The immature stages of *Elachista zonulae* (Sruoga, 1992) (Lepidoptera: Elachistidae)

Tomasz Baran

Baran, T. 2009: The immature stages of *Elachista zonulae* (Sruoga, 1992) (Lepidoptera: Elachistidae). — Entomol. Fennica 20: 239–244.

The morphology of larva and pupa, as well as larval mines of *Elachista zonulae* (Sruoga, 1992) are described and illustrated for the first time. *Carex firma* Host is reported as a new host plant of the species; previously only *Carex sempervirens* Vill. was known to be host plant of *E. zonulae*. Some information on life history of this elachistid moth is also provided. The mature larva is 4.5–5.5 mm long. Pupation takes place usually at base of leaf blade of the food plant. The species is univoltine and hibernates as young larva.

T. Baran, University of Rzeszów, Department of Invertebrate Zoology, Cegielniana 12, 35-959 Rzeszów, Poland; E-mail: tbaran@univ.rzeszow.pl

Received 12 November 2008, accepted 13 January 2009

1. Introduction

A local, xeromontane elachistid moth *Elachista zonulae* has relatively recently been described from Central Asia (Sruoga & Puplesis 1992). In Europe, it has so far been recorded only from mountains of Slovakia, Poland (Tokár *et al.* 1999, Tokár *et al.* 2002, Baran 2003), Austria, and France (Kaila & Varalda 2004) where it was encountered at altitudes from about 1,000 to about 1,900 m above sea level. However, almost nothing has hitherto been known about preimaginal stages of this micro-moth, i.e. merely one mountain *Carex* species – *C. sempervirens* Vill. was given as larval food plant by Baran (2003). In this paper a detailed account of the morphology and biology of developmental stages of *E. zonulae* is presented.

Within the family Elachistidae *s.s.*, the taxon belongs to the *juliensis* subgroup of the *tetragonella* group. This subgroup has for a long time been taxonomically very confused, and only lately the status of some of its members has been clarified by Kaila & Varalda (op. cit.).

2. Material and methods

The study was conducted in the Białego Valley (950 m) and the Sarnia Skała Mt. (1,350–1,370 m) during 2004–2007 (Poland, the Tatra Mts.; UTM grid system – DV 25).

For morphological research, 20 larvae, 14 pupae, and 16 mines on *Carex firma* of *Elachista zonulae* were examined. The chaetotaxy was studied after maceration of larvae in 10% KOH. Terminology used for preimaginal structures mainly follows Hinton (1946), Hasenfuss (1980), Patočka (1999), and Baran (2002).

Abbreviations: T1–T3 – thoracic segments 1–3; AI–AX – abdominal segments I–X.

3. Results

3.1. Morphology of last instar larva (Figs 1–4)

Length 4.5–5.5 mm. Body dark olive, usually with faint yellowish tint; dorsal line whitish or

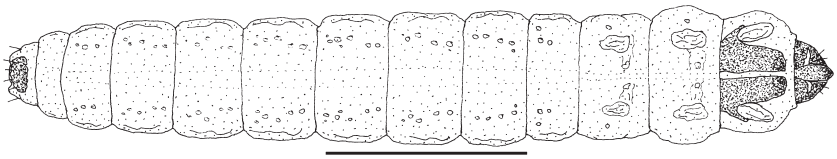

Fig. 1. Mature larva of *Elachista zonulae*. Scale bar 1.3 mm.

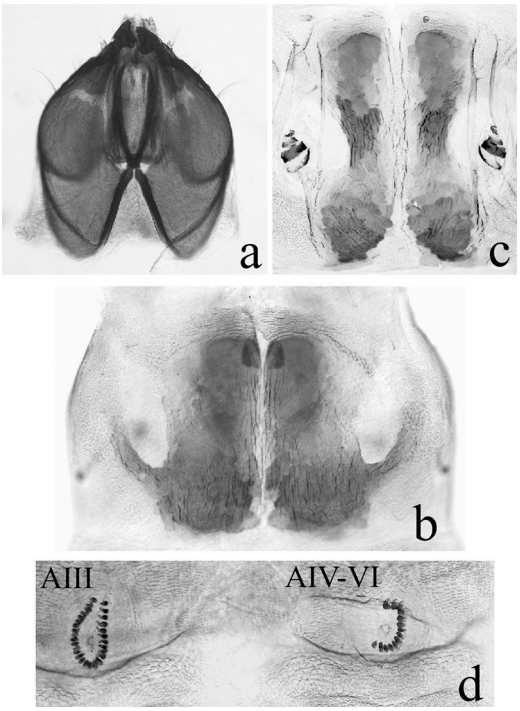

Fig. 2. Larval structures. – a. Head. – b. Dorsal prothoracic shield. – c. Ventral prothoracic shield. – d. Crochets of ventral prolegs.

