

The distribution, ecology and conservation status of the Spinose Skipper *Muschampia cribrellum* (Eversmann, 1841) at the western limit of its range in Europe (Hesperiidae)

VLAD DINCĂ¹, ZDRAVKO KOLEV² & RUDI VEROVNIK³

¹ Departament de Genètica i Microbiologia, Universitat Autònoma de Barcelona, Bellaterra, Spain; sudistu@yahoo.com

² Division of Entomology, Finnish Museum of Natural History, FIN-00014 Helsinki, Finland; zkolev72@gmail.com

³ University of Ljubljana, Biotechnical Faculty, Department of Biology, Večna pot 111, 1000 Ljubljana, Slovenia; rudi.verovnik@bf.uni-lj.si

Abstract. Based both on published and original data, we provide an overview on the distribution, ecology and conservation status of *Muschampia cribrellum* (Eversmann, 1841) at the western limit of its range. We report the presence of the species in four countries (Romania, Bulgaria, Republic of Macedonia and Serbia) with a total of 28 confirmed sites out of which 11 are mentioned here for the first time. The presence of *M. cribrellum* in Hungary is questioned due to lack of relevant material. We discuss the past, current and potential distribution of *M. cribrellum* in each of the countries involved. Special attention is given to ecological and conservation aspects by discussing key factors (behaviour, phenology, habitat requirements and preimaginal stages) involved in the species distribution, dynamics and survival.

Résumé. Basé sur des données publiées et inédites, nous fournissons une synthèse concernant la distribution, l'écologie et l'état de conservation de *Muschampia cribrellum* (Eversmann, 1841) aux limites occidentales de sa répartition. Nous rapportons la présence de l'espèce de quatre pays (Roumanie, Bulgarie, République de Macédoine et Serbie) avec au total 28 localités confirmées dont 11 sont mentionnées ici pour la première fois. La présence de *M. cribrellum* en Hongrie est douteuse étant donné l'absence de matériel concret. Nous traitons la distribution historique, actuelle et potentielle de *M. cribrellum* dans les pays impliqués. Une attention particulière est accordée à l'écologie et à l'état de conservation, en discutant des facteurs clés (comportement, phénologie, exigences de l'habitat et états pré imaginaires) impliqués dans la répartition, la dynamique et la survie de l'espèce.

Zusammenfassung. Auf Grundlage bereits publizierter sowie originaler Daten wird ein Überblick über die Verbreitung, die Ökologie und den Schutzstatus von *Muschampia cribrellum* (Eversmann, 1841) für das westliche Verbreitungsareal gegeben. Wir bestätigen das Vorkommen der Art für vier Länder (Rumänien, Bulgarien, Mazedonien und Serbien) mit insgesamt 28 Vorkommen, wovon 11 zum ersten publiziert werden. Die Anwesenheit von *M. cribrellum* in Ungarn ist mangels relevanten Materials fraglich. Wir diskutieren die historische, rezente und zukünftige Verbreitung von *M. cribrellum* für die in diese Studie einbezogenen Länder. Durch die vertiefte Diskussion über Schlüsselfaktoren (wie Verhalten, Phänologie, Habitatansprüche und Präimaginalstadien) werden besonders ökologische wie auch Naturschutzaspekte berücksichtigt, die entscheidend für die Verbreitung, Dynamik und das Überleben dieser Art sind.

Introduction

The Spinose Skipper *Muschampia cribrellum* (Eversmann, 1841) is one of the rarest and least known skippers in Europe west of the former Soviet Union. It was described from the “South Ural and the Volga Basin” at the easternmost limit of Europe. The species range extends over a large area roughly covering south-eastern and eastern Europe, then extending eastwards across southern Siberia, Amur region, Mongolia and northern China (Gorbunov 2001, Tshikolovets 2003, 2005, Tolman & Lewington 1997, 2008).

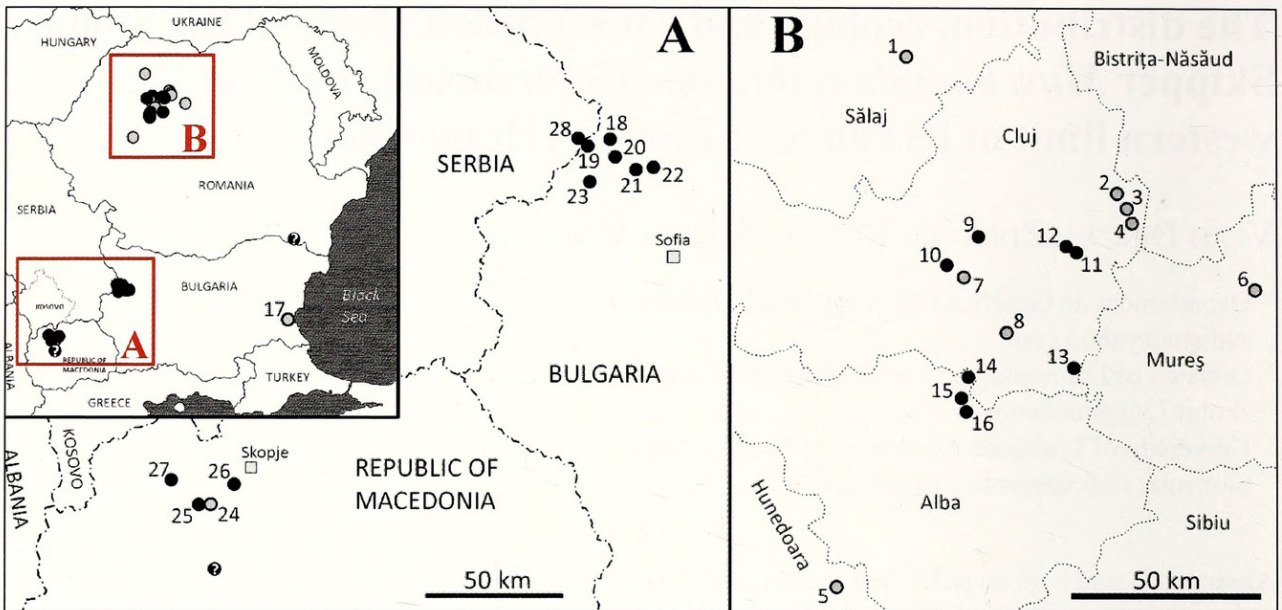


Fig. 1. Inset: general distribution of *M. cribrellum* at the western limit of its range in Europe. **A.** Recorded sites in the central Balkans. **B.** Recorded sites in Transylvania (Romania). The numbers refer to the localities from Tab. 1. Grey-filled circles – records prior to 1990; Black dots – records beginning with 1990; ? – Records requiring confirmation. Map by Z. Kolev.

However, considering the western limit of its distribution, the species is poorly known and localized, being reported from a handful of sites in only four countries: Romania (Rothschild 1912; Rákossy & Goia 1997; Rákossy 2000; Kovács et al. 2001, 2002; Rákossy et al. 2003; Goia & Dincă 2008; Székely 2008), the Republic of Macedonia (Lorković 1983; Jakšić 1988, 1998; Schaidler & Jakšić 1989), Bulgaria (Kolev 2003; Abadjiev & Beshkov 2007) and Hungary (Higgins 1975; Tolman & Lewington 1997, 2008; Tolman 2001; Tshikolovets 2003, 2005; Lafranchis 2004; Nekrutenko & Tshikolovets 2005). New data provided in this paper reveal the presence of *M. cribrellum* in a fifth country, namely Serbia (Fig. 1). The presence of the species in Hungary is questioned given the lack of recent reliable data.

