https://doi.org/10.24386/LepHung.2022.18.1.5 HU ISSN 2732-3854 (print) | HU ISSN 2732-3498 (online)

Lepidopterologica Hungarica 18(1): 5–21. | https://epa.oszk.hu/04100/04144

Received 30.12.2021 | Accepted 18.01.2021 | Published: 26.01.2022 (online) | 06.26.2022 (print)
ZooBank: https://zoobank.org/References/CCD7222C-9CDB-4856-B9FA-2C7A400EF501

Zenodo: https://zenodo.org/record/6414610#.YkwsQdvP0wg

Distribution and bionomy of *Lyonetia ledi* Wocke, 1859 – a review with notes (Lepidoptera, Lyonetiidae)

Imre Fazekas

Citation. Fazekas I. 2022: Distribution and bionomy of *Lyonetia ledi* Wocke, 1859 – a review with notes (Lepidoptera, Lyonetiidae). – Lepidopterologica Hungarica 18(1): 5–21.

Abstract. *Lyonetia ledi* Wocke, 1859 is a very rare and little-known member of the Palearctic fauna. The populations can be very inconspicuous and can therefore have been passed unnoticed during previ-ous field studies. It is emphasized that the Palaearctic fauna further study and that habitats of *Lyonetia ledi* and other rare or declining species may yet be found. In Central Europe, *Lyonetia ledi* is very spo-radically distributed in only a few isolated localities. It is critically endangered in Switzerland, Austria, the Czech Republic, and Germany. It is considered an extinct species in Romania. Its occurrence in Hungary is based on an erroneous report. The centres of its European range are the Polish lowlands, the Baltic region, and the marshy, swampy areas of Scandinavia. The plains of Eastern Europe are little known and almost unexplored, although there are many potential habitats. The study of the vast Asian territories of Russia has much to offer. With 21 figures.

Keywords. Lepidoptera, *Lyonetia ledi*, distribution, bionomy, ecology, Palaearctic, Nearctic.

Author's address. Imre Fazekas | Pannon Institute | 7625 Pécs, Magaslati út 24. | Hungary
E-mail: fazekas@lepidoptera.hu

Introduction

The family Lyonetiidae is cosmopolitan and includes about 200–210 described species. The group is poorly known and needs taxonomic work. Lyonetiids are extremely small moths, usually with wingspans 9–12 mm. The frons is smooth scaled, and the base of the antenna forms an eye cap. The larvae are leaf or twig miners, usually of dicotyledonous plants.

There are several publications on the geographic distribution and bionomics of *Lyonetia ledi* (see references). Some of the older literature is uncertain and requires detailed revision. Many specimen collections have not been published. This applies mainly to European and Asian areas. One aim of this study is to describe the geographical distribution pattern of the species. The preliminary distribution map also shows large geographical areas where the spe-cies is not yet known. Some erroneous occurrence data that incorrectly refer to this species are pointed out.

It was particularly important to study the Hungarian and Romanian occurrences in the Carpathian Basin, because this region is the so-called fluctuation zone of the species. Accord-ing to botanical research, the Bátorliget marsh in eastern Hungary is a relict of the Ice Age. Gozmány (1965) indicated the 'potential' occurrence of *Lyonetia ledi* in this boggy area. This is considered by several literature sources (see Fauna Europaea) as a possible locality, alt-hough no verified specimens are known from the area. Pollen analytical studies (Csinády 1954) have shown that the preferred food plants of *Lyonetia ledi* did not exist in postglacial times in eastern Hungary.

In this paper. The results of personal studies so far are summarised, which will provide a basis for further research.

Material and method

All published literature, given under References, has been critically analysed. Korean, Russian, Scandinavian, and Central European researchers and been consulted, who reviewed specimens from their personal collections, and are acknowledged below. Several European habitats were studied personally.

Results

Lyonetia ledi Wocke, 1859 (Fig. 1.)
Jahres-Bericht der Schlesischen Gesellschaft für Vaterländische Kultur **37**, p.101.
Locustypicus nach Wocke (1859: 100): "im Seebade Misdroy auf der Insel Wollin" [Polen, Woiwodschaft Westpommern, Insel Wolin, Ostseebad Międzyzdroje].

Synonym: *Lyonetia candida* Braun, 1916, The Canadian Entomologist 48: 140–141. Locus typicus: "California, Santa Cruz Big Trees".

Previous records: Baraniak 1996, Baryshnikova 2007, 2019, Bengtsson & Johansson 2011, Buszko 1981, Buszko 2017, Buszko & Nowacki 2017, Deutschmann & Zessin 2009, Gozmány & Szőcs1965, Huemer & Schmid 2021, Ivinskis & Rimšaité 2018, Kozlov *et al.* 2014, Kuroko 1964, Laštůvka & Liška 2011, Marek *et al*. 1991, Matveev & Zolotuhin 2018, Reiprich 1992, Rennwald & Rodeland 2021, Robinson *et al.* 2010, Seksyaeva 1981, Shin et al. 1983, Sobczyk *et al.* 2018, Spuler 1910, Sterneck & Zimmermann 1933, Vavra 2000, Wocke 1874.

Diagnosis: Wingspan 8–11 mm. Head, frons and thorax shining white; labial palpus whitish tinged with pale fuscous externally; antennae 1 1/3 length of forewing, pale fuscous, becoming white towards the base, eyecup shining white. Abdomen greyish-fuscous above, shining white below. Forewing whitish on inner two-thirds; three strigulae from apical blotch to costa; two V-shaped light spots opposite each other on costal and dorsal margins; variable patches sometimes present in the medial space or along dorsum. The circular apical dot, apical transverse and apical pencil form a very characteristic complex.

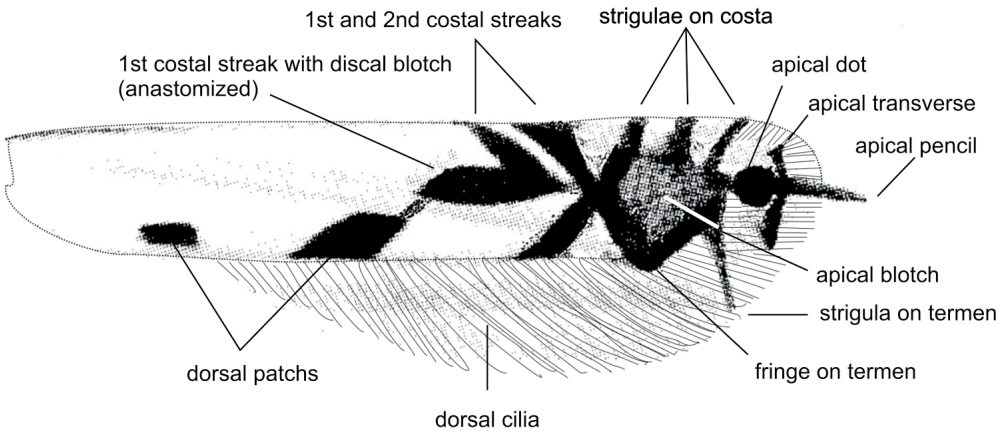
Male genitalia: arms of gnathos not fused, rather long protruded upwardly or inwardly curved, apices slightly forked; valva oblong, cucullus protruded; saccus triangularly pointed. Aedeagus stout, tapered towards incised and two-pointed apex.

