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***Zygaena diaphana* (Brünnich, 1763) is a cryptic taxon that has been misidentified in Hungary (Lepidoptera: Zygaenidae)**

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Abstract. The author has reviewed recently published specimens under the name *Zygaena diaphana* in Hungary. He concludes that the identification is incorrect. All specimens belong to the species *Zygaena purpuralis*. He discusses the reasons for the misidentification. Historical analysis of Hungarian and international research on the species-complex of *Zygaena purpuralis-minos-diaphana*. In his opinion, questions of taxonomy, bionomics and geographical distribution of the species-complex are problematic in many respects and not well understood. The paper is illustrated with habitus images, genitalia diagrams and maps.

Keywords. Lepidoptera, Zygaenidae, *Zygaena diaphana*, misidentification, Hungary.

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Zusammenfassung. Der Autor hat kürzlich veröffentlichte Exemplare unter dem Namen *Zygaena diaphana* überprüft in Ungarn. Er kommt zu dem Schluss, dass die Identifizierung falsch ist. Alle Exemplare gehören zu der Art *Zygaena purpuralis*. Er erörtert die Gründe für die falsche Identifizierung. Historische Analyse der ungarischen und internationalen Forschung über den Artenkomplex von *Zygaena purpuralis-minos-diaphana*. Seiner Meinung nach sind Fragen der Taxonomie, der Bionomie und der geografischen Verbreitung des Artenkomplexes in vielerlei Hinsicht problematisch und nicht gut verstanden. Der Beitrag ist mit Habitus Bildern, Genitalien-Diagrammen und Karten illustriert.

Introduction

The traditional species inventories are subject to a high risk of overlooking cryptic species. In particular, large-scale comparison of morphology for most species is hardly possible due to the lack of sufficient comparative material in reference collections and often too many species to be studied in detail. Furthermore, a morphology-based approach does not consider a very important part of biodiversity, namely genetic diversity (Huemer & Wieser 2023). This is particularly true for the Hungarian micro-moth fauna.

I started studying the Hungarian Zygaenidae species in the second half of the 1970s. One reason for this was that many taxa were misidentified in Hungarian collections and publications. Hungarian researchers did not have an adequate definition book in their hands. Most of them used Gozmány's work published in 1963 in the "Fauna Hungariae" series. This publication was a Hungarian adaptation of Alberti's publications, with few good habitat descriptions.

I have summarized the comprehensive study of the Hungarian Zygaenidae fauna in two major monographs (Fazekas 2009, 2021). In this present paper, I deal with the species complex *Zygaena minos-purpuralis-diaphana*. I have written about this complex before, but since then Schmidt (2022) has reported seven specimens of *Zygaena diaphana* from the Bakony Mountains in Central Hungary. I consulted Peter Schmidt, who told me he is not competent in identifying Zygaenidae species. The museum in Kaposvár bought the private collection of the late Ferenc Sebök in 2002. Sebök was an amateur lepidopterologist from Várpalota, Hungary, who collected 90% of his insects from nearby Várpalota and the Eastern-Bakony Mountains. Altogether, the collection includes around four thousand specimens of 648 species, including nationally rare taxa. Amongst material, Peter Schmidt found seven examples identified as *Zygaena diaphana*. Unfortunately, Schmidt did not verify the identification but accepted Ferenc Sebök's determination. Thus, the name *Zygaena diaphana* appeared in a Hungarian publication (Schmidt 2022, p. 57): "*Zygaena diaphana* Staudinger, 1887: VPFH: 7 pl. 1999.06.27."

I have examined the specimens, including examination of the genitalia; the identifications proved to be wrong. All the specimens belong to *Zygaena purpuralis*.

Material and methods

The specimens were examined under a stereo microscope at different magnifications. Specimens from different geographical areas of Hungary were compared with the problem specimens listed in the study section. Genitalia dissections were done in accordance with Robinson (1976). Some of the genitalia were mounted in Euparal on slides; others are preserved in micro-vials filled with glycerol.

Results

Zygaena purpuralis (Brünnich, 1763)

Sphinx purpuralis Brünnich, 1763; in Pontoppidan, Den Danske Atlas 1: 686, pl. 30. fig. Locus typicus: Denmark, Sjælland.

