

DISCRIMINATING CHARACTERS IN CENTRAL EUROPEAN SPECIES OF *ECDYONURUS* EATON

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At present no key exists comprising all Central European species of *Ecdyonurus*. In the following paper the reliability of discriminating characters is discussed for *E. venosus*, *E. forcipula*, *E. macani*, *E. torrentis*, *E. starmachi*, *E. aurantiacus*, *E. ruffii*, *E. dispar*, *E. submontanus*, *E. subalpinus*, *E. picteti*, *E. helveticus*, *E. austriacus*, *E. zelleri*, *E. insignis*. Characters examined include colouration, morphological structures, phenology, ecological aspects, size and possible artifacts. All of them show a fairly wide range of variation and only for few species is identification rendered possible by a single character. Based on the results of the foregoing study a combination of characters is used to provide a key for male imagines and last instar nymphs.

INTRODUCTION

The genus *Ecdyonurus*, established by EATON in 1868 and restricted by ZURWERRA & TOMKA (1985) is represented by about 31 species in Europe, at least 15 of them distributed in Central Europe. Notwithstanding the fact that all of them have been described or redescribed within the last 30 years, diagnosis on species level is still considered to be difficult; routine determination in the applied sciences including ecological, faunistical and saprobiological investigations is hampered by the lack of a key for nymphal and imaginal stages. Preparations for a key for the Austrian species of Ephemeroptera (BAUERNFEIND, 1994, 1995) provided an opportunity to examine a comparatively large material and led to an overall evaluation of the discriminating characters already in use. No attempt has been made to apply statistical methods; the material available is not sufficiently homogenous to render an analysis of variation mathematically meaningful. Figure numbers in the text refer to the figures in BAUERNFEIND (1995).

MATERIAL

The following collections have been used: Naturhistorisches Museum Wien, Oberösterreichisches Landesmuseum Linz, the collection of the late Dr. G. Pleskot (now in the care of Dr. Humpesch, Mondsee) and the author's collection.

