Revision of the *Hylaea fasciaria* (Linnaeus, 1758) species group in the western Palaearctic (Lepidoptera: Geometridae, Ennominae)

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**Abstract**

The Palaearctic *Hylaea fasciaria* (Linnaeus, 1758) species group is revised (Lepidoptera: Geometridae, Ennominae). Four taxa are considered valid at species level: *H. fasciaria* (Linnaeus, 1758), *H. pinicolaria* (Bellier, 1861), *H. compararia* (Staudinger, 1894) and one new species, *H. mediterranea*, from Italy: Sicily, Calabria and Molise. The following taxonomic changes are proposed: *Ellopia cedricola* Wehrli, 1919, from Turkey is downgraded to subspecies of *Hylaea fasciaria* (Linnaeus, 1758) (revised status), *Hylaea fasciaria cleui* Leraut, 1993, from France is downgraded from subspecies to synonymy with *H. fasciaria fasciaria* (Linnaeus, 1758) (new synonymy) and *Ellopia compararia* Staudinger, 1894, from Algeria is raised from subspecies of *Hylaea fasciaria* (Linnaeus, 1758) to species status (revised status). *Hemithea squalidaria* O. G. Costa, 1848 from southern Italy was placed in the genus *Hylaea*, but it is reverted to its original combination as its taxonomic status is uncertain. Adults, male and female genitalia and distribution maps are illustrated for all species. DNA barcodes are presented for most taxa studied.

**Key words:** new species, new status, new synonymy, revised status, DNA barcode

**Introduction**

The geometrid genus *Hylaea* Hübner, 1822 has been considered to contain 13 putative species in the Palaearctic, the Nearctic and in the Neotropical regions (Scoble 1999). This view was questioned by Pitkin (2002), who noted that all Neotropical species placed in *Hylaea* appear not to belong to the genus, and true members of the genus are restricted to the Palaearctic region. This view was not adopted by Scoble and Hausmann (2007), who listed 12 putative species; virtually the same as Scoble (1999), except removing the Mexican *H. myandaria* (Walker, 1860) from the list. When Leraut (2009) proposed *Pungeleria poeymirouaui* (Oberthür, 1922), described from Morocco, to be transferred to *Hylaea*, and *H. compararia* to be downgraded to a subspecies of *H. fasciaria* (Linnaeus, 1758), the number of putative *Hylaea* species is four, with few taxa whose taxonomic status is uncertain.

The species of the Palaearctic *Hylaea fasciaria* (Linnaeus, 1758) species group (Geometridae: Ennominae) are diagnosable by external characters. The species are medium-sized, wingspan being about 30–40 mm. Wings are various shades of green, red-brown to greyish, forewings have rather straight, whitish medial and postmedial lines and hindwings have whitish postmedial line. The caterpillars are needle-mimics (illustrated for instance in Ebert 2003; Porter 2010; Lepiforum 2013), and those have been recorded to feed on conifer trees, *H. fasciaria* mostly on *Pinus sylvestris*, *Picea abies*, *Abies alba* and on *Larix* (Mikkola et al. 1989, Ebert 2003) and *H. pinicolaria* on *Pinus laricio* (Bellier 1861; Robinneau 2007). Adults are nocturnal.

Three holistic views on the Palaearctic *Hylaea fasciaria* species group exist. Prout (1912–1916) considered...
three taxa valid at species level: *H. fasciaria* (Linnaeus, 1758), *H. pinicolaria* (Bellier, 1861) and *H. compararia* (Staudinger, 1894). Further two taxa were combined to *Hylaea*, but the genus association was uncertain: *H. squalidaria* O. G. Costa, 1848 from southern Italy and *H. duponti* (Mabille, 1906) from Spain. Prout clearly mentions (p. 322) that the latter is most likely misplaced in *Hylaea*.

Wehrli (1929) considered four taxa valid at species level: *H. compararia* (Staudinger, 1894), *H. fasciaria* (Linnaeus, 1758), *H. cedricola* (Wehrli, 1929) and *H. pinicolaria* (Bellier, 1861). He also illustrated lateral photographs of the male genitalia of these four taxa, showing that the morphological differences among the taxa are minimal. *Ellopia duponti* Mabille, 1906, which is illustrated in Culot (1919–1920), was proposed to be a junior synonym of *Adalbertia castiliaria* (Staudinger, 1900). No original material on *H. squalidaria* was available for study, and on the basis of original description (O. G. Costa 1848), Wehrli considered it potentially closely related to *H. compararia*.

Later Wehrli (1939–1954) repeated the above-mentioned findings, including a note that no further information on *H. squalidaria* has surfaced. *Hylaea* has recently been classified to the Ennominae tribe Campaeini (Vives Moreno 1994; Viidalepp 1996; Leraut 1997; Hausmann et al. 2011).