References: Alberti 1954; Alberti 1958–1959; Fazekas 1984; Fazekas 1998; Fazekas 2000; Fazekas 2002; Fazekas 2009; Fazekas 2013; Fazekas 2021; Fernández-Rubio 2005; Forster & Wohlfahrt 1960; Freina & Witt 2001; Gozmány 1963; Nahimič. & Tarmann 2016; Nahimič 2019; Naumann et al. 1999; Rennwald 2023; Reiß 1966; Rennwald 2023; Rézbányai 1979; Schmidt 2022; Stamm 1970.

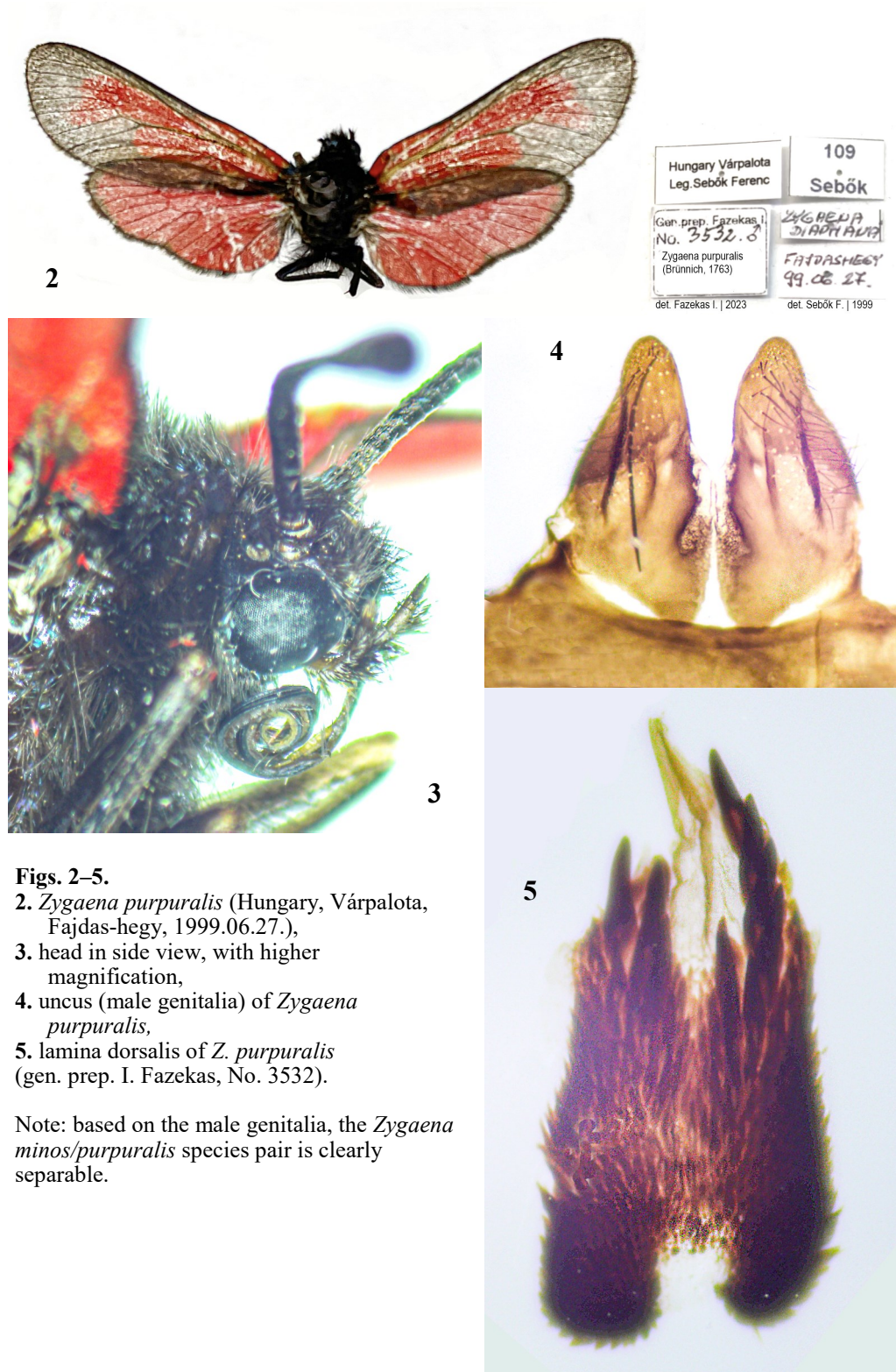
Examined Materials: 7 ex, Hungary, Várpalota, Fajdas-hegy, 1999.06.27., leg. et det. Sebők Ferenc, misidentification: *Zygaena diaphana*. Revised by Imre Fazekas, gen. prep. No. 3532, ♂, in coll. Rippl-Rónai Museum, Kaposvár.