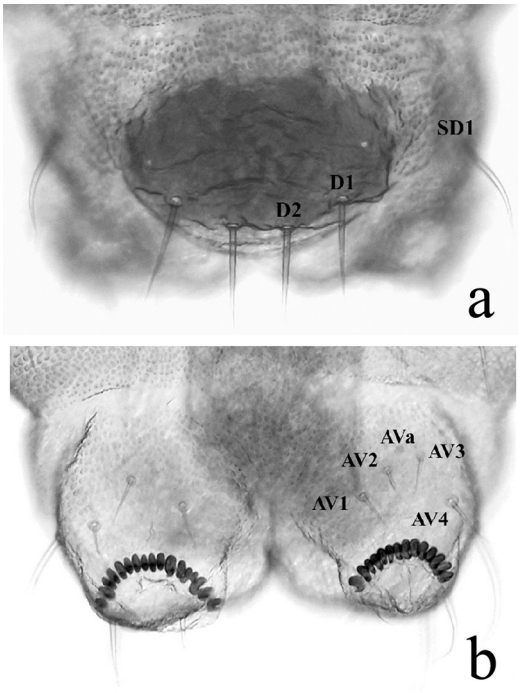

Fig. 3. Larval abdominal segment X. – a. Dorsal view. – b. Ventral view.

whitish green especially on abdominal segments, narrow on thorax, and rather indistinct, broadened on abdomen. Head clearly tapered, generally dark brown, but frons often somewhat paler; adfrontal lines and their lateral branches whitish (Fig. 2a). Dorsal prothoracic shield (Fig. 2b) consists of two, well sclerotized plates; the single plate more or less trapezoid or rectangular, with narrow, lateral, oblique extension at about posterior 1/3, very dark brown, but sometimes darker at most anterior area. Ventral prothoracic shield (Fig. 2c) divided into two longitudinal sclerites; the sclerites narrow but distinctly bulbous in posterior part, somewhat paler than dorsal prothoracic shield, especially in posterior part. Anal shield (Fig. 3a) comparatively large, well sclerotized, more or less rounded laterposteriorly, coloured like dorsal prothoracic shield or somewhat paler, sometimes darker at edges. On pro-, meso-, and metathorax, ovoid, slightly depressed areas present; integument of these areas generally lacks microsculpture. Sclerites of thoracic legs distinct, dark brown; legs of T1 clearly smaller than those of T2–3. Crochets of ventral prolegs uniordinal; those of AIII arranged in ellipse, but its inner part with small gap, and those of AIV–AVI arranged in a posterior arc, i.e. there is large anterior gap, and only sometimes a few crochets in anterior section may be present on AIV (Fig. 2d).

Chaetotaxy (Figs 3a–b and 4). T1. – XD1, D1, D2, and MXD1 on prothoracic shield; D1 and D2 almost in vertical line; XD1 anterior to D2. XD2, SD1, SD2 somewhat ventral to prothoracic shield; SD2 (very small seta) dorsoposterior to SD1; SD1 closer to SD2 than to XD2. L group