**Material and methods**

The study is based on materials housed at the following collections. The type material examined is specified under each taxon. BMNH, The Natural History Museum, London, United Kingdom; Fiumi, Private collection of Gabriele Fiumi, Forlì, Italy; Flamigni, Private collection of Claudio Flamigni, Bologna, Italy; Müller, Private collection of Bernd Müller, Berlin, Germany; P. Sihvonen, Private collection of Pasi Sihvonen, Veikkola, Finland; Skou, Private collection of Peder Skou, Vester Skerninge, Denmark; ZMH, Zoological Museum, University of Helsinki, Finland; ZSM, Zoologische Staatssammlung München, Germany. The study focuses on the Palaearctic taxa of the *Hylaea fasciaria* group; the habitus-based definition is given in the introduction. We have excluded the Moroccan *H. poeymiraui* (Oberthür, 1922) from this study, because it does not confirm with the habitus-based definition, but we acknowledge that it is closely related as it shares with the focal group similar male genitalia, including the aedeagus with an additional arm (illustrated in Leraut 2009).

Distribution maps are based on examination of authentic specimens, and they were created by compiling label data from collection specimens. These data were supplemented by adding data from recent faunistic inventories of Norway (Aarvik et al. 2000), Finland (Hulden et al. 2000; Kullberg et al. 2001), the Netherlands (Anonymous 2013), Austria (Huemer & Malicky 2009), Spain (Redondo et al. 2009), United Kingdom (Hill et al. 2011) and south-western Germany (Ebert 2003). The taxa were delimited on the basis of combining data from morphology, biology and DNA barcodes. The genitalia and the abdomen were prepared following methods described by Hardwick (1950). The aedeagus was photographed during dissection, and afterwards the vesica was everted from the same sample. The method allows documentation of uneverted and everted vesica from a single specimen. The male vesica was everted via the caecum that was cut open by placing the aedeagus inside a hypodermic syringe (Sihvonen 2001).

For the DNA analyses, one or two legs were removed from each dried specimen and stored in an individual tube, which in most cases contained ethanol. DNA extraction, amplification, and sequencing of the barcode region of the mitochondrial cytochrome c oxidase I (COI) gene (658 base pairs) were carried out in the Canadian Centre for DNA Barcoding, Ontario, Canada, using standard high throughput protocols (Ivanova et al. 2006; deWaard et al. 2008), those are described at CCDB (2013). Sequence divergence within and between species was calculated using the Kimura 2-parameter model (Kimura 1980) and the neighbour-joining algorithm (Saitou & Nei 1987), as implemented in BOLD (http://www.boldsystems.org/).

**Results and discussion**

The examined material illustrates that in the Palaearctic *Hylaea fasciaria* group both male and female genitalia are uniform, differences between the taxa are minute, and these structures were found to be not very informative to
distinguish taxa at species or subspecies level. The same applied both to the external and internal genitalia structures. The differences are mostly quantitative, and variation is found in the shape of valva, distribution of cornuti on vesica, shape of additional arm of the aedeagus, size of the signum, degree of sclerotisation of the lamella antevaginalis and overall size of the female genitalia. Certain structures in the genitalia pictures (e.g., the uncus and valva shape), appear slightly different, but those are not diagnostic in the species level unless specifically mentioned. Many of these structures vary within species, but intraspecific variation is not illustrated. Further, the structures may be slightly distorted under the coverglass, giving skewed impressions.

External characters, most notably the habitus, were found to be more diagnostic and provide more detailed resolution between the taxa. This is an unusual trait in the Geometridae, as typically the genitalia provide further diagnostic differences, even more so, than the external features. DNA barcodes proved useful, providing detailed information, which were in agreement with the external characters. Interspecific distances were found to range from 3.3% to 4.0% in the three examined species of this genus whilst their mean intraspecific variation ranges from 0.0% to 0.21% (average 0.13%).

The caterpillars of the taxa, whose biologies are known, feed exclusively on needles of conifer trees. Few taxa appear monophagous, restricted to one tree species only, but this is potentially an artefact resulting from insufficient data. The caterpillars of *H. fasciaria* have been recorded to feed on numerous conifer trees, for instance on *Pinus sylvestris,* *Picea abies,* *Abies alba* and on *Larix* (Mikkola et al. 1989; Ebert 2003). Little is known about potential regional host-plant preferences of certain populations.

Four taxa are considered valid at species level: *H. fasciaria* (Linnaeus, 1758), *H. mediterranea* new species, *H. pinicoloria* (Bellier, 1861) and *H. compararia* (Staudinger, 1894). *Hemithea squalidaria* O. G. Costa, 1848 from southern Italy was placed in the genus *Hylaea,* but it is reverted to its original combination as its taxonomic status is uncertain.