In addition to the scarcity of European records, only limited and scattered information is available on the habitat requirements of the species which is generally known to be associated with steppes, dry meadows on mountain slopes or screes (e.g. Korshunov & Gorbunov 1995; Rákossy & Goia 1997; Gorbunov 2001; Tshikolovets 2003, 2005). Detailed data on the biology of *M. cribrellum* is even scarcer and of questionable reliability (especially for Europe). Despite its fragmented and highly restricted range at the western limit of the distribution, the species is not considered threatened in Europe (van Swaay & Warren 1999) due to its predominantly Asian distribution and reported stable population sizes in Russia.

Given the facts presented above, the overall information on *M. cribrellum* at the western limit of its distribution is sporadic and often of unknown reliability. Therefore, our aim is to collate all available published and recent unpublished data on the distribution, ecology and conservation status of the Spinose Skipper in the area west of the former Soviet Union. This will hopefully stimulate further research on this very local and poorly known species and facilitate its legal protection in the countries concerned.



Fig. 2. The botanical reserve Fânațele Clujului (Transylvania, Romania, ca. 500 m, 1.vi.2006) hosts almost 100 butterfly species among which *M. cribrellum*. Photo V. Dincă.

Distribution of *M. cribrellum* at the western range limit in Europe

West of the Black Sea, *M. cribrellum* has been reported from four countries: Romania, Bulgaria, Republic of Macedonia, and Hungary. The presence of the species in Serbia has not been mentioned previously and is reported here for the first time. Rákossy & Goia (1997) mentioned *M. cribrellum* from Greece too, but the paper does not provide additional data or relevant references and no other studies known to us support this statement. *M. cribrellum* was not listed among the Greek butterflies in the comprehensive work of Pamperis (1997) and, based on records from neighbouring countries, was only considered as potentially present in the northern and eastern borders of the country (Pamperis 2009).

Romania

The majority of the records of *M. cribrellum* at the western limit of its European distribution come from Romania. More precisely, all but one of the Romanian sites lie in Transylvania (Fig. 1B, Tab. 1). The species was first noted from Romania by Rothschild (1912) based on material collected by Karl Predota in 1911 from four localities in Cluj (Buza, Năsal, Feldioara) and Sălaj (Surduc) Counties. These records represented the first data proving the presence of *M. cribrellum* west of the former Soviet Union. Although there are no doubts regarding the accuracy of the identifications (the dorsal and ventral sides of one specimen are illustrated in Rothschild's paper), the species was never recorded again from any of these localities. Subsequently (1928–1931), the species was collected from the surroundings of Cluj-Napoca (Fânațele Clujului, Dealul



Fig. 3. The xeric terraces with steppe-like vegetation from Suatu (Transylvania, Romania, ca. 380 m, 8.vii.2006) represent an optimal habitat for *M. cribrellum*. Photo V. Dincă.

Sf. Pavel and Valea Popii) (Cluj County) (Popescu-Gorj 1964; Căpușe & Kovács 1987; Rákossy 1988), and also from Ardeu-cetate (Hunedoara County) (Popescu-Gorj 1964). Recent records confirmed the presence of *M. cribrellum* in the surroundings of Cluj-Napoca, mainly at Fânațele Clujului (Szabó 1982; Rákossy & Goia 1997; Rákossy & Lászlóffy 1997; Goia & Dincă 2008) (Fig. 2) and on Dealul Sf. Pavel (Goia & Dincă 2008). A new population of *M. cribrellum* was discovered in 1978 at Toldal (Mureș County) near Reghin city (Moldoveanu et al. 1980; Szábo 1982). Based on material collected during 1975–1989, Rákossy & Viehmann (1991) recorded *M. cribrellum* as rare from Cheile Tureni (calcareous gorges in Cluj County). One of the recently still occupied sites was discovered in 1980 at Suatu (Cluj County) (Rákossy & Goia 1997; Rákossy 2000; Dincă & Vila 2008) (Fig. 3). Additionally, *M. cribrellum* was reported as relatively common at Vișoara (Kovács et al. 2001, 2002), and one specimen was found at Căianu Mic (Cremene et al. 2003) (both localities in Cluj County).

The most recent, previously unpublished records of *M. cribrellum* come from the eastern part of the Western Carpathians, namely the area of Buru (Cluj County) – Rimetea (Alba County) – Colțești (Alba County) (Figs 1B, 4). The new sites and the corresponding observations are provided below:

- near the main road north to Rimetea, ca. 1 km before the entrance in the village, at the end of May 2005: two specimens were observed mud-puddling (A. L. Viborg pers. obs.);
- Colțești (ca. 1.5 km east of the village) at the end of May 2005: five specimens (C. J. Luckens pers. obs., A. L. Viborg pers. obs.);



Fig. 4. Several flowery meadows on calcareous ground surrounding the village of Rimetea (Transylvania, Romania, 500–650 m, 18.vii.2006) are suitable habitats for *M. cribrellum*. Photo V. Dincă.

- steep rocky slope ca. 2 km south of Buru at the end of May 2005: three specimens; ditto, the end of May 2008: eight to ten specimens (A. L. Viborg & T. Friis-Larsen, pers. obs.);
- the western outskirts of Rimetea in a flowery glade with sparse low trees on May 31.v.2009: one female (N. Greatorex-Davis leg. et coll., Z. Kolev det.).

The only Romanian record of *M. cribrellum* from outside Transylvania is a male collected on 31.v.1986 from Canaraua Fetei (Constanța County, southern Dobrogea) (Rákosy 2000). This record (Fig.1) might require confirmation, as *M. cribrellum* was not mentioned as present in Dobrogea in the subsequently published Romanian Lepidoptera Catalogue (Rákosy et al. 2003) and in the recent book on the butterflies of Romania (Székely 2008).

Bulgaria

The first record of *M. cribrellum* from Bulgaria was based on two males collected in 1974 around the city of Burgas on the Black Sea coast (Fig. 1), but regrettably more precise locality data are lacking (Kolev 2003). Chronologically the next, hitherto unpublished record consists of three specimens in excellent condition which bear locality labels “West Bulgarien, Umg[ebung]. Dragoman” [West Bulgaria, vicinity of Dragoman town] on 24.vi.1987 (1 male), 29.vi.1987 (1 female) and 15.vi.1989 (1 male) and are deposited in the collection of G. Kuna. The original collector, J. Leidenfrost, is deceased and it is thus not possible to obtain first-hand informa-

Tab. 1. The sites from where *M. cribrellum* has been recorded west of the former Soviet Union. The numbers correspond to those used in Fig. 1.