E. aurantiacus (BURMEISTER, 1839): numerous nymphs, 31♂, 5♀ (Austria, Czechia).

E. austriacus KIMMINS, 1958: numerous nymphs and imagines (Austria).

E. dispar (CURTIS, 1834): numerous nymphs (Austria, Germany, Czechia) and imagines (Austria, Czechia).

E. forcipula (PICTET, 1843-1845): 3♂, 4 nymphal exuviae; France (Pyrenees), leg. Thomas.

E. helveticus (EATON, 1885): 15 nymphs, 11♂ (Austria), 4 nymphs, 4♀ (Switzerland).

E. insignis (EATON, 1870): numerous nymphs and imagines (Austria).

E. macani THOMAS & SOWA, 1970: numerous nymphs (Austria, Germany) and imagines (Austria).

E. picteti (MEYER-DÜR, 1864): numerous nymphs and imagines (Austria).

E. ruffii GRANDI, 1953: 3 nymphs, 1♂, 2♀ (partly on slides; France, leg. Fontaine) and 3♂ (Austria).

E. starmachi SOWA, 1971: numerous imagines and nymphs (Austria, Slovakia).

E. subalpinus (KLAPALEK, 1907): numerous nymphs, 3♂ (Austria)

E. submontanus LANDA, 1969: numerous nymphs and imagines (Austria).

E. torrentis KIMMINS, 1942: numerous nymphs (Austria, England, Germany), 6♂, 5♀ (Austria, Slovakia).

E. venosus (FABRICIUS, 1775): numerous nymphs and imagines (Austria, Germany, Czechia).

E. zelleri (EATON, 1885): numerous nymphs and imagines (Austria).

The nomenclature generally follows PUTHZ (1978) with the exception of *E. austriacus*, which is currently considered a distinct species after the revision by HEFTI & TOMKA (1986). The species group name *E. ruffii*, established by Martha GRANDI (1953) in honour of Professor Sandro Ruffo, represents the original spelling and is therefore to be preserved unaltered according to article 32(b) of the International Code of Zoological Nomenclature. Correctness of the original spelling in the sense of the Code is not invalidated by incorrect latinization or use of an inappropriate connecting vowel [ICZN 32(ii)]; the original author, when forming the genitive case directly from a modern personal name, determines the stem of that name [ICZN 31(ii)]. It is clearly evident that Grandi intended to use Ruffius as latinized form for the Italian name Ruffo and no inadvertent error can be proved. *Ecdyonurus ruffii* is therefore the correct original spelling, the spelling «*E. ruffoi*» (proposed by BELFIORE & D'ANTONIO, 1991) must be rejected as an unjustified emendation [ICZN 33(iii)]. Until fur-

ther evidence is available the views of THOMAS (1968) expressed in his redescriptions of *E. forcipula* and *E. venosus* have been adopted for the present purpose (cf. BAUERNFEIND, 1990). Nevertheless adequate nomenclatural decisions may be necessary in the future based on a synoptic revision of the genus *Ecdyonurus*.

At present two groups (without nomenclatural consequences) are commonly recognized: «venosus»-group and «helveticus»-group. Two further group names have been proposed: «forcipula»-group (JACOB & BRAASCH, 1986) and «corsicus»-group (BELFIORE, 1987, extralimital). Assignment of species to groups is not entirely consistent within different authors. HEFTI & TOMKA (1988) as well as BELFIORE & BUFFAGNI (1994) recently subdivided the «helveticus»-group in East-European and West-European species. Until a revision of all European species gives further evidence, grouping in *Ecdyonurus* must be considered somewhat provisional; in the following the term «helveticus»-group is used in the sense of the last revision by HEFTI *et al.* (1989). Characters used to separate the species groups in *Ecdyonurus* are discussed below.

CHARACTERS USED FOR SPECIES-GROUPS

Nymphs

Number of comb-shaped bristles on the maxilla: In the «helveticus»-group 20 comb shaped bristles or more (JACOB & BRAASCH, 1984, auct.sequ.) and in the «venosus»-group less than 20 (usually 14-19) are considered typical. In the material examined 20-22 bristles have been observed exceptionally also in *E. venosus* and, more frequently, in *E. submontanus*. For the latter LANDA (1970) described a range of 22-24 bristles.

Bristles on distal edge of hypopharyngeal superlinguae: In the «venosus»-group the dense pilosity reaches well over the apex of the superlingua, in the «helveticus»-group there are only a few, short hairs in the apical region. No exceptions were found in the material examined.

Strong bristles on ventral side of labrum: Bristles along the sides of the ventral groove of the labrum: are either stout, somewhat curved and arranged in one row («venosus»-group) or relatively weak, straight and arranged in a (sometimes irregular) double row, the latter feature characterizing the «helveticus»-group (BELFIORE & BUFFAGNI, 1994). The character was consistent in the material examined.

Hairs on the outer margin of maxilla: BELFIORE & BUFFAGNI (1994) found more than 3 hairs on the outer margin of maxilla in the «venosus»-

group and 0-2 in the «helveticus»-group. The character is sometimes very difficult to see; in the material examined the range seemed rather wide and no regular distribution to groups could be confirmed.

Imagines

Inner apical sclerite of penis: In the «venosus»-group it is straight, conical and orientated along the body-axis. In the «helveticus»-group the apical sclerite is laterally elongated, with a sharp angle in middle and covering about half the distal margin of the penis lobes (BOGOESCU & TABACARU, 1962).

Colouration: With exception of *E. subalpinus* (and extralimital members of the group) abdominal colouration is almost uniform within West European species of the «helveticus»-group and lacks the oblique pleural stripe that is more or less pronounced in species of the «venosus»-group. The abdominal ganglionic chain is usually not pigmented in the «venosus»-group (few exceptions in the material examined) while species of the «helveticus»-group show distinct violet pigmentation over the entire length.

