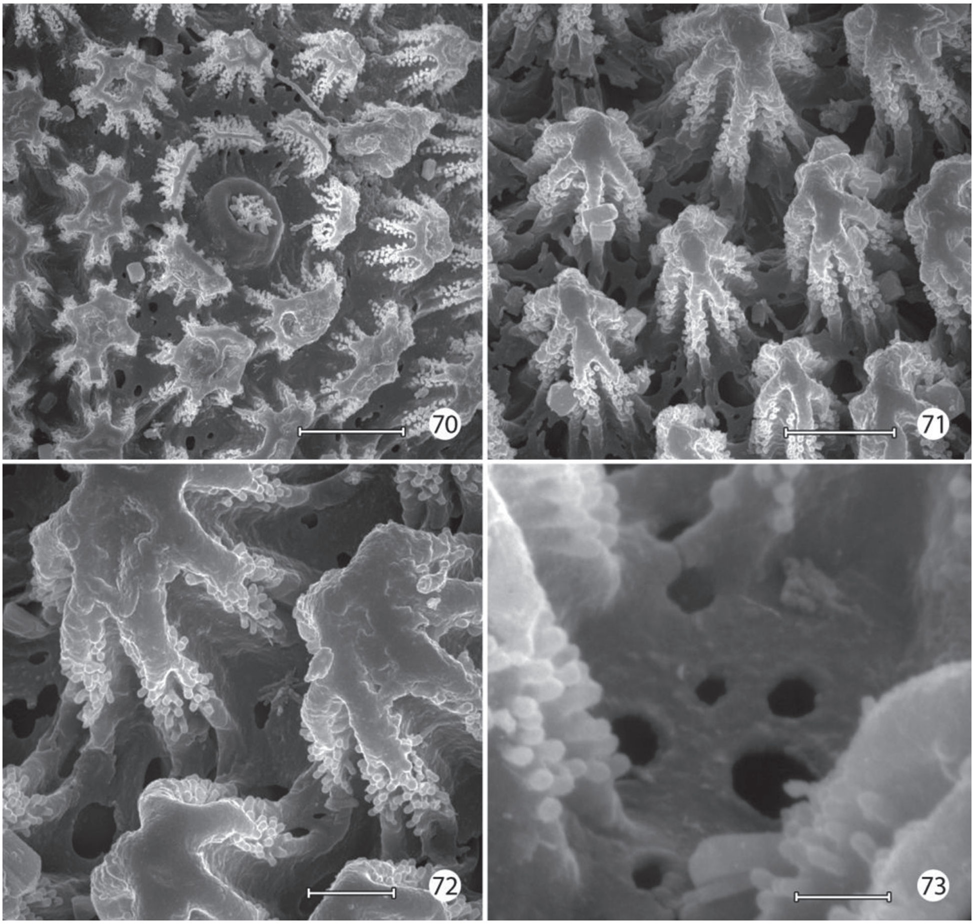
Holotype. ♂, CANADA: BRITISH COLUMBIA: Belcarra, 49° 17'59.11" N, 122°55'30.88"W, Alt. 25 m., 8 Jun 2008, visual sweep, Dave G. Holden, specimen

CNCLEP00067716, CNC slide MIC5768, Barcode of Life Project, leg removed, DNA extracted, digital image captured, (CNC).

Paratypes. CANADA: BRITISH COLUMBIA: Belcarra Park, 49.3107°N, 122.9263°W, alt. 13 m: 2 ♂, 24 May 2009, day sweep, Dave G. Holden, specimen # CNCLEP00076632–00076633 [both DNA barcoded] (CNC); 13 ♂, 1 ♀, 1 Jun 2009, day sweep, Dave G. Holden, specimens # CNCLEP00076634–00076639, 00077846–00077853, CNC slides MIC5765, MIC5767, MIC5766, MIC5570, MIC5571 [all DNA barcoded] (CNC); 2 ♂, 2 Jun 2009, day sweep, Dave G. Holden, specimens # CNCLEP00076640–00076641 [both DNA barcoded] (CNC). Maple Ridge, Univ. of British Columbia Research Forest, 49.277679°N, 122.553870°W, 259 m: 1 ♂, 1 Jun 2011, visual sweep, Dave G.Holden (CNC). Fraser Mills: 6 ♂, 7 ♀, 11 June 1921, L. E. Marmont, SEM slide USNM 18431, slides USNM 33919, 98001, 98002, 98004; 27 ♂, 7 ♀, 15 Jun 1922, E. H. Blackmore collector, slides USNM 17503, 18410–18411, 34282, 91785, 97991, 98000, 98003, 98005, 98009–98017 (BMNH, CNC, USNM). Squamish, Diamond Head Trail: 1 ♂, 12 Aug 1963; 2 ♂, 14 Aug 1963, W.R.M. Mason, specimens # CNCLEP00077292–00077294, CNC slide MIC1826 (CNC). Mt Seymour, 49.337368°N, 122.957695°W, 292 m: 1 ♂, 21 Jun 2011, visual sweep, Dave G.Holden (CNC). Glacier National Park, Loop Trail, 1140 m, 51.254°N, 117.538°W, 1 ♀, 16 Jul 2010, malaise trap, specimen #10BBCLP-2914 [DNA barcoded], CNC slide MIC5769 (BIO). UNITED STATES: WASHINGTON: Clallam Co: Olympic National Park, sweeping on Soleduck Trail to Deer Lake, 1000 m: 3 ♂, 15 Jul 1998, D. R. Davis, slide USNM 34302 (USNM). Olympic Peninsula, Port Angeles, 245m, N48,07924° W123,42990° ± 50m: 3 ♂ , 1 ♀, 20 Jun 2010; 1 ♂, 20.6.2010, 15:45h, Hausenblas and Zeller-Lukashort (ONPS). Olympic Peninsula, Sol Duc Hot Springs Rd, 390m, N48,06385° W123,99565° ± 50m: 1 ♂, 21 Jun 2010, 13:00h, Hausenblas and Zeller-Lukashort, slide AP-Nr 42/2010 Christof Zeller (ONPS). Olympic Peninsula, Kalaloch, 10m N47,61131° W124,37588° ± 50m: 1 ♂, 23 Jun 2010, 17:00h, Hausenblas and Zeller-Lukashort (ONPS). Olympic Peninsula, Hoh Rainforest Rd, 130m N47,81641° W124,05161 ± 50m: 21 ♂ , 3 ♀, 22 Jun 2010, 16:15h, Hausenblas and Zeller-Lukashort (CZC). Grays Harbor Co: Elma: 46.9738°N, 123.2945°W, yel st trp, 1 ♀, 27 Jun 2011, G. Kohler, WSDA 978–1008A (WSCAD). King Co: Asahel Curtis picnic area: 47.3951°N, 121.4677°W, 1 ♂, 27 Jul 2011, hand col, C. Looney, WSDA W666–1129A, B (WSCAD, USNM). Stevens Pass, Hwy 2, 14.5 km E Skykomish, 645 m., 47.7143°N, 121.1722°W: 1 ♂, 8 Jul 2010, afternoon sweep, J.-F. Landry and D.G. Holden, specimen #CNCLEP00082605, CNC slide MIC5739 [DNA barcoded] (CNC). Mason Co: Skokomish River Rd: 47.3019°N, 123.1858°W, 4 ♂ , 2 ♀, 17 Jun 2011, hand col, C. Looney, WSDA W666–1131A-E (WSCAD, USNM). Pierce Co: Fort Lewis: 1 ♂, 29 May 1951, R. Schuster, Essig Museum slide 0152, (UCB). Snohomish Co: East Arlington Co. Park: 1 ♂, 29 Apr 1979, L. Massell, e. *Lepidozia* liverwort, slide USNM 98006 (USNM). 6 mi. E of Verlot: 1 ♂, collected 26 Mar 1979, emerged 2 May 1979, reared from liverwort, *"Jungermannia obovata"* L. Russell (USNM). Thurston Co: Evergreen State College,