No.	Locality	Province	Alt. (m)	Lat N	Long E	Country
1	Surduc	Sălaj	200–300	47° 15'	23° 20'	Romania
2	Năsal	Cluj	300–400	46° 56'	24° 06'	Romania
3	Buza	Cluj	350–450	46° 54'	24° 08'	Romania
4	Feldioara	Cluj	350–450	46° 52'	24° 09'	Romania
5	Ardeu (cetate)	Hunedoara	400–450	46° 00'	23° 08'	Romania
6	Toldal	Mureș	400–500	46° 42'	24° 35'	Romania
7	Cluj-Napoca (valea Popii)	Cluj	400–500	46° 44'	23° 34'	Romania
8	Cheile Tureni	Cluj	450–500	46° 36'	23° 42'	Romania
9	Cluj-Napoca (Fânațele Clujului)	Cluj	500	46° 50'	23° 37'	Romania
10	Cluj-Napoca (dealul Sf. Pavel)	Cluj	450	46° 46'	23° 31'	Romania
11	Suatu	Cluj	350–450	46° 47'	23° 57'	Romania
12	Căianu Mic	Cluj	350–400	46° 48'	23° 56'	Romania
13	Viișoara	Cluj	330–430	46° 31'	23° 56'	Romania
14	2 km S of Buru	Cluj	400–450	46° 30'	23° 35'	Romania
15	W and N outskirts of Rimetea	Alba	500–650	46° 27'	23° 34'	Romania
16	1.5 km E of Colțești	Alba	600–650	46° 25'	23° 35'	Romania
?	Canaraua Fetei (Băneasa)	Constanța	20–100	44° 03'	27° 39'	Romania
17	Burgas	Burgas	5–100	42° 31'	27° 26'	Bulgaria
18	Gubesh	Sofia	1000–1300	43° 05'	23° 02'	Bulgaria
19	Golesh	Sofia	900	43° 04'	22° 56'	Bulgaria
20	NE of Godetch	Sofia	750	43° 01'	23° 04'	Bulgaria
21	W of Zavidovtsi	Sofia	700–800	42° 59'	23° 09'	Bulgaria
22	Iskretz	Sofia	550–650	42° 59'	23° 14'	Bulgaria
23	Chepán massif	Sofia	800–1100	42° 56'	22° 56'	Bulgaria
24	Nova Breznica	–	900	41° 53'	21° 16'	Macedonia
25	4 km W of Nova Breznica	–	1000	41° 53'	21° 13'	Macedonia
26	Mt. Vodno	–	950	41° 57'	21° 23'	Macedonia
27	Grupčín (28 km W of Skopje)	–	500	41° 58'	21° 07'	Macedonia
?	Treska Valley (near Gorna Belica)	–	500–1100	41° 41'	21° 15'	Macedonia
28	12 km NE of Dimitrovgrad	–	980	43° 05'	22° 54'	Serbia

tion about the precise locality (G. Kuna, pers. comm. to Z. Kolev), but it is almost certainly the imposing calcareous massif Chepán (highest point 1210 m). This is a southern branch of the Stara Planina mountain chain which rises just north-east of Dragoman town and forms a natural focus point for any collecting activity there. On a visit to Chepán on 7.vi.2007, Z. Kolev together with Stoyan Beshkov did not encounter the species, though note was taken of the extensive steppe-like rocky slopes with an unusual abundance of *Potentilla*. During a subsequent visit to the same place on 10–11.vi.2007, S. Beshkov and Boyan Tsvetkov collected a single female of *M. cribrellum* among numerous specimens of *Pyrgus carthami* (Hübner, 1813)

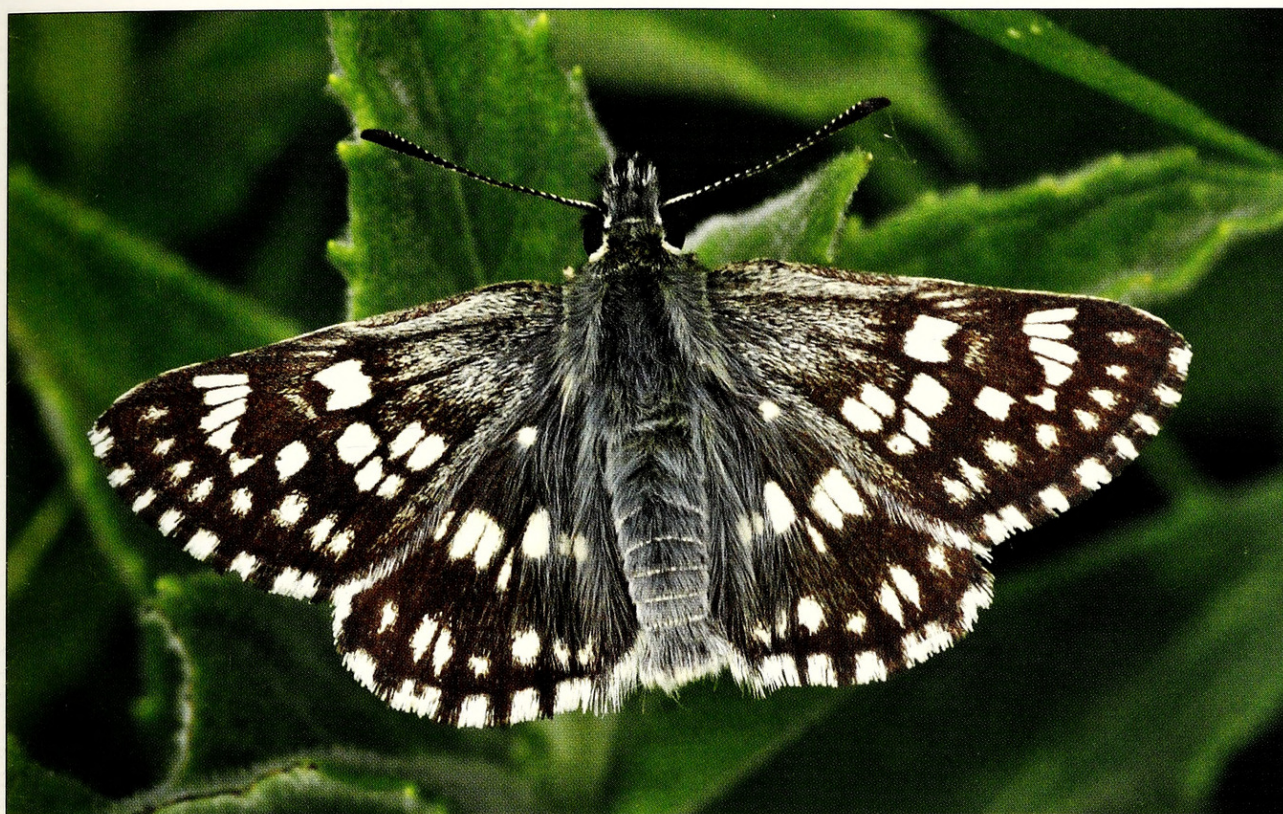


Fig. 5. A fresh *M. cribrellum* male perching on vegetation at a mud-puddling site near Gubesh village (western Bulgaria, ca. 1000 m), 10.vi.2009. Photo Z. Kolev.

(S. Beshkov, pers. comm. to Z. Kolev). This female is the basis for the brief mention of *M. cribrellum* from Chepán by Abadjiev & Beshkov (2007: 196). On 13.vi.2008, Z. Kolev and Nikolay Shtinkov visited this massif with the express purpose of finding *M. cribrellum*. The search was unsuccessful despite covering a wider habitat gradient ranging from the aforementioned exposed, dry south-facing slopes at higher altitude (900–1100 m) to moister gullies with lush vegetation at lower altitude (800–900 m). Another attempt to locate *M. cribrellum* on the Chepán massif in June 2008 also failed (M. Lindberg, pers. comm. to Z. Kolev). However, through purposeful search in 2008 and 2009, Markus Lindberg (pers. comm. to Z. Kolev) has discovered several other localities of *M. cribrellum* elsewhere in the region of western Stara Planina. Z. Kolev and N. Shtinkov were also able to locate one of these populations in 2009 (Fig. 5). The new localities and the respective numbers of specimens are as follows (Tab. 1, Fig. 1A):

- canyon above Golesh village, 26.v.2008: 4 males (M. Lindberg obs.);
- slopes north of Gubesh village, 27.v.2008: ca. 15 males (M. Lindberg obs.); ditto, 9.vi.2009: 18 males, 2 females (M. Lindberg obs.); ditto, 10.vi.2009: 13 males (Z. Kolev & N. Shtinkov obs., 9 males leg. & coll. Z. Kolev);
- river valley at the north-eastern edge of Godetch town, 29.v.2008: 1 male (M. Lindberg obs.);
- limestone quarry near Iskrets town, 11.vi.2009: 1 male (M. Lindberg obs.);
- valley of Iskrets River, west of Zavidovtsi village, 28.v.2008: 1 male (M. Lindberg obs.).