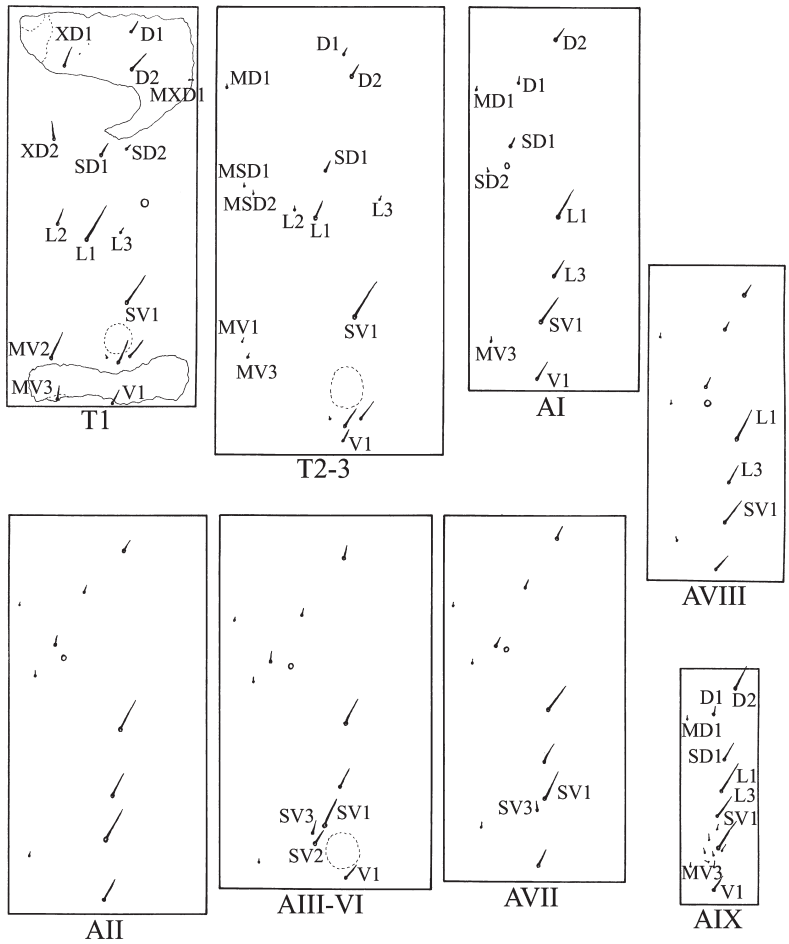

Fig. 4. Setal map of last instar larva of *E. zonulae*.

trisetose; L2 and L3 (very small seta) dorsal to L1. SV1 above coxa. MV2 and MV3 (not proprioreceptors) almost in vertical line. V1 posterior to MV3. T2–3. – D1 (very small seta) dorsal and somewhat anterior to D2. SD group unisetose (SD2 absent). L group trisetose; L2 and L3 very small setae; L1 closer to L2 than to L3. SV1 dorsal to, and V1 ventral to coxa. On the segments, proprioreceptors MD1, MSD1, MSD2, MV1, and MV3 present; MV1 and MV3 close to each other, in oblique line. AI. – D1 ventroanterior to D2. SD group bisetose; SD1 more or less dorsal to spiracle; SD2 (very small seta) ventroanterior to SD1, and more or less anterior to spiracle. L group bisetose; L1 and L3 almost in vertical line; L3 shorter than L1. SV1 and V1 almost in vertical line. On the segment proprioreceptors MD1 and MV3 occur. AII. – Arrangement of the setae similar to that of the previous segment, but MD1 more remote from D1, and SD1 and SD2 more anteroventral to spiracle. AIII–VI. – Arrangement of MD1, D, SD, and L groups similar to that of AII. SV group trisetose; SV3 and SV2 shorter than SV1. MV3 anterior and dorsal to V1. AVII. – Arrangement of MD1, D, SD, and L groups similar to that of AIII–VI. SV group bisetose; SV3 (small seta) ventroanterior to SV1. MV3 anterior and between SV3 and V1. AVIII. – Generally, arrangement of the setae similar to that of the previous segment, but SV group unisetose. AIX. – D group bisetose; D1 (small seta) anteroventral to D2. MD1 more or less anterior to D1. SD1 ventral and slightly posterior to D1. L group bisetose; L3 somewhat shorter than L1. L1, L3, SV1 and V1 almost in vertical line. MV3 anteroventral to SV1. On the segment, some small setae scattered next SV1. AX. – On the anal shield, only D1 and D2 setae,