Diagnosis. Length of the forewings: ♂♂ 13–16 mm, ♀♀ 14–14 mm. Very similar to *Zygaena minos* species. However, the forewings are broader, and the red stripes are more extensive. The apex of the central stripe is often spread out like a fan. Six-spotted, spots confluent to form their streaks: 1. 2+4, 3+5+6. There are many formats known about the Hungarian geographical areas. The most certain way to identify these variations is by genital examination. Distinguishing between the two species based on the larva is easy: the larva of *Z. purpuralis* is yellow and the larva of *Z. minos* is white.

Genitalia. The most important species markers are the uncus and lamina dorsalis forms. The uncus apex is wider and more pronounced than the *Z. minos* apex. The apex of the *Z. minos* is tapering, and arching. The lamina dorsalis at *Zygaena purpuralis* is long, narrower, and concave in the middle, much wider in *Zygaena minos*, and convex medially.



Fig. 1. The specimens examined, which were incorrectly identified as *Zygaena diaphana*: Hungary, Várpalota, Fajdas-hegy, 1999.06.27., leg. et det. Sebők Ferenc. Correct identification: *Zygaena purpuralis* (det. I. Fazekas).



Figs. 2–5.

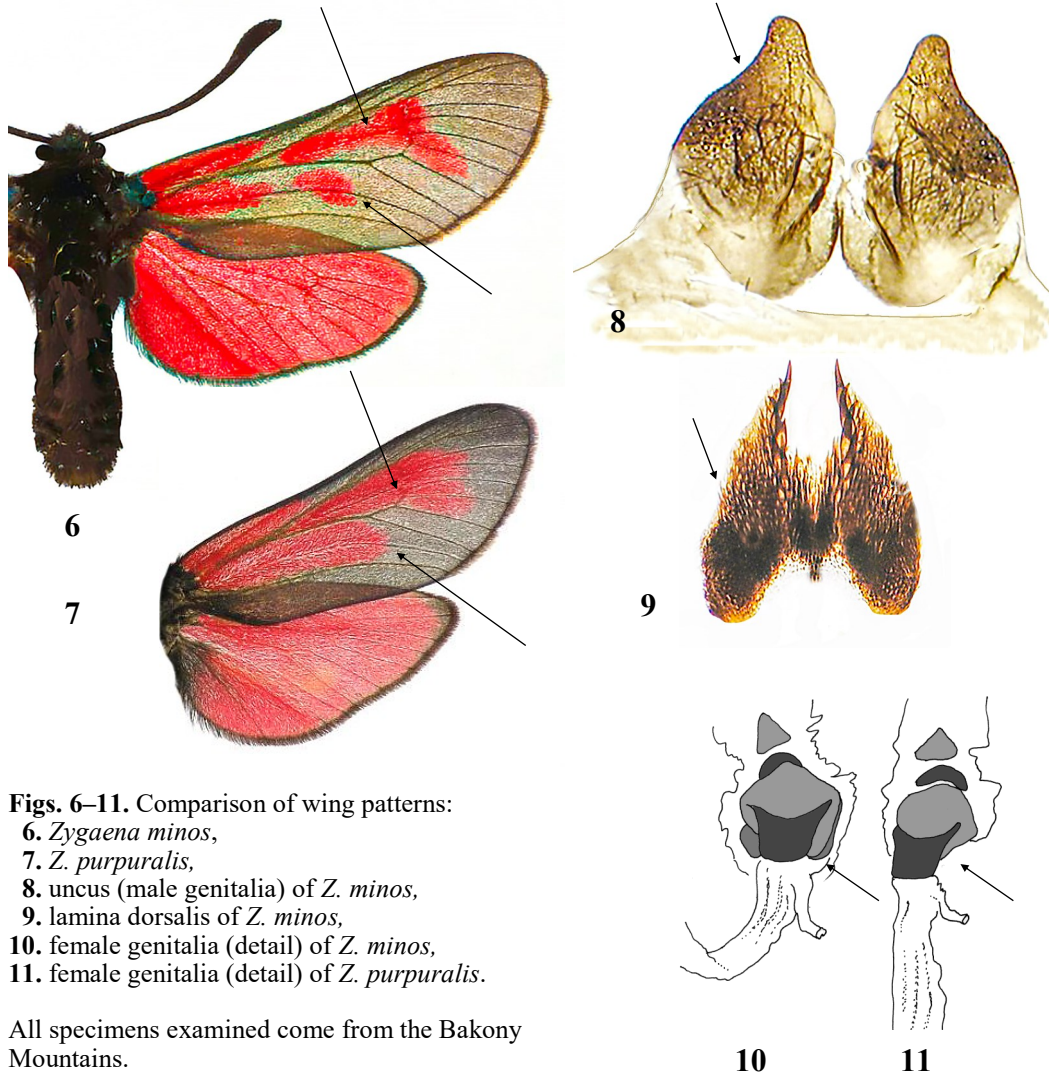
2. *Zygaena purpuralis* (Hungary, Várpalota, Fajdas-hegy, 1999.06.27.),

