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New Data on Rare Zygaenidae (Lepidoptera) and Their Habitats in Eastern Serbia

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Abstract: In the years 2014-2017, we conducted a study in eastern Serbia in order to find rare Zygaenidae species and identify their suitable habitats. *Adscita albanica* and *Zygaena diaphana* were recorded in Serbia for the first time while *Z. laeta* was recorded for the second time. Here we provide new data on the occurrences of *Rhagades pruni*, *Jordanita graeca*, *Z. punctum* and *Z. brizae*, all of which are known from very few localities in Serbia. Additional information on habitat, larval host-plants and nectar plants was collected in the field. With exception of *J. graeca*, this is the first time that these zygaenid species have been linked to a particular plant association and habitat type in Serbia. Arid subcontinental steppic grasslands are considered as the primary habitats for the investigated species in eastern Serbia. Threats and conservation aspects are discussed.

Key words: *Rhagades, Adscita, Jordanita*, *Zygaena*, habitat types, plant associations

Introduction

Zygaenidae have similar biology to butterflies which are used as biodiversity indicators in Europe (van Swaay et al. 2013). They are sedentary and usually don't fly more than 200-300 m from the occupied site (Naumann et al. 1999). Diurnal activity and conspicuous appearance make Zygaenidae easy to survey in the field (Naumann et al. 1999). They have a complex life cycle and every stadium can use different habitat types and resources. In contrast to butterflies, Zygaenidae are not widely used as indicator species because their ecology is not studied sufficiently, except in Western and Central Europe. Zygaenidae have been shown to react rapidly to pesticides and they are among the first insects that disappeared from contaminated sites (Tarmann 2009). They can also indicate butterfly species richness (Franzén & Ranius 2004). Zygaenidae mainly occupy open natural grasslands (Naumann et al. 1999). Adults very much depend on nectaring upon plants, especially species of *Knautia*, *Scabiosa*, *Cephalaria* and *Dipsacus* (Naumann et al. 1999). Through identifying the habitats, host-plants and nectar plants we make an attempt to better understand how these moths will respond to changes in their habitat; such precise knowledge is necessary for appropriate evaluation of threatened status and conservation measures for Zygaenidae species.

Knowledge on distribution of Zygaenidae in Serbia is poor but it is improving. In the last several years, new faunistic data have been obtained and four species were reported as new for the country (Nahirnić et al. 2011, 2012, Tarmann 2012). At present 27 species of Zygaenidae are recorded from Serbia (Jakšić 2016). Still very little is known on their ecology. Data from eastern Serbia are especially scarce. The only comprehensive paper is that of Jakšić & Zlatković (2015), but it is confined to Jelašnička Klisura Gorge. The aim of this paper is to present data on the distribution, ecology and habitat requirements of rare Zygaenidae in eastern Serbia.

Materials and Methods

Study area

Eastern Serbia is characterised by number of mountains intersected with valleys and gorges. These mountains are of low and medium altitude with the highest peaks of 2168 m on Stara Planina Mts and 1800 m on Mt. Suva Planina. The examined area comprises the mountains and gorges of the Balkan mountain system of eastern Serbia around the Nišava River Valley in the municipalities of Knjaževac, Svrljig, Niš, Bela Palanka, Pirot and Dimitrovgrad. Study localities are shown in Fig. 1 and Tab. 1.We targeted sun-exposed, calcareous rocky slopes in particular, but other habitat types in close vicinity were also inspected. The geological bedrock is limestone except at localities 2 and 4, which are on limestone and dolomites and locality 12 which is limestone and marls. Karst geomorphology on a limestone and dolomites geology provides suitable habitat for thermophilous species and especially where the slopes are exposed to the south microclimate allows thermophilous species to occur at altitudes greater than 1000 m. The Nišava River Basin is influenced by the Pontic and sub-Mediterranean climate through the Struma River Valley and the Sofia Basin. The climate in the region can be characterised as semi-arid sub-continental.

The vegetation of the studied area is characterised by high floristic diversity, with both sub-Mediterranean and Mediterranean floristic elements in its composition as well as numerous endemic and relict steppe species (Jušković et al. 2010, Marković et al. 2015a).The presence of large areas of thermophilous stone ground is due to the long-term anthropogenic degradation of the primary potential vegetation, resulting in considerable abundance of plant species with the Mediterranean and sub-Mediterranean distribution pattern. Deciduous forest of Hungarian and Turkey oak (*Quercetum frainetto-cerris* Rudski 1949) is widespread and is considered to be climax in the eastern Serbia region (Mišić et al. 1978). Different degradation stages of this community and its derivates with Oriental hornbeam (*Carpinus orientalis* Miller) are well represented (Marković et al. 2015b). There are also fragments of relict polydominant forests (Mišić 1982, Marković 2013). Thermophilic meadows and grasslands are seminatural in origin, and then (in some cases) grazed. The largest areas of the specified type of vegetation occur on the south and southwest-facing slopes of the mountains, with shallow and dry soil.

