***Meteorus acerbiavorus* sp. nov. (Hymenoptera, Braconidae), a gregarious parasitoid of *Acerbia alpina* (Quensel) (Lepidoptera, Arctiidae) in North Finland**

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The new gregarious parasitoid *Meteorus acerbiavorus* sp. nov. (Hymenoptera, Braconidae) was reared from the cocoons of *Acerbia alpina* (Quensel) (Lepidoptera, Arctiidae) in north-western Finnish Lapland. This species belongs to *Meteorus rubens* (Nees) species group and differs from the most related *M. rubens* in the following features: the eyes densely setose; the median lobe of the mesoscutum, scutellum, mesopleuron, and the hind coxa entirely or at least partly rugulose-granulate or rugose-areolate and sometimes with granulation; the ovipositor subapically with distinct dorsal node; the ventral borders of the first metasomal tergum weakly separated by narrow space in its basal half; the colour of the body and legs mostly or entirely dark; the fore wing more or less darkened. Phylogenetic relationships among several *Meteorus* species close to *M. rubens* including new *M. acerbiavorus* were investigated based on DNA sequence fragments of the mitochondrial COI and the nuclear 28S rDNA genes. The discussions on the species groups of *Meteorus*, on distribution of *Acerbia alpina* in the Holarctic and on its known parasitoids are presented.

Keywords: Braconidae; Hymenoptera; *Meteorus*; gregarious parasitoid of Arctiidae; new species; DNA analysis; result

Introduction

The species of the braconid genus *Meteorus* Haliday, 1835 are abundant koinobiont endoparasitoids of the larvae of (mainly) Lepidoptera and of Coleoptera with a world-wide distribution (Yu et al. 2005). The fauna of this genus was revised for several territories of the Palaearctic region: for the West and Central Europe (Huddleston 1980), for the European part of Russia (Tobias 1986) and Russian Far East (Belokobylskij 2000), for Japan (Maetô 1986, 1988a, 1988b, 1989a, 1989b, 1990a, 1990b), and China (Chen and Wu 2000). In spite of these revisions, the species diversity of this genus in the Palaearctic region is not fully known and new taxa are still found in the northern territories of Europe (this paper; Stigenberg & Ronquist in prep.).

The higher level classification of the genus *Meteorus* (and the closely related *Zelee*) is still subject to discussion. Some authors place these two genera in the tribe

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Meteorini, of the subfamily Euphorinae (Tobias 1966; Shenefelt 1969; Maetô 1986, 1988a, 1988b, 1989a, 1989b, 1990a; Quicke and Achterberg 1990; Chen and van Achterberg 1997), while other authors (Muesebeck 1923; Maetô 1990b; Shaw 1985, 1997; Shaw and Huddleston 1991; Chen and Wu 2000) preferred to place these two genera in a separate subfamily Meteorinae closely related to Euphorinae. Li et al. (2003) were the first to present a molecular phylogenetic analysis of the Euphorinae, which was based on the D2 region of 28S rRNA. Their analysis showed that the only tribes for which their analysis provided some evidence for monophyly were Meteorini and Microctonini. Additional results were presented in a preliminary phylogeny based on molecular data (gene 28S rDNA D2 region) and morphological characters by Shi et al. (2005), which was later reassessed by Pitz et al. (2007). The datasets used in these studies includes the genes 16S, 18S and 28S. Unfortunately, only 10 Euphorinae genera were included, making the results less illuminating with respect to Euphorinae relationships. In some of the trees by these latter authors, *Meteorus* and *Zelee* (Meteorini) were basal and sister to the rest of the Euphorinae genera included. An extensive sampling of taxa from Euphorinae s.l. (including Meteorini, Neoneurini and Blacini/Blacinae), a thorough simultaneous molecular and morphological phylogenetic study with added fundamental information about the biology of these groups may help to understand the real taxonomic position of all these taxa.

Most of the *Meteorus* species are solitary larval parasitoids of numerous groups of Lepidoptera, as well as a few families of Coleoptera, on beetle larvae living in wood or in bracket fungi (Huddleston 1980; Maetô 1990b). Only a few species are gregarious parasitoids of lepidopteran hosts, among them in the Palaearctic region *M. rubens* (Nees) and *M. heliophilus* Fischer on Noctuidae (Huddleston 1980) as well as several tropical species (Muesebeck 1939; Nixon 1943; Huddleston 1983; Zitani et al. 1997; Shaw and Nishida 2005). On the other hand, only a few species of this genus (*M. abscissus* Thomson, *M. bakeri* Cook and Davis and *M. camptolomae* Watanabe) are known to be solitary parasitoids of the larvae of the family Arctiidae (Maetô 1990b). This paper contains information about a new gregarious species of *Meteorus* for the Palaearctic region with development on the arctiid larva *Acerbia alpina* (Quensel). These *Meteorus* specimens were reared from its cocoon.