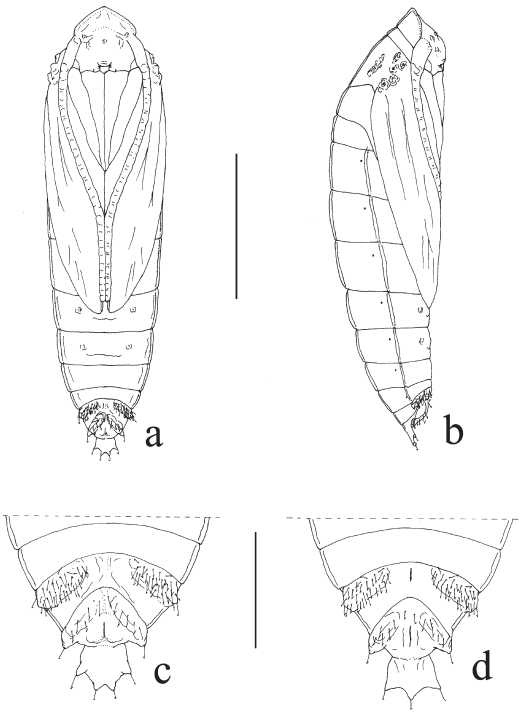

Fig. 5. Pupa. – a. Ventral view. – b. Lateral view. – c. Caudal part of female abdomen. – d. Caudal part of male abdomen. Scale bar 1.2 mm for (a–b) and 0.4 mm for (c–d).

Fig. 6. Immatures of *E. zonulae*. – a. Pupa. – b. Mature larva within mine on leaf of *Carex firma*.

as well as a pore present. SD1 ventral to the shield. AV1 and AV4 more caudally and more remote from each other than AV2 and AV3; AVa more or less anterior to and between AV2 and AV3.

3.2. Morphology of pupa (Figs 5a–d and 6a)

Length 3–3.7 mm. Body pale brown, ridges and ventral side of abdomen may be paler (beige brown), with two dark brown, rather wide lateral streaks on dorsal side. The streaks running from mesonotum to last segment of the abdomen, and narrowing towards mesonotum and caudal end (dark streaks widest on AI–AIII). Vertex somewhat protruding over frons; from ventral view, it forms triangular in outline hood. Labrum well indicated, triangular caudally, situated deeper in relation to somewhat protruding clypeus. Antenna with small protrusions, ends somewhat before forewing apex, reaches it, or rarely extends slightly beyond the apex; both antennae meet somewhat beyond midlength of forewings. Proboscis extends somewhat beyond 1/3 forewing length. Foreleg somewhat shorter than proboscis. Midleg ends somewhat beyond half of forewing length. Forewing with some convex veins, more clearly indicated in basal area. The wing ends about midlength of AV or reaches its posterior margin. Hindwing runs slightly beyond anterior margin of AII. Hindtarsus sometimes visible next to antenna apex. On the ventral side of AV–AVI, proleg scars present. Female genital opening usually indistinct, and male one well-defined, comma-like situated on AIX near posterior margin of AVIII. Ventrolaterally, AIX with elongate, oblique areas densely covered with short hook-like setae. From ventral view, AX well-demarcated, semi-triangular in outline, laterally with oblique, more or less projected protrusions sparsely covered with hook-like setae; the segment laterocaudally produced into 2, more or less conical protrusions ending with hook-like setae; on the other hand, dorsomedially, AX produced into plate-like cremaster bearing usually 4 (rarely 3) small, finger-like extensions (2 ones caudally, and 2 ones more laterally) ending with setae;

Fig. 7. Larval mines of *E. zonulae* on leaves of *Carex firma*.

cremaster directed caudally or caudoventrally. Pupa bears rather sharp main ridges. Dorsal ridge runs from vertex to AX, and lateral ridges run from AII to AIX. Abdominal spiracles as small protrusions placed somewhat dorsally to lateral ridges (the spiracles of AII and AVIII situated closer to the ridges than the others). On mesonotum, about midlenght and on either side of dorsal ridge, 1 short, elongate nodule-like ridge present; more laterally, 1 elongate (close to anterior margin) and a few more or less rounded nodules developed.