Our studied localities are situated in protected (3, 4, 7, 9, 10b-d and 12) and not protected (1, 2, 5, 6, 8, 10a and 11) areas. Fieldwork in protected areas was done on the basis of permits provided by the Ministry of Environment, Mining and Spatial Planning, Republic of Serbia, No. 353-01-389/2016-17, dated from 08.04.2016. and No. 353-01-834/2017-17, dated from 11.05.2017.

Sampling

Several field trips were conducted during the four-year period of 2014-2017. Adults moths were sampled by an entomological net and reference specimens were collected. Eggs and caterpillars were searched for on their host-plants with several eggs and larvae taken for rearing. Adult specimens of

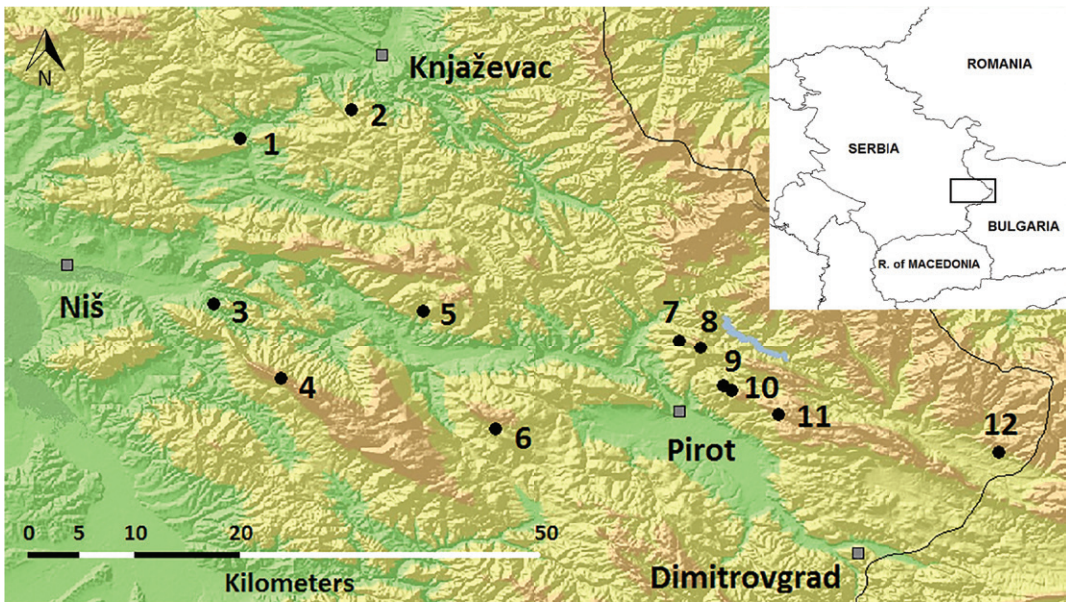

Fig. 1. Map of the study area with localities.

Jordanita graeca, *Adscita albanica* and *Z. diaphana* were identified on the basis of genitalia. Genitalia slides were prepared following standard procedure (Robinson 1976) and determined according to Naumann et al. (1999).

Habitats

The collected plant material was identified according to Josifović et al. (1970-1977) and the nomenclature was adjusted according to Tutin et al. (1964-1980, 1993). Plant associations were identified using Braun-Blanquet (1964) phytosociological methods that were applied for phytocoenological analysis. In some cases the identification of a given association was not possible due to the transitional character of vegetation or due to phytocenologically understudied vegetation type in Serbia such as *Prunus spinosa* communities. Habitat types were identified according the EUNIS classification (DAVIES et al. 2004) and the National system for the classification of hab-

Fig. 2. Habitats and localities of Zygaenidae species. a – Svrljiški Timok River Gorge (1) locality where *Rhagades pruni*, *Zygaena diaphana* and *Z. punctum* occur; b – Mt. Suva Planina, Devojački Grob (4), locality where *Adscita albanica* occurs; c – Mt. Vidlič, Crni Vrh (10a) habitat where *Jordanita graeca* and *Z. brizae* were found, May aspect, with noticeable pink flower heads of *Carduus cardicans*; d – Mt. Šljivovički Vis (6), habitat where *A. albanica* and *Z. laeta* were found; e – Stara Planina Mts, Gornji Krivodol (12) habitat where *Z. diaphana* and *Z. punctum* were found; f – Mt. Šljivovički Vis (6) habitat where *Z. punctum* was found. Numbers in brackets correspond to those in Table 1. and Table 2. (Photos by Ana Nahirnić, photo 2b by Predrag Jakšić)

Table 1. Sampling sites of Zygaenidae. Numbers of sites are same as those given on Figure 1.