CHARACTERS USED ON SPECIES LEVEL

Nymphs

Since LESTAGE (1917, 1919) numerous characters have been used to separate *Ecdyonurus* nymphs on the species level.

Colouration: With the exception of *E. insignis* (well known black pattern on abdominal sternites) no specific pattern of colouration could be found (cf. RAWLINSON, 1939). In some species characteristic subimaginal colouration is clearly visible under the nymphal cuticle of last instar nymphs: oblique lateral stripes on abdominal pleurae are obvious in *E. aurantiacus* and *E. dispar*, in *E. ruffii* the dorsal abdominal triangles are discernible (Fig. 321).

KIMMINS (1942) drew attention to tarsal colouration. In typical specimens tarsi show dark pigmentation either over the total length (most species), on the basal and distal part (*E. torrentis*, *E. dispar*; less pronounced in *E. macani*, *E. aurantiacus*) or on the distal part only (*E. venosus*). Although the character must not be

neglected, unequivocal determination is frequently impossible; in few specimens atypical colouration could be observed.

Shape of head: KIMMINS (1942) et auct. sequ. found the sides of the head somewhat flattened in *E. torrentis* but more rounded in *E. venosus*. Intermediate forms are not uncommon and make many cases somewhat doubtful.

Length of antennae: Mentioned by LESTAGE (1917, 1919) but distinct differences could not be confirmed.

Mouthparts: Labrum: The relation between total breadth and distance between the insertions has been successfully used to separate *E. dispar* and *E. aurantiacus* (THOMAS, 1968). Labrum in *Ecdyonurus* is relatively weakly chitinized and is often subject to distortions in microscopical slide preparation. Shape and size ratio should therefore be observed in situ. Differences have been found between most species examined and although the range of variation seems considerable, further investigations are necessary. The shape of the strong bristles on the ventral side of the labrum (group character) is also slightly different but provided no reliable character for species separation during the present study.

Mandibles: «Teeth» on outer and inner incisor show no significant differences (cf. MACAN, 1949). The number of bristles on the left prostheta was without exception found to be higher than on the right prostheta. The thin and often bifid bristles are sometimes difficult to count and in a few cases the exact number remained doubtful. Nevertheless differences in the number of bristles of the left prostheta were obvious between some species, although considerable overlap was observed. Lowest numbers were found in *E. dispar* and *E. aurantiacus* (5-9, usually 7) and highest in *E. starmachi* and *E. venosus* (8-17, usually 13); most species show a range of 6-12 (usually 9) bristles.

Maxilla: The number of comb-shaped bristles (group character) seems not significantly different between species, but constantly lower numbers (14-17) have been found in *E. aurantiacus*, *E. dispar*, and *E. ruffii*. Most species of the «venosus»-group have 17-19 bristles whereas 20-24 are typical for the «helveticus»-group. For *E. venosus* and *E. submontanus* see number of comb-shaped bristles on the maxilla. Little difference was found in the number of

pointed teeth on the 5th comb-shaped bristle within species (usually about 15); only 7-10 teeth were observed in *E. ruffii*, but material was very limited. Generally those teeth are very delicate and difficult to count and their number changes from inner to outer end of the row.

Labium: Shape of glossae (THOMAS, 1968; HEFTI et al., 1988). Differences were difficult to assess and showed considerable overlap within the material examined.

Pronotal projections: In full grown (last instar) nymphs pronotal projections are usually characteristic (Figs 219-232). Little overlap has been observed between species in «venosus»-group, more so in «helveticus»-group. Shape of outer margin, apex, direction and length of projection in relation to breadth of semipronotum (a:b; Fig. 218) provide useful characters for species separation (except *E. venosus* / *E. torrentis*). The ratio total breadth: total length of half pronotum (MACAN, 1949: Fig. 1) was usually less distinctive. Differences in measurements taken from slide mounts, exuviae or in situ conditions have to be considered. For standardizing, slide preparation with maximum flattening of (half) pronotum should be preferred showing characters most markedly for comparison and repeatability.

