https://doi.org/10.17221/33/2023-PPS

The importance of local faunal research of moths for plant protection: an example from an agricultural landscape in central Europe

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Citation: Hrubešová V., Šefrová H., Laštůvka Z. (2023): The importance of local faunal research of moths for plant protection: an example from an agricultural landscape in central Europe. Plant Protect. Sci., 59: 348—355.

Abstract: The study was carried out in the agricultural landscape (mosaic of an urban environment, gardens, grassland, fields, small forests and semi-natural non-forest habitats) in central Europe (southeast Czechia) in 2021. A light trap was used for trapping (207 nights). A total of 485 moth species and 5 170 individuals were captured. Eurytopic species dominated the area, 72% of species and 89% of individuals. Fifty-nine species are considered pests (12%), representing 25% of individuals. The seasonal dynamics of selected harmful species were evaluated and discussed. Species of semi-natural dry and wet habitats were represented by 14%, i.e. a proportion comparable to pests, but with only 4% of individuals. The numbers of species and individuals recorded and the Shannon-Wiener diversity and evenness indices are lower than at natural sites. Yet, overall biodiversity is relatively high, including the presence of some rare, ecologically, or zoogeographically remarkable species.

Keywords: agricultural landscape; Lepidoptera; light trap; pests; natural habitat species

Entomological investigations are usually carried out in natural habitats, with the aim of capturing the local species composition and revealing occurrence of remarkable (rare, endangered, bioindicative) species. In intensively used agricultural landscapes or residential environments, similar surveys are usually considered "unattractive" and, therefore, relatively uncommon (Hluchý & Dobšík 1984; Wolda et al. 1994; Šafář 2010). However, their numbers are increasing due to insect declines and efforts to change landscape structure to support biodiversity (Kadlec et al. 2009; Ekroos et al. 2010; Botham et al. 2015). Alternatively, research in these habitats is focused on a very limited spectrum of harmful species (the Central Institute for Supervising and Testing in Agriculture light trap network) or is targeted at opportunities to control methods of individual harmful species.

This research aimed to investigate the moth fauna of the agricultural landscape, with a primary focus on what harmful species occur there (which important crops may damaged) and what share they have in the overall moth assemblage, i.e. also to determine the overall moth diversity