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Experience from a light trap Lepidoptera survey in a populated settlement: effects of meteorological factors and changes in lunar phases

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abstract

In the framework of the research, light trap Lepidoptera collections were carried out in the territory of a settlement (Velyki Berehy, Zakarpatska Oblast, Ukraine), which is bordered by nature reserves, forests, and agricultural areas, as well as by the remains of a large marsh (Szernye bog) that had been drained in the past. A Jermy light trap with a household LED bulb was used to capture the moths and butterflies. In addition to assessing the Lepidoptera fauna of the area, the study aimed to find out which species of Lepidoptera are attracted to energy-saving light bulbs commonly used in households in a settlement located in a habitat-diverse environment. In addition to the artificial light pollution conditions and other anthropogenic influences of the settlement, the direction and magnitude of the effects of temperature, relative humidity, cloud cover, wind speed, and moon phase parameters at the time of collection on the flight trends of nocturnal Lepidoptera species were also investigated. A total of 97 days of collecting between May 2018 and May 2019 resulted in the collection of 122 Lepidoptera species from 16 families. In terms of their ecological requirements, species were found in closed and open forest, forest edge, scrub, meadow, actively cultivated and abandoned agricultural areas, as well as in dry and wet areas. Several species considered being agricultural, forestry, or horticultural pests were identified, but not in abundance. Among the environmental variables, temperature variation showed a strong significant positive correlation with daily species numbers and abundance, while relative humidity, wind speed, cloud coverage and moon phases showed varying degrees of negative correlation, but were generally weak. The effects of the interactions of natural and man-made environmental influences on living organisms are difficult to assess objectively, but their research is of paramount importance for the long-term effective conservation of habitats of particular conservation value and for the preservation of their biodiversity.

Досвід дослідження метеликів з використанням світлових пасток у населеному пункті: вплив метеорологічних факторів і змін місячних фаз

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Резюме. У рамках дослідницької роботи проводився збір метеликів за допомогою світлових пасток у межах населеного пункту (с. Великі Береги, Україна, Закарпатська обл.), який обмежений природоохоронними територіями, лісами та сільськогосподарськими угіддями, а також залишками раніше осушеного великого торф'яного болота Сернє. Для вилову метеликів використовували світлову пастку, оснащену звичайною побутовою світлодіодною лампою. Крім оцінки фауни метеликів досліджуваної території, проаналізували, зокрема, які види метеликів приваблюють енергозберігаючі лампи, що часто використовуються в домогосподарствах у зазначеному населеному пункті. Крім впливу штучного світлового забруднення й інших антропогенних чинників поселення на тенденції літання нічних активних видів метеликів, також дослідили напрямок і ступінь впливу температури та відносної вологості повітря, хмарності, швидкості вітру та місячних фаз, зафіксованих під час вилову. У результаті збору зразків, який проводився протягом 97 днів (з травня 2018 р. до травня 2019 р.), зібрали представників 122 видів метеликів, які належать до 16 родин. Стосовно екологічних особливостей – траплялись види, характерні для густих суцільних і розріджених лісів, узлісся, чагарників, луків, активно оброблених і занедбаних сільськогосподарських територій, а також сухих і вологих локацій. Крім того, ідентифікували кілька видів, які можна вважати шкідниками з точки зору сільського господарства, лісівництва, чи садівництва, але не в масовому масштабі. Зазначимо, що зміна температури навколишнього середовища показала значну позитивну кореляцію з показниками добової чисельності видів та особин, а відносна вологість, швидкість вітру, хмарність та місячні фази показали різну за ступенем, але по суті слабку негативну кореляцію. Важко об'єктивно судити про наслідки взаємодії природних і штучних впливів навколишнього середовища на живі істоти, але дослідження особливо цінних середовищ існування має велике значення для ефективної, довгострокової природоохоронної діяльності та збереження біорізноманіття.

Ключові слова: Lepidoptera, світлова пастка, погодні умови, місячні фази, Закарпаття.

Introduction

The aim of the light trap collection was to assess the species composition of the Lepidoptera fauna in a selected settlement in the Carpathian Basin, to investigate which species of moths and butterflies are attracted by the LED bulb, which is nowadays considered to be a traditional technology and is often used in local households, and to investigate how weather conditions and lunar cycles influence the success of the collections. Specialised light sources are commonly used in light trapping studies in the literature, but are not commonly used in everyday life in populated settlements, and insects are not exposed to them more often. The settlement of Velyki Berehy (Zakarpatska Oblast, Ukraine) was chosen as the study site because it is surrounded by inhabited areas with extensive forest stands and agricultural land, as well as Ramsar-status floodplain forest. The settlement is bordered by the Borzha River from the east and is 126 metres above sea level. The area can be considered as the edge of the former Szernye bog, which used to be a swampy-boggy area of up to 100 km^2 in wet seasons, surrounded by the settlements of Kid'osh, Velyki Berehy, Nove Selo, Fornosh, Dertsen, Haty, and Yanoshi. It gradually dried up as a result of drainage work beginning in the 1840s and continuing after 1945. In the 1980s and 1990s, small stands of roundleaf sundew (*Drosera rotundifolia*) and common bladderwort (*Utricularia vulgaris*), which were the original wetland indicator species, were still present in the region, but these have now largely disappeared or declined [Lakatos & Dalmai 1998].

Despite the transformation of the landscape, habitat history is likely to continue to play an important role in the evolution of the flora and fauna of the area.

With respect to the Lepidoptera fauna of the whole Transcarpathian region, recent collections by Geryak [2010; 2012; 2021], Popov [2004], Lyashenko [2009], Szanyi *et al.* [2015 a, b; 2018], Kanarsky *et al.* [2011], and Matsiakh & Kramarets [2020] added a significant amount of data to our knowledge.

Szanyi *et al.* [2015 a, b; 2018] recorded 560 Lepidoptera species in the vicinity of the Velyka Dobron Wildlife Reserve, while Geryak [2010] recorded 498 Lepidoptera species during his comprehensive county-wide survey, including several species not previously identified in Transcarpathia and considered to be new to the area.

The research also wanted to find out how the effectiveness of a trap light, operated by a household light bulb of rather low luminous intensity, in a populated area considered to be somewhat light-polluted, is affected by variations in relative humidity, wind speed, cloud cover, and moon phase, in terms of both species and individuals. In the future, the elimination of the harmful effects of light pollution will also become an increasingly important issue in the design of nature reserves to better protect species. It is now well established that weather conditions and cyclical variations in lunar brightness clearly influence the flight patterns of many insect species and affect the effectiveness of light-trapping collection methods, but the extent of their influence and their weight at the species level is not yet sufficiently understood [Steinbauer *et al.* 2011; Jonason *et al.* 2014]. Recent research suggests that for insects, the spectral composition of nocturnal lighting may be more biologically important than light intensity [Longcore & Rich 2015].