**Taxonomy**

*Hylaea fasciaria* (Linnaeus, 1758)

*fasciaria fasciaria* Linnaeus, 1758, Syst. Nat. (Ed. 10) 1: 521, (*Phalaena* (*Geometra*)). Europe. (Holo)type female (Linnean Society of London, UK) (examined externally).

*biliosata* Villers, 1789, Linn. ent. 2: 386, pl. 6, fig. 22 (female), (*Phalaena* *alaena* *Geometra*). Syntype(s), [France]: Bressia (=Bresse, near Lyon). Scoble (1999) gave the type locality as [Italy]: Brescia, but this is incorrect.


*neutriaria* Hufnagel, 1767, Berlin Mag. 4 (5): 520, (*Phalaena*). Syntype(s), [Germany]: Berlin region.

*prasinaria* Denis & Schiffermüller, 1775, Ankündung syst. Werkes Schmett. Wienergegend: 96, (*Geometra*). Syntype(s), [Austria]: Vienna district. [Junior primary homonym of *Phalaena Geometra prasinaria* Hufnagel, 1767.]

*prosapiaria* Linnaeus, 1758, Syst. Nat. (Ed. 10) 1: 522, (*Phalaena* *Geometra*). Syntypes (Linnean Society of London, UK), Europe [probably near Åbo (=Turku, Finland)] (examined externally).

*rufofasciosa* Esper, 1794, Die Schmett. 3 Suppl. (5–6): 58, pl. 90, pl. 4, 5, (*Phalaena* *Bombyx*).

*viridifasciosa* Esper, 1794, Die Schmett. 3 Suppl. (5–6): 58, pl. 90, figs 6, 7, (*Phalaena* *Geometra*). Syntypes male, female, [Europe].

*fasciaria cedricola* Wehrli, 1929, Mitt. Münch. Ent. Ges. 19: 319, pl. 24, fig. 3; pl. 25, fig. 9, 10, (*Ellopia*). Syntypes 9 males, 2 females (Zoologisches Forschungsinstitut und Museum Alexander Koenig, Bonn, Germany), [Turkey (former Syria)]: Achyr Dagh, Bertiz Jala, 1800 m (examined, including genitalia) [originally as sp., downgraded from species rank (Scoble 1999)] [revised status]. Herewith downgraded from species to subspecies rank quoting the absence of differential features in the genitalia and the exact barcode-sharing with *H. fasciaria.* See subspecies description below.


**Description.** **External characters and pregenital abdomen** (diagnostic characters underlined) (Figures 1, 6): Wingspan male 27–35 mm, female 34–39 mm. Ground colour variable (see Variation), dominant colours being different shades of reddish-brown and green. Medial lines often whittish (see Variation). Medial line angled before
costa, basal part moves away from costa (not parallel with costa). Postmedial line angled before costa, weakly angled outwards oninner margin. Medial area often slightly darker than rest of wing, narrowest in middle. Hindwings with postmedial line visible only. Terminal line and fringes near forewing apex normally concolorous with wings. Hindwing postmedial line distinct, curved. Discal spots absent. Wings below as above, but paler. Frons pale-brown to brown-red, thorax and abdomen concolorous with wings. Area between antennae (vertex) white. Antennae white dorsally, male antennae bipectinate, female antennae weakly fasciculate. Hindleg tibia of both sexes with 2+2 spurs. Tymanal organs medium-sized. Stermites and tergites 3–8 of both sexes undifferentiated.

**Male genitalia** (diagnostic characters underlined) (Figure 10): Uncus setose, subapical part rather wide, apex short, roundish. Socii small, setose. Gnathos absent. Valva narrow, apex wider dorsally, sparsely setose. Valva with subapical spine (occasionally with two spines) in ventral margin. Valva base with narrow, symmetric, sclerotised extension. Transtilla wide plate, anterior margin with two concavities. Juxta small, with two setose patches. Saccus very elongated, weakly curved laterally. Aedeagus narrow, caecum long. Aedeagus with straight additional arm, distance between aedeagus and additional arm narrow, apex not expanded, weakly dentate. Vesica opens at approximately 90 degrees angle. Vesica evenly narrowing tube, base with straight row of microcornuti.

**Female genitalia** (diagnostic characters underlined) (Figure 14): Papillae anales wide, setose. Apophyses posteriores long, straight. Apophyses anteriores about 1/4 length of apophyses posteriores. Lamella postvaginalis large, horizontally striated, partly sclerotised. Lamella antevaginalis often large, margin roundish, weakly sclerotised ridge. Sterigma with membranous, flower-like frill. Ductus bursae short, weakly sclerotised laterally. Posterior part of corpus bursae narrow, rather long, sclerotised, surface granulate. Anterior part of corpus bursae round, membranous. **Signum absent or minute, roundish.**

**Distribution** (Figure 18). Eurasian. In Europe from northern Scandinavia to central Iberian peninsula, central Italy and Greece and from British Isles to Ural mountains. In central Italy the species occurs surely in Tuscany and in the northern Marche, while the identity of specimens from Abruzzo must be confirmed by further research. Outside Europe eastwards through southern Siberia to Transbaikal (Dahuria) and Sakha regions East of Lake Baikal, in Caucasus region (subspecies *flavella* (Wehrli)) and Turkey (nominate subspecies in the north-westernmost part). In the rest of Turkey replaced by subspecies *cedricola* (Wehrli).