3. head in side view, with higher magnification,

4. uncus (male genitalia) of *Zygaena purpuralis*,

5. lamina dorsalis of *Z. purpuralis* (gen. prep. I. Fazekas, No. 3532).

Note: based on the male genitalia, the *Zygaena minos/purpuralis* species pair is clearly separable.



Figs. 6–11. Comparison of wing patterns:
 6. *Zygaena minos*,
 7. *Z. purpuralis*,
 8. uncus (male genitalia) of *Z. minos*,
 9. lamina dorsalis of *Z. minos*,
 10. female genitalia (detail) of *Z. minos*,
 11. female genitalia (detail) of *Z. purpuralis*.

All specimens examined come from the Bakony Mountains.

Research and literature reviews

For many decades, Hungarian moth researchers have worked on the basis that it is not easy to distinguish between the species *Zygaena purpuralis*, *Z. diaphana*, *Z. pimpinellae*, and *Z. minos*. This was the problem faced by Lajos Kovács at the turn of the 20th century (see Fazekas 2013), but the confusion was later compounded for those who used Forster and Wohlfahrt's (1960) book on Central Europe or Gozmány's (1963) "Fauna Hungariae" fauna book to organize their collections. Forster's book was considered by many to be a "genus-splitting" exercise since it sought to elevate names such as *Mesembrynus*, *Cirsiphaga*, *Hyala*, *Silvicola*, etc. to genus level and in doing so, rather than helping research on the Central European Zygaenidae, it added to the already confusing taxonomic and nomenclatural confusion. At this time, Burchard Alberti (1965) was also overly critical, strongly criticizing Forster: "... all the subgenera of *Zygaena* are listed as separate genera. This position contradicts all practical needs." From a Hungarian point of view, the basic root of the problem is to be found in the fact that the "*minos*" described by Denis and Schiffermüller (1775) from the Vienna Basin escaped the attention of Abafi-Aigner

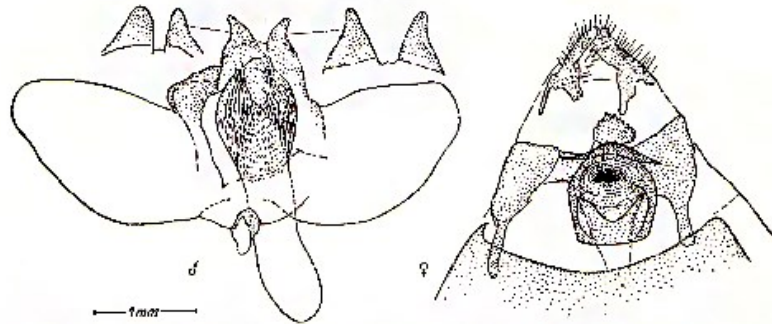
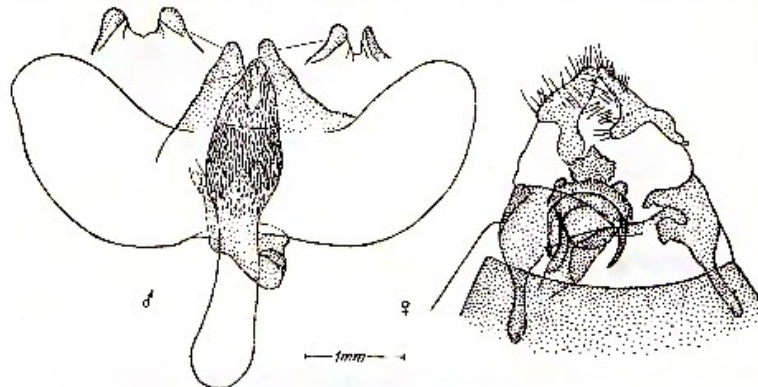
Abb. 44. Genitalapparat von *Mesembrynus sareptensis* Krul. (Nach Svensson)Abb. 45. Genitalapparat von *Mesembrynus purpuralis* Brün. (Nach Svensson)