Material and Methods

Study site

In the immediate vicinity of the designated collecting site (geocoordinate: 48.2337, 22.7490) in the inner part of the settlement of Velyki Berehy there are residential buildings and gardens with fruit trees (*Prunus domestica, Prunus armeniaca, Prunus persica, Prunus cerasus, Malus domestica, Pyrus communis,* and *Juglans regia)*. Outside the settlement there are ploughs, pastures, vineyards, and woods (Fig. 1). To the north of the settlement is the formerly drained Szernye bog, and to the east is a forest of 2 466 ha, divided by the Borzha River. Parts of the forest are under multiple protection. The Atak–Borzhava Ramsar site (283.4 ha) contains more than 300 plant species. The Borzhava section of the Tisza Valley Regional Landscape Park was previously designated here, as well as the Atak area (52 ha), a botanical natural monument of state importance, and the Borzha local importance protected area (302 ha) [EP 2022[1]; Kish *et al.* 2009].

According to the phytogeographical classification, within the Central European flora of the Holarctic floristic kingdom, the area belongs to the Pannonicum floristic province of the Lower Plain (Eupannonicum) floristic province of the Northern Plain (Samicum) floristic province [Simon 1952]. Typical communities are Querco-Fagetea oak-ash-siliceous groves, Fraxino-pannonicaea-Ulmetum with 100-300 years old specimens. The canopy is dominated by *Quercus robur*, *Fraxinus excelsior*, *Ulmus minor*, and *Acer campestre*. The shrub layer is characterised by *Cornus sanguinea*, *Euonymus europaeus*, *Crataegus monogyna*, *Crataegus oxycanta*, and *Hedera helix.* In the grassland, in addition to Fagetalia species, *Allium ursinum*, *Crocus heuffelianus*, *Anemona nemorosa*, *Asarum europaeum*, *Gagea lutea*, *Lathyrus vernus*, *Circea lutetiana*, *Carex pilosa*, *Carex remota*, and *Aegopodium podagraria* are common. There are also the highly diverse Carici elongatae-Alnetum and Fraxino pannonicae Alnetum communities of the class Alnetea glutinosae. At canopy level, *Alnus glutinosa*, *Ulmus leavis*, and *Fraxinus excelsior* are typical. The shrub layer is rich in *Frangula alnus* and *Viburnum opulus*, and the grassland layer is rich in sedge species (*Carex acutiformis, Carex elongata,* and *Solanum dulcamara)*. Stoyko [2009] also mentions the association Fraxineto-excelsiori-angustifolii-Qercetum-roburis aegopodiosum, whose grassland is dominated by *Aegopodium podagraria, Asarum europaeum, Gallium odoratum, Hedera helix, Millium effusum,* and *Carex brizoides*, as well as by *Carex remota, Gallium aparine, Geum rivale, Glechoma hederaceae,* and other species.

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[1] EP–Report on the State of the Natural Environment of Transcarpathia Oblast in 2022—Transcarpathian State Administration, Department of Ecology and Natural Resources, Uzhhorod, 2013 [Доповідь про стан навколишнього природного середовища Закарпатської області за 2012 рік — Закарпатська обласна державна адміністрація, Департамент екології та природних ресурсів, Ужгород, 2023]. https://ecozakarpat.gov.ua/wp-content/nd/2021_ecopasport.pdf

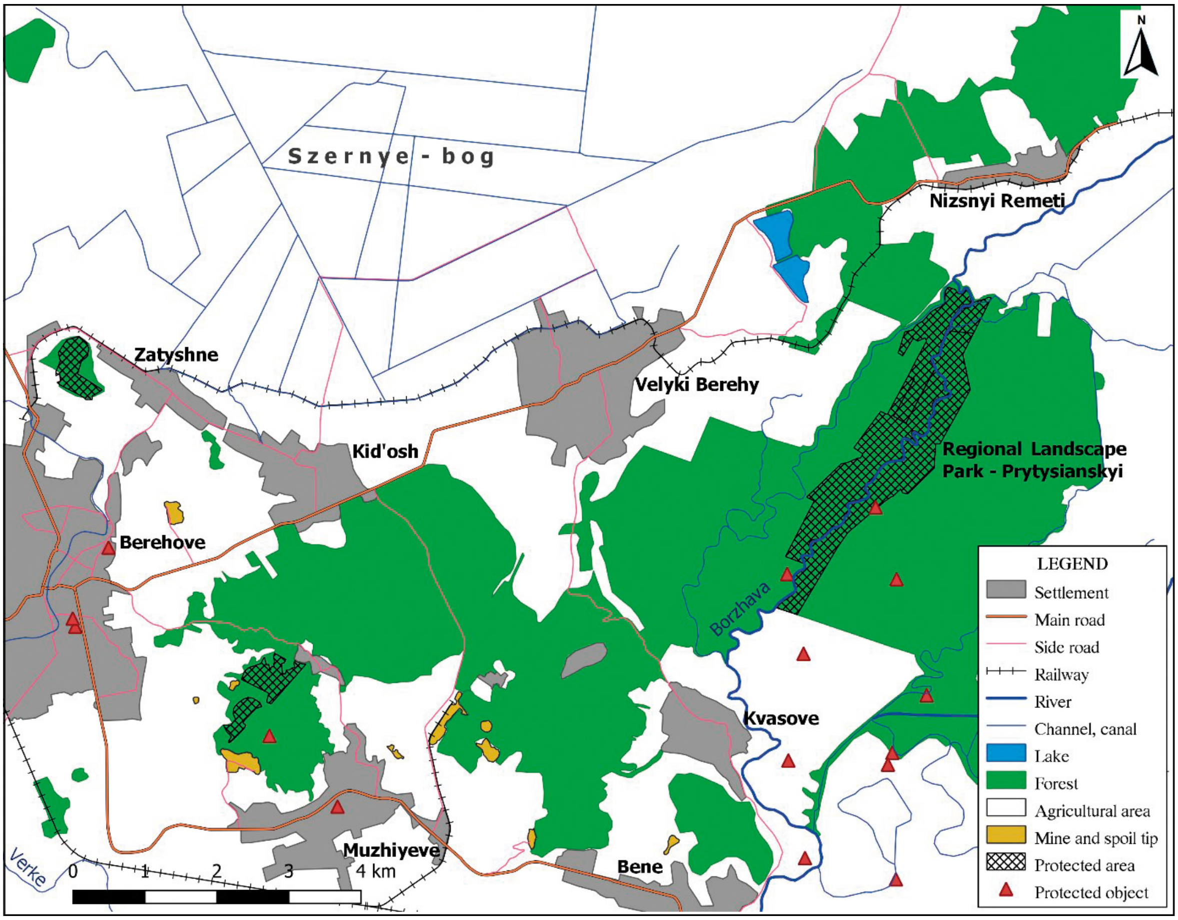

Fig. 1. Map of the study area.
Рис. 1. Карта досліджуваної території.