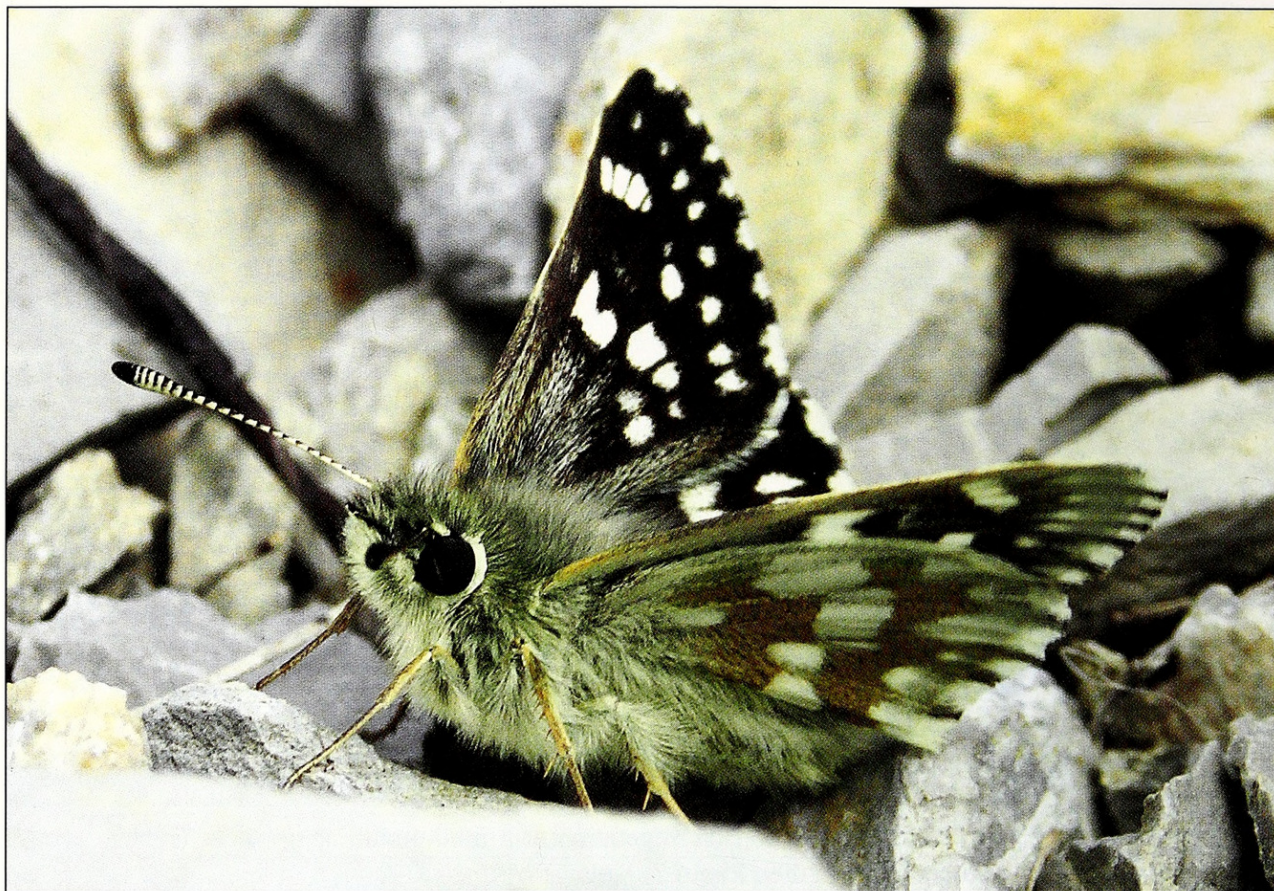


Fig. 6. A fresh male of *M. cribrellum* observed on a stony road NE of Dimitrovgrad (Serbia, 980 m, 17.v.2007). Photo C. van Swaay.

Serbia

There are no published records of *M. cribrellum* for Serbia. One male was observed and photographed in south-eastern Serbia (Fig. 6), mud puddling on the road north-east of Dimitrovgrad just 2 km from the Bulgarian border (Fig. 1A). The observation was made on 17.v.2007 by a group of lepidopterists working on the project Prime Butterfly Areas in Serbia, namely Predrag Jakšić, Milan Đurić, Ivan Dodok, Kars Veling and Chris van Swaay (van Swaay, pers. comm. to R. Verovnik). This discovery is to be expected in view of the recent records from western Bulgaria (Abadjiev & Beshkov 2007; see above), which come from a karstic region of western Stara Planina that extends across the border well into Serbia.

Republic of Macedonia

The Spinose Skipper was first reported for the Republic of Macedonia by Lorković (1983) based on his revision of the material collected by Slavoljub Jakonov. More than 10 fresh males were collected on the eastern slopes of Mt. Suva Planina near Nova Breznica village on 8.vi.1980. During a visit to the only confirmed site for the Republic of Macedonia in 2008, two males were found on the karstic plateau 4 km west of the known site (Fig. 7). Additionally, at least 3 specimens were observed on the southern slopes of Mt. Vodno approximately 15 km north-east of the previously mentioned localities (Verovnik & Micevski 2009). Another hitherto unpublished record is a fresh



Fig. 7. The xeric terrain with steppe like vegetation on the ridge east of Kozjak lake (Republic of Macedonia, 1050 m, 8.vi.2008) where a fresh male of *M. cribrellum* was observed. Photo K. Veling.

male collected by Peter Russell on 1.v.1990 near Grupčin village (ca. 28 km west of Skopje) (P. Russel, pers. comm. to R. Verovnik).

The distribution map of the species in the atlas of Schaider & Jakšić (1989) indicates a locality in the upper part of the Treska valley, in the vicinity of Gorna Belica village. The provenance of that record is still unknown as those authors did not record the species themselves, nor did they provide a reference. However, the record is plausible in view of the continuous karstic terrain encompassing it and the valid records further to the north.

Hungary

Several authors mentioned *M. cribrellum* for eastern Hungary (Higgins 1975; Tolman & Lewington 1997, 2008; Tolman 2001; Tshikolovets 2003, 2005; Lafranchis 2004; Nekrutenko & Tshikolovets 2005; Pljushtch et al. 2005) but evidence for this is wanting. The species is absent from the guide to the butterflies of the eastern part of Central Europe (Slamka 2004) as well as from the online list of butterflies of Hungary maintained by the Hungarian Lepidopterological Society (Tamás & Mihály 2009). The published checklist of the fauna of Hungary (Varga et al. 2005) mentioned that the records of *M. cribrellum* from this country “are only from the early XXth century”. We were informed by Zoltán Varga that these reports are most likely due to confusion with older records from western Romania, once part of the Austro-Hungarian Empire (Z. Varga,

pers. comm. to Z. Kolev and V. Dincă, 28.v.2009). A similar statement was made by Rákosy & Goia (1997).

Conclusions on distribution

By critically processing the available data on the distribution of *M. cribrellum* at the western limit of its range, we conclude that the species presence is currently confirmed in four countries: Romania, Bulgaria, Macedonia and Serbia (Fig. 1). A total of 28 confirmed sites were identified, of which 16 lie in Romania, seven in Bulgaria, four in the Republic of Macedonia and one in Serbia (Tab. 1). Two more reported sites require reconfirmation, namely Canaraua Fetei (Dobrogea, Romania) and the surroundings of Gorna Belica (Treska Valley, Republic of Macedonia).