Lateral abdominal projections: For comparison the 5th sternite (slide preparation of exuvia) was used (Figs 237-242). Ratio of length: basal breadth may help to single out *E. macani* (usually 1:1) within the «venosus»-group, but variation seems considerable and there may be also secondary sexual differences. Direction and ratio length of projection to total length of sternite has also been used as discriminating character (*E. macani* / *E. torrentis*; *E. ruffii*). In the «helveticus»-group lateral projections are generally shorter and almost uniform between species.

Hind margin of tergites: Allows immediate separation of *E. austriacus* (and *E. parahelveticus*, *E. alpinus*; not included in present study). No distinctive differences have been found in the material examined.

Gills: Presence of a tuft of filaments on gill 7 immediately singles out *E. insignis*. The shape of gill 1 is a useful additional character for most species in the «venosus»-group (Figs 202-210), less so in the «helveticus»-group. Length to

(maximum) breadth ratio showed considerable overlap between species and was of very limited use; in *E. aurantiacus* the usual ratio found was 2,2-2,6 and in *E. macani* 2,3-2,8 but shape of gill 1 immediately separates the two species. Relation length of gill 1 to length of longest gill (usually gill 4 or 5) was used by MACAN (1949) and FONTAINE (1964), but found of little value in the material examined. For the separation of *E. zelleri* and *E. helveticus* the number of filaments on gill 1 (BELFIORE & BUFFAGNI, 1994) was used as a differentiating character while HEFTI *et al.* (1989) tried length: width ratio of gill 4; both characters seem subject to considerable variation but nevertheless useful in typical specimens. The shape of gill 7 may also be sufficiently stable to provide an additional character for at least some species.

Ratio length: breadth of hind femora: The character should be sufficiently stable to provide additional information to distinguish at least some species. Care has to be taken because of considerable differences between measurements in situ and those taken from slide mounts; there were also slight indications for differences between sexes. General shape (especially symmetry) may also be characteristic, e.g. whether the hind femur is widest in its middle or distal part (cf. HEFTI *et al.*, 1989).

Bristles on surface of femora (Figs 233-236): The character has been proven useful in the «venosus»-group but shows a wide range of variation. The shape of bristles often changes from the proximal to the distal part and may be misleading in younger larvae (cf. PUTHZ, 1973). Differences between fore, middle and hind legs are also sometimes characteristic (e.g. *E. macani*). Long acutely pointed bristles on all femora are typical for most species in «venosus»-group. In *E. dispar* they are clearly stouter, in *E. ruffii* long with slightly blunt points. Clearly spatulate bristles (although sometimes quite narrow) are found in *E. aurantiacus* and *E. starmachi* usually on all femora, but in *E. macani* mainly on the fore femora. Microscopical preparation is sometimes necessary to distinguish between apically broken (orabraded) bristles and spatulate ones. Differences are distinctive when considering the general impression, occasional occurrence of atypically formed bristles should not be significant. In the «helveticus»-group the tips

of femoral bristles are more or less markedly rounded or spatulate and generally only of very limited use in species separation.

Bristles on hind margin of femora: short stout bristles on the ventral side near hind margin (Fig. 216) are to be found in most species, but not in *E. helveticus*, *E. zelleri* and *E. austriacus*. Tarsal claws: number of teeth on tarsal claws shows considerable intraspecific variation but usually «trends» are discernible; the character may be of use as an additional character at least in some populations. Indications for sexual dimorphism have been reported by THOMAS & SOWA (1970).

Subimagines

Wings: In most species subimaginal wings are of mottled appearance, sometimes distinctly banded (*E. torrentis*, *E. austriacus*) or almost uniformly dark grey (*E. zelleri*); intergrading patterns are not uncommon, but typical specimens are easily discerned.

Abdominal colour pattern: Generally colour patterns are less marked than in imagines, but in many cases sufficiently characteristic to allow assignation to species. Very little differences are found within most members of the «helveticus»-group.