The climate type of the area, according to the Köppen–Geiger classification [Kottek *et al.* 2006], is warm summer humid continental (Dfb). According to the CarpatClim climate atlas [Szalai *et al.* 2013[2]], the mean annual temperature is 9.7°C based on grid point data from 1875 for the period 1961–2010. The coldest month is January (–2.4°C) and the warmest is July (20.1°C). The summer and winter seasons are well defined. On average over many years, the mean temperature in the months of December–January–February is below 0°C, and monthly mean temperatures in the period April–October are above 10°C. The average annual rainfall is 690 mm. The annual rainfall is relatively even. The wettest month is June (78 mm) and the driest is March (45 mm).

Field work

The Jermy-type light trap used in the collections was placed at a height of 3 metres above the ground. The light source was a 9 W LED bulb with a colour temperature of 4500 K (close to the spectral composition of natural light).

The trap was operated between 8 pm and 5 am (CET) between 1 May 2018 and 7 May 2019 for a total of 97 days on the following days: 2018.05.01–02, 05.04–05, 05.12–13, 05.19–20, 05.27–28, 05.28–29, 06.01–02, 06.03–04, 06.06–07, 06.09–10, 06.14–15, 06.15–16, 06.18–19, 06.19–20, 06.24–25, 07.01–02, 07.02–03, 07.04–05, 07.05–06, 07.12–13, 07.13–14, 07.16–17, 07.24–25, 07.25–26, 07.26–

[2] Szalai, S., I. Auer, J. Hiebl, J. Milkovich, T. Radim, [et al.]. 2013. Climate of the Greater Carpathian Region. Final Technical Report. European Commission – JRC, www.carpatclim-eu.org.

27, 07.28–29, 07.29–30, 07.30–31, 08.02–03, 08.03–04, 08.04–05, 08.06–07, 08.09–10, 08.10–11, 08.12–13, 08.17–18, 08.19–20, 08.21–22, 08.24–25, 08.26–27, 08.27–28, 08.30–31, 09.01–02, 09.04–05, 09.06–07, 09.07–08, 09.10–11, 09.12–13, 09.14–15, 09.17–18, 09.19–20, 09.25–26, 09.27–28, 09.29–30, 10.07–08, 09–10, 10.11–12, 10.12–13, 10.14–15, 10.15–16, 10.17–18, 10.19–20, 10.27–28, 10.29–30, 10.30–31, 11.04–05, 11.05–06, 11.07–08,11.09–10, 11.11–12, 11.13–14, 11.14–15, 11.17–18, 11.19–20, 11.21–22, 11.24–25, 03.06–07, 03.11–12, 2019.03.14–15, 03.21–22, 03.23–24, 03.24–25, 03.26–27, 03.29–30, 03.30–31, 04.02–03, 04.04–05, 04.09–10, 04.11–12, 04.18–19, 04.19–20, 04.24–25, 04.25–26, 04.26–27, 04.29–30, 05.01–02, and 05.06–07.

The moths and butterflies that arrived in the catcher were stunned with ethyl acetate and collected in the morning hours each day, then preserved by freezing until taxonomic identification. For taxonomic identification of the moths and butterflies, the recommendations of the Catalogue of Life[3] and the International Commission on Zoological Nomenclature[4] were used.

Data analysis

Statistical processing of our results was performed in Microsoft Excel 2019 and PAST 4.50 (Hammer et al. 2001). For meteorological data, data from Station 12786: Záhony (Hungary) were used [OGIMET[5]]. Daily % of lunar disk values were taken from the Almanac official astronomical website [AOAW[6]] database. Diversity relationships of the Lepidoptera fauna of the study area were determined using Shannon diversity calculations [Pielou 1975] and Buzas and Gibson's evenness values (eH/S, where H is the Shannon–Weaver index, S is the number of species). Relationships between environmental variables and individual Lepidoptera species and diversity relationships were analysed using redundancy analysis [RDA, Legendre & Legendre 1998] and linear correlation analysis. To decide which of the species have a significantly defined frequency, i.e. are not randomly present in the area at a given time, a modified statistical test for hypothesis of probability evenness [Vincze 1975] was applied. To decide which are the species with significant definite frequency—i.e. it is not random that they are present in a given place at a given time— the statistical test for hypothesis of probability evenness has been used (Vincze 1975). This can be applied to the problem as it follows: in a given ε probability level, we can determine a critical interval with h_1 and $h_2>h_1$ borders. If there is, at least, one *S* species with f_S frequency, so that $f_S>h_2$, we cannot consider the distribution of the species direction to be even. In this case, *S* is called a characteristic *species* (CSP), otherwise, it is a non-characteristic species (NSP) on $1-\varepsilon$ probability level. From a zoocoenological point of view, species with absolute abundance higher than the h_2 upper limit of f_S need to be considered in more detail. The values of h_1 and h_2 are:

$$h_1 = p_0 n - u_\varepsilon \sqrt{np_0(1-p_0)} \qquad \text{and} \qquad h_2 = p_0 n + u_\varepsilon \sqrt{np_0(1-p_0)}$$

where p_0 is the basic probability of occurrence of a species (assuming uniform distribution in the area), i.e. now, since 122 species are distinguished $p_0 = 1/122 = 0.008$, *n* is the total number of cases (sample size: total number of individuals per species). The u_ε can be defined in the following correlation:

$$2\Phi(u_\varepsilon) - 1 = 1 - \varepsilon$$

where $\Phi\Phi\ (x)$ is the distribution function of the standard normal distribution, ε is the probability threshold for the occurrence of a species f_S times out of *n* cases under the assumption of a basic probability p_0. Thus, if $\varepsilon = 0.0027$ [Dévényi & Gulyás 1988], then $u_\varepsilon = 2.98$.

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[3] https://www.catalogueoflife.org/

[4] https://www.iczn.org/the-code/the-international-code-of-zoological-nomenclature/

[5] OGIMET – Weather Information Service – 12786: Zahony (Hungary). Accessed on 10. 04. 2022. https://www.ogimet.com

[6] AOAW: Almanac official astronomical website: https://www.almanac.com/astronomy/moon/calendar/CT/Hungary/

If the relative frequency of species Rf_S is given in %, then the limits of the critical interval are $H_1 = 100h_1/n$, $H_2 = 100h_2/n$. The characteristic species with the highest relative abundance is considered the dominant species (DSP).