Female genitalia: morphologically very different from other *Lyonetia* species. Ostium bursae broad and large, cup-shaped; ductus bursae broad, ductus seminalis opening into corpus bursae; corpus bursae rounded, without signum.

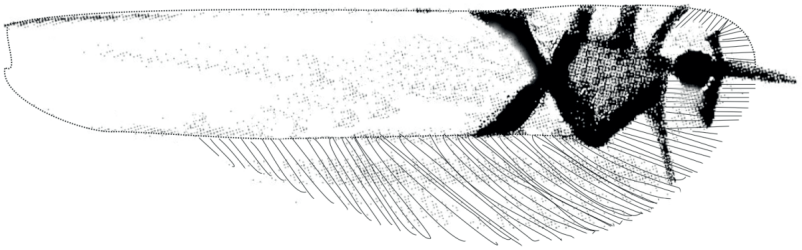
Distribution: *Lyonetia ledi* is a very widespread Holarctic species. It is known trans Palaearctic from central Europe to Scandinavia and Russia. It is known along the Volga River, north of the Caucasus, in the Omsk region, in the Altai region, in the Lake Baikal area; in the Russian Far East, mainly in the Amur region, in Shiota-Alin, as far as Vladivostok. There may be populations in the southern Siberian landscapes of Russia, but the area has not been surveyed. It is widespread in South Korea and on the Japanese islands. No data yet available from North Korea and the Northeast of China.

Special attention should be paid to the area beyond the Ural Mountains. In particular, the marshlands of the Irtysh and Ob rivers and the tributaries of the Yenisei and Lena rivers. The huge geographical protection of Sakhalin and Kamchatka is also in question.

In the Nearctic, *L. ledi* is found in Canada including British Columbia Yukon Territory, Quebec, Mingan Island, Prince Edward Island, Newfoundland, Labrador, and Nova Scotia, and in USA in California. Some consider it to be a boreal species; others emphasize its circumpolar distribution (Huemer & Schmid 2021). Most populations are highly fragmented and relict. Its provisional Palaearctic distribution is shown in Figure 17. European localities are highlighted in Figure 15.



Diagrammatic representation of the right forewing of Lyonetia ledi

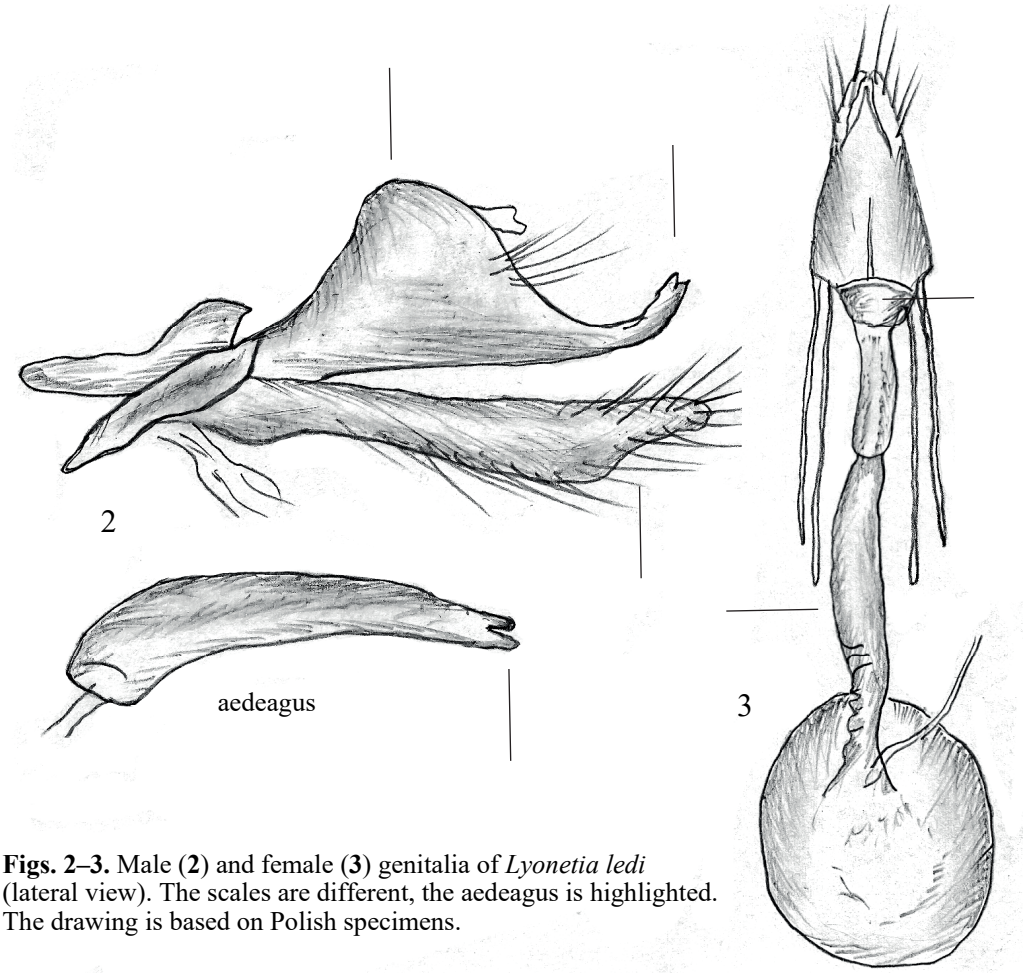


Inner two-thirds of the right forewing of Lyonetia ledi free of spots,
lacking discal and dorsal spots

The typical pattern of Lyonetia ledi is an interconnected complex of lines and spots in the outer third of the forewing. With dominant V-shapes.

Fig. 1. Diagrammatic representation and forewing pattern of *Lyonetia ledi*

According to Baraniak (1996) *L. ledi* is known from the following countries in Europe: Norway, Denmark, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Poland, Czech Republic, Slovakia, Germany, France, Austria, Romania. Data from Belarus and Ukraine should be checked, but the occurrence of the species is certainly based on correct identification.