Figures 64–69. *Micropterix* species (England), larval morphology **64** Prothoracic leg (arrow: tactile vesicle of coxa) (50 µm) **65** Detail of tactile vesicle in fig. 64 (10 µm) **66** Abdominal segments 5–10 showing prolegs 5–8 and sucker-like anal proleg (100 µm) **67** Abdominal proleg (20 µm) **68** Detail of apex of abdominal proleg (10 µm) **69** Dorsal abdominal setae (50 µm). (Scale lengths in parentheses).

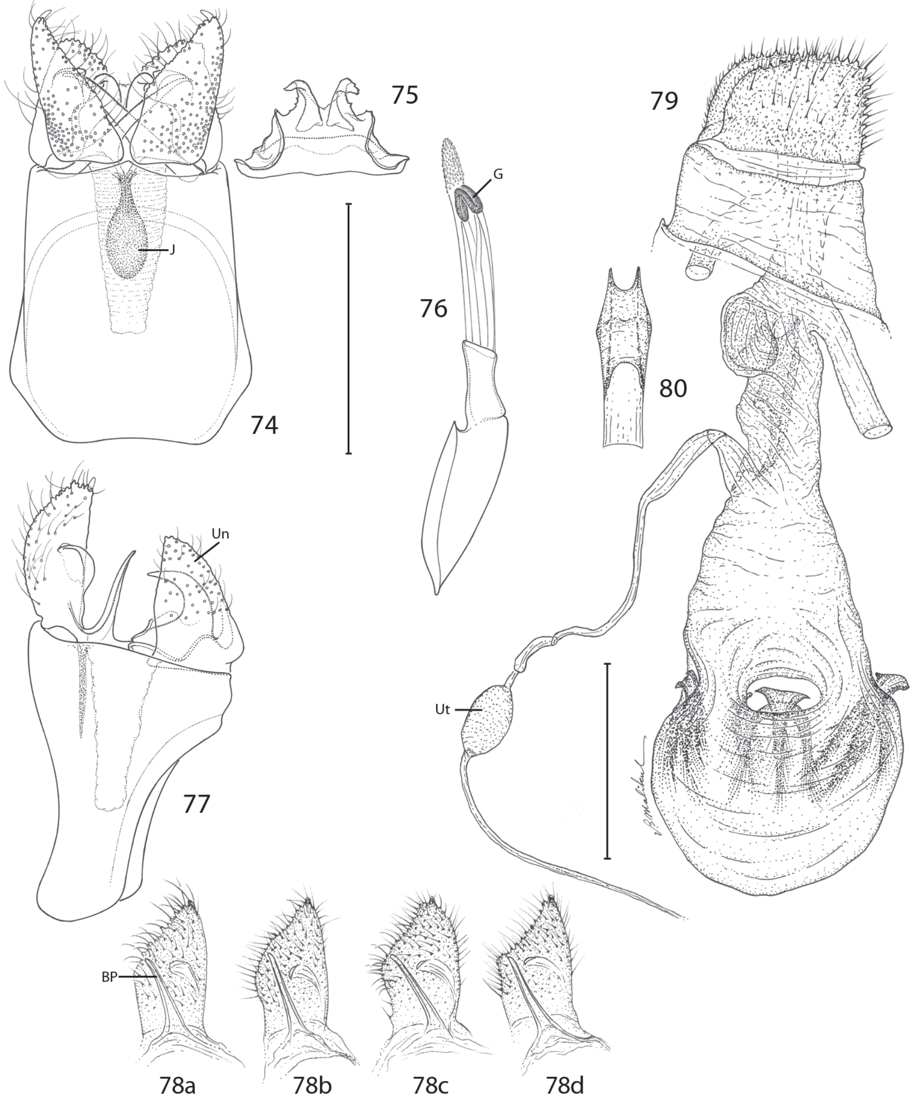


Figures 70–73. *Micropterix* species (England), larval morphology **70** Lateral plastron surface of abdomen showing micropapillae around broken scale base (20 µm) **71** Detail of plastron Fig. 70 showing cuticular openings between micropapillae (10 µm) **72** Detail of fig. 71 (5 µm) **73** Detail of cuticular openings in Fig. 71 (2 µm). (Scale lengths in parentheses).

47.0791°N, 122.9750°W, 2 ♂, 25 Jun 2011, hand col, C. Looney & E. Lagasa, WSDA 666–1130A, B (WSCAD, USNM).

Additional specimen examined, excluded from type material: CANADA: BRITISH COLUMBIA: Glacier National Park, Loop Trail, 1140 m, 51.254°N, 117.538°W, 1 ♀, 16 Jul 2010, malaise trap, specimen #10BBCLP-2914 [DNA barcoded] (BIO).

Distribution (Fig. 32). *Epimartyria bimaculella* is known from northwestern Washington and southern British Columbia. Most British Columbia records are from the southwesternmost corner in the periphery of the Vancouver area, reflecting a more intense collecting effort in that region. One record from the Rocky Mountains of Glacier National Park, BC suggests a significantly broader distribution.



Figures 74–80. *Epimartyria auricrinella*, Genitalic morphology **74–78** Male, USNM slides 16615, 34372 **74** Genital capsule, ventral view (0.5 mm); J: juxta (medial plate) **75** Sternum X (gnathos) **76** Aedeagus (G: gonopore (phallotreme) **77** Genital capsule, lateral view (Un: uncus, (tergum X) **78a** Valva, lateral view, inner side (BP: basal process), slide USNM, 34372, Ottawa, Ontario **78b** slide MIC5762, Lac Brûlé, Quebec **78c** slide MIC5764, Wilderness State Park, Michigan **78d** slide MIC5761, Lac Brûlé, Quebec **79–80** Female, USNM slide 17501, Mt. Albert, Quebec **79** Oviscape, lateral view (Ut: utriculus) (0.5 mm) **80** Genital sclerite, ventral view. (Scale lengths in parentheses).