No.	Locality	Latitude	Longitude	Altitude (m a.s.l.)
1a, b	Svrljiški Timok River Gorge, near Niševac vil.	43°28'16"	22°05'28"	420
2a, b	Mt. Tresibaba, Tresibaba pass, near Raskrsje vil.	43°30'14"	22°12'57"	680
3a, b	Jelašnička Klisura Gorge	43°16'32"	22°04'07"	335-380
4	Mt. Suva planina, Devojački Grob	43°11'27"	22°09'02"	1311
5	Svrljiške planine Mts, above Mokliště vil.	43°16'39"	22°17'50"	640-700
6	Mt. Šljivovički Vis, east from Šljivovik vil.	43°08'37"	22°22'43"	900
7a, b	Mt. Vidlič, Srednja Glama, near Koprivštica vil.	43°14'05"	22°36'37"	980
8	Mt. Vidlič, Srednja Glama, Marino Livađe	43°14'35"	22°35'08"	930
9	Mt. Vidlič, Mali Vrh summit	43°11'32"	22°38'09"	1100
10a	Mt. Vidlič, Crni Vrh summit, W slope	43°11'03"	22°38'35"	895
10b	Mt.Vidlič, Crni Vrh summit, W slope	43°11'12"	22°38'43"	975
10c,d	Mt.Vidlič, Crni Vrh summit, W slope	43°10'51"	22°38'52"	1115
11a	Mt. Vidlič, Basarski Kamen	43°09'38"	22°42'18"	1290
11b	Mt. Vidlič, Basarski Kamen	43°09'35"	22°41'53"	1180
11c	Mt. Vidlič, Basarski Kamen	43°09'14"	22°42'01"	1055
12	Stara planina Mts, Gornji Krivodol vil., Rudina	43°07'06"	22°56'45"	980-1000

itats (Lakušić & Medarević 2010). Since the habitat names in the latter source are given only in Serbian language, here we propose our own translations into English. Natura 2000 habitat types were identified according to European Commission (2007). Plant associations or habitat characteristics, EUNIS habitat types and Serbian national classification habitat types are given in Table 2.

Results

***Rhagades pruni* ([Denis & Schiffermüller], 1775)**

Material examined: 1b – 14.06.2017; 2a – 23.06.2014; 7b – 14.06.2015.

Remarks: The main habitats in the Balkan Peninsula and other warmer parts of Europe are open scrub in hilly regions where the host-plants are mainly different species of the genus *Prunus* (Naumann et al. 1999). *Crataegus* spp., *Pyrus* spp., *Rosa canina* L. and *Rubus* sp. are also reported as host-plants (de Freina & Witt 2001). *Rhagades pruni* is a rare species in Serbia with reports from few localities (Jakšić 2016).

Several males and one pair *in copula* were observed on Vidlič Mt. (7b) in the morning hours (8:30-09:30). Bushes of *Crataegus monogyna* Jacq. were shaken in order to disturb the moths. *Prunus spinosa* L. was very rare in this habitat. Moths were found only in one small patch along a 5 km transect in suitable habitats. In the Svrljiški Timok River Gorge (Fig. 2a) several stands of *P. spinosa* were shaken and at two of them *Rh. pruni* was disturbed and caught. Its habitat choice depends mainly on the host-plant since the moths have a reduced proboscis and don't search for nectar; as a result adults are not to be seen feeding on flowers and this may be a reason why they are considered to be local and rare. Shaking of the bushes and careful observation can be helpful. Beating the bushes proved to be successful for finding *Rh. pruni* in our study and without this technique specimens could have been very easily overlooked. *Rh. pruni* can also be attracted to synthetic sex pheromones, although with this method habitat from where they are attracted may not be observed always.

***Adscita albanica* (Naufock, 1926)**

Material examined: 4 – 15.07.2015; 6 – 21-22.06.2017; 10d – 15.06.2015, 21.06.2017.