Male genitalia: The group character on the inner apical sclerite of the penis is discernible but specific characters are only weakly developed, often rendering decision doubtful.

Imagines

Size: Although both wing length as well as body length show fairly wide intraspecific variation, still size may be used (with caution) as a helpful additional character; sexual size dimorphism has to be considered and in species with a prolonged flight period specimens caught later in the season usually are smaller (especially marked in *E. venosus*).

Colouration: Colour patterns are generally little developed in the «helveticus»-group, but are group-specific except in *E. subalpinus* (and extralimital East European species which exhibit a similar pattern within the sub-group). Sufficiently stable differences are found in the «venosus»-group. Well marked characteristic pattern on sternites (*E. insignis*, Fig. 322) or tergites (*E. ruffii*, Fig. 321) allows easy separa-

tion of these species. Pleural stripes are superficially similar in most species but closer inspection shows different basic patterns useful for the separation of confusing species.

Wings: Marked differences in colouration of longitudinal and transversal veins easily distinguish *E. aurantiacus* (THOMAS, 1968; PUTHZ, 1973). Otherwise wing venation provides no differentiating characters, the number and arrangement of crossveins in the pterostigmatic area is highly variable (although extent of branching may be typical for some populations).

Eyes: There are slight differences in shape and colouring (presence or absence of stripes) observable in the complex eyes of males, but intraspecific variation and post mortem changes are considerable. In the «venosus»-group the complex eyes of males are usually touching or almost touching, whereas they are clearly separated in *E. starmachi*, the space between their inner borders is almost equal to the breadth of the middle ocellus.

Foreleg in males: length relation between different parts (tibia: tarsus, first: second tarsal joint) has been used widely for species separation in Ephemeroptera. Reliability especially in *Ecdyonurus* has been rejected (among other characters) by RAWLINSON (1939) and HARKER (1986); in the material examined no evidence for clearcut differences could be found and the character should be only of limited value.

Male genitalia: The shape, presence or absence of projections on hind margin of styli (forceps base, Figs 326-328) may be used with caution as additional character in some species, but deviations from the typical situation are numerous (*E. venosus*, *E. dispar*, *E. submontanus*, *E. austriacus*). Outward shape of penis (slightly different in dorsal and ventral view) and structure offer various discriminating characters (Figs 323-339). Penes are liable to deformations, either after copulatory movements (cf. HARKER, 1986) or during handling; slide preparation almost always leads to artificial distortions, especially when freshly collected material is mounted. Also critical-point-drying for electron microscopy not infrequently causes artifacts. Folds in sclerites, or titillators orientated other than parallel, are typical symptoms for distortion and in such cases general shape and structure has to be interpreted with great caution. Care must also be taken to orientate the

penis in a way that avoids any foreshortening of the lobes during examination.

Besides the specifically typical outline also the general shape of the lateral sclerite and inner apical sclerite (group character) are distinctive. In the «helveticus»-group the basal sclerite offers additional features.

PHENOLOGY

All species examined are supposed to be univoltine (LANDA, 1968), but *E. venosus* may either develop two generations a year under favourable conditions or show prolonged time of flight due to retarded hatching (end of April to beginning of November). Although flight time is to a certain extent variable between different sampling localities depending on environmental parameters, most species are on the wing only for a comparatively short period of the year. Emergence of typical spring species (*E. torrentis*, *E. macani*, *E. starmachi*, ?*E. subalpinus*) shows practically no overlap with summer species (*E. dispar*, *E. aurantiacus*, *E. submontanus*, *E. insignis*, ?*E. ruffii*). No such differences have been observed in members of the «helveticus»-group with strictly mountainous distribution, obviously due to the short time of suitable climatic conditions in their habitat. At least in some cases however the date of capture should help to check correctness of determination.

ECOLOGICAL RANGE

Although relatively little is known about ecological ranges in mayflies, rough limits for vertical distribution and typical habitats can be assumed for most of the species examined, excluding at least part of them for a given locality (BAUERNFEIND *et al.*, 1995).