Etymology. The species name is derived from the Latin *bi;* (two, double) and *maculella* (little spot) in reference to the two, small, pale yellowish spots present on the forewings.

Epimartyria pardella **(Walsingham)**

http://species-id.net/wiki/Epimartyria_pardella

Figs 3, 8, 13–17, 32, 88–96

Micropteryx pardella Walsingham 1880: 83.

Epimartyria pardella (Walsingham) 1898: 161.– Kearfott in Smith 1903: 125.– Dyar 1903: 581.– Meyrick 1912: 6.– McDunnough 1939: 110.– Davis 1983: 5; 1984: 341.– Kristensen 1984b: 97.– Tuskes and Smith 1984: 40.– Nye and Fletcher 1991: 113.– Poole 1996: 716.– Hashimoto 2006: 43.– Powell and Opler 2009: 33.

Diagnosis: Adults of *E. pardella* most resemble those of *E. bimaculella* in possessing dark fuscous forewings marked by pale golden spots. Four spots are present on the forewing of *pardella* with two of these located across the distal third of the wing. In contrast, a total of two yellowish spots occur in *bimaculella*, with only a single large costal spot present beyond the middle of the forewing. In the male genitalia, the caudal lobes of sternum X (uncus) are more simple than those of the other members of *Epimartyria* in consisting of more shallow, rounded lobes compared to being curved and more slender in the males of *auricrinella and bimaculella.*

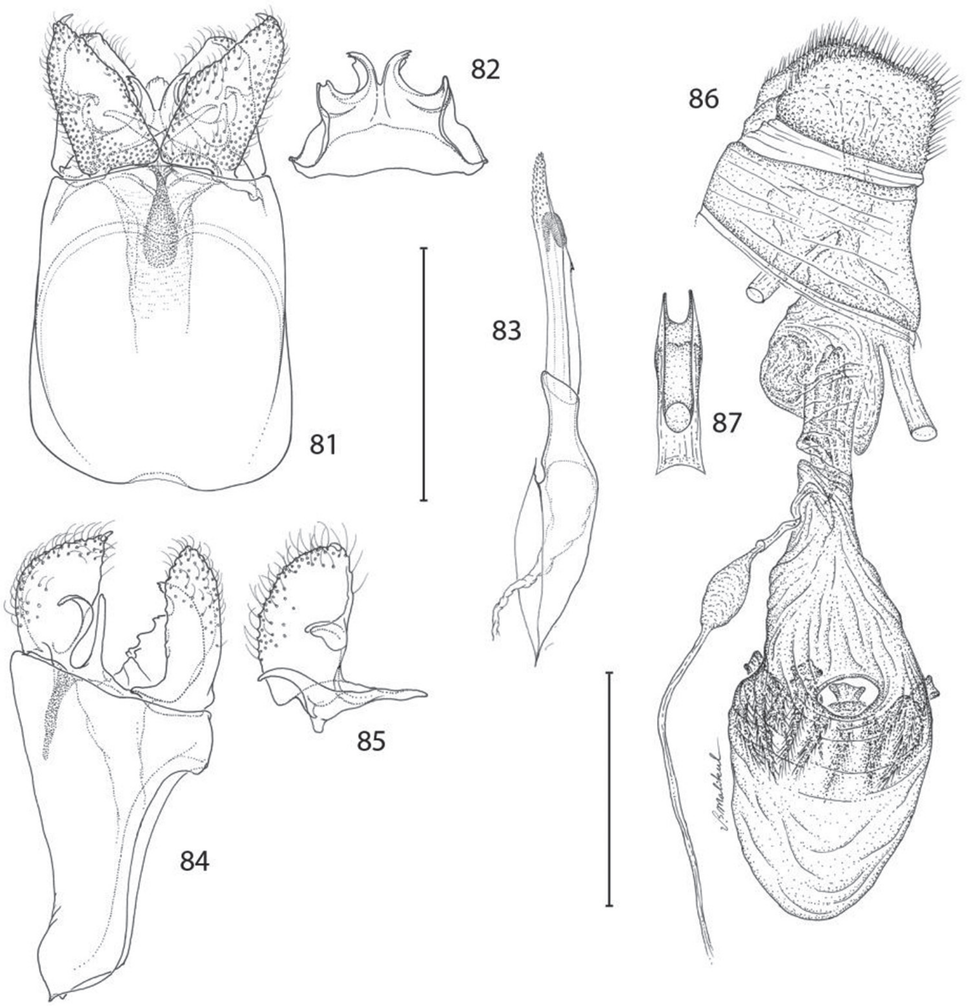
Adult (Figs 3, 8)**.** *Head*: Vestiture light orange brown. Antenna with vestiture of scape and pedicel concolorous with head; scales of flagellum pale golden yellow. Labial palpus pale brown to cream.

Thorax: Dark fuscous with coppery to purplish luster. Tegula concolorous with head. Forewing dark fuscous with coppery to purplish luster dorsally, marked with four, pale yellowish spots; the largest, irregularly rectangular and slightly oblique spot extends from costa approximately halfway across the distal third of wing; a smaller, more oval spot opposite costal spot on dorsal margin; an oblique basal spot arising midway along dorsal margin and extending halfway across wing to base of radial vein; a fourth, smallest spot at base of wing; forewing less iridescent ventrally; fringe pale yellow along termen, more gray along dorsal margin. Forewing length: 5.0–5.5 mm. Hindwing mostly gray, becoming darker and slightly iridescent toward apex; fringe gray; fringe light to dark gray. Legs medium to dark brown dorsally, paler brown ventrally and over tarsomeres; epiphysis present, ~ 1/3 the length of foretibia and arising slightly beyond its midlength.

Abdomen: Piliform scales light to dark brown.

Male genitalia (Figs 88–92): Tergum X with more slender caudal lobes. Caudal apex of sternum X (gnathos) not deeply divided, with short, triangular caudal lobes and without accessory lateral lobes. Valva short, ventral length less than 1/3 the maximum midventral length of segment IX; apex rounded and bearing a short, stout subapical spine; mesal surface smooth, without median process; elongate basal process nearly equal to length of valva. Dorsal branch of phallus more depressed, with subapical margins bearing short, paired spines, gonopore with less thickened radial folds than in previous two species.

Female genitalia: (Figs 93–96): As described for genus. Caudal end of genital sclerite deeply furcated; length of furcations exceeding length of short, undivided base.