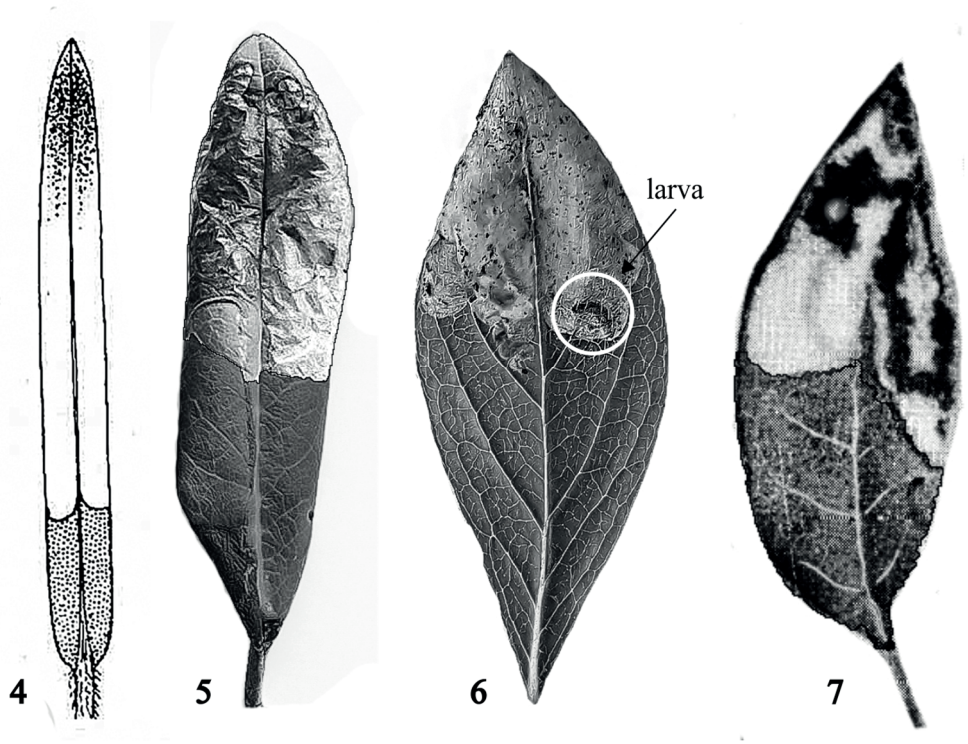


Figs. 2–3. Male (**2**) and female (**3**) genitalia of *Lyonetia ledi* (lateral view). The scales are different, the aedeagus is highlighted. The drawing is based on Polish specimens.

These European territories are certainly home to numerous populations. On page 11 of Karsholt and Razowski's (1996) book, we see an incomplete map. Belarus and Ukraine are replaced by empty white space. These European countries are completely omitted from the book. This was a mistake.

Bionomy and ecology

Habitat: *Lyonetia ledi* is considered to be a tyrphobiontic species (Spitzer *et al*. 1996) because it is restricted to peat bogs. According to Huemer & Schmid (2021), the Swiss habitat (Graubünden, Ardez, SE Sur En, 1760 m, 46°45'38"N; 10°11'11.7"E) is completely different and can be characterized as a northern exposed subalpine *Larici-Piceetum* plant association dominated by *Larix decidua* and *Picea abies*, interspersed *Pinus cembra*, *Betula pendula* and *Alnus alno betula*. This biotope is in a north-facing, steep avalanche gully at the bottom of which remaining snow masses may persist into early summer and provide unique microclimatic conditions.



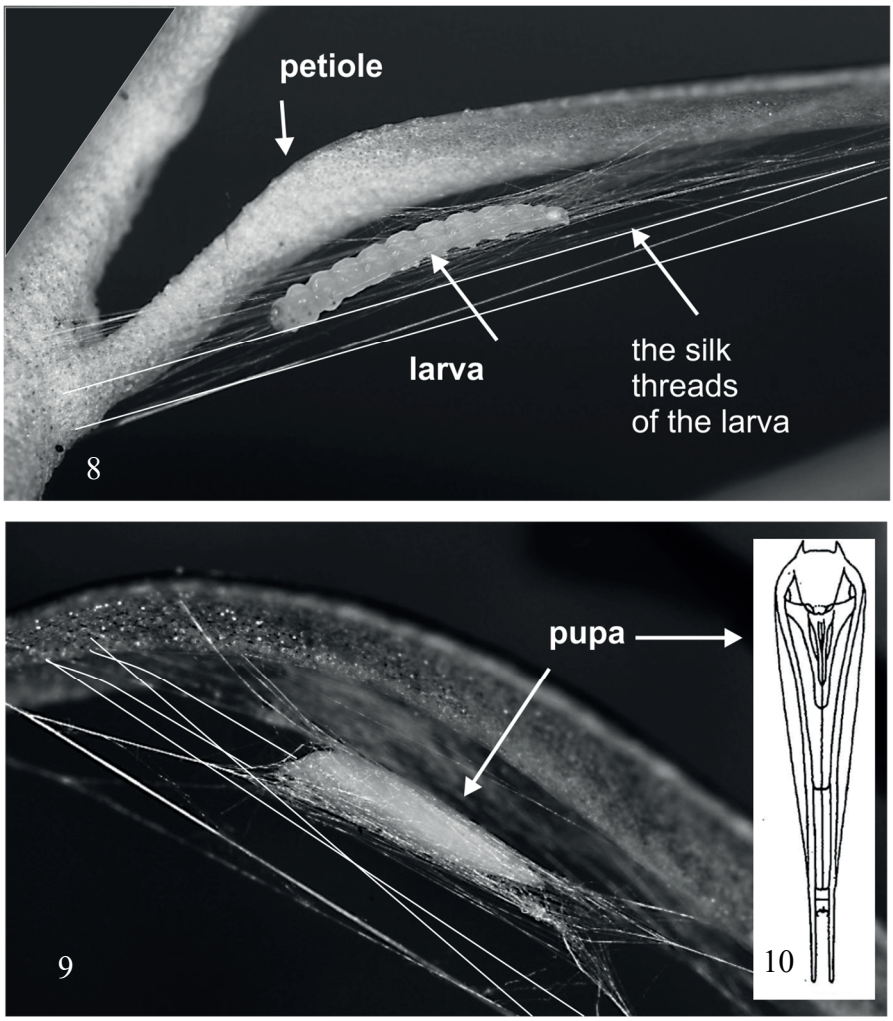
Figs. 4–7. *Lyonetia ledi* larval mine in leaf of foodplants from Europe to Japan: (**4**) *Rhododendron tomentosum* (Buszko 1981), (**5**) *R. ferrugineum* (Huemer & Schmid 2021), (**6**) *Rhododendron* sp. in Korea (Shin et al. 1983), (**7**) *R. mucronulatum* (Kuroko 1964).
Figures not to scale. Redrawn from the original and modified.

Foodplants spectrum: Europe and Asia: *Rhododendron tomentosum*(= *Ledum palustre*), *R. ferrugineum, R. indicum, Myrica gale*. Japan: *Rhododendron dauricum, R. kaempferi, R. pentadrum* (= *Menzieria pentadra*). North America: *Rhododendron occidentale, R. albilorum* (Kuroko 1964; Robinson *et al*. 2010, Huemer & Schmid 2021). *Rhododendron hirsutum* is a potential foodplant in the Alps. The range of food plants is probably wider, especially in the *Rhododendron* genus. The ovipositor of the female is specialized for piercing plant tissues.

According to most observations (see literature), the young larva first mines a narrow passage and moves along it towards the tip of the leaf, where a blotch is formed; small leaves may be mined out completely. The larva makes a few slits in the side of the blotch away from the tip, through which most of the frass is ejected. The larva eventually leaves this mine, to make new blotches in one or two more leaves, which turn yellow like the first one. Mines are invariably in the upper parts of the plant. Pupation outside the mine, in a cocoon that hangs freely in a sort of hammock fastened under a new leaf, which becomes inflated.

The larvae seem to be regularly infested by parasitic wasps of *Diadegma* cf. *semiclausum,* (Ichneumonidae) and an unidentified species of Ichneumonidae as several cocoons were found that were already empty (Huemer & Schmid 2021).