**Phenology.** Bivoltine. In southern Europe from April to May, and from August to September (Robineau 2007; Redondo *et al.* 2009), in central Europe from May to October, distinction between generations not clear (Ebert 2003). In northern Europe (data from Finland, Figure 19), from mid-May to October, distinction between generations not clear (Finnish Entomological database 2013). Caterpillar overwinters.

**Biology.** Caterpillar feeds on the needles of *Pinus sylvestris*, *Picea abies*, *Abies alba*, *Larix decidua* (Mikkola *et al.* 1989; Ebert 2003; Robineau 2007). Subspecies *cedricola* (Wehrli) has been reared in captivity on *Pseudotsuga menziesii* (Bernd Müller, pers. comm.). Adults are nocturnal, attracted to light.

**Habitat.** Coniferous forests, and less frequently in areas with coniferous trees such as Nordic wetlands. Altitude range from sea level to 1300 m in central Europe (Ebert 2003) and up to 2300 m in the Pyrenees (Redondo *et al.* 2009).

**Similar species.** All four species in Palaearctic *Hylaea fasciaria* species group are similar. The diagnostic, external characters shown in Figures 6–9 are somewhat tentative and should not be used in isolation, but should be combined with information on biology, collecting locality, male and female genitalia and DNA barcodes. An overview of diagnostic morphological features is given in Table 1.

**Genetic data.** Genetically comparatively homogeneous in Europe and Transcaucasia (n=40, from 11 countries), mean intraspecific variation 0.21%, maximum variation 1.71%. The taxon *cedricola* from Turkey exactly barcode-sharing (n=10), mean intraspecific variation 0.13%, maximum variation 0.46%. Nearest species: *Hylaea mediterranea* (minimum pairwise distance 3.3%). See Figure 26.

**Variation** (Figure 1). Highly variable. Ground color varies from grey-reddish to dark grey, to yellowish-green and to various shades of green. Various shades of reddish-brown are dominant in northern Europe, and in northern parts of Scandinavia only these colours exist, whereas in southern Europe various shades of green (*f. prasinaria*) are dominant. In many areas both colour morphs coexist. Position, width and colour of medial lines variable, those often stand out weakly in reddish-brown specimens, being almost concolorous with wings, grey or blueish-grey. In green specimens the medial lines are usually white, thinner in females. Numerous infrasubspecific forms have been described, those are summarised in Prout (1912–1916), Wehrli (1939–1954) and in Leraut (2009). *H. fasciaria* ssp. *cedricola* (Wehrli) (Figures 1h, 1i) has wings rather dark green, medial lines are whitish and close to each other.

Forewing margin is weakly concave below apex. Only green specimens are known. We retain taxon valid at subspecies level, due to the concave forewing margin, the narrow medial area and the conspicuous transverse lines not reaching the forewing costa. The taxon is, according to current knowledge, allopatric and restricted to Turkey (and Near East?). *H. fasciaria* ssp. *flavella* (Wehrli) (Figure 1e) has wings grey-yellowish, and forewing medial line is not visible near costa. We have not had access to extensive materials from the Transcaucasus, apart from two specimens from Georgia. Those were DNA barcoded, and they grouped together with other *H. fasciaria* specimens. The type specimen of *flavella* has not been located (collection is not mentioned in the original description), thus we have not been able to establish the identity of the Georgian specimens relative to *flavella*. We follow Wehrli (1939–1954, p. 507), who cited Heydemann (1942), in his decision to raise the taxon to subspecies rank, and retain taxon valid at subspecies level. The taxon is, according to current knowledge, allopatric and restricted to Armenia (Transcaucasus). Scoble (1999) did not mention the taxon at all, Viidalepp (1996) consided it valid at subspecies level.