More than half (16, representing 57%) of the currently known sites for *M. cribrellum* west of the former Soviet Union lie in Transylvania (Romania). However, only half of these sites have published records of *M. cribrellum* after 1990 (Tab. 1, Fig. 1B) with three of them being reported here for the first time. This may not necessarily be a consequence of local extinctions, but lack of recent research activities in most of the areas involved. Many of the sites represent “islands” of habitats with influences of the Pannonian steppes well known for their particular flora and fauna (e.g. Suatu, Căianu, Viișoara, Fânațele Clujului, Toldal) (Figs 2, 3), while others are characterized by the presence of a calcareous ground (e.g. Cheile Tureni, Rimetea, Colțești, Buru) (Fig. 4). Taking into account the record from south-eastern Romania (Canaraua Fetei), the habitat spectrum for *M. cribrellum* in this country may be even wider as Canaraua Fetei is a mixture of karst and Balkanic forest-steppe areas. Adding the very limited butterfly data available for many parts of Romania, it is difficult to evaluate the potential distribution of *M. cribrellum* in the country. However, all Romanian localities with old records of *M. cribrellum* could still hold populations of the species, so directed research is highly recommended. In addition, potential populations could be present in unaltered habitat patches with Pannonian steppe influences that still survive locally in central and western Transylvania. An example is the area between Cluj and Dej or Luduș and Târgu-Mureș (Rákosy & Goia 1997). The karstic area from the eastern part of the Western Carpathians (from where recent records are already available) is also promising. The calcareous area of Cheile Mada – Cheile Glodului near Ardeu (Hunedoara County) might provide new records of *M. cribrellum* given the fact that the species has been recorded from Ardeu almost a century ago. Several other calcareous areas similar to those from the Western Carpathians or from Ardeu are scattered in Transylvania and across the country, so there is high potential for the discovery of new populations. Moreover, if the record from south-eastern Romania (Canaraua Fetei) is accurate, then several sites in Dobrogea may have populations of *M. cribrellum* as the region as a whole has a pronounced steppe character and certain karst areas do occur (e.g. Cheile Dobrogei).

Currently, seven localities of *M. cribrellum* are known from Bulgaria. All but one of these lie in western Stara Planina, in what is the largest continuous region of open karst in the country. Based on present data it can be expected that the species is widespread

all over this karst area in Bulgaria and Serbia. Thus, in Bulgaria its range may extend eastward up to and including the gorge of Iskar River, although it is not yet recorded despite considerable collecting there (see Beshkov 2000 for an overview of literature). In Serbia the potential range of *M. cribrellum* is at least twice as large, as the same hilly calcareous region extends from the Bulgarian border westward all the way to the town of Niš (Z. Kolev, pers. obs. 10.viii.2009). In addition, two other areas in the same general region appear promising for *M. cribrellum*, due to their calcareous character and general appearance based on satellite imagery. The first is Mt. Suva Planina, a dry and steep karst mountain 20 km south-east from Niš (not to be confused with the similarly dry mountain in the Republic of Macedonia, where *M. cribrellum* does occur!). The second is a 85 km-long chain of largely karstic hills which starts 15 km south of Zaječar town in eastern Serbia and extends along the northern foothills of Stara Planina all the way to Montana town in western Bulgaria. These hills are very similar in geomorphologic terms to the region in Western Stara Planina where *M. cribrellum* is apparently widespread, and their butterfly fauna, with the exception of Suva Planina, is very poorly known (Jakšić 2003). Research specifically aimed at *M. cribrellum* would be thus highly desirable in all of these regions including Suva Planina, considering how easily the species may be overlooked even in its optimal habitats.

In the Republic of Macedonia, judging from the precisely known records and satellite imagery, the potential area where *M. cribrellum* may occur extends in an arc from Raduša village near the border with Kosovo and Mount Vodno just south of Skopje westward to Gostivar town and thence south to Brod and Debrešte villages. Further research in this lepidopterologically very rich region, including a verification of the record from the vicinity of Gorna Belica in Schaidler & Jakšić (1989), is desirable.

Behaviour and biology

Behaviour

The adults of *M. cribrellum* have a fast flight typical of a skipper, with the males often displaying territorial behaviour (V. Dincă pers. obs., Verovnik & Micevski 2009). The butterflies feed on various flowers, including *Potentilla* (Rosaceae), the reported larval host-plant (R. Verovnik pers. obs.). The males were also observed mud-puddling (Fig. 8). Among butterflies this activity is almost exclusively restricted to males (Boggs & Jackson 1991), and it has been shown that males of the Hesperiid *Thymelicus lineola* (Linnaeus, 1758) gather sodium dissolved in water at puddles and transfer it to females during mating. The proposed explanation for this phenomenon is that sodium is essential in egg production in quantities greater than the female can provide (Pivnick & McNeil 1987). Apparently, in *M. cribrellum* the need for sodium and possibly other dissolved nutrients can be exceptionally great, as witnessed by the observed local abundance of males at puddles versus their total absence from the adjacent probable breeding habitats (where both the females of the species and *Potentilla* are present) in western Bulgaria. For comparison, males of *Pyrgus carthami*, the most abundant skipper accompanying *M. cribrellum* in Western Bulgaria, are common both at puddles (Fig. 8) and on flowers



Fig. 8. Two *M. cribrellum* males (red arrows) mud-puddling together with a large group of *Pyrgus carthami* and single *P. sidae* and *P. alveus*, near Gubesh village (western Bulgaria, ca. 1000 m), 10.vi.2009. Photo Z. Kolev.

on the adjacent xeric slopes (Z. Kolev pers. obs.). This observation is in line with the observations of Pivnick & McNeil (1987), who found that while only males of *T. lineola* mud-puddled, they also comprised 75–80% of the surrounding population.

While the usual rarity of females of *M. cribrellum* presents a difficulty for the study of the exact habitat preferences and autecology, the strong attraction of the males to puddles should facilitate general faunistical research, as efforts to track down new populations can be concentrated in a relatively small area of the potentially suitable terrain.

Phenology. The available data indicate that in our focus region the butterfly is univoltine and its main flight period is in the second half of May and June. Some specimens, however, may already fly in the beginning of May (e.g. the fresh male collected in the Republic of Macedonia near Grupčin village on 1.v.1990) or as late as August. The two males from E Bulgaria (Burgas) are very fresh and their labels state the date of collecting as 10.viii.1974 (Kolev 2003). Whether this is an example of partial second generation or delayed emergence is unknown, but such late-flying specimens are also known from the main range of *M. cribrellum*. Korshunov & Gorbunov (1995) reported that the species is bivoltine (mid-May/August) in the Asian part of Russia while Korshunov (2002: 167) reported that the species flies from mid-May till mid-August.

Pre-imaginal biology

Hardly anything is known of this aspect of the life cycle of *M. cribrellum*. A claim widely repeated in literature is that the larvae feed on cinquefoils (*Potentilla* spp., Rosaceae)



Fig. 9. Habitat of *M. cribrellum* on the southern slope of Mt. Chepán (Bulgaria), ca. 1000 m, 13.vi.2008. Photo Z. Kolev.