The preferred foodplant of *Lyonetia ledi* is *Rhododendron tomentosum*, a shrub which occurs in coniferous forests, forest margins, marshes and wet meadows, at elevations of between 400 and 1400 m. The known range of *Rhododendron tomentosum* is in Eurasia and North



Figs. 8–10. Larva (**8**) and pupa (**9**) of *Lyonetia ledi* on *Rhododendron ferrugineum.* Modified and supplemented following the publication of Huemer & Schmid (2021). (**10**) The ventral view of the pupa after Kuroko (1964).

America: Alaska, Alberta, Aleutian Islands, Altai, Amur, Austria, Baltic States, Belarus, British Columbia, Buryatia, Central European Russia, Chita, Czech Public (Moravia), Eastern European Russia, Finland, Germany, Greenland, Inner Mongolia, Irkutsk, Kamchatka, Kazakhstan, Khabarovsk, Korea, Krasnoyarsk, Kurile Islands, Labrador, Magadan, Manchuria, Manitoba, Mongolia, Northern European Russia, North-western Europe, Norway, Nunavut, Ontario, Poland, Primorye, Quebec, Sakhalin, Saskatchewan, Sweden, Tuva, Ukraine, Western Siberia, Yakutskiya, Yukon. It thrives on peaty soils, especially in moss and lichen tundra, and is widely distributed in the countries from which *L. ledi* has been recorded. A specific example ecoregion of occurrence is in the South Hudson Bay taiga, particularly on the floor of Black spruce dominant forests, where there are considerable local topographic depressions that form localised wetlands.

The geographic range of the food plant matches the range of *Lyonetia ledi,* but populations of the moth appear to be isolated and fragmented. According to unconfirmed sources, *Rhododendron tomentosum* was also present in Romania but became extinct. This may explain the collection of *Lyonetia ledi* specimens in the 1924–1925's in the marshland of the "Fehér-Körös" river (Borosjenő [Inue]. No further specimens have been collected since then.

The other most important food plant of *Lyonetia ledi* is *Myrica gale*, which is widely distributed in the northern hemisphere, but there are large gaps in its distribution. It is scattered throughout northern North America, as far south as Virginia and as far east as the Far East of Asia. In Europe, *M. gale* has a distinctly Atlantic and north-western distribution (Holm & Holm 1991), from north-western Spain to central Germany and north-western Russia, including the Baltic coastal zone (Behre 1999). In Finland it also grows on the edges of inland lakes (Svoboda *et al*. 1998). In temperate North America it inhabits riverbanks and freshwater lakes (Berliner & Torrey 1989). *Myrica gale* var. *tomentosa* occurs in northern Japan, Sakhalin, and eastern Siberia. Preston and Hill (1997) refer to *M. gale* as a sub-oceanic boreal temperate.

What do we know about the newly discovered food plant*?* Habitat and ecology of *Rhododendron ferrugineum*: This is an Alpine perennial shrub found throughout montane areas in acidic soils associated with pine. In the past decades the northern Alps have been subject to a decrease in disturbance from pasture which has caused *Rhododendron ferrugineum* to flourish. It can reproduce sexually by selfing and outcrossed seeds or vegetatively through layering, which usually occurs downslope at 50 or 60 years of age. Heavy snow cover allows branches to root in the ground. It also produces many flowers and seeds (Castroviejo *et al.* 1993, Escaravage *et al.* 1998). *Rhododendron ferrugineum* is endemic to the Mediterranean and west-central Europe at elevations between 1600–2200 metres, predominantly in the Alps and the Pyrenees (Valdés 2009, Gibbs *et al.* 2011, Malicki *et al.* 2019). Its presence and distribution in Croatia, Albania, Serbia, and Slovenia requires confirmation. *Rhododendron ferrugineum* is an abundant species in montane areas of the Alps and Pyrenees. This species is classified as Least Concern in view of its relatively wide distribution, stable populations, and no major threats.

The northernmost occurrence of *Rhododendron ferrugineum* has been found in southern Poland (Malicki *et al.* 2019). The newly described population of *Rhododendron ferrugineum* is the northernmost and most isolated population of this subalpine shrub species. It is located approximately 350 km north from the nearest populations in the Austrian Alps. The provenance and character of this population have long been enigmatic and, in general, it has not been accepted as a native element of the regional flora.

There are known cases of *Rhododendron* introductions in the Polish mountains (Karkonosze Mts. See Malicki *et al.* 2019), mostly in the nineteenth century. The plant community of *R. ferrugineum* was classified into the Genista pilosa-Vaccination alliance. Of particular note is the discovery of *Rhododendron ferrugineum* in Poland. It is a potential habitat for *Lyonetia ledi*. It is probably a transition zone towards upland and lowland marshy swamp populations. Detailed research should be carried out here.

Larval life and pupation (Figs. 4–10)

According to the old literature and recent observations (see references), the larva, after hatching, pierces the upper leaf epidermis and forms a mine in the leaf parenchyma, in which it is well protected from bad weather and predatory insects, spiders and birds. The mine starts with a long corridor that widens as the larva grows and ends in a large square blotch where frass is deposited. When it is time to pupate, the caterpillar leaves the leaf and forms a web on the underside of one of the leaves. It then makes an elaborate 'hammock' of fine silken threads, in which pupation takes place.

Fig. 11. The geographical distribution of *Rhododendron ferrugineum* in Europe (after Valdés 2009, Gibbs *et al.* 2011; supplemented and amended). The black arrow points to the recently found site in Poland. For details of the Polish site, see Malicki et al. (2019).

Flight period of adults and occurrence with notes

The flight period varies from one area to another and is not yet known precisely. The first specimens can be collected at light in April, and subsequently from spring to autumn, with peak numbers in July and August, and on into late October and early November. Voucher specimens are ubiquitous in the larger collections. Probably bivoltine. It is thought to overwinter as an imago, but this has not yet been unequivocally demonstrated. Recent research in Switzerland is reported in detail by Huemer and Schmid (2021).

Reports from other countries are summarised below

Belarus: Yevgeniy Derzhinsky wrote (in e-mail) the following about the occurrences in Belarus: "*Lyonetia ledi* has been recorded in some papers, but most of them are without clear information about locations where this species was found. Only information like ''this species occurs rarely at peat bogs in Belarus'' or ''peat bogs in the northern part of Belarus''. Only one more or less clear record somewhere near this point: 54°48'34.0"N | 26°53'39.3"E° was found."

The site is in the Naroch National Park which is near Minsk and has an area of 97.3 thousand hectares. 17% of Park is covered by lakes. Altogether, there are about 40 lakes surrounded by untouched forests with rare species of animal. The Naroch National Park is very important in the Eastern European Plain, where many undetected populations of *Lyonetia ledi* may occur. Such so-called "stepping stones" are essential for the maintenance of population relationships. Without adequate information, we do not know the current state of research on the ecology of this species.

Czech Republic: According Vavra (2000) the moth is a monophagous, tyrphobiontic species. In 1999, large numbers of larvae and pupae were found for the first time on the small peat bog PP Nad Dolskym Eminem. Its presence on the foodplant is so obvious that it is unlikely to have escaped attention in previous years. According to Vavra (2000) *Lyonetia ledi* is found in eutrophic tall-herbed meadows which are permanently damp in the upper soil layer and are mown once or twice a year, and in unmown, waterlogged meadows with species-rich vegetation. The closest known Czech locality is Jestrebi–Konvalinkovyvrch Podmokel (Sterneck & Zimmermann 1933).

