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Pseudochazara amymone (Lepidoptera, Nymphalidae) in Albania: Variability analysis, androconial scales and new distributional data

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Abstract. For the first time a comparison of variable external characters of a series of males and females of *Pseudochazara amymone* (Brown, 1976) from southern Albania is conducted. *Pseudochazara amymone*, flying together with *P. mniszechii tisiphone* (Brown, 1980), was local and quite common in steep valleys on ophiolite substrate on two separate mountains, one of which is a recently discovered locality by Eckweiler (2012), while the other one is a new locality. An analysis of external characters of all specimens from the two localities suggests no statistically significant differences. In the field, patrolling *P. amymone* males are easily distinguished from *P. mniszechii tisiphone* males but this is not the case for females, and therefore we provide determination keys for males and females of these two species. These are based on a statistical analysis of a specimen series from one Albanian *P. mniszechii tisiphone* population compared with all *P. amymone* in this study. Photographs of androconia, copula and some extreme forms of *P. amymone* are presented. To encourage further research in this poorly explored country a map is included, showing all historical records of Papilionoidea from literature, including our own observations.

Samenvatting. Voor het eerst wordt een vergelijking gepubliceerd van de variabele uiterlijke kenmerken van een reeks mannetjes en wijfjes *Pseudochazara amymone* (Brown, 1976) uit Zuid Albanië. *Pseudochazara amymone* was lokaal en vrij algemeen in steile valleien op ophioliet gesteente in twee gescheiden gebergten en vloog samen met *P. mniszechii tisiphone* (Brown, 1980). Aan de auteurs werd bevestigd dat het eerste gebied de recent, door Eckweiler (2012) gevonden plaats is. Het tweede gebied is nieuw. Een analyse van de uitwendige kenmerken van alle exemplaren uit de twee gebieden suggereert geen significante verschillen. In het veld kunnen patrouillerende *P. amymone* mannetjes gemakkelijk onderscheiden worden van *P. mniszechii tisiphone* mannetjes maar dit is niet het geval bij de wijfjes. Daarom zijn determinatiesleutels voor beide taxa opgenomen (zowel voor mannetjes als wijfjes). Deze zijn gebaseerd op een statistische analyse van een Albanese *P. mniszechii tisiphone* populatie met alle *P. amymone* in deze studie. Foto's van de androconia, copula en sommige extreme vormen van *P. amymone* worden getoond. Om verder onderzoek aan te moedigen in dit zwak onderzocht land is een landkaart opgenomen die alle historische Papilionoidea gegevens inclusief onze eigen observaties weergeeft.

Resumé. For første gang gennemføres en sammenligning af de varierende eksterne kendetegn på en serie hanner og hunner af *Pseudochazara amymone* (Brown, 1976) fra det sydlige Albanien. *Pseudochazara amymone* forekom sammen med *P. mniszechii tisiphone* (Brown, 1980) lokalt, men ret almindeligt, i stejle dale med ofiolitiske mineraler i to adskilte bjergområder, hvoraf det ene er en nyligt opdaget lokalitet af Eckweiler

(2012), og det andet er en ny lokalitet. En analyse af alle eksemplarers eksterne kendetegn fra de to områder viser ingen statistisk signifikante forskelle. I felten kan patruljerende *P. amymone* hanner let adskilles fra *P. mniszechii tisiphone* hanner, men dette er ikke tilfældet med hunnerne, og derfor gives bestemmelsesnøgler til hanner og hunner af disse to arter. Disse er baseret på en statistisk analyse af en serie eksemplarer fra en albansk *P. mniszechii tisiphone* population og alle *P. amymone*. Fotos af duftskæl, parring og visse ekstreme former af *P. amymone* præsenteres. For at tilskynde andre til at foretage videre undersøgelser i dette så dårligt udforskede land inkluderes et udbredelseskort over alle hidtidige fund af Papilionoidea nævnt i litteraturen, inklusive vore egne fund.

Introduction

Brown's Grayling, *Pseudochazara amymone* (Brown, 1976) was discovered by John Brown in early July 1975 in NW Greece (type locality: "mountains just north of Ioannina") based on four males (Brown 1976) and years later a single female (oral communication). Since then, despite many efforts, almost all searches for this butterfly in Greece have turned out negative and no other voucher specimens are available. A lot of strange rumours, describing a rocket speed flight and strange nuptial behaviour, often followed these negative searches (Cuvelier 2010). Since its discovery, *P. amymone* has been the subject of speculation like hardly any other butterfly species in Europe and a myth has been created around it. Its taxonomic status is still uncertain. Because of the close resemblance in the genitalia of Albanian *amymone* with Turkish *Pseudochazara mamurra* (Herrich-Schaffer, [1846]), Eckweiler (2012) treated *amymone* as a subspecies of *P. mamurra*. DNA analysis might shed additional insights on the taxonomic position of the taxon *amymone* and is underway by an independent group (oral comm. Verovnik). In this article we chose to follow Fauna Europaea (de Jong 2013), which gives this taxon species status.

Albania is a country that, due to its political (50 years of communist regime and civil war) and infrastructural situation, only recently became open for travelling and lepidopterological investigation. Large parts of the country remain unexplored. It is not surprising that *P. amymone* remained undiscovered in Albania until recently. Here the faunistical elements of central Europe meet with those from the Balkans, the Mediterranean and Asia Minor.

Eckweiler had the idea to start searching for *P. amymone* in Albania in 2010. In July 2010 he discovered a first single *P. amymone* male and, in July 2011, five further males and one female in southern Albania. Before the publication of his observations, this discovery was again surrounded by mysterious communications. But at least this time strong proof of its existence, supported by the photographs of voucher specimens, was soon given (Eckweiler 2012). A short message on Facebook from van Swaay during the summer of 2012 also mentioning a few *P. amymone* from Albania was the only other evidence known to us at that time. This message included a photograph of a male *Pseudochazara*, sitting with closed wings that looked quite different from *Pseudochazara mniszechii tisiphone* (Brown, 1980). But even with both sources, the locality remained obscure and the given information again supported the extreme rarity of the butterfly. The article (Eckweiler 2012) made some suggestions concerning a potentially wider distribution area in Albania than the single undisclosed locality where the *P. amymone* had been found and the need for further surveys. Based on all of this, a joint trip to Albania was planned by the authors with the objective to search for further evidence and to study the biology of *P. amymone* in the country.

As this taxon is often associated with Turkish *Pseudochazara mamurra* (Herrich-Schäffer, 1852) (Gross 1978; Tolman and Lewington 1997; Eckweiler 2004; Tshikolovets 2011; Eckweiler 2012), we used Google Earth to search for potential localities of *P. amymone* similar to Turkish habitat photographs (Hesselbarth et al. 1995). With the available good resolution of satellite photographs it is possible to recognize the colour of the geological substrates together with a lot of topographical details. Such places seemed quite common in Albania and were far too numerous for a dedicated search. Pamperis (1997) also mentioned that in one Greek locality *P. amymone* is sympatric with *P. mniszechii tisiphone*, but flying at the end of the flight time of *P. mniszechii tisiphone*. This suggests a geology of dark red soil as in typical *Pseudochazara* biotopes. The habitat photograph from the Eckweiler paper (2012) also was suggestive of such soils and the pink flowers were an interesting clue for future field research. A geological map from Monjoie et al. (2008) helped us focus our research strictly on the south-eastern Albanian province of Korçë. On Google Earth these areas, mentioned as ophiolite nappes in the maps, looked a lot like some Turkish biotopes with steep, dark red, dry slopes in river valleys. Combined with the information about altitude, this enabled us to be very selective concerning target areas.

Our second objective was to explore areas in Albania that had never been explored before for butterflies. Before this field trip, we searched for all historical data from the sparse literature about Albanian butterflies. Maps of species and a global distribution map clearly showed how poor is the coverage for this country. We also intended to survey other areas in the provinces of Korçë, Kolonjë, Përmet, Tepelenë and Skrapar to increase the knowledge of the butterfly fauna from Albania in general. The detailed results of all our own observations will be published in a future faunistic publication.

Abbreviations

AL: androconium length; AB: androconium breadth; A: ratio AL/AB; FW: forewing; HW: hindwing; MM: Morten Schneider Mølgaard; N°: number; N/A: not applicable; oc.: ocelli; SC: Sylvain Cuvelier; SD: standard deviation; subm.: submarginal; UNS: underside; UPS: upperside; Var: variable.

Material and methods

Sample collecting and database construction

In two localities in the Albanian province Korçë (Boboshtiçë and Gjergjeviçë) males and females of *P. amymone* and *P. mniszechii tisiphone* were netted by both authors. A search for all potential references on the butterflies of Albania was made during the preparation for the trip. The relevant publications were gathered from different sources in order to build a database including as much historical data as possible (Abadjiev and Beshkov 1996a, b; Alberti 1965; Beshkov 1994; Beshkov 1995; Beshkov and Misja 1995; Gaskin 1990; Misja and Kurrizi 1984; Moucha 1963a, b; Murraj 1972; Płóciennik et al. 2009; Popescu-Gorj 1971; Rebel 1913; Rebel 1918; Rebel and Zerny 1931; Verovnik and Popović 2013a, b). Only the data from all species with rather precise indications of the locality were included in an Excel spreadsheet with coordinates in decimal degrees that were defined with Google Earth and an online coordinate conversion tool (Montana State University 2014). All data from our personal observations were included in this database. During our surveys, coordinates were obtained in the field with a GPS (Garmin Etrex Legend). A map of Albania was adapted for use with DMAP distribution mapping software to produce distribution maps per species and one global coverage map of all Albanian butterfly species. During history the borders of Albania have changed. Some historical data now in fact concern localities that are situated in Montenegro, Kosovo and Macedonia. To be as complete as possible, we have maintained these observations in the coverage map.

Study of external characters

Since the discovery of *P. amymone* by Brown (1976), as far as is known to the present authors, there have been only 10 male and two female voucher specimens collected and included in publications. *Pseudochazara* species are very variable and difficult to identify. No comparative studies on the external characters of a good number of *P. amymone* specimens have been published so far and we had no precise idea about the variability of the external characters of both sexes.

The male holotype, figured in black and white, was for a long time the only documented picture of this species (Brown 1976). In his article, Brown described the external characters based on a very small series of four males: "*Upperside* similar to *graeca* but wings more rounded and with notably broad clear orange postdiscal bands more or less broken by grey-brown ground colour along v4 of forewing and enclosing blind black oc. in S 2, 5 and minute black oc. in S 3, 4 on forewing. Sex brand inconspicuous. Hindwing sometimes with small black ocellus in S 2 and dark grey submarginal line broken by orange along veins. Marginal grey band thin (1–2 mm wide). *Underside* ground colour pale yellow-grey but variable. Hindwing irrorate with darker scales and indistinct striae. Forewing length 26–27 mm. Female. Unknown."

Luckily, the two original photographs from this publication were available and they allow a better comparison. For this purpose, Jos Dils (Belgium) kindly provided the two photographs of the male holotype (Brown 1976) (Fig. 1). On the underside of the photograph it is written: "WATSONI ? Clench & ~~CHS~~ SCH" looking like a link to a *Pseudochazara* species from Afghanistan (Fig. 1). However, as we never received a reply from Brown, it is not possible to fully understand this detail.

Recently, two prepared male specimens were figured by Eckweiler (2012) that look different from the holotype but with such a small sample size it is difficult to estimate if this is within the normal range of variability. Concerning females, for a long time there was only one figure (Tolman and Lewington 1997) but recently a first photograph of the upper- and underside of a single female from Albania became available (Eckweiler 2012). Even fewer photographs of the butterfly in nature have been published and for all these documents there remained a degree of uncertainty concerning the final determination (Cuvelier 2010, Eckweiler 2012).

In the field, fresh males of *P. amymone* look quite different when flying than *P. mniszechii tisiphone* and identification is possible in a fair number of cases. As *Pseudochazara* species almost never sit with open wings, reliable identification in the field is often based on the underside of the wings and for both sexes it is difficult and depends on the freshness of the butterflies. Therefore we also sampled *P. mniszechii tisiphone* (Figs 5a–h) at Boboshtiçë, where this butterfly was extremely common, in order to compare the two taxa and to obtain determination keys for males and females of both species.

Potential variables of the external characters were selected and included in an Excel workbook containing separate worksheets per species and gender. After this first selection, the colour of the fringes was discarded as a variable due to the difficulty of formulating measurable criteria.

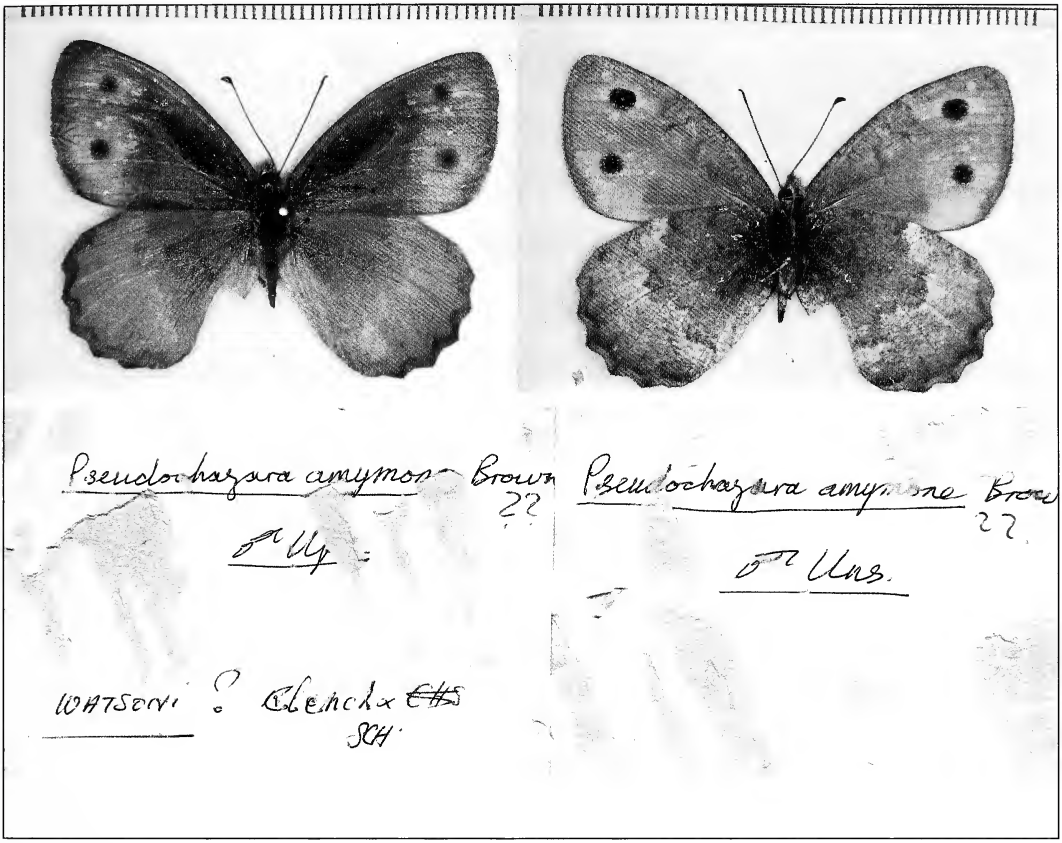

Figure 1. Upper and underside of the *P. amymone* holotype photographs, holotype collected in the mountains just N. of Ioánnina, Epiros, Greece, 650m, 10.vii.1975 (photograph: SC).

Drawings of measurement on UPS and UNS are included in Appendix 1. The following variables were analyzed: UPS FW: Var 1: length of FW from apex to point of attachment to thorax, fringes included (mm); Var 2: visual assessment of the oc. in S2 and S5 (blind= 0, white pupil= 1); Var 3: visual assessment of the number of spots in S3 and S4 (0, 1 or 2); Var 4: width of the submarginal band across the centre of the ocellus in S2 (mm); Var 5: Var 4/Var 1 (%); Var 6: visual assessment of the conspicuous sex brand in cell (absent= 0, present= 1). UPS HW: Var 7: visual assessment of the number of oc. in the submarginal area (0, 1, 2 or 3); Var 8: width of the submarginal band along vein 3 (mm); Var 9: Var 8/Var 1 (%). UNS FW: Var 10: visual assessment of the oc. in S2 and S5 (blind= 0, white pupil = 1); Var 11: visual assessment of the pale area from ocellus in S5 to the cell (uniform= 0, contrasted = 1); Var 12: visual assessment of the number of spots in S3 and S4 (0, 1 or 2); Var 13: visual assessment of the marginal line (diffuse= 0, sharp= 1); Var 14: visual assessment of the fine black line-shape markings in the basal area of the cell (absent= 0, present= 1); Var 15: length of the ocellus in S5 (mm); Var 16: shortest distance from the white centre of the ocellus in S5 to the margin (mm); Var 17: Var 15/Var 1 (%); Var 18: Var 15/Var 16 (%); Var 19: Var 16/Var 1 (%). UNS HW: Var 20: visual assessment of the number of oc. in the submarginal area (0, 1, 2 or 3); Var 21: visual assessment of the median band (absent= 0, present= 1);

We photographed the upper- and underside of all male and female specimens of *P. amymone* and *P. mniszechii*, each of us in our personal reference collections. A scale bar was included with each specimen (Appendix 1b). Each digital image was imported into Paint Shop Pro v. 6.02. A straight vector line was drawn on the butterfly in its own layer to measure the exact length of the desired parameter. Afterwards, the vector line was rotated into horizontal position and then moved onto the scale bar under the butterfly, making it possible to measure length in millimetres, at an accuracy level of 0.25 mm. The whole dataset was used for two analyses: a) a variability study between the two *P. amymone* populations and b) a comparison between all *P. amymone* and *P. mniszechii tisiphone*. Statistical analysis was performed with StatSoft STATISTICA 12. The Mann-Whitney U test was used to test for differences at 0.05 significance level in a two-tailed test.

Study of androconial scales

Androconial scales were removed from the upperside of the forewings of one *P. amymone* and one *P. mniszechii tisiphone* and photographed with a calibrated 5 megapixel Dino-Lite AD-7013MZT digital microscope with adjustable magnifications. The length and breadth of the androconia were measured according to the description by Wakeham-Dawson (2000) but at maximum magnification (×500).

Cartography

DMAP, distribution mapping software: http://www.dmap.co.uk/. — Dr. Alan Morton, Blackthorn Cottage, Chawridge Lane, Winkfield, Windsor, Berkshire, SL4 4QR, UK.

Results

Field notes

On 15.vii.2013, late in the afternoon, we started our search for *P. amymone* in a narrow valley with very steep slopes near Boboshtiçë (province of Korçë). On the dark red-grey slopes our attention was attracted by cushions of pink flowers that we identified as *Acantholimon echinus* (L.) Boiss. (Plumbaginaceae) and the whole area looked very similar to the published habitat photograph (Eckweiler 2012). The rest of the day we explored this area and found some *P. mniszechii tisiphone*, but we had not had a glimpse of *P. amymone*. We were, however, quite certain that we had to be near its habitat.

The next morning, 16.vii.2013, we entered deeper into the river valley and searched at 1100–1200 m altitude on SSW exposed steep rocky slopes with parts of loose gravel. On this ophiolite substrate (Fig. 2a) with characteristic red-grey colour, scattered tall grasses were growing, but otherwise the area was almost devoid of vegetation (Fig. 2b). Here *P. amymone* had just emerged and males (Fig. 2d) were already flying quite commonly. We observed the males showing a typical territorial behaviour: patrolling and chasing away other males. The females were searching for nectar sources and egg-laying places in the scattered tall grasses that were present in the biotope. The rumours of a rocket speed flight and strange nuptial behaviour appeared not to be true. The species is not shyer than other species in the genus *Pseudochazara*.

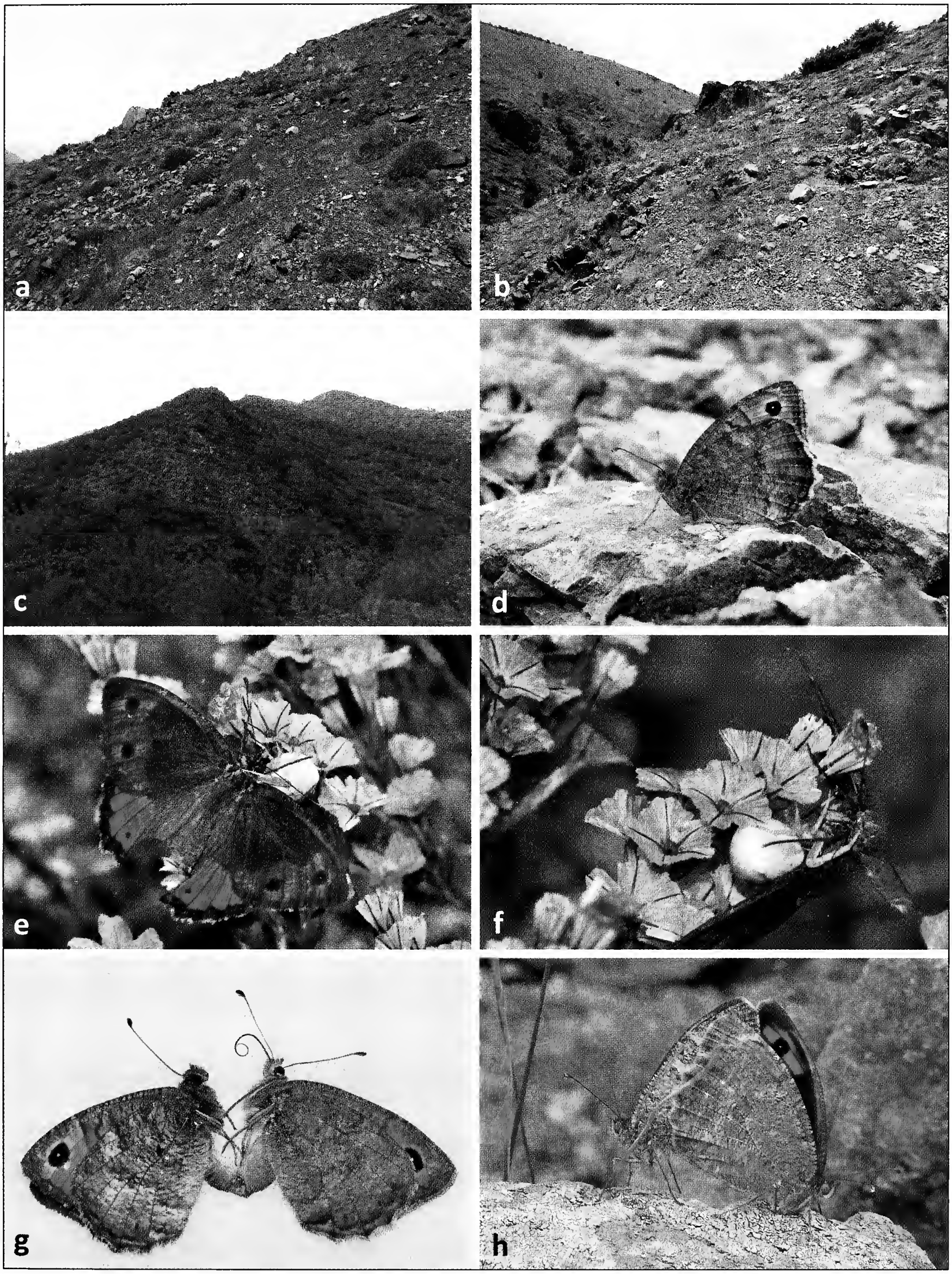

Figure 2. a–b. Habitat of *P. amymone*, Boboshtiçë, Albania, 16.vii.2013. **c.** Habitat of *P. amymone*, Gjergjeviçë, Albania, 18.vii.2013. **d.** ♂ *P. amymone*, Boboshtiçë, Albania, 16.vii.2013 (photographs: MM). **e.** ♂ *P. amymone* caught by a crab spider, Boboshtiçë, Albania, 18.vii.2013. **f.** *T. onustus* holding a ♂ *P. amymone*, Boboshtiçë, Albania, 18.vii.2013 (photographs: SC). **g.** Copula of *P. amymone*, Boboshtiçë, Albania, 16.vii.2013 (coll. & photograph: SC). **h.** Copula of *P. mniszechii tisiphone*, Gjergjeviçë, Albania, 18.vii.2013 (photograph: MM).

On 18.vii.2013, early morning, we again visited this locality and observed that some males were already getting worn. One male *P. amymone* (Fig. 2e), seen from afar sitting with open wings on flowers of *A. echinus*, had been caught by a crab spider (Fig. 2f) that was identified by Rop Bosmans (Belgium) as *Thomisus onustus* (Walckenaer, 1805), a common species in the Balkans. This butterfly also shows typical injuries on the hind wings caused by lizards that were common in the habitat. Females were already more numerous than two days earlier. Here, *P. amymone* flies sympatrically with *P. mniszechii tisiphone*. The males of these two species are easily distinguished in the field, but this is not the case for females. Flying males of *P. amymone* look smaller and also show a much more pronounced orange and black contrast. Although the females of *P. amymone* are a little smaller, this cannot be observed in the field. They also do not exhibit the contrasting orange and black colours and this makes it difficult in the field to distinguish females of these two species.

In Boboshtiçë, we observed the first ever known copula (Fig. 2g) and a pale form (Figs 3g–h) of a male *P. amymone*. After our trip, Eckweiler confirmed (oral comm., August 2013) that this was the locality where he originally discovered *P. amymone* in Albania.

During these explorations, on 18.vii.2013, we were able to extend the known distribution of *P. amymone* by approximately 25 km to the west, as the crow flies, as we discovered it in another remote mountain range in the westernmost part of the province of Korçë. This mountain range is physically separated from Boboshtiçë by a 10 km broad river valley, at 850 m altitude.

Entering a remote valley, we observed steep rocky slopes orientated to the SSW on ophiolite substrate, as we had seen in Boboshtiçë. On climbing these slopes we immediately observed a large population of *P. amymone*. The new biotope is situated near Gjergjeviçë (Fig. 2c) and in the upper part of the known altitudinal distribution (Pamperis 2009) of *P. amymone*, being at an altitude of 1200–1400 m. It has the same characteristics as the biotope at Boboshtiçë, except for one major difference: the presence of scattered bushy vegetation whereas the habitat at Boboshtiçë is completely open. We observed that *P. amymone* near Gjergjeviçë is also sympatric with and even outnumbering *P. mniszechii tisiphone* and here a copula of this species was photographed (Fig. 2h). The flight period of *P. amymone* was apparently the same as in Boboshtiçë, due to the general freshness of most of the specimens and the presence of good numbers of females as observed in the morning of the same day at Boboshtiçë.

Variability of *P. amymone* from two Albanian populations

To our big surprise, we noticed *P. amymone* was not rare at all in the two biotopes (Boboshtiçë and Gjergjeviçë) and that the habitat in both localities was very large but difficult, if not impossible, to explore. Nevertheless we sampled enough voucher specimens to get a better idea of the range of variation in external characters and to make a comparative study on the habitus of these two separate populations of *P. amymone*.

There are two limitations of our dataset which require further attention in the future when new populations are discovered. The sample size of 38 males and 19 females for such variable butterflies remains suboptimal and the sample size of the two localities is not equal. The range and mean of all variables for the two populations is given in Table 1. Males and females are figured (Figs 3a–h, 4a–f). All the variables of the two populations clearly overlap and there was not a single variable showing clear differences between the two populations. For these reasons the measure-

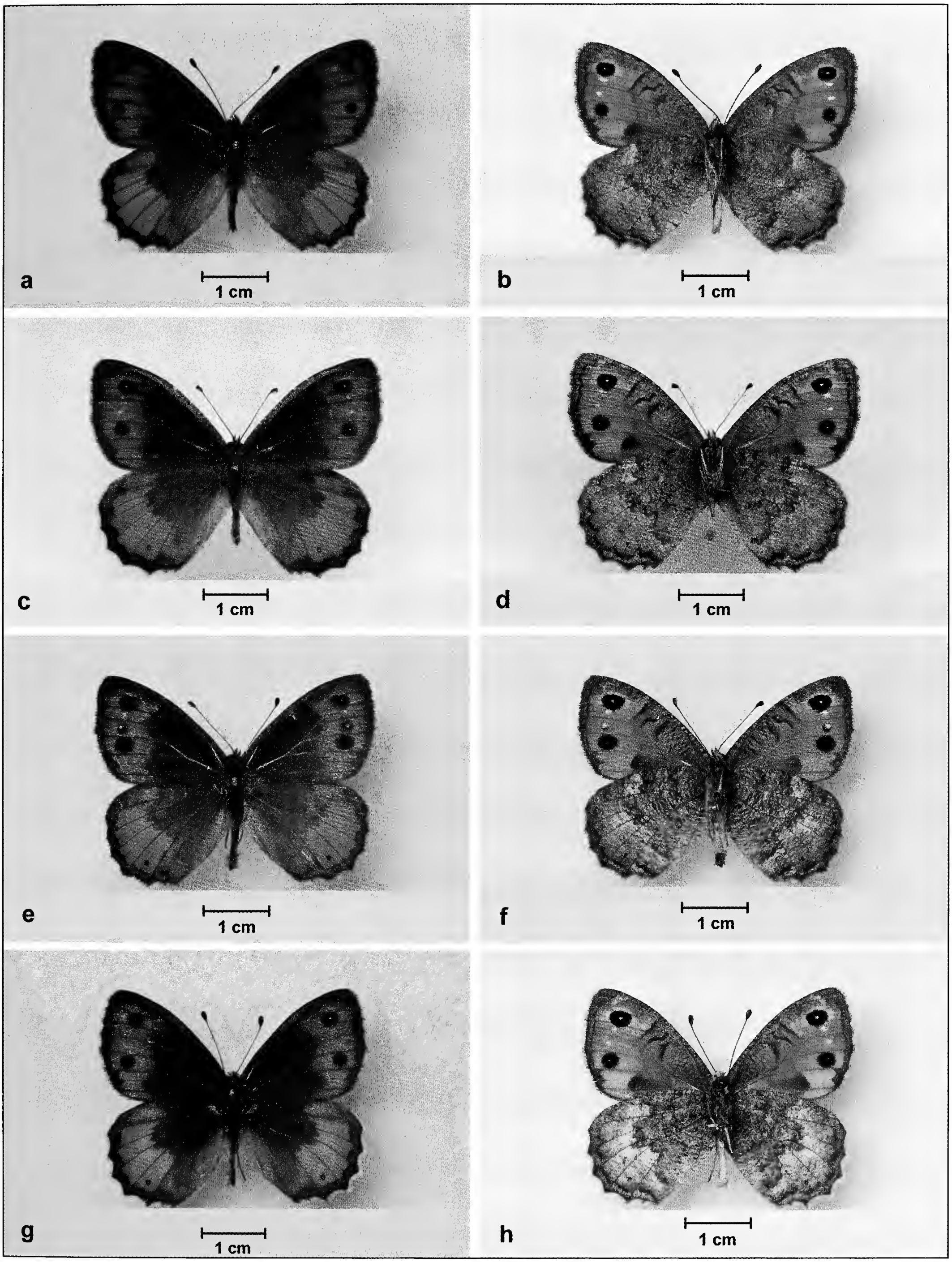

Figure 3. Variability in *P. amymone*. **a–b.** ♂ typical upper- and underside, Boboshtiçë, Albania, 16.vii.2013 (coll. & photograph: SC). **c–d.** ♂ typical upper- and underside, Gjergjeviçë, Albania, 18.vii.2013 (coll. & photograph: MM). **e–f.** ♂ aberration, upper- and underside, Boboshtiçë, Albania, 16.vii.2013 (coll. & photograph:

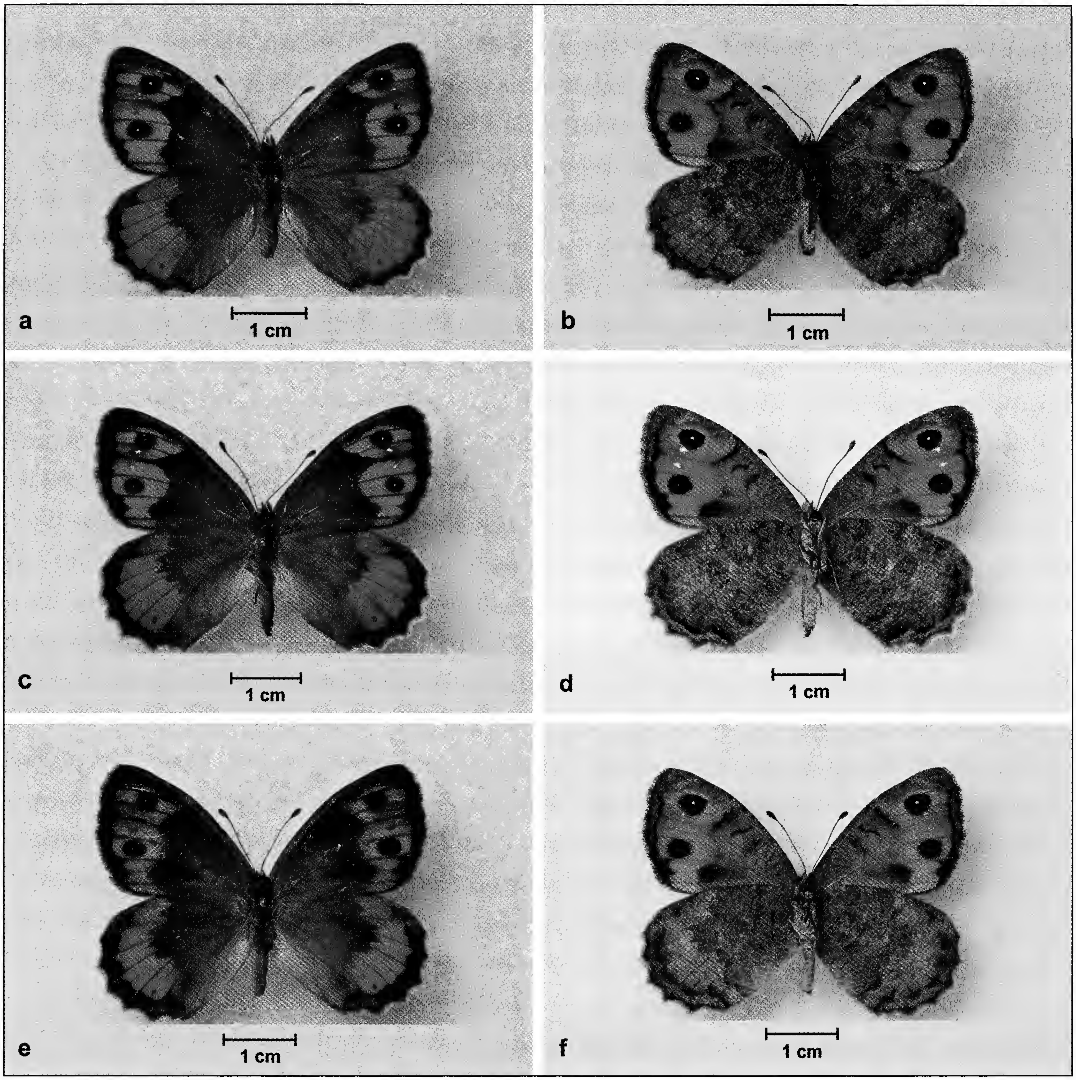

Figure 4. Variability in *P. amymone*. **a–b.** ♀ typical *P. amymone* upper- and underside, Gjergjeviçë, Albania, 18.vii.2013. **c–d.** ♀ typical *P. amymone* upper- and underside, Boboshtiçë, Albania, 16.vii.2013. **e–f.** ♀ dark form upper- and underside, Gjergjeviçë, Albania, 18.vii.2013. (Coll. & photographs: SC).

ments from the two populations can be pooled together for the comparison between Albanian *P. amymone* and *P. mniszechii tisiphone*.