Fig. 12. Forster and Wohlfahrt's (1960) book genitalia diagrams of "*Mesembrynus sareptensis*" (above) and „*M. purpuralis*" (see text for details).

and Pável (1896), Abafi-Aigner (1907) and later Gozmány (1963). Of course, this is hardly surprising, since a major specialist such as B. Alberti (1958) did not even mention the name "*minos*" in his comprehensive Palearctic revision. Based on the former work of Alberti, Gozmány prepared, in 1963, the first definitive work on Hungarian Zygaenids.

According to Gozmány (1963), in Hungary "*Zygaena diaphana* STGR. ssp. *pimpinellae* GUHN." taxon occurs. The stripes on the forewing are very narrow, often only half as wide as the spines, braided, broken into patches, shorter. The axe-shaped end of the second stripe shrinks, and only the lower corner extends downwards between the veins m_3 - u_1 . Otherwise remarkably like the *Zygaena purpuralis* species. The author has not provided a picture or drawing of the wing habitus. In the male genitalia, the lamina dorsalis is broad, almost semi-ovate, with its larger spines closer to the margins of the lobes (Fig. 125: C-D). 33-36 mm. Gozmány (1963) adopted the diagram of the lamina dorsalis from Alberti, redrawn. Unfortunately, he did not give the exact date of Alberti's publication; one can only assume that Alberti's publications are from 1954 or 1958-1959.

In his work Alberti (1958, Plates 30, 31, 32) reported the lamina dorsalis of *Zygaena diaphana* and *Z. purpuralis* species from several sites. According to Alberti, the morphology of

the lamina dorsalis is highly variable. It is exceedingly difficult to orientate and identify species. This may have led to inconsistent identification of species by several researchers and publications.

I have dealt with the complex taxonomic, bionomic, and geographical distribution of *Zygaena purpuralis-minos-diaphana* in almost all my publications (see references). My research has so far only confirmed the species *purpuralis* and *minos* from Hungary.

Fazekas wrote the following about *Zygaena minos* in his 2009 book: Due to earlier taxonomical problems, the exact geographical distribution of *Z. minos/purpuralis* species-pair is only partially known. The author gives a detailed analysis of the differential features of the species-pair and has begun a complete revision of the Hungarian collection (Fazekas 2002: 148 p.). Habitat: the widespread species is ecologically non-flexible; mainly on hills and in mountains of medium height, on dry meadows, on pastures and waysides at altitudes from 90 m to 900 m. Larval foodplants: *Eryngium campestre*, *Falcaria vulgaris*, *Pimpinella saxifraga*. Phenology: univoltine from early June to mid-August. Distribution and conservation status in Hungary: uncertain due to incomplete research. Known only in local populations.

In the book above, the species *Zygaena purpuralis* is described as follows: Known mainly in the mountains, on the low hills, and locally on the plains. Phenology: univoltine, from late May to early August. Larva oligophagous: *Thymus pannonicus*, *T. praecox*, *T. serphyllum*. Habitat: This widespread species is ecologically very flexible; rock and slope steppes, white oak scrub woodlands, sweet chestnut woodlands, on closed loess and sand steppes. Distribution and conservation status in Hungary: locally distributed species which can occur in large numbers in favourable places.

Nahirnić's (2016, 2019) research on the Balkans has once again drawn my attention to the problem of the possible occurrence of "*diaphana*" in Hungary. Nahirnić (2019) declares *Zygaena diaphana* Staudinger, 1887 (and immediately *Zygaena smirnovi* Christoph, 1884) to be a bona species. The rationale for this move lies in a local co-occurrence of *Z. minos* and "*Z. diaphana*" in southwestern North Macedonia (based on old label data alone!) and distinctive features of the male genitalia. Different caterpillar food plants (*Pimpinella saxifraga* for *Z. minos*, *Eryngium* species for "*Z. diaphana*") are also included as justification for the separation at the species level. This step is not followed here, because the alleged sympatric occurrence is by no means convincingly substantiated at the population level, and the separation according to food plants of the caterpillars is far more complicated and does not follow such a clear boundary. Hofmann & Tremewan (2017: 65–75) in a separate chapter "Chapter 3. The *Zygaena purpuralis/minos* complex: an example of complicated taxonomy in *Zygaena* species" dealt in detail with all the arguments presented by Ana Nahirnić at meetings and had convincingly clarified that in terms of a biospecies concept, it makes no sense at all to want to separate the taxa at the species level.