Results and Discussion

Lepidoptera fauna of the area

As a result of the collections, 604 individuals of 122 species of 16 Lepidoptera families were indentified (Table 1), including 43 species of the family Noctuidae, 28 of the family Geometridae, 13 of the family Crambidae, 9 of the family Erebidae, 8 of the family Pyralidae, 7 of the family Torticidae, 3 of the family Lasiocampidae, 2 of the family Pterophoridae, 1 of the family Plutellidae, 1 of the family Yponomeutidae, 1 of the family Notodontidae, 1 of the family Nolidae, 1 of the family Gelechiidae, 1 of the family Drepanidae, 1 of the family Hepialidae, and 2 of the family Nymphalidae.

Table 1. **Lepidoptera species observed during the research**

Таблиця 1. **Види метеликів, які спостерігалися під час досліджень**

Species	Family	Species	Family	Species	Family
1. Abrostola triplasia	*No*	*42. Diacrisia sannio*	*Er*	*83. Mythimna turca*	*No*
2. Acronicta rumicis	*No*	*43. Diaphora mendica*	*Er*	*84. Nomophila noctuella*	*Cr*
3. Aedia leucomelas	*No*	*44. Diasemia reticularis*	*Cr*	*85. Ochropleura plecta*	*No*
4. Agapeta hamana	*To*	*45. Dichomeris limosellus*	*Gl*	*86. Oncocera semirubella*	*Py*
5. Agriopis aurantiaria	*Ge*	*46. Dioryctria sylvestrella*	*Py*	*87. Operophtera brumata*	*Ge*
6. Agriopis bajaria	*Ge*	*47. Dolicharthria punctalis*	*Cr*	*88. Orthosia gothica*	*No*
7. Agrochola litura	*No*	*48. Earias clorana*	*Nl*	*89. Orthosia gracilis*	*No*
8. Agrochola lota	*No*	*49. Egira conspicillaris*	*No*	*90. Orthosia incerta*	*No*
9. Agrotis exclamationis	*No*	*50. Eilema lutarella*	*Er*	*91. Orthosia opima*	*No*
10. Allophyes oxyacanthae	*No*	*51. Elaphria venustula*	*No*	*92. Ostrinia nubilalis*	*Cr*
11. Anania hortulata	*Cr*	*52. Ematurga atomaria*	*Ge*	*93. Pandemis cerasana*	*To*
12. Anania verbascalis	*Cr*	*53. Emmelia trabealis*	*No*	*94. Pararge aegeria tircis*	*Ny*
13. Angerona prunaria	*Ge*	*54. Epione repandaria*	*Ge*	*95. Pelosia muscerda*	*Er*
14. Anticlea derivata	*Ge*	*55. Erannis defoliaria*	*Ge*	*96. Peribatodes rhomboidaria*	*Ge*
15. Aphomia sociella	*Py*	*56. Eucarta amethystina*	*No*	*97. Phragmatobia fuliginosa*	*Er*
16. Ascotis selenaria	*Ge*	*57. Eucosma conterminana*	*To*	*98. Pleuroptya ruralis*	*Cr*
17. Autographa gamma	*No*	*58. Eupsilia transversa*	*No*	*99. Plutella xylostella*	*Pl*
18. Axylia putris	*No*	*59. Eurhodope rosella*	*Py*	*100. Poecilocampa populi*	*La*
19. Camptogramma bilineata	*Ge*	*60. Gluphisia crenata*	*Nt*	*101. Pseudeustrotia candidula*	*No*
20. Catarhoe rubidata	*Ge*	*61. Hedya nubiferana*	*To*	*102. Pterophorus pentadactyla*	*Pt*
21. Catoptria falsella	*Cr*	*62. Helicoverpa armigera*	*No*	*103. Pyrausta aurata*	*Cr*
22. Celypha rivulana	*To*	*63. Homoeosoma sinuella*	*Py*	*104. Pyrausta purpuralis*	*Cr*
23. Cerastis rubricosa	*No*	*64. Hydraecia micacea*	*No*	*105. Rivula sericealis*	*Er*
24. Chiasmia clathrata	*Ge*	*65. Hypomecis roboraria*	*Ge*	*106. Scoliopteryx libatrix*	*Er*
25. Chlorissa cloraria	*Ge*	*66. Hypoxystis pluviaria,*	*Ge*	*107. Scopula flaccidaria*	*Ge*
26. Chrysoteuchia culmella	*Cr*	*67. Hypsopygia costalis*	*Py*	*108. Scopula immorata*	*Ge*
27. Cleora cinctaria	*Ge*	*68. Idaea dimidiata*	*Ge*	*109. Scopula rubiginata*	*Ge*
28. Clepsis pallidana	*To*	*69. Ipimorpha subtusa*	*No*	*110. Synaphe punctalis*	*Py*
29. Cnaemidophorus rhododactyla	*Pt*	*70. Lacanobia oleracea*	*No*	*111. Thalera fimbrialis*	*Ge*
30. Colotois pennaria,	*Ge*	*71. Lasiocampa quercus*	*La*	*112. Thetidia smaragdaria*	*Ge*
31. Conisania luteago	*No*	*72. Ligdia adustata*	*Ge*	*113. Tholera decimalis*	*No*
32. Conistra erythrocephala	*No*	*73. Lithophane ornitopus*	*No*	*114. Thyatira batis*	*Dr*
33. Conistra rubiginosa	*No*	*74. Lycia hirtaria*	*Ge*	*115. Timandra comae*	*Ge*
34.Conistra vaccinii	*No*	*75. Macdunnoughia confusa*	*No*	*116. Trachea atriplicis*	*No*
35. Cosmia pyralina	*No*	*76. Malacosoma neustria*	*La*	*117. Triodia sylvina*	*He*
36. Cucullia umbratica	*No*	*77. Mamestra brassicae*	*No*	*118. Tyta luctuosa*	*Er*
37. Cydalima perspectalis	*Cr*	*78. Metacrambus carectellus*	*Cr*	*119. Vanessa atalanta*	*Ny*
38. Cydia pomonella	*To*	*79. Miltochrista miniata*	*Er*	*120. Xanthorhoe ferrugata*	*Ge*
39. Deltote bankiana	*No*	*80. Myelois circumvoluta*	*Py*	*121. Xestia c-nigrum*	*No*
40. Deltote pygarga	*No*	*81. Mythimna albipuncta*	*No*	*122. Yponomeuta plumbella*	*Yp*
41. Diachrysia stenochrysis	*No*	*82. Mythimna l-album*	*No*		

Note: Noctuidae—*No*, Geometridae—*Ge*, Crambidae—*Cr*, Erebidae—*Er*, Pyralidae—*Py*, Tortricidae—*To*, Lasiocampidae—*La*, Pterophoridae—*Pt*, Nymphalidae—*Ny*, Plutellidae—*Pl*, Yponomeutidae—*Yp*, Notodontidae—*Nt*, Nolidae—*Nl*, Gelechiidae—*Gl*, Drepanidae—*Dr*, Hepialidae—*He*

In terms of numbers of individuals, as well as species, species from the families Noctuidae (147) and Geometridae (140) dominated, with 90 species from the family Crambidae, 38 from the family Erebidae, 73 from the family Pyralidae, 48 from the family Torticidae and 25 from the family Lasiocampidae, 3 from the family Pterophoridae, 7 from the family Plutellidae, 3 from the family Yponomeutidae, 1 from the family Notodontidae, 1 from the family Nolidae, 1 from the family Gelechiidae, 1 from the family Drepanidae, 1 from the family Hepialidae, 24 from the family Hephalidae, and 2 from the family Nymphalidae.