**Remarks.** *H. fasciaria* ssp. *cleui* Leraut, illustrated in Leraut (2009) and Hausmann (2001; fig. 66), (Fig. 1g is also close) is downgraded from subspecies rank to junior synonym to the nominal subspecies of *H. fasciaria* (Linnaeus). Wings are purple-pink to crimson-red and medial lines are ash grey. Taxon is known from southern French Alps. In the adjacent Valesia (southern Switzerland, >200 specimens examined in the ZSM) such forms are dominant but mixed with green and red forms, potentially supporting the existence of a cline. This indicates that *cleui*, although locally dominant phenotype, does not constitute a subspecies because it lacks disjunct external features, and it is questionable whether the southern French Alps populations are geographically isolated from other populations in the Alps. DNA barcodes are not available, so far, for French Alps populations.
FIGURE 18. Distribution area of *Hylaea fasciaria* (Linnaeus) in the West Palaearctic region. The distribution area, where the species occurs frequently, is shown in grey. The examined records, which appear outside that area, are shown in black symbols.

Table 1. An overview of diagnostic morphological features in the Palearctic *Hylaea fasciaria* species group. See Figures 1–9 for the external characters, 10–13 for the male genitalia and 14–17 for the female genitalia. The shape and size of the lamella antevaginalis in the female genitalia is variable, and should be treated with caution.

<table>
<thead>
<tr>
<th>Character</th>
<th><em>H. fasciaria</em></th>
<th><em>H. mediterranea</em></th>
<th><em>H. pinicolaria</em></th>
<th><em>H. compararia</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>forewing medial line</td>
<td>angled, not parallel with costa</td>
<td>curved, not parallel with costa</td>
<td>curved, parallel with costa</td>
<td>weak, not parallel with costa</td>
</tr>
<tr>
<td>forewing postmedial line</td>
<td>angled at costa, angled outwards near inner margin</td>
<td>weakly angled at costa, evenly curved near inner margin</td>
<td>angled at costa, evenly curved near inner margin</td>
<td>weak, straight</td>
</tr>
<tr>
<td>hindwing postmedial line</td>
<td>distinct, curved</td>
<td>distinct, curved</td>
<td>distinct, curved</td>
<td>weak, straight</td>
</tr>
<tr>
<td>Reddish specimens</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Fringes at forewing apex</td>
<td>usually concolorous with wings</td>
<td>red</td>
<td>red</td>
<td>whitish</td>
</tr>
<tr>
<td>Uncus shape</td>
<td>subapical part rather wide</td>
<td>subapical part narrow</td>
<td>subapical part narrow</td>
<td>subapical part narrow</td>
</tr>
<tr>
<td>Apex of aedeagus arm</td>
<td>not enlarged</td>
<td>not enlarged</td>
<td>not enlarged</td>
<td>enlarged</td>
</tr>
<tr>
<td>Cornuti</td>
<td>straight row</td>
<td>straight row</td>
<td>straight row</td>
<td>angled row, reaching aedeagus apex</td>
</tr>
<tr>
<td>Signum</td>
<td>small/minute</td>
<td>large</td>
<td>small/minute</td>
<td>absent</td>
</tr>
<tr>
<td>Lamella antevaginalis</td>
<td>often large, margin concave</td>
<td>often large, margin concave</td>
<td>often large, margin concave</td>
<td>small/minute</td>
</tr>
<tr>
<td>Distribution</td>
<td>Pan-European, eastwards to Russia: Yakutia</td>
<td>Italy: Sicily, Calabria, Molise</td>
<td>France: Corsica</td>
<td>Algeria, Tunisia</td>
</tr>
</tbody>
</table>

**Hylaea mediterranea** Sihvonen, Skou, Flamigni, Fiumi & Hausmann, new species

**Description.** External characters and pregenital abdomen (diagnostic characters underlined) (Figures 2, 7):
Wingspan male 31 mm (n=4), female 37–41 mm (n=4). Wings light green, medial lines white. Medial line curved before costa, basal part moves away from costa (not parallel with costa). Postmedial line rather straight, only weakly curved, barely angled before it reaches costa near apex and evenly curved outwards on inner margin. Medial area concolorous with rest of wing. Terminal line and fringes concolorous with wings, forewing apex dark red. Hindwing postmedial line distinct, curved. Discal spots absent. Wings below as above, but paler. Frons red-brown, thorax and abdomen concolorous with wings. Area between antennae (vertex) white. Antennae white dorsally, male antennae bipectinate, female antennae fasciculate. Hindleg tibia of both sexes with 2+2 spurs. Tympanal organs medium-sized. Sternites and tergites 3–8 of both sexes undifferentiated.

**Male genitalia** (Figure 11): Generally as in *H. fasciaria* (Linnaeus) and *H. pinicolaria* (Bellier). Aedeagus with additional arm, apex not expanded in *H. mediterranea* (apex expanded in *H. compararia*). Base of vesica with straight row of microcornuti in *H. mediterranea* (vesica with angled row of microcornuti, reaching aedeagus apex in *H. compararia*). Uncus relatively narrower before wide apex in *H. mediterranea* (uncus relatively wider before wide apex in *H. fasciaria* and *H. pinicolaria*, but the differences are not clear-cut).