Denmark: According to Ole Karsholt (pers. comm.) *Lyonetia ledi* is a local and rare species in Denmark, known from only two localities in the north-eastern islands, where moths have been collected in July and August near *Myrica gale* plants.

France: According to Lucienne Nel (pers. comm.) "This species, to my knowledge, was reported with doubt in the Catalog of Lhomme (1923), - IV-IX, Alpes-Maritimes: Cannes (Millière); Cher: Sommerère (Sand). These records remain unconfirmed, and the presence of the species in France is regarded as doubtful."

Hungary: the occurrence of *Lyonetia ledi* in Hungary has to be considered in some detail, because there is a lot of misunderstanding about it. Gozmány (1965) wrote in detail about *Lyonetia ledi* in his booklet Fauna Hungariae, in square brackets, indicating that the species had not yet been captured in the country, but its presence is likely. The square brackets have been misinterpreted by researchers unfamiliar with the Hungarian language, expecting them to mean presence unconfirmed. In his work, Gozmány did not cite any literature sources. According to him, *Lyonetia ledi* is a species with a central European distribution, which has not been collected in Hungary, but may possibly occur in the Bátorliget marsh. He also names the foodplants *Ledum palustre* and *Myrica gale*, neither of which occur in Hungary, so it is not clear why the author assumed their 'possible' occurrence in Hungary, and specifically in the Bátorliget marsh.

The palaeoecological research was carried out on Bátorliget marsh, a Nature Reserve area approximately 2 km west of the Hungarian-Romanian border, on the northern edge of the Great Hungarian Plain. This region, named by Nyírség and surrounded by the high ridge of Carpathians (running in NW to SE) and the flat expanses of the Great Hungarian Plain to the West, makes a unique geographical position in Europe. It is located on the border of two very different environmental zones, not only in terms of the geological situation but in the association of ecological zones. Bátorliget marsh represents a combination of fauna and flora characteristic in mountainous regions of the Carpathians and the Great Hungarian Plain. Flora and fauna of the marsh include several species being rare to the Hungarian lowland although widespread in mountain regions.

Csinády (1954) conducted thorough pollen analytical studies in the area. He did not find any pollen from potential food plants of *Lyonetia ledi.* Therefore, neither *Rhododendron* spe-

Figs. 12–13.
Csinády Gerő (**12**) [1902–1970]
Gozmány László (**13**) [1921–2006]

cies nor *Myrica gale* lived in this ancient marsh, which is considered by Hungarian botanists as a postglacial remnant. Thus, albeit hypothetically, we can conclude that there is no likelihood that *Lyonetia ledi* lived in this lowland area in the past. The hypothesis of Gozmány (1965), who expected the species to occur in Hungary from here, is erroneous. In my opinion, the distribution range of the species is consistent with the biogeographical history of the preferred food plants.

Japan: In Japan (see Kuroko 1964) the number of generations is unknown, but larvae have been collected from the beginning to the end of June and from the middle to the end of July, and the adults appeared from the end of June to the middle of July and from the end of July to the beginning of August. Foodplants: *Rhododendron dauricum*, *R. kaempferi* (600–1000 m, according to Wilson it is a sun-loving plant, 'seen to best advantage in open thickets on mountain slopes'), *R. japonicum, R. pentadrum* (= *Menzieria pentadra*, native to Japan, Kuril Is. and Sakhalin).

North Korea: My colleague Bong-Kyu Byun informed me about the North Korean populations based on literature data. To his knowledge, only one site is known so far, in Suweon township (Shin *et al.* 1983). There is also more news from the Weolaksan Mountains.

Lithuania: According to Povilas Ivinskis (pers. comm.), *Lyonetia ledi* in Lithuania is the key species of marshland rural. The species throughout Lithuania. Bred specimens in collections: Alytus district (Zhuvintas Biosphere Reservation), Alytus district (Puniošilas (forest), Kretinga district (Šventoji, 2 km to east), Molėtai district (near Dubingiai), Panevėžys district (Raguva, forest), Šalčininkai district (Rūdninkai, former military area), Šilutė district (Žalgirai, forest), Švenčionis district (Januliškis, Petreežeris lake bog), Purviniškiai, forest lakes bogs,Trakai district (Aukštadvaris Regional Park, Riezničia, Kerėplis lake bogs), Vilnius district (Dūkšteliai bog, Raudonojibala bog), Varėna district (Dzūkija National Park: Katra, Musteika. Varėna district Burbonys, Puodžiainraised bogs, Zarasai district (Dūkštos env.).

Poland: Throughout Poland in raised bogs and in a boggy marsh (Buszko 1981). Bivoltine, in June and from the end of September to the spring of the following year. The larva mines the top leaves of *Rhododendron tomentosum* (= *Ledum palustre*) and occasionally *Myrica gale*. During its lifetime it changes leaves two or three times. According to Buszko (pers. comm. 29.11.2021) *Lyonetia ledi* is widespread but local in Poland. In some sites it is abundant. It occurs almost everywhere where *Rhododendron tomentosum* (= *Ledum palustre*) is present with clear preference for boggy pine forests and raised peat bogs.

Romania: Examined specimens; 1 ex, Borosjenő [Ineu], '924. VII. 2. Diószeghy, 1 ex, Borosjenő, '925. XI. 11. Diószeghy (in coll. Hungarian Natural History Museum, Budapest).

Fig. 14.
Dioszeghy László (1877–1942); Hungarian painter, Lepidoptera collector, entomologist. He was a thorough and meticulous collector. A significant part of his collection is kept in the Natural History Collection of the Szekler National Museum. Many of his specimens are in the British Museum and the Hungarian Museum of Natural History. He is the only collector of the *Lyoneti ledi* species in Romania.

These are specimens from a very old collection. No more recent specimens are known. It is possible that there are still specimens in some museums or private collections, but none have been investigated. Here it is noted that according to maps from 100–150 years ago, the Romanian Borosjenő (Ineu in Romanian) and its region were ecologically suitable for the existence of populations of *Lyonetia ledi*. Today this is less likely, but with thorough search, it is not impossible for the species to be found again.
(See in https://www.arcanum.com/en/technology/historical-maps/)

Russia: The moths fly from July to August in European Russia, being recorded in October in Khabarovsk Territory. The species is known to form the northern race distinguished from the southern one by the fore-wing pattern (Kuroko, 1964). This race is recorded for the first time in Russia on the basis of the material collected by V. P. Ermolaev in the Khabarovsk Territory (see Baryshnikova 2007).

Slovakia: first collected in Slovakia in 1989 near the Polish border (Sucha Hora). For more information see Marek *et al*. (1991). In his paper, Reiprich (1991) refers to the previous publication but expands it. According to him, larvae are observed in the months V–VI and VII –IX, and the imago is observed in July, and from September, when it overwinters until April. Since then, no new information has been published. This Slovak population is very close to the well-known Polish populations (see distribution map). It is questionable how isolated the population is and whether there is a genetic link to Polish populations. It can be assumed that there are still hidden populations in the mountain ranges of the Carpathians, awaiting a similar discovery as the recently discovered Swiss population (cf. Huemer & Schmid 2021).