Two *P. amymone* specimens exhibited asymmetry between right and left side. This was the case for one male with one spot in S3-S4 on the left FW UPS and no marking on the right FW. One female had one black ocellus on the left side of the HW UNS and two on the right side.

There seem to be a few marked differences between *P. amymone* from Albania and the original description by Brown (1976). It is clear that the holotype (Fig. 1) is not fresh and probably the paratypes were even more worn. A few butterflies in our study that were less fresh also have a clearer appearance and tend to become more orange in the postdiscal bands of the FW UPS. We

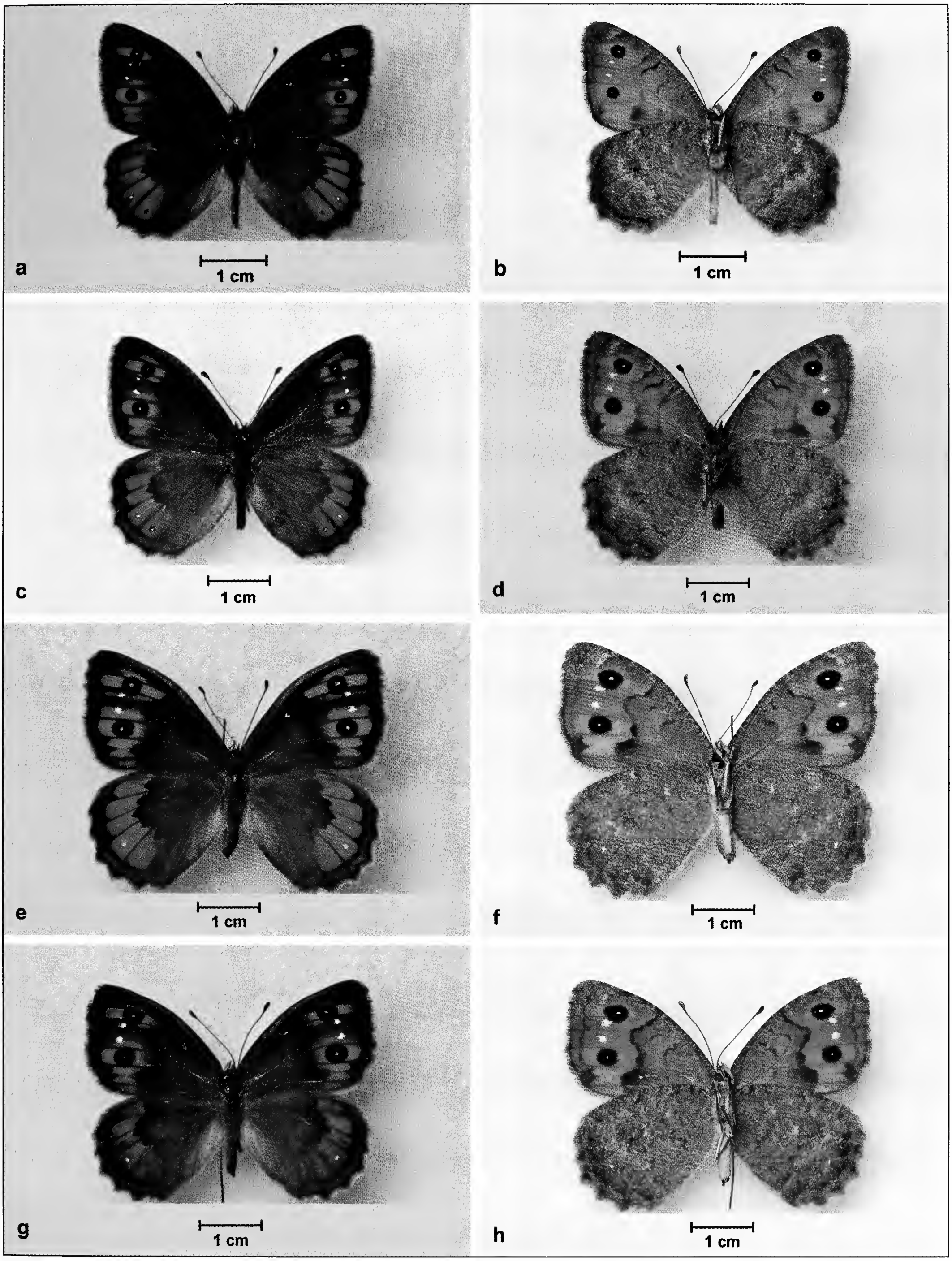

Figure 5. Variability in *P. mniszechii tisiphone*. **a–b.** Typical ♂ upper- and underside, Boboshtiçë, Albania, 16.vii.2013. **c–d.** ♂ typical upper- and underside, Boboshtiçë, Albania, 16.vii.2013. **e–f.** ♀ typical upper- and underside, Boboshtiçë, Albania, 16.vii.2013. **g–h.** ♀ dark form upper- and underside, Boboshtiçë, Albania, 18.vii.2013. (Coll. & photographs: SC).

Table 1. Measurements of *P. amymone* from Boboshtiçë versus *P. amymone* from Gjergjeviçë.

	P. amymone	Males (n=30) Boboshtiçë				Males (n=8) Gjergjeviçë			
		Range (min-max)		SD	Mean	Range (min-max)		SD	Mean
UPS	Var 1: FW length from thorax to apex (mm)	22.00	25.00	0.76	24.08	22.50	24.50	0.65	23.50
	Var 2: FW white pupils in black oc. S2, S5 (N°)	0.00	1.00	0.25	0.93	0.00	1.00	0.35	0.88
	Var 3: FW spots S3, S4 (N°)	0.00	2.00	0.82	0.57	0.00	2.00	0.89	0.75
	Var 4: FW width subm. band oc. S2 (mm)	5.50	7.25	0.44	6.54	5.75	6.75	0.37	6.31
	Var 5: FW width subm. band oc. S2/ FW length (%)	23.40%	30.43%	1.87%	27.18%	24.49%	28.72%	1.52%	26.87%
	Var 6: FW sex brand position (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 7: HW oc. (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 8: HW width subm. band vein 3 (mm)	6.00	8.25	0.52	7.28	6.00	7.75	0.62	6.94
	Var 9: HW width subm. band vein 3/ FW length (%)	25.53%	35.23%	2.01%	30.25%	26.09%	32.98%	2.34%	29.51%
UNS	Var 10: FW white pupils in black oc. S2, S5 (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 11: FW oc. S5 towards cell paler area (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 12: FW spots in S3, S4 (N°)	0.00	2.00	0.37	1.93	0.00	2.00	0.71	1.75
	Var 13: FW marg. line (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 14: FW basal area cell: black markings (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 15: FW oc. S5 length (mm)	2.50	4.00	0.33	3.04	2.70	3.25	0.20	3.03
	Var 16: FW oc. S5 length/FW length (%)	10.83%	16.33%	1.30%	12.60%	11.74%	14.22%	0.93%	12.91%
	Var 17: FW oc. S5 length/FW centre oc. S5-margin (%)	49.52%	80.00%	8.17%	60.73%	52.17%	65.00%	4.97%	58.58%
	Var 18: FW centre oc. S5-margin (mm)	4.00	5.50	0.36	5.03	5.00	5.75	0.29	5.19
	Var 19: FW centre oc. S5-margin/FW length (%)	16.33%	22.92%	1.58%	20.88%	21.28%	23.96%	0.94%	22.07%
	Var 20: HW oc. (N°)	1.00	1.00	0.00	1.00	0.00	1.00	0.35	0.88
	Var 21: HW median band (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	P. amymone	Females (n=14) Boboshtiçë				Females (n=5) Gjergjeviçë			
		Range (min-max)		SD	Mean	Range (min-max)		SD	Mean
UPS	Var 1: FW length from thorax to apex (mm)	24.00	27.00	0.84	26.14	24.00	26.00	0.71	25.00
	Var 2: FW white pupils in black oc. S2, S5 (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 3: FW spots S3, S4 (N°)	1.00	2.00	0.36	1.86	0.00	2.00	0.89	1.40
	Var 4: FW width subm. band oc. S2 (mm)	7.00	8.25	0.41	7.48	6.50	7.50	0.37	6.95
	Var 5: FW width subm. band oc. S2/ FW length (%)	26.92%	32.35%	1.57%	28.63%	25.00%	30.00%	1.79%	27.83%
	Var 6: FW sex brand position (0-1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Var 7: HW oc. (N°)	1.00	2.00	0.43	1.21	1.00	1.00	0.00	1.00
	Var 8: HW width subm. band vein 3 (mm)	7.00	8.75	0.50	7.86	7.00	8.00	0.55	7.40
	Var 9: HW width subm. band vein 3/ FW length (%)	25.93%	33.33%	1.85%	30.07%	26.92%	32.00%	2.31%	29.62%

UNS	Var 10: FW white pupils in black oc. S2, S5 (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 11: FW oc. S5 towards cell paler area (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 12: FW spots in S3, S4 (N°)	2.00	2.00	0.00	2.00	2.00	2.00	0.00	2.00
	Var 13: FW marg. line (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 14: FW basal area cell: black markings (0-1)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 15: FW oc. S5 length (mm)	3.00	3.75	0.29	3.35	3.00	4.00	0.44	3.61
	Var 16: FW oc. S5 length/FW length (%)	11.11%	14.42%	1.15%	12.81%	12.00%	16.00%	1.59%	14.43%
	Var 17: FW oc. S5 length/FW centre oc. S5-margin (%)	45.93%	71.43%	8.50%	56.51%	54.55%	66.67%	4.95%	61.02%
	Var 18: FW centre oc. S5-margin (mm)	5.25	6.75	0.49	5.98	5.50	6.25	0.29	5.90
	Var 19: FW centre oc. S5-margin/FW length (%)	19.44%	25.96%	1.92%	22.88%	22.00%	25.00%	1.13%	23.60%
	Var 20: HW oc. (N°)	1.00	2.00	0.51	1.43	1.00	2.00	0.45	1.20
	Var 21: HW median band (0-1)	0.00	1.00	0.52	0.50	1.00	1.00	0.00	1.00

have clearly shown that many characteristics are much more variable within a single population than described by Brown (1976). We presume, until more material becomes available, that Greek *P. amymone* falls within the given range of variability.

Determination keys between *P. amymone* and *P. mniszechii tisiphone*

The maximal range and mean of all variables for the two species are shown in Table 2. An overview of the statistical significance status of all variables is shown in Table 3. Some variables of *P. amymone* and *P. mniszechii tisiphone* did not overlap at all. Some differences are present in both sexes, others are only present in males. Below we list the variables that can be used in distinguishing *P. amymone* and *P. mniszechii tisiphone*.

Var 13: UNS FW submarginal line in both sexes (Figs 6a–b). This line is always sharp in *P. amymone* and diffuse in *P. mniszechii tisiphone*.

Var 14: UNS FW basal area of the cell in both sexes (Figs 6c–d). There are always black linear markings inside this area in *P. amymone* which are absent in *P. mniszechii tisiphone*.

Var 6: UPS FW sex brand position in males (Figs 6e–f). *P. amymone* has a black sex brand over the whole cell and the androconial field is extending to the inner margin of the FW. *P. mniszechii tisiphone* does not have a sex brand in the cell and the androconial field is covering only half of the cell towards the inner margin of the FW.

Var 7: UPS HW number of oc. in males (Figs 6g–h). There is 1 ocellus in *P. amymone* and 2 oc. in *P. mniszechii tisiphone*. Females of the two species have both a range of 1 to 2 oc.

The wingspan of the females was in many cases useful in the field for the identification but one *P. mniszechii tisiphone female* falls in the upper range of *P. amymone*.

Table 2. Measurements of pooled data of *P. amymone* versus *P. mniszechii tisiphone*.

		Males (n=38) *P. amymone*				Males (n=15) *P. mniszechii tisiphone*			
		Range (min-max)		SD	Mean	Range (min-max)		SD	Mean
UPS	Var 1: FW length from thorax to apex (mm)	22.00	25.00	0.77	23.96	24.50	27.00	0.70	26.30
	Var 2: FW white pupils in black oc. S2, S5 (N°)	0.00	1.00	0.27	0.92	1.00	1.00	0.00	1.00
	Var 3: FW spots S3, S4 (N°)	0.00	2.00	0.82	0.61	2.00	2.00	0.00	2.00
	Var 4: FW width subm. band oc. S2 (mm)	5.50	7.25	0.43	6.49	5.00	6.50	0.51	5.85
	Var 5: FW width subm. band oc. S2/ FW length (%)	23.40%	30.43%	1.79%	27.11%	18.87%	25.00%	1.77%	22.24%
	Var 6: FW sex brand position (0-1)	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
	Var 7: HW oc. (N°)	1.00	1.00	0.00	1.00	2.00	2.00	0.00	2.00
	Var 8: HW width subm. band vein 3 (mm)	6.00	7.75	0.55	7.21	5.50	7.50	0.54	6.47
	Var 9: HW width subm. band vein 3/ FW length (%)	25.53%	35.23%	2.07%	30.09%	21.30%	27.78%	1.92%	24.59%
UNS	Var 10: FW white pupils in black oc. S2, S5 (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 11: FW oc. S5 towards cell paler area (0-1)	1.00	1.00	0.00	1.00	0.00	1.00	0.26	0.07
	Var 12: FW spots in S3, S4 (N°)	0.00	2.00	0.45	1.89	2.00	2.00	0.00	2.00
	Var 13: FW marg. line (0-1)	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
	Var 14: FW basal area cell: black markings (0-1)	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
	Var 15: FW oc. S5 length (mm)	2.50	4.00	0.30	3.03	2.25	3.25	0.28	2.71
	Var 16: FW oc. S5 length/FW length (%)	10.83%	16.33%	1.23%	12.67%	8.65%	12.50%	0.94%	10.31%
	Var 17: FW oc. S5 length/FW centre oc. S5-margin (%)	49.52%	80.00%	7.60%	60.28%	40.00%	55.00%	5.01%	48.89%
	Var 18: FW centre oc. S5-margin (mm)	4.00	5.75	0.35	5.06	5.00	6.25	0.44	5.57
	Var 19: FW centre oc. S5-margin/FW length (%)	16.33%	23.96%	1.54%	21.13%	18.52%	24.04%	1.64%	21.17%
	Var 20: HW oc. (N°)	0.00	1.00	0.16	0.97	0.00	2.00	0.62	1.67
	Var 21: HW median band (0-1)	1.00	1.00	0.00	1.00	0.00	1.00	0.41	0.80
		Females (n=19) *P. amymone*				Females (n=20) *P. mniszechii tisiphone*			
		Range (min-max)		SD	Mean	Range (min-max)		SD	Mean
UPS	Var 1: FW length from thorax to apex (mm)	24.00	27.00	0.94	25.84	27.00	31.50	1.27	29.43
	Var 2: FW white pupils in black oc. S2, S5 (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 3: FW spots S3, S4 (N°)	0.00	2.00	0.56	1.74	2.00	2.00	0.00	2.00
	Var 4: FW width subm. band oc. S2 (mm)	6.50	8.25	0.46	7.34	7.25	10.00	0.63	8.48
	Var 5: FW width subm. band oc. S2/ FW length (%)	25.00%	32.35%	1.62%	28.42%	25.44%	31.75%	1.56%	28.79%
	Var 6: FW sex brand position (0-1)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Var 7: HW oc. (N°)	1.00	2.00	0.37	1.16	1.00	3.00	0.51	1.95
	Var 8: HW width subm. band vein 3 (mm)	7.00	8.75	0.54	7.74	6.00	9.00	0.77	7.41
	Var 9: HW width subm. band vein 3/ FW length (%)	25.93%	33.33%	1.93%	29.95%	20.69%	29.03%	2.12%	25.17%

UNS	Var 10: FW white pupils in black oc. S2, S5 (N°)	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
	Var 11: FW oc. S5 towards cell paler area (0-1)	1.00	1.00	0.00	1.00	0.00	1.00	0.47	0.30
	Var 12: FW spots in S3, S4 (N°)	2.00	2.00	0.00	2.00	2.00	2.00	0.00	2.00
	Var 13: FW marg. line (0-1)	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
	Var 14: FW basal area cell: black markings (0-1)	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
	Var 15: FW oc. S5 length (mm)	3.00	4.00	0.34	3.42	3.25	4.50	0.29	3.85
	Var 16: FW oc. S5 length/FW length (%)	11.11%	16.00%	1.43%	13.24%	10.48%	15.00%	1.11%	13.12%
	Var 17: FW oc. S5 length/FW centre oc. S5-margin (%)	45.93%	71.43%	7.86%	57.70%	41.94%	64.29%	5.32%	54.55%
	Var 18: FW centre oc. S5-margin (mm)	5.25	6.75	0.44	5.96	6.50	8.00	0.40	7.09
	Var 19: FW centre oc. S5-margin/FW length (%)	19.44%	25.96%	1.74%	23.07%	22.22%	25.81%	1.09%	24.10%
	Var 20: HW oc. (N°)	1.00	2.00	0.50	1.37	1.00	3.00	0.60	1.55
	Var 21: HW median band (0-1)	0.00	1.00	0.50	0.63	0.00	1.00	0.51	0.55

Table 3. Overview of the statistical significance of Mann-Whitney U tests of all variables of *P. amymone* versus *P. mniszechii tisiphone*. Males DF = 51, females DF = 37. *P* values below 0.05 are shown in bold.

	Z♂	**p♂**	**Z♀**	**p♀**
Var 1: FW length from thorax to apex (mm)	-0.873	0.38430	2.694	**0.00714**
Var 2: FW white pupils in black oc. S2, S5 (N°)	-0.838	0.40090	0.195	0.84930
Var 3: FW spots S3, S4 (N°)	-2.890	**0.00386**	0.495	0.62414
Var 4: FW width subm. band oc. S2 (mm)	2.048	**0.04036**	1.889	0.05876
Var 5: FW width subm. band oc. S2/FW length (%)	1.995	**0.04550**	0.265	0.79486
Var 6: FW sex brand position (0-1)	3.994	**0.00006**	N/A	N/A
Var 7: HW oc. (N°)	-1.995	**0.04550**	1.340	0.18024
Var 8: HW width subm. band vein 3 (mm)	0.859	0.38978	0.130	0.89656
Var 9: HW width subm. band vein 3/FW length (%)	1.971	**0.04884**	-1.709	0.08726
Var 10: FW white pupils in black oc. S2, S5 (N°)	0.004	1.00000	0.005	1.00000
Var 11: FW oc. S5 towards cell paler area (0-1)	3.994	**0.00006**	-3.794	**0.00016**
Var 12: FW spots in S3, S4 (N°)	-0.417	0.67448	0.005	1.00000
Var 13: FW marg. line (0-1)	3.994	**0.00006**	-3.794	**0.00016**
Var 14: FW basal area cell: black markings (0-1)	3.994	**0.00006**	-3.794	**0.00016**
Var 15: FW oc. S5 length (mm)	-0.810	0.41794	-0.635	0.52870
Var 16: FW oc. S5 length/FW length (%)	-0.512	0.61006	0.480	0.63122
Var 17: FW oc. S5 length/FW centre oc. S5-margin (%)	-1.466	0.14156	0.405	0.68916
Var 18: FW centre oc. S5-margin (mm)	1.736	0.08186	-0.475	0.63836
Var 19: FW centre oc. S5-margin/FW length (%)	1.757	0.07840	-0.030	0.97606
Var 20: HW oc. (N°)	0.796	0.42372	-0.685	0.49650
Var 21: HW median band (0-1)	2.732	**0.00634**	-0.595	0.55520

Androconial scales of *P. amymone* and *P. mniszechii tisiphone*

The dense sex band in the FW cell makes it difficult to isolate the androconial scales (Fig. 7a) of *P. amymone*. Scales with quite different shapes, sometimes bright silver-grey (Fig. 7b), were found in this area and created confusion. The type of these scales is unclear to the authors.

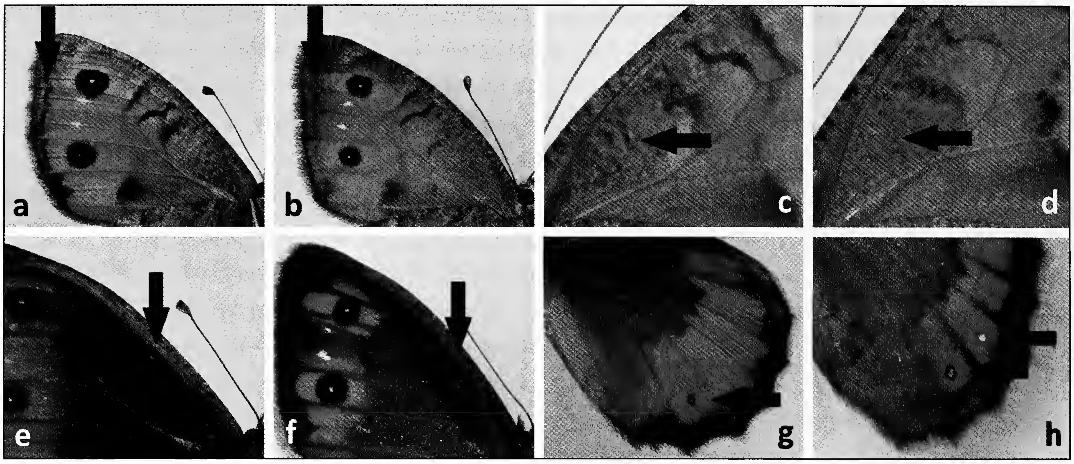

Figure 6. Visualization of the significant difference between *P. amymone* (**a, c, e, g**) and *P. mniszechii tisiphone* (**b, d, f, h**). Var 13 (**a–b**), Var 14 (**c–d**), Var 6 (**e–f**), Var 7 (**g–h**).

According to the criteria of Gross, the androconial scales of *P. amymone* (Fig. 7c) are in general of type 7 (Gross 1978) but few were found where the diameter of the lamina decreased immediately from the basal stalk tasowards the apex. These are more closely resembling a type 6 androconial scale. AL= 0.42 mm, AB= 0.05 mm and A= 8.4. These data are near the values for *P. mamurra* in Wakeham-Dawson and Kudrna (2000). Also the shape of the scales from *P. amymone* falls within the ranges of *P. mamurra* (Wakeham-Dawson and Kudrna 2000; Wakeham-Dawson and Kudrna 2005). The androconia of *P. amymone* are much larger and of a different shape than *P. graeca* (Wakeham-Dawson, 2000). The androconial scales of *P. mniszechii tisiphone* (Fig. 7d) are different in shape, transitional type 5-6 with dimensions: AL= 0.33 mm, AB= 0.027 mm and A= 12.19.

Coverage of historical data and personal observations

Additional field work in other localities of the province of Korçë and in the provinces Kolonjë, Përmet, Tepelenë and Skrapar fill an important gap in the documented distribution of the butterflies from south-eastern Albania. The coverage map (Fig. 8) shows historical data (red dots), the two areas where *P. amymone* was found (blue letters B and G) and all new places that were surveyed by the authors (green dots).

Discussion and conclusion

The discovery of *P. amymone* on a new isolated mountain and the fact that large parts of Albania with similar geological origins still remain unexplored suggest that *P. amymone* might be more widely distributed than previously thought. With further field research on slopes in steep river valleys, not necessarily with ophiolites, the species will undoubtedly be discovered at new sites.

The butterfly probably has a more restricted and fragmented distribution in Greece due to the less frequently present favoured type of geological substrate. This idea is already supported by the almost complete lack of evidence despite the many efforts of numerous lepidopterists since the discovery of the butterfly by Brown (1976). Using geological data, we suggest that the research in

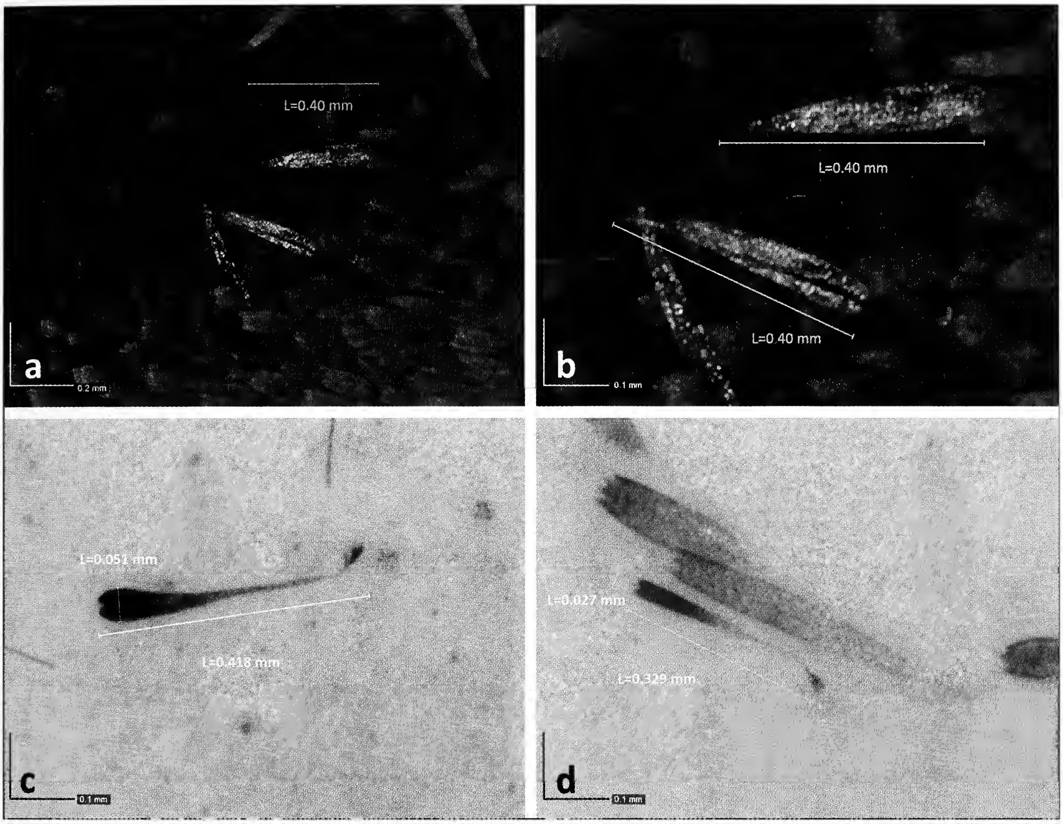

Figure 7. a. UPS FW sex brand of ♂ *P. amymone* (× 250), Boboshtiçë, Albania, 16.vii.2013. **b.** UPS FW scales in sex brand of ♂ *P. amymone* (× 500), Albania, 16.vii.2013. **c.** Androconial scale of ♂ *P. amymone* (× 500), Boboshtiçë, Albania, 16.vii.2013. **d.** Androconial scale of ♂ *P. mniszechii tisiphone* (× 500), Boboshtiçë, Albania, 16.vii.2013. (Coll. & photographs: SC).

Greece should be extended because areas with ophiolite substrate are present over a wider part of continental Greece, whereas they are hardly present near Ioannina. Understanding more fully the habitat requirements of *P. amymone*, it now looks possible to elucidate the mystery of its whereabouts in Greece in order to undertake any conservation measures if needed.