According to Gerhard Tarmann (pers. comm. on 08. iii. 2023), *Zygaena diaphana* is a separate species and different from *Zygaena minos*. In his letter to me, he wrote: "I do not agree with Hofmann & Tremewan. I think Ana Nahirnić is right. I saw all the Balkan material myself and the genitalic differences are constant. Moreover, *Z. minos* has a different distribution."

Hofmann & Tremewan (2020: pp. 187–188) summarize their extensive discussion: "Summarizing one can say that western, northern and central European populations live exclusively on *Pimpinella* spp., while these plants are not recorded from Anatolia, where *Eryngium* spp. and *Falcaria* ssp. are known as larval host-plants; also in Iran and the southern Balkans and eastern Greece *Eryngium* spp. are the host-plants, while further north in the Balkans an overlap or mix of larval host-plants is to be expected."

Conclusions

Morphological and genital studies have not confirmed the occurrence of *Zygaena diaphana* in Hungary. Based on the literature, the taxonomic status of *Zygaena diaphana* is uncertain. Further molecular phylogenetic studies are needed to confirm the species' status. It is questionable whether the northern distribution boundary now drawn in the Balkan Peninsula is real or whether it occurs much further north or west. The *Zygaena* species identification is critical to biodi-

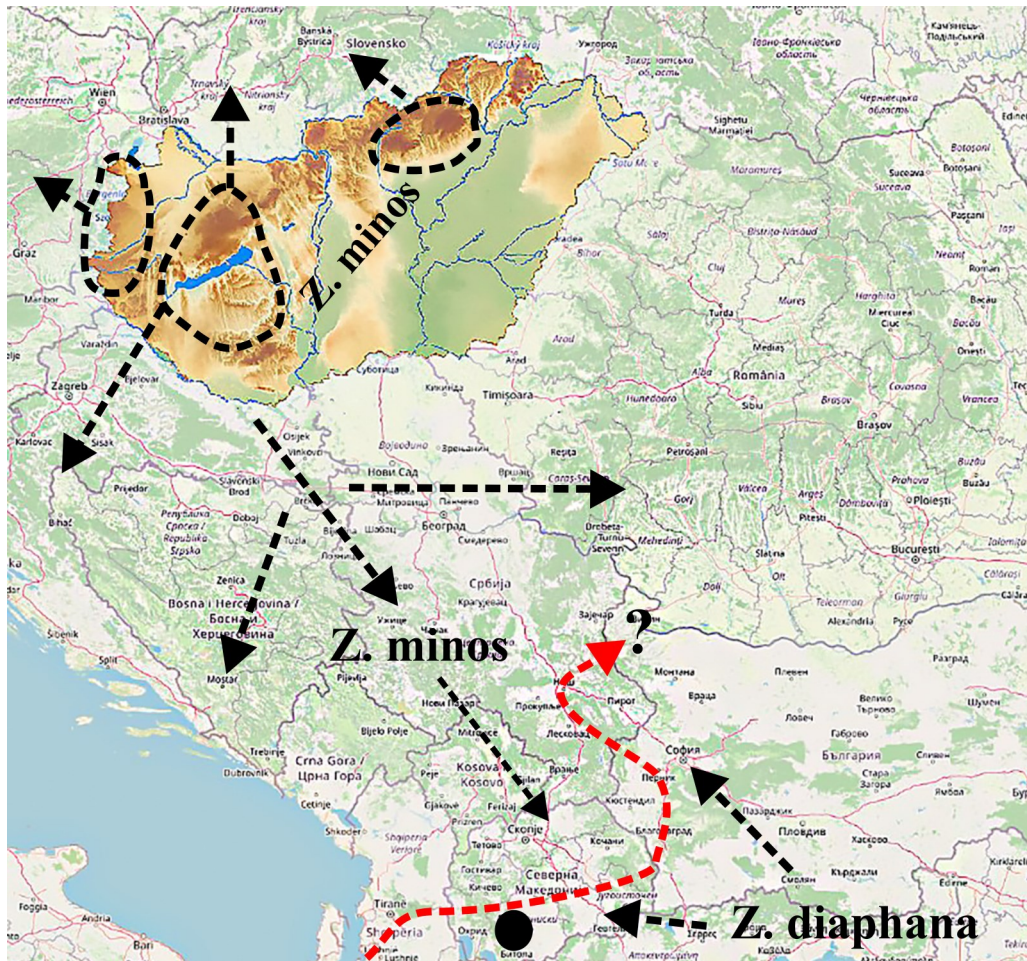


Fig. 13. Schematic distribution pattern of the species pairs *Zygaena minos/diaphana* in Hungary and the north-western Balkans. The red line indicates the boundary of the two species. The black circle is the first evidence of the sympatric occurrence of the two taxa after Nahirić (2019).