(Higgins & Riley 1980; Chinery 1989; Korshunov & Gorbunov 1995; Gorbunov 2001; Korshunov 2002; Tshikolovets 2003; Nekrutenko & Tshikolovets 2005). Tolman & Lewington (1997, 2008) also reported *Potentilla* but added that this requires confirmation. We have to agree, since we have been unable to trace the provenance of this information or receive independent confirmation thereof. It must be kept in mind that all other *Muschampia* species for which the larval host-plant is reliably known, use *Phlomis* spp. (Lamiaceae) (Hesselbarth et al. 1995; Tolman & Lewington 1997, 2008; Tuzov et al. 1997; Wagner 2009). We only have circumstantial evidence in favour of the possible use of *Potentilla* as a larval host-plant, i.e. the occurrence of *M. cribrellum* on slopes with abundant *Potentilla* and no *Phlomis* both in our region (Z. Kolev & S. Beshkov pers. obs., R. Verovnik pers. obs.) and in Siberia for the subspecies *obscurior* Staudinger, 1892 (J. Kullberg pers. comm. to Z. Kolev). In addition, Szabó (1982) mentioned *Astragalus* sp. (Fabaceae) as a larval food-plant for Romanian *M. cribrellum*, but this assertion lacked further details or literature references, so that we strongly question its accuracy. Therefore, concerted research on the pre-imaginal biology of *M. cribrellum* is urgently needed.

Habitat requirements

In Romania, *M. cribrellum* occurs in relatively dry habitats with more or less pronounced (Pannonian) steppe character, such as hay meadows, grassland fallows and pastures (e.g. Suatu, Vișoara, Fânațele Clujului, Căianu Mic, Toldal) (Figs 2, 3), as



Fig. 10. Another aspect of the southern slope of Mt. Chepán (Bulgaria), ca. 950 m, 13.vi.2008. Pine plantations on the slopes in the background are marked with red arrows. Photo Z. Kolev.

well as in more or less xeric calcareous flowery meadows (e.g. Buru, Cheile Tureni, Rimetea, Colțești) (Fig. 4). In particular the first group of habitats is maintained at a suitable succession stage mostly through human intervention by extensive grazing and mowing. *M. cribrellum* flies at altitudes that usually range between 300 and 650 m, but the (uncertain) record from Canaraua Fetei is below 100 m.

In West Bulgaria, Serbia and Republic of Macedonia, *M. cribrellum* predominantly occurs in open grassy steppe-like habitats with diverse flowering vegetation on rocky, roughly south-facing calcareous slopes (Figs 7, 9, 10). While some of these habitats, e.g. parts of Mt. Chepán (Fig. 9), may be naturally open due to their steep incline and arid karst character, it is no exaggeration to say that considerable areas have been made suitable for *M. cribrellum* by human activities such as regular extensive grazing or deforestation. The males may leave the breeding habitat for nearby mud-puddling sites, in one case 200 m away (Z. Kolev pers. obs.). In the Balkan Peninsula, the butterfly has been recorded mostly from ca. 500 m to 1300 m, which is markedly higher than the Romanian range. In fact, the species may occur even higher, as the altitudinal range of continuous suitable terrain in Western Stara Planina extends up to ca. 1500 m. Only one record from our region is from near sea-level: Burgas city on the Black Sea coast.

Conservation considerations

The Spinose Skipper is not considered threatened in Europe (van Swaay & Warren 1999) owing to reported stable population sizes and range in all countries with presence



Fig. 11. Habitat of *M. cribrellum* overgrown by *Pinus* plantations at Căianu Mic (Transylvania, Romania, 400 m, 6.v.2006). Photo V. Dincă.

of this species in Europe. These assessments were most probably done on the basis of the best expert judgement as no detailed studies on distribution changes or population sizes for *M. cribrellum* are known to the authors. Certainly, the current and known past range in Romania shows that the species may have declined in its range over the last decades. However, this trend is hard to evaluate as many of the original sites have not been visited recently and new sites are still being discovered. In Bulgaria the species may be locally extinct, e.g. in the vicinity of Burgas due to urbanisation, small-scale agriculture and other degradation such as overgrowing (Kolev 2003) of the man-made steppe-like habitats that have existed there (Stoyanoff 1926). However, in reality this region is extremely poorly known and further research there is necessary before it can be claimed that this or any other of the several rare steppe butterfly species that have been collected there in the early XXth century are now extinct (Kolev 2003). The karst region of western Stara Planina, the main stronghold of *M. cribrellum* in Bulgaria, contains extensive areas that are superficially suitable for *cribrellum*, which means that further populations of the species most probably exist there. Since the presence of *M. cribrellum* in the region was detected only in 1987, and most records are only from the last three years, there are no data for evaluating population trends. Little is known about the changes of distribution in eastern Ukraine and especially southern Russia which possibly holds the largest populations of this species in Europe. Nekrutenko & Tshikolovets (2005) mentioned that *M. cribrellum* is extremely local in Ukraine where it has a poorly known distribution and requires conservation measures. Pljushtch et al. (2005) mentioned only six (mostly old) records for Ukraine. A similar situation exists

for European Russia from where only 11 widely separated records (some old or requiring confirmation) have been mentioned by Pljushtch et al. (2005).

The size of the populations of *M. cribrellum* known in Europe is difficult to assess without data inferred from monitoring activities. However, for a few sites that were visited for several years, it seems that the population size is modest. This is for example the case of the populations in the vicinity of Cluj (Transylvania) which seem to be very small as only five to ten adults per generation have usually been observed (Rákossy & Lászlóffy 1997; Goia & Dincă 2008). One exception may be the population from Suatu (Transylvania) (Fig. 3), where the species is relatively abundant on terraces of abandoned vineyards (Dincă pers. obs.). Low numbers also apply to most localities in western Bulgaria: although *M. cribrellum* can apparently be locally abundant there, in most places the numbers of specimens recorded during a single visit have remained well below ten. Besides, abundance of males localised at mud-puddling sites may misrepresent the actual abundance of the species in the larger area. The Bulgarian observations so far indicate that females of the species in the actual breeding habitat (even adjacent to mud-puddling sites with greater abundance of males) are apparently very rare. If we consider that the species occurs at low densities over the whole western limit of its distribution and within a relatively small area of occupancy, the total population size in Europe could easily be below the threshold value for a threat status according to the Red List criteria. Even by adding the currently known populations from Ukraine and European Russia, the situation does not improve significantly as for these regions there are surprisingly few reliable records available (Pljushtch et al. 2005). However, the vast steppe area of Ukraine and European Russia requires extensive rigorous studies which are likely to lead to the discovery of further populations of *M. cribrellum*.

What remains in terms of evaluation of the threat status is the extreme fragmentation of the range of the species in Europe and indirect evidence of endangerment based on the habitat requirements of the species. *Muschampia cribrellum* is a habitat specialist limited to steppe refuges and according to Schmitt & Rákossy (2007) its most preferred habitat type is young grassland fallows. As such habitats are maintained only through low-intensity agriculture in the majority of the known sites, either abandonment or intensification could be deleterious for the local populations of the species. Circumstantial evidence for such phenomena is known in Macedonia (Verovnik & Micevski 2009) and Romania (overgrowing by shrubs, *Robinia* or *Pinus* - see Fig. 11). In Bulgaria, the planting of dense pine stands on karstic slopes has locally affected *cribrellum* habitats in western Stara Planina. The most extensive of these plantations are around Godetch town and along the southern slope of Mount Chepán and adjacent hills around Dragoman town (Z. Kolev, pers. obs., Fig. 10), but their extent is limited relative to the total area of habitats potentially suitable for *M. cribrellum*. In the long run, the decline or cessation of traditional land use could be considered as the most important threat. Due to ongoing human population decline in rural areas and unfavourable European Union (EU) common agriculture practices this process has already started. With abandonment of traditional extensive grazing practices, large-scale losses of suitable habitats for *M. cribrellum* at the western edge of its distribution are inevitable.