During the examination of the Albanian material it became clear that *P. amymone* is a very variable species and that the original description (Brown 1976) did not cover the whole range of variability, partly because of the very restricted number of studied butterfly vouchers. Pamperis (1997: 348-349, fig. 3.7.10; 2009: 499, fig. 3.5.11) shows figures with characteristic marks on the underside of *P. amymone* in comparison with other Greek species of *Pseudochazara*. The black and white figure of *P. amymone* focuses on a black base of the HW UNS and a pale dentate line in the postdiscal area with more contrast than in other *Pseudochazara* species. This black base is not a striking feature of the Albanian specimens. Darker grey scales in that area are sometimes visible in both *P. amymone* and *P. mniszechii tisiphone*. The dentate line was visually assessed as Var. 21 showing overlap and for both species this variable was sometimes scored as absent. In external

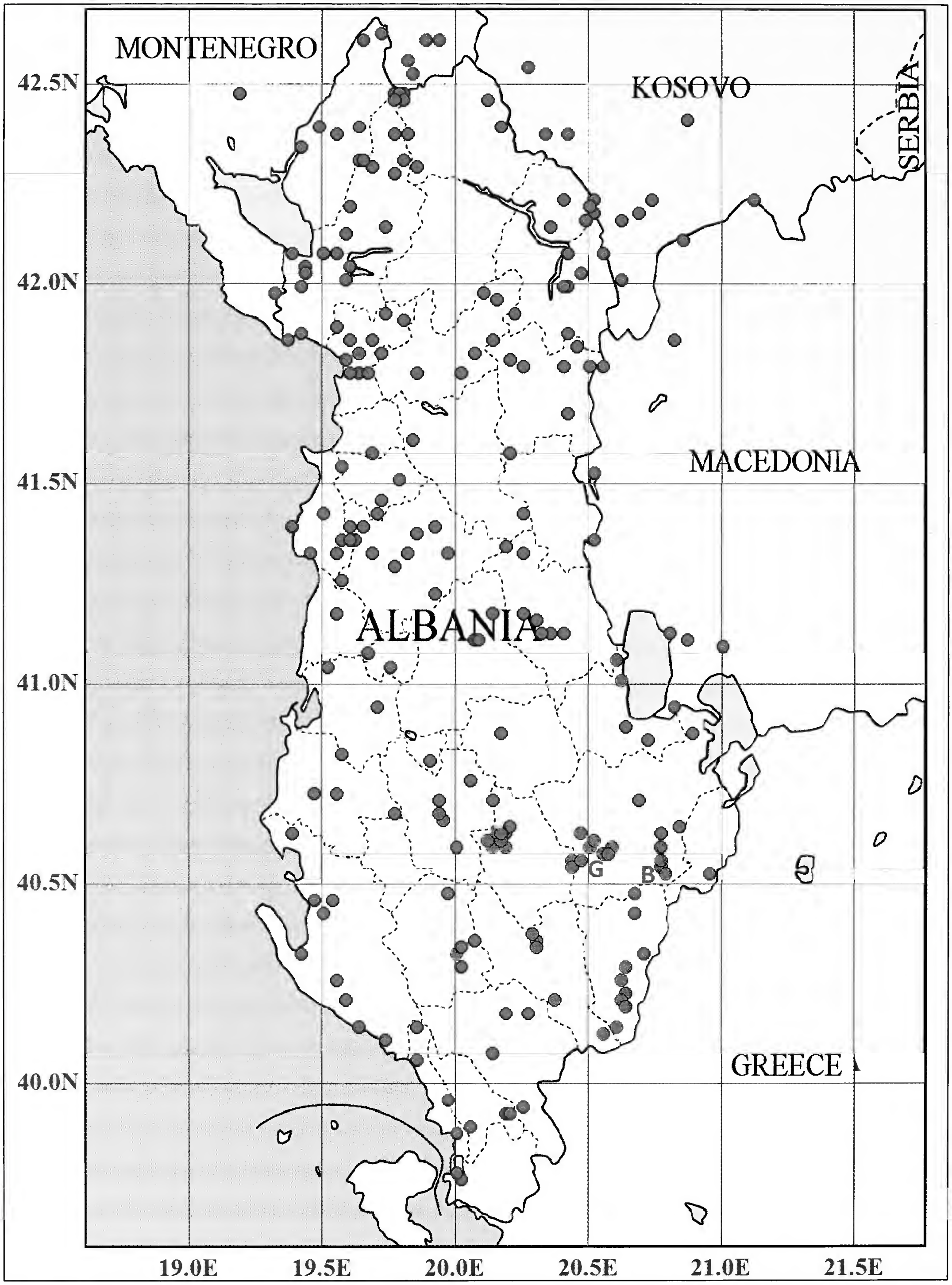

Figure 8. Coverage of historical data and personal observations: map of Albania indicating Papilionoidea observations from literature (●) and from observations by the authors (●). **B:** Boboshtiçë; **G:** Gjergjeviçë: localities of *P. amymone*.

features, Pamperis (1997: 351; 2009: 500) in analogy with Brown (1976), focuses on the orange brown band in the postdiscal area.

The only feature for Greek *P. amymone* that seems different is the presence of the broad and clear orange postdiscal bands. Only for older butterflies from Boboshtiçë and Gjergjeviçë is there a tendency to paler orange postdiscal bands. This potential difference should be documented by studying material from new localities including additional material in this dataset to increase the sample size. Adding material from Greece to get an idea about the full range of the external characters of this taxon seems mandatory. A few other criteria seem specific to *P. amymone* in comparison with *P. mniszechii tisiphone*. It became clear that *P. mniszechii tisiphone* is a very variable species too.

Despite clear differences in the androconial scales, it would be interesting to make an analysis of external characters with the very similar *P. graeca*, a species that has never been found in the same locality with *P. amymone*.

The androconial scale of *P. amymone* falls within the range of the different subspecies of *P. mamurra* and this result supports the treatment by Eckweiler of *P. amymone* as a potential subspecies of *P. mamurra*. Even though androconia have been used as a taxonomic character for distinguishing species of the genus *Pseudochazara*, no comment is given here as independent DNA analysis is ongoing and will be published soon.

We encourage entomologists to visit Albania during different periods of the year to do research not only for *P. amymone* but also to survey large parts of the country that are poorly explored for butterflies. It will certainly help to significantly improve knowledge about the distribution of many taxa in the south-western Balkans.

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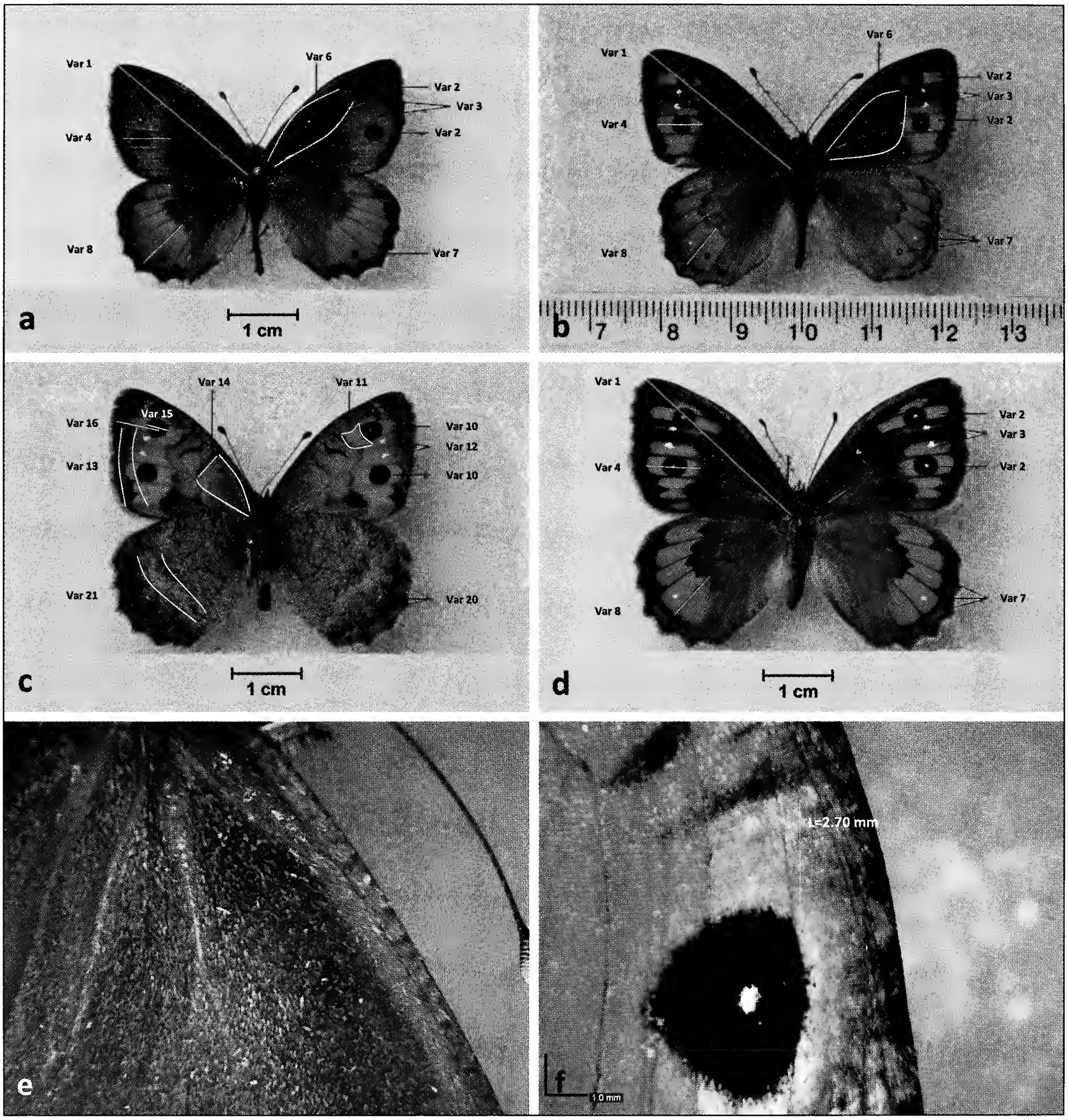
Appendix 1



Variables of *P. amymone* and *P. mniszechii tisiphone*. **a.** UPS variables of ♂ *P. amymone*, Boboshtiçë, Albania, 16.vii.2013. **b.** UPS variables of ♂ *P. mniszechii tisiphone*, Boboshtiçë, Albania, 16.vii.2013. **c.** UNS variables of ♂ *P. mniszechii tisiphone*, Boboshtiçë, Albania, 16.vii.2013. **d.** UPS variables of ♀ *P. mniszechii tisiphone*, Boboshtiçë, Albania, 16.vii.2013. **e.** Sex brand of ♂ *P. amymone* (×30), Boboshtiçë, Albania, 16.vii.2013. **f.** UNS pale area from ocellus in S5 towards cell, *P. amymone* (×32), Boboshtiçë, Albania, 16.vii.2013. (Coll. & photographs: SC).

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Record of *Borearctia menetriesii* (Eversmann, 1846) (Lepidoptera, Erebidae, Arctiinae) larva on *Aconitum rubicundum* Fischer (Ranunculaceae) in Eastern Siberia

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Abstract. In this note we report the first record of *Borearctia menetriesii* (Eversmann, 1846) (Erebidae: Arctiinae) larva on a native host plant, *Aconitum rubicundum* Fischer (Ranunculaceae). This aconite species is a close relative of *A. lycoctonum*, which is widespread across Eurasia, but has a scattered distribution in Fennoscandia. The majority of *B. menetriesii* localities are situated within the distribution range of *A. lycoctonum* and other aconite taxa, which are diverse and widespread in the Eastern Palaearctic. However, only two of the six westernmost *B. menetriesii* localities in Finland are in accordance with sporadic records of *A. lycoctonum*. Our record confirms that *B. menetriesii* is a polyphagous species like most other boreal Arctiinae. We have expanded the list of a few Lepidoptera species which can use *Aconitum* spp. as suitable host plants despite the fact that they are poisonous for insects because of high alkaloid content.

Introduction

The Menetries's tiger moth *Borearctia menetriesii* (Eversmann, 1846) (Erebidae: Arctiinae) is the most enigmatic representative among the Palaearctic arctiine moths. The biology of this large and colorful species is poorly known because of its extremely low abundance throughout its distribution range (Lappi et al. 2004; Dubatolov 2010; Bolotov et al. 2013). Only single specimens were found in the majority of known localities, and sometimes the records are separated from each other by many decades (Bolotov et al. 2013).

Krogerus (1944) experimentally identified three available host plants in Finland, including *Taraxacum* spp. (Asteraceae), *Plantago* ssp. (Plantaginaceae) and *Polygonum* ssp. (Polygonaceae). In a preliminary report on the food preference of the larvae, Saarenmaa (2014) lists 15 plant species which *B. menetriesii* larvae preferred or accepted during experiments, including *Larix* spp. (Pinaceae), *Rubus chamaemorus* L., *R. idaeus* L., *R. saxatilis* L. and *Potentilla palustris* (L.) Scop. (Rosaceae), *Menyanthes trifoliata* L. (Menyanthaceae), *Rumex crispus* L., *Polygonum persicaria* L. and *P. lapathifolium* L. (Polygonaceae), *Plantago major* L. (Plantaginaceae), *Ribes rubrum* L. (Grossulariaceae), *Salix phylicifolia* L. (Salicaceae), *Taraxacum officinale* Weber (Asteraceae), *Vaccinium uliginosum* L. (Ericaceae) and *Viola riviniana* Rchb. (Violaceae). He noted that the larch species might be a significant food plant over the majority of the *B. menetriesii* range. However, all those data are based exclusively on these laboratory experiments. There is the unique observation

Figure 1. The last instar larva of *B. menetriesii* on *Aconitum rubicundum* Fischer, Baikalo-Lensky Nature Reserve, 9.viii.2013 (photo: O. E. Berlov).

in natural habitat in Finland in June 1920 of a larva having climbed a spruce trunk (Krogerus 1944). Here we report the first record of a feeding larva on a native host plant in the Baikalo-Lensky State Nature Reserve, Eastern Siberia.

Observations

Locality: Eastern Siberia, the Baikal Lake Area, the Bolshoy Anay River terrace, 53°56’19”N, 107°24’35”E, ca 770 m alt., mixed coniferous taiga forest with herb-*Equisetum*-moss plant cover (locality description and photo: Suppl. material 1: Table S1, Fig. S1). A last instar larva of *B. menetriesii* was collected alive on *Aconitum rubicundum* Fischer (Ranunculaceae) 9.viii.2013 (Figs 1–3) and was placed in a cage that was taken to the Irkutsk city. In captivity, the larva had a daytime feeding activity and consumed only fresh *A. rubicundum* leaves which we had collected from the same locality as the larva. The leaves were completely eaten by 15.viii.2013. Unfortunately, we could not find any aconite species in the city surroundings. The larva did not accept *Taraxacum* spp. and *Plantago* spp. leaves which we placed in the cage and it was found dead on 22.viii.2013. An additional larva was captured dead in a pitfall trap at the same locality on 10.viii.2013. The collected larvae were 32–35 mm long.

Discussion

The observed host plant, *A. rubicundum*, is distributed in Central and Eastern Siberia, and is closely related to the widespread Eurasian *A. lycoctonum* (Malyschev and Pechkova 1993) and might even represent its eastern subspecies (Ivanova 1978). These two species (or subspecies) were separated

Figures 2–3. *Aconitum rubicundum* Fischer, the host plant of *B. menetriesii*, Baikalo-Lensky Nature Reserve. **2.** An inflorescence, upstream of the Pravaya Kirenga River, 14.vii.2006 (photo: N.V. Stepantsova). **3.** A leaf at the *B. menetriesii* locality, 9.viii.2013 (photo: O. E. Berlov).

on minor diagnostic features, particularly the location and density of hairs on the stem and leaf blade; both have identical chromosome number (2n = 16) (Malyschev and Pechkova 1993). All Russian *B. menetriesii* localities are situated within the distribution range of *A. lycoctonum* and other aconite taxa, which are especially diverse and widespread in the Eastern Palaearctic, including 26 species in Siberia and 37 species in the Russian Far East (Jalas and Suominen 1989; Malyschev and Pechkova 1993; Kharkevich 1995; Bolotov et al. 2013). In boreal Russia, various aconite species are abundant in the plant cover of river valleys and humid alpine meadows (Peshkova 1985; Malyschev and Pechkova 1993; Kharkevich 1995) where *B. menetriesii* most frequently occurs (Bolotov et al. 2013). For example, *A. lycoctonum* is one of the dominant plant species in the *B. menetriesii* habitat in the Sotka River Valley, Arkhangelsk Region (Bolotov et al. 2013). However, *A. lycoctonum* has a scattered distribution in Finland (Jalas and Suominen 1989; Lampinen et al. 2014), and only two of the six Finnish *B. menetriesii* localities are near sites where this plant species was recorded (Suppl. material 1: Fig. 2S).

Aconite species have a strong insecticidal activity (Yuan et al. 2012) because of their high alkaloid content (Azimova and Yunusov 2013). Eighteen alkaloids were isolated from *A. lycoctonum* (Azimova and Yunusov 2013). *A. rubicundum* contains at least nine diterpenoid alkaloids (Nishanov et al. 1991).

The HOSTS database (Robinson et al. 2010) listed only 16 Lepidoptera species feeding on *Aconitum* spp. The majority of these species are polyphagous (12 of them), including *Euproctis similis* (Fuessly, 1775), a unique Erebidae representative. According to other sources (Vorbrodt and Müller-Rutz 1914; Freina and Witt 1987; Bellmann 2003), there are two Arctiinae species recorded on *Aconitum* spp., *Arctia flavia* (Fuessly, 1779) on *A. lycoctonum* ssp. *vulparia* (Rchb.) Nyman and *Diaphora sordida* (Hübner, 1803) on *A. napellus* Linnaeus.

Our record confirms that *B. menetriesii* is a polyphagous species like most other boreal Arctiinae (Dubatolov 1990), but additional experiments are needed for an appropriate evaluation of the role of *Aconitum* spp. as a host plant for European populations of *B. menetriesii.*

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Supplementary material 1

The collection locality of *Borearctia menetriesii* larvae in Eastern Siberia and records of *Aconitum lycoctonum* and *Borearctia menetriesii* in Finland.

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Explanation note: Table S1, Figs S1–S2.

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Contribution to the knowledge of the butterfly fauna of Albania

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Abstract. Albanian insect fauna is one of the least studied in Europe. In 2012 and 2013 surveys were undertaken with the aim of improving the knowledge of the distribution of butterflies, particularly in the southern part of the country. This research has resulted in the publication of three new species records for Albania. Here we add two new species to the list of native butterflies of Albania, *Melitaea ornata* Christoph, 1893 and *Cupido alcetas* (Hoffmannsegg, 1804). We recorded a total of 143 species including several confirmations of historical published records.

The total number of species has consequently increased to 198, which is comparable with butterfly diversity in neighbouring countries. Unlike its neighbours, Albania has preserved many of its traditional agricultural practices and consequently its rich fauna has been well protected during the last decades. However, with the opening up of the country to outside influences this will undoubtedly change as the process of intensification has already started in more populated coastal areas. It is therefore imperative to identify important butterfly areas in need of conservation and to take decisive measures to preserve traditional agricultural practices.

Introduction

Albania is a European country in the south-eastern Mediterranean region. Its total area is 28,748 km^2, with 28.5% of its surface area exceeding 1000 m in altitude making it one of the most mountainous countries in Europe. It has diverse landscapes, ranging from high mountains in the north and east to an extensive coastline in the west. The climate benefits from both Mediterranean and Central European influences, with mean January temperatures ranging between –3° to 10°C and mean July temperatures varying between 17° to 25°C. Rainfall ranges from 600 mm to over 3000 mm in high mountain areas (Weatheronline 2014). Albania is in the contact zone between Central European and Mediterranean fauna and is a part of the Mediterranean biodiversity 'hotspot' (Cuttelod et al. 2008) with exceptionally rich fauna and flora (MMPAU 2007; Radford et al. 2011). A recent revision of the butterfly fauna of Albania resulted in an updated checklist of 196 species (Verovnik and Popović 2013a), and with possible additional species to be discovered it is one of the richest butterfly countries in Europe.

Lack of interest in butterflies by the local community, inadequate funding and political isolation during Communist times has left the butterfly fauna of Albania amongst the least studied in the Balkans. Southern Albania in particular has never been extensively studied and only the accounts of a few scientific surveys have been published (Gaskin 1990; Abadjiev and Beshkov 1996a; Abadjiev and Beshkov 1996b; Misja 2005; Verovnik and Popović 2013b; Cuvelier and Mølgaard 2015). This paper provides additional information on the distribution of butterflies in Albania, listing and discussing the species that have been recorded during the last two years of field surveys. It is a continuation of a recent initiative to increase the knowledge of butterfly diversity and distribution in Albania providing a platform for further butterfly research in this country (Verovnik and Popović 2013a, 2013b). A comparison of Albanian fauna with its neighboring countries is presented, and the threats, as a result of the transition from traditional to modern agricultural practices, are discussed.

Methods

The surveys of butterfly fauna, carried out by several groups of researchers, started in July 2012 and continued in 2013. Butterflies were observed, photographed and identified in the field, with only a few specimens collected for further study and identification. Butterfly identification was based on Tolman and Lewington (2008) and Lafranchis (2004). Additionally, *Pieris balcana* Lorković, 1970 was identified consulting the website of Ziegler (2013), and *Melitaea ornata* Christoph, 1893 was confirmed using DNA barcoding gene COI (Verovnik, unpublished data). Male genitalia measurements were taken only from collected specimens of *Leptidea sinapis* (Linnaeus, 1758) (Hubrechts 2013; Maes, unpublished data). Taxonomy and nomenclature follow van Swaay et al. (2010) and/or Fauna Europaea.

We compared the number of species observed in Albania to the number of species observed in neighbouring countries. The total number of species in Albania was compiled from all available data, excluding species that are not native to the region (sensu IUCN 2012). The number of species observed in neighbouring countries is in accordance with the Red List of European Butterflies (van Swaay et al. 2010).

The study took place in five southern Albanian counties (Korçë, Elbasan, Gjirokastër, Fier and Berat) concentrating mainly on the mountain regions of Mali i Moravës, Gramoz (Mali i Gramozit), Ostrovicë, Devoll River Gorge, Mt. Tomorri and on Mt. Nemërçkë near Gjirokastër. In total 68 localities were visited, but these were subsequently grouped into 30 larger locations (Fig. 1):

1. Ohrid lake, close to the Village of Urahë (41°03'45"N; 20°37'28"E; 811 m). Road verges, rocky slopes with shrubs.
2. Korçë, Drenovë, gorge NE of the village (40°35'19"N; 20°48'25"E; 1075 m). Dry rocky slopes with limited vegetation cover.

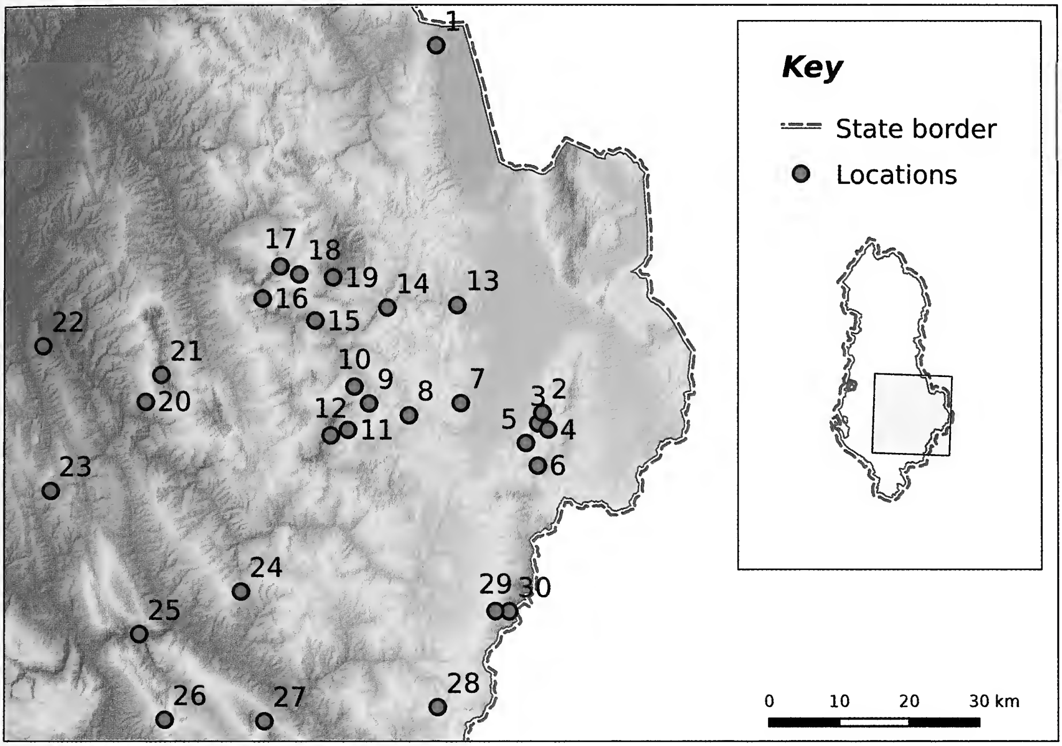

Figure 1. Map of Albania with the position of study locations.

3. Korçë, Drenovë, gorge SE of the village (40°34'29"N; 20°47'59"E; 1075 m). Dry rocky slopes with limited vegetation cover.
4. Korçë, Drenovë, Parku Kombëtar Bredhi i Drenovës, SE of the village (40°34'01"N; 20°49'00"E; 1170 m). Forests and forest clearings close to a stream and open, rocky habitats in the lower parts of the valley.
5. Korçë, Boboshtiçë, valleys and gorges E of the village (40°32'59"N; 20°46'45"E; 1040 m). Dry rocky slopes with limited vegetation cover.
6. Korçë, Boboshtiçë, on the road to Dardhë (40°31'15"N; 20°47'57"E; 1565 m). Forests, forest clearings and meadows close to the main road.
7. Korçë, Lavdar, in the valley E of the village (40°36'05"N; 20°40'08"E; 992 m). Open, rocky habitats with limited shrubs and trees, meadows.
8. Voskopojë, Gjergjevicë, small gorge on the road E of the village (40°35'07"N; 20°34'53"E; 1269 m). Dry rocky slopes with shrubs and grasses.
9. Voskopojë, Lekas Village (40°36'01"N; 20°30'52"E; 991 m). Dry rocky slopes with shrubs and trees, meadows.
10. Voskopojë, along the road NW of the Village of Tudis (40°37'18"N; 20°29'21"E; 1204 m). Dry rocky slopes with shrubs and trees, meadows.
11. Voskopojë, along the road SW of the Village of Marjan (40°33'57"N; 20°28'45"E; 1225 m). Flowery meadows with shrubs and trees.

12. Voskopojë, Mali i Ostroviçës (40°33’30”N; 20°26’59”E; 1231 m). Flowery meadows on slopes.
13. Devoll Gorge, W of the small town of Maliq, before the gorge (40°43’39”N; 20°39’45”E; 825 m). Dry rocky habitats with limited vegetation cover.
14. Devoll Gorge, along the road E of the Village of Strelcë (40°43’24”N; 20°32’40”E; 689 m). Dry rocky slopes with limited vegetation cover.
15. Devoll Gorge, on the road Gjinkas-Moglicë (40°42’22”N; 20°25’20”E; 508 m). Dry rocky slopes with limited vegetation cover on calcareous terrain.
16. Devoll Gorge, on the road Moglicë-Bratilë (40°44’03”N; 20°19’59”E; 385 m). Dry rocky slopes with limited vegetation cover.
17. Gramsh, Grabove e Posthme, in the gorge below the village (40°46’33”N; 20°21’47”E; 880 m). Dry rocky slopes with limited vegetation cover, overgrown slopes.
18. Gramsh, Lenie, in the village and along the stream below (40°45’57”N; 20°23’40”E; 992 m). Orchards, overgrown gravel stream beds.
19. Gramsh, Maja e Valamarës, on the ridge S of the summit (40°45’43”N; 20°27’07”E; 2088 m). High mountain grasslands (some parts intensively grazed), forest fragments and rocky terrain.
20. Berat, Mali i Tomorrit foothills, E of the Village of Poliçan (40°36’01”N; 20°08’13”E; 662 m). Dry rocky slopes with shrubs and trees.
21. Berat, Mali i Tomorrit, south facing slopes below the mountain ridge (40°38’06”N; 20°09’46”E; 2339 m). Alpine scree slopes with limited grass cover.
22. Berat, Drobonik, along the road S of the village (40°40’16”N; 19°57’38”E; 416 m). Open woodlands.
23. Berat, Gllavë (40°29’05”N; 19°58’34”E; 909 m). Dry rocky slopes with shrubs and trees.
24. Permet, Bejkollare (40°21’26”N; 20°18’02”E; 926 m). Dry rocky slopes with shrubs and trees, meadows.
25. Tepelene, at the entrance of the gorge, close to the Village of Kelcyre (40°18’04”N; 20°07’47”E; 261 m). Dry, calcareous terrains, ruderal areas.
26. Gjirokaster, Cajupi (40°11’31”N; 20°10’25”E; 1387 m). Dry, calcareous terrains partially covered with low shrubs, pastures.
27. Gjirokaster, Sheper ridge (40°11’27”N; 20°20’30”E; 1698 m). Dry, mountain grasslands, rocky slopes.
28. Ersekë, along the road from Leskovik to Ersekë (40°12’36”N; 20°37’57”E; 1098 m). Dry flowery meadows.
29. Ersekë, Rehove, lower slopes of Gramoz Mts. above the village (40°20’00”N; 20°43’43”E; 1547 m). Grasslands, rocky terrains and pastures.
30. Ersekë, Rehove, at the ridge of the Gramoz Mts. (40°19’59”N; 20°45’7”E; 2147 m). High mountain grasslands, pastures and rocky terrain.

Results

During our field surveys in Albania, we recorded a total of 143 butterfly species, from 66 genera and 5 families. Overall it is a total of 1415 records from 68 locations. *Cupido alcetas* (Hoffmannsegg, 1804) and *Melitaea ornata* were recorded for the first time in Albania. A single male specimen of *C. alcetas* was observed in the vicinity of Lavdar Village, in dense grassland close to the forest edge. A single worn female of *M. ornata* was collected above the gorge SE of Drenovë Village.