3.3. Bionomics

The flat egg is laid in basal part of leaf of *Carex firma*. The initial mine is thin, *Stigmella*-like, often meandering up and down. Then it gradually widens generally towards leaf tip. When the larva reaches the area situated near leaf tip, it starts mining downward. The mine may occupy distally the entire or almost entire leaf width; its most distal part is often divided into a few galleries. The whole mine frequently takes almost the total leaf length (on an average it is 3.5–6 cm long). The mine is somewhat wrinkled especially on the distal surface, and for the most part it is filled with rather dense frass (Figs. 6b and 7). Proximal part of the mine is pale brown, often more or less tinged with red especially along the edges; distal part of the mine is whitish or whitish green, full-depth and fairly transparent (older mines are generally pale brownish). The larvae can sometimes change the leaves. Because *Carex firma* forms dense tufts and has short and stiff leaves, mines of *E. zonulae* are rather difficult to detect. In the nature, pupae may be found in basal parts of leaves on which larvae were mining, as well as in basal parts of dry or fresh intact leaves of *Carex firma*. The pupa is attached to a substrate by the caudal end of abdomen and silken girdle that is situated between AIV and AV or AV and AVI; sometimes the larvae pupate also under very loose cocoon composed of only few silk filaments. In the captivity, pupal stage lasts 11–12 days. In the Tatra Mts., mature larvae were found from last days of May to the first half of June. Thus, it is thought that the species is single-brooded, and overwinters as young larval stage. *E. zonulae* inhabits rather open, xerothermic grasslands on calcareous ground; larvae are often met mining *Carex firma* growing directly on exposed rocks (Fig. 8).

Fig. 8. Habitat of *E. zonulae* in Poland – the Sarnia Skała Mt. in the Tatra Mountains.

4. Discussion

Generally, literature information on morphology of immature stages of Elachistidae *s.s.* is scant. This situation concerns especially detailed chaetotaxy of larvae that is almost unknown. On the other hand, pupal morphology of many Central European species has been examined a short

time ago by Patočka (1999). For this reason, it is difficult to compare larval stage of *E. zonulae* with that of other related species. On the basis of author's unpublished data, larva of this elachistid species superficially is most similar to larva of *E. occidentalis* Frey, 1882. However, the larva of the latter has paler head (pale brownish), and its dorsal prothoracic shield bears shorter and weaker lateroposterior projections. Besides, *E. zonulae* can be differentiated from some other members of the *tetragonella* group, such as *E. cinereopunctella* (Haworth, 1828), *E. albidella* Nylander, 1848, *E. utonella* Frey, 1856, *E. trapeziella* Stainton, 1849, and *E. serricornis* Stainton, 1854 first of all by its general shape of the dorsal prothoracic shield (Fig. 2b).

As regards chaetotaxy, a distinct ventral position of D1 in relation to D2 on AI–VIII is probably phylogenetically valuable feature. Such position of D setae has hitherto been found also in *E. nolckeni* Šulcs, 1992 (Baran 2002) that is distantly related species to *E. zonulae*. Therefore, it could not be excluded that this character state may prove to be important in the phylogeny of the family. All relatives of the family Elachistidae *s.s.* have a position of these setae typical in Lepidoptera, i.e. D1 is placed more dorsally than D2. However, it is must be added that this condition is found within genus Elachista too – e.g. in *E. baltica* Hering, 1891 (Baran & Buszko 2005). Moreover, the presence of a few additional small setae close to SV1 of AIX is also a peculiar characteristic of *E. zonulae* larva. These setae perhaps belong to so-called secondary setae, and if such, they would have been discovered in the family for the first time. Interestingly, on the anal shield of the species there are only two setae and one pore (on each side); a position of the pore corresponds to position of D3 seta of many other elachistids (T. Baran, unpublished), and most likely it represents an 'evolutionary remainder' of the seta. Thus, the pore is not homologous with a pore that can be often encountered in many larvae of Lepidoptera that have four setae (SD1, D1, D2, D3) and one pore on the anal shield.

Considering a phenetic aspect of pupae, *E. zonulae* is very similar to *E. occidentalis*, the pupa of which is, however, often longer and has usually ill-defined cremaster projections especially those placed most caudally. On the other hand, the pupae of *E. cinereopunctella, E. albidella, E. utonella,* as well as *E. trapeziella* posses a more or less elongated cremaster without projections, and *E. serricornis* lacks this structure at the caudal end of the abdomen (Patočka 1999, T. Baran, unpublished).

Finally, it is worth noticing that *E. zonulae* is till now the only known micro-moth in Europe whose larvae mine leaves of *Carex firma*. Even as, the species is also found mining on *Carex sempervirens* (Baran 2003) this sedge species seems to be merely a facultative host plant of *E. zonulae*.

Acknowledgements. I would like to thank Dr. Lauri Kaila (Finland) and an anonymous reviewer for their valuable comments on the manuscript.

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