Materials and methods

Material and abbreviations

Five cocoons of *Acerbia alpina* were collected by Harry Lonka in Jehkats (Finland, EnL = Enontekiö Lapland; EUREF-FIN ETRS-TM35FIN coordinates N 7676 E 254) on 10 June 2009. From two cocoons moths emerged; the other three were parasitized and on 16–22 June 2009 numerous males and females of *Meteorus* emerged. A part of the material was mounted by H. Lonka and Dr. Guy Söderman, but most of the specimens were stored in alcohol. Veli Vikberg received the specimens in alcohol for further study and we used it for preparation of this paper. Two specimens, one female (NHRS-HYME 5223, DNA no. 179) and one male (NHRS-HYME 5222, DNA no. 180) were used for DNA sequences and are voucher specimens. In June 2006 Marko Mutanen also visited Jehkats and found here two cocoons of *A. alpina* which were parasitized by *Meteorus* species. From this material DNA was extracted from one male specimen (NHRS-HYME 5241, DNA no. 185). Two cocoons of *Acerbia alpina* were collected on 2 June 1992 in EnL: Lossujärvi (Uniform grid reference 27°E

769:326) by Juha Kytömaa. One of the cocoons was parasitized and the tube with this cocoon and the emerged parasitoids was put into a freezing box and later given to Veli Vikberg. When opened, the cocoon contained a dead larva of *Acerbia* and 92 cocoons of *Meteorus*. Out of these cocoons 36 males and nine females of *Meteorus* had emerged. Some specimens had died inside their cocoons and the development of many others had been stopped by unknown reasons. These *Meteorus* parasitoids were paler than the previous mentioned material. Three specimens, one female (NHRS-HYME 5246, DNA no. 183) and two males (NHRS-HYME 5245, DNA no. 188 and NHRS-HYME 5247, DNA no. 187) were used for DNA sequences and are voucher specimens. All extracted DNA is stored at the Molecular Systematics Laboratory at the Swedish Museum of Natural History (Stockholm). The taxa analysed are listed in the Appendix with their identification numbers and GenBank accession numbers. The number of cocoons of *Meteorus* in one host cocoon varies between 39 and 98; males and females are about as numerous. Unfortunately the rearings were performed so that exact numbers cannot be given.

The terminology of morphological features, measurements and sculptures follows Belokobylskij and Tobias (1998), the nomenclature for the wing venation follows Belokobylskij and Tobias (1998) and within parenthesis van Achterberg (1979). The following abbreviations are used: POL – postocellar line; OOL – ocular-ocellar line; Od – maximum diameter of lateral ocellus. The type material is housed at the Zoological Institute of the Russian Academy of Sciences (St Petersburg, Russia; ZISP), Nationaal Natuurhistorisch Museum (Leiden, the Netherlands; RMNH), Swedish Museum of Natural History (Stockholm, Sweden; NHRS), Finnish Museum of Natural History, University of Helsinki (Helsinki, Finland; MZH), and in private collections of Harry Lonka (Helsinki; CHL), Guy Söderman (Helsinki; CGS) and Veli Vikberg (Turenki; CVV).

DNA sequence data

DNA extractions from legs or whole specimens of six specimens, either female or male, of this new species were sequenced (Appendix). Two genes were sequenced. Both the genes CO1 and 28S D2 are widely used within Hymenoptera (Rokas et al. 2002; Zaldivar-Riverón et al. 2006, 2008; Buffington et al. 2007) to resolve several taxonomic level relationships. The 28S D2 gene is used mostly for higher level taxonomy because of its slower substitution rates and CO1 for the lower level relationships (Zaldivar-Riverón et al. 2006). The CO1 primers used were designed by Folmer et al. (1994) (LCO 5'GGT CAA CAA ATC ATA AAG ATA TTG G3'; HCO 5'TAA ACT TCA GGG TGA CCA AAA AAT CA3') (665 bp). The 28S D2 primers were used by Campbell et al. (1993) (fwd: 5'AGT CGT GTT GCT TGA TAG TGC AG3' and rev: 5'TTG GTC CGT GTT TCA AGA CGG G3') (649 bp). The polymerase chain reaction (PCR) program for CO1 had an initial 5-min denaturation at 94°C, followed by 40 cycles at 94°C for 15 s, 46°C for 15 s and 72°C for 15 s and ending with a 10-min extension period at 72°C. The program for 28S D2 had an initial 4-min denaturation at 95°C, followed by 40 cycles at 94°C for 30 s, 55°C for 30 s and 72°C for 30 s and ending with a 10-min extension period at 72°C. PCR products were purified using EXOFAP (EXO1 and FastAP). Gene regions were sequenced with the same primers as in the PCRs using the BigDye™ Terminator ver. 3.1 Cycle Sequencing Kit (Applied Biosystems). Sequencing reactions were purified using the DyeEx 96 kit (QIAGEN)

and cycle sequencing reactions were run on an ABI Prism 3100 Genetic Analyzer (Applied Biosystems) (all accordingly to the manufacturers instructions). For assembling and viewing the sequence data and contigs the Pregap4 and Gap4 modules of the Staden package (Staden et al. 1998) were used. The sequences were further processed in BioEdit (Hall 1999) and 28S D2 was aligned using MAFFT online version (Katoh et. al. 2009), the best algorithm was determined by the program. CO1 was aligned by eye. The 28S D2 sequence was gathered for all specimens and the CO1 was not recovered from specimens 5245 and 5247.