Remarks: *Adscita albanica* is distributed in Ukraine, Russia and the Balkan Peninsula (Efetov & Tarmann 2014). It is one of the rarest and least studied Zygaenidae species on the Balkan Peninsula where based on reliable records it occurs in Mt. Pashtrik in Albania (Naufock 1926), the surroundings of Bitola and Šar-planina Mts in FYR Macedonia (Buresch & Tuleschkow 1943, Daniel et al. 1951, Daniel 1964), Mt. Smólikas, Mt. Pangéo Mt. and Mt. Órvilos in Greece (Coutsis 1979, 2017) and Mt. Vitosha, Vladaya Gorge and Mt. Lyulin in Bulgaria (Drenowsky 1934, Alberti 1966). Apart from Coutsis (1979), who mentioned its habitat as flowery clearing in deciduous forest on Mt. Pangéo, these published records lack information about precise locality and habitat. In nature host-plants of *A. albanica* are *Geranium sanguineum* L. and *G. columbinum* L., while in captivity it can feed on other *Geranium* and *Erodium* species (Efetov 2005).

Here we report *A. albanica* for the first time in Serbia. The localities in Serbia represent the northernmost records on the Balkan Peninsula. At Crni Vrh on Mt. Vidlič it was observed in a limestone dry clearing with abundant *G. sanguineum* surrounded by two deciduous forests *Fagetum submontanum* (Rudski 1949) B. Jovanović 1976 *carpinetosum betuli* E. Vukićević 1956 and relict polydominant forest *Fago-Aceri intermedii-Coryletum colurnae* B. Jovanović 1953. In these forests *Geranium purpureum* Vill. and *G. macrorrhizum* L. were found, respectively. Twelve *Geranium* species are mentioned for Crni Vrh (Marković 2014, this study). Crni Vrh is covered by a mosaic of dry grassland, shrub and deciduous forest and with various *Geranium* spe-

Table 2. Description of studied localities with plant associations and habitat types. Site numbers are same as those in Table 1.

Site	Plant association or habitat characteristics	EUNIS classification	Serbian national classification
1a	*Euphorbio myrsiniti-Dichanthietum ischaemi* R. Jovanović 1955 (syn. *Myrsiniteto-Ischaemetum* R. Jovanović 1955)	E1.21 Helleno-Balkanic *Satureja montana* steppes	C1.311 Arid shrub-grassy carbonate bedrock with myrtle spurge (*Euphorbia myrsinites*)
1b	Open deciduous shrubland with high occurrence of *Prunus spinosa*	F3.241 Central European subcontinental thickets	B2.1E1 Blackthorn thicket (*Prunus spinosa*)
2a			
2b	Arid steppe-like grasslands with semi-shrubs, on shallow ground, surrounded by rocks	E1.2 Perennial calcareous grassland and basic steppes	C1.32 Arid carbonate meadows and bedrock
3a	*Sanguisorbo-Festucetum valesiacae* Danon 1960 (syn. *Poterio-Festucetum valesiacae* Danon 1960)	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.321 Arid carbonate meadow of volga fescue (*Festuca* gr. *valesiaca*)
3b	*Euphorbio myrsiniti-Dichanthietum ischaemi* R. Jovanović 1955 (syn. *Myrsiniteto-Ischaemetum* R. Jovanović 1955)	E1.21 Helleno-Balkanic *Satureja montana* steppes	C1.311 Arid shrub-grassy carbonate bedrock with myrtle spurge (*Euphorbia myrsinites*)
4	*Carici humilis-Stipetum pulcherrimae* R. Jovanović 1955 (*Humileto-Stipetum grafianae* R. Jov. 1955.)	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.328 Arid carbonate bedrock with feather-grass (*Stipa pulcherrima*)
5a			
5b	*Potentillo-Caricetum humilis* R. Jovanović 1955 subas. *artemisietosum camphoratae* Diklić 1962	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.32C Arid carbonate bedrock with dwarf sedge (*Carex humilis*)
6			
7a	Arid steppe-like grasslands on rocky slope with S-W exposition	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.32 Arid carbonate meadows and bedrock
7b	*Carpinetum orientalis serbicum* Rudski 1940 emend. B. Jovanović 1953	F3.24 Subcontinental and continental deciduous thickets	B2.511 Oriental hornbeam thickets (*Carpinus orientalis*)
8	Closed mesophilous grasslands on a flat plain terrain	E2.1 Permanent mesotrophic pastures and aftermath-grazed meadows	C2 Mesophilous grasslands
9	*Bromo-Festucetum valesiacae* Danon et Blaženčić 1978	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.321 Arid carbonate meadow of Volga fescue (*Festuca* gr. *valesiaca*)
10a	*Carici humilis-Stipetum pulcherrimae* R. Jovanović 1955 (syn. *Humileto-Stipetum grafianae* R. Jov. 1955.)	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.328 Arid carbonate bedrock with feather-grass (*Stipa pulcherrima*)
10b	*Potentillo-Festucetum valesiacae* Nikolić 1972	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.321 Arid carbonate meadow of Volga fescue (*Festuca* gr. *valesiaca*)
10c			
10d	*Potentillo-Caricetum humilis* R. Jovanović 1955 subas. *artemisietosum camphoratae* Diklić 1962	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.32C Arid carbonate bedrock with dwarf sedge (*Carex humilis*)
11a	*Carici humilis-Stipetum pulcherrimae* R. Jovanović 1955 (syn. *Humileto-Stipetum grafianae* R. Jov. 1955.)	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.328 Arid carbonate bedrock with feather-grass (*Stipa pulcherrima*)
11b	*Bromo-Festucetum valesiacae* Danon et Blaženčić 1978	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.321Arid carbonate meadow of Volga fescue (*Festuca* gr. *valesiaca*)
11c	*Agrostietum capillaris* Z. Pavlović 1955	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.326 Arid carbonate grasland of common bent (*Agrostis* gr. *vulgaris*)
12	*Potentillo-Caricetum humilis* R. Jovanović 1955 subas. *artemisietosum camphoratae* Diklić 1962	E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*)	C1.32C Arid carbonate bedrock with dwarf sedge (*Carex humilis*)