**Female genitalia** (Figure 15): Generally as in *H. fasciaria* and *H. pinicolaria* (Bellier), but with following quantitative difference: signum large in *H. mediterranea* (signum absent or minute in *H. fasciaria*, *H. pinicolaria* and in *H. compararia*). Genitalia are large in *H. mediterranea* (genitalia considerably smaller in *H. compararia*). Shape and size of the lamella antevaginalis, and width and length of the posterior part of the corpus bursae are variable and should be treated with caution.

**Distribution** (Figure 20). Type specimens originate from Sicily (Italy, DNA barcoded), one specimen from Calabria (Italy, taken out of a longer series and DNA barcoded) and three specimens from Molise (Italy, DNA barcoded). One further specimen has been reported from the island of Marettimo, West of Sicily (L. Dapporto, pers. comm., not DNA barcoded). Outside this the distribution area needs verification. Some specimens from Greece, for instance from Mount Parnassos, Karpenision and Lesvos, are externally similar, but the female signum is small, thus not agreeing with the Italian material. DNA barcodes are not available, so far, for Greek populations.

**Phenology.** Bivoltine: In Sicily it flies from late May (rarely early May) to early July and from late August to late October (Flamigni et al. in press).

**Biology.** The species has been reared (G. Fiumi and D. Righini) from the Etna Mountain, Sicily. Female laid eggs on May 1st (Figure 22), the caterpillars fed on the needles of *Pinus sylvestris* and *Picea abies* (Figure 23), the first pupa was observed on June 26th (Figure 24) and the first adult (Figure 25) emerged on 11 July. *Pinus sylvestris* and *Picea abies* are not present in Sicily; in the collecting localities *Pinus laricio* and *P. halepensis* are common.

**Habitat** (Figure 21). In pine forests and places with more scattered pine trees. Altitude range from sea level to 1780 m (Flamigni et al. in press).

**Similar species.** All four species in the Palaearctic *Hylaea fasciaria* species group are similar. The diagnostic, external characters shown in the Figures 6–9 are somewhat tentative and should not be used in isolation, but should be combined with other information including biology, collecting locality, male and female genitalia and DNA barcodes. An overview of diagnostic morphological features is given in Table 1. The taxon *squallidaria* (as judged from the original figure) differs in the straight forewing medial line, not curved at costa; forewing medial and postmedial lines at large distance, thus the medial area very broad; hindwing postmedial line strongly curved, parallel to termen.

**Genetic data.** Genetically homogeneous in Calabria, Molise and Sicily (n=8), mean intraspecific variation 0.19%, maximum variation 0.46%. Nearest species: *Hylaea fasciaria* (minimum pairwise distance 3.3%). See Figure 26.

**Variation.** Little variation in habitus observed, so far. Forewing postmedial line is straight or weakly curved outwards on inner margin. The specimens from Calabria (Italy) often have the forewing postmedial line clearly angled before it reaches costa. Only light green specimens are known.

**Etymology.** The species name *mediterranea* refers to the Mediterranean area, where the species occurs.
FIGURE 20. Distribution areas of *Hylaea mediterranea* new species, *H. pinicolaria* (Bellier) and *H. compararia* (Staudinger). The distribution areas, where the species occurs frequently, are shown in grey. The type localities of *Hemithea squalidaria* O. G. Costa are shown with open circles.

**Hylaea pinicolaria** (Bellier, 1861)

*pinicolaria* Bellier, 1861, Annls Soc. ent. Fr. (4) 1 (1): 29, pl. 2, fig. 12, (*Ellopia*). Syntype(s), Corsica (mountains of). Bellier's collection was apparently included in the C. Oberthür collection, which is currently housed in the Natural History Museum, London, UK. Despite searches, we have not located the type.

**Description.** External characters and pregenital abdomen (Figures 3, 8) (diagnostic characters underlined): Wingspan male 32–34 mm, female 39–42 mm. Wings light green, medial lines white. Medial line curved before costa, basal part parallel with costa. Postmedial line rather straight, only weakly curved, angled before it reaches costa well before apex and evenly curved outwards on inner margin. Medial area concolorous with rest of wing. Terminal line and fringes concolorous with wings, *forewing apex dark red*. Hindwing postmedial line distinct, curved. Discal spots absent. Wings below as above, but paler. *Frons red-brown*, thorax and abdomen concolorus with wings. Area between antennae (vertex) white. Antennae white dorsally, male antennae bipectinate, female antennae fasciculate. Hindleg tibia of both sexes with 2+2 spurs. Tympanal organs medium-sized. Sternites and tergites 3–8 of both sexes undifferentiated.