Large summer warm streams and rivers up to 300 m above sea level (Epi- Metapotamal) are typical for *E. ruffii*, *E. aurantiacus* and *E. insignis*, the latter reaching higher upstream. In rivers of the colline region (Meta-Hyporhithral) *E. venosus* and *E. dispar* are common, sometimes associated with *E. torrentis*, *E. macani* and *E. insignis* in smaller numbers. Relatively summer warm becks and

brooks between 200 to 700 m a.s.l. are inhabited by *E. subalpinus*, *E. macani* and *E. starmachi*, *E. venosus* preferring the colder types of similar watercourses. The habitat preferences between *E. venosus* and *E. torrentis* mentioned by MACAN (1949) from the British Isles could not be confirmed for Central Europe, the latter species seems generally less common in this area and more patchily distributed. Highland rivers (often slightly acidic) between 400 and 800 m a.s.l. may hold *E. submontanus*, sometimes associated with *E. dispar* and *E. venosus*. Cold torrents and rivers of a more alpine character above 800 m a.s.l. are typical for *E. picteti*, *E. zelleri* and *E. austriacus*, the latter colonizing cold rivers descending from higher mountain slopes down to about 400 m a.s.l., meeting the upstream range of *E. venosus*. *E. helveticus* and *E. forcipula* seem restricted to streams in high mountain regions well above 1200 m above sea level.

CONCLUSIONS

No clearcut meristic characters could be found to separate the 15 examined species of *Ecdyonurus*. Intraspecific variation seems considerable and descriptive characters show with few exceptions a certain degree of overlap. Nevertheless all species are clearly defined by a combination of characters in nymphal and imaginal stages as well. For correct separation on species level it seems advisable, to take into consideration as many character states as possible to create a species profile that allows an adequate interpretation.

APPENDIX

Key to last instar nymphs

- 1 Surface of all femora exclusively with pointed bristles. Notch on ventral side of labrum with one row of stout, slightly curved, bristles 2
- Surface at least of fore femora with spatulate or apically clearly rounded bristles. Notch on ventral side of labrum with one or two rows of strong bristles 8
- 2(1) Abdominal sternites with obvious pattern (blackdots and stripes, Fig. 322). Gill 1-7 with a bunch of filaments *Ecdyonurus insignis*
- (1) Abdominal sternites without clearly defined pattern. Gill 1-6 only with a bunch of filaments 3

- 3(2) Pronotal projections slightly directed outwards (Fig. 220). Under the nymphal cuticle an obvious subimaginal pattern on abdominal tergites discernible (Fig. 321) *Ecdyonurus ruffii*
- (2) Pronotal projections directed parallel to body axis or slightly bent inwards. No obvious subimaginal pattern on abdominal tergites 4
- 4(3) Pronotal projections short (Figs 226, 230), a:b > 3:1. Hind femora relatively slender, at least three times as long as broad. Length of body usually 10-12 mm 5
- (3) Pronotal projections markedly longer (Figs 219, 221), a:b < 3:1. Hind femora broader, less than three times as long as broad. Length of body usually above 12 mm 6
- 5(4) Gill 1 very broad (Fig. 208). Sides of pronotum strongly rounded (Fig. 226). Tarsi darkened in proximal and distal part. Tarsal claws with 3 teeth *Ecdyonurus dispar*
- (4) Gill 1 very narrow (Fig. 202). Sides of pronotum less rounded (Fig. 230). Tarsi uniformly dark. Tarsal claws with two teeth *Ecdyonurus submontanus*
- 6(4) Left prostheca with less than 10 bristles. Tarsi darkened in proximal and distal part. Tarsal claws usually with three teeth. Gill 7 parallel sided *Ecdyonurus torrentis*
- (4) Left prostheca with more than 10 bristles. Tarsi uniformly dark or darkened in distal part. Tarsal claws usually with two teeth. Gill 7 spatulate, apically slightly broader 7
- 7(6) Pronotal projections directed parallel to body axis, bluntly pointed at apex (Fig. 219). Lateral abdominal projections of fifth sternite long, about one third of length of sternite. Tarsi darkened in distal part *Ecdyonurus venosus*
- (6) Pronotal projections slightly bent inwards, broadly rounded at apex. Lateral abdominal projections of fifth sternite short, about one fourth of length of sternite. Tarsi uniformly dark *Ecdyonurus forcipula*
- 8(1) Hypopharyngeal superlinguae with dense pilosity reaching well over apex (Fig. 211). Maxilla usually with less than 20 comb-shaped bristles. Ventral notch of labrum with one row of stout, slightly curved, bristles 9
- (1) Hypopharyngeal superlinguae at apex only with few short hairs (Fig. 212). Maxilla usually with more than 20 comb-shaped bristles. Ventral notch of labrum with two rows of straight bristles («helveticus»-group) 11
- 9(8) Outer margin of pronotum strongly curved. Pronotal projections short (Fig. 227), a:b > 3:1. Subimaginal pattern (oblique violet stripe) on abdominal pleurae obvious. Gill 1 very broad, broadly rounded at apex (Fig. 209) *Ecdyonurus aurantiacus*
- (8) Outer margin of pronotum only slightly curved. Pronotal projections longer. Abdomen without obvious subimaginal pattern. Gill 1 somewhat triangular, tapered at apex 10