The sequences of these six specimens were run together with 43 sequences of *Meteorus* including several species of the *Meteorus rubens* species group (see Appendix for taxa and GenBank accession numbers). The datasets for the two genes were analysed separately and combined. The data were run using MrBayes 3.1.2 (Huelsenbeck and Ronquist 2001) under the GTR + I + Gamma model using default settings. The analysis was run with 5 000 000 generations with sample frequencies every 1000 generations. After the analysis 25% of the generations were eliminated in burn-in. Three separate analyses for each dataset were performed, all producing similar trees. The final combined analysis was run with taxa with sequences from both 28S D2 and CO1.

Taxonomic part

Meteorus acerbiavorus Belokobylskij, Stigenberg and Vikberg, sp. nov.
(Figures 1A–L, 2A–G, 3A–L, 5A, 5B)

Type material

Holotype. female, “Finland 767:325. Enontekiö Lapland: Jehkats, June 2009, Harry Lonka leg.”, “From cocoon of *Acerbia alpina* Quensel (Arctiidae)” (ZISP).

Paratypes

Three females and three males (ZISP), four females and two males (RMNH), two females (NHRS-HYME 5221 and 5223) and two males (NHRS-HYME 5222 and 5240) (NHRS), three females and three males (MZH), seven females and seven males (CHL), five males and two females (CGS) and six females and two males (CVV). Two females, two males, “Finland 7679:3254. EnL (= Enontekiö Lapland): Jehkats, ex cocoon of *Acerbia alpina* taken 2006, Marko Mutanen leg.” (ZISP), one female (NHRS-HYME 5242) and three males (NHRS-HYME 5241, 5243 and 5244) (NHRS). Three females, four males, “Finland 769:326. EnL: Lossujärvi, ex cocoon of *Acerbia alpina* taken 2.6.1992, Juha Kytömaa leg.” (ZISP); one female and two males (RMNH), one female (NHRS-HYME 5246) and two males (NHRS-HYME 5245 and 5247) (NHRS), one female and three males (MZH), and one female and 20 males (CVV). Paratypes collected by H. Lonka are labelled with identical or nearly identical labels as holotype or uniform grid reference 767:325 is replaced by EUREF-FIN grid reference 7676:8254.

Description

Female (holotype). Body length 4.6 mm; fore wing length 3.9 mm.

Figure 1. Morphological characters of the female of *Meteorus acerbiavorus* sp. nov. (A) head, front view; (B) head, dorsal view; (C) head, lateral view; (D) basal and apical segments of antenna; (E) mesosoma, lateral view; (F) hind femur; (G) apical segments and claw of hind tarsus; (H) metasoma, lateral view; (I) first tergum of metasoma, dorsal view; (J) first tergum of metasoma, ventral view; (K) fore wing; (L) hind wing. Scale bar: a – for (K), (L) (1 mm); b – for (E) (1 mm); c – for (G) (0.5 mm); d – for (H–J) (1 mm); e – for (A–D), F (1 mm).

Figure 2. Morphological characters of the female of *Meteorus acerbiavorus* sp. nov. (photos): (A) habitus, lateral view; (B) head, dorsal view; (C) head, lateral view; (D) head, front view; (E) fore and hind wings; (F) mesosoma, lateral view; (G) first metasomal tergum, dorsal view.

Figure 3. Morphological characters of *Meteorus acerbiavorus* sp. nov. specimens collected by H. Lonka ((A), (D), (G), (J)), M. Mutanen ((B), (E), (H), (K)) and J. Kytömaa ((C), (F), (I), (L)) (photos): (A–C) – mesoscutum; (D–F) – mesoscutum and scutellum; (G–I) – mesopleuron; (J–L) – first metasomal tergum.

Head transverse, its width 1.7 times median length, 1.1 times width of mesoscutum. Head behind eye (dorsal view) distinctly and convex-roundly narrowed. Transverse diameter of eye (dorsal view) 1.3 times longer than temple. Frons flat, without medial tubercle, but with shallow and rather wide crenulate longitudinal median furrow. Ocelli medium-sized, arranged in triangle with base 1.5 times its sides; POL

2.0 times Od, 1.2 times OOL, Od 0.6 times OOL. Eye oval, with long and rather dense setae, weakly convergent below (front view of head), 1.5 times as high as broad. Malar space height 0.3 times height of eye, equal to basal width of mandible. Minimum width of face 0.8 times its maximum width at level of antennal sockets, 1.3 times its median height, 0.9 times high of eye. Subocular suture distinct. Tentorial pits rather large, distance between pits 2.2 times distance from pit to eye; diameter of pit about 0.5 times distance from pit to eye. Clypeal suture distinct and complete. Clypeus strongly convex, its lower margin almost straight and without tubercle, with fine flange; clypeal width 1.8 times its median height, 0.9 times minimum width of face. Mandible rather distinctly twisted. Occipital carina complete, fused ventrally with hypostomal carina. Palpal segments weakly thickened.