cies it should meet the habitat requirements of this species. This locality is inside the Nature Park "Stara Planina" and no threat was observed during visits in 2014-2017. Sheep and cows are present only in the foothill of Crni Vrh. One possible threat could be grazing which would cause xeriphication of habitats and loss of host-plant. On Mt. Suva Planina one male of *A. albanica* was found at Devojački Grob (4) (Fig. 2b) with widely developed xeric grasslands association, *Carici humilis – Stipetum pulherrimae*, on the main ridge. In close vicinity, on the other side of this ridge, the northerly exposed, very steep slopes are covered with *Fagetum montanum serbicum* Rudski 1949 em. B. Jovanović 1967. This locality is inside the Special Nature Reserve "Suva Planina". It is very inaccessible; a threat to the moth could be posed by overgrowth of the vegetation. Sites where *A. albanica* was found were on the edge of closed depressions in karst landscape, known as dolines in karst terminology. Due to climate inversion microclimatic conditions in dolines are more suitable for mesophilous vegetation than outside. Dolines are inaccessible for pasture or tree cutting. On Vidlič and Šljivovički Vis *G. sanguineum* was abundant at maximal distance of 20 m from forest edge. All specimens were observed resting, nectaring and copulating on *G. sanguineum* and even when they were disturbed they did not disperse outside the *G. sanguineum* patches.

***Jordanita graeca* (Jordan, 1907)**

Material examined: 2b – 23.06.2014; 9 – 13.06.2015; 7a, 7b, 8 – 14.06.2015; 10a – 04.07.2014; 10c – 15.06.2015.

Remarks: *Jordanita graeca* is a xerothermophilous species of Ponto-Mediterranean distribution. It inhabits dry grassy plains or slopes and steppe (Naumann et al. 1999, Efetov 2005). Larvae feed on *Carduus* spp., *Centaurea* spp., *Cirsium* spp. *Jurinea sordida* Stev. and *Xeranthemum annuum* L. (Naumann et al. 1999). It is a very local species in Serbia known from only three localities, namely Mt. Fruška Gora and Miljakovac (Belgrade) (Nahirnić et al. 2012, Tarmann 2012) and Jelašnička Klisura Gorge (Jakšić & Zlatković 2015).

Jakšić & Zlatković (2015) previously reported habitats for *J. graeca* in Jelašnička Klisura. Based on these and our new data we conclude that it usually inhabits E1.2 Perenial calcareous grassland and basic steppe, especially E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*). We observed several specimens on Mt. Vidlič on Mali Vrh (9) while one male was nectaring on *Erysimum diffusum* Ehrh. (Brassicaceae). Potential host-plants observed at this habitat were: *Centaurea stoebe* L. subsp. *stoebe* and *Xeranthemum annuum*. On Mt. Vidlič (10a) (Fig. 2c) potential host-plants were *Centaurea stoebe* subsp. *stoebe* and *Carduus candicans* Waldst. & Kit ssp. *globifer* (Velen.) Kazmi (Asteraceae). At Marino Livađe (8), also on Mt. Vidlič it was found in mesophilic meadow resting at noon on a very hot day. This mesophilic habitat is surrounded by dry grasslands which are primary habitats for *J. graeca*.

***Zygaena brizae* (Esper, 1800)**

Material examined: 3b – 30.05.2016; 10a – 17.05.2015, 29.05.2015; 10c – 29.05.2015, 06.06.2016; 11a, 11c – 30.05.2015.