Of the 122 Lepidoptera species collected, 29 species reached a relative abundance of at least 1%. Of these, *Oncocera semirubella* was the most abundant (7.5%), but *Ostrinia nubilalis* (5.3%), *Celypha rivulana* (5.1%), *Timandra comae* (4.6%), and *Triodia sylvina* (4.0%) also had a considerable proportion (Fig. 2).

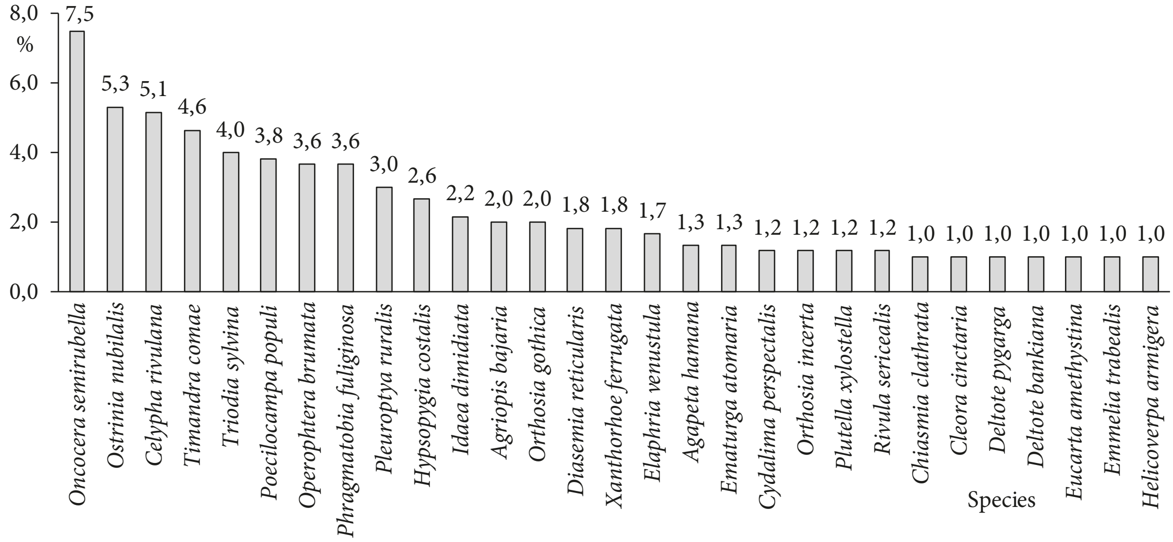

Fig. 2. Quantitative ratios of Lepidoptera species identified in the samples that reached or exceeded a relative abundance of 1%.
Рис. 2. Кількісні співвідношення видів метеликів, ідентифікованих у зразках, які досягли або перевищили відносну частоту 1%.

Table 2. **Number of species (SP_n) captured in the total period and in each month.**
Таблиця 2. **Кількість видів (SP_n) уловлених за весь період і по місяцях.**

Months	SP_n	*DSP*	DSP_{Rf}	*CSP*	CSP_n	CSP_{SRf}	CSP_{ARf}	NSP_n	NSP_{SRf}	NSP_{ARf}
May	10	*P. xylostella*	18.2	*P. xylostella*	1	18.2	18.2	9	81.8	9.1
June	28	*O. semirubella*	13.6	*A. hamana, H. costalis, O. semirubella*	3	33.3	11.1	25	66.7	2.7
July	54	*C. rivulana*	8.9	*C. rivulana, O. nubilalis, O. semirubella*	3	25.0	8.3	51	75.0	1.5
August	53	*T. comae*	10.6	*C. rivulana, O. nubilalis, O. semirubella, P. fuliginosa, T. sylvina, T. comae*	6	45.7	7.6	47	54.3	1.2
September	27	*T. sylvina*	17.3	*O. semirubella, P. ruralis, T. sylvina*	3	42.7	14.2	24	57.3	2.4
October	11	*A. bajaria*	41.7	*A. bajaria*	1	41.7	41.7	10	58.3	5.8
November	9	*O. brumata*	40.7	*O. brumata, P. populi*	2	81.5	40.7	7	18.5	2.6
March	8	*O. gothica*	21.7	*O. gothica*	1	21.7	21.7	7	78.3	11.2
April	19	*O. gothica*	17.5	*C. cinctaria, O. gothica*	2	32.5	1.0	17	67.5	4.0
Full period	122	*O. semirubella*	7.5	*A. bajaria, C. rivulana, D. reticularis, H. costalis, I. dimidiata, O. brumata, O. gothica, O. nubilalis, O. semirubella, P. populi, P. fuliginosa, P. ruralis, T. sylvina, T. comae, X. ferrugata*	15	53.0	3.5	107	47.0	15

Note: dominant species (DSP), its relative frequency (DSP_{Rf}), characteristic species (CSP), their number (CSP_n), combined relative frequency (CSP_{SRf}) and average relative frequency (CSP_{ARf}), number of non-dominant species (NSP_n), their combined relative frequency (NSP_{SRf}) and average relative frequency (NSP_{ARf})

домінуючий вид (DSP), його відносна частота (DSP_{Rf}), типовий вид (CSP), їх кількість (CSP_n), їх сукупна відносна частота ($CSPS_{Rf}$) і середня відносна частота ($CSPA_{Rf}$), кількість нетипових видів (NSP_n), їх сукупна відносна частота (NSP_{SRf}) і середня відносна частота (NSP_{ARf})