Antenna almost filiform, thickened, about 0.9 times as long as body, 27-segmented. Scape 1.6 times longer than maximum width. First flagellar segment 2.8 times longer than its apical width, equal to second segment. Penultimate segment 1.4 times longer than its width, 0.35 times as long as first flagellar segment, 0.8 times as long as apical segment. Apical segment pointed apically and with short spine.

Mesosoma length 1.5 times its height. Notauli shallow, wide, complete, coarsely rugose-reticulate with granulation. Prescutellar depression deep, almost straight, with five rather fine carinae, rugulose between carinae, 0.4 times as long as scutellum. Scutellum distinctly convex, without lateral carinae, posteriorly with deep and rather short transverse depression divided medially by high carina. Sternaulus shallow, wide, weakly curved, entirely coarsely rugose-reticulate with granulation. Propodeum (in lateral view) roundly convex in anterior half, strongly, weakly curvedly and vertically in posterior half.

Wings: fore wing 3.0 times longer than its maximum width. Radial (marginal) cell narrow and shortened, 3.5 times longer than maximum width. Metacarp (1–R1) 1.1 times longer than pterostigma, 5.0 times longer than distance between top of radial (marginal) cell and top of wing. Radial vein (r) arising behind middle of pterostigma, from its apical 0.4. Second radial abscissa (3–SR) almost equal to first abscissa (r), 0.1 times as long as the weakly curved third abscissa (SR1), 0.4 times as long as first radiomedial vein (2–SR), 0.5 times as long as second radiomedial vein (r-m). Second radiomedial (submarginal) cell short, its length 1.1 times maximum width. Recurrent vein (m-cu) weakly antefurcal. Discoidal (discal) cell shortly petiolate, 1.4 times longer than its maximum width. Distance from nervulus (cu-a) to basal vein (1–M) almost equal to nervulus (cu-a) length. Hind wing 3.8 times longer than wide. Second abscissa of mediocubital vein (1–M) 0.9 times as long as nervellus (cu-a) and basal vein (1r-m).

Legs: hind femur slender, 5.6 times longer than wide. Inner spur of hind tibia about 0.3 times as long as hind basitarsus. Second segment of hind tarsus 0.4 times as long as basitarsus, 1.3 times longer than third segment, 1.8 times longer than fifth segment (without pretarsus). Claws rather slender, weakly curved apically, without lobe or tooth.

Metasoma 1.1 times longer than head and mesosoma combined. First tergum with fine dorsope, with very small spiracular tubercles near its middle, ventral borders of tergum weakly separated at short distance in its basal half. Length of first tergum 2.0 times its apical width; apical width 2.8 times its minimum width. Second suture very shallow, but more or less distinct. Length of second and third terga combined 1.6 times larger than basal width of second tergum, 0.9 times their maximum width. Ovipositor

subapically with distinct dorsal node. Ovipositor sheath 1.25 times longer than first tergum, almost as long as hind femur, 0.65 times as long as costal vein (C+SC+R) of fore wing.

Sculpture and pubescence: frons widely smooth, anteriorly with curved striation and with short striae along the median line. Anterior half of vertex almost smooth, its posterior half densely and distinctly punctate and with rather coarse rugosity laterally. Face distinctly and densely transversely striate with fine granulation; clypeus distinctly punctate-rugose. Temple almost smooth in anterior half and coarsely sub-vertically striate and with dense granulation and rugulosity in posterior half. Median lobe of mesoscutum densely and rather coarsely rugose-granulate, mostly rugose-reticulate in the posterior third; lateral lobes rather distinctly and more or less sparsely punctate, with rugulosity anteriorly, usually smooth between punctulae. Scutellum entirely coarsely rugose-areolate. Mesopleuron entirely coarsely and densely rugose-reticulate, widely with small and dense additional granulation. Propodeum entirely coarsely reticulate-areolate, with rather fine median longitudinal carina. Hind coxa entirely coarsely rugose-reticulate, dorsally with distinct, transverse and weakly undulate striation. Hind femur distinctly and densely punctate, almost smooth below. First metasomal tergum densely and smoothly striate, rugulose-striate in the basal quarter. Remaining metasomal terga smooth. Mesoscutum entirely covered by short and dense pale setae.

Colour: body black, metasoma behind first tergum dark reddish brown, reddish brown posteriorly and ventrally. Antennae entirely black. Palpi reddish brown basally, faintly paler apically. Legs dark reddish brown to reddish brown, hind coxa almost black. Ovipositor sheath dark brown. Wings faintly and evenly infusate. Pterostigma brown, faintly paler basally; costal vein (C+SC+R) almost black.