Remarks: *Zygaena brizae* is a xeromesophilic species with a Ponto-Mediterranean distribution. The larva feeds on *Cirsium* spp., *Onopordum* spp., *Carduus* spp. and *Jurinea* spp. (Efetov 1990, Naumann et al. 1999). It is a very local species on the Balkan Peninsula and in Serbia it is reported from Bački Monoštor, Košutovački potok in Ibarska Klisura Gorge (Jakšić & Ristić 1999), Deliblato Sands, Stol and Petrovo selo (Nahirnić et al. 2012) and Sonta (Šašić et al. 2016). This species seems to be easily overlooked and probably not distinguished from *Z. purpuralis* (Brünnich, 1763) which is larger and has a wider distal part of the middle streak on the forewing.

The majority of the habitat types for *Z. brizae* belong to E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*). *Carduus candicans* was present in the same habitat as *Z. brizae* in 10a, 10cb and 9b, and especially abundant at 10a thus we assume that it can be a potential host-plant for caterpillars. Several individuals were noticed at 10a (Fig. 2c), some of them resting and other nectaring on *C. candicans*. We suppose that the pollen noticed on hairs of the thorax and head of *Z. brizae* belongs to this plant species. In this way *Z. brizae* can be considered a pollinator of this comparatively rare plant.

***Zygaena diaphana* Staudinger, 1887**

Material examined: 1a – 05.08.2016, 4th to 5th instar larvae; 2b – 14.06.2014 – adults; 3b – 14.07.2016, 3th to 4th instar larvae; 12 – 16.06.2015 – adults, 27-29.05.2016 – last instar larvae, 22.07.2016 – first to third instar larvae.

Remarks: The species rank of *Z. diaphana* was reinstated by Nahirnić (2016). For a long time it was considered to be conspecific with *Z. minos*. Adults can be mixed with *Z. minos* and *Z. purpuralis*, however, genitalia, larvae and host-plants are different, although the female genitalia of *Z. diaphana* and *Z. minos* show no differences. *Z. diaphana* is distributed in Albania, Macedonia, Bulgaria, Greece and Turkey (Naumann et al. 1983, Nahirnić et al. 2013, Nahirnić 2016). Host-plants are *Eryngium amethystinum* L., *E. campestre* L. and *Falcaria vulgaris* Bernh. (Naumann et al. 1983, Efetov 1990, Hofmann & Tremewan 2017).

Zygaena diaphana is not yet known from Serbia. The nearest locality is the Kresna gorge (Bulgaria), ca. 155 km distant from Gornji Krivodol (Stara Planina Mts). Mt. Tresibaba is the northernmost locality of *Z. diaphana*. As there are more suitable habitats in whole eastern Serbia, it would be no surprise to find this species further in the north. The closest locality for *Z. minos* is at Mt. Domogled in Romania, ca. 150 km from Mt. Tresibaba.

Previous data on habitats and host-plants of *Z. diaphana* in the whole Balkans do not exist. All larvae which we found were feeding on *E. campestre*. *Zygaena diaphana* habitats in eastern Serbia can be grouped in one habitat type E1.2 Perennial calcareous grassland and basic steppes. The habitats where we found the species are with low vegetation and presence of bare ground and rock outcrops. Other habitats of *Z. diaphana* in the Balkan Peninsula show xerothermic character as well (A. Nahirnić, pers. obs.). In eastern Serbia it occurs in diverse landscapes such as karst gorges of Svrljiški Timok River (Fig. 2a) and Jelašnička Klisura, Tresibaba mountain pass and in higher altitudes in the mountain like Stara planina on south-westerly exposed slopes (Fig. 2e).

***Zygaena laeta* (Hübner, 1790)**

Material examined: 6 – 22.06.2017, one last instar larva.

Remarks: *Zygaena laeta* is a Ponto-Mediterranean faunal element found from Austria and the Czech Republic to Turkey, Lebanon and southern Russia (Naumann et al. 1999). *Eryngium* species are confirmed to be its host-plants (de Freina & Witt 2001).

To date *Z. laeta* has been recorded only once in Serbia, near Prizren in 1986 (Jakšić 1986). Our discovery on Mt. Šljivovički Vis presents only the second locality in the country.

There are two main parts of its distribution in Europe: in the north it is found in the Czech Republic, Slovakia, eastern Austria and Hungary, whilst in the south it is established in Greece, Republic of Macedonia, southern Serbia and most of Bulgaria, Dobrogea in Romania and Turkish Thrakia (Thrace). Between these two areas of distribution there is a gap, with a single known locality at Băile Herculane in Romania near the border of Serbia. With our discovery on Mt. Šljivovički Vis this gap is partially filled out. The distance to Băile Herculane (in the north) is ca. 193 km and the nearest site in the southern area is Sofia (in the SE) at a distance of ca. 90 km. We assume that *Z. laeta* is continuously distributed along the line of Băile Herculane – Šljivovički Vis – Sofia since there are suitable habitats in this area.