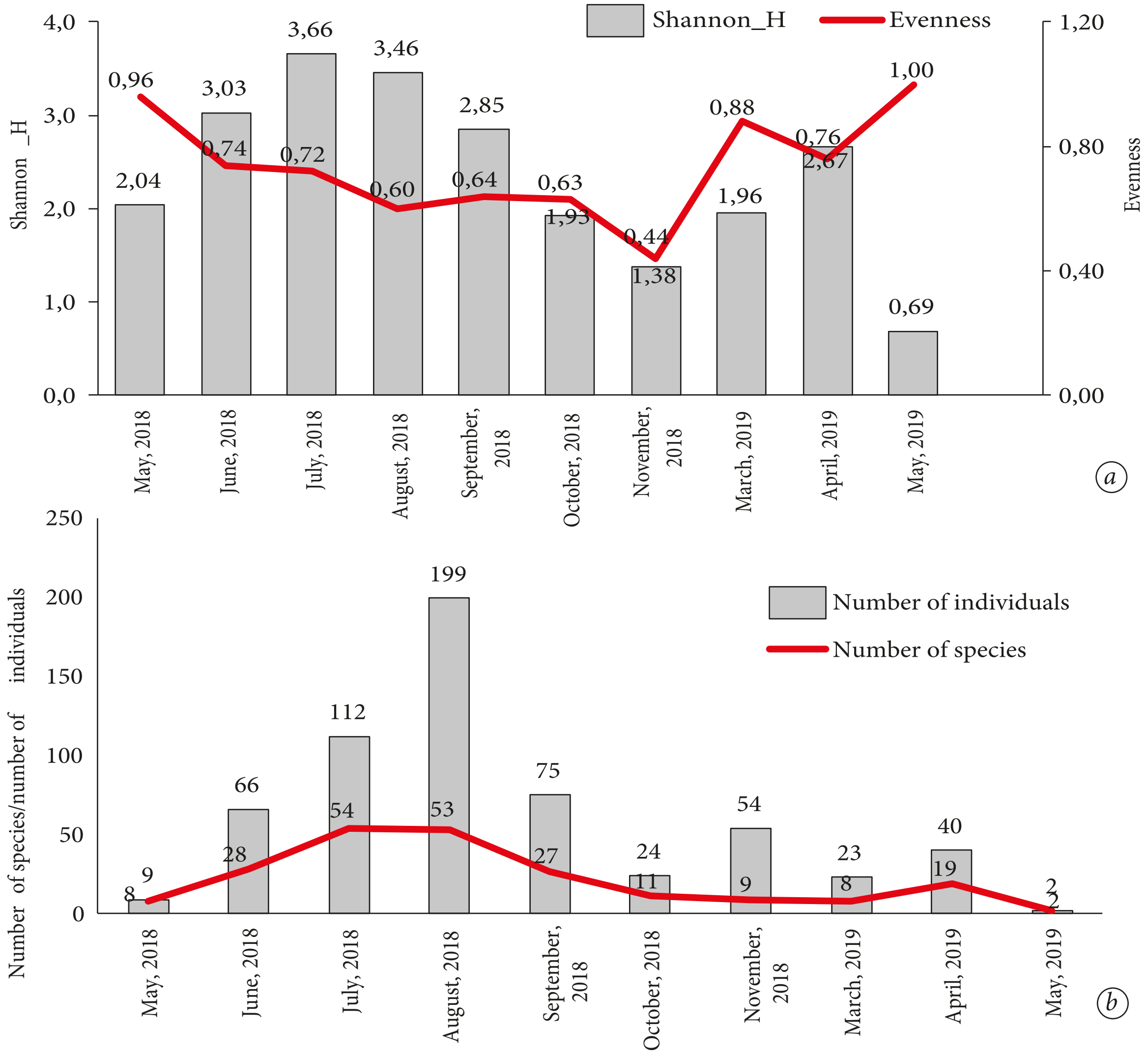

Fig. 3. Monthly trends in Shannon Diversity and Evenness (A) and species number and number of individuals (B) during the study period.

Рис. 3. Індекс різноманітності Шеннона і вирівняність (A) та зміна кількості видів і чисельності особин (B) по місяцям протягом досліджуваного періоду.

While all months had a dominant species, *Oncocera semirubella* was dominant throughout the June–September period. This species, which feeds mainly on legumes (Fabaceae), grows up to two generations per year and was observed in the samples during most of the study period. Looking at the number of species and number of individuals in each month, the highest values were found between June and September, with a maximum in August for both variables. Shannon's diversity values were higher in spring and summer and lower in autumn, while the evenness indices showed higher values in March, April, and May (Fig. 3, Table 2).

The data on species composition (122 species) were compared with the results of previous light trapping, scent trapping, and visual observation of Geryak's [2018] field collections in the vicinity to identify species belonging to six families of the taxon Noctuoidea (Notodontidae, Nolidae, Arctiidae, Lymantriidae, Erebidae, and Noctuidae). In his research, he reports 498 species from Transcarpathia. In the narrower surroundings of Velyki Berehy, he reports the occurrence of 217 species (6 families) at Ardai Hill in Berehovo, 185 species (6 families) at Muzhiyeve, 23 species (5 families) at Yanoshi, and 142 species of common occurrence.

In the present study, 54 species of the taxon Noctuoidea (Notodontidae 1, Nolidae 1, Erebidae 9, and Noctuidae 43) were identified. Comparing the species list of Geryak [2018] for the area around Velyki Berehy (Ardai Hill, Muzhiyeve, and Yanoshi) and the general distribution with the results of the present study, an agreement was found for 50 Lepidoptera species, which clearly indicates that further systematic survey studies are needed and further spatial descriptions of species can be expected in the future.

The relationship between environmental variables and Lepidoptera fauna

The monthly abundance and number of species of moths and butterflies collected in the study area were also compared with six environmental variables. The relationship between the abundance of the species captured and the temperature, relative humidity, wind speed, cloud cover, and moon phases were examined using linear correlation, regression, and redundancy analyses. The correlation between variables was sought by considering the mean, minimum, and maximum values of environmental factors and the values for different intervals of the sampling period.

Table 3. **The linear correlation (r) coefficient between the number of individuals and species per case and the relationship between the environmental factors (bold: significant relationship, p = 0.05 probability level).**

Таблиця 3. **Значення коефіцієнта лінійної кореляції (r), що виражає залежність між чисельністю особин і кількістю видів та окремими факторами середовища (жирний шрифт: значущий зв'язок, на рівні ймовірності p=0,05).**

Variables		Number of individuals time period (GMT+2)			Number of species time period (GMT+2)		
		14–23h	20–23h	20–05h	14–23h	20–23h	20–05h
Temperature (T), °C whole period	mean	**0.614**	**0.705**	**0.645**	**0.730**	**0.604**	**0.740**
	min	**0.582**	**0.617**	**0.633**	**0.699**	**0.705**	**0.711**
	max	**0.580**	**0.586**	**0.621**	**0.686**	**0.697**	**0.738**
Temperature (T), °C Jun–Nov.	mean	**0.601**	**0.634**	**0.640**	**0.742**	**0.762**	**0.757**
	min	**0.571**	**0.645**	**0.633**	**0.719**	**0.645**	**0.734**
	max	**0.557**	**0.619**	**0.619**	**0.684**	**0.758**	**0.758**
Relative humidity (RH), % whole period	mean	–0.053	–0.140	–0.092	–0.137	**–0.217**	–0.144
	min	–0.116	–0.164	–0.157	–0.194	**–0.262**	**–0.254**
	max	–0.119	–0.097	0.000	–0.075	–0.141	–0.027
Relative humidity (RH), % Jun–Nov.	mean	**–0.223**	**–0.340**	**–0.325**	**–0.347**	**–0.439**	**–0.393**
	min	–0.010	**–0.341**	**–0.339**	–0.076	**–0.468**	**–0.465**
	max	–0.192	**–0.310**	**–0.209**	**–0.284**	**–0.359**	**–0.236**
Wind speed (WS), m/s	mean	–0.149	–0.111	–0.094	–0.125	–0.147	–0.104
Cloud cover (CC), %	mean	–0.137	–0.049	–0.160	–0.130	–0.129	**–0.219**
Moonlight, %	---		–0.103			–0.105	