Variation

Body length 4.3–4.6 mm; fore wing length 3.8–4.0 mm. Transverse diameter of eye (dorsal view) 1.2–1.4 times longer than temple. Ocellar triangle with base 1.3–1.5 times its sides; POL 2.0–2.2 times Od, 1.1–1.3 times OOL, Od 0.55–0.65 times OOL. Malar space height 0.25–0.3 times height of eye, 0.9–1.0 times basal width of mandible. Antenna with 25 ($n = 4$), 26 ($n = 2$) or 27 ($n = 2$) flagellomeres. First flagellar segment 2.7–3.0 times longer than its apical width, 1.0–1.1 times as long as second segment. Penultimate segment 1.4–1.7 times longer than its width, 0.55–0.8 times as long as apical segment. Length of mesosoma 1.5–1.6 times its height. Fore wing 2.9–3.2 times longer than its maximum width. Metacarp (1–R1) 1.1–1.25 times longer than pterostigma, 3.5–5.0 times longer than distance between top of radial (marginal) cell and top of wing. Recurrent vein (m-cu) weakly antefurcal or interstitial. Distance from nervulus (cu-a) to basal vein (1–M) 0.7–1.0 times nervulus length. Hind femur 5.5–6.8 times longer than wide. Second segment of hind tarsus 1.6–1.8 times longer than narrow fifth segment (without pretarsus). Length of first tergum 1.9–2.1 times its apical width; apical width 2.8–3.0 times its minimum width; dorsope more or less distinct. Length of second and third terga combined 1.5–1.6 times larger than basal width of second tergum, 0.9–1.0 times their maximum width. Ovipositor sheath 1.2–1.4 times longer than first tergum, 0.6–0.7 times as long as costal vein of fore wing.

Male. Body length 4.2–4.6 mm; fore wing length 3.6–3.8 mm. Head behind eye (dorsal view) almost parallel-side in anterior half distinctly and almost linearly narrowed in posterior half. Transverse diameter of eye (dorsal view) 1.1–1.2 times

longer than temple. Eye very weakly convergent below (front view of head). Distance between tentorial pits 2.8–3.0 times distance from pit to eye. Width of clypeus 1.7–1.9 times its median height, 0.8–0.85 times minimum width of face. Antenna setiform, with 24 ($n = 15$), 25 ($n = 11$) or 27 ($n = 2$) flagellomeres. Scape 1.3–1.5 times longer than maximum width. First flagellar segment 2.5–2.8 times longer than its apical width, 0.95 times as long as second segment. Apical segment apically without spine. Scutellum less strongly sculptured, rather finely rugulose medially, with curved transverse striae anteriorly. Propodeum with rather distinct median longitudinal carina. Second radial abscissa (3–SR) of fore wing 0.5–0.7 times as long as first abscissa (r), 0.06–0.10 times as long as third abscissa (SR1), 0.2–0.35 times as long as first radiomedial vein (2–SR). Recurrent vein (m-cu) almost interstitial or very weakly antefurcal. Hind femur thicker, 4.8–5.8 times longer than wide. Second segment of hind tarsus 1.4–1.6 times longer than narrow fifth segment (without pretarsus). Metasoma 0.8–1.0 times as long as head and mesosoma combined. First tergum often with distinct spiracular tubercles and more or less distinct dorsope; length of tergum 1.8–1.9 times its apical width; apical width 2.9–3.0 times its minimum width. Length of second and third terga combined 1.4–1.5 times larger than basal width of second tergum, almost equal to their maximum width. Metasoma dorsally entirely black. Otherwise similar to female.

Biology. *M. acerbiavorus* sp. nov. is a gregarious larval parasitoid of *Acerbia alpina* Quensel (Arctiidae) reared from the cocoon of the moth. The parasitoid cocoons (Figure 48) are brown and their sizes are 5.0×1.9 –2.0 mm.

Diagnosis

Meteorus acerbiavorus sp. nov. run in Huddleston's (1980) revision of the western Palaearctic *Meteorus* to *M. rubens* (Nees) (Figures 4A–G, 5C, 5D), which is a widely distributed species in the Palaearctic region (Huddleston 1980; Tobias 1986; Belokobylskij 2000; Chen and Wu 2000). Both species have a low number of antennal segments, the ventral borders of the first tergum joined or almost joined (separated only by approximately 25 μ m), weakly curved toothless claws and medium-sized ocelli. The new species differs from *M. rubens* in having the eyes densely setose (sparsely in *M. rubens*), the median lobe of mesoscutum entirely or mostly rugulose-granulate or granulate (usually widely smooth with punctation in *M. rubens*), the scutellum entirely or at least marginally rugose-areolate (widely smooth in *M. rubens*), the mesopleuron medially entirely or almost entirely coarsely and densely rugose-reticulate with granulation (widely smooth in *M. rubens*), the hind coxa widely coarsely sculptured (widely smooth in *M. rubens*), the ovipositor subapically with distinct dorsal node (small and indistinct in *M. rubens*), the ventral borders of first metasomal tergum weakly separated by narrow space in its basal half (distinctly joined in short submedian part in *M. rubens*), the body entirely or widely black (mostly pale brown or yellowish brown in *M. rubens*), and the fore wing more or less darkened (hyaline in *M. rubens*).