- 10(8) Length of body usually less than 12 mm. Pronotal projections slightly bent inwards (Fig. 229). Left prostheca with more than 12 bristles. Spatulate bristles on surface of all femora. Tarsal claws with two teeth *Ecdyonurus starmachi*
- (8) Length of body usually more than 13 mm. Pronotal projections orientated parallel to body axis (Fig. 223). Left prostheca with less than 10 bristles. Spatulate bristles on surface of fore femora only. Tarsal claws usually with three teeth *Ecdyonurus macani*
- 11(8) Hind margin of abdominal tergites with pointed teeth only (Fig. 217a) 12
- (8) Hind margin of tergites with broadly rounded triangular teeth, intersected by smaller pointed teeth (Fig. 217b) *Ecdyonurus austriacus*
- 12(11) Ventral side of hind femora near hind margin with a row of short stout bristles (Fig. 216) 14
- (11) Ventral side of hind margin of hind femora without a row of short stout bristles 13
- 13(12) Gill 1 relatively narrow, at least three times longer than broad. Pronotal projections rounded at apex (Fig. 224) *Ecdyonurus picteti*
- (12) Gill 1 shorter, about 2.5 times longer than broad. Pronotal projections asymmetrically pointed, inner side strongly curved (Fig. 222) *Ecdyonurus subalpinus*
- 14(12) Gill 1 usually with relatively few (<30) filaments, gill 4 usually two times longer than broad (Fig. 213). Outer margin of pronotum distinctly curved, broadly rounded at apex (Fig. 225). Body size smaller than 12 mm *Ecdyonurus zelleri*
- (12) Gill 1 usually with more (>40) filaments. Gill 4 relatively narrow, seldom two times longer than broad (Fig. 214). Outer margin of pronotum only slightly curved (Fig. 231), pronotal projection pointed at apex. Body size longer than 12 mm *Ecdyonurus helveticus*
- (2) Abdominal tergites without triangular pattern 4
- 4(3) Longitudinal veins in forewing yellowish brown, transversal veins black. Penis (Fig. 332) *Ecdyonurus aurantiacus*
- (3) Wing venation of forewing almost unicolourous, no striking differences between longitudinal and transversal veins 5
- 5(4) Lobes of penis laterally distinctly expanded, almost rectangular or «boot»-shaped. Styliger (forceps base) with or without projections 6
- (4) Lobes of penis laterally less expanded, triangular or rounded. Styliger (forceps base) always with projections (Fig. 328) 7
- 6(5) A distinct step between lateral and basal sclerite (Fig. 329). Apical sclerite obtuse, moderately projecting. Styliger usually without projections (Fig. 326). Abdominal pleurae with reddish-purple triangular spot *Ecdyonurus venosus*
- (5) A slight notch between lateral and basal sclerite. Apical sclerite pointed, distinctly projecting and curved outwards. Styliger usually with projections. Abdominal pleurae with indistinct brown spot or stripe *Ecdyonurus forcipula*
- 7(5) Lateral sclerite broad, almost quadrangular 8
- (5) Lateral sclerite narrower, at least twice longer than broad 9
- 8(7) Projections of styliger (forceps base) usually concave on inner margin, asymmetrical (Fig. 327). Lobes of penis broadly rounded (Fig. 334). Abdomen yellowish, with marked oblique dark stripes on pleurae *Ecdyonurus dispar*
- (7) Projections of styliger usually very prominent and narrow. Lobes of penis laterally triangular (Fig. 335). Abdomen sepia coloured, pleurae with indistinct darker brown stripes *Ecdyonurus submontanus*
- 9(7) Fore legs and dorsal side of thorax almost black. Penis (Fig. 330) *Ecdyonurus macani*
- (7) Fore legs and dorsal side of thorax light brown 9