From data so far published on *Z. laeta* habitats in the Balkans (Karnoschitzky 1954, Micevski et al. 2018) we can only conclude that it is found in open areas where deciduous forests are primary potential vegetation. Despite intensive search for *Eryngium*-feeders, we found only one final instar larva feeding on *E. campestre* at Mt. Šljivovički Vis (Fig. 2d). This is in concordance with the majority of published works, which report that only single individuals have been found (Buresch & Tuleshkow 1943, Daniel 1964). Possible reasons for being so local and rare can be the behaviour and small population size of the species which make it easily overlooked.

***Zygaena punctum* Ochsenheimer, 1808**

Material examined: 1a – 05.08.2016, 4th to 5th instar larvae, 14.06.2017, one half-grown larva; 3a, 3b – 30.05.2016 – last instar larvae; 3a – 14.07.2016, first and second instar larvae; 3a – 09.06.2017 – half-grown larvae and one adult male; 3b – 09.06.2017 – last instar larvae, pupae; 5a, 5b – 18.05.2016 – last instar larvae, 17.07.2016, first and second instar larvae; 6 – 19.05.2016, last instar larvae, 21.05.2017 – last instar larvae; 10a – 17.05.2015; 11b – 22.07.2016, eggs; 12 – 27-29.05.2016, last instar larvae.

Remarks: *Zygaena punctum* Ochsenheimer, 1808 is an expansive Ponto-Mediterranean faunal element. It is a xerothermophilic species and a specialist on *Eryngium* species. The moth is known in Serbia from the Vojvodina Province at Deliblato Sands (Rothschild 1909-1917, Nahirnić et al. 2012). Although just possible, we consider data for Stol, Bor and Gamzigradska Banja Spa, reported in Zečević & Radovanović (1974) and Zečević (2002) doubtful, since *Z. punctum* has not been traced in Zečević's collection (Nahirnić et al. 2012).

Zygaena punctum was found to be widely distributed across the study area, more so than any other species. It was observed at almost every site where *E. campestre* was abundant. Larvae were abundant, sometimes with several larvae on one plant or 2-3 individuals on the same leaf. It was especially abundant at Mt. Šljivovički Vis (Fig. 2f) and at Gornji Krivodol on the Stara Planina Mts (Fig. 2e). Apart from Jelašnička Klisura (3a), where a single male was found, no adults were observed in spite of several localities being visited during the flight period. A possible explanation might be fluctuations of population size or a high level of parasitism. In such cases searching for eggs and larvae on *E. campestre* is very useful technique for finding *Z. punctum*. All habitats where *Z. punctum* was observed can be grouped into EUNIS habitat type E1.2 Perennial calcareous grassland and basic steppes, of which the majority belongs to E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*).

As in the case with *Z. punctum*, both *Z. laeta* and *Z. diaphana* also feed only on *E. campestre* in eastern Serbia, since no other *Eryngium* species is common in the wider region. None of these three species have been found in habitats affected by undue human pressure in vicinity of our study localities. *E. campestre* is widely distributed and common in the studied area but *Z. laeta* and *Z. diaphana* were found on one and four sites, respectively. *Zygaena punctum* possibly has a broader ecological niche in comparison to *Z. diaphana* and *Z. laeta* as its larvae have been found in open and half-shady habitats, while those of *Z. diaphana* and *Z. laeta* occurred only in open habitats. We assume that when succession takes place and the abundance of *E. campestre* decreases, *Z. punctum* will be the last to disappear from habitats where it is syntopic with *Z. diaphana* and *Z. laeta*.