Due to the very poorly known situation in eastern Ukraine and southern Russia no definitive threat status could be given to the species on European level, but the near threatened status (NT) should be used to indicate that declines are present or anticipated for this species. On EU level the status of vulnerable (VU) should be implemented due to very small area of occupancy, extreme fragmentation, apparently small total population size, and contiguous decline anticipated from habitat loss. The new discoveries should certainly not be treated as recent expansions, but more as a result of the lack of faunistic research in the region and scarcity of the species. The habitats of the Spinose Skipper are very rich in butterflies and host many rare or threatened species in Europe, e.g. in Romania *Muschampia tessellum* (Hübner, 1803), *Colias chrysotheme* (Esper, 1781), *Pseudophilotes bavius* (Eversmann, 1832), and *Plebejus sephirus* Frivaldsky, 1835), in Bulgaria *Plebejus sephirus*, *Polyommatus eroides* (Frivaldszky, 1835), *Coenonympha leander* (Esper, 1784) (Z. Kolev, pers. obs.), and in the Republic of Macedonia *Euchloe penia* (Freyer, 1851) (Verovnik & Micevski 2009). Therefore the designation of the threat status to EU populations of the Spinose Skipper would have a wider positive effect. At national level, *M. cribrillum* has been legally protected in Romania since 2005 (see also Rákossy 2006). Regrettably, the species was inexplicably excluded from the list of target species for the project Prime Butterfly Areas in Bulgaria, even though it was recorded in the course of the project and was mentioned in the final publication (Abadjiev & Beshkov 2007). This unfortunate misjudgement must be corrected as soon as possible, not only in view of the rarity and localization of *M. cribrillum* in Bulgaria, but also because it is a very suitable “umbrella species” for the protection of the prime steppe-like habitats in western Stara Planina.

Currently, autecological studies on the Spinose Skipper are badly needed as well as precise mapping of its distribution and evaluation of the potential threats. Only with such precise information can the guidelines for conservation and management plans for long term survival of the species at its western limit of distribution be made.

Acknowledgments

Our thanks go to Stoyan Beshkov, Gerd Kuna, Markus Lindberg, Chris van Swaay, Zoltán Varga, Arne Viborg, Torben Friis-Larsen, Christopher Luckens, Charles Derry, Duncan Trew, Morten Mølgaard, Nick Greatorex-Davis and Matt Rowlings for providing relevant information. We also thank S. Beshkov and Nikolay Shtinkov for their pleasant and inspiring company during the Bulgarian collecting trips in 2007, 2008 and 2009, and Jaakko Kullberg for the information on habitat preferences of Siberian *M. cribrillum*. We are grateful to Peter Russell for the permission to use his record of *M. cribrillum* from the Republic of Macedonia and Chris van Swaay and Kars Veling for the photographs. Many thanks to S. Cuvelier for comments on the manuscript and for writing the French abstract and to an anonymous referee for writing the German abstract. Support for this research was provided by the Ministerio de Ciencia e Innovación project (CGL2007-60516/BOS) to V. Dincă.

References

- Abadjiev, S. & S. Beshkov 2007. Prime Butterfly Areas in Bulgaria. – Pensoft, Sofia. 222 pp.
 Beshkov, S. 2000. Lepidoptera species (Macrolepidoptera) recorded and reported from the Western Stara Planina Mountain, NW Bulgaria. – *Entomologica Romanica* 5: 11–43.

- Boggs, C. L. & L. A. Jackson 1991. Mud puddling by butterflies is not a simple matter. – *Ecological Entomology* **16** (1): 123–127.
- Căpușe, I. & A. Kovács 1987. Catalogul colecției de lepidoptere „László Diószeghy” de la Muzeul Județean Covasna, Sfântu Gheorghe. – Institutul de Speologie „Emil Racoviță”, București. 400 pp.
- Chinery, M. 1989. *New Generation Guide to the butterflies and day-flying moths of Britain and Europe*. – University of Texas Press, Austin. 320 pp.
- Cremene, C., L. Rákossy & A. Erhardt 2003. Diversity of Macrolepidoptera in steppe habitats of Căianu Mic (Cluj). – *Entomologica Romanica* **7**: 5–14.
- Dincă, V. & R. Vila 2008. Improving the knowledge on Romanian Rhopalocera, including the rediscovery of *Polyommatus amandus* (Schneider, 1792) (Lycaenidae) and an application of DNA-based identification. – *Nota Lepidopterologica* **31** (1): 3–23.
- Goia, M. & V. Dincă 2008. Structura și răspândirea faunei de lepidoptere diurne (Hesperioidea & Papilionoidea) în împrejurimile municipiului Cluj-Napoca și aspecte actuale ale influenței antropozoogene asupra mediului de viață al acestora. – *Buletin de informare entomologică* **17**: 139–197.
- Gorbunov, P. 2001. *The butterflies of Russia: classification, genitalia, keys for identification* (Lepidoptera: Hesperioidea and Papilionoidea). – Thesis, Ekaterinburg. 320 pp.
- Hesselbarth, G., H. van Oorschot & S. Wagener 1995. *Die Tagfalter der Türkei unter Berücksichtigung der angrenzenden Länder*, vols. 1–2. Selbstverlag Sigbert Wagener, Bocholt, Germany. 1354 pp.
- Higgins, L. G. 1975. *The Classification of European butterflies*. – Collins, London. 320 pp.
- Higgins, L. G. & N. D. Riley 1980. *A field guide to the butterflies of Britain and Europe*. 4th ed. – Collins, London. 384 pp.
- Jakšić, P. 1988. Privremene karte rasprostranjenosti dnevnih leptira Jugoslavije (Lepidoptera, Rhopalocera). – *Jugoslavensko entomološko društvo 1* (Editiones separatae), Zagreb. 215 pp.
- Jakšić, P. 1998. Male genitalia of butterflies on Balkan Peninsula with a check-list. – František Slamka, Bratislava. 144 pp.
- Jakšić, P. 2003. Dnevni leptiri (Lepidoptera: Hesperioidea i Papilionoidea) Suve Planine. – *Zaštita prirode* **54** (1–2): 71–87.
- Kolev, Z. 2003. First record of *Muschampia cribrellum* in Bulgaria, with a review of the recorded distribution of genus *Muschampia* in the country (Lepidoptera: Hesperioidea). – *Phegea* **31** (1): 15–21.
- Korshunov, Yu. 2002. *The butterflies of North Asia*. – KMK, Moscow. 424 pp. [in Russian].
- Korshunov, Yu. & P. Gorbunov 1995. *Butterflies of the Asian part of Russia. A handbook*. – Ural University Press, Ekaterinburg. 202 pp. [in Russian].
- Kovács, S., L. Rákossy, Z. Kovács, C. Cremene & M. Goia 2001. Lepidoptera (Fluturii). Pp. 81–114. – In: Rákossy, L. & S. Kovács (eds.): *Rezervația “Dealul cu fluturi” de la Vișoara*. Societatea lepidopterologică română, Cluj-Napoca.
- Kovács, S., L. Rákossy, Z. Kovács, C. Cremene & M. Goia 2002. Lepidoptere din Rezervația naturală „Dealul cu fluturi” de la Vișoara (jud. Cluj). – *Buletin de informare Societatea lepidopterologică română* **12** (1–4): 47–85.
- Lafranchis, T. 2004. *Butterflies of Europe*. – Diatheo, Paris. 351 pp.
- Lorković, Z. 1983. A new *Syrichtus* and two doubtful *Pyrgus* species for the fauna of Yugoslavia (Lep., Hesperioidea). – *Acta entomologica Jugoslavica* **19**: 33–41.
- Moldoveanu, M., A. Haltrich & V. Dely 1980. Die Tagfalter (Papilionoidea u. Hesperioidea) aus der nördlichen Teil des Mureș-Kreise. – *Societatea de științe Biologice din R. S. R., Filiala Reghin, Studii și comunicări*: 71–86.
- Nekrutenko, Yu. & V. Tshikolovets 2005. *The Butterflies of Ukraine*. – Rayevsky Scientific Publishers, Kyiv. 231 pp. [in Ukrainian].
- Pamperis, L. N. 1997. *The Butterflies of Greece*. – Bastas-Plessas, Athens. 574 pp.
- Pamperis, L. N. 2009. *The Butterflies of Greece*. – Editions Pamperis, Athens. 768 pp.
- Pivnick, K. A. & J. N. McNeil 1987. Puddling in butterflies: sodium affects reproductive success in *Thymelicus lineola*. – *Physiological Entomology* **12**: 461–472.
- Pljushtch, I. G., D. V. Morgun, K. E. Dvornik, N. I. Rubin & I. A. Solodovnikov 2005. *Butterflies (Hesperioidea and Papilionoidea) of Eastern Europe – a database*. CD-Rom, ISBN 985-90000-5-0. – Lysandra, Minsk-Kyiv-Moscow.