Figures 81–87. *Epimartyria bimaculella*, Genitalic morphology **81–85** Male, USNM slide 18410, Fraser Mill, British Columbia **81** Genital capsule, ventral view (0.5 mm) **82** Sternum X (gnathos) **83** Aedeagus **84** Genital capsule, lateral view **85** Valva **86–87** Female, USNM slide 33919, Fraser Mill, British Columbia **86** Oviscape, lateral view (0.5 mm) **87** Genital sclerite, ventral view. (Scale lengths in parentheses).

Egg. White; dimensions 0.44 × 0.44 mm. Tuskes and Smith (1984) report the ova are flattened, circular and smooth when first deposited but soon become spherical and covered with numerous minute projections similar to those reported for *Micropterix calthella* (L.) by Lorenz (1961). The eggs were observed to hatch in 21 days at 22°C.

Larva. Not examined. The following description has been summarized from Tuskes and Smith (1984): Body length 4.3 to 4.6 mm; width 1.4 mm; height 1.2 mm. The body tapering at both ends with highest and broadest point at abdominal segment 4. Dorsal and lateral surface brown to dark brown, ventral surface light brown.

Head. Length 0.5 mm, diameter 0.27 mm. Brown. Antennae prominent, 3-segmented and situated on small tubercles located on dorsal lateral portion of head. Stemmata with 5 facets and located near base of antenna. Labrum simple with a pair of 3-segmented palpi. Mandibles simple and dark brown. Head diameter of first and second instar larvae 0.11 and 0.22 mm, respectively.

Thorax: Prothorax distinctly narrower than mesothorax. Prothoracic shield with 10 peg-like setae, 8 on the anterior and lateral border and 2 dorsally. Mesothorax with 8 setae, 6 on dorsal and lateral anterior portion of gray brown pigmented area, and 2 just ventral to this pigmented area. Setae of metathoracic segment similar to those of mesothorax except subdorsal (D2) seta is greatly reduced in size. All thoracic segments have additional small micro-seta just dorsal to each true leg. Thoracic legs brown, with 3 segments (excluding coxa) and simple claw.

Abdomen: Abdominal segments Al to A8 (and T2 and T3) with serrated knobs which form a dorsal and lateral ridge; areas between ridges concave. The mid-dorsal area concave with a small dark depression present on posterior of segments T2 to A8. Segments Al to A8 each with one dorsal seta (length 0.18 mm) atop dorsal ridge. Segments Al to A8 with reduced, almost microscopic subdorsal (D2) seta (length 0.04 mm) and prominent lateral seta (length 0.12 mm) on lateral ridge. Dorsal. subdorsal and lateral setae occur in brownish pigmented area which has rough and wrinkled appearance. Dorsal and lateral intersegmental area constricted and may contain series of 8 to 20 microscopic dots. Cuticle ventral to lateral ridge smooth and light brown. Series of brown dots form pattern around protuberance that usually support a small seta. Conical ventral prolegs occur on segments Al to A8, with a small, sclerotized protuberance present on ventral surface of each. Segments A9 and Al0 fused and with enlarged simple sucker. Spiracles posterior and ventral to lateral setae.

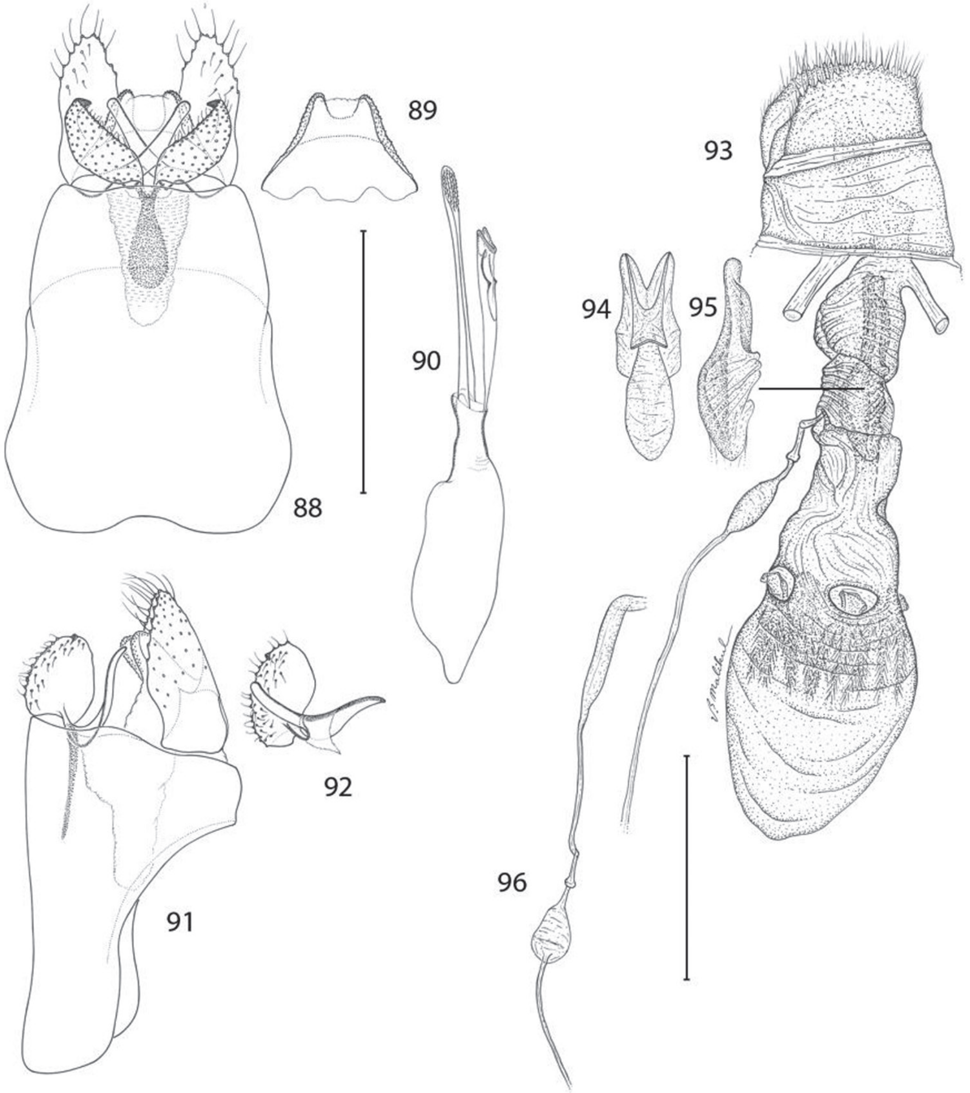
Larval hosts. Hepaticophyta**:** Conocephalaceae: *Conocephalum conicum* (L.) Dumort.; Pelliaceae: *Pellia* species, with the latter host preferred from rearings (Tuskes and Smith 1984).

Pupa. Not examined. Exarate, decticous; white to light brown.