Discussion

Habitats

All habitat types where we recorded rare Zygaenidae are more or less common in eastern Serbia and increased sampling effort in suitable habitats would probably show that all species are widespread in this region. EUNIS habitat type E1.22 Arid subcontinental steppic grassland (*Festucion valesiacae*) can be considered as the priority habitat type for rare Zygaenidae in eastern Serbia. According to the Serbian national classification, which is locally more precise than EUNIS, habitat type C1.311 Arid shrub-grassy carbonate bedrock with myrtle spurge (*Euphorbia myrsinites*) was suitable for *Z. brizae*, *Z. diaphana* and *Z. punctum*, C1.32C Arid carbonate bedrock with dwarf sedge (*Carex humilis*) for *A. albanica*, *Z. diaphana*, *Z. laeta* and *Z. punctum,* C1.321 Arid carbonate meadow of Volga fescue (*Festuca* gr. *valesiaca*) for *J. graeca, Z. brizae* and *Z. punctum* and C1.328 Arid carbonate bedrock with feather-grass (*Stipa pulcherrima*) for *Z. punctum*, *J. graeca* and *Z. brizae*. The most important plant associations for their occurrence were *Carici humilis-Stipetum pulcherrimae* and *Potentillo-Caricetum humilis*. Concerning Natura 2000 classification, the majority of the habitat types are grouped in a 6240 * Sub-pannonic steppic grasslands which is priority habitat type. EUNIS habitat types belonging to E1.2 correspond to Natura 2000 type 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*), considered as important orchid sites. In the national legislation of Serbia, C1.311 is a habitat type of priority conservation importance (Lakušić & Lazarević 2010). In this habitat type we found *Z. brizae*, *Z. diaphana* and *Z. punctum*.

Conservation

Quarries for limestone cause direct and irreversible destruction of habitats for rare Zygaenidae. Afforestation with Black pine (*Pinus nigra* Arnold) was done at every study site or in its vicinity. The negative consequences are of a long-term nature

and are primarily due to increasing shading over time, which causes change in the composition and structure of former grassland and also facilitates encroachment of shrubs and trees. The spreading of the invasive tree species *Ailanthus altissima* (Mill.) Swingle also has shading effect. The most important and widely spread threat, however, is vegetational succession following abandonment of traditional agriculture. We can divide rare Zygaenidae species in three groups which require different management. The first group consists of pasture and early-succession species *J. graeca*, *Z. brizae*, *Z. diaphana*, *Z. laeta* and *Z. punctum* whose host-plants are spiny species (*E. campestre*, *Carduus* spp., *Cirsium* spp.). Vassilev et al. (2011) found an increase of these plant species in pastures grazed by sheep compared to abandoned pastures. These host-plants are considered undesirable species in pastures, and management usually involves their removal; this is an understandable action that could usefully be halted in particular areas where they are proven to host rare species of Zygaenidae. Continuous light grazing should be applied, with lower intensity on steep and eroded slopes. Light sheep grazing was applied for at least 20 years at the same habitat on Vidlič (10a) where *J. graeca*, *Z. brizae* and their potential host-plant *C. candicans* were abundant and presents a good example of suitable habitat and appropriate management. The most suitable habitats for *Z. diaphana*, *Z. laeta* and *Z. punctum* are the early successional stages of natural and semi-natural grasslands with very low level of ruderalisation and invasion of shrubs and trees. Succession and afforestation change light conditions and do not favour *E. campestre,* the only host-plant for *Z. diaphana, Z. laeta* and *Z. punctum*. The spreading of *A. altissima* is evident in Jelašnička Klisura Gorge where it affects habitats for the heliophilous species *J. graeca*, *Z. brizae*, *Z. diaphana* and *Z. punctum*. The second group is mid-successional species *A. albanica* whose host-plant is *G. sanguineum*, a diagnostic species of abandoned semi-natural grasslands (Vassilev et al. 2011). Accordingly, grazing should be avoided where *A. albanica* occurs and further succession should be prevented by shrub cutting. *Rh. pruni* is a species of the third group. Species like *Rh. pruni* benefit from late-succession as its host-plants are shrub species. Even though suitable habitats for *Rh. pruni* are widespread in all of Serbia, this species occurs very locally. Clearing of shrubs and trees may be applied in order to restore grasslands, however this measure should not be intense and mosaic of habitats should be maintained. While taking some management actions it should be taken in account that rare species with different habitat preferences can occur at only dozens metres far from each other. This is the case with *A. albanica*, *J. graeca* and *Z. brizae* at Crni Vrh, *A. albanica*, *Z. laeta* and *Z. punctum* at Šljivovički Vis and *Rh. pruni*, *J. graeca* and *Z. diaphana* at Tresibaba pass.

Conclusions

Our study revealed the presence of seven rare Zygaenidae species that were known from very few localities in Serbia, including two species, *A. albanica* and *Z. diaphana*, which are reported here for the first time. The Balkan mountain system in eastern Serbia hosts suitable habitats for rare Zygaenidae species, especially those preferring warm and arid habitats. Such habitats usually support a sparse coverage of low vegetation and are, therefore, threatened by becoming overgrown. In eastern Serbia landscapes of arid, rocky grasslands on calcareous substrates in gorges, mountain slopes or plateaus are mostly outside formally protected areas so that management is challenging. Further similar studies in other parts of Serbia are needed for evaluation of the conservation status of Zygaenidae species.

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