Ukraine: Bidzilya reported (pers. comm. in e-mail) on the status of the species in Ukraine Oleksiy and stated that *Lyonetia ledi* has been recorded from two localities in Western Ukraine: "Rzesna Polska", currently a district within the city of Lviv, and "Mikuliczyn", now Mikulichin in Ivano-Frankivsk region (Schille 1930: p. 284). According to Bidzilya, no recent observations are known.

Fragmentation and extinction

Human use of the landscape by urbanisation, agriculture, mining and so on has resulted in its significant fragmentation across Europe. The elements that previously formed a coherent matrix are now isolated patches. Fragmentation not only results in significant habitat loss, but also leads to the disappearance of some, with their associated species (Harker *et al*. 1999). Most of the remaining habitat patches are not large enough to provide habitat for viable populations of *Lyonetia ledi*. Remaining habitat patches are becoming increasingly impoverished, and dispersal between patches may be significantly reduced. A species may be absent from a potential isolated patch partly because it cannot get there, and partly because its extinction is more significant than its establishment. White & Walker (1997) suggest that species with lower competitive ability may be favoured because of their better dispersal ability.

Discussion

Lyonetia ledi is susceptible to extinction in Central Europe because of the isolation of extant populations. There is also a lack of information about population densities and their dynamics. This species does not have protected status in Europe. The limited mobility of adults also limits the colonization of new habitats. Thus, any pressure exerted on the remaining habitat by external factors will also affect the populations of *Lyonetia ledi*. For this reason, we consider the knowledge of the ecological preferences of habitat and population dynamics to be extremely important to better formulate any future management and protection implications.

Despite their geographical isolation, there are no significant differences between the habitus pattern of *Lyonetia ledi* from Central Europe and those from Eurasia. This lack of phenotypic diversity between the various isolated populations requires further study with different methods.

Based on more analytical evolutionary, causal, and zoogeographical analyses, we should take better account of the more fragmented zoogeographical regions or subregions that have recently appeared in several publications (see Ficetola *et al*. 2017 and others). These zoogeographical maps clearly show that *Lyonetia ledi* is absent from the so-called "Arctic-Siberian" (sub)region of the Palaearctic, which has always been treated as a unified region. Most of the sites are in the Eurasian region, but also appear in the Sino-Japanese sub-region. The Holarctic, circumpolar designation of the species should be revised. In evolutionary terms, we are probably dealing with a Nearctic-Eurasian-Sino-Japanese faunal element with several centres.

In Europe, it is clear that the boreal region is the centre of distribution of *Lyonetia ledi*. It is highly fragmented in the continental region and has a strong peripheral position in the alpine region. These populations are relict, highly isolated remnants of the postglacial period. Their survival in these ecological niches is uncertain.

Acknowledgements
Many colleagues have assisted in the preparation of this study. Some provided reference to old literature, others looked through the collections in their own institution, or shared with me many chorological and ecological observations. The study remains incomplete, but it will certainly trigger further research. The following colleagues are thanked by name: Svetlana Baryshnikova (RU), Bengt A. Bengtsson (SE), Bong-Kyu Byun (KP), Oleksiy Bidzilya (UA), Jaroslaw Buszko (PL), Yevgeniy Dzerzhinsky (BY), Konstantin Efetov (RU), Peter Huemer (AT), Povilas Ivinskis (LT), Tim Karisch (D), Ole Karsholt (DK), Gergely Katona (HU), Irén Kocs (RO), Zdenek Laštůvka (CZ), Lucienne Nel (FR), Gábor Pastorális (SK). Sergey Sinev (RU), Jukka Tabell (FI), Jaan Viidalepp (EE). Finally, I am indebted to my friend Barry Goater (UK) who did the linguistic proofreading of the manuscript.

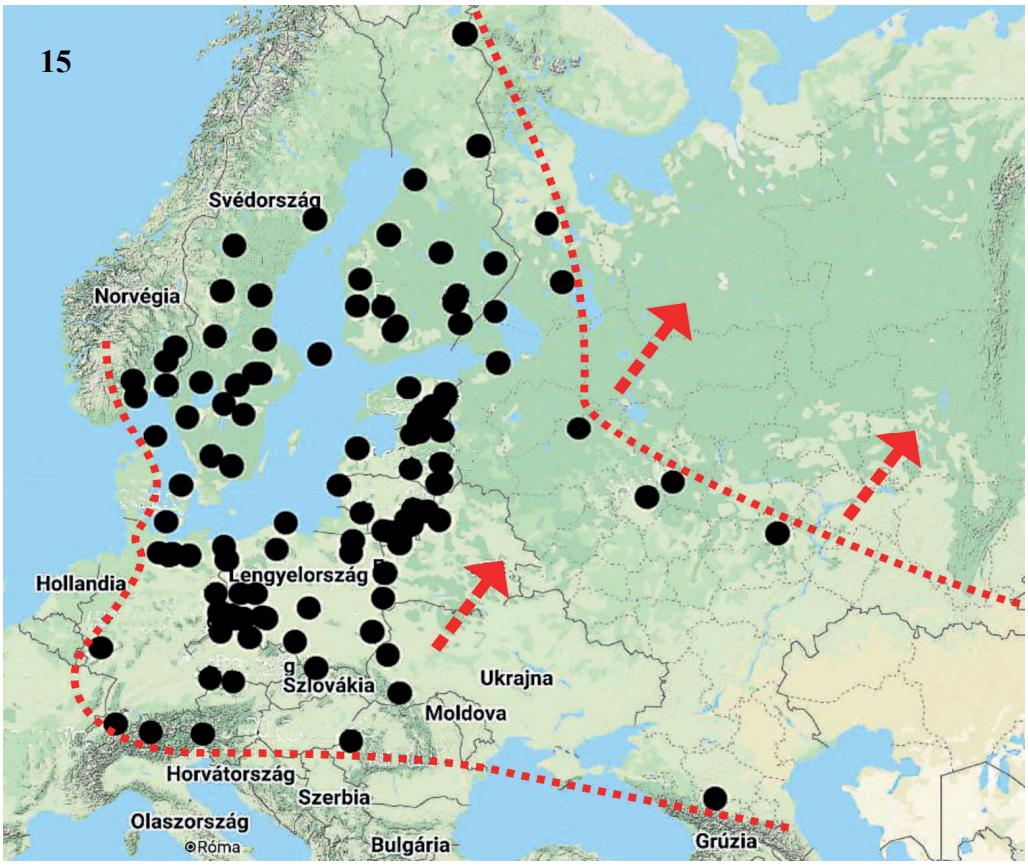


Fig. 15.
Geographical distribution pattern of *Lyonetia ledi* in Europe. Preliminary map, based on verified locality data. Dotted red lines indicate hypothetical distribution limits. Red arrows indicate the direction of potential spread.
The map clearly shows the geographical areas where further research is needed.
Note: Country names are in Hungarian.