Table 3 shows the most closely related values of the linear correlation coefficient and the regression coefficient. The critical value of the correlation coefficient for the significance level p = 0.05 in this case (n = 97) is $r_{0.05} = 0.199$, i.e. the weak negative relationship between wind speed and the number of species captured during the sampling period (r = –0.147) and the number of individuals (r = –0.149) is not significant. There is also a weak but significant relationship with relative humidity (r = –0.468) and cloud cover (r = –0.219), especially for minimum values, with a negative sign, i.e. the lower the humidity and cloud cover, the more species and their individuals were found in the area. The strongest stochastic correlation is observed between the number of species captured per case and the mean temperature (r = 0.758). The coefficient of determination ($r^2 = 0.575$), i.e. about 58% of the total variance in the number of species captured, can be explained by a linear regression on the air temperature during the sampling period, while the remaining 42% is due to other abiotic and/or biotic factors, possibly due to chance.

The daily species count and total number of individuals data, as well as the five environmental variables analysed using redundancy distribution analysis (RDA), also showed similar relationships (Fig. 4). The first axis explained 37.09% of the variability in the variables ($r^2 = 0.3794$; F = 11.13; permutation test, n = 999; p = 0.001). Daily variation in temperature was considered to be one of the most significant factors in the evolution of species number and individual count data over time. At the species level, a stronger relationship was found for *O. semirubella* (86), *C. rivulana* (22), and *O. nubilalis* (92), but this was not considered significant. In this comparison, no strong and characteristic relationships at species level were found for relative humidity, cloud cover, wind speed, and moon phases, with the correlation values of the species being more clustered around the origo.

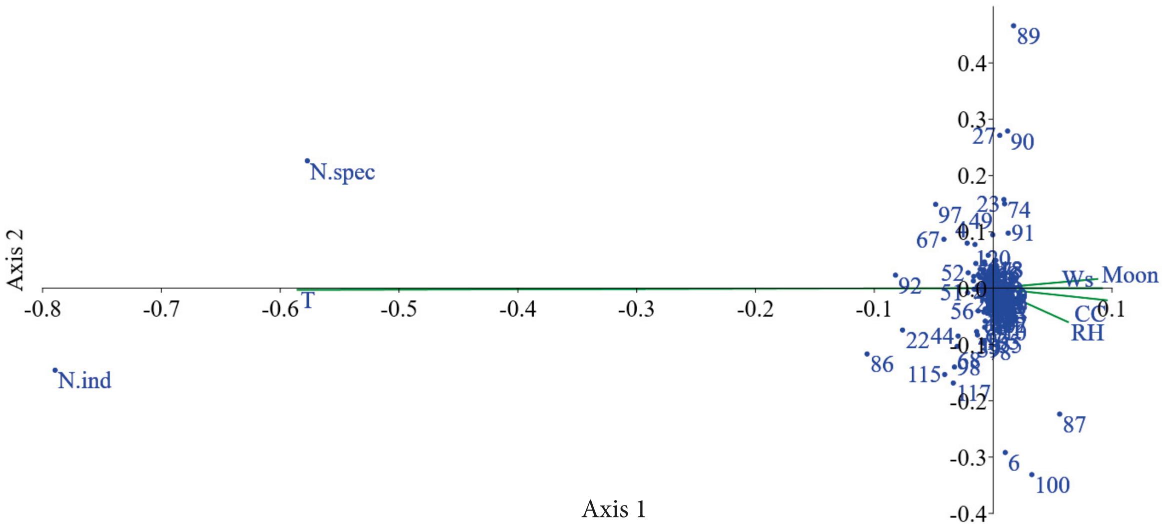

Fig. 4. Result of the redundancy analysis on the number of Lepidoptera species and the five environmental variables studied (N.spec—number of species; N.ind—number of individuals, the blue numbers refer to the number of species in the previous list).

Рис. 4. Результат аналізу надмірності (редунданції), виконаного на даних чисельності видів метеликів і на 5 досліджуваних змінних середовища (N.spec—кількість видів, N.ind—кількість особин, сині цифри позначають порядкові номери метеликів перелічені у попередньому списку).

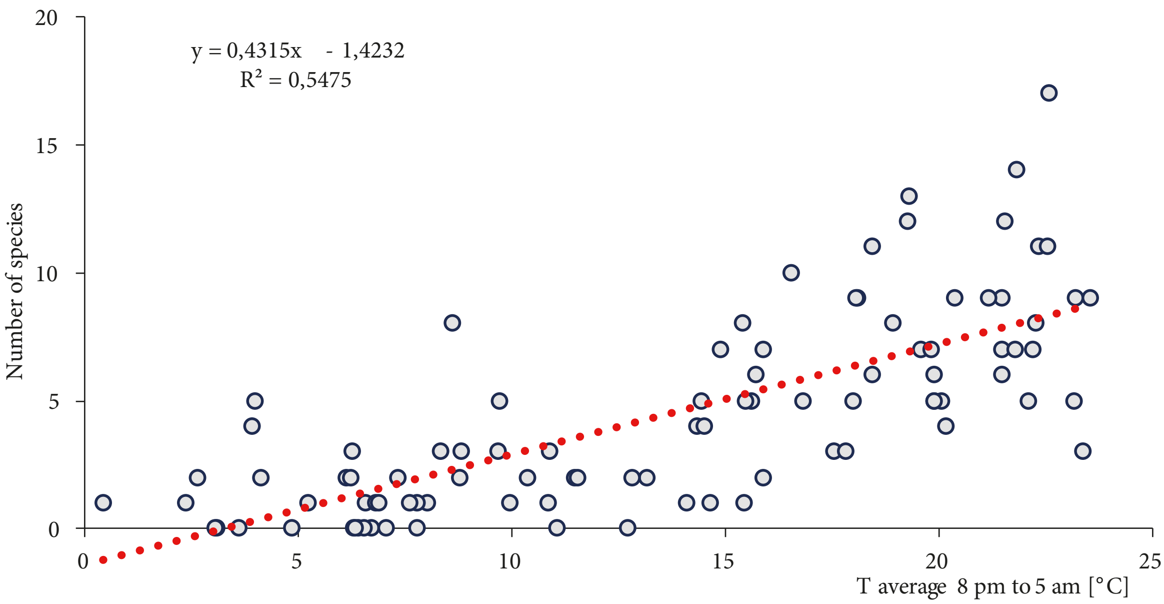

Fig. 5. Relationship between average air temperature (between 8 pm and 5 am on the night of sampling) and the number of species captured.