This new species distinctly differs from the North American *M. dimidiatus* (Cresson) (Muesebeck 1923) in having the second abscissa of mediocubital vein (1–M) of hind wing not longer than nervellus (cu-a) and basal vein (1r-m) (longer in *M. dimidiatus*), the eyes weakly convergent below (distinctly convergent in *M. dimidiatus*), the second radial abscissa (3–SR) of fore wing usually equal to the first abscissa (r) (longer in *M. dimidiatus*), and the first metasomal tergum mostly strongly striate

Figure 4. Morphological characters of the female of *Meteorus rubens* (Nees) (photos): (A) habitus, lateral view; (B) head, dorsal view; (C) head, lateral view; (D) head, front view; (E) mesoscutum and scutellum, dorsal view; (F) mesosoma, lateral view; (G) first metasomal tergum, dorso-lateral view.

(finely rugulose-striate in *M. dimidiatus*). This new species is a gregarious parasitoid of arctiid *Acerbia alpina* Quensel in comparison with *Desmia funeralis* (Hübner) (Pyralidae) as a host of solitary *M. dimidiatus*.

Figure 5. Tips of ovipositor, lateral view (photos): (A), (B) – *Meteorus acerbiavorus* sp. nov.; (C), (D) – *M. rubens* (Nees).

Remarks

Studied material of *M. acerbiavorus* sp. nov. reared by three collectors in different time in two localities (Jehkats and Lossujärvi) of Enontekiö Lapland showed distinct differences in the colouration and sculpture of the body. The material by H. Lonka (Jehkats, 2009) (Figure 3A, 3D, 3G, 3J) is almost completely dark and with widely distributed coarse sculpture on mesosoma (including entirely coarsely rugose-striate scutellum). The specimens collected in the same locality by M. Mutanen (2006) (Figure 3B, 3E, 3H, 3K) are also mainly black but with paler red areas on the head behind the eyes and on the metasoma behind the petiole. Scutellum of these specimens medially with smoothed and fine sculpture, mesopleuron usually with more large smooth areas and the basal part of petiole mainly smooth. The most aberrant specimens belong to the material collected by J. Kytömaa (1992) in Lossujärvi (Figure 3C, 3F, 3I, 3L). These specimens have the palest colouration of the body with a red ring around eyes, reddish basal half of petiole and yellowish brown to reddish brown second metasomal tergite, and widely light reddish brown legs. The sculpture of this material is basically less strong having more widely smooth or almost smooth lateral lobes of mesoscutum, posterior areas of mesopleuron and median part of scutellum, and basal 0.3 of petiole. This material also has one female and one male with deformed first tergum, which is short and strongly widened in its distal half.

Discussion

Arctiid host and its parasitoids

The host, *Acerbia alpina* (Quensel) (Arctiidae) (Figure 6A–E), of the new *Meteorus* parasitoid has a circumpolar Holarctic distribution and is known in the northernmost Fennoscandia, Polar Urals and Taimyr Peninsula, from the high mountains of Central Asia (Altai and Sayan) those east of the Baikal Lake, from Kamchatka, Alaska and arctic parts of Canada (Sotavalta 1963, 1965; Hydén et al. 2006). The nominate subspecies of this moth is known from Sweden (only from Nissuntjärro in Abisko area), Norway, Finland and its area reaches northern Ural, Jamal and Taimyr peninsula; in Asia and America it is replaced by three other subspecies. In Finland

Figure 6. Different stages of *Acerbia alpina* (Quensel): (A) adult of *A. alpina*, dorsal view; (B) adult of *A. alpina* on cocoon; (C) full-grown caterpillar; (D) cocoon of the moth in Jehkats; (E) cocoon of the moth infested by parasitoids in Jehkats; (F) opened cocoon of the moth from Lossujärvi with cocoons of *M. acerbiavorus*. Photos (A–E) taken by Harry Lonka, photo (F) by Pekka Malinen.

the species is found only on highest fields of the Kilpisjärvi area (Enontekiö Lapland, EnL) (Marttila et al. 1996). The copulated moth female can lay 150–330 eggs and their polyphagous caterpillars have seven instars. The young instars can over-winter one or several times. Full-grown instars have an obligatory diapause and before pupating it makes a cocoon early in spring (Sotavalta et al. 1980). The typical habitat of this species is a more or less grassy alpine heath with *Cassiope tetragona*, *Polytrichum* spp. and various lichen species (Soininmäki 2007). The pale greyish cocoon (Figure 6D, 6E) is 30.0–40.0 mm long and 15.0–20.0 mm wide, and is attached to

rocks and surrounding vegetation (usually mosses). The moth emerges in two to three weeks after pupation (Figure 6B).

The cocoons of *A. alpina* have attracted many Finnish lepidopterists since the first cocoon was found in 1962 on the top of Saana. The correct biotope of this moth was found by Soininmäki (2007), and in 2003 and 2006 he and his companions found 49 and 61 cocoons respectively at two separate localities (the former was more northern than the later locality). In the material of 2003, 19 cocoons contained living pupa of the moth and 30 were empty or they were parasitized, and in 2006, 30 and 31 cocoons were found accordingly. The cocoons which contained parasitoids were darker in colour than the cocoon of the living moth. These reared parasitoids were named as “some chalcidoids of the superfamily Chalcidoidea” (Soininmäki 2007). Two cocoons contained an empty puparium of a large tachinid.