versity and distribution patterns. Among the most widely used are the biological species concept, which is based on reproductive isolation, and the phylogenetic species concept, which is based on reciprocal monophyly. In contrast, morphology-based taxonomy usually appeals to the phenetic species concept, which remains a key framework for species identification in practice. The last decade has witnessed the growing availability of genetic methods for species identification, providing a valuable complement to morphological taxonomy.

According to Gavrilets (2003) there are three main modes of speciation that differ in terms of the assumed degree of gene flow: allopatric, parapatric, and sympatric speciation. The results of comparative morphology be interpreted alongside other lines of evidence, with molecular species delimitation, population genetics, and ecology. In the case of the *Zygaena diaphana* species, it is difficult to decide whether it is a "good" species or a so-called "beginner" species.

Acknowledgements

Thank you to Peter Schmidt (H-Kaposvár) for providing Zygaenidae specimens for examination. I thank Gerhard Tarmann (A-Innsbruck) for valuable information on the manuscript. I especially thank Colin W. Plant (UK-Bishops Stortford) for his linguistic corrections and comments on a draft of this paper.

Összefoglalás

A *Zygaena diaphana* (Brünnich, 1763) Magyarországon tévesen azonosított rejtélyes taxon (Lepidoptera: Zygaenidae)

Fazekas Imre

A magyar Zygaenidae fauna átfogó vizsgálatát két monográfiában foglaltam össze (Fazekas 2009, 2021). Jelen dolgozatban a *Zygaena minos-purpuralis-diaphana* fajkomplexummal foglalkozom. Erről a fajkomplexumról már korábban is írtam, de azóta Schmidt (2022) hét *Zygaena diaphana* példányt mutatott ki a Bakony hegységből, s amelyet korábbi kutatásaim nem igazoltak.

Konzultáltam Schmidt Péterrel, aki elmondta, hogy nem kompetens a Zygaenidae fajok azonosításában. A kaposvári múzeum 2002-ben vásárolta meg a néhai Sebők Ferenc magángyűjteményét. Sebők amatőr lepidopterológus volt Várpalotáról, aki rovarainak 90%-át a Várpalotán és a Kelet-Bakony hegységben gyűjtötte. A gyűjteményben összesen 648 faj mintegy négyezer példánya található, köztük nagyon ritka taxonok. Ebben az anyagban Schmidt Péter hét olyan példányt talált, amelyeket *Zygaena diaphana* névvel cédulázott fel Sebők Ferenc. Sajnos Schmidt nem ellenőrizte az azonosítást, hanem elfogadta Sebők Ferenc meghatározását. Így jelent meg a *Zygaena diaphana* név egy magyarországi publikációban (Schmidt 2022, 57. o.): "*Zygaena diaphana* Staudinger, 1887: VPFH: 7 pl. 1999.06.27."

A hét példányt megkaptam vizsgálatra. Bebizonyosodott, hogy az összes példány egyértelműen a *Zygaena purpuralis* (Brünnich, 1763) fajhoz tartozik: revid. et det. Fazekas I., gen. prep. No. 3532, ♂, in coll. Rippl-Rónai Museum, Kaposvár. A *Zygaena diaphana* nevet törölni kell a Schmidt (2022) fajlistájából.