- Popescu-Gorj, A. 1964. Catalogue de la collection de lépidoptères „Prof. A. Ostrogovich” du Museum d’Histoire Naturelle „Grigore Antipa”, Bucarest. – Ed. Museum „Grigore Antipa”, Bucarest. 320 pp.
- Rákósy, L. 1988. A valuable collection of Lepidoptera in the Zoological Museum of the University in Cluj-Napoca (Part II). – *Studia Universitatis Babeş-Bolyai, Biologia* **33** (1): 72–95.
- Rákósy, L. 2000. Lepidopterologische Biodiversität eines kleinräumigen steppenartigen Naturschutzgebietes in Siebenbürgen (Suatu, Transsylvanien, Rumänien). – *Entomologica Romanica* **4**: 49–68.
- Rákósy, L. 2006. U.E. și legislația pentru protecția lepidopterelor din România. Buletin de informare Entomologică **16**: 89–96.
- Rákósy, L. & M. Goia 1997. *Muschampia tessellum* (Hübner, 1803) și *M. cribrillum* (Eversmann, 1841) în fauna României. (Lepidoptera, Hesperiiidae). – Buletin de informare Societatea lepidopterologică română **8** (3–4): 155–162.
- Rákósy, L. & Z. Lászlóffy 1997. Fauna de macrolepidoptere de la Fânățele Clujului (Lepidoptera) (Cluj, România). – Buletin de informare Societatea lepidopterologică română **8** (3–4): 165–186.
- Rákósy, L. & I. Viehmann 1991. Argumente în favoarea unei rezervații naturale în Cheile Turului. – *Ocrotirea Naturii și a Mediului înconjurător* **35** (1–2): 15–25.
- Rákósy, L., Goia, M. & Z. Kovács 2003. Catalogul Lepidopterelor României / Verzeichnis der Schmetterlinge Rumäniens. – Societatea Lepidopterologică Română, Cluj-Napoca. 446 pp.
- Rothschild, C. 1912. – *Verhandlungen und Mitteilungen des Siebenbürgischen Vereins für Naturwissenschaften, Hermannstadt* **62** (1): 1–32.
- Schaider, P. & P. Jakšić 1989. Die Tagfalter von jugoslawisch Mazedonien. – Selbstverlag Paul Schaidler, München. 288 pp.
- Schmitt, T. & L. Rákósy 2007. Changes of traditional agrarian landscapes and their conservation implications: a case study of butterflies in Romania. – *Diversity and Distributions* **13**: 855–862.
- Slamka, F. 2004. Die Tagfalter Mitteleuropas - östlicher Teil. – Published by the author. 288 pp.
- Stoyanoff, N. 1926. On the origin of the xerothermic plant element in Bulgaria. – *Journal of Ecology* **14** (1): 138–154.
- Szabó, A. 1982 Date cu privire la răspândirea lui *Muschampia cribrillum* Ev. în Transilvania. – Societatea de științe Biologice din R. S. R., Filiala Reghin, Studii și comunicări **2**: 307–310.
- Székely, L. 2008. The butterflies of Romania / Fluturii de zi din România. – Brastar Print Brașov. 305 pp.
- Tamás, T. & K. Mihály 2009. Szalkay József Magyar Lepkészetű egyesület. – URL <http://macrolepidoptera.hu>. (Accessed on 16.ix.2009.).
- Tolman, T. 2001. Photographic guide to the butterflies of Britain and Europe. – Oxford University Press. 305 pp.
- Tolman, T. & R. Lewington 1997. Field Guide of the Butterflies of Britain and Europe. – Collins, London. 320 pp.
- Tolman, T. & R. Lewington 2008. Collins Butterfly Guide. – Collins, London. 384 pp.
- Tshikolovets, V. V. 2003. Butterflies of Eastern Europe, Urals and Caucasus. – Kyiv-Bрно. 176 pp.
- Tshikolovets, V. V. 2005. The Butterflies of Ukraine. – Zbirnik Prats Zoologichnogo Muzeyu, Kyiv **37**: 13–62.
- Tuzov, V. K., Bogdanov, P. V., Devyatkin, A. L., Kaabak, L. V., Korolev, V. A., Murzin, V. S., Samodurov, G. D. & E. A. Tarasov 1997. Guide to the butterflies of Russia and adjacent territories (Lepidoptera, Rhopalocera). Volume 1. Hesperiiidae, Papilionidae, Pieridae, Satyridae. – Pensoft, Sofia-Moscow. 480 pp.
- Van Swaay, C. & M. Warren 1999. Red Data Book of European Butterflies (Rhopalocera). – *Nature and Environment* **99**. 260 pp.
- Varga, Z., Ronkay L., Bálint Zs., László Gy. & L. Peregovits 2005. Checklist of the fauna of Hungary. Volume 3. Macrolepidoptera. – Hungarian Natural History Museum, Budapest. 114 pp.
- Verovnik, R. & B. Micevski 2009. On the presence of *Syrichthus cribrillum* (Eversmann, 1841) (Lepidoptera: Hesperiiidae) in the Republic of Macedonia. – *Entomologist’s Gazette* **60**: 232–236.
- Wagner, W. 2009. Europäische Schmetterlinge und ihre Ökologie: *Muschampia tessellum*. – URL http://www.pyrgus.de/Muschampia_tessellum.html. (Accessed on 8.x.2009.).



Dinca, Vlad, Kolev, Zdravko, and Verovnik, Rudi. 2010. "The Distribution, Ecology and Conservation Status of the Spinose Skipper *Muschampia Cribrellum* (Eversmann, 1841) At the Western Limit of Its Range in Europe (Hesperiidae)." *Nota lepidopterologica* 33, 39–57.

View This Item Online: <https://www.biodiversitylibrary.org/item/179105>

Permalink: <https://www.biodiversitylibrary.org/partpdf/147472>

Holding Institution

Smithsonian Libraries and Archives

Sponsored by

Biodiversity Heritage Library

Copyright & Reuse

Copyright Status: In Copyright. Digitized with the permission of the rights holder

License: <http://creativecommons.org/licenses/by-nc-sa/3.0/>

Rights: <https://www.biodiversitylibrary.org/permissions/>

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at <https://www.biodiversitylibrary.org>.