Cocoon. Not examined. Brown, oval in general form, measuring 5.5 × 4.5 mm; primarily of silk with small fragments of vegetation attached.

Biology (Fig. 8)**.** Tuskes and Smith (1984) observed the eggs of *E. pardella* to be deposited in June on the underside of liverwort thalli singly or in small clusters of up to five eggs. They are white, measuring ~ 0.40 × 0.44 mm, and are flattened, circular, and smooth when first deposited but become spherical within a short time and covered with a series of small projections. First instar larvae ~ 0.75 mm long were reported to emerge in about 21 days (at 22°C). The larvae are rather inactive (in captivity) and are usually found on the underside of the thalli during the day. When disturbed or inactive the head may be withdrawn into the thorax. Pupation occurs within a thin walled, tightly woven brown cocoon close to the ground and attached to vegetation with strands of coarse silk.

Adults begin to emerge in late May with the flight season ranging from late May to mid- July and peak flight activity in June at the Prairie Creek State Redwood Park



Figures 88–96. *Epimartyria pardella*, Genitalic morphology **88–92** Male, USNM slide 16613, Arcata, California **88** Genital capsule, ventral view (0.5 mm) **89** Sternum X (gnathos) **90** Aedeagus **91** Genital capsule, lateral view **92** Valva **93–96** Female, DRD slide 4528, Kneeland, California **93** Oviscape, lateral view (0.5 mm) **94** Genital sclerite, ventral view **95** Genital sclerite, lateral view **96** Ductus spermathecae, showing variation of vesicle position. (Scale lengths in parentheses).

locality. Tuskes and Smith reported the adults to be relatively inactive, remaining motionless for hours and seldom travelling more than 30 cm. They are known to be diurnal and most active between 0900 and 1930 h. Adult feeding by *E. pardella* has not been reported, but the adults were observed drinking water by lowering their heads to the moisture. Moths can die in less than two days if deprived of moisture but may survive in captivity from 9 to 18 days when provided with water.

Tuskes and Smith concluded that *E. pardella* possessed a two year life cycle similar to that proposed for *E. auricrinella* (Davis 1987). In captivity eggs deposited in June 1981 became adults in June 1983. In the field they frequently collected second instar larvae during the adult flight period.

Lectotype. ♂ (present designation), "OREGON: Klamath Co: nr. Redwood Creek, Coast: 26 June 1872, Wlsm. 90591; B.M. Genitalia Slide No. 25352; *Epimartyria* (= *Micropteryx* Wlsm.) *pardella* Wlsm. PARATYPE; Lectotype ♂, *Epimartyria pardella* Wlsm. (BMNH)." The lectotype has been selected from a series of five syntypes collected **"**on the borders of the forest of "redwood" (*Taxodium sempervirens*) near the coast, in southern Oregon, at the beginning of June 1872" (Walsingham 1880).

Material examined. UNITED STATES: CALIFORNIA: Humbolt Co: Arcata: 1 ♂, 11 Jun 1969, slide USNM 16613, wing slide USNM 18441 (USNM). Fern Canyon: 1 ♀, 18 Jun 1977, N. J. Smith, slide DRD 4529 (UCB). Fern Canyon, Prairie Creek State Park: 3 ♂, 19 Jun 1981, Ann & Paul Tuskes; 1 ♂, 20 Jun 1981, P. Tuskes, 3 ♂, Ann & Paul Tuskes (USNM). Kneeland: 69 Prairie Lane: 1 ♂, 17 Jun 2001, 2 ♂, 18 Jun 2001, 1 ♂, 29 Jun 2001, 1 ♂, 30 Jun 2001, R. S. Wielgus, diurnal flight in wet meadow below house, slide USNM 34278 (USNM); 1 ♀, 22 Jun 2003, R. S. Wielgus, slides DRD 4528, 4529 (UCB). Trinity Co: Forest Glen: 2 ♀, 25 May 1973, J. Doyen (UCB). OREGON: Klamath Co: nr. Redwood Creek, Coast: 1 ♂ (lectotype), 26 June 1872, Wlsm. 90591; B.M. Genitalia Slide No. 25352, (BMNH). Multnomah Co: Benson State Park, Multnomah Falls: 2 ♂, C. V. Piper, 1 ♂, wing slide USNM 91788 (USNM).

Distribution (Fig. 32**).** *Epimartyria pardella* is known from northwestern California and northern Oregon. California localities and the type locality in Oregon are near the coast in redwood forests. The most northern Oregon locality occurs in the Columbia River valley.

Remarks. Information included in this report on the immature stages and life history of *E. pardella* has been quoted or summarized from the thorough study of this species by Tuskes and Smith (1984) at the Prairie Creek State Redwood Park, California. In addition to possible color differences, two major morphological differences noted in their description of the larva of *E. pardella* from that observed for *E. auricrinella* include: (1) 10 versus 11 (in *auricrinella*) peg-like setae on each side of the prothorax, and (2) D2 of metathorax and abdominal segments 1–8 greatly reduced in *pardella* (as reported also in *Austromartyria*, Gibbs 2010, and for the abdomen in *Agrionympha*, Gibbs and Kristensen 2011). Although examples of the larva, pupa, and cocoon of this species were reportedly deposited in the collections of the California Academy of Sciences, San Francisco, CA by Tuskes and Smith (1984), attempts to locate and borrow this material for study were unsuccessful. The skeletomuscular anatomy of the male genitalia of *E. pardella* was reviewed by Kristensen (1984b).

DNA barcoding

A total of 44 specimens yielded barcode sequences, of which 40 were full-length at 658 bp (Appendix 1). Geographic representation of barcoded specimens was primarily dictated by the availability of recently collected material (<20 years), and consequently restricted to a few localities which do not represent the entire range of the species (Fig. 32). Three barcode sequences of *Epimartyria* were available in GenBank, two for *auricrinella* and one for *pardella* (from Lees et al. 2010). The *auricrinella* sequences were identical to haplotype A1 from specimens collected at Gatineau Park, QC, a locality from which a series was examined but not barcoded (see 'Material examined' under *auricrinella*). The *pardella* sequence was one base pair different from haplotype P1 from a specimen collected at the same locality although on a different date. These sequences were not included in the analyses because the vouchers could not be examined and their haplotype similarity would not have affected the outcome of the analyses.

Neighbour-joining analysis resulted in three distinct clusters that corresponded to the three species as defined here on the basis of morphology (Fig. 12a). *Epimartyria pardella* was the most distant species with mean distances of 4.52% and 5.09% from *E. bimaculella* and *E. auricrinella*, respectively. Morphologically it is the most distinct of the three species in genitalia. *Epimartyria auricrinella* and *E. bimaculella* seemed to be genetically closer to each other, with a mean distance of 2.57%. Morphologically, their genitalia are also more similar. Intraspecific sequence variation was small in *E. bimaculella* at 0.2% ± 0.1 and a minimum of three haplotypes could be distinguished. Two specimens with either short sequences or ambiguous sites were not assigned as haplotypes. In contrast, *E. auricrinella* showed a high amount of sequence divergence resulting in 7 subclusters representing different haplotypes. Pairwise divergence ranged from 0.16–2.69% (1.63% ± 0.832), with 9 out of 21 comparisons showing over 2% divergence (Table 1).