**Male genitalia** (Figure 12): Generally as in *H. fasciaria* (Linnaeus) and *H. mediterranea*. Aedeagus with weakly curved additional arm, apex not expanded in *H. pinicolaria* (additional arm straight in *H. fasciaria*, apex expanded in *H. compararia*). Base of vesica with straight row of microcornuti in *H. pinicolaria* (vesica with angled row of microcornuti, reaching aedeagus apex in *H. compararia*).

**Female genitalia** (Figure 16): Generally as in *H. fasciaria* and *H. mediterranea*, but with following quantitative difference: signum large in *H. mediterranea* (signum absent or minute in *H. fasciaria*, *H. pinicolaria* and in *H. compararia*). Genitalia are large in *H. pinicolaria* (genitalia considerably smaller in *H. compararia*).
Shape and size of the lamella antevaginalis, and width and length of the posterior part of the corpus bursae are variable and should be treated with caution.

**Distribution.** Endemic to Corsica (France).

**Phenology.** According to Robineau (2007) it is univoltine, but this is true probably only at higher altitudes (where it flies from June to early August), while on the coast the species has been collected from May to June and from October to November (Rungs 1982).

**Biology.** Larva has been recorded to feed on needles of *Pinus laricio* (Bellier 1861, Robineau 2007) and on *P. pinaster (= maritima)* (Mabille 1867). In captivity it has been reared on *Pinus sylvestris* (Reisser, 1929). Larva is a twig or needle-mimic, green, with transverse yellowish stripes or reddish-brown with diamond-shaped patterns dorsally (Lepiforum 2013).

**Habitat.** In pine forests and places with more scattered pine trees. It is found mostly in the mountains from 500 to 1500 metres, but it occurs also at sea level (Rungs 1982).

**Similar species.** All four species in Palaearctic *Hylaea fasciaria* species group are similar. The diagnostic, external characters shown in Figures 6–9 are somewhat tentative and should not be used in isolation, but should be combined with information on biology, collecting locality, male and female genitalia and DNA barcodes. An overview of diagnostic morphological features is given in Table 1.

**Genetic data.** Genetically homogeneous (n=4), mean and maximum intraspecific variation 0.0%. Nearest species: *Hylaea fasciaria* (minimum pairwise distance 3.9%). See Figure 26.

**Variation** (Figure 3). Very little. Ground colour varies from light green to light yellowish-green. Only green specimens are known.

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**Hylaea compararia** (Staudinger, 1894), revised status

compararia Staudinger, 1894, Dt. ent. Z. Iris 7: 289, (*Ellopia?*). Syntypes male, female, Algeria, near Tenied el Had.

**Description.** External characters and pregenital abdomen (Figures 4, 9) (diagnostic characters underlined): Wingspan male 28–30 mm, female 29–31 mm. Small species, wings dull green, medial lines weak, whitish. Medial line absent or very weak, basal part not parallel with costa. Postmedial line weak, straight, angled before it reaches costa well before apex, straight on inner margin. Medial area concolorous with rest of wing. Terminal line and fringes whitish, forewing apex whitish. Hindwing postmedial line weak, straight. Discal spots absent. Wings below as above, but paler. Frons pale brown, thorax and abdomen concolorus with wings. Area between antennae (vertex) white. Antennae white dorsally, male antennae bipectinate, female antennae fasciculate. Hindleg tibia of both sexes with 2+2 spurs. Tympanal organs medium-sized. Sternites and tergites 3–8 of both sexes undifferentiated.

Male genitalia (Figure 13): Generally as in *H. fasciaria* (Linnaeus), *H. mediterranea* and *H. pinicolaria* (Bellier). Aedeagus with additional arm, apex expanded in *H. compararia* (not expanded in above-mentioned species). Base of vesica with angled row of microcornuti, reaching aedeagus apex in *H. compararia* (with straight row of microcornuti, not reaching aedeagus apex in above-mentioned species).

Female genitalia (Figure 17): Generally as in *H. fasciaria*, *H. mediterranea* and *H. pinicolaria*, but with following quantitative differences: genitalia small in *H. compararia* (large in above-mentioned species). Signum absent or minute in *H. compararia* (signum large in *H. mediterranea*). Shape and size of the lamella antevaginalis, and width and length of the posterior part of the corpus bursae are variable and should be treated with caution.

**Distribution.** Known from northern Algeria (>100 specimens in the NHM), cf. Prout (1912–1916) and Tunisia (one male in ZSM).

**Phenology.** Potentially bivoltine. Specimens have been taken in May, June, July and in September.

**Biology.** No data. Larva potentially feeds on needles of coniferous trees.

**Habitat.** According to the original description (Staudinger, 1894: 289) ‘putatively in coniferous forest’.

**Similar species.** All four species in Palaearctic *Hylaea fasciaria* species group are similar. *H. compararia* is small, medial lines are weak, microcornuti in vesica reach the aedeagus apex and signum is absent or minute (*H. fasciaria*, *H. mediterranea* and *H. pinicolaria* are larger, medial lines are more visible, microcornuti in vesica do not reach the aedeagus apex and signum is larger). The diagnostic, external characters shown in Figures 6–9 are somewhat tentative and should not be used in isolation, but should be combined with other information including...
biological, collecting locality, male and female genitalia and DNA barcodes. An overview of diagnostic morphological features is given in Table 1.