Some parasitoids of *Acerbia alpina* were previously recorded in the literature. One cocoon found on Herschel Island of Arctic Canada contained parasitoids of *Amblyteles* sp. (Hymenoptera, Ichneumonidae) (Gibson 1920). Sotavalta et al. (1980) informed that single caterpillar yielded tachinid larvae when full-grown. Several cocoons were found by E. Laasonen and others containing a dead larva or pupa of the moth and parasitoid pupal shells. O. Sotavalta found in July 1974 on a cliff edge near a mountain summit in the Utukok River area (NW. Alaska) one large brownish cocoon (possibly belonging to *Acerbia*) which contained a dead caterpillar and two tachinid puparia, from which a number of chalcidoid hyperparasitoids emerged.

The “chalcidoid” parasitoids mentioned by Soininmäki (2007) could be some species of Braconidae, but it is impossible to confirm determination of these parasitoids because all specimens were thrown away (Soininmäki, pers. comm.). Vikberg has examined parasitoids that emerged from 11 different cocoons of *Acerbia alpina* and they all belonged to the same species of *Meteorus*. The only other gregarious braconid wasp that has been reared from the cocoon of *A. alpina* was a *Cotesia* sp. These were collected on July 1999 by K. and T. Nupponen in Krasnyi Kamen (1000 m, Polar Ural of Russia) and 74 males and 114 females of *Cotesia* sp. (Braconidae: Microgastrinae) emerged from this cocoon.

The described *M. acerbiavorus* sp. nov. is the first correctly determined gregarious parasitoid of this large size arctiid moth from the Finnish Lapland. All *Meteorus* species and their closely related taxa are known as parasitoids of coleopteran or lepidopteran larvae. *M. acerbiavorus* quite possibly finished their development and emerged from the last caterpillar instar or prepupa which is situated inside the already produced cocoon of *Acerbia alpina*.

Morphological grouping and molecular phylogeny of Meteorus

In the revision of the Japanese species of the genus *Meteorus* Haliday, Maetô suggested to group together species of this genus into species groups. He included a key of these groups in one of his revision papers on this genus (Maetô 1990a). He designated seven species groups. The largest species group, the *M. pulchricornis* group, was additionally divided into five subgroups. The *M. rubens* group comprises only two species, *M. rubens* (Nees) and *M. heliophilus* Fischer, and is characterized by the synapomorphy: ovipositor distinctly swollen and with a minute dorsal notch on the

apical part (Maetô 1990b). These two species were also known as the only Palaearctic region taxa having gregarious development in exposed-living caterpillars, especially of the Noctuidae. The polymorphic and large *M. pulchricornis* group as well as the *M. ictericus* group are proposed by Maetô (1990b) to be possibly closely related to *M. rubens* group. According to a large molecular analysis containing over 150 specimens of *Meteorus* by J. Stigenberg & Ronquist (in prep.) the members of *M. ictericus* group are placed very far from the *M. rubens* group. In our analysis presented here this is evidenced by the distant placement of *M. ruficeps*, the species closest to *M. ictericus*, to the so called *M. pulchricornis* group.

These species groups suggested by Maetô were later used by J. Chen and Z. Wu in their study of the Chinese species (Chen and Wu 2000). They described a third species within the *M. rubens* group, namely *M. latus* Wu and Chen, from Jilin Province of North-Eastern China.

Additional new gregarious species related with *M. rubens* is described in this paper. Two new cryptic or semi-cryptic species, previously considered as members of the polymorphic *M. rubens*, will be further studied in J. Stigenberg's revision of the European species of *Meteorus* (Stigenberg & Ronquist in prep.). These cryptic or "molecular species" were found when molecular analyses were performed. Within these sequenced Swedish specimens of the "*M. rubens* complex" there are none or only a few unstable external morphological characters for identification. Both the separate and the combined molecular phylogenetic analysis of *M. acerbiavorus* sp. nov. distinctly shows its relation with *M. rubens* sensu lato and its separate basal position in comparison with other *M. rubens* forms. It is important to understand that the gregarious *M. acerbiavorus* sp. nov. is not characterized with the main autapomorphic feature of this group. The ovipositor (second valvula) of *M. acerbiavorus* sp. nov. is wedge-shaped and with a distinct notch in the apical third (Figure 5A, 5B), whereas in the *M. rubens* group the ovipositor is swollen and without or with a minute dorsal notch (Figure 5C, 5D).

Among our specimens of *M. acerbiavorus* there are some morphological differences in structure. We obtained identical sequences of both 28S and CO1 for all of these specimens. Identical sequences can either mean that the specimens really belong to the same, morphologically rather variable species, or it might indicate that the molecular markers used do not evolve at a sufficient speed in this group to provide resolution among closely related species. Another explanation for identical sequences in mitochondrial markers would be inherited endosymbionts like *Wolbachia* (Hurst & Jiggins 2005) which have sometimes been shown to lead to introgression of foreign mitochondria into a different species (Whitworth et al. 2007). Further studies will show whether the variation in structure and colour is indicative of multiple biological species or just shows the variability within *M. acerbiavorus*.