A teljesség igénye nélkül röviden áttekintem, hogy mi vezethetett a téves identifikációhoz. A magyar lepkekutatók évtizedek óta abból indultak ki, hogy a *Zygaena purpuralis*, *Z. diaphana*, *Z. pimpinellae* és a *Z. minos* fajok megkülönböztetése nem könnyű. Ezzel a problémával már Kovács Lajos is szembesült a múlt század derekán (lásd Fazekas 2013), de a zürzavar később tovább fokozódott azok számára, akik Forster és Wohlfahrt (1960) Közép-Európáról szóló könyvét vagy Gozmány (1963) "Fauna Hungariae" című faunakötetét használták a magyarországi Zygaenidae fajok azonosítására. Forster könyvét sokan "nemzetségsztó" próbálkozásnak tartották, mivel olyan neveket, mint a *Mesembrynus*, *Cirsiphaga*, *Hyalia*, *Silvicola* stb. igyekezett nemzetségszintre emelni, és ezzel ahelyett, hogy segítette volna a közép-európai Zygaenidae-k kutatását, inkább tovább növelte az amúgy is zavaros rendszertani és nevezéktani zürzavart. Ebben az időben Burchard Alberti (1965) erősen bírálta Forstert, amikor így írt: "... a *Zygaena* összes alnemzettségét külön nemzetséggként sorolja fel. Ez az álláspont ellentmond minden gyakorlati igénynek". Forster és Wohlfahrt (1960, pp. 87–90) hosszan ír a "382. *Mesembrynus purpuralis* Brünn." és a "383. *Mesembrynus sareptensis* Krul" fajokról, és Svensson-ra hivatkozva ("Nach Svensson") sematikus csáp és genitália ábrákat is közölt, de az irodalmi forrást nem adta meg. A "*diaphana*" név a könyvben nincs megemlítve.

Magyar szempontból a probléma alapvető gyökere abban keresendő, hogy a Denis és Schiffermüller (1775) által a Bécsi-medencéből leírt "*minos*-ok" elkerülték Abafi-Aigner és Pável (1896), Abafi-Aigner (1907), majd Gozmány (1963) figyelmét is. Ez persze aligha meglepő, hiszen egy olyan jelentős szakember, mint B. Alberti (1958) átfogó palearktikus revíziójában még a "*minos*" nevet meg sem említette. Alberti korábbi munkája alapján Gozmány 1963-ban elkészítette a magyarországi zygaenidák első áttekintő művét.

Gozmány (1963) szerint Magyarországon a "*Zygaena diaphana* STGR. ssp. *pimpinellae* GUHN." taxon fordul elő. A szerző nem mellékelte képet vagy rajzot a szárnyhabitusról. Gozmány (1963) a lamina dorsalis ábráját Alberti-től vette át, átrajzolva. Sajnálatos módon nem adta meg Alberti publikációjának pontos hivatkozását; csak feltételezhetjük, hogy Alberti publikációi 1954-ből vagy 1958–1959-ből származnak. Gozmány (1963) Forster és Wohlfahrt 1960-as közép-európai könyvére faunafüzetében nem hivatkozik.

A *Zygaena purpuralis-minos-diaphana* összetett rendszertani, bionómiai és földrajzi elterjedésével szinte valamennyi publikációmban foglalkoztam (lásd a hivatkozásokat). Kutatásaim eddig csak a *Zygaena purpuralis* és a *Z. minos* fajokat igazolták Magyarországról.

Nahirić (2016, 2019) Balkán-kutatásai ismét felhívták a figyelmemet a "*diaphana*" taxonra. Ennek indoklása a *Zygaena minos* és a *Zygaena diaphana* helyi szimpatrikus előfordulásában rejlik Észak-Macedónia délnyugati részén, valamint a hím ivarszervek megkülönböztető jegyeiben. Az eltérő hernyó tápláléknövények (*Pimpinella saxifraga* a *Z. minos* esetében, *Eryngium* fajok a "*Z. diaphana*" esetében) szintén a fajszintű elkülönítés indoklásaként szerepelnek. Egyes szerzők (Hofmann & Tremewan (2017: 65–75) vitatják a *Zygaena diaphana* faji státuszát, míg mások így Gerhard Tarmann szerint (pers. comm. 2023.03.08.) a *Zygaena diaphana* egy különálló faj, és különbözik a *Zygaena minos*-tól. Nekem írt levelében a következőket közölte: "Nem értek egyet Hofmann & Tremewan-nal. Úgy gondolom, hogy Ana Nahirić-nak van igaza. Magam láttam az összes balkáni anyagot, és a genitális különbségek állandóak. Ráadásul a *Z. minos*-nak más az elterjedése".

Véleményem szerint a *Zygaena* fajok azonosítása kritikus fontosságú a biológiai sokféleség és az elterjedési minták szempontjából, ezért a *Zygaena diaphana* faji státuszának megerősítéséhez további molekuláris filogenetikai vizsgálatokra van szükség. Kérdéses, hogy a most meghúzott északi elterjedési határ a Balkán-félszigeten valós-e, vagy sokkal északabbra vagy nyugatabbra is előfordul (lásd Fig. 13).

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