The list of recorded species from southern Albania with localities depicted as numerals from the methods section and observation dates in brackets following each locality:

Family Hesperiidae

1. *Pyrgus armoricanus* (Oberthür, 1910) Observations: 16 (22.vii.2013)
2. *Pyrgus serratulae* (Rambur, 1839) Observations: 27 (25.vii.2013), 29 (12.vii.2012)
3. *Pyrgus cinarae* (Rambur, 1839) Observations: 6 (11.vii.2012), 26 (24.vii.2013), 27 (25.vii.2013)
4. *Spialia orbifer* (Hübner, 1823) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 12 (19.vii.2013), 15 (22.vii.2013), 16 (23.vii.2013), 22 (22.vii.2013), 27 (25.vii.2013)
5. *Spialia phlomidis* (Herrich-Schäffer, 1845) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 15 (22.vii.2013)
6. *Muschampia proto* (Ochsenheimer, 1808) Observations: 25 (24.vii.2013)
7. *Carcharodus alceae* (Esper, 1780) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 15 (22.vii.2013), 16 (22.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
8. *Carcharodus lavatherae* (Esper, 1783) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012)
9. *Carcharodus floccifera* (Zeller, 1847) Observations: 4 (21.vii.2013), 12 (19.vii.2013), 27 (25.vii.2013), 30 (12.vii.2012)
10. *Carcharodus orientalis* Reverdin, 1913. Observations: 5 (11.vii.2012), 20 (21.vii.2013), 21 (21.vii.2013)
11. *Erynnis tages* (Linnaeus, 1758) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 18.vii.2013), 7 (21.vii.2013), 10 (17.vii.2013), 12 (19.vii.2013), 15 (22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 24 (20.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
12. *Erynnis marloyi* (Boisduval, 1834) Observations: 23 (22.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
13. *Thymelicus acteon* (Rottemburg, 1775) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 14 (10.vii.2012), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013)
14. *Thymelicus lineola* (Ochsenheimer, 1808) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (15.vii.2013, 16.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 11 (19.vii.2013), 15 (10.vii.2012), 27 (25.vii.2013), 29 (12.vii.2012)
15. *Thymelicus sylvestris* (Poda, 1761) Observations: 2 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 8 (17.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 14 (10.vii.2012), 16 (23.vii.2013), 21 (21.vii.2013)
16. *Hesperia comma* (Linnaeus, 1758) Observations: 27 (25.vii.2013)
17. *Ochlodes sylvanus* (Esper, 1777) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 11 (19.vii.2013), 13 (10.vii.2012)

Family Papilionidae

18. *Parnassius apollo* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 8 (17.vii.2013, 18.vii.2013), 12 (19.vii.2013), 16 (22.vii.2013), 19 (23.vii.2013), 30 (12.vii.2012)

19. *Parnassius mnemosyne* (Linnaeus, 1758) Observations: 12 (19.vii.2013), 21 (21.vii.2013, 25.vii.2013), 30 (12.vii.2012)
20. *Papilio machaon* Linnaeus, 1758. Observations: 1 (15.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013), 7 (21.vii.2013), 8 (17.vii.2013), 14 (10.vii.2012, 22.vii.2013), 15 (22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 20 (21.vii.2013), 21 (21.vii.2013, 25.vii.2013), 22 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (14.vii.2013), 29 (12.vii.2012)
21. *Iphiclides podalirius* (Linnaeus, 1758) Observations: 1 (15.vii.2013), 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 20 (21.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012)

Family Pieridae

22. *Aporia crataegi* (Linnaeus, 1758) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 6 (11.vii.2012), 8 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 14 (10.vii.2012), 29 (12.vii.2012)
23. *Pieris rapae* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013),10 (17.vii.2013), 12 (19.vii.2013), 13 (10.vii.2012), 15 (10.vii.2012), 16 (22.vii.2013, 23.vii.2013), 18 (23.vii.2013), 19 (23.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 30 (12.vii.2012)
24. *Pieris mannii* (Mayer, 1851) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 6 (11.vii.2012), 10 (17.vii.2013), 12 (19.vii.2013), 14 (22.vii.2013), 15 (10.vii.2012), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 18 (23.vii.2013), 19 (23.vii.2013), 21 (25.vii.2013), 22 (22.vii.2013), 25 (24.vii.2013)
25. *Pieris ergane* (Geyer, 1828) Observations: 2 (21.vii.2013), 8 (17.vii.2013), 14 (22.vii.2013), 16 (23.vii.2013), 17 (23.vii.2013), 21 (21.vii.2013), 27 (25.vii.2013)
26. *Pieris balcana* Lorković, 1970. Observations: 6 (11.vii.2012)
27. *Pieris napi* (Linnaeus, 1758) Observations: 8 (18.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 14 (22.vii.2013), 16 (23.vii.2013), 18 (23.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013)
28. *Pontia edusa* (Fabricius, 1777) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 9 (17.vii.2013), 10 (17.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 22 (22.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)
29. *Euchloe ausonia* (Hübner, 1804) Observations: 3 (21.vii.2013)
30. *Colias aurorina* (Herrich-Schäffer, 1850) Observations: 5 (11.vii.2012), 6 (11.vii.2012), 26 (24.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)
31. *Colias alfacariensis* Ribbe, 1905. Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 17 (23.vii.2013), 20 (21.vii.2013), 24 (20.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)

32. *Colias croceus* (Fourcroy, 1785) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013,18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 18 (23.vii.2013), 19 (23.vii.2013), 20 (21.vii.2013), 21 (25.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)
33. *Gonepteryx rhamni* (Linnaeus, 1758) Observations: 5 (11.vii.2012), 6 (11.vii.2012), 7 (21.vii.2013), 12 (19.vii.2013), 14 (22.vii.2013), 19 (23.vii.2013), 21 (25.vii.2013), 27 (25.vii.2013), 30 (12.vii.2012)
34. *Gonepteryx cleopatra* (Linnaeus, 1767) Observations: 27 (25.vii.2013)
35. *Gonepteryx farinosa* (Zeller, 1847) Observations: 26 (24.vii.2013)
36. *Leptidea sinapis* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 18 (23.vii.2013), 20 (21.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012)
37. *Leptidea duponcheli* (Staudinger, 1871) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 7 (21.vii.2013), 14 (10.vii.2012), 15 (10.vii.2012, 22.vii.2013)

Family Lycaenidae

38. *Thecla betulae* (Linnaeus, 1758) Observations: 16 (22.vii.2013, 23.vii.2013)
39. *Favonius quercus* (Linnaeus, 1758) Observations: 29 (12.vii.2012)
40. *Satyrium acaciae* (Fabricius, 1787) Observations: 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 11 (19.vii.2013), 15 (10.vii.2012), 29 (12.vii.2012)
41. *Satyrium ilicis* (Esper, 1779) Observations: 6 (11.vii.2012), 13 (10.vii.2012), 15 (10.vii.2012)
42. *Satyrium spini* (Denis & Schiffermüller, 1775) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 6 (11.vii.2012), 9 (17.vii.2013), 11 (19.vii.2013), 15 (10.vii.2012), 21 (25.vii.2013), 27 (25.vii.2013)
43. *Satyrium w-album* (Knoch, 1782) Observations: 6 (11.vii.2012), 9 (17.vii.2013)
44. *Callophrys rubi* (Linnaeus, 1758) Observations: 6 (11.vii.2012)
45. *Lycaena phlaeas* (Linnaeus, 1761) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 13 (10.vii.2012), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013), 21 (21.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
46. *Lycaena dispar* (Haworth, 1802) Observations: 5 (11.vii.2012)
47. *Lycaena virgaureae* (Linnaeus, 1758) Observations: 6 (11.vii.2012), 12 (19.vii.2013), 21 (25.vii.2013), 29 (12.vii.2012)
48. *Lycaena tityrus* (Poda, 1761) Observations: 2 (21.vii.2013), 5 (11.vii.2012), 12 (19.vii.2013), 16 (22.vii.2013), 29 (12.vii.2012)
49. *Lycaena alciphron* (Rottemburg, 1775) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 12 (19.vii.2013), 14 (10.vii.2012)
50. *Lycaena thersamon* (Esper, 1784) Observations: 6 (11.vii.2012), 14 (10.vii.2012), 15 (10.vii.2012)

51. *Lycaena candens* (Herrich-Schäffer, 1844) Observations: 30 (12.vii.2012)
52. *Lampides boeticus* (Linnaeus, 1767) Observations: 14 (10.vii.2012), 27 (25.vii.2013)
53. *Leptotes pirithous* (Linnaeus, 1767) Observations: 5 (11.vii.2012), 7 (21.vii.2013), 15 (10.vii.2012), 24 (20.vii.2013)
54. *Tarucus balkanica* (Freyer, 1844) Observations: 25 (24.vii.2013)
55. *Cupido minimus* (Fuessly, 1775) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 5 (15.vii.2013, 16.vii.2013), 6 (11.vii.2012), 11 (19.vii.2013), 12 (19.vii.2013), 19 (23.vii.2013), 27 (25.vii.2013)
56. *Cupido osiris* (Meigen, 1829) Observations: 7 (21.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012)
57. *Cupido alcetas* (Hoffmannsegg, 1804) Observations: 7 (21.vii.2013)
58. *Celastrina argiolus* (Linnaeus, 1758) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (15.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 10 (17.vii.2013), 14 (10.vii.2012), 15 (10.vii.2012), 17 (23.vii.2013), 18 (23.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013)
59. *Phengaris alcon* (Denis & Schiffermüller, 1775) Observations: 6 (11.vii.2012), 27 (25.vii.2013)
60. *Phengaris arion* (Linnaeus, 1758) Observations: 4 (21.vii.2013), 6 (11.vii.2012)
61. *Iolana iolas* (Ochsenheimer, 1816) Observations: 6 (11.vii.2012), 7 (21.vii.2013), 14 (10.vii.2012), 27 (8-19.vii.2013)
62. *Scolitantides orion* (Pallas, 1771) Observations: 16 (23.vii.2013)
63. *Pseudophilotes vicrama* (Moore, 1865) Observations: 3 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 8 (18.vii.2013), 10 (17.vii.2013), 15 (10.vii.2012), 27 (25.vii.2013)
64. *Plebejus sephirus* (Frivaldzky, 1835) Observations: 27 (25.vii.2013)
65. *Plebejus argus* (Linnaeus, 1758) Observations: 5 (11.vii.2012, 16.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012), 15 (10.vii.2012), 23 (22.vii.2013), 24 (20.vii.2013), 28 (20.vii.2013)
66. *Plebejus idas* (Linnaeus, 1761) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013), 16 (22.vii.2013), 18 (23.vii.2013), 23 (22.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012)
67. *Aricia eumedon* (Esper, 1780) Observations: 12 (19.vii.2013)
68. *Aricia agestis* (Denis & Schiffermüller, 1775) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 12 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 18 (23.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012)
69. *Aricia artaxerxes* (Fabricius, 1793) Observations: 5 (16.vii.2013), 6 (11.vii.2012), 21 (25.vii.2013)
70. *Aricia anteros* (Freyer, 1838) Observations: 12 (19.vii.2013)
71. *Cyaniris semiargus* (Rottemburg, 1775) Observations: 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 11 (19.vii.2013), 12 (19.vii.2013), 16 (23.vii.2013), 30 (12.vii.2012)
72. *Polyommatus damon* (Denis & Schiffermüller, 1775) Observations: 8 (17.vii.2013), 12 (19.vii.2013)
73. *Polyommatus ripartii* (Freyer, 1830) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 15 (22.vii.2013), 27 (25.vii.2013)

74. *Polyommatus admetus* (Esper, 1783) Observations: 2 (21.vii.2013), 3 (21.vii.2013),4 (21.vii.2013), 5 (11.vii.2012, 18.vii.2013), 7 (21.vii.2013), 10 (17.vii.2013), 14 (10.vii.2012, 22.vii.2013), 15 (22.vii.2013), 18 (23.vii.2013), 23 (22.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012)
75. *Polyommatus escheri* (Hübner, 1823) Observations: 9 (17.vii.2013), 10 (17.vii.2013), 14 (10.vii.2012, 22.vii.2013), 15 (22.vii.2013), 16 (22.vii.2013), 28 (20.vii.2013)
76. *Polyommatus amandus* (Schneider, 1792) Observations: 5 (11.vii.2012), 6 (11.vii.2012), 12 (19.vii.2013), 14 (10.vii.2012)
77. *Polyommatus thersites* (Cantener, 1835) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 9 (17.vii.2013), 15 (10.vii.2012), 23 (22.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012)
78. *Polyommatus dorylas* (Denis & Schiffermüller, 1775) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 6 (11.vii.2012), 16 (23.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
79. *Polyommatus daphnis* (Denis & Schiffermüller, 1775) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 7 (21.vii.2013), 9 (17.vii.2013), 11 (19.vii.2013), 14 (10.vii.2012), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013), 20 (21.vii.2013), 24 (20.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013)
80. *Polyommatus coridon* (Poda, 1761) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 7 (21.vii.2013), 9 (17.vii.2013), 16 (23.vii.2013), 26 (24.vii.2013)
81. *Polyommatus bellargus* (Rottemburg, 1775) Observations: 4 (21.vii.2013), 5 (11.vii.2012), 12 (19.vii.2013), 14 (10.vii.2012), 15 (10.vii.2012, 22.vii.2013), 16 (23.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013)
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83. *Polyommatus eros* (Ochsenheimer, 1808) Observations: 30 (12.vii.2012)

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84. *Libythea celtis* (Laicharting, 1782) Observations: 21 (25.vii.2013), 26 (24.vii.2013)
85. *Apatura iris* (Linnaeus, 1758) Observations: 6 (11.vii.2012), 8 (18.vii.2013)
86. *Apatura ilia* (Denis & Schiffermüller, 1775) Observations: 13 (10.vii.2012)
87. *Limenitis reducta* (Staudinger, 1901) Observations: 4 (21.vii.2013), 6 (11.vii.2012),8 (17.vii.2013), 11 (19.vii.2013), 14 (22.vii.2013), 24 (20.vii.2013),26 (24.vii.2013), 27 (25.vii.2013)
88. *Nymphalis antiopa* (Linnaeus, 1758) Observations: 11 (19.vii.2013), 21 (25.vii.2013)
89. *Nymphalis polychloros* (Linnaeus, 1758) Observations: 11 (19.vii.2013)
90. *Aglais io* (Linnaeus, 1758) Observations: 4 (21.vii.2013), 6 (11.vii.2012), 12 (19.vii.2013), 14 (10.vii.2012), 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013)
91. *Aglais urticae* (Linnaeus, 1758) Observations: 6 (11.vii.2012), 12 (19.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 30 (12.vii.2012)

92. *Vanessa atalanta* (Linnaeus, 1758) Observations: 11 (19.vii.2013), 14 (10.vii.2012), 18 (23.vii.2013), 21 (25.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 30 (12.vii.2012)
93. *Vanessa cardui* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 12 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012), 18 (23.vii.2013), 19 (23.vii.2013), 20 (21.vii.2013), 21 (21.vii.2013, 25.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012)
94. *Issoria lathonia* (Linnaeus, 1758) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 10 (17.vii.2013), 11 (19.vii.2013), 14 (10.vii.2012), 18 (23.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)
95. *Polygonia c-album* (Linnaeus, 1758) Observations: 4 (21.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 15 (22.vii.2013), 17 (23.vii.2013), 18 (23.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
96. *Argynnis pandora* (Denis & Schiffermüller, 1775) Observations: 2 (21.vii.2013), 6 (11.vii.2012), 14 (10.vii.2012), 21 (25.vii.2013), 29 (12.vii.2012)
97. *Argynnis paphia* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013), 14 (10.vii.2012), 15 (10.vii.2012), 16 (23.vii.2013), 24 (20.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013)
98. *Argynnis aglaja* (Linnaeus, 1758) Observations: 4 (21.vii.2013), 6 (11.vii.2012), 9 (17.vii.2013), 10 (17.vii.2013), 12 (19.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
99. *Argynnis adippe* (Denis & Schiffermüller, 1775) Observations: 4 (21.vii.2013), 6 (11.vii.2012), 9 (17.vii.2013), 10 (17.vii.2013), 15 (10.vii.2012)
100. *Argynnis niobe* (Linnaeus, 1758) Observations: 4 (21.vii.2013), 6 (11.vii.2012), 12 (19.vii.2013), 19 (23.vii.2013), 24 (20.vii.2013), 27 (25.vii.2013)
101. *Brenthis hecate* (Denis & Schiffermüller, 1775) Observations: 5 (16.vii.2013)
102. *Brenthis daphne* (Bergsträsser, 1780) Observations: 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 14 (10.vii.2012)
103. *Boloria graeca* (Staudinger, 1870) Observations: 30 (12.vii.2012)
104. *Boloria euphrosyne* (Linnaeus, 1758) Observations: 19 (23.vii.2013)
105. *Boloria dia* (Linnaeus, 1767) Observations: 2 (21.vii.2013), 5 (11.vii.2012)
106. *Melitaea phoebe* (Denis & Schiffermüller, 1775) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 8 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 14 (10.vii.2012), 19 (23.vii.2013), 22 (22.vii.2013), 25 (24.vii.2013), 29 (12.vii.2012)
107. *Melitaea didyma* (Esper, 1779) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 6 (11.vii.2012), 8 (17.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 15 (10.vii.2012), 21 (21.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 29 (12.vii.2012)
108. *Melitaea trivia* (Denis & Schiffermüller, 1775) Observations: 15 (10.vii.2012), 16 (23.vii.2013), 21 (25.vii.2013), 23 (22.vii.2013), 27 (25.vii.2013), 30 (12.vii.2012)
109. *Melitaea athalia* (Rottemburg, 1775) Observations: 4 (21.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 11 (19.vii.2013), 17 (23.vii.2013), 29 (12.vii.2012)
110. *Melitaea ornata* Christoph, 1893. Observations: 3 (21.vii.2013)
111. *Euphydryas aurinia* (Rottemburg, 1775) Observations: 15 (10.vii.2012)

112. *Melanargia galathea* (Linnaeus, 1758) Observations: 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)
113. *Melanargia russiae* (Esper, 1783) Observations: 8 (17.vii.2013, 18.vii.2013), 12 (19.vii.2013), 21 (21.vii.2013, 25.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
114. *Melanargia larissa* (Geyer, 1828) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 20 (21.vii.2013), 21 (21.vii.2013, 25.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012), 30 (12.vii.2012)
115. *Hipparchia syriaca* (Staudinger, 1871) Observations: 1 (15.vii.2013), 9 (17.vii.2013), 24 (24.vii.2013)
116. *Hipparchia fagi* (Scopoli, 1763) Observations: 2 (21.vii.2013), 5 (16.vii.2013, 18.vii.2013), 8 (17.vii.2013, 18.vii.2013), 15 (22.vii.2013), 16 (23.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 27 (20.vii.2013), 29 (12.vii.2012)
117. *Hipparchia senthes* (Fruhstorfer, 1908) Observations: 15 (10.vii.2012), 17 (23.vii.2013), 29 (12.vii.2012)
118. *Hipparchia statilinus* (Hufnagel, 1766) Observations: 16 (22.vii.2013, 23.vii.2013)
119. *Chazara briseis* (Linnaeus, 1764) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013), 7 (21.vii.2013), 8 (18.vii.2013), 14 (10.vii.2012, 22.vii.2013), 15 (22.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
120. *Pseudochazara anthelea* (Hübner, 1824) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (16.vii.2013, 18.vii.2013), 8 (18.vii.2013), 14 (10.vii.2012), 15 (22.vii.2013), 16 (22.vii.2013), 28 (14.vii.2013)
121. *Pseudochazara mniszechii* (Herrich-Schäffer, 1851) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 18.vii.2013), 8 (17.vii.2013, 18.vii.2013), 28 (14. vii.2013)
122. *Pseudochazara amymone* Brown, 1976. Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013, 18.vii.2013), 8 (18.vii.2013), 14 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013)
123. *Satyrus ferula* (Fabricius, 1793) Observations: 2 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013), 8 (17.vii.2013), 16 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
124. *Brintesia circe* (Fabricius, 1775) Observations: 1 (15.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 17 (23.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012)
125. *Arethusana arethusa* (Denis & Schiffermüller, 1775) Observations: 3 (21.vii.2013)

126. *Erebia medusa* (Denis & Schiffermüller, 1775) Observations: 12 (19.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 30 (12.vii.2012)
127. *Erebia gorge* (Hübner, 1804) Observations: 21 (21.vii.2013, 25.vii.2013)
128. *Erebia rhodopensis* Nicholl, 1900. Observations: 30 (12.vii.2012)
129. *Erebia ottomana* Herrich-Schäffer, 1847. Observations: 12 (19.vii.2013), 19 (23.vii.2013), 30 (12.vii.2012)
130. *Erebia melas* (Herbst, 1796) Observations: 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 30 (12.vii.2012)
131. *Maniola jurtina* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012, 15.vii.2013, 16.vii.2013, 18.vii.2013), 6 (11.vii.2012), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012), 15 (10.vii.2012), 16 (22.vii.2013), 17 (23.vii.2013), 18 (23.vii.2013), 21 (21.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 29 (12.vii.2012)
132. *Hyponephele lycaon* (Rottemburg, 1775) Observations: 2 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013, 18.vii.2013), 8 (17.vii.2013, 18.vii.2013), 9 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 29 (12.vii.2012)
133. *Hyponephele lupina* (Costa, 1836) Observations: 8 (17.vii.2013)
134. *Aphantopus hyperantus* (Linnaeus, 1758) Observations: 4 (21.vii.2013)
135. *Pyronia tithonus* (Linnaeus, 1767) Observations: 7 (21.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012), 15 (22.vii.2013), 17 (23.vii.2013), 18 (23.vii.2013), 20 (21.vii.2013), 24 (20.vii.2013)
136. *Coenonympha rhodopensis* Elwes, 1900. Observations: 12 (19.vii.2013), 19 (23.vii.2013), 30 (12.vii.2012)
137. *Coenonympha pamphilus* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012), 7 (21.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 13 (10.vii.2012), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013)
138. *Coenonympha arcania* (Linnaeus, 1761) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 4 (21.vii.2013), 5 (11.vii.2012), 6 (11.vii.2012), 8 (17.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 12 (19.vii.2013), 16 (22.vii.2013), 17 (23.vii.2013)
139. *Coenonympha orientalis* Rebel, 1910. Observations: 6 (11.vii.2012), 12 (19.vii.2013), 19 (23.vii.2013), 30 (12.vii.2012)
140. *Pararge aegeria* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 4 (21.vii.2013), 7 (21.vii.2013), 18 (23.vii.2013), 27 (25.vii.2013)
141. *Lasiommata megera* (Linnaeus, 1767) Observations: 2 (21.vii.2013), 3 (21.vii.2013), 5 (11.vii.2012, 16.vii.2013, 18.vii.2013), 7 (21.vii.2013), 8 (17.vii.2013, 18.vii.2013), 10 (17.vii.2013), 11 (19.vii.2013), 14 (10.vii.2012, 22.vii.2013), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 19 (23.vii.2013), 21 (21.vii.2013, 25.vii.2013), 22 (22.vii.2013), 23 (22.vii.2013), 24 (20.vii.2013), 25 (24.vii.2013),26 (24.vii.2013), 27 (25.vii.2013), 28 (20.vii.2013), 30 (12.vii.2012)
142. *Lasiommata maera* (Linnaeus, 1758) Observations: 2 (21.vii.2013), 6 (11.vii.2012), 15 (10.vii.2012, 22.vii.2013), 16 (22.vii.2013, 23.vii.2013), 17 (23.vii.2013), 21 (21.vii.2013), 23 (22.vii.2013), 25 (24.vii.2013), 26 (24.vii.2013), 27 (25.vii.2013)
143. *Kirinia roxelana* (Cramer, 1777) Observations: 27 (25.vii.2013)

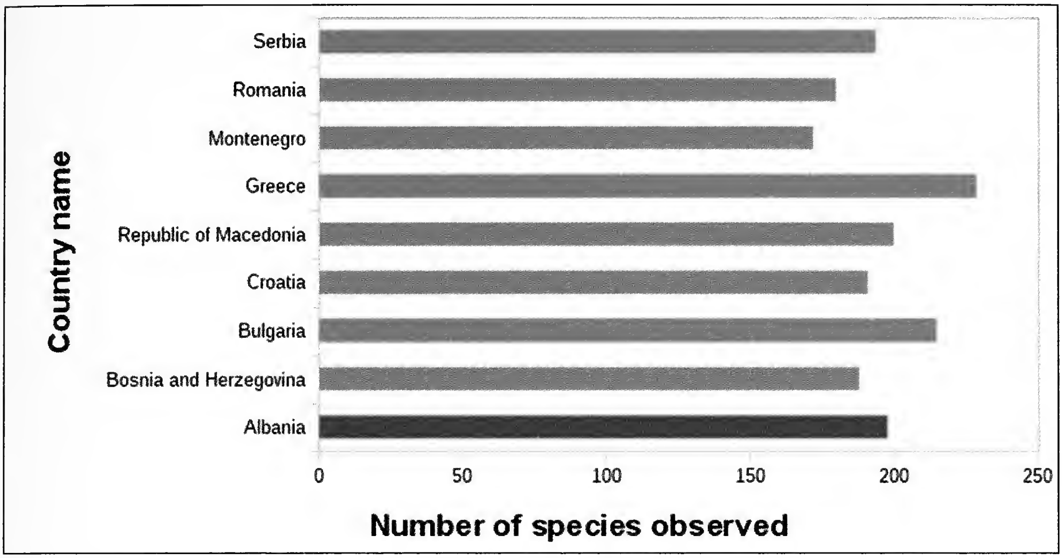

Figure 2. The total number of butterfly species recorded in Albania compared with its neighbouring countries.

If we include all the published records, the total number of butterfly species recorded in Albania has risen to 198, which equates to 41% of the total European butterfly fauna. Compared with its neighbouring countries (Fig. 2) only Greece (229), and Bulgaria (215) have more recorded species, while other countries have similar diversity.

Discussion

During the two years of field studies in southern Albania, five new species were recorded for the country. *Colias aurorina*, *Apatura iris* and *Pieris balcana* were observed during the first survey in 2012 (Verovnik and Popović 2013b). *Cupido alcetas* and *Melitaea ornata* were added in 2013. The presence of both species in Albania is not unexpected, although *C. alcetas* is rare in the neighbouring Republic of Macedonia (Schaider and Jakšić 1989) and Greece (Pamperis 2009). This butterfly could be easily overlooked due to its similarity with *C. decoloratus* and *C. argiades*, both of which have previously been recorded from Albania (Rebel and Zerny 1931). As only historical publications are available for reference, misidentifications cannot be excluded. *C. alcetas* is possibly more widespread in Albania as it frequents a variety of habitats (Pamperis 2009) preferring more humid, sheltered or overgrown biotopes along streams or rivers. *M. ornata*, on the other hand, is possibly more widespread in the southern Balkans with several records from the Republic of Macedonia (Verovnik et al. 2010; Verovnik 2012), Serbia (Jakšić 2011) and Croatia (Koren and Štih 2013). However, it is very similar to the more widely distributed *M. phoebe*, and therefore easily overlooked (Tóth et al. 2013). Identification from studying the overwintering larvae of both species is usually required to confirm its presence (Russell et al. 2007; Tóth and Varga 2010).

Additionally, we confirm the presence of *Erebia rhodopensis* in Albania. Our record, from the Gramoz Mts., is the first authenticated record for the country. Its presence in the Gramoz Mts. was not unexpected, as it is common on the Greek side of the same mountain range (Pamperis 2009).

The species had previously been reported in Albania from Mt. Kobilica in the Shar Mts. (Rebel and Zerny 1931). However this mountain currently lies on the border between Kosovo and the Republic of Macedonia. There is a possibility that it is also present on the Albanian part of the Shar Mts., further west of Mt. Kobilica.

Among other species that have been recorded one of the most notable is the Balkan endemic *Pseudochazara amymone* which has only recently been discovered in Albania (Eckweiler 2012). Its distribution in Greece still remains unknown, although it has been reported from several sites (Pamperis 2009). Based on our surveys, more detailed information is now available on its distribution, threats (Verovnik et al. 2014), habitat selection, life cycle, morphology and variability (Gascoigne-Pees et al. 2014; Cuvelier and Mølgaard 2015).

In addition to those discovered by Verovnik and Popović (2013b), two other colonies of *Colias aurorina* were discovered in 2013 on calcareous ridges east of Gjirokaster on Mt. Nemëçkë (Loc. 26) and Mt. Lunxhërisë (Loc. 27), extending the known range of this species in Albania by 50 kilometres to the west.

Albania has a similar number of species in comparison to its neighbours (Fig. 2), highlighting the importance of this region for butterfly conservation. The additional number of butterfly species recorded in Greece and Bulgaria can be explained by the fact that more faunistic surveys have been carried out in these countries and they both have a much larger surface area. Greece, in particular, supports many local species found only on its offshore islands close to mainland Turkey, and these species are absent from the rest of Europe (Pamperis 2009). More detailed and well organized surveys in Albania should certainly result in a more complete list of butterflies for this country.

In particular, the mountains in the northern part of the country which experience a more continental climate may harbour some additional species such as *Leptidea juvernica* (Williams, 1946), *Neptis sappho* (Pallas, 1771), *Limenitis populi* (Linnaeus, 1758), *Limenitis camilla* (Linnaeus, 1764), *Melitaea diamina* (Lang, 1789), *Melitaea arduinna* (Esper, 1783), *Nymphalis vaualbum* (Denis & Schiffermüller, 1775), and *Minois dryas* (Scopoli, 1763), whilst higher up in the mountains *Plebejus optilete* (Knoch, 1781), *Erebia alberganus* (De Prunner, 1798) and *Pyrgus andromedae* (Wallengren, 1853) could also be discovered. Additionally, early spring surveys of the gorges in the eastern part of the country could provide new records, potentially of *Anthocharis damone* (Boisduval, 1836), *Euchloe pennia* (Freyer, 1852) and *Pseudophilotes bavius* (Eversmann, 1832).

As traditional low intensity farming is economically non-profitable, many parts of the Balkan Peninsula have suffered from rural depopulation resulting in an aging population. Abandonment of rural communities has resulted in the breakdown of traditional agricultural practices (Karoglan Todorović 2013), especially low intensity cattle farming. Historically, traditional grazing and mowing have created semi natural habitats supporting a diversity of species including butterflies. Abandonment of agriculture and the decline in the number of livestock has resulted in the shrinking of species-rich grasslands and, consequently, biodiversity loss (van Swaay et al. 2012). However, the situation in Albania is complex. Statistically, Albanian rural communities are characterized by large number of small farms and the smallest average farm and plot size of all the Balkan countries (Kazakova and Stefanova 2010). Modernisation of agricultural practices has not been implemented, especially in the mountainous parts of the country, where traditional cattle grazing is still carried out. However, Albania is now open to the agricultural practices adopted by other European countries and it is only a matter of time before changes will take place, resulting in the loss of the preserved mosaic of habitats. Urgent measures regarding nature conservation in Albania are therefore needed as neglecting the situation would almost certainly lead to a dramatic reduction of its native fauna and flora.

It is of paramount importance to complete the faunal list and to initiate nature conservation guidelines, especially when adopting new agricultural policies. With respect to butterflies, results from faunistic surveys would help pave the way for new initiatives regarding butterfly conservation with the prospect of implementing a network of Prime Butterfly Areas (PBAs; see van Swaay and Warren 2003) . Mali i Moravës, Gramoz (Mali i Gramozit), Devoll River Gorge, Mt. Tomorri and areas on Mt. Nemercke are among top candidates for PBAs, but there are many more areas to be identified. We hope that this contribution will stimulate more people to study the rich flora and fauna of Albania.

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We wish to express our thanks to Heribert Hanisch for his additional records of *I. iolas* and *P. mniszechii*. Funding for the initial survey in 2012 was in part provided by the Mohamed bin Zayed Species Conservation Fund.

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Biology and distribution of the declining moth *Ethmia pyrausta* (Pallas, 1771), with description of the larva (Gelechioidea, Depressariidae, Ethmiinae)

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Abstract. Records of *Ethmia pyrausta* (Pallas, 1771) from the Baltic countries, the British Isles and Fennoscandia are listed. All known aspects of habitat requirements, larval biology and adult behaviour, mostly based on our own observations in the field, are described. Instructions for conservation and habitat management are presented. The larva is described and illustrated in detail.

Introduction, material and methods

Ethmia pyrausta (Pallas, 1771) (Figs 1, 2) is one of the rarities in the European fauna of the subfamily Ethmiinae. The species occurs sporadically in the hemiboreal zone in western and central parts of the Palaearctic region. Most of the records are old and the species is considered to be declining at least in its European distribution range. Although the larval host plant(s) and the flight period of the adult are known, there are very scarce data available on the behaviour of larvae and adults, as well as on the preferred habitats of the species.

During 2002–2006, the present occurrence and status of the populations of all protected Lepidoptera species was evaluated on the Åland Islands in the SW Finnish archipelago by Faunatica Oy (Nupponen et al. 2007). One of the fifteen focal species was *E. pyrausta*, which was known to have occurred on the islands, but no confirmed records of the species existed since the 1950s. One abundant population was discovered in 2005 by Kari Nupponen in the central part of the main island, where there were two studies of the larval behaviour (in July 2005 and 2006; Figs 3, 4). The species was also recorded close to the southern coast of Åland, where a single male was observed in early June, 2006, by Erkki and Leena Laasonen. Ene and Urmas Jürivete discovered another abundant population of *E. pyrausta* from SE Estonia in 2007, and adult behaviour was studied there in May 2008.

The description of the larva (below, Figs 5–10) is based on two caterpillars from Finström, Åland Island (25.vii.2006, see Table 1). The larvae were preserved in ethanol in the field, and later studied by Matti Ahola. The hypopharyngeal complex, mandibles and labrum of the larval head

Figure 1. Adults of *Ethmia pyrausta* (Pallas, 1771) (Finland, Al: Finström, e.l., larvae found 25.vii.2006 on *Thalictrum flavum*).

were dissected and mounted on slide. The chaetotaxy was studied from larvae in alcohol, and the living larva (Fig. 4) was photographed to show the habitus. Naming of the setae follows Hinton (1946) as interpreted by Ahola and Silvonen (2005).

Distribution

Ethmia pyrausta was described from the Samara region, the eastern part of European Russia, in the 18th century (Sattler 1967). There are two recent records of *E. pyrausta* from the steppes of the Ural Mountains (Nupponen in press) and another one from Uljanovsk district (W. Mey, pers. comm.), but apparently the species is very rare in the Volgo–Ural region. In Russia, the species is known to occur widely but sporadically in the hemiboreal zone, from Karelia in the west to the Baikal region in the east (Sinev 2008). It is also known from Mongolia (Ulan-Bator) and China (Kuldzha, Xinjiang) (Dubatolov et al. 1997, Dubatolov 2014). In western Europe, *E. pyrausta* occurs only in Scotland, Sweden, Finland and the Baltic countries.

In Scotland, *E. pyrausta* is restricted to the Highlands. It was known by a single specimen discovered in May 1853 on the banks of the River Shin, until two specimens were unexpectedly found in 1996 in the Cairngorms (about 1000 m a.s.l.) (Anonymous 2014; Kimber 2014). Subsequently several further specimens were found, one at Loch Vrotachan on the NNW end of Cairnwell, Aberdeenshire (810 m a.s.l., 28.v.2001), one at the River Averon close to Loch Morie, East Ross-shire (8.v.2008), one on the slopes of Ben Griam Mor in 2012, and 15 specimens in Croick Estate (24. iv.–31.v.2014) (Anonymous 2014).