To assess whether the high amount of intraspecific divergence may be correlated with morphological variation, geography, or both, representatives of each haplotype were further subjected to a parsimony analysis. Maximum-parsimony analysis performed on unique haplotypes (7 for *auricrinella*, 3 for *bimaculella*, 1 for *pardella*) resulted in three most parsimonious trees, of which the strict consensus is illustrated (Fig. 12b). Of the 658 base pairs of the full barcode dataset, 607 were constant and 51 were variable, of which only 25 were parsimony-informative. The MP cladogram was similar to the NJ tree in that the three morphospecies were retained as separate, well-supported clades. Despite high sequence variation within the *auricrinella* clade, support for internal nodes was generally weak.

The haplotype network (Fig. 12c) resulted in a similar topology, with the three species separated from each other. In some cases, several haplotypes were present among specimens from the same locality (Fig. 32). For *bimaculella*, there were three haplotypes with 1–2 base pair differences from the type locality of Belcarra, BC, which were collected microsympatrically, two of which on the same date (Appendix 2). Similarly, for *auricrinella*, four haplotypes were present at Lac Brûlé, QC, of which three were

Table 1. Percent mitochondrial cytochrome c oxidase I (COI) sequence divergence among 11 unique haplotypes of three *Epimartyria* species. Cells below diagonal = distances in %; cells above diagonal = standard error estimates.

	A1	A2	A3	A4	A5	A6	A7	B1	B2	B3	P1
auricrinella A1		0.15	0.26	0.36	0.49	0.57	0.52	0.62	0.60	0.60	0.78
auricrinella A2	0.16		0.21	0.33	0.51	0.59	0.54	0.60	0.58	0.58	0.78
auricrinella A3	0.47	0.31		0.40	0.57	0.64	0.59	0.65	0.64	0.63	0.82
auricrinella A4	0.94	0.78	1.10		0.57	0.59	0.59	0.63	0.62	0.62	0.81
auricrinella A5	1.73	1.89	2.21	2.37		0.49	0.50	0.59	0.57	0.59	0.84
auricrinella A6	2.20	2.37	2.69	2.53	1.73		0.21	0.69	0.67	0.67	0.89
auricrinella A7	1.88	2.04	2.37	2.53	1.73	0.31		0.65	0.63	0.63	0.87
bimaculella B1	2.53	2.37	2.69	2.69	2.37	3.18	2.85		0.14	0.21	0.79
bimaculella B2	2.37	2.20	2.53	2.53	2.21	3.01	2.69	0.16		0.15	0.78
bimaculella B3	2.36	2.20	2.52	2.52	2.37	3.01	2.69	0.31	0.15		0.78
pardella P1	4.80	4.80	5.14	5.14	5.14	5.47	5.13	4.63	4.47	4.47	

1–2 base pair apart but one (A5) was more than 10 bp divergent. At that locality haplotypes A1, A2 and A5 were present among specimens collected microsympatrically on the same date on two consecutive years (8 Jul 2002, 29 Jun 2003). Haplotype A4 from Tennessee, was closer to haplotypes A1–A3 from Lac Brûlé than to A5 from the same locality. The two localities are over 1300 km apart. Haplotypes A6 and A7 from Michigan were the most divergent, despite being geographically closer to Lac Brûlé than to Tennessee. The majority of barcode sequences came from a single locality for each of *auricrinella* and *bimaculella*. Thus it appears that higher haplotype diversity is associated with denser barcode sampling at single localities.

Genitalia were examined in several specimens of *auricrinella* representing the different haplotypes (Appendix 2). This showed slight variation in the shape of the male valva, in which the inner margin varied from evenly rounded to medially angulate (Fig. 78b–d). Several specimens showed various intermediate states of this condition from having a barely suggested median angle to a sharp one. The angulation differed slightly between the two valvae on some specimens. Likewise slight variation was observed in the depth of the apical notch of the uncus, which was a little deeper or a little more sharply V-shaped in some whereas it was proportionally shallower and more obtusely V-shaped in others. The lateral dentation and recurved distal lobes of the gnathos also displayed minor variations. The variation observed in male genitalia was present across haplotypes from the same locality and seemed unrelated to geography. Males were predominant in all series examined, thus fewer females were compared. No detectable variation was observed in the latter.

Thus we consider the variation in both haplotypes and morphology to be intraspecific. Although a 2% minimal divergence threshold is commonly observed to separate species, and in particular Lepidoptera (Hebert et al. 2009), this rule of thumb is not universal and instances of high intraspecific divergence (Schmidt and Sperling 2008) or shared haplotypes among closely related species (Lumley and Sperling 2010) are known. It has been hypothesized that geographical isolation is likely a major factor in the speciation and diversification of Micropterigidae due to their low vagility, narrow habitat requirement, and frequent allopatry (Imada et al. 2011). Further study involving much broader haplotype sampling of mtDNA and possibly nuclear genes will be required to elucidate the genetic structure of *Epimartyria* populations and whether cryptic species may be present.

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Appendix I

Sample information for the *Epimartyria* specimens included in the DNA barcode analysis. Sample IDs are specimen identifiers; Barcode IDs (or Process IDs in BOLD) are sequence identifiers. Details of collecting data, images, sequences, and trace files for the 44 specimens listed are available in the Barcode of Life Database (BOLD) (www.barcodinglife.org) in the project codes indicated.