Key to imagines

- 1 Apical sclerite of penis conical, without lateral elongation (Fig. 323). Abdominal ganglionic chain usually without distinct violet pigmentation («venosus»-group) 2
- Apical sclerite of penis narrow, clearly bent and elongated laterally, covering about half of the distal margin (Fig. 325). Abdominal ganglionic chain usually with distinct violet pigmentation («helveticus»-group) 11
- 2(1) Abdominal sternites with obvious black pattern (Fig. 322), penis (Fig. 324) *Ecdyonurus insignis*
- (1) Abdominal sternites without clearly marked black pattern 3
- 3(2) Abdominal tergites with characteristic triangular pattern (Fig. 321), penis (Fig. 323) *Ecdyonurus ruffii*
- 10(9) Fore wings longer than 13 mm. Penis lobes clearly triangular, hind margin of lateral sclerite straight (Fig. 331). Abdominal tergites yellowish with reddish brown marks on anterior border *Ecdyonurus torrentis*
- (9) Fore wings shorter than 12mm. Penis lobes laterally rounded, hind margin of lateral sclerite sinous (Fig. 333). Anterior border of abdominal tergites yellowish without reddish brown markings *Ecdyonurus starmachi*
- 11(1) Lobes of penis clearly rounded, apical sclerite regularly curved, pointed at distal end (Fig. 325). Abdominal segments yellowish, tergites on posterior margin bordered with black *Ecdyonurus subalpinus*
- (1) Lobes of penis laterally enlarged. Apical sclerite angular, broadly rounded at distal end. Abdominal seg-

- ments reddish brown, not bordered with black. Abdominal pleurae with light «L»-shaped pattern 12
- 12(11) Apical sclerites slightly bent, their posterior borders forming an obtuse angle (Fig. 336). Projections of styliiger (forceps-base) prominent with inner margin concave *Ecdyonurus austriacus*
- (11) Apical sclerites almost rectangular, their posterior borders forming a straight line. Projections of styliiger less prominent with inner margin straight or convex 13
- 13(12) Basal sclerite with prominent teeth orientated obliquely to axis of symmetry (Fig. 338) *Ecdyonurus picteti*
- (12) Basal sclerite with less prominent teeth orientated perpendicularly to axis of symmetry 14
- 14(13) Lobes of penis clearly expanded laterally and beak-shaped. Lateral sclerite slender, situated near basal sclerite. Basal sclerite narrow (Fig. 337) *Ecdyonurus helveticus*
- (13) Lobes of penis less expanded laterally, trapezoidal with obtuse lateral borders. Lateral sclerite broad, situated in middle of lobe. Basal sclerite broad, triangular (Fig. 339) *Ecdyonurus zelleri*

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