**Genetic data.** Data not available.

**Variation** (Figure 4): Little: in most specimens forewing medial line is absent or very weak, postmedial line is weak but visible. Some females have forewing margin slightly concave below forewing apex.

**Remarks.** *Ellopia (?) compararia* Staudinger has been considered valid at species level, for instance in Prout (1912–1916) and Wehrli (1939–1954) until Leraut (2009) downgraded it to subspecies of *H. fasciaria* (Linnaeus). Of the four species in the Palearctic *Hylaea fasciaria* complex, this is the most distinct, diagnosable by external characters and by the male and female genitalia. We consider *H. compararia* (Staudinger) valid at species level (status revised).

**Hemithea squalidaria** O. G. Costa, 1848, combination and status uncertain

*squalidaria* O. G. Costa, 1848, Fauna Regno Napoli (Ent.): [331], pl. (Geom.) 2, fig. 4, (*Hemithea*). Syntype(s), [Italy]: Adriatic coast: San Cataldo, near Lecce; Tyrrenian coast: [Lago di] Patria [near Naples].

*Hemithea squalidaria* O. G. Costa, 1848 from southern Italy (Figure 5a) is a problematic taxon due to the lack of type material. Only the original, hand-drawn colour illustration on the taxon exists (reprinted in Figure 5a). Prout (1912–1916) combined *squalidaria* with *Ellopia* Stephens (=*Hylaea*), due to its similarity with *H. compararia* (Staudinger, 1894). Wehrli (1939–1954), in the absence of material, treated *squalidaria* putatively valid at species level, as did Scoble (1999).

If *Hemithea squalidaria* belonged to the genus *Hylaea*, in theory it could be conspecific with *H. mediterranea*. *Hemithea squalidaria* has rather straight and well developed forewing medial lines, and the hindwing postmedial line is clearly curved (Figure 5a), whereas the forewing antemedial line is curved towards the costa and the hindwing postmedial line is only slightly curved in *H. mediterranea* (Figures 2, 7). Costa (1848) gives *squalidaria*’s wingspan as 13 linee, which is 2.33 cm, assuming he used the old Sicilian definition of line, one line being equal to 1/12 of an Sicilian ounce. Costa also reported the same wingspan for *Thetidia smaragdaria* (Fabricius, 1787), which is generally smaller than *Hylaea* specimens. Further, the specimen has simple (fasciculate?) antennas and long labial palpi, thus different from *Hylaea* (males). Therefore, in our opinion, the original hand-drawn illustration of *H. squalidaria* and the description of the taxon reported in Costa's text (e.g. the wingspan of ca. 23 mm) exclude the possibility of *Hemithea squalidaria* being conspecific with *H. mediterranea* (smallest *H. mediterranea* male available to us has a wingspan of 31 mm, smallest female is 37 mm). *Hylaea compararia* and *H. fasciaria* are externally different and, according to the current knowledge, they do not occur in southern Italy.

Based on the illustration (reprinted in Figure 5a), we are unable to exclude the possibility that *H. squalidaria* may be a species of the subfamily Geometrinae. There are potentially several Geometrinae species, which live at the sea-level in southern Italy that may be relevant in this context.

*H. squalidaria* was described by Oronzo Gabriele Costa, the father of Achille Costa, and it is possible that the type specimen(s) of the taxon no longer exist. Turati (1911) visited the Costa Collection in the Zoological Museum of Naples, Italy, and he does not mention *squalidaria*. Only two wings, thorax and head with an antenna of *Megalycinia serraria* (Costa, 1882) (Ennominae) are mentioned in the article. Also Concì (1975) reports that part of the A. Costa collection is destroyed. Due to the unavailability of the type material, we are unable to place the taxon *squalidaria* in the genus *Hylaea*. We revert it to its original combination, and its taxonomic combination and status are uncertain, being potentially valid at species level and potentially belonging to another genus in the subfamily Geometrinae (see discussion above). We have been unable to trace a candidate for a neotype designation basing on a specimen from southern Italy that would fit well enough the habitus of the figure from the original description.
FIGURE 26. Neighbour joining tree (Kimura 2-parameter distance model for COI-5P marker) for European Hylaea specimens. Terminals with specimen ID-number and species name from BOLD.
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References


http://dx.doi.org/10.1111/j.1471-8286.2006.01428.x

http://dx.doi.org/10.1007/bf01731581


http://dx.doi.org/10.1046/j.1096-3642.2002.01200.x