Species of *Epimartyria*	Locality	Sample ID	Barcode ID	GenBank Accession	Sequence Length	BOLD Project Code
auricrinella	Canada: QC: lac Brûlé	CNCLEP00002816	MNAC969-11	JN306512	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00002817	MNAC970-11	JN306513	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00002818	MNAC971-11	JN306514	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00002819	MNAC972-11	JN306515	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007712	MNAC974-11	JN306516	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007713	MNAC975-11	JN306517	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007714	MNAC976-11	JN306518	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007715	MNAC977-11	JN306519	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007716	MNAC978-11	JN306520	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007717	MNAC979-11	JN306521	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007718	MNAC980-11	JN306522	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007719	MNAC981-11	JN306523	648[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00007720	MNAC982-11	JN306524	658[0n]	ZEUNA
auricrinella	USA: MI: Wilderness SP	CNCLEP00068782	MNAC984-11	JN306525	585[0n]	ZEUNA
auricrinella	USA: MI: Wilderness SP	CNCLEP00068783	MNAC985-11	JN306526	658[0n]	ZEUNA
auricrinella	USA: MI: Wilderness SP	CNCLEP00068785	MNAC987-11	JN306527	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00068787	MNAC989-11	JN306528	658[0n]	ZEUNA
auricrinella	Canada: QC: lac Brûlé	CNCLEP00068788	MNAC990-11	JN306529	658[0n]	ZEUNA
auricrinella	USA: TN: UoTennessee Field Stn	DNA-ATBI-3323	LGSMD549-05	GU088371	658[0n]	LGSMD
auricrinella	Canada: QC: lac Brûlé	jflandry0031	MEC031-04	GU095823	628[1n]	MEC
auricrinella	Canada: QC: lac Brûlé	jflandry0725	MEC725-04	GU095821	658[0n]	MEC
auricrinella	Canada: QC: lac Brûlé	jflandry0726	MEC726-04	GU095822	658[0n]	MEC
bimaculella	Canada: BC: Glacier NP	10BBCLP-2914	BBLPD916-10	JN801469	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00067716	MNAJ565-09	GU693563	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076632	MNAC991-11	JN306530	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076633	MNAC992-11	JN306531	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076634	MNAC993-11	JN306532	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076635	MNAC994-11	JN306533	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076636	MNAC995-11	JN306534	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076637	MNAC996-11	JN306535	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076638	MNAC997-11	JN306536	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076639	MNAC998-11	JN306537	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076640	MNAC999-11	JN306538	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00076641	MNAC1000-11	JN306509	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077846	MNAL648-10	HQ965294	658[1n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077847	MNAL649-10	HQ965295	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077848	MNAL650-10	HQ965296	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077849	MNAL651-10	JN801470	315[0n]	ZEUNA

Species of *Epimartyria*	Locality	Sample ID	Barcode ID	GenBank Accession	Sequence Length	BOLD Project Code
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077850	MNAL652-10	HQ965297	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077851	MNAL653-10	JN801471	658[12n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077852	MNAL654-10	HQ965298	658[0n]	ZEUNA
bimaculella	Canada: BC: Belcarra Pk	CNCLEP00077853	MNAL655-10	HQ965299	658[0n]	ZEUNA
bimaculella	USA: WA: 14.5 km E Skykomish	CNCLEP00082605	MNAD991-11	JN801472	658[0n]	ZEUNA
pardella	USA: CA: Kneeland	DRD-08-4201	NAMUM303-08	JN801473	658[0n]	ZEUNA

Appendix 2

Specimen data for haplotype analysis of *Epimartyria*. Haplotypes marked with an asterisk were selected for the parsimony analysis.

Species	Hap	SampleID	Length	Dissection	Sex	Locality	Collecting Date
auricrinella	A1	CNCLEP00002817	658		M	QC: lac Brûlé	29-Jun-2003
auricrinella	A1	CNCLEP00002818	658		M	QC: lac Brûlé	29-Jun-2003
auricrinella	A1	CNCLEP00002819	658		M	QC: lac Brûlé	29-Jun-2003
auricrinella	A1	CNCLEP00007713	658	MIC 5758	F	QC: lac Brûlé	08-Jul-2002
auricrinella	A1*	CNCLEP00007714	658	MIC 5762	M	QC: lac Brûlé	08-Jul-2002
auricrinella	A1	CNCLEP00007715	658		M	QC: lac Brûlé	08-Jul-2002
auricrinella	A1	CNCLEP00007716	658		F	QC: lac Brûlé	08-Jul-2002
auricrinella	A1	CNCLEP00007717	658	MIC 5763	F	QC: lac Brûlé	08-Jul-2002
auricrinella	A1	CNCLEP00007720	658	MIC 5757	M	QC: lac Brûlé	08-Jul-2002
auricrinella	A1	CNCLEP00068787	658		F	QC: lac Brûlé	02-Jul-2000
auricrinella	A1	jflandry0726	658	USNM 34322	M	QC: lac Brûlé	04-Jul-2004
auricrinella	A2*	CNCLEP00007712	658	MIC 5755	M	QC: lac Brûlé	08-Jul-2002
auricrinella	A3*	CNCLEP00068788	658	MIC 5756	M	QC: lac Brûlé	02-Jul-2000
auricrinella	A4*	DNA-ATBI-3323	658	MIC 5759	F	TN: UoTN stn	22-May-2005
auricrinella	A5	CNCLEP00002816	658		M	QC: lac Brûlé	29-Jun-2003
auricrinella	A5*	CNCLEP00007718	658	MIC 5753	M	QC: lac Brûlé	08-Jul-2002
auricrinella	A5	jflandry0725	658	MIC 5754	F	QC: lac Brûlé	04-Jul-2004
auricrinella	A5?	CNCLEP00007719	648	MIC 5760	M	QC: lac Brûlé	08-Jul-2002
auricrinella	A5?	jflandry0031	628 [1n]	MIC 5761	M	QC: lac Brûlé	29-Jun-2003
auricrinella	A6*	CNCLEP00068783	658	MIC 5752	M	MI: Wilderness SP	30-Jun-1992
auricrinella	A6?	CNCLEP00068782	585		M	MI: Wilderness SP	30-Jun-1992
auricrinella	A7*	CNCLEP00068785	658	MIC 5764	M	MI: Wilderness SP	30-Jun-1992
bimaculella	B1	CNCLEP00076633	658		M	BC: Belcarra	24-May-2009
bimaculella	B1	CNCLEP00076635	658	MIC 5771	F	BC: Belcarra	01-Jun-2009
bimaculella	B1	CNCLEP00076638	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B1	CNCLEP00076639	658	MIC 5767	M	BC: Belcarra	01-Jun-2009
bimaculella	B1	CNCLEP00076640	658		M	BC: Belcarra	02-Jun-2009
bimaculella	B1	CNCLEP00077846	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B1*	CNCLEP00077847	658	MIC 5765	M	BC: Belcarra	01-Jun-2009

Species	Hap	SampleID	Length	Dissection	Sex	Locality	Collecting Date
bimaculella	B1	CNCLEP00077848	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B1	CNCLEP00077852	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B2	10BBCLP-2914	658	MIC 5769	F	BC: Glacier NP	16-Jul-2010
bimaculella	B2	CNCLEP00076632	658		M	BC: Belcarra	24-May-2009
bimaculella	B2	CNCLEP00076634	658	MIC 5770	M	BC: Belcarra	01-Jun-2009
bimaculella	B2	CNCLEP00076636	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B2	CNCLEP00076637	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B2	CNCLEP00076641	658		M	BC: Belcarra	02-Jun-2009
bimaculella	B2	CNCLEP00077850	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B2	CNCLEP00077853	658		M	BC: Belcarra	01-Jun-2009
bimaculella	B2*	CNCLEP00082605	658	MIC 5739	M	WA: Skykomish	08-Jul-2010
bimaculella	B3*	CNCLEP00067716	658	MIC 5768	M	BC: Belcarra	08-Jun-2008
bimaculella	B?	CNCLEP00077849	315		M	BC: Belcarra	01-Jun-2009
bimaculella	B?	CNCLEP00077851	658[12n]	MIC 5766	M	BC: Belcarra	01-Jun-2009
pardella	P1*	DRD-08-4201	658		?	CA: Kneeland	21-Jun-2008

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BOOK REVIEW

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A long-awaited book about fossil arachnids Book review: Dunlop JA, Penney D (2012) Fossil Arachnids. Monograph Series Volume 2. Siri Scientific Press, Manchester, 192 pp.