The final combined phylogenetic tree with the two genes COI and 28S D2 (Figure 7) shows that the groups proposed by Maetô (1990b) do not hold with the gene sequence data. On our tree *M. rubens* sensu lato forms a single clade (posterior probability 1.0) with *M. abscissus* Thomson, *M. pulchrichornis* (Wesmael), *M. obsoletus* (Wesmael) and *M. versicolor* (Wesmael) from the *M. pulchrichornis* and *M. versicolor* subgroups of the *M. pulchrichornis* group. Possible autapomorphic characters for this clade with respect to the *M. colon* subgroup are: (1) a short and relatively stout ovipositor and (2) the antefurcal or interstitial position of the recurrent vein (m-cu) in the fore wing, and symplesiomorphic character is weakly convergent or not

Figure 7. Phylogram combined Bayesian analysis with the two genes COI and 28S D2 region using GTR+I+Gamma model. *Centistes* Foerster (Euphorinae) used as outgroup. Values at nodes indicate posterior probability. Branch lengths are proportional to estimated change.

convergent eyes in anterior view. The molecular data additionally show that the character of a joined ventral margins of the first tergum (not joined at all or either joined at the basal half or just medially) appeared/disappeared several times during the evolution of the *Meteorus* taxa [see Figure 4G, the species *M. abscissus* (not joined) and *M. pulchricornis* (joined medially), *M. versicolor* (joined at the basal half) and *M. rubens* (joined medially)].

The aforementioned groups and subgroups are distinctly separated at the molecular level from other species groups used for the present study [*M. micropterus* Haliday, *M. tabidus* (Wesmael), *M. obfuscatus* (Nees) and *M. vexator* Haliday]. The divergence of *M. micropterus* is supported morphologically by the large and not twisted mandibles. The placement of the other three species is supported by: (1) first tergum not joined below the ventral margins; (2) the presence of distinct dorsope; and (3) the weakly twisted mandibles. A combined phylogenetic analysis based on both morphological and molecular evidence, on as many *Meteorus* species as possible from different populations, may help to understand the real contents of the species groups as well as their relationships.

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Appendix

Species used in the analysis

The taxa included in the molecular analysis with their ID numbers (abbreviation n.a. means “not available”).

Taxa	NHRS-HYME ID	DNA voucher nr	28S D2	COI	Combined
Centistes	n.a	AB071	X	X	X
abscissus	5126	104	X	X	X
abscissus	5216	162	X	X	X
abscissus	5214	177	X	X	X
acerbiavorus	5223	179	X	X	X

(Continued)

Appendix. (Continued).

Taxa	NHRS-HYME ID	DNA voucher nr	28S D2	CO1	Combined
acerbiavorus	5222	180	X	X	X
acerbiavorus	5246	183	X	n.a	-
acerbiavorus	5241	185	X	X	X
acerbiavorus	5247	187	X	X	X
acerbiavorus	5245	188	X	n.a	-
cinctellus	5076	24	X	X	X
cinctellus	4916	53	X	X	X
cinctellus	4915	54	X	X	X
colon	5097	60	X	X	X
colon	5099	62	X	X	X
micropterus	5106	69	X	X	X
micropterus	5107	70	X	X	X
obfuscatus	4979	22	X	X	X
obfuscatus	5158	141	X	X	X
obsoletus	5007	13	X	X	X
pulchricornis	5027	15	X	X	X
pulchricornis	5149	129	X	X	X
rubens	5212	163	X	X	X
rubens	5215	178	X	X	X
ruficeps	5048	71	X	X	X
sp. aff. abscissus	4891	10	X	X	X
sp. aff. cinctellus 1	5177	2	X	X	X
sp. aff. cinctellus 2	n.a	16	X	X	X
sp. aff. cinctellus 2	5052	17	X	X	X
sp. aff. cinctellus 2	n.a	119	X	X	X
sp. aff. cinctellus 2	5213	173	X	X	X
sp. aff. cinctellus 3	n.a	4	X	X	X
sp. aff. cinctellus 3	5073	5	X	X	X
sp. aff. cinctellus 3	5170	19	X	X	X
sp. aff. cinctellus 3	5175	20	X	X	X
sp. aff. cinctellus 3	5172	78	X	X	X
sp. aff. cinctellus 3	5125	100	X	X	X
sp. aff. cinctellus 3	5128	105	X	X	X
sp. aff. obfuscatus	n.a	102	X	X	X
sp. aff. rubens 1	5140	120	X	X	X
sp. aff. rubens 1	5141	121	X	X	X
sp. aff. rubens 2	5142	122	X	X	X
sp. aff. rubens 2	5143	123	X	X	X
tabidus	5058	18	X	X	X
versicolor	5065	21	X	X	X
versicolor	5148	128	X	X	X
versicolor	5150	130	X	X	X
versicolor	5151	131	X	X	X
vexator	5108	72	X	X	X