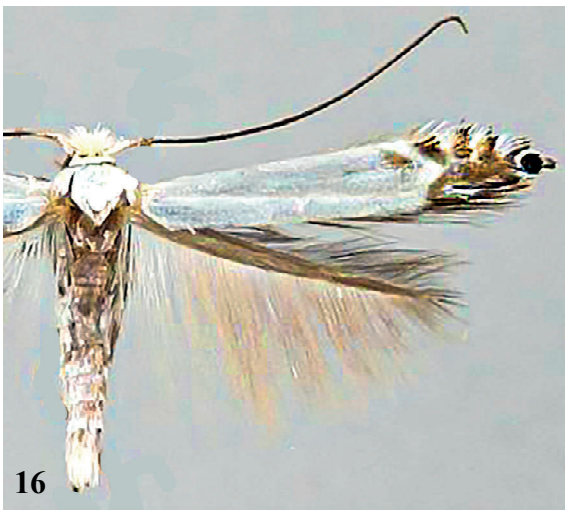
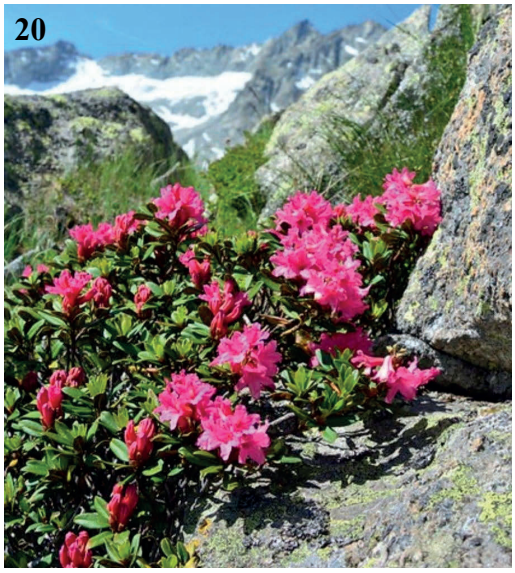


Fig. 16.
Lyonetia ledi, adult, Finnland, Nordsavo, (photo: R. Siloaho)

Fig. 17. The geographical distribution of *Lyonetia ledi* in the Palaearctic. The apparent center of its distribution is central and northern Europe. Not yet known in the Arctic-Siberian sub-region. In southern Siberia it has a trans-Palaearctic distribution, but with highly fragmented populations. The southern limits of its range are the Alps, Carpathians, and Caucasus mountains.

Figs. 18–21.
Preferred habitats of *Lyonetia ledi* in the Palaearctic,
18, Poland, with *Rhododendron tomentosum*,
19, Russian Far East, Arkhangelsk region, marshland,
20, Alps, with *Rhododendron ferrugineum*.
21, *Lyonetia ledi, adult* (photo: Hlasek J.)



References

Baraniak E. 1996: Subfamily Lyonetiinae, pp. 62–63. In Karsholt O. & Razowski J. (eds): The Lepidoptera of Europe. – Apollo Books, Stenstrup, 380 p.

Baryshnikova S. V. 2007: A Review of the Lyonetiid Moths (Lepidoptera, Lyonetiidae): II. The Subfamilies Lyonetiinae and Bedelliinae. – Entomological Review, 87(3): 361–367.

Baryshnikova S. V. 2019: Lyonetiidae. In Sinev S. Yu. (ed.): Catalogue of the Lepidoptera of Russia. 2nd edn. – Zoological Institute of the Russian Academy of Sciences, St. Petersburg, pp. 51–51. [448 p.]

Behre K-E. 1999: The history of beer additives in Europe – a review. – Vegetation and Archeobotany 8: 35–48.

Bengtsson B. Å. & Johansson R. 2011: Nationalnyckeln till Sveriges flora och fauna. Fjärilar: Bronsmalar–rullvingemalar. Lepidoptera: Roeslerstammiidae–Lyonetiidae. – Art Databanken, SLU, Uppsala, 494 p.

Buszko J. & Nowacki J. [eds] 2017: A Distributional Checklist of the Lepidoptera of Poland. – Polish Entomological Monographs, 13, 222 p.

Buszko J. 1981: Cemiostomidae, Phyllocnistidae, Lyonetiidae, Oinophilidae. – Klucze do oznaczania owadow polski, 27 (25–28): 1–58.

Buszko J. 2017: Lyonetiidea. [in] Buszko J. & Nowacki J. [eds] 2017: A Distributional Checklist of the Lepidoptera of Poland. – Polish Entomological Monographs, 13: 32.

Castroviejo S., Aedo C., Lainz M., Morales R., Muñoz Garmendia F., Nieto Feliner G. & Paiva J. (eds). 1993: Flora Iberica. Volume 4. Real Jardín Botaníco, C.S.I.C. Servicio de Publicaciones, Madrid.[I]-LIV, [1]–730 p.

Csinády G. 1954: A bátorligeti láp története a pollenanalizis tükrében. – Földrajzi Értesítő 5: 684–694.

Deutschmann U.& Zessin W. 2009: Bericht über die Mikrolepidopteren-Tagung in Schwerin-vom 3–5.10. 2007. – Virgo 12 (1): 4–7.

Escaravage N., Questiau S., Pornon A., Doche B. & Taberlet P. 1998: Clonal diversity in a Rhododendron ferrugineum L. (Ericaceae) population inferred from AFLP markers. – Molecular Ecology 7: 975–982.

Ficetola G. F., Mazel F. & Thuiller 2017: Global determinants of zoogeographical boundaries. – Nature Ecology & Evolution 1, 0089:1–7. | DOI: 10.1038/s41559-017-0089

Gibbs D., Chamberlain D. &Argent G. 2011: The Red List of Rhododendrons. – Botanical-Gardens Conservation International, FFI, IUCN.

Gozmány L. & Szőcs J. 1965: Molylepkék I. Microlepidoptera I. – Fauna Hungariae 76: 1–214.

Harker D., Libby G., Harker K., Evans S. & Evans M. 1999: Landscape Restoration Handbook (2nd edition). – Lewis Publishers, 884 p.

Huemer P. 2013: Die Schmetterlinge Österreichs (Lepidoptera). System-atische und faunistische Checkliste. – Studiohefte 12, Innsbruck, 304 p.

Huemer P. & Schmid J. 2021: Relict populations of *Lyonetia ledi* Wocke, 1859 (Lepidoptera, Lyonetiidae) from the Alps indicate postglacial host-plant shift to the famous Alpenrose (Rhododendron ferrugineum L.). – Alpine Entomology 5: 101–106.
DOI 10.3897/alpento.5.76930

Irving E. & Hebda R. 1993: Concerning the Origin and Distribution of Rhododendrons. – Journal American Rhododendron Society47(3): 139–146.

Ivinskis P. & Rimšaté J. 2018: Check-list of the Lithuanian Lepidoptera. – Vilnius, 135 p.

Jong Ok, Shin Young-min, Noh Seung-jin, Lee Bong-woo & Oh Seung-hwan 2019: A checklist of leaf-mining moths (Insecta: Lepidoptera) and host plants in Korea. – Issued by National Arboretum Forest Biodiversity Research Division, Pocheon, Korea, 167 p.

Khela S. 2021: *Rhododendron ferrugineum*. The IUCN Red List of Threatened Species [accessed 24.11.2021]. Available from: https://doi.org/10.2305/IUCN.UK.2013-2.RLTS.T2030-07A2758537.en

Kuroko H. 1964: Revisional studies on the family Lyonetiidae of Japan (Lepidoptera). – Esakia 4: 1–61.