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For a long time palaeoarthropodology has been ticking over in the background with publications mainly restricted to taxonomic papers in scientific journals. The deficit of more general overview works as a resource of background information for neontologists as well as palaeontologists was recently addressed for insects (Rasnitsyn and Quicke 2002; Grimaldi and Engel 2005). Now, for the first time this void has been filled for arachnids also, by two of the leading researchers in palaeoarachnology: Jason Dunlop (Germany) and David Penney (UK). Between them they have published more than 200 papers on the subject, including collaborative studies employing the latest cutting edge techniques (Dunlop et al. 2011a, b). The volume is dedicated to Professor Paul A. Selden (USA) who mentored both authors during the early stages of their academic careers. The volume opens with a very nice Rhynie palaeohabitat reconstruction by Richard Bizley (UK) showing that arachnids, in this case trigonotarbids, were amongst some of the first animals in early terrestrial ecosystems, approximately 410 million years ago. This is followed by a plate of drawings by J. Henry Blake showing the diversity of fossil spiders from the Tertiary Florissant deposits of North America, first published in 1890.

Following the dedication, foreword, a list of museum acronyms and a useful illustration of the geological timescale included for reference purposes, the work begins with an introduction to arachnids from a palaeontological perspective. This provides some historical references and then explains what arachnids are with regard to their anatomy, in order to provide the relevant information for what follows in the later chapters. This anatomical discussion is rather basic, but further order-specific details are provided later. The next of the introductory chapters concerns techniques for preparation and study of fossil arachnids. Here the authors allude to the different kinds of preservation seen in both amber and non-amber fossil deposits and how to extract the best morphological information out of the perserved arachnids, including the use of the latest techniques such as X-ray computed tomography. The authors do not go into detail here, but the work is fully referenced in order that the interested reader can pursue these subjects further if so desired.

The next chapter is unique in the arachnological literature to date and consists of a key to all 16 arachnid orders fossil and extant. This is a rather simple key focussing on features that are likely to be seen preserved in fossils and the basic body plan of each order is clearly illustrated to support the text. It is worth mentioning at this point that there are no other keys in the book and that it will not be of direct use in identifying fossils to family level and beyond, expect for a few rare instances, where a fossil specimen under investigation may correspond well to one of the photographs provided. This is unlikely to be the case for a spider in amber given their extreme diversity, but quite possible for a phalangiotarbid preserved in an ironstone nodule. The introductory section concludes with a discussion of the evolutionary relationships of the arachnids and closely related groups, which is nicely summarized in an evolutionary tree showing the hypothetical relationships and the known geological ranges of all orders. The tree is supported by a table of comparative diversity of fossil and extant species for each order. It should be noted that there are some discrepancies between these species richness numbers and those provided by Zhang (2011). However, the summary figures in Zhang (2011) do not add up correctly when the individual papers are examined. Given that the authors maintain a fossil arachnid database (Dunlop et al. 2012) that is updated every six months, it can be assumed that their numbers, at least for described fossil taxa, are the most accurate available.

Next follows the main content of the book, with chapters devoted to each arachnid order covered in detail. These include: Scorpiones, Opiliones, Phalangiotarbida, Palpigradi, Pseudoscorpiones, Solifugae, Acariformes, Parasitiformes, Ricinulei, Trigonotarbida, Uraraneida, Araneae, Haptopoda, Amblypygi, Thelyphonida and Schizomida. Each of these chapters follows a standardized format with an introduction followed by the following headed sections: Classification, Diagnostic characters, Descriptive characters (carapace, eyes, chelicerae, pedipalps, legs, opisthosoma, body size), Palaeodiversity (Palaeozoic, Mesozoic, Cenozoic), Fossil localities (Palaeozoic, Mesozoic, Cenozoic), Families recorded as fossils, Palaeoecology, and ending with a section on Important studies. The text is comprehensive, authoritative and fully referenced throughout, although more details and additional figures could have been devoted to the range of morphological variation of extant species within each order. The descriptive details provided do not do justice to the variation in seen in extant forms, although they should serve to facilitate identification of problematic arachnid compression fossils to order level. In addition, there could have been more in-depth coverage on the various systematic hypotheses that have been proposed (and are still unresolved) for some of the orders e.g. the mites and ticks, and even superfamilies within orders (e.g. Eresoidea in Araneae) although this may have tipped the arachnologist-palaeontologist-general biologist balance the book has aimed to achieve. Each chapter includes photographs of Recent species (for the extant orders) in order that non-arachnologists can contextualize the fossils. This section of the book is richly illustrated with large, photographs (mainly in colour) of both amber and non-amber fossils. The quality of the photographs is excellent and demonstrates the remarkable preservation of arachnids even in fossils dating back to the Carboniferous and beyond. Many of the fossils illustrated are types and repository data for all specimens illustrated are provided.

The final chapter, entitled Perspectives, summarizes what the authors hope to, and have achieved in the preceding pages. They also discuss how they expect palaeoarachnological research to develop in the future with particular regard to new fossils and new localities, the application of new imaging technologies and modern systematic methods, how palaeoarachnological data may be useful in modelling and predicting the consequences of tropical deforestation and global climate change, and the contribution that fossils can make to callibrating molecular clocks. The volume ends with an extensive bibliography and a taxonomic index to families and genera.

In terms of production, the book is of a high standard, well bound in a hard cover with end papers and printed on high quality, thick glossy paper meaning there is no show through from the reverse side of each page, although some may consider the margins a little too narrow. The text is of an easily readable appropriate size and has been very tightly copy edited. Scientific jargon has been kept to a minimum in order that the work can be more broadly accessible to non-academics. The photographs are large and very sharp, making the book a pleasure to the eye; even without the text the book would warrant a place in arachnological libraries purely based on the range and quality of the photographs, the majority of which have not been published elsewhere, at least not in colour and at such a large size.

In summary, we can highly recommend this book as absolutely unique within the arachnological literature to date. There is barely any overlap with previously published books on arachnids, which usually only briefly touch on the fossil record. It will fill a long-standing void on the shelves of arachnological libraries, and will be of interest to palaeontologists and neontologists alike, both as a source of reference or merely to browse through the stunning images it contains.

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