In Sweden, *E. pyrausta* has declined severely. It has been recorded in eight provinces in the central part of the country (Gustafsson 2012). However, only from two provinces, viz. Uppland and Dalarna, are there rather recent records. Here the moth occurs along the River Dalälven, but no records are known from the most recent years (Nils Ryrholm, pers. comm.).

In Finland, *E. pyrausta* occurs with certainty only on the Åland Islands, where it is apparently declining due to habitat loss. Most records are from the 1940s and 1950s, and many populations have vanished since (Nupponen et al. 2007). Since the 1950s, there are only confirmed records from two localities. Additionally, there is a single record of the species from the southern coast of the Finnish mainland (Helsinki, 1 larva, 1946; Hyönteistietokanta 2014), thus its occurrence in southern Finland cannot be excluded.

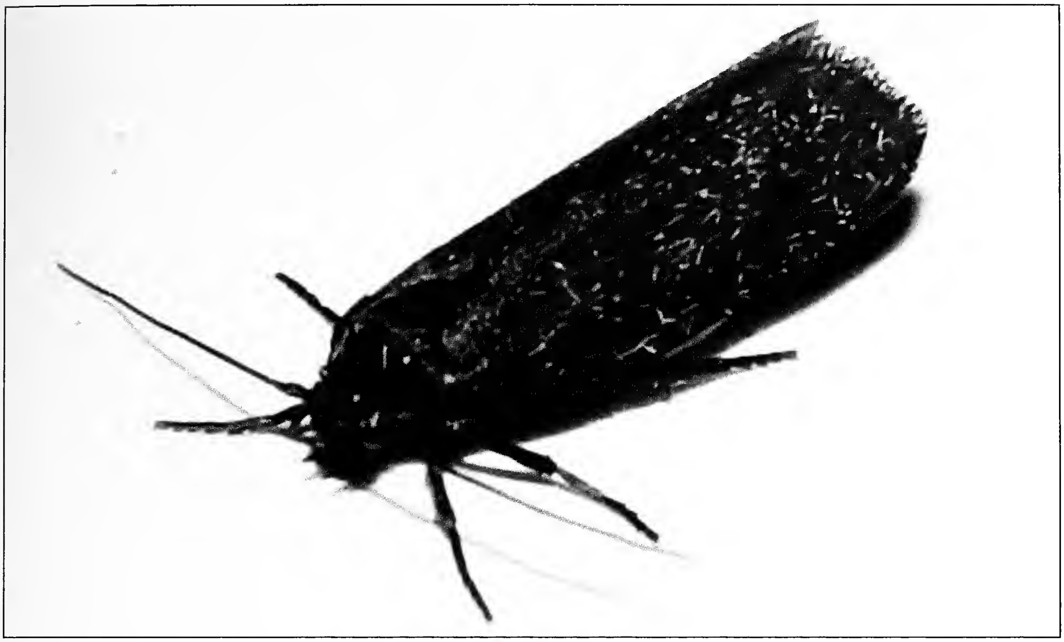

Figure 2. Female of *Ethmia pyrausta* in resting posture (Finland, Al: Finström, e.l., larva found 25.vii.2006).

Figure 3. Moist meadow in Finström, central Åland Islands. Habitat of *Ethmia pyrausta* (photo: K. Nupponen).

Figure 4. Larva of *Ethmia pyrausta* on *Thalictrum flavum* (Finland, Al: Finström, 19.vii.2005) (photo: K. Nupponen).

In the Baltic countries, the species occurs sporadically in Latvia (Šulcs and Šulcs 1978, Savenkov and Šulcs 2010) and Estonia (Nolcken 1871, Petersen 1924, Jürivete and Õunap 2008). There is also one locality for the species in northern Lithuania close to the Latvian border (Povilas Ivinskis, pers. comm.). The Finnish and Baltic records of *E. pyrausta* known to us are listed in Table 1.

Description of the larva

Larvae of the genus *Ethmia* have a chaetotaxy generally typical of Lepidoptera, with one exception: D2 setae of abdominal segment 9 are laterad of D1 unlike other Gelechioidea, but similar

Table 1. Records of *Ethmia pyrausta* (Pallas, 1771) from Finland and the Baltic countries.

Locality	Date	Specimens	Observer(s)	Notes
			FINLAND	
Al: Geta	1920s	5	J. Montell	
Al: Jomala, Gottby utäng	9.v.1943	1 male, 1 female in copula	M. Donning	
Al: Finström	1945	Ca. 30 larvae, reared 10 adults	A. Nordman	
N: Helsinki	viii.1946	1 larva	J. Grönvall	
Al: Eckerö, Öra 671:309	1947 & 1948	Several larvae	A. Nordman & J. Waselius	
Al: Eckerö, Skag 671:309	1948	Larvae, emerged 6 adults	A. Nordman	
Al: Geta	1952	Several larvae, emerged 6 adults	M. von Schantz	
Al: Eckerö, Skag 671:309	1952	Larvae, emerged >30 adults	H. Bruun	
Al: Lemland	1956	Larvae, emerged 9 adults	O. Nylund	
Al: Finström, Norrö	1950s	Larvae	H. Bruun	
Al: Hammarland	1950s	?	H. Bruun, unpubl.	Not confirmed
Al: Eckerö, Skag 671:309	1970s	1 larva	J. Kangas	Doubtful record, identification not confirmed
Al: Lemland	8.vii.1984	1 larva	E. Peltonen	Doubtful record, identification not confirmed
Al: Finström 670:310	19.vii.2005	28 larvae	K. Nupponen/ Faunatica Oy	
Al: Lemland, Flakaviken 667:312	8.vi.2006	1 male	E.M. & L. Laasonen/ Faunatica Oy	
Al: Finström 670:310	25.vii.2006	150 larvae	K. Nupponen/ Faunatica Oy	
			ESTONIA	
E Saaremaa, Pihtla	1859–1867	Several males, 1 female	Nolcken	Dates of records: 28.iv.–10.v.1865 several, 10.–17.v.1866, 29.v.–6.vi.1867 about 5 adults
E Saaremaa, Pihtla	1866–1867	Larvae	Nolcken	Half-grown larvae in late June, 1866
Tallinn, Habersti (near lake Harku)	30.v.1900	2 males	Petersen (1924)	
SE Estonia	After 1950	?	J. Luig, unpubl.	
Tallinn, Pääsküla	20.v.2003	1 male	A. Lindt	By light trap
SE Estonia, river Piusa, Veski	v.2007	1 male	R. Haverinen	By light trap
SE Estonia, river Piusa, Veski	24.vi.2007	>20 larvae	E. & U. Jürivete	
SE Estonia, river Piusa, Veski	12.v.2008	>20 males	E. & U. Jürivete	
SE Estonia, river Piusa, Veski	v.2008	1 male	E. Öunap	
SE Estonia, river Piusa, Veski	17.v.2014	1 male	E. & U. Jürivete	
			LATVIA	
Salaspils	v, <1889	1	Teich	
Salaspils	viii, <1889	Larvae	Teich	

Locality	Date	Specimens	Observer(s)	Notes
Salaspils	16.v.1976	13	A. & I. Šulcs	
Salaspils	21.v.1977	1	A. & I. Šulcs	
Salaspils	22.v.1978	6	A. & I. Šulcs	
Krievupe (Riga district)	5.vi.1987	1 male	A. Titov	
W-Latvia, Ķemeri (Apšupe)	1.vi.1993	1 male	N. Savenkov	
W Latvia, Ķemeri (Kūdra)	23.v.1995	1 male	A. Titov	
W Latvia, Ķemeri (Kūdra)	10.v.1998	1 male	A. Titov	
SE Latvia, Šķaune	v.2005	1 male	I. Šulcs	By light
SE Latvia, Šķaune	6.vii.2006	Several larvae	N. Savenkov	
			LITHUANIA	
N Lithuania, Dukstyna reserve (near Ukmerge town)	1970s	Larvae	P. Ivinskis	

to Cryptolechiinae (Kaila 2004, Heikkilä et al. 2014). Setae A1–3 and L1 on head form a nearly straight line, and secondary setae are present on abdominal SV groups, including both the prolegs and the 9th abdominal segment. *E. pyrausta* differs from other ethmiine species by having secondaries only on 9th abdominal segment.

Head morphology: Head semiprognathous, rather rounded, surface smooth but not shining, frontoclypeus slightly longer than epicranial suture, adfrontal suture joined to epicranial suture before vertical notch. Six stemmata present on each side, nearly equal in size but stemma 2 slightly smaller, stemmata 5 and 6 in line with caudal margin of antennal socket. Spinneret tubular, tapering distad and proximad, about three times as long as wide. Labial palpi slender, segment Lps1 two times longer than wide, seta Lp1 about twice as long as segment Lps2, seta Lp2 as long as Lps1 (Fig. 5). Stipular setae shorter than Lp2 of labial palpi, position on chitinised part of prementum. Hypopharynx largely bare, median and lateral parts of posterior region covered with tiny spines (Fig. 6). Laciniogalea of maxillae with stout sensilla, Ss2 thicker than Ss1 on galeal lobe and St1 thinner than St2–3. Maxillary palpi with stout third segment, longer than second one (Fig. 7). Cutting margin of mandible with very tiny ventral tooth and with straight and smooth edge of second dorsal tooth. Other teeth unspecialized. Three inner ridges present on inner surface of mandible. Labrum with low and rather large notch, seta LR1 situated on level with LR2, setae LR5 and LR6 separately on line with seta LR4 (Fig. 8).

Chaetotaxy: Position of P1 setae on level with AF2 on head, distance P1–P1 shorter than P2–P2, setae A1, A2 and A3 situated straight on line. Setae D1 and D2 of prothoracic shield close to each other, seta SD2 also on shield but SD1 not. Three L setae and two SV setae present on prothorax; L1 distinctly ventrad of L2 and L3. Thoracic segments Th2–3 have D1 and D2 setae close to each other and SD1 close to SD2, all on same pinaculum, seta SV1 on large pinaculum and microseta MD1 also on pinaculum. Three L setae and two MSD microsetae without pinacula, one additional sclerotized plate present behind D setae (Fig. 9). Abdomen has large pinacula separately around D1 and D2 setae on segments Ab1–7, position of seta D1 cephalad from D2 on segment Ab9, setae SD1 and SD2 on same pinaculum on segments Ab1–8 and larger pinacula around setae

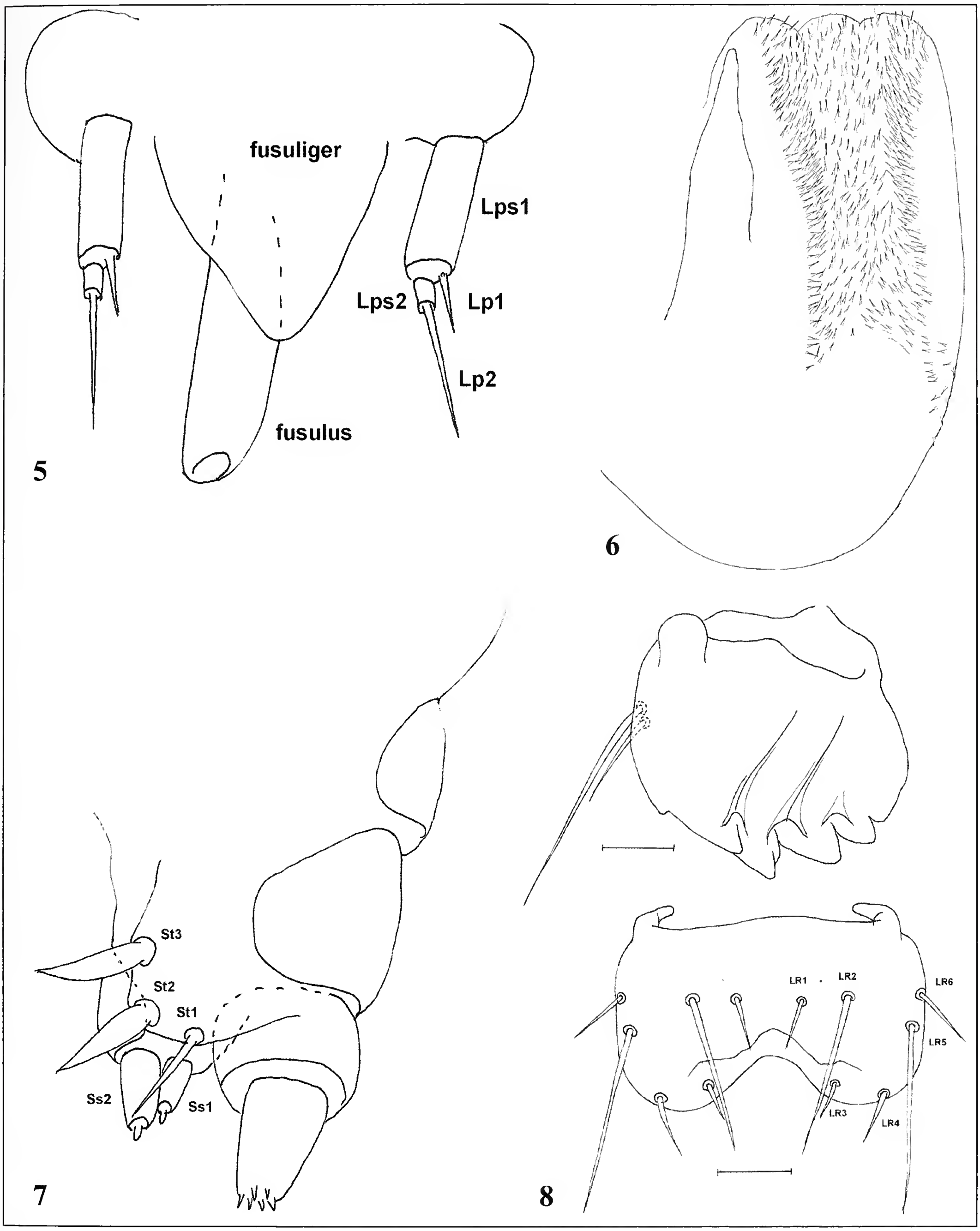

Figure 5-8. *Ethmia pyrausta*: **5.** Morphology of mouthparts, spinneret and labial palpi in dorsal view; **6.** Hypopharynx from dorsal view; **7.** Maxillae with maxillary palpi and sensilla of galeal and lacinial area; **8.** Labrum and left mandible (scale bar = 0.1 mm).

L3 and V1 on segments Ab1–7. Setae L1 and L2 situated close to each other on segments Ab1–9, seta L3 present also on segment Ab9. Small pinaculum around seta L2 on segments Ab1–5. Three SV setae present on segments Ab1–6, two SV setae on segments Ab7–8 and one long SV and numerous secondary setae on segment Ab9 (Fig. 10). Anal shield with D1 setae on level with SD2, setal distance D2–D2 longer than D2–SD1 and small spines present between setae D2–D2 (Fig. 9). Seta D2 long on abdominal segments Ab1–Ab9 but seta SD1 longer on anal shield. Crochets of abdominal prolegs biordinal in mesal penellipse.

Larval habitus: Head smooth with pale green postclypeus, adfrons, dorsal part of frons and narrow stripe from adfrons behind stemmata; head otherwise black. Sides of prothoracic shield and pinacula of body black. Broad orange flecks in place of middorsal and spiracular lines, dorsal zone between middorsal line and D2 setae dark greenish especially on thorax, but larva otherwise dull white.

Notes on the biology

The habitats of *E. pyrausta* are open and sunny moist meadows, often located at the shore or riverside (Fig. 3). Ovipositing females apparently prefer microhabitat with rather sparse, lower vegetation and warmer microclimate than in the adjacent grassy areas. Usually such a habitat exists as a narrow belt between forest and dense stands of *Salix* or *Phragmites*. The species has never been found in forests, even in localities where the host plant is abundant in semi-shadowed open patches within the forest. A common feature for localities of *E. pyrausta* is that they are open to the southeast or east, and sunshine reaches the spots in the early morning.

The larva is oligophagous on *Thalictrum* species (Ranunculaceae). In Finland, the only recorded host plant is *Thalictrum flavum* L. (Fig. 4), probably due to the fact that other species of *Thalictrum* do not occur or are very rare in the region where *E. pyrausta* occurs. In Estonia, larvae have also been found on *Thalictrum aquilegiifolium* L. (Nolcken 1871, Petersen 1924) and *T. lucidum* L. (E. & U. Jürivete, pers. comm.). In an average season, larvae are of detectable size from late June and they pupate in the first half of August. They feed on flower-buds, flowers and seeds. Full-grown larvae feed also on leaves, but only when all seeds are eaten up. Larvae live singly and freely on the host plant, although sometimes two to three larvae have been observed on one plant. Contrary to what is stated in the literature (e.g. Emmet 1979) we did not detect any webs made by larvae on the plants. The presence of larvae can be presumed from the evidence of partly eaten seeds. However, larvae of some other Lepidoptera feed on seeds of *Thalictrum* too, and sometimes they occur sympatrically with *E. pyrausta*, e.g., the geometrid *Gagitodes sagittatus* (Fabricius, 1787). Therefore, the occurrence of *E. pyrausta* should always be confirmed by direct observation of a larva, not just by feeding damage.

Larval behaviour was studied three times: twice on the Åland Islands (19.vii.2005 and 25.vii.2006) and once in the south-eastern Estonia (24.vi.2007). The larva is predominantly nocturnal. On Åland, three larvae were observed on 19.vii.2005 at 6 p.m. and 25 larvae from 11:30 p.m. to 00:15 a.m. (local summer time, i.e. +3 h GMT). On 25.vii.2006 in the same locality, there were no signs of larvae earlier in the day (3–4 p.m.), while about 150 almost full-grown larvae were observed at night from 11:30 p.m. to 1 a.m. In SE Estonia, altogether more than 20 larvae of various ages were observed on 24.vi.2007 at dusk. Larvae become active at dusk, and climb onto the host plant to eat seeds. They eat during a rather brief period (maximally half an hour), and then return to hide in the litter. The larvae move rapidly and drop onto the ground very easily when disturbed. Later at night they are less

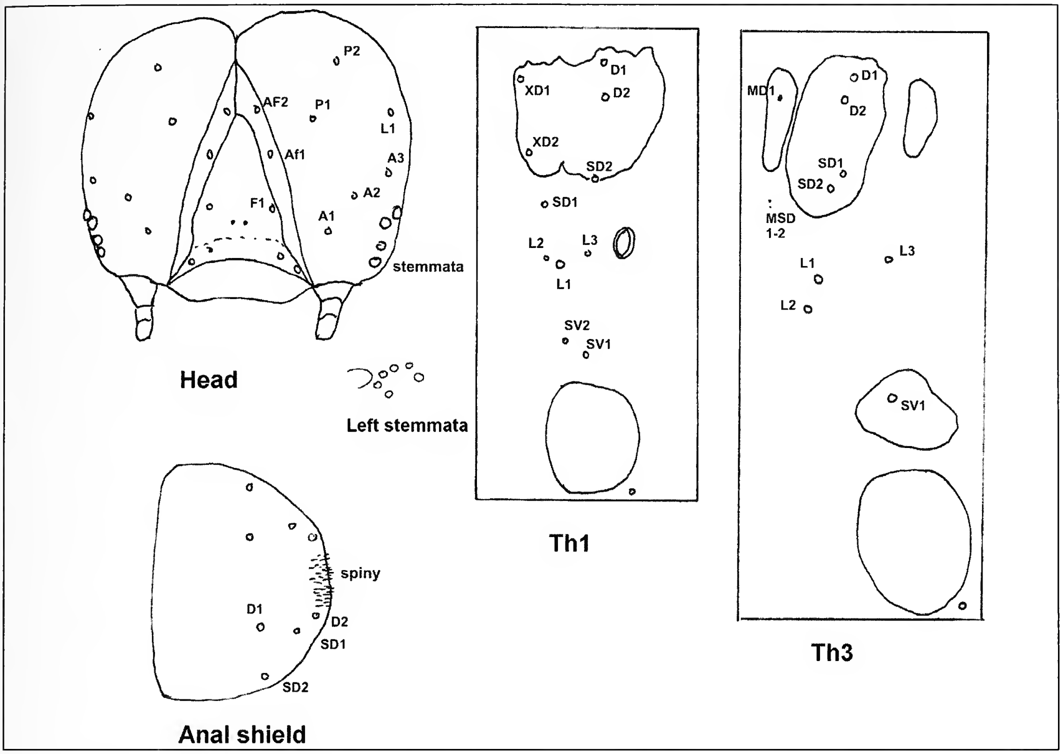

Figure 9. *Ethmia pyrausta*: Chaetotaxy of head, thorax and anal shield, and left stemmatal ring.

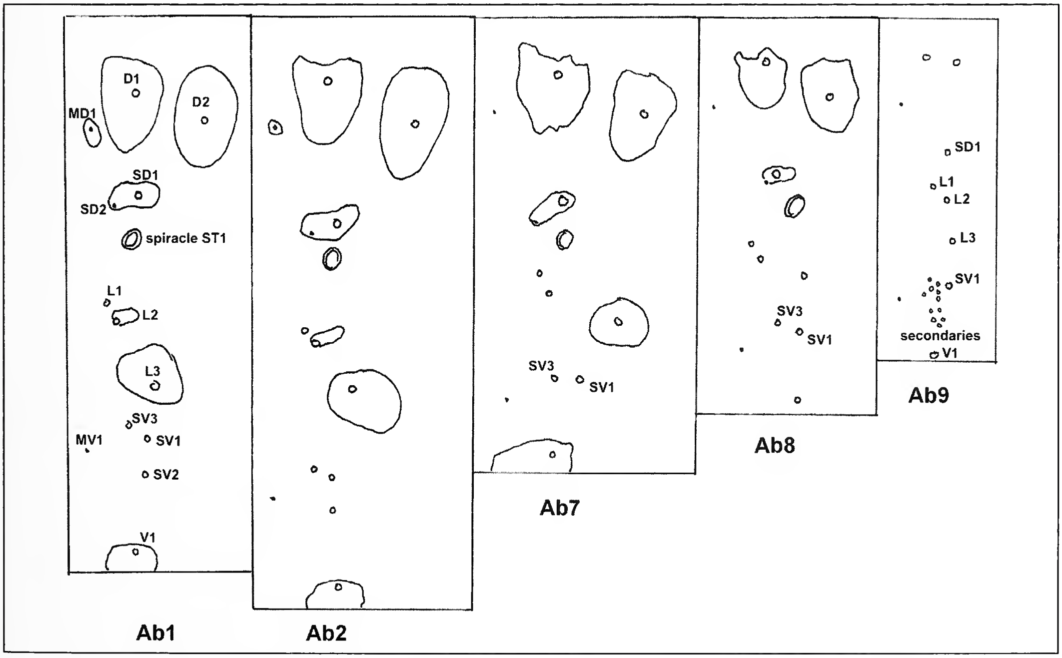

Figure 10. *Ethmia pyrausta*: Chaetotaxy of abdomen.

active, possibly due to decreasing temperature and especially fog that often forms in such habitats at night. During the second half of the night and daylight, larvae are mainly hiding in the soil, and only occasionally visit their host plants to feed. Nolcken (1871) detected larvae on their host during daylight, but he did not present further notes on the time of the records. Pupation takes place in a dirty white or pale yellow cocoon in detritus on the ground. We did not rear any parasitoids from the larvae. It is also possible that the behaviour of parasitized larvae changes and, thus, they cannot be observed with the same methods.

The main flight period is in May with a peak about one to two weeks after budburst of birch. In years with a late season and close to the seashore, the flight period starts later and extends even to mid-June. Nolcken (1871) recorded adults in the period 28 April to 6 June (in 1865–1867), but the annual flight period did not last more than two weeks. The adult of *E. pyrausta* is predominantly diurnal. Occasionally, males fly at night too and come to light, usually on extremely warm nights. In south-eastern Estonia, the behaviour of adults was studied on 12.v.2008. The previous night was cold and the temperature decreased to +1°C in the second half of the night. In the morning, the sky was clear and sunshine heated the wet vegetation from early morning. The first *E. pyrausta* male was observed at 7:30 a.m., while the temperature was still low. Most males became active just after 8 a.m., and over 20 individuals were observed between 8 a.m. and 9 a.m. After that, flight virtually stopped. During the active flight period, males were flying rather slowly and close to the ground (height of flight about 1 m), probably searching for females. Šulcs and Šulcs (1978) recorded similar 'swarming' of *E. pyrausta* in early morning. Males appear to re-activate at the middle part of the day between 10 a.m. and 2 p.m., when the moths fly rapidly, straighter and higher (height of 2.5–3 m) than in the morning (Nolcken 1871; U. Jürivete unpublished; E. Õunap pers. comm.). It is difficult to observe rapidly flying dark moths, and because of that, the species is seldom recorded by chance. As far as we know, there are no records of an evening flight of *E. pyrausta*. Females do not seem to fly much, but prefer to sit among the vegetation and presumably attract males.

Conservation

Ethmia pyrausta shows a highly sporadic distribution throughout its known range. It has apparently declined at least in the western parts of the range. For example, the occupancy of *E. pyrausta* was systematically studied in 34 patches of *T. flavum* – including traceable previous findings – throughout the Åland Islands in 2005 and 2006, but it was present in only one open and sunny patch (Fig. 3) (Nupponen et al. 2007). On the other hand, the population in that patch was relatively large. Based especially on the negative trends in various habitat characteristics, e.g. decreasing amount and quality and high degree of fragmentation, the species has been rated as threatened both in Finland (Kaitila et al. 2010; CR: criteria B1ab(iii)c(iv)+2ab(iii)c(iv)) and Sweden (Bengtsson et al. 2010; EN: criteria B2ab(i,ii,iii,iv,v)).

Ethmia pyrausta requires host plants that are growing in full sunshine. Therefore, the main reason for the decline, at least in Finland and Sweden, is overgrowing of moist meadows after cessation of grazing. All management activities should be performed late in the season, i.e. in August at the earliest. This should ensure that *E. pyrausta* larvae have time to pupate before management starts. Further, *Thalictrum* is highly vulnerable to grazing (Anonymous 2014; own observations) and only late-season grazing or mowing can be recommended. Unfortunately, such late-season management has almost ended in Sweden and Finland, even though plenty of herbivorous insect species are highly dependent on it (Dahlström et al. 2008). In management, the first thing to take care of is to create and maintain open sunny patches of moist meadow with plenty of host plants. Habitats occupied by *E. pyrausta* are regularly dominated by *Filipendula ulmaria* (Rosaceae), and usually the main aim is to reduce its abundance by mowing. If meadows are mown, only areas without *Thalictrum* should be cut. However, in meadows that are grazed earlier than recommended, *F. ulmaria* protects plants growing among it against grazing, so reasonable amounts of *F. ulmaria* in microhabitats with *Thalictrum* are beneficial in those cases (Anonymous 2014).

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Multivariate indices as estimates of dry body weight for comparative study of body size in Lepidoptera

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Abstract. Comparative studies on the size of adult Lepidoptera (moths and butterflies) frequently rely on single linear estimates of body size, namely of forewing length or wingspan. As the shape of the wings of these insects – in fact, of all body parts – differs from one taxon to another, such estimates of body mass may not be adequate for comparisons across a wide taxonomic range. Using the length and width of the forewing, thorax and abdomen, as well as the wing area of 375 species and their correlations with dry body weight, several composite indices were determined that might be used in different circumstances. As the coefficients of determination from the multivariate regression models were rather high ($R^2>0.96$), the results are believed to be reliable. A critical re-evaluation of the results indicates that important variations in the regression slopes described here would be expected, if at all, only from species with unusual body shapes. Incidentally, the bivariate relationships are in agreement with former comparative work on Lepidoptera and other terrestrial insects in that the relationship between body weight and single linear measurements follows a slightly negatively allometric trend, implying comparatively lighter bodies at the largest body sizes and relatively heavier ones at the shortest body sizes.

Introduction

As one of the hyper-diverse insect taxa, the order Lepidoptera is well suited for comparative work on subjects of broad biological relevance such as the evolution of body size and its correlation with other traits (e.g., Nilsson and Forsman 2003; Simonsen and Kristensen 2003; Allen et al. 2011; Ribeiro and Freitas 2011; Symonds et al. 2012). This requires an estimate of body size that is valid across distantly related subtaxa, as a broad taxonomic coverage would be of interest for recovering long-term evolutionary trends or patterns.

Although body mass, or weight, is generally accepted as an accurate measure of size for Lepidoptera (e.g., Miller 1977), adult body weight has been rarely used in comparisons across species, and if so, only within a relatively narrow taxonomic framework (e.g., Agosta and Janzen 2005; Davis et al. 2012). In fact, the published data on body weight cover a small number of the known moth and butterfly species. This is largely due to the practical difficulties of obtaining live (fresh) adults from a wide array of taxa and geographic regions for weighing in standard conditions. Most often, the adult size of these insects has been estimated in one of two ways, depending on the purposes of the study. The first consists of using body length or an alternative linear measure (such as head width) to estimate body mass, based on the generally good correlations between those measurements and fresh or dry body weight across large numbers of species of invertebrates (Sample et al. 1993; Hódar 1996 and references therein). This approach is frequently utilized in ecological studies on e.g. biomass production or on the diet of insectivore vertebrates (Hódar 1997; Heyman and Gunnarson 2011; Legagneux et al. 2012) as well as in fresh water ecology (Benke et al. 1999). The second context is that of ecological or evolutionary work on the Lepidoptera based on interspecific comparisons of one linear measurement of the adult wings (generally well correlated to adult body weight: Nylin et al. 1993; Miller 1977, 1997). Here, the most popular metrics are wingspan (the distance between the tips of the forewings of a set specimen, or twice the distance between the tip of one of the forewings to the center of the thorax) and forewing length (e.g., Hawkins and Lawton 1995; Beck and Kitching 2007; Hamback et al. 2007).

Wings are the most relevant structure of these insects to the human eye, and there are good reasons for wing size to be correlated with body mass for functional reasons, as Lepidoptera are flying insects. However, some degree of structural variation affecting the relationship between wing size and body weight has been documented at several taxonomic levels including the intra-specific one (Van Dyck et al. 1997; Tiple et al. 2009; Shreeve et al. 2009; Symonds et al. 2012). As already stated by Miller (1977), the broad body architecture is likely to differ markedly between the members of distantly related taxa of similar body weights, so that more precise estimates of body mass of species in varied taxonomic positions require a more elaborate combination of linear measurements. It is conceivable that a multivariate approach based on several variables correlated with body weight might achieve this purpose.

The main objective of this study was to determine a composite index based on several linear estimates that could predict accurately the dry body weight of set specimens (e.g., from museum collections or even scale illustrations) irrespective of the species phylogenetic position. The reason for selecting dry body mass instead of fresh body weight is of a practical nature: because these insects are usually preserved as dried samples in scientific collections, the possibility to test and re-elaborate any results is far more feasible than obtaining reliable fresh (live) weights from the same set of species. The second objective was to determine the sensitivity of such an index to sample size (the number of species), taxonomic diversity and morphological heterogeneity as a means to measure its robustness (if it is to be applied to species different from those used to fit it).

Methods

To avoid heterogeneity caused by the patterns of sexual dimorphism in adult size, the comparison was restricted to adult males from any available source, totaling 665 individuals from 375 species distributed among 61 families. The selection emphasized the diversity of size within and across families and included samples from any region in the world that could be processed.