Laštůvka Z. & Liška J. 2011: Annotated checklist of moths and butterflies of the Czech Republic (Insecta: Lepidoptera). – Biocont Laboratory, Brno, 148 p.

Lhomme L.1923– [63]:Catalogue des Lépidoptères de France et de Belgique, Microlepidoptera, Vol.II: 1–1253 (2 parts), ed. L. Lhomme, the Carriol by Douelle (Lot)

Malicki M., Pusz W., Ronikier M. & Suchan T. 2019: Population characteristics, habitat, and conservation status of Rhododendron ferrugineum L. (Ericaceae), a glacial relict new to Poland. Acta Societatis Botanicorum Poloniae 88(3):3634. [1–9]. https://doi. org/10.5586/asbp.3634

Marek J., Laštůvka A. & Vávra J. 1991: Faunistic records from Czechoslovakia. Lepidoptera: Gracillariidae, Bucculatricidae, Lyonetiidae, Coleophoridae, Cosmopterigidae. – Acta Entomologica Bohemoslovaca 88: 217–222.

Matveev A. V. & Zolotuhin V. V. 2018: Ledumleaf-mining Lyonetia ledi Wocke, 1859 – new species of Lyonetiidaemoth (Lepidoptera) for the center of European part of Russia. – Priroda Simbirskogo Povolzhia 19: 177–179.

Reiprich A. 1992: Prírastky motýlej fauny na Slovensku v roku 1991. – Správy Slovenskejentomologickej spoločnosti, Bratislava, 4 (2): 7–14.

Rennwald E. & Rodeland J. 2021: LepWiki (Bestimmungshilfe). https:// lepiforum.org/wiki/page/Lyonetia_Ledi [accessed 12.10.2021]

Robinson G. S., Ackery P. R., Kitching I. J., Beccaloni G. W. & Hernández L. M. 2010: HOSTS – A Database of the World's Lepidopteran Host-plants. – Natural History Museum, London. http://www.nhm.ac.uk/ hosts(accessed18.12.2021).

Schille F. 1930: Fauna motyli Polski. II. In: Prace Monografi cz ne Komisji Fizjograficznej. Vol. 7. – PAU, Kraków, pp. 1–358.

Seksyaeva S.V. 1981: Lyonetiidae (Leucopteridae). In A Key to Insects of the European Part of the USSR. – Nauka, Leningrad, Vol. 4, Part 2, pp. 420–430.

Shin Yoo-Hang, Park Kyu-Tek & Nam Sang-Ho 1983: Illustrated Flora & Fauna of Korea Vol. 27. Insecta (IX). – Ministry of Education, Korea, 1053 p.

SobczykT., Stöckel D., Graf F., Jornitz H. & Karisch T. 2018: Die Schmetterlingsfauna (Lepidoptera) der Oberlausitz. 6. Kleinschmetterlinge (Microlepidoptera) 2. Teil. – Entomologische Nachrichten und Berichte Beiheft 24: 1–496.

Spitzer K., Jaroš J., Lichtenberger F. & Malicky H. 1996. Die Biodiversität der Pürgschachenmoores im steirischen Ennstal und ihr Schutzwert. – Zeitschrift der Arbeitsgemeinschaft österreichischer Entomologen 48: 87–97.

Preston Ch. D. & Hill M. O. 1997: The geographical relationships of British and Irish vascularplants. – Botanical Journal of the Linneana Society 124: 1–120.

Spuler A. 1910: Die Schmetterlinge Europas, Band 2. – Stuttgart, 523 p.

Standovár T., Tóth Z. & Simon T. 1991: Vegetation of the Bátorliget Mire Reserve. In: Mahunka S. (ed.): The Bátoliget Nature Reserves – after forty years. Studia Naturalia No. 1. Vol. 1. Hungarian Natural History Museum, Budapest, pp. 57–118.

Sterneck J. & Zimmermann F. 1933: Prodromus der Schmettcrlingsfauna Bohmens II. Microlepidoprera. – Karlsbad, 168 p.

Sushko G. G., Piskunov V. I. 2007: [Moths (Lepidoptera: Protoheterocera, Pyralidodea) of the Raised Bogs of Belarusian Poozerye]. – Vesnik of Vitebsk State University. – 3(45):134–138 (in Russian)

Valdés B. 2009: with contributions from Raab-Straube, E. von and Parolly, G. 2009. Ericaceae. In: Euro+MedPlantbase - the information resource for Euro-Mediterranean plant diversity. Berlin (Available at: http://ww2.bgbm.org/EuroPlusMed/).

Vávra J. 2000: Lepidopteran fauna (Lepidoptera) of Vysoka Lipa near Jetfichovice and surroundings in the Labskepiskovce Landscape Protected Area. – Sbornik Okresného muzea v Moste, rada prirodovedna 22: 87–106.
White P. S. & Walker J. L. 1997: Approximating nature's variation: selecting and using reference information in restoration ecology. – Restoration Ecology5: 338–349.
Wieser C. 2018: Weitere Erstfunde und bemerkenswerte Schmetter-lingsnachweise aus Kärnten (Insecta: Lepidoptera). Rudolfinum. – Jahrbuch des Landesmuseums für Kärnten 2017: 285–291.
Wocke F. 1859: Bericht über die Thätigkeit der entomologischen Sektion im Jahre 1859. II Lepidoptera. – Jahres-Bericht der Schlesischen Gesellschaft für Vaterländische Kultur 37: 98–101.
Wocke M. F. 1874: Verzeichnis der Falter Schlesiens. II. Microlepidoptera. – Zeitschrift für Entomologie, N. F. (4): 1–108., I–IV.

Important literature visited on the internet (accessed from 01-09-2021 to 14-01-2022):
- https://upload.wikimedia.org/wikipedia/commons/2/24/Myrica-gale-distribution-map.svg
- https://besjournals.onlinelibrary.wiley.com/doi/full/10.1046/j.1365-2745.2000.00522.x
- https://tc.copernicus.org/articles/12/3265/2018/
- https://www.cambridge.org/core/journals/quaternary-research/article/abs/evaluation-of-the-regional-vegetation-and-climate-in-the-eastern-alps-austria-during-mis-34-based-on-pollen-analysis-of-the-classical-baumkirchen-paleolake-sequence/D325E3B9525A1A6D4807CFE30F5A8C5A
- http://insecta.pro/taxonomy/11619
- https://portal.nature.cz/publik_syst/nd_nalez-public.php?idTaxon=29961
- https://baza.biomap.pl/en/taxon/species-lyonetia_ledi/default/tr/y/cf/y
- https://maps.arcanum.com/hu/map/europe-19century-secondsurvey/?layers=158%2C164&bbox=2362257.7427335735%2C5983158.296122818%2C2430859.975619519%2C6008344.296942784
- https://laji.fi/en/taxon/MX.59164
- https://fauna-eu.org/cdm_dataportal/taxon/395e1a61-d17c-45cd-b580-b94eadbd5d32#distribution (03.01.2022)
- https://ars.els-cdn.com/content/image/1-s2.0-S0367326X13000166-fx1_lrg.jpg
- https://nl.pinterest.com/pin/674414112957085097/ (Rhododendron ferrugineum)