Рис. 5. Кореляція між середньою температурою повітря (в ніч відбору проб між 20:00 та 05:00) та кількістю уловлених видів.

The heat-island effect, which is increasingly studied in terms of its ecological effects on inhabited settlements, is likely to have less impact on the spatial distribution of insect communities in a village of the size and location of Velyki Berehy in summer than, for example, anthropogenic light pollution in the form of moonlight. Where urban heat island effects and anthropogenic light pollution are more pronounced, there may be noticeable changes in the phenology of Lepidoptera species. Warmer environments accelerate insect growth, and light pollution increases the length of the moths and moths and butterflies' diurnal active period, mutually disrupting their normal adaptation to natural seasonal changes [Merckx *et al*. 2021].

The extent to which species frequencies vary with temperature can be expressed by linear regression between variables. The slope of the best-fitting line in the equation $y = ax + b$, the regression coefficient, is also the sensitivity of the dependent variable (y, i.e. number of species) to a unit change in the value of the independent variable (x, i.e. temperature) [Obádovics 2003].

This means that, statistically, no species is found below 3.5°C, and then a 1°C change (increase) in temperature causes an average 1.2-fold increase in the number of species. It can also be said that a rise in night-time temperature from 5°C to 10°C causes on average 3 times as many species to become active (2.5 times as many individuals) as a rise from 20°C to 25°C.

In terms of the frequency distribution of the number of individuals by temperature, overall, most individuals (259) occurred on the warmest nights (between 8 pm and 5 am, Figs. 5–6) with temperatures between 20–25°C. There was also a weak negative correlation between the % of the daily size of the Moon disk and the number of species ($r = -0.105$) and the number of individuals ($r = -0.103$).

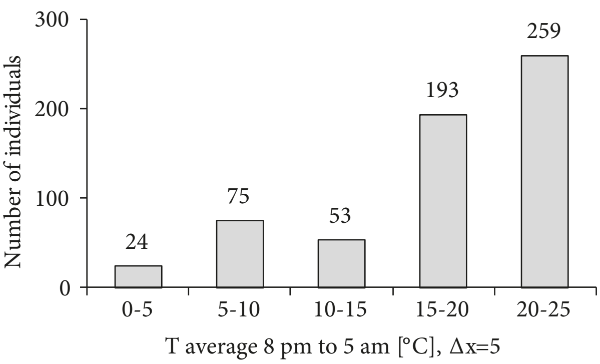

Fig. 6. Frequency distribution of individuals by air temperature.

Рис. 6. Частотний розподіл особин за температурою повітря.

Conclusions

The trap, equipped with a conventional household LED light bulb, attracted a total of 122 Lepidoptera species during the study period. Although the species with a relative frequency of more than 1% are mostly common, the habitat diversity of the study area can be traced through the composition of the Lepidoptera fauna. In addition to species associated with cultivated areas and considered as agricultural, horticultural, and silvicultural pests (*O. nubilalis, O. semirubella, T. sylvina, P. ruralis, E. atomaria, C. perspectalis, P. xylostella, H. armigera,* and *H. costalis*), species typical of woodlands and forest edges (*X. ferrugata, R. sericealis*), meadows (*D. reticularis, C. rivulana,* and *A. hamana*), as well as marshes (*I. dimidiata, E. amethystina,* and *E. venustula*), floodplains (*I. dimidiata, E. amethystina,* and *E. venustula*), abandoned vineyards (*D. pygarga*) and dry areas (*E. trabealis*) were also represented. For the complete list of species, no Lepidoptera species from the Red Data Book of Ukraine were detected, but *V. atalanta* and *P. aegeria* are found in the IUCN Red List with Least Concern (LC) classification. Experience shows that the species number and species composition of the Lepidoptera fauna of the area is not yet complete, as only a scant third of the species already known from previous surveys in the area were found. The role of the environmental variables studied in the faunistic indicators is obviously overshadowed by the fact that the samples were collected in a residential area. It was observed that during periods of low humidity and dry weather, moths and butterflies arrived at the light trap in higher numbers. As the average temperature increased, both species and individual numbers increased. Species-level differences may also exist in this respect. For example, in the case of the polyphagous species *O. brumata*, which was common in the sample collections, the results of light trap collections in Hungary showed a strong relationship between the gradient of individuals of the species and the sum of the amount of rainfall in June and the number of hours of sunshine in October [Kúti *et al*. 2010].

Previous literature is also inconsistent on the effects of light pollution and moonlight on Lepidoptera. For moonlight, we found a weak negative correlation with diurnal changes in species and number of individuals, indicating that fewer insects were collected by the light trap during periods of stronger moonlight. In terms of the direction of the phenomenon, our results are in line with a large body of relevant studies that stronger moonlight reduces the number of insects captured. This phenomenon may be due to the fact that the light from the trap is less effective on lighter nights, collecting from a smaller area, and the intense moonlight may naturally help to orient insects that are active at night [Nowinszky 2000].

Similar experiences exist with moths and butterflies and other nocturnal insects: Rubio-Palis [1992] on the malaria vector species *Anopheles nuneztovari*, Nag & Nath [1991] on *Agrotis ipsilon*, Shrivastava *et al*. [1987] on *Spodoptera litura*, Yela & Holyoak [1997] on species of the family Noctuidae, Nowinszky & Puskás [2009] on *Ostrinia nubilalis*, Gebresilassie *et al*. [2015] on *Phlebotomus orientalis*, and Mishra *et al*. [1999] on *Agrotis flammatara* reported that low numbers of individuals were detected on nights close to the full moon, with more intense drawing activity during waning moon phase than during waxing moon phase. For other species, however, it is not clear that stronger moonlight results in higher catches. There are also suggestions that moonlight may extend the night flight period, leading to an increase in the number of insects captured [Nowinszky 2000]. In light trapping studies of *Scotinophara coarctata*, Ito *et al*. [1993] found higher numbers of insects during the full moon and lower numbers during the new moon. Studies by Bowden & Jones [1979] also showed that *Delia coarctata* had the highest number of individuals during the full moon.

In addition to naturally occurring night-time light sources, the ecological and metabolic effects of artificial light pollution on insects and their interactions with each other may further complicate the issue [Longcore & Rich 2015; Boyes *et al*. 2021]. These results have revealed trends and relationships in Lepidoptera faunal composition and responses to environmental drivers, but species-level specificities and associated habitat effects often nuance the direction and magnitude of these trends.

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