Measurements

The measurements were performed on dry set (pinned or spread), complete male specimens. When fresh adults were available, these were first dried in the position traditionally used for these insects in entomological collections. The measures described below were taken in one of four ways: (a)

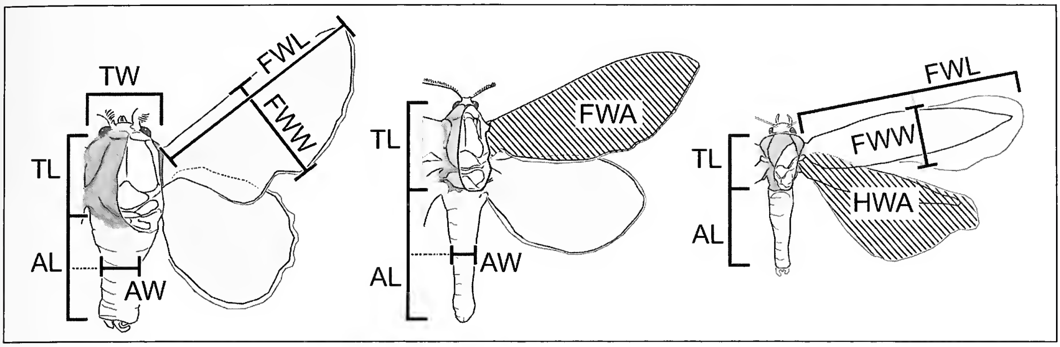

Figure 1. Slightly idealized representations of three typical adult Lepidoptera (left to right: Lasiocampidae, Hepialidae, Gelechiidae) to illustrate the variables measured. The right side of the thoraces is represented as devoid of the scale cover to make more evident the limits of this tagma. The three drawings are scaled to the same forewing length. Linear measurements are indicated by bars and areas by a striped pattern. FWL = fore wing length, FWW = forewing width, FWA = forewing area, HWA = hind wing area, TL = thorax length, TW = thorax width, AL = abdomen length, AW = abdomen width.

under a stereomicroscope with an ocular micrometer, (b) on a digitized scale drawing made with an optical camera lucida adapted to a stereomicroscope (× 10 to × 40), (c) on a digital photograph of the specimen taken together with a standard scale bar, taken either with a macro lens (up to 1:1) or on a photo microscope at low magnification, or (d) with a Vernier caliper (exceptionally in the case of some of the largest moths). The program ImageJ (Rasband 2012) was used to measure the digitized images.

Six linear measurements (in mm) were taken (Figure 1): thorax length (TL), thorax width (TW, taking the point of insertion of the fore wings as a reference), abdomen length (AL) excluding terminal hair pencils or protruding genital appendages, abdomen width (AW, taken at the midpoint of the line represented by AL), forewing length (FWL, from the insertion of the wing on its costal margin to its apex including the fimbriae) and forewing width (FWW, the distance between edges following a line perpendicular to FWL at its midpoint). In addition, the area of the fore- and hindwings (including the fringes) were recorded (FWA, HWA, as mm^2). The mean species values are available as Supplementary material (Suppl. material 1: nexus format text).

Repeated measures and replicates

To estimate the magnitude of error measurement, the mean within sample and mean within species coefficients of variation were calculated after replicated measurements taken on each individual and between individuals within species.

(1) Every measurement was taken twice for each specimen using two different methods among those detailed above (most frequently a, b and c), on two different dates.
(2) Whenever possible two male specimens of approximately the same size (judged from wingspan by naked eye) of the species were processed. However, replications were not always possible as data from single representatives of a number of species were included if this contributed to an increase in the taxonomic or geographic coverage of the species selection.

Dry body weight

The insects were dried to a constant weight at 60° for 48 hours (72 h for the largest specimens). The pins, if present, were removed carefully (but see below). The weight of the whole specimen was determined to the nearest 0.01 mg in a Mettler AT261 balance (species of wingspan of ca. 15 mm or above) or in a Mettler Toledo XP6 microbalance with precision of 0.001 mg (individuals smaller than that size).

Pinned specimens

Although medium or larger sized collection specimens can generally be de-pinned and remounted without much difficulty, there is always some risk of damage. For a small number of loaned specimens (ca. 20 individuals) the weight of the pins was estimated, then subtracted from that of the dry mounted specimen. Samples of 10 individual pins from four different brands and numbers (gauges): 000, 00, 0 and 1 to 6 (all with nylon heads and 37 mm long) were measured and weighed. The weights were taken to the nearest 0.01 mg, and the widths measured with a precision of 0.0179 mm under a binocular microscope with an ocular scale line. The relationship between the log-transformed weights and widths was highly consistent: $\log_{10}$(pin weight in mg) = 2.339 + 1.908 $\log_{10}$(pin diameter in mm), $R = 0.997$, $P < 0.0001$, n = 350.

Small moths

The smallest moths (broadly corresponding to the heterogeneous assemblage of the “microlepidoptera”) posed some special difficulties, which handicapped the use of reference collections as sources of size data. These moths are fragile and very likely to be damaged if treated in the way described above, and even though they are frequently mounted on smaller pins (‘minutiae’, weighting 0.69–3.15 mg for widths of 0.10 and 0.20 mm respectively) the small variation in the length of these tiny metal pieces represents an excessive error in terms of the specimen dry weight. Moreover, as the genital pieces are of interest for identification, collection specimens frequently lack the abdomen or a large part of it as it was removed for identification. Finally, most of them cannot be easily identified to species level without expertise. For these reasons the data from several families in this category were obtained from a small reference collection at the author’s department. This hosts expert-identified specimens collected two decades ago at a single site, so new samples were taken at the same location during 2011–2012 to reasonably cover the lower part of the size range, although at the cost of low geographic variation.

Multivariate models

All the variables were transformed to their decimal logarithms. This facilitated comparisons with results from earlier research (as most size-weight relations have been modelled using the equation weight = a × size^b: Reiss 1989; Ganihar 1997), linear-regression approaches as well as some demands of the comparative method adopted (described below). After log-transformation, all the variables fitted reasonably to the normal distribution with Kolmogorov-Smirnov test values of $d < 0.049$, $P > 0.05$ in all instances (Suppl. material 2: frequency distribution graph).

The multivariate models were fitted using the General Regression Models module of Statistica (Statsoft 2004). For model selection, a manual iterative forward-backwards procedure was adopted to exclude redundant variables.

Independent contrasts and phylogenetic hypothesis

The method of phylogenetically independent contrasts (Felsenstein 1985; Harvey and Pagel 1991) was used to control for phylogenetic effects. The contrasts were calculated using the software PDAP:PDTREE (Midford et al. 2009) integrated in the package Mesquite (Maddison and Maddison 2011). Branch lengths were set to equal length (1.00), and the polytomies were estimated as single contrasts, which were calculated after the original output.

The working hypothesis on phylogenetic relationships was built according to the classification proposed by van Nieukerken et al. (2011), with the relationships above the family level adapted after the tree topologies from Kawahara and Breinholt (2014) complemented by Regier et al. (2009, 2013), Mutanen et al. (2010), Bazinet et al. (2013) and Martijn et al. (2014). Further information was gathered from other recent literature (details available in Suppl. material 3: documentation on phylogeny).

In the absence of any other references, the formal classifications of Fauna Europaea (Karsholt et al. 2013) for the European species and of the Lepindex database (Beccaloni et al. 2013) for other geographic regions was adopted. The tree was assembled manually; preference was given to the most recent results, or to those with the highest statistical support, but keeping any former hypotheses if these have not been contradicted. Thus, except in face of conflicting evidence the formal taxa at the levels of superfamily, family, subfamily and genus were adopted even when their monophyletic status had not been corroborated in all instances. The tree topology and data are available from the Suppl. material 4 and 1 (4: tree topology, 1: tree nexus format). The resulting dendrogram showed high resolution (ca. 77%), which of course is overoptimistic in terms of strictly phylogenetic criteria.

Regressions were done through the origin to estimate the correlations and slopes. After a multivariate regression model was obtained, Least Squares Regression was used to estimate the intercept for the working data set keeping the evolutionary slopes already obtained.

Robustness of the models

The number of species and of supraspecific taxa available for this study was obviously small if compared to the estimated number of existing species in the order Lepidoptera (more than 150,000 species: van Nieukerken et al. 2011). Thus, one further question can be posed – to what extent are the results presented sensitive to the addition of new taxa? The relationship between the errors in the predicted weight data and the diversity in body size, morphology (excluding body weight) and taxonomy were determined. The underlying idea is that any sources of diversity that are positively correlated to large errors in the predictions should denote species' features liable to modify significantly the models obtained.

The error in the predicted dry body weight (DBW) values were measured as the mean of the absolute values of the residuals from the two best fit models (described below) calculated for randomly selected subsets of *n* species, where n = 5, 10, 25, 50, 100, 150, 200, 250, 300 and 350. Forty replicates were taken at each n plus one more sample consisting of the whole data set. The taxonomic and structural diversities of each of such 401 species samples were estimated using the following attributes:

(a) Species diversity: the number of species in each sample.
(b) Variation in dry body weight: the standard deviation of the log-transformed dry body weights.

(c) Structural variation. This variable was intended to account for structural/anatomical variation as reflected by the measurements taken, irrespective of body weight. To do this, each of the eight variables were regressed on body weight, one at a time. The residuals of such bivariate regressions were used as the new variables, now linearly independent of body weight. Applying Principal Component Analysis to this set of residuals (Bartlett's Sphericity test $X^2 = 344.24$, $P < 0.001$; KMO index = 0.72) resulted in three components accounting for 66.96% of the variance (respectively 41.51%, 14.59% and 10.86%). The standard deviation in these three components (weighted by the respective contribution of each component) was used as an index of structural (body shape) diversity, linearly independent from dry weight.

(d) Taxonomic/phylogenetic diversity. This was tentatively estimated in four alternative ways: (1) Number of clades (absolute number of supra-specific nodes). (2) Phylogenetic diversity (PH): the number of clades or nodes represented in the sample minus one, plus the number of species as defined by Faith (1992), with all branches set to 1.00. (3) Relative Phylogenetic Diversity (RPD, the number of clades above the species level divided by the number of species). And (4) Taxonomic Distinctness (Clarke and Warwick 1998; Allen et al. 2009); this was calculated using the software PAST (Hammer et al. 2001) after simplifying the number of taxonomic categories to 10 which included the suborders, superfamilies, families, subfamilies and genera plus five intermediate levels.

As the relationships between the mean residuals and these variables tended to be asymptotic rather than linear, the bivariate and multivariate regressions were performed using Generalized Regression Models and the logarithmic link function.

Results

Size range

The dry body mass of the selected species covered a range of variation of nearly five orders of magnitude, from 0.03 mg to more than 2 g, corresponding to forewing lengths of between 1.8 mm and 110 mm (see Suppl. material 2 and 5; 2: frequency distribution; 5: mean by superfamily). The lightest and smallest species belonged to the genus *Stigmella* (Nepticulidae, with one male weighting 0.034 mg), while two males of the reputedly longest-winged moth, the Erebiidae *Thysannia agrippina* (Cramer, 1776) (see e.g. Kons 1998) had dry weights of 916–1,300 mg and one male of the Saturniidae *Attacus atlas* (L., 1758) weighed 1,126 mg. However the heaviest specimen weighed belonged to the hawk-moth family (*Cocytius* sp., Sphingidae, which exceeded 2.1 grams).

The replicated measurements (Table 1) suggested that the forewing and thoracic linear dimensions may reflect lower proportions of error than the abdomen length or width measurements when taken of the same specimen. Although the estimates between pairs of individuals from the same species differed to some extent, it was clear that the highest amount of variation was accounted for by the abdomen data. Forewing length appeared to be even more constant than the thorax measurements within individuals. This might reflect a bias in the observer's abilities, although it is also likely that the reference landmarks to measure wing length (the tegulae and the tip of the wing) are more obvious than the other reference structures, especially when the body is coated by a dense cover of hair-like scales.

Table 1. Estimate of measurement error for dry body weight and six linear measurements, measured as a percentage of the mean. The values given are the mean coefficients of variation (100·CV) (± 1 SD) averaged across individuals (from duplicated measurements on each specimen, $n = 662$) and from different replicates of the same species (within species, $n = 328$).

	Within individuals	**Within species**
Dry weight (DBW)	----	13.334 ± 9.905
Forewing length (FWL)	2.317 ± 2.477	5.706 ± 4.138
Forewing width (FWW)	3.177 ± 3.843	6.174 ± 6.826
Thorax length (TL)	3.760 ± 3.915	5.611 ± 4.748
Thorax width (TW)	3.032 ± 3.345	5.424 ± 4.901
Abdomen length (AL)	4.450 ± 4.499	8.631 ± 6.769
Abdomen width (AW)	5.982 ± 6.473	9.541 ± 6.678

Table 2. Relationships between dry body weight and the test variables based on the species mean values, estimated both by bivariate regression (left four columns) and in a multivariate regression model (right three columns; intercept = -0.489, multiple $R = 0.983$, adjusted $R^2 = 0.965$). The β values represent the relative contribution of each variable in the multivariate model.

	Bivariate regression				**Multivariate regression**		
Variable	***R***	**Slope**	***P***	**Intercept**	**β**	**Slope**	***P***
FWL	0.939	2.772	<0.001	-2.137	-0.060	-0.178	0.359
FWW	0.920	1.989	<0.001	-0.320	-0.044	-0.095	0.390
TL	0.975	2.718	<0.001	-0.445	0.407	1.135	<0.001
TW	0.957	2.902	<0.001	-0.173	0.189	0.572	<0.001
AL	0.948	2.790	<0.001	-1.173	0.082	0.241	0.029
AW	0.936	2.529	<0.001	0.553	0.150	0.404	<0.001
FWA	0.941	1.266	<0.001	-1.174	0.274	0.368	0.008
HWA	0.926	1.279	<0.001	-1.136	0.011	0.015	0.862

Bivariate regressions and preliminary multivariate regressions

The results from bivariate regressions of DBW on the other variables as well as the full multivariate results (with all the variables in the model) are presented in Table 2 (species means, all $R > 0.92$) and Table 3 (independent contrasts, all $R > 0.82$). The effects of the linear estimates of wing size (FWL and FWW), although significant in the bivariate comparisons performed on the species data, were outweighed by those of the forewing area (FWA) in the multivariate approach. Across the contrasts, FWL had a significant but negative effect in the regression models suggesting a complex relationship between body weight and wing size and shape.

Multivariate regression model selection

Several alternative models fit by stepwise regression were calculated with multiple *R* values above 0.979 in all instances. Models 1 and 2 (Table 4; Figure 2) are those with the highest multivariate *R* based in the species raw data and in the independent contrasts respectively. These two models included the effects of wing area, which may be more difficult to measure in spread specimens. However, because of their highest fits they were used as the basis for the last/next step. Several

Table 3. Relationships between dry body weight and the test variables based on the independent contrasts, estimated by bivariate regression (left three columns) and by multivariate regression (right three columns; multiple $R = 0.914$, adjusted multiple $R^2 = 0.833$). All regressions were forced through the origin (no intercept). The β values represent the relative contribution of each variable in the multivariate model.

	Bivariate regression			**Multivariate regression**		
Variable	***R***	**Slope**	***P***	**β**	**Slope**	***P***
FWL	0.835	2.489	<0.001	-0.146	-0.434	0.091
FWW	0.813	2.132	<0.001	0.040	0.104	0.547
TL	0.891	2.663	<0.001	0.376	1.122	<0.001
TW	0.859	2.632	<0.001	0.185	0.568	0.001
AL	0.817	2.353	<0.001	0.055	0.159	0.257
AW	0.817	2.185	<0.001	0.149	0.398	0.003
FWA	0.840	1.153	<0.001	0.301	0.448	0.003
HWA	0.821	1.210	<0.001	0.015	0.022	0.843

Table 4. The two multivariate models with highest *R* scores among those fitted using the species mean values (1) and the phylogenetically independent contrasts (2). The statistics given are the coefficients of the intercepts and slopes (Coeff.), β values (relative contribution of each variable after standardization) and *P* (significance). The multivariate statistics are represented at the base of the table. The regression based on the independent contrasts was done through the origin (without intercept, statistics in the two bottom rows); the intercept given (-0.553) was fitted a posteriori for the species values in the data set using the slopes (coefficients) stated.

	(1) Species means			**(2) Independent Contrasts**		
	Coeff.	**β**	***P***	**Coeff.**	**β**	***P***
Intercept	-0.180	---	0.207	-0.553	---	<0.001
FWL	-0.745	-0.252	0.015	---	---	---
FWL^2	0.183	0.148	0.013	---	---	---
FWA	0.346	0.257	<0.001	---	---	---
TL	1.149	0.412	<0.001	1.087	0.395	<0.001
TW	0.622	0.205	<0.001	0.616	0.167	<0.001
AL	0.312	0.106	0.005	---	---	---
AW	0.368	0.136	<0.001	0.408	0.109	<0.001
FWA	---	---	---	0.378	0.294	<0.001
Model statistics						
R	0.9828			0.981		
F(*P*)	$F_{7,367} = 1489.83$ ($P < 0.0001$)			$F_{4,371} = 1409.32$ ($P < 0.0001$)		
R [origin]	---			0.9140		
F(*P*) [origin]	---			$F_{3,287} = 351.54$ ($P < 0.0001$)		

alternatives (Suppl. material 6: alternative models) should allow estimations of DBW in circumstances that are frequent in entomological collections such as specimens without abdomen or with its distal end missing due to identifications based in the external genitalia.

Robustness of the models

The regressions of the estimated error of the predictions (measured as the mean of the absolute value of the residuals) on the indicators of taxonomic, size and structural diversity led to the same

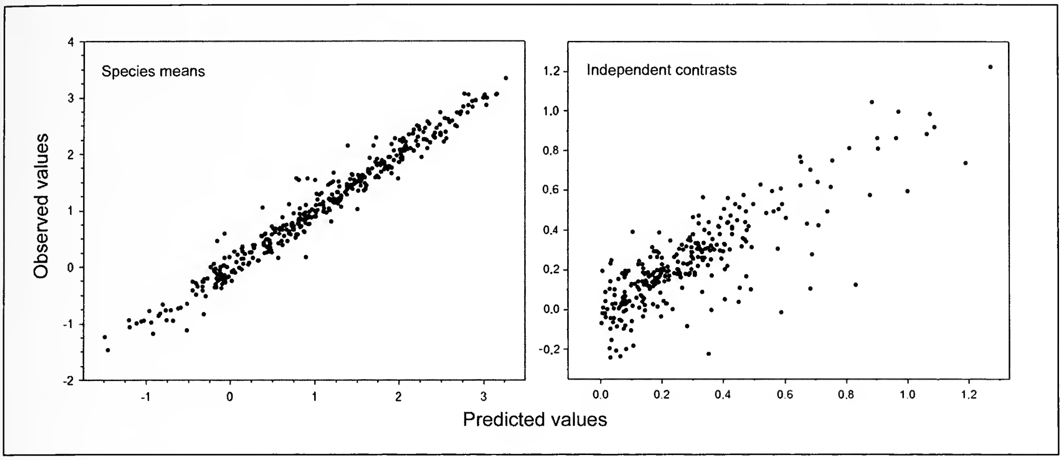

Figure 2. Dispersion plots illustrating the fit (predicted on observed weights) of the two multivariate models of highest R^2 scores based on the raw species data (above) and the independent contrasts (below) (respectively, models 1 and 2 in Table 4).

Table 5. Sensitivity of the best models to several sources of diversity in the species selected. Relationships between the deviations of the predicted data (mean absolute residuals from 401 subsets of 5–375 species) based on the multivariate models 1 and 2 (from Table 4) and several alternative estimates of structural diversity (number of species, taxonomic and phylogenetic diversity, morphology and body weight), estimated through multiple regression. The contributions of the variables are represented in the upper (Coeff. = coefficient, Wald = Wald's statistic) and the multivariate statistics in the lower rows. The Ordinary Least Squares (OLS) R^2 values calculated a posteriori for the two multiple regression models are given for comparison. PH = Phylogenetic diversity, RPD = Relative Phylogenetic Diversity.

	Model 1			**Model 2**		
Variable	**Coeff.**	**Wald**	***P***	**Coeff.**	**Wald**	***P***
Number of species	0.0003	1.837	0.175	0.0003	1.166	0.280
Body Weight diversity	0.0125	1.752	0.186	0.0053	0.268	0.604
Morphological diversity	0.0965	40.349	<0.0001	0.0867	27.582	<0.0001
Taxonomic distinctness	0.0032	0.718	0.396	0.0018	0.195	0.659
Number of clades	-0.0003	1.917	0.166	-0.0002	1.191	0.275
PH	-0.00002	0.014	0.906	-0.00003	0.027	0.870
RPD	-0.0143	16.371	<0.0001	-0.0161	17.527	<0.0001
Model statistics						
Deviance/DF	0.0022			0.0033		
Log-likelihood	470.817			445.012		
OLS R^2 (P)	0.168 ($P < 0.0001$)			0.163 ($P < 0.0001$)		

results in the bivariate and multiple tests, irrespective of the data analyzed (species values or independent contrasts); thus, for simplicity, only the multivariate results are presented in Table 5. Only two of the variables had significant effects with opposite signs: morphological diversity (with a positive coefficient) and the relative phylogenetic diversity (with a negative effect).

Discussion

The results generally show high correlations between all linear dimensions of the Lepidopteran body, or the wing areas, and total dry body weight. This is not surprising given the relatively important range of sizes covered and, especially, because a functional link between the variables measured and total body size should exist in insects that must be able to fly effectively such as the male specimens of moth and butterfly species studied.

The results are consistent with the fact that the wings of Lepidoptera are thin structures (thus relatively light even if comparatively broad and evident) while the largest proportion of the body weight is determined by the weight of the main thoracic and abdominal structures. Forewing length is a popular estimate of body size in butterflies and moths as it is easier to measure than other body dimensions. However, this measure has by itself a lower predictive power of dry body weight than the thoracic dimensions (length and width) or, depending on the method used, abdomen length. Thus, wingspan, taken as the distance from the midpoint of the thorax to the tip of the forewing, would in theory be more accurate than the length of the wing alone as it would partly account for thorax width. However, as stated by Miller (1977) the estimate of 'wingspan' most widely used in the specialized literature is the distance between the tips of the two forewings, where the spreading technique is a potential source of error. Alternatively, some of the body dimensions, especially the abdomen width, tend to be measured with lower accuracy than wing size. In spread collection specimens, the abdomen is frequently deformed and contracted to different degrees, and measurements made on the thorax may be hindered by the dense scale/hair clothing of some of these insects. Under these circumstances a composed 'body size index' appears to be a practical alternative measurement to body weight, particularly when different species are to be compared.

For the linear measurements that are more directly related to body length, such as the thoracic and abdominal lengths, the slopes determined across the species means (2.7–2.8, see Table 2) are exactly in the same range as those found for the relationship between body length and dry mass in terrestrial and aquatic insects on a wider taxonomic scope (2.6 to 2.9: Rogers et al. 1976; Schoenert 1980; Bugherr and Meyer 1997; Benke et al. 1999), or within the order Lepidoptera (Ganihar 1997). Hódar (1996) obtained slopes in the range 2.8–2.9 for the regressions of body weight on head width for butterflies and moths. This supports the idea that dry body mass correlates to single linear measurements such as body length following a slightly negative allometric trend (that is, with a slope slightly below 3.0 which would be expected for the volume to length ratio), at least if estimated by Least Squares Regression. Values of the slope based on the independent contrasts tend to be more conservative (Table 3). However generalizing on these grounds remains difficult since single linear surrogates of body weight may well vary among taxa (e.g. from 2.1 to 2.9 between two families of Lepidoptera; Miller 1977, 1997).

Among the several drawbacks of the present results is the fact that intraspecific variation has not been controlled for, and cannot be distinguished from other sources of error. This may be acceptable under the assumption that intraspecific variation in body weight is generally higher than interspecific variation for the same trait. Given this and the widespread phenomenon that intraspecific allometric trends follow different (generally less steep) slopes than the interspecific trends in animal taxa (e.g. Harvey and Pagel 1991), one corollary is that the body mass indexes presented here are probably not suitable for determining dry body weights accurately within a species. One further limitation of the results presented concerns the estimation of dry body weight in living or fresh (not dried) adults of Lepidoptera, because all the body parts experience some degree of contraction after drying (including the wings; Van Hook et al. 2012); these effects are especially noticeable in the abdomen. In such cases, a suboptimal model (Suppl. material 6: alternative models) could be used as an approximation, or alternatively the bivariate relationships of body weight to forewing length or area as given in Table 2.

Of course, it is likely that the predictive accuracy of the regression models selected can be improved by spreading the selection of species. The results in Table 5 suggest that this would neither be achieved simply by increasing the number of species compared nor by broadening their variance in body weight; instead, it seems that the amount of error in the predictions is primarily correlated with the proportion of morphological diversity of the species compared (irrespective of their body weight) relative to their phylogenetic diversity. In other words, the results may be relatively stable unless for species selections featured by extreme variations in wing and body shape, from subtaxa of Lepidoptera not represented in the sample analyzed.

Although the comparative method of independent contrasts is statistically robust in the absence of accurate estimates of branch lengths, the contrasts are calculated by dividing the differences between each pair of values at a node by the estimated evolutionary distances (derived directly from the branch lengths; Felsenstein 1985). This is a source of uncertainty when the precise value of the regression slopes is of interest. Further, the overall value for the slope of a relationship within a large taxon may represent, in some instances, the average of several slopes featuring the different subtaxa (e.g., for butterflies: García-Barros 2002). Thus, although the formulae derived from the independent contrasts might be suitable for the estimation of dry body weight in species from taxa not prospected in this work, it may be subject to criticism and re-evaluation. The fact that their fit to the data was slightly lower than that based on the raw species data may simply reflect some degree of over-sampling on closely related species, but on the basis of the results and for species similar to those selected preference is given to model 1 (Table 4), or alternatively to models 5 and 6 (presented in Suppl. material 6: alternative models).

Conclusion

The fact that the multivariate approaches presented here showed high R^2 scores (> 0.94) for a much wider range of size, morphology and taxonomic variety than that in any former comparable study on Lepidoptera suggest that, although liable to be refined, they may represent a useful tool for comparative work when a wide taxonomic scope is necessary.

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Supplementary material 1

Nexus format text.

Authors: Enrique Gracía-Barros

Data type: Adobe PDF file

Explanation note: Tree topology for the phylogenetic hypothesis adopted, to be used as input in applications reading nexus (requires some slight previous edition).

Supplementary material 2

Frequency distribution graph.

Authors: Enrique García-Barros

Data type: Adobe TIF file

Explanation note: Frequency distribution of the dry body weight data (mg) across the species studied.

Supplementary material 3

Documentation on phylogeny.

Authors: Enrique García-Barros

Data type: Adobe PDF file

Explanation note: This is a list of references including the most relevant sources of information used to build the hypothesis on phylogenetic relationships which were not quoted in the main text.

Supplementary material 4

Tree topology.

Authors: Enrique García-Barros

Data type: Adobe PDF file

Explanation note: Graphic display (dendrogram) to show the hypothesis on phylogenetic relations adopted in this work, after the sources quoted in the main texta and in the file: Supplementary material 3.

Supplementary material 5

Mean by superfamily.

Authors: Enrique García-Barros

Data type: Adobe PDF file

Explanation note: Mean dry body weight and wing length by superfamily, and sample sizes.

Supplementary material 6

Alternative models.

Authors: Enrique García-Barros

Data type: Adobe PDF file

Explanation note: Alternative or suboptimal regression models derived from the species means or from the independent contrasts.

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Description of immature stages of *Xestia brunneopicta* (Matsumura, 1925), with a key to the mature larvae of the European species of *Xestia* (*Pachnobia*) (Lepidoptera, Noctuidae)

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Abstract. Immature stages of *Xestia brunneopicta* (Matsumura, 1925) are described and illustrated from an *ex ovo* rearing. The female was collected during a Finnish-Russian expedition to the province of Chita in East Siberia in 2013. Eggs were laid in a plastic jar at Chara Sands on the 7th of July. Larvae hatched between the 20th and 21st of July. Rearing of larvae was undertaken in Finland by four lepidopterologists. A key is given that includes the known European larvae of the subgenus *Pachnobia* Guenée, 1852 sensu Lafontaine et al. (1998), mostly based on the morphology and larval chaetotaxy. The closest relatives on the basis of larval morphology are discussed.

Introduction

The early stages of *Xestia brunneopicta* (Matsumura, 1925) have remained undescribed in spite of its wide distribution from Magadan to the East-Siberian Tuva in Russia (Kononenko 2005) and rarely also in Kuusamo, Finland (Mikkola et al. 1989). Ahola and Silvonen (2011) described larvae found in nature in 1982 (Kuusamo) and 1992 (Kuusamo, Kuhmo) as *X. brunneopicta* on the basis of their differences in chaetotaxy and habitus compared to those of *X. gelida* (Sparre-Schneider, 1883). However, through the recent findings, we can now state that the larvae of *X. gelida* and the real *X. brunneopicta* are very distinct from each other, particularly in their outer appearance, as shown in this paper. The Finnish larvae formerly reported as *Xestia brunneopicta* are now re-identified as those of *X. gelida* even though some of their characters differ slightly from other individuals of *X. gelida* examined. Egg, larva and pupa of *X. brunneopicta* are described and illustrated.

Pachnobia was described by Guenée, 1852 as a genus and based on the type-species *Pachnobia carnea*, a misidentification of *Noctua tecta* (Hübner, 1808) (Poole 1989). In Poole's catalogue (1989) *Pachnobia* was included as a synonym in the large genus *Xestia* Hübner, 1818. Lafontaine (1998) arranged *Xestia* into four subgenera: *Xestia*, *Megasema* Hübner, 1821, *Pachnobia* and *Rad-*

dea Alpheraky, 1892. Two subgenera, *Anomogyna* Staudinger, 1871 and *Schoyenia* Aurivillius, 1883, were included in *Pachnobia*, because of larval characters. We follow here this opinion, although some other concepts have been published later (for instance Beck 1999, Fibiger and Hacker 2005, Ahola and Silvonen 2011). A key to the larvae of 18 European species of *Xestia* (*Pachnobia*) is provided and it is mainly based on their morphology and chaetotaxy.

Materials and methods

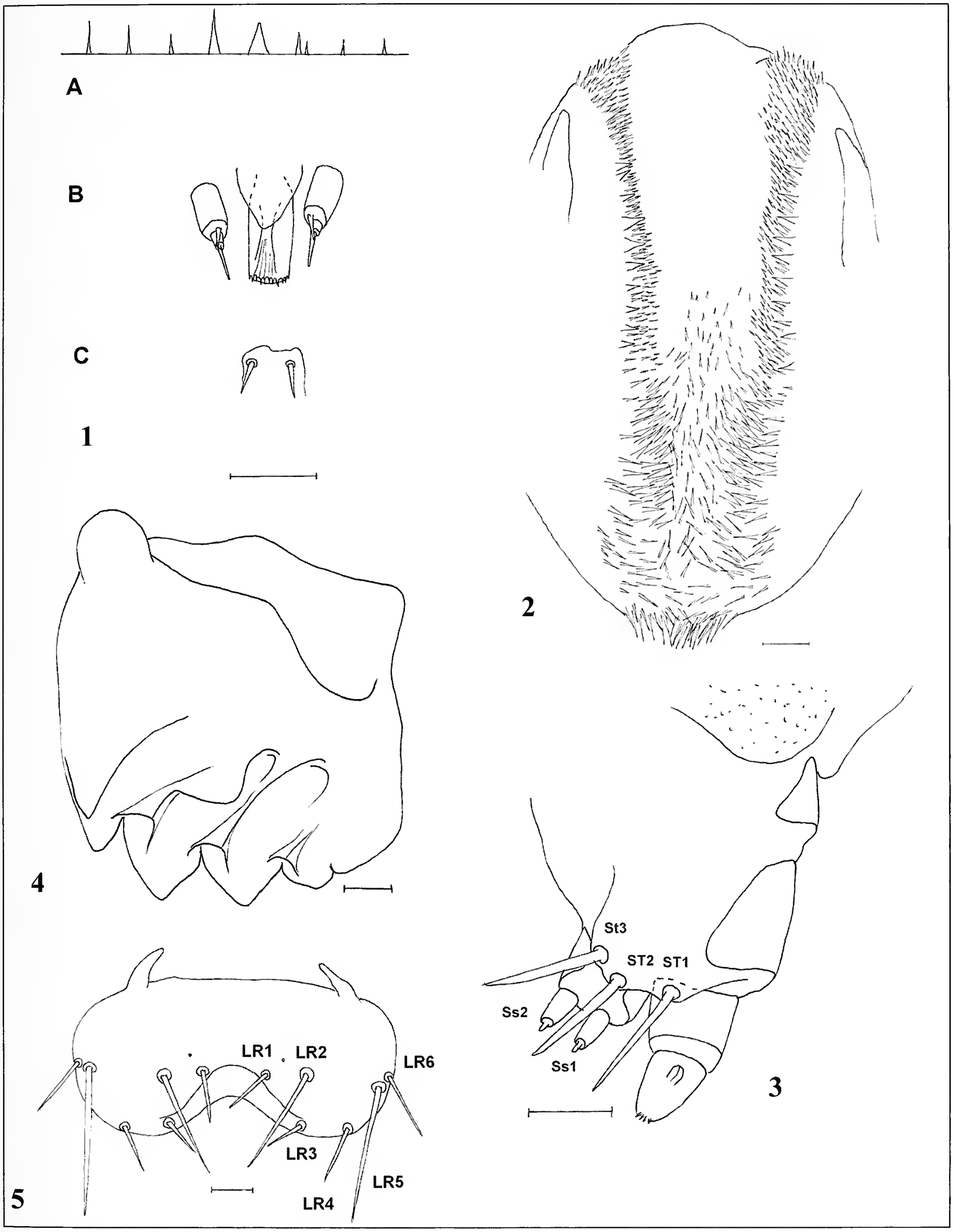
The larval material originates from a female collected during an expedition to the province of Chita in East Siberia, N56.87133, E118.18302, at an elevation of 750 m.a.s.l. on 7.vii.2013 by Hannu Saarenmaa. Seventy-two eggs were laid on the needles of *Larix gmelini* Rupr. (Pinaceae) in a plastic jar at Chara Sands 7 –10 July. The rearing of eggs was carried out in Finland by HS and 60 larvae hatched after two weeks on 20–21 July. All larvae were reared under different lamps from 18 to 24 hours of light every day, because the northern larvae grow faster in continuous daylight. Twenty larvae grew to maturity during autumn and went into diapause instead of pupating. We follow Beck (2000) in descriptions of cuticular ornaments. Two larvae were prepared by dry inflating. Larval chaetotaxy nomenclature follows Hinton (1946) while pupal follows Patočka and Turčáni (2005). The hypopharyngeal complex, mandibles and labrum were dissected and preserved on a slide to study the morphology.

Descriptions of immature stages

Egg (Fig. 6): The eggs were laid on the needles of *Larix gmelini*. Shortly after laying they were whitish grey, but fertile eggs darkened in two days. The micropyle area became dark reddish brown, and the narrow zone around the micropyle was reddish brown

Morphology of full-grown larva (Figs 1–5): Spinneret flat, 2.5× as long as wide, ventral lip straight, dorsal lip short-fringed, longitudinal grooves present on dorsal surface. Base segment of labial palp (Lps1) about 2× as long as wide, second segment (Lps2) 1/5 as long as Lps1, labial palp seta Lp1 slightly longer than Lps2, seta Lp2 shorter than Lps1 (3/5) and 2× as long as Lp1. Hypopharynx with long spines on anterior surface above spinneret, distolateral spines slightly longer and stouter than distomedian spines, spines on lateroposterior part forming row of 8–10 differentiated, triangular teeth, lateral surface above this row densely covered with tiny spinules, posterior area of medial part bare. Stipular setae below spinneret shorter than seta Lp2 of labial palp, situated in front of prementum. Mandible with two setae on outer surface, six teeth on cutting margin, three ridges on inner surface terminating in low protuberances before cutting margin and triangular tooth on first ridge. Maxillary palp three-segmented, second segment longer than galeal lobe, sensillum styloconicum of galeal lobe as long as end segment of maxillary palp, three sensilla trichodea present. Labrum with low, rounded notch. Epicranial suture slightly shorter than height of frons. Six stemmata present, distance between second (Oc2) and third (Oc3) stemma greater than those between Oc1–Oc2 or Oc3–Oc4, distance Oc1–Oc2 greater than Oc3–Oc4. Abdominal prolegs on abdominal segments 3– 6 (Ab3–6) equal in size, crochets uniordinal, 17–20 on Ab3, 22–24 on Ab6 and 26–28 in Ab10. Body without warts or other protuberances.

Chaetotaxy resembling that of other members of *Pachnobia*: Setae of head and body rather long when compared to the height of the spiracle on Ab8: P1 on head 3.1–3.3×, D2 on Ab2 1.6–1.9×, D2 on Ab7 1.3–1.5× and D2 on Ab8 2.1–2.2× height of spiracle 8. Seta SD1 hair-like on thorax and



Figures 1–5. *X. brunneopicta*, morphology of larval mouth parts. **1**. A. Scheme of spines of hypopharynx, from left: distoanterior, distomedial, distoposterior, distolateral, lateral tooth, posterior dorsolateral, posterior medial and lateroposterior spines. B. Spinneret and labial palpi in dorsal view. C. Stipular setae in frontal view. **2**. Hypopharynx in dorsal view. **3**. Left maxilla in dorsal view. **4**. Left mandible in oral face. **5**. Labrum in dorsal view. Scale 0.1 mm.

Table 1. Relevant distances between setae of larva of *Xestia brunneopicta*. Ab = abdominal segment.

Segment	Ratio of distances	Range	Mean	N
Head:	AF1–AF2/AF1–F1	1.5–1.6	1.55	2
	P1–A2/A1–A2	3.3–3.7	3.5	2
	SO1–SO2/SO2-SO3	2.0–2.7	2.4	2
Metathorax:	SD2–L1/SD1–SD2	0.7–1.0	0.8	2
Abdomen:				
Ab2	SD1–SD2/SD2–spiracle 2	1.4–1.5	1.45	2
	SV1–SV3/SV1–SV2	0.8–0.9	0.86	2
Ab7	SD1–SD2/SD2–spiracle 7	1.8–2.2	2.0	2
	L2–L3/L3–SV1	0.7–0.9	0.8	2
Ab9	D2–SD1/D1–SD1	0.6–0.8	0.7	2
Ab10	D2–SD1/D2–D2	2.2–2.9	2.6	2
	D1–D1/D2–D2	2.6–3.8	3.2	2

Ab9, tonofibrillary platelet present below seta SD1 on meso- and metathorax and two SV setae on Ab1. Relevant larval setal distances are presented in Table 1.

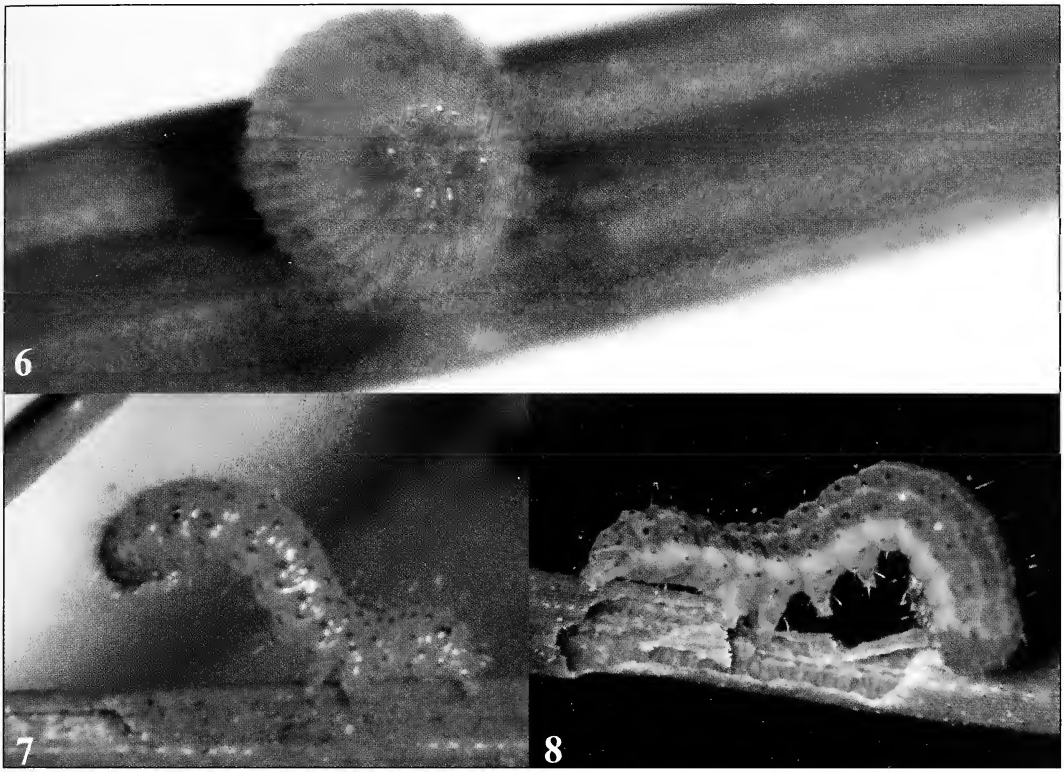
First instar larva: Length about 2 mm. Head pale brown, body pale greenish grey with small dark-brown setal bases. Prolegs on Ab3–6 well developed, those on Ab3–4 much smaller (Fig. 7).

Second instar larva: Length about 4 mm. Head brown. Dorsal region greenish, ventral region pale yellowish green, setal bases dark brown. Narrow, whitish dorsal and subdorsal lines present, shields on thoracic segments 1 (Th1) and Ab10 pale brown (Fig. 8).

Third instar larva: Length about 7–9 mm. Head brown, stripes visible but weak. Shields pale brown, dorsal lines yellowish, not sharp-edged on shields. Dorsal zone green with white, narrow, middorsal and subdorsal lines without darker margins, setal bases small, pale green. Subdorsal zone dark olive green, spiracular line yellowish white, broad. Pleural and ventral zones pale green (Fig. 9).

Fourth instar larva (Fig. 10): Length 14–18 mm: Head brown, netfields visible but translucent, frons and anterior zone green, brown setal points on brown bases. Thoracic and anal shields pale brown, dorsal and subdorsal lines present as yellowish white flecks on prothoracic shield but absent on anal shield. Body green on dorsal region with pale green or with whitish elements, yellowish green between abdominal segments, dark green on ventral subdorsal zone. Middorsal line nearly white, broad, continuous, subdorsal line slightly narrower, broken into spots. Spiracular line broad, yellowish white, sharply bordered above dark green ventral subdorsal zone. Ventral region pale green. Setal points black on dorsal region with dark green dorsal/whitish ventral bases.

Penultimate and last instar (Figs 11–12): Length of last instar larva 35–40 mm. Head brown, stripes brown, reticulate structure with brown bands and pale brown, weakly visible netfields. Frons and anterior zone greenish, adfrons brown, ocellar zone pale yellowish brown, setal points dark brown. Prothoracic shield darker green than body, with narrow pale grey middorsal line, subdorsal line not visible, shield caudally bordered with narrow, blackish grey colour. Anal shield greenish brown, lines not visible, sutures brown, setal points blackish brown. Dorsal and ventral regions of body green, middorsal and subdorsal lines white, narrow, short and broken, not visible on Ab9–10, both lines with dark-green margins. Dorsal part of spiracular line visible, white, narrow, dorsally dark violet-green border, ventrally no border. Dorsal and subdorsal zones mottled by small, white elements and longitudinal violet-green colour elements; dorsal zone with diffuse wedge-shaped diamond figures; setal points of D1 and



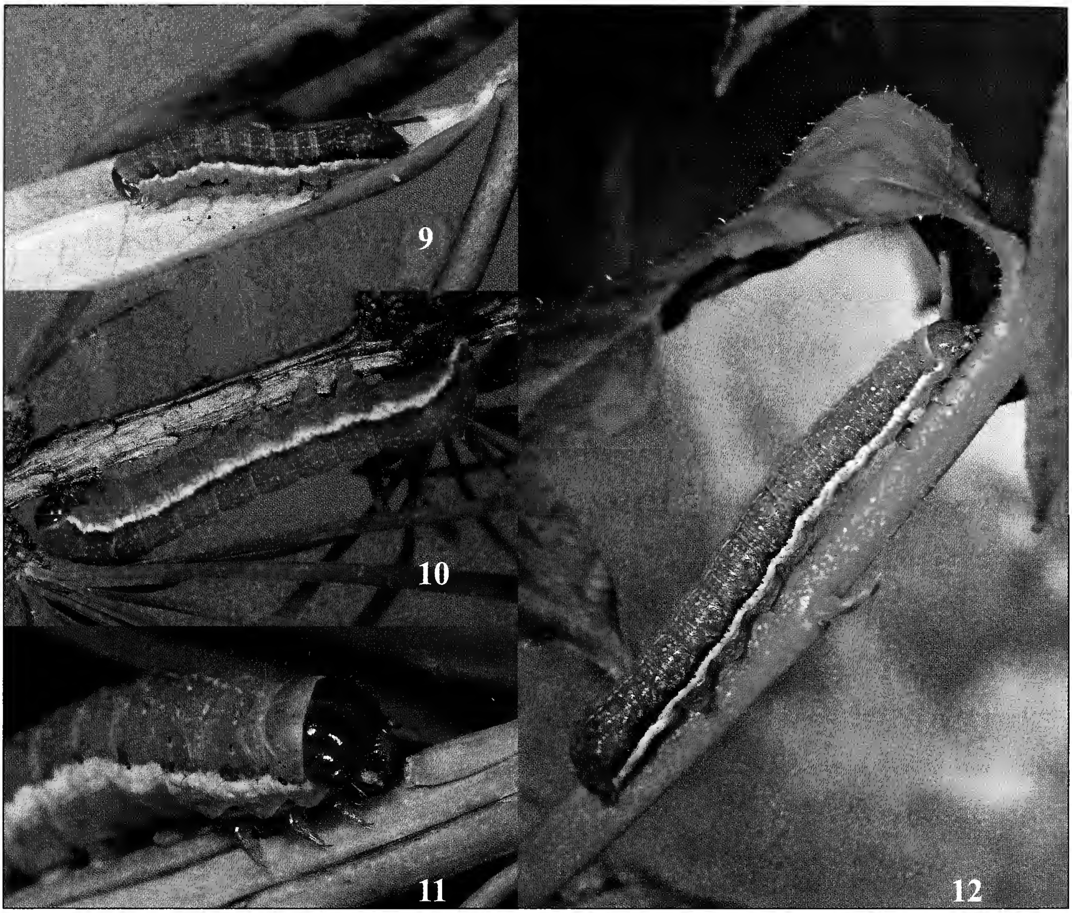
Figures 6–8. Egg and small larvae of *X. brunneopicta*. **6.** Egg on needle of *Larix gmelini* (Photo: M. Ahola). **7.** The 1st instar larva on needle of *Larix sibirica* (Photo: M. Ahola). **8.** The 2nd instar larva on needle of *Larix sibirica* (Photo: M. Ahola).

D2 black with small white bases, microsetae MD1 and MD2 on common large and white base on metathorax, other MD1 bases also white but small. Spiracles yellowish with black edges. Thoracic legs with green coxae and pale brown tibiae, prolegs green.

Pupa (Figs 13–14): Dark brown. Frons without tubercles or projections, labium and labial palpi visible, proboscis exceeding caudal margin of Ab4, prothoracic femora visible, thoracic legs adjacent to antennae. Abdominal spiracles narrow, Ab5–7 without elevated transverse ridge in front of spiracles, without transverse row of spines or lateral spines; punctuation present close to bases of Ab4–7. Cremaster short, flat, quadrangular, with transverse dorsal and ventral furrows and three pairs of setae, D2 close together, short and hook-like, D1 longer than D2, stout, L1 short and stout, situated beside D2 on caudal margin of cremaster. Pupation after hibernation without feeding in flimsy weak cocoon.

Observations on rearing and host plants

Larvae hatched on July 20 and 21. They were in a plastic jar where they could choose between plants *Larix sibirica* Maxim. (Pinaceae), *Vaccinium myrtillus* L. (Ericaceae) and *Polygonum aviculare* L. (Polygonaceae). About 40 of the 60 larvae chose *L. sibirica* or *V. myrtillus* and the rest chose *P. aviculare*. Five larvae died during the first week for unknown reasons. After about a week the group of larvae was divided amongst four Finnish lepidopterists. It appeared later that young

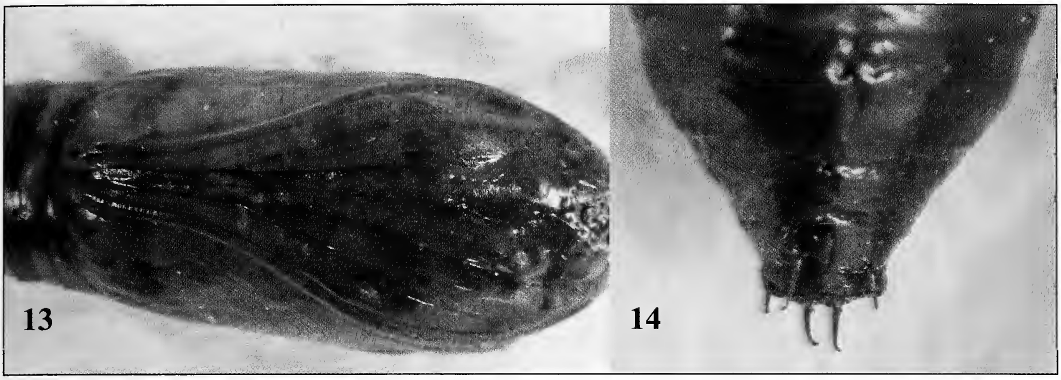


Figures 9–12. *X. brunneopicta* larvae. **9**. The 3rd instar larva on *Andromeda polifolia* L. (Photo: K. Silvonen). **10**. The 4th instar larva on *Larix decidua* Miller (Pinaceae) (Photo: K. Silvonen). **11**. Last instar larva with darker brown head (Photo K. Silvonen). **12**. Mature larva on *Salix phylicifolia*. (Photo: P. Puntila).

larvae could feed also on *Poa annua* L. (Poaceae) and *Salix phylicifolia* L. (Salicaceae). Full-grown larvae were rather polyphagous in laboratory conditions, feeding also on *Rubus idaeus* L. (Rosaceae), *Alnus incana* (L.) Moench (Betulaceae), *Salix* sp. (Salicaceae) and *Lonicera xylosteum* L. (Caprifoliaceae). Larvae were mostly reared under a lamp.

Notes on natural environments

The collecting site of the female in Chara Sands is a peculiar dune habitat with occasional springs, bogs and coniferous tree patches. It does not represent the typical habitat of the species. During the trip (3–12 July) other localities near Chara were investigated, for which another article on the results of the expedition is under preparation (Saarenmaa et al., in prep.). *X. brunneopicta* was common across all sites, but it seemed to be more frequent in the lowlands than in the mountain valleys. Typical habitat for the species is forested bog with *Larix gmelini* (Fig. 15). However, it was most numerous in low *Salix* and *Alnus* vegetation on the banks of the Chara River. Other spe-



Figures 13–14. *X. brunneopicta* pupae. **13.** Pupa in ventral view. **14.** Cremaster of pupa in dorsal view (Photos: M. Ahola).

cies typical for these localities include several other *Xestia* (*Pachnobia*) species such as *X. atrata* (Morrison, 1874), and also *Polia altaica* (Lederer, 1853), *P. conspicua* (A. Bang-Haas, 1912), *P. vespertilio* (Draudt, 1934), *P. vesperugo* Eversmann, 1856, and the arctiine *Borearctia menetriesii* Eversmann, 1846.

Key to the larvae of subgenus *Pachnobia*

Larvae of the subgenus *Pachnobia* differ from subgenera *Megasema* and *Xestia* in chaetotaxy and morphology. Dorsal setae are long in *Pachnobia*, seta D2 on Ab8 is more than twice as long as height of spiracle of same segment, whereas it is about as long as height of spiracle in subgenera *Megasema* and *Xestia*. Also, setal distances P1–P2 (head) and V1–V1 (Ab7) differ on average (Table 2). Spinneret of larvae in subgenus *Pachnobia* is long, about 1.5–5.0× as long as wide, flat (except *X. liquidaria*), dorsal margin with short fringes (without fringes in *X. liquidaria*) and ventral margin straight. *Megasema* and *Xestia* larvae have a short spinneret, 1.0–1.5× as long as wide (except 2–3× in *X. collina*, *castanea* and *agathina*), dorsal margin with longer fringes and ventral margin more or less bilobed. Body colour and pattern vary a lot. Larva of *X. liquidaria* is peculiar with a tubular spinneret but long dorsal setae as in subgenus *Pachnobia*.

Larvae of European species of *Xestia* (*Pachnobia*) *albonigra* (Kononenko, 1981) and *X.* (*Pachnobia*) *thula* Lafontaine & Kononenko, 1983 are still unknown, and are not included in the following key.

1 Netstructure of head negative, netfields darker than bands, spinneret tubular, distal part of hypopharynx bare, without spines or granules, subdorsal line wide, white, spiracular line absent. Ratio of setal distance L1–L3/L1–L2 on Th3 varies 0.9–1.0, mean 1.1, N = 2 and on Ab2 ratio of setal distances SD1–SD2/SD2–ST2 varies 4.5–5.3, mean 4.9, N = 2 .... *Xestia* (*Pachnobia*) *liquidaria* (Eversmann, 1848)

– Netstructure of head positive, netfields paler than bands, spinneret flat, distal part of hypopharynx covered with spines or granulated, lines of body vary. Ratio of setal distance L1–L3/L1–L2 on Th3 varies 1.2–3.3, mean 1.8, N = 146 and ratio of setal distances SD1–SD2/SD2–ST2 on Ab2 varies 1.1–4.3, mean 2.2, N = 137 2

Figure 15. Typical habitat of *X. brunneopicta* and the other species mentioned in the article. Chara River with richer vegetation on its banks is 100 meters to the left (Photo: H. Saarenmaa).

Table 2. Differences in chaetotaxy between larvae of *Pachnobia* and *Megasema* + *Xestia*. Ab = abdominal segment, ST = spiracle.

Ratio between setal distances:	Pachnobia range	Mean	N	Megasema and range	Xestia mean	N
Head: P1–P1/P1–P2	1.4–2.9	2.1	152	2.0–4.1	3.0	66
Ab7: V1–V1/SV1–V1	0.4–1.7	0.8	153	0.3–1.1	0.5	66
Length of seta						
D2Ab8/height of ST8	1.4–5.4	2.6	139	0.7–1.6	1.0	66

2 Mandible without inner teeth or sometimes low swelling present on first ridge, transverse cleft of hypopharynx not visible, setae very long, length of seta D2 on Ab8 more than 3× height of spiracle on same segment (mean 3.4, range 2.2–5.0, N = 27), *X. borealis* differs (2.2–2.5) 3

– Mandible with 1–2 triangular teeth, hypopharyngeal transverse cleft usually present, setae shorter, length of seta D2 on Ab8 about 2× height of spiracle on same segment (mean 2.3, range 1.4–4.2, N = 109), *X. sincera* differs (3.5–4.2) 9

3 Mandible with low swelling on first ridge, location of pore XDc close to seta XD2 on prothoracic shield (ratio XD1–XDc/XD2–XDc ranges 2.1–6.0, mean 3.3, N = 7), on anal shield setal distance D1–SD2 longer than D1–D2 (ratio D1–SD2/D1–D2 ranges 1.1–1.5,

mean 1.3, N = 7). Head small, thorax tapered towards head, setal bases D1 and D2 as white, sharp-edged full-bases 4

– Mandible without swelling on first ridge, location of pore XDc more distant from seta XD2 on prothoracic shield (ratio XD1–XDc/XD2–XDc ranges 1.4–3.0, mean 2.1, N = 20), on anal shield setal distance D1–SD2 mostly shorter than D1–D2 (ratio D1–SD2/D1–D2 ranges 0.8–1.3, mean 0.9, N = 18). Thorax not tapering towards head, setal bases D1 and D2 yellowish, greyish or absent and not sharp edged 5

4 Dorsal zone pale violet whitish with darker arrow-chevron figure, subdorsal zone blackish, subdorsal line yellowish white ventrally bordered by black diagonal bands, spiracular line pale brownish beige, paler than greyish-brown pleural zone .... *Xestia* (*Pachnobia*) *fennica* (Brandt, 1936)

– Dorsal zone uniformly red-brown without arrow-chevron figure, subdorsal zone dark red-brown dorsally, subdorsal line whitish broken to few flecks, spiracular line reddish beige like pleural zone .... *Xestia* (*Pachnobia*) *rhaetica* (Staudinger, 1871)

5 Hypopharynx with row of long posterior lateral spines, about as long as distal lateral spines, distance between ocelli Oc1–Oc2 shorter than that of Oc2–Oc3 (ratio Oc1–Oc2/Oc2–Oc3 ranges 0.6–0.8, mean 0.7, N = 7), seta P1 on head shorter than 1.5× seta D2 on Ab2 (ratio P1/D2 range 1.2–1.5, mean 1.4, N = 7), on anal shield distance D1–D1 more than 3× that of D2–D2 (ratio D1–D1/D2-D2 range 2.9–4.1, mean 3.4, N = 7). Frons and stripes black or blackish brown on head, coxae of thoracic legs black, subdorsal lines yellowish on prothoracic and anal shields 6

– Hypopharynx with row of shorter posterior lateral spines, shorter than distal lateral spines, or without differentiated spines in this area, distance between ocelli Oc1–Oc2 about as long as that of Oc2–Oc3 (ratio Oc1–Oc2/Oc2–Oc3 ranges 0.8–1.7, mean 1.1, N = 13), seta P1 on head longer than 1.5× seta D2 on Ab2 (ratio P1/D2 range 1.5–2.0, mean 1.7, N = 7), on anal shield distance D1–D1 about 2x that of D2–D2 (ratio D1–D1/D2–D2 range 1.2–2.9, mean 2.1, N = 12). Head with brownish or grayish frons and stripes, coxae of thoracic legs paler, subdorsal lines whitish or grayish on shields 7

6 Spinneret about 1.5× as long as wide. Dorsal zone of larva darker reddish grey, black, wedge-shaped flecks above subdorsal line wide, coming into contact with both D1 and D2 bases on Ab8, this line sharp also on shields, pinacula at bases of D setae visible only on Ab9 .... *Xestia* (*Pachnobia*) *laetabilis* (Zetterstedt, 1839)

– Spinneret about 2× as long as wide. Dorsal zone of larva pale grey with reddish tinge, black wedge-shaped flecks above subdorsal line narrow, coming into contact only with D2 bases, this line obscure, broken into spots on shields, pinacula at bases of D setae present on Ab1–9 .... *Xestia* (*Pachnobia*) *distensa* (Eversmann, 1851)

7 Differentiated posterior lateral spines absent on hypopharynx, seta Lp1 of labial palpus unusually long, about 4× length of second segment of labial palpus, seta P1 on head shorter than epicranial suture (ratio P1/Es range 0.8–0.9, mean 0.8, N = 3), setal distance SD1–SD2 about 2× as long as distance between seta SD2 and spiracle on Ab2 (ratio SD1–SD2/SD2–spiracle ranges 1.8–2.1, mean 2.0, N = 3). Subdorsal zone lichen patterned with blackish grey and whitish elements, spiracular line yellowish white, broad,

widely broken below spiracles by ground color and blackish ....*Xestia* (*Pachnobia*) *borealis* (Nordström, 1933)

– Differentiated posterior lateral spines may be weak but present on hypopharynx, seta Lp1 of labial palpus shorter, at most 2× length of second segment of labial palpus, seta P1 on head longer than epicranial suture (ratio P1/Es range 1.1–2.0, mean 1.5, N = 10), setal distance SD1–SD2 about 3× distance between seta SD2 and spiracle on Ab2 (ratio SD1–SD2/SD2–spiracle ranges 2.3–3.7, mean 2.8, N = 10). Subdorsal zone not lichen patterned, spiracular line obscure or absent 8

8 Labial palpus with seta Lp2 as long as first segment, setal bases without pinacula on abdomen, number of crochets on Ab6 29–33, distance between setae D2–D2 short on anal shield (ratio D1–D1/D2–D2 ranges 1.9–2.9, mean 2.5, N = 5). Larva with prominent, white middorsal and subdorsal lines on dorsal region, subdorsal line bordered by black wedge-shaped dorsal flecks.............................*Xestia* (*Pachnobia*) *lyngei* (Rebel, 1923)

– Labial palpus with seta Lp2 shorter than first segment, setal bases with pinacula on abdomen, number of crochets on Ab6 18–20, distance between setae D2–D2 long on anal shield (ratio D1–D1/D2–D2 ranges 1.2–1.7, mean 1.5, N = 5). White dorsal lines narrow, not prominent, and black wedge-shaped flecks absent on dark brown dorsal region........ ....*Xestia* (*Pachnobia*) *quieta* (Hübner, 1813)

9 Skin of distal region of hypopharynx granulated with a few spines or bare, mandible with two inner teeth, setal distance D2–SD2 2× as long as XD2–SD2 on prothorax (range 1.7–2.8, mean 2.1, N = 15), length of seta D2 on Ab8 shorter than 2× as long as height of spiracle (length D2 Ab8/height of spiracle ST8 varies 1.4–2.0, mean 1.7, N = 15). Frontal stripe of head pale greyish brown, much paler than cervical stripe, and spiracular line of abdomen absent or obscure 10

– Skin of distal region of hypopharynx smooth and densely covered with spines, mandible with 1–2 teeth, setal distance D2–SD2 slightly longer than XD2–SD2 on prothorax (range 1.0–2.7, mean 1.4, N = 119), length of seta D2 on Ab8 longer than 2× as long as height of spiracle (length D2 Ab8/height of spiracle ST8 varies 1.7–5.0, mean 2.6, N = 121). Frontal stripe of head mostly of same colour as cervical stripe, and spiracular line usually visible 11

10 Distance between setae D2–D2 on anal shield longer than height of spiracle of Ab8 (ratio D2–D2/height of spiracle ranges 1.0–1.3, mean 1.1, N = 6), setal distance D1–D1 on anal shield about 2× as long as D2–D2 (ratio D1–D1/D2–D2 ranges 1.7–2.3, mean 2.0, N = 6). Larva dark reddish brown, middorsal line weak, whitish, mostly covered by blackish brown margins.....................................*Xestia* (*Pachnobia*) *alpicola* (Zetterstedt, 1839)

– Distance between setae D2–D2 on anal shield shorter than height of spiracle of Ab8 (ratio D2–D2/height of spiracle ranges 0.7–0.8, mean 0.8, N = 3), setal distance D1–D1 on anal shield about 3× as long as D2–D2 (ratio D1–D1/D2–D2 ranges 2.7–3.0, mean 2.9, N = 3). Larva yellowish brown, middorsal line whitish, more visible because of narrower margins...*Xestia* (*Pachnobia*) *albuncula* (Eversmann, 1851)

11 Mandible with two inner teeth, setal distance SD1–SD2 mainly less than 2× that of SD1–spiracle on Ab2 (ratio SD1–SD2/SD1–spiracle varies 1.1–3.3, mean 1.8, N= 48), *X. atrata* with longer SD1–SD2 (range 2.1–3.3, N = 5). Larva brown, subdorsal line not touching bases of setae D2... 12

– Mandible with one triangular inner tooth, setal distance SD1–SD2 mainly more than 2× that of SD1–spiracle on Ab2 (ratio SD1–SD2/SD1–spiracle varies 1.4–4.3, mean 2.3, N= 44), *X. gelida* and *X. brunneopicta* with short SD1–SD2 (1.4–2.4, N = 16). Ground colour varies, subdorsal line usually touching bases of D2 setae 14

12 nner tooth on first ridge of mandible quadrangular, distance between ocelli Oc1–Oc2 on head longer than that of Oc2–Oc3 (ratio Oc1–Oc2/Oc2–Oc3 ranges 1.0–1.4, mean 1.2, N = 5), seta D2 closer to spiracle on Ab2 (ratio SD1–SD2/SD2–spiracle ranges 2.1–3.3, mean 2.7, N = 5). Dorsal and ventral regions of body of same color, spiracular line indistinct.. *Xestia* (*Pachnobia*) *atrata* (Morrison, 1874)

– Inner tooth of mandible triangular, distance between ocelli Oc1–Oc2 on head shorter than that of Oc2–Oc3 (ratio Oc1–Oc2/Oc2–Oc3 ranges 0.5–1.0, mean 0.8, N = 44), seta D2 more distant from spiracle on Ab2 (ratio SD1–SD2/SD2–spiracle ranges 1.1–2.5, mean 1.7, N = 43). Ventral region of body paler than dorsal region, spiracular line visible and bordered sharply against subdorsal zone.. 13

13 Frontal stripe of head pale brown or pale greyish brown, paler than cervical stripe, bases of setae D1 and D2 of abdomen ventrally yellowish white, spiracular line with yellowish white dorsal part and mottled by reddish brown elements.. .... *Xestia* (*Pachnobia*) *speciosa* (Hübner, 1813)

– Frontal stripe dark greyish brown like cervical stripe, bases of D1 and D2 of abdomen ventrally whitish, small spiracular line without differentiated white dorsal part and not mottled by brown elements...................... *Xestia* (*Pachnobia*) *viridescens* (Turati, 1919)

14 Larva green, mottled with small, white elements, without prominent pattern, dorsal, subdorsal and spiracular lines white, narrow. Setal distance D1–D2 of Ab9 about ½ distance D1–SD1 (ratio D1–D2/D1-SD1 range 0.5–0.7, mean 0.6, N = 2).................................. .... *Xestia* (*Pachnobia*) *brunneopicta* (Matsumura, 1925)

– Larva not uniformly green, dark dorsal pattern present on body, lines variable. Setal distance D1–D2 of Ab9 about as long as distance D1–SD1 (ratio D1–D2/D1–SD1 range 0.7–1.3, mean 1.0, N = 42).. 15

15 Spinneret long, more than 3× as long as wide and tapered apically; setal distance SD1–SD2 less than twice as long as that of SD2–spiracle on Ab8 (except *aequaeva* 2.5–3.1 ×), range 1.4–3.1, mean 1.8, N = 19. Ground colour of larva distinctive dark grey with dorsal pinacula or dorsal zone pinkish cream and subdorsal zone blackish........................... 16

– Spinneret shorter, less than 3× as long as wide with parallel sides; setal distance SD1–SD2 more than 2× as long as that of SD2–spiracle on Ab8 (except *sincera* 1.5–1.9 ×), range 1.5–4.5, mean 2.5, N = 102. Ground colour of larva different 17

16 Larva dark grey with large black pinacula on dorsal region, spiracles black, number of crochets on Ab10 varies 17–24 (N = 2), setal distance L1–L3 on metathorax about 3× that of L1–L2 (range 2.6–3.3, mean 2.9, N = 2).. .... *Xestia* (*Pachnobia*) *aequaeva* (Benjamin, 1934)

– Pinacula absent on dorsal region, ground colour different, spiracles yellowish, number of crochets on Ab10 varies 26–43 (N = 19) setal distance L1–L3 about 1.5× that of L1–L2 (range 1.2–2.0, mean 1.5, N = 19) on metathorax. Dorsal zone of larva pale pinkish cream, white, usually only ventrad from seta D2 visible subdorsal lines with blackish dorsal border, subdorsal zone blackish brown ....*Xestia* (*Pachnobia*) *gelida* (Sparre-Schneider, 1883)

17 Tiny spinules present distally on middle of posterior part of hypopharynx and partly forming transverse rows, inner tooth of mandible small, seta SD1 on abdominal segments more distant from spiracle (on Ab8 ratio SD1–spiracle/height of spiracle ranges 1.9–3.5, mean 2.3, N = 5). Body blackish grey and whitish, lichen patterned, middorsal line white, enlarged on posterior parts of abdominal segments, subdorsal line whitish, enlarged towards seta D2, spiracular line broad, white with dark breaks below spiracles and dorsally bordered by black wavy margin .... *Xestia* (*Pachnobia*) *sincera* (Herrich-Schäffer, 1851)

– Spines absent on middle posterior part of hypopharynx, inner teeth of mandible robust, seta SD1 on abdominal segments closer to spiracle (on Ab8 ratio SD1–spiracle/height of spiracle ranges 0.9–1.7, mean 1.3, N = 26). Body brown or yellowish-brown, not lichen patterned, lines vary but spiracular line not prominent and its dorsal margin straight 18

18 Seta Lp2 of labial palpus short, 2/5 of length of base segment, spinneret slightly shorter than 2× as long as wide, setal distance XD1–XD2 about 2× as long as XD2–SD2 on prothorax (ratio XD1–XD2/XD2–SD2 range 2.0–2.5, mean 2.1, N = 10), on Ab2 distance SV1–SV3 longer than SV1–SV2 (ratio SV1–SV3/SV1–SV2 range 1.0–1.9, mean 1.3, N = 10). Larva reddish brown, dorsal lines whitish, narrow, both bordered with blackish fleck at anterior parts of segments, spiracular line yellowish white, sharp edged, figures of dorsal zone obscure ....*Xestia* (*Pachnobia*) *tecta* (Hübner, 1808)

– Seta Lp2 of labial palpus long, about 2/3–1 × length of base segment, spinneret 2–2.5 × as long as wide, setal distance XD1–XD2 about 1.5× that of XD2–SD2 on prothorax (ratio XD1–XD2/XD2–SD2 range 1.2–1.9, mean 1.5, N = 17), on Ab2 distance SV1–SV3 shorter than SV1–SV2 (ratio SV1–SV3/SV1–SV2 range 0.5–1.1, mean 0.8, N = 17). Larva yellowish or grayish brown with broad dorsal lines of same colour, bordered with sharp, black, narrow margins, subdorsal line without ventral margin, markings of dorsal zone like thin arrow-head chevron figure on Ab1–8, spiracular line of same colour, dorsally bordered with sharp, blackish margin ....*Xestia* (*Pachnobia*) *lorezi* (Staudinger, 1891)

Discussion

The appearance of the larval stages of *X. brunneopicta* differs greatly from those of *X. gelida* and *X. fabulosa* (Ferguson, 1965). This is a surprise considering the adult of *X. brunneopicta* has been considered to be closely related to them (Lafontaine et al. 1998). The larva of *X. fabulosa* is similar to that of *X. gelida* and therefore we supposed that the larva of *X. brunneopicta* could resemble this species as well. Ahola and Silvonen (2011) described larvae close to *X. gelida* as possible *X. brunneopicta* from Kuusamo and Kuhmo in Finland. These three larvae differ from *X. gelida* in having a paler dorsal zone, shorter visible part of the middorsal line, the subdorsal line is broken into flecks, has a narrower black dorsal margin of subdorsal line, is not enlarged on Ab7–8 and has a wider white dorsal part of the spiracular line. Also, setal positions are slightly different, and SD1 is more distant from the spiracles. However, we now rather see these differences as variation in *X. gelida.*

Many Noctuidae have green larvae. For example, in Europe there are more than 140 species with such larvae. Larvae with green bodies and narrow white dorsal and subdorsal lines are not so common, but still about 40 species have such larvae. However, a quarter of them can occur in the same northern areas with *X. brunneopicta*. In Finland larvae of *Orthosia gothica* (Linnaeus, 1758) and *O. incerta* (Hufnagel, 1766) resemble those of *X. brunneopicta*. The brown head and position of the spiracles above the spiracular line on Ab7 separates *X. brunneopicta* readily from *Orthosia* species. *Xestia* includes also two European species with green larvae, namely *X. ochreago* (Hübner, 1790) and some variations of *X. castanea* (Esper, 1798). They have, however, short dorsal setae, and the head is green.

DNA barcodes of *X. brunneopicta* differ from those of *X. gelida* and *X. fabulosa* by a minimum of 6.47% and 6.73% genetic distance, respectively (Marko Mutanen, pers. comm.), also suggesting that *X. brunneopicta* is perhaps not a very close relative of these species. Based on the COI sequences from one Finnish and one Russian specimen of *X. brunneopicta*, the closest relatives of *X. brunneopicta* are *X. lorezi* (4.44%), *X. sincera* (4.60%) and *X. ursae* (McDunnough, 1940) (4.61%), but many other *Xestia* species show less than 6% divergence as well. Based on DNA barcodes, no other *Xestia* species is a very close relative of *X. brunneopicta*, and based on both larval morphology and DNA barcodes, its sister species remains unclear.

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In Memoriam: Niels Peder Kristensen (1943–2014)

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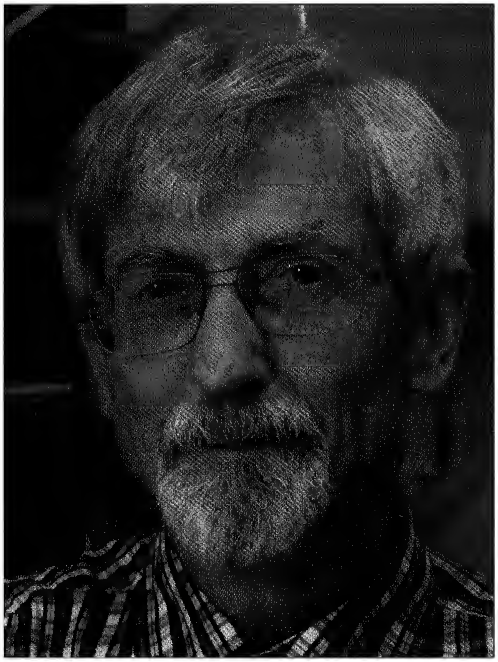

Figure 1. Niels Peder Kristensen, March 2nd 1943 – December 6th 2014 (photo: Birgit Nielsen).

Niels Peder Kristensen, Honorary Member and former president of SEL, passed away on Saturday December 6th 2014 in Copenhagen. While his death was not unexpected, its timing came earlier than we had thought or hoped. His loss is felt widely and intensely.

Born on March 2nd 1943, Niels was the second child of Thorkil and Ellen Christine Kristensen (nee Nielsen). His father was an academic, politician and thinker who served as Minster of Finance in two different government cabinets, and later as General Secretary of the OECD. Growing up in such an environment undoubtedly had a profound influence on Niels' own world view, one which was powerfully international in its expression, yet retaining a strong interest and deep concern for Danish issues – local and national.

Niels developed an interest in entomology and lepidopterology in particular at an early age, and once told TJS about the first time, when eight years old, he visited the Entomology Department at the Zoological Museum in Copenhagen (ZMUC) 'clutching his father's hand'. After completing high school at Birkerød Statsskole in 1961, Niels enrolled as a biology student at the University of Copenhagen, and quickly became a regular visitor to the Entomology Department of the Museum, where he had already started as a volunteer during his last years at high school. In 1965, while still a student, he published his first paper, which was on the faunistics of Danish cicadas. From the very start of his scientific career, one of Niels' abiding interests was the evolution (particularly evolutionary morphology) of primitive Lepidoptera. Indeed, the work for his Mag. Scient. degree was on the comparative morphology of the primitive glossatan family, Eriocraniidae. During this study, Niels spent the academic year 1966–67 at the University of Bristol, working with the eminent and extremely knowledgeable British entomologist Howard E. Hinton, who was at that time pioneering the use of scanning electron microscopy in entomology. It was while working with Hinton that Niels came to appreciate the value of SEM in comparative morphology. Through it, he made the surprising discovery (published in 1970) that the most primitive Lepidoptera have flat, solid wing scales (i.e. lacking an internal lumen), a condition contrasting strongly with the hollow wing scales generally found in Lepidoptera.

After obtaining his Mag. Scient. degree in 1968, Niels was offered a tenure-track position at the ZMUC as *Amanuensis* (Assistant Professor). He was promoted to Associate Professor in 1972 and appointed as Full Professor of Entomology in 1995. In 1970, Niels visited one of Europe's foremost comparative invertebrate morphologists, Jean Chaudonneret, at the Université de Dijon where he enhanced considerably his skills in insect histology and semi-thin sectioning. Working with Hinton, Chaudonneret and Karl G. Wingstrand, the professor of comparative morphology at the University of Copenhagen, unquestionably had a profound influence on Niels' development as a scientist. He often referred to the effect these three mentors had on his career. Niels was also deeply interested in the analytical methods used in evolutionary research. Together with fellow entomologist Nils Møller Andersen and the palaeontologist Niels Bonde, he was a pioneer in Denmark, and more widely in Scandinavia, of Hennig's phylogenetic systematics, and his cladistic analyses of the higher-level relationships of butterflies in 1976 remained the standard work on the subject until the study by de Jong et al. (1996) 20 years later.

From the very start of his career, Niels was deeply interested in the morphology and phylogeny of the higher insects. In 1975 he published (Z. zool. Syst. Evolut.-forsch. 13, pp. 1–44) one of his most influential papers: "The phylogeny of hexapod 'orders'. A critical review of recent accounts". Thirty years later, Grimaldi and Engel (2005, p. 144) referred to this work as "perhaps the single most important paper in systematic entomology". This publication formed the basis of his five updated reviews of the subject. The last of these was published in Eur. J. Ent. in 1999, while perhaps the most notable of them is the 1991 text-book chapter "Phylogeny of extant hexapods" in "The Insects of Australia", which should be mandatory reading for all students of systematic entomology. Over the years Niels authored or co-authored a number of papers on higher Hexapod relationships especially on the lower Hexapod orders, Trichoptera, the enigmatic New Zealand mecopteran family Nannochoristidae, Neuroptera, and of course Mantophasmatodea—the first new insect order to be described for 90 years, the description of which he co-authored in 2004.

It was, however, the Lepidoptera that remained Niels' main interest, and the majority of his publications are on that order. They range in scope from nomenclatural and faunistic notes to higher-level phylogenetics and to the exceptionally detailed, comparative morphological studies of primitive Lepidoptera. More than anything else, these exquisite studies became his professional hallmark. His early enthusiasm for scanning electron microscopy and histology were combined with transmission electron microscopy and became methodological cornerstones in his work throughout his working life. Much of his productivity, particularly in the first half of his career, led to highly detailed studies of little-understood structures and organ systems of primitive Lepidoptera, including overall head and neck anatomy, mouthpart morphology, anatomy of the alimentary canal, structure of the trachaea system, comparative morphology and anatomy of male and female genitalia, and wing scales and vestiture. Niels' work on primitive Lepidoptera morphology and anatomy was always embedded in the context of higher Lepidoptera evolution, and his ultimate goal was to establish the early evolutionary patterns within the order, thereby creating a sound basis for further studies higher up the lepidopteran tree. In 1978 and 1979 he also described two new families of primitive Lepidoptera, the basal hepialoid family

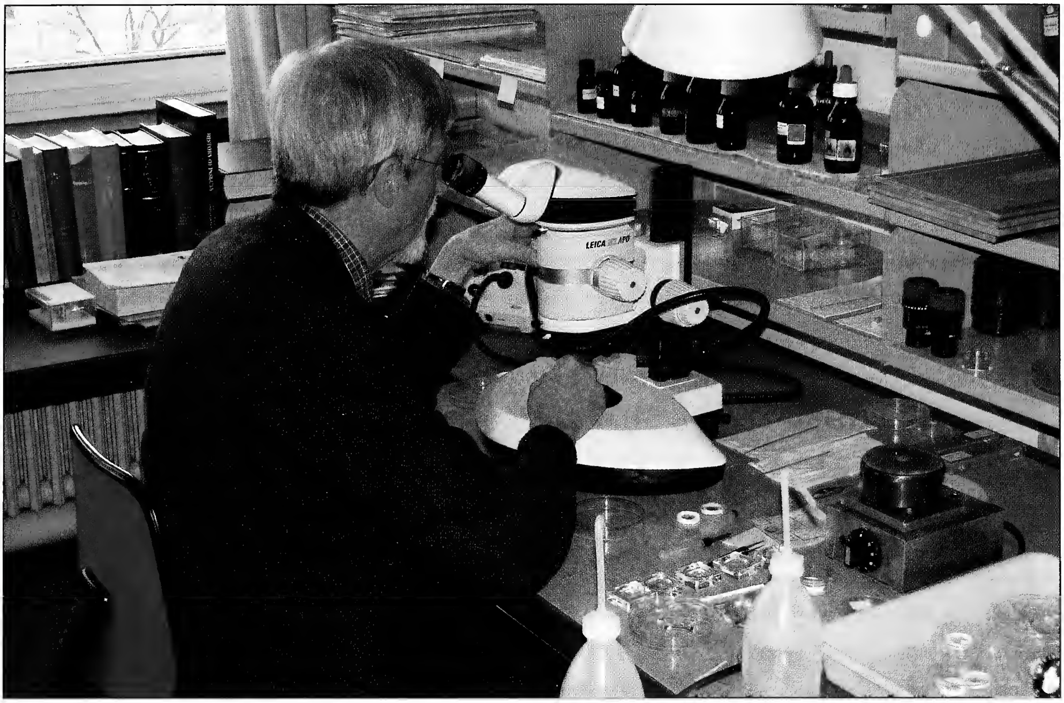

Figure 2. Niels studying his beloved homoneuran Lepidoptera (photo: TJS).

Neotheoridae and the non-ditrysian family Heterobathmiidae (the latter in collaboration with the late Ebbe S. Nielsen). His work on primitive Lepidoptera phylogeny and comparative morphology culminated in his Dr Scient. dissertation "Studies on the morphology and systematics of primitive Lepidoptera" published in Steenstrupia in 1984. Until the modifications introduced by the very recent advent of phylogenomic studies and especially the surprising discovery of a new primitive moth family from Australia, this remained the standard work on the evolution of the homoneurous Lepidoptera.

In the early 1990s Niels was appointed the editor-in-chief of the two Lepidoptera volumes of the Handbook of Zoology. This immense undertaking was to dominate his professional life for the following decade. The two volumes, which were published in 1998 and 2003, defined the latter part of his career as much as his work on higher Hexapod phylogeny and comparative Lepidoptera morphology had shaped his early and mid career, although he continued his work on these topics until illness forced him to stop just weeks before his death. Niels had anticipated writing or co-authoring a substantive part of the first volume. He did not, however, expect to have made a similar input to the second volume, which was on morphology and physiology. Having to do so resulted in a much greater effort on his part than he had intended: moreover, it required him to write about subjects on which he did not consider himself an expert. The result, nevertheless, stands as a landmark publication and a tribute to Niels' capacity and breadth of knowledge. The Handbook would have been more than enough of a mega-project for most of us, so it is remarkable that Niels also spent much time and effort during his last years editing a book on the insects of Greenland instead of completing some of his own research projects. While he certainly believed in the value of the Greenland work, his resolve was propelled by that innate sense of responsibility and conscientiousness that were so evident in his personal makeup.

After the mammoth task of completing the Handbook, Niels returned to his work on primitive Lepidoptera — at least as much as his administrative duties permitted. At the time of his death, he was involved in long-term studies of several groups: Micropterigidae with G. W. Gibbs and D. L. Lees; Mnesarchaeidae with G. W. Gibbs; Hepialoidea with TJS. A phylogenomic study of the non-ditrysian lineages (part of the LepTree project), of which he was a senior co-author, was submitted just weeks after his death (and was dedicated to him). But his most significant contribution in the last stage of his career was the discovery and description of an extraordinary homoneuran family from Kangaroo Island, Australia (the so-called Kangaroo Island Moth, or KIM) and its significance for modifying our understanding of early Lepidoptera evolution. The paper was, to his great pleasure, accepted for publication before his death.

Besides being a leading research scientist, Niels was a highly engaging and inspiring teacher and supervisor. Early in his career, he wrote, in Danish, a detailed yet concise compendium of systematic entomology ("Systematisk Entomologi" 1974), which for years was the standard textbook on the subject at the University of Copenhagen. For over two decades he was a driving force behind an advanced course in systematic entomology and insect morphology, which was taught biennially at the University. Niels' lectures displayed not only the depth of his learning, but were rich in subtle humour, a quality of which he was a master. TJS recalls a particular entomology lecture (in 1996) in which Niels was explaining the morphology of the thorax, including flight mechanisms. To ensure that the students understood the complex ways in which insects move their wings to minimize drag, he demonstrated by lying face down on a table, still clad in jacket and tie and with his feet sticking out, waiving his arms in the air! While this performance was not characteristic of most university professors, it worked — TJS resolved there and then to do his graduate studies under Niels' supervision.

Throughout his career, Niels supervised several Masters and PhD students and postdoctoral fellows. He took a deep interest in their well-being, both professional and personal, and derived immense pleasure from their subsequent successes while keeping in close contact with them after they graduated. (After graduating and moving away from Copenhagen, TJS spent numerous hours on the phone with Niels discussing his own work, Niels' work, the world in general and entomology in particular.) It was therefore also with great sadness and regret that he found himself writing obituaries for two of his most talented PhD students, the coleopterist Michael Hansen and the lepidopterist Ebbe S. Nielsen, both of whom died prematurely in the year 2000. Niels considered the more sociological aspects of entomology and lepidopterology to be integral parts of the (informal) training of a student. TJS recalls numerous meetings with Niels, intended to be brief, but often extending to a couple of hours, and invariably covering a wide range of aspects such as the history of science, the works (present and past) of other entomologists, anecdotes, amateur entomology, entomology and society. One of Niels' great qualities as a supervisor was that hallmark of all top supervisors — he had an intuitive understanding of the level and extent of supervision needed to fit the individual student, endeavouring always to bring out the best in him or her.

Niels started collecting butterflies and moths as a schoolboy, and although he never built up a large collection, this activity influenced his choice to become a biologist and a specialist in Lepidoptera. At that time there was no tradition for lepidopterology at the ZMUC, and Niels was the first academically trained lepidopterist at the museum — despite being advised by the head of the entomology department at that time, S. L. Tuxen, to find a more *scientific* group! Later he often defended collecting Lepidoptera, arguing that is an important way to get young people interested in entomology.

Niels appreciated deeply (serious) amateur lepidopterists, being well aware that major parts of the Lepidoptera collections in larger museums had been collected by them. He valued their efforts, spoke positively and warmly about them and did much to help them, for example through his work for societies with large amateur memberships, by advising on scientific matters and in providing help to get collecting permits.

While Niels enjoyed experiencing Lepidoptera and other insects in nature, and he would often run a mercury vapour light at his summer cottage, he was not primarily a field worker. He felt, and indeed demonstrated, that he could serve the study of Lepidoptera best by focusing his exceptional skills on the study of key taxa at the museum bench.

Besides his research and teaching, Niels shouldered a substantial administrative burden at the ZMUC, at which he spent his entire career. This included several stints as Chair or Deputy Chair of the Entomology Department, two periods as Deputy Director of the museum, and three years as Director. He was also Head of Zoology at the newly designated Natural History Museum of Denmark from 2004–2006. Although his heart remained in his research, he carried out these time-consuming administrative responsibilities conscientiously and with a great sense of love and concern for the museum.

Throughout his career, Niels was deeply involved in entomological and lepidopterological societies. He was President of the Danish Entomological Society from 1989 to 1999, Council member of the International Congress of Entomology from 1988 to 2004 (Deputy Chair 2000–2004), and of course President of the SEL from 1998 to 2007, and Chair of the SEL congress in Korsør, Denmark in 2002. One of Niels' long-standing ambitions was to hold a joint European-North American Lepidoptera Congress. Although this did not take place during his own tenure as President, he was very pleased to see the first joint meeting of the Lepidopterists' Society and SEL in Denver, Colorado in 2012 (even if he could not attend the meeting himself).

During his career, Niels received many honours and awards, a testimony to his achievements and pre-eminence in his field. He was a member of the Danish Academy of Natural Sciences, a member of the Royal Danish Academy of Sciences and Letters, a corresponding member of the Finnish Entomological Society, an honorary 'Foreign member' of the Linnean Society of London (1998), an honorary member of Sociedad Hispano-Luso-Americana de Lepidopterologia (SHILAP), an honorary member of the Danish Entomological Society, an honorary research fellow at the Natural History Museum, London, an honorary member of Gesellschaft für Biologische Systematik, an honorary member of Societas Europaea Lepidopterologica, an honorary fellow of the Royal Entomological Society, and an honorary member of the Russian Entomological Society. In 1988 he was awarded the 'Karl Jordan Medal' (Lepidopterists' Society) for "outstanding original research in lepidopterology", in 1999 he received the Joachim Jungius-Medaille (J.J.Gesellschaft der Wissenschaften, Hamburg) for "herausragender Leistungen in Wissenschaft und Forschung", and in 2014 shortly before his death he gained the 2014 Linnean Medal (Zoology).

Niels cared deeply about the future of European entomology and lepidopterology and was dismayed by the progressive decline of staff numbers and funds at several major research institutions (including his own in Denmark). He believed firmly in the need for basic research, and that in publicly funded institutions such as museums it should be possible for researchers to focus on academically interesting questions that do not necessarily have immediately obvious economic, social or medical benefits.

Unsurprisingly, Niels' standing, awareness and understanding of wider socio-political issues in science led to him being asked to act as Director of the ZMUC. While he had an interest in university politics and administration, his real love was for his research, but he accepted the position (doing two terms of service) partly from a sense of duty, and partly because he felt that the position should be held by an acknowledged researcher rather than a mandarin. Having high ethical standards, Niels rarely sought the easiest solution to any problem, but rather the one that he thought to be right. He was a conscientious leader, made great efforts to keep abreast of relevant matters and always made time for his colleagues, whatever their level in the organization. He undoubtedly suffered during his extended directorship, both as a result of these personal qualities and through the loss of most of his time for research. Alas, he had to endure more frustration due to seemingly endless cuts to the museum's funds. But when the Ministry of Education and Research ordered cuts of several positions at the museum, he felt he could no longer accept the responsibility for running the institution and stepped down in protest.

Niels was critical of the plans for a new natural history museum in Copenhagen, which would have resulted in newer but reduced facilities. He was particularly disturbed about the idea of demolishing the ZMUC building, which had been purpose built and which he considered to be still fit for purpose. During his later years he spoke and wrote against the idea, and was disappointed that the management of the Natural History Museum of Denmark, and many of his colleagues, did not agree with him. He also expressed concern about the appointment at the museum of scientists with little experience of collections-based research.

At the time of his death, Niels had settled into a productive retirement: relieved of administrative responsibilities, it was a phase of his life that he was enjoying thoroughly. So it is heart-breaking that he missed the prolonged and active retirement he would have found so fulfilling. Moreover, it leaves the scientific community bereft of the many works that would surely have been produced by him. The entomological world has become a much poorer place without Niels' profound knowledge and insight, his generosity of spirit, his conscientiousness and his quiet humour. For all these qualities he is and will continue to be missed deeply. He was also a loving family man and our deepest condolences are extended to his wife Else and their daughters.

HAVAMAL (Our translation)
Livestock die
Kinsman dies
We all die just the same
Only one thing I know which never dies
The judgment of a dead man's life.

HAVAMAL (Danish)
Fæ dør
Frænde dør
Dør selv på samme vis
Kun et ved jeg som aldrig dør
Dommen over død mands liv

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Book Review: Die Widderchen des Iran [The burnet moths of Iran]

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T. Keil 2014: Die Widderchen des Iran. 17. Beiheft der Entomologischen Nachrichten und Berichte. 461 pp. ISSN: 0232-55535. Price: €238.

The first research on the zygaenid fauna of Iran goes back to the first half of the 19th century with the description of the two taxa, *Zygaena cuvieri* Boisduval (1828) and *Z. haematina* Kollar, 1849. Only a short time later new material came to Europe which had been collected by Joseph Haberhauer and Hugo Christoph under partly very adventurous circumstances during their expeditions to Iran. This led to the description of another five taxa. Just before the Second World War, Fred Brandt brought spectacular material to Europe. He had travelled alone in 1936 through the northern Iran (Elburz, Kuh-e Binaloud) and in 1937 and 1938 to then hitherto unknown regions of southern and eastern Iran as far as the Afghan and Pakistan borders where he collected exceptional material that included many new species. Although the interest in the zygaenid fauna of Iran increased after the Second World War and also the habitats and the biology and ecology of some species were described, it was not until about 20 years ago that a new area of research on the Iranian Zygaenidae began. Axel Hofmann, Bernard Mollet, Clas Naumann, Gerhard Tarmann, W. Gerald Tremewan and Thomas Keil are the most important contributors to this new development of research. Thomas Keil visited Iran alone more than 30 times during the last 17 years. Consequently, the number of relevant publications increased significantly. Most papers were published in various journals. Except for contributions by Axel Hofmann and W. Gerald Tremewan as well as the papers by Mohmoud Karami, Clas Naumann and W. Gerald Tremewan on the genus *Zygaena* Fabricius, 1775, there was no comprehensive work available, especially not for the subfamily Procridinae. This gap has now been closed by Thomas Keil's book "Die Widderchen des Iran".

This book is impressive by its size alone and by its generously designed binding in a linen hard cover. That the text is published in two languages is not a great novelty. However, that the German text is completely translated into Farsi by Maryam and Hossein Rajaei and that also the book is published completely in Roman letters (German text) and in Farsi calligraphy (Iranian text) is exceptional. It is an acknowledgement to the hospitality of Iran's people and shows respect to Iran's environment. Moreover, Iranian scientists can now rely on a profound standard work on Zygaenidae which documents in an impressive way the diversity and unique status of the Iranian zygaenid fauna. It is to be hoped that this work will influence future decisions on preserving the environment of Iran.

The book begins with a general part that contains information about the geography of Iran, its climate and its biotopes. This is followed by an attempt to associate the different Zygaenidae species to faunistic subunits, followed by comments on endangered taxa and a list of the terminology of morphological characters mentioned in the book. In an annotated list of species, 25 Procridinae

(22 of them confirmed for Iran) and 42 Zygaenidae (41 of them confirmed for Iran) are mentioned. The remaining four species (not yet confirmed for Iran) can be found most probably also in Iran based on the present knowledge of their distribution. Not only the high number of taxa but also the high number of 30 endemic species shows the exceptional character of Iran's zygaenid fauna.

In the systematic part 67 species are mentioned. The text is presented in a concise form and gives information about the distribution of each species (global and in Iran), the morphology (descriptions of imagines and early stages), and the ecology (habitats, larval host-plants, habits). The text is accompanied by colour plates of aesthetically superb quality which also include the imagines as for the early stages (in most cases). Some of the larvae are figured several times in different instars and colour variations. The selected format of the images with 8.5 × 12.5 cm allows the recognition of even the smallest details. Some of the magnifications in large format are exceptional, e.g. *Zygaenoprocris* (*Keilia*) *minna* (Efetov, 1991) on p. 105, *Zygaena* (*Mesembrynus*) *nocturna nocturna* Ebert, 1974, on p. 161. The author of this review had the opportunity to collaborate in the ongoing Swiss book series 'Schmetterlinge und ihre Lebensräume'. He therefore knows very well what an enormous amount of work with lots of associated frustration is required to produce such a documentation of pre-imaginal stages, especially of the Zygaenidae. This group has especially complicated diapause rhythms that are a real challenge for anyone who tries to rear species from egg to imago. It is amazing to note how great Thomas Keil's tolerance against such frustrations must have been to be able to achieve such an impressive result.

The following chapter is devoted to the genitalia structures. These are essential especially for the identification of the Procridinae. The genitalia of males and females are figured in black and white photography. The size of the figures is well chosen and allows recognition of the relevant characters clearly. Only in a few cases in the male genitalia (e.g. *Zygaenoprocris rjabovi* (Alberti, 1928) on p. 340 and *Z. khorassana* (Alberti, 1939) on p. 341) will the reader have some difficulties to recognise the form of the cornuti on the vesica in the phallus. The main reason for this seems to be the fact that the sclerotisation of the phallus is of very different intensity. Perhaps in such cases line drawings could have given a better result. The female genitalia are well recognisable. However, in some cases it could have helped to figure them in different views (dorsal, lateral, ventral).

Another highlight of this book are the aquarelle paintings produced by Anja Spindler. These are of superb quality and can be compared with those of František Gregor (e.g. in Tarmann, G. M., Zygaenid Moths of Australia) or Peter Wymann (e.g. in Lepidopteren-Arbeitsgruppe, Schmetterlinge und ihre Lebensräume, vols 1–3). The work contains 31 colour plates with these paintings illustrating 186 specimens that are reproduced three times their natural size. This allows an impressive overview and is an aesthetic highlight.

The next chapter deals with the distribution. For 66 species distribution maps are provided. The localities are listed under 'Verbreitung im Iran' with the treatment of the respective species in the systematic part.

Under the headline 'Nahrungspflanzen der Raupen' there follows on 16 colour plates that are a compendium of larval host-plants. The whole of the information is based on personal research by Thomas Keil. We can see that although many larval host-plants can be already identified to species level there is still a significant number left where only the genus is known. There is still a lot research to do. This chapter is followed by a comprehensive picture gallery of Iranian habitats for zygaenids. It is almost a dream for a European entomologist to see these exceptional habitats in Iran.

Last but not least an extensive list of literature and the contents list are provided. Moreover, a summary of Thomas Keil's scientific activities that were often accompanied by his wife Christine Keil provides the book with a nice ending.

Some small recommendations for additions should a second edition ever be published are: mention the sexual dimorphism in some species; introduce a paragraph dealing with 'similar species' for easier identification; give chorological data; explain genitalia characters for a differential diagnosis (especially for Procridinae).

This work is the result of extraordinary dedication and is a milestone in Zygaenidology. It will be a solid base for any future research.

(Translated from German by Gerhard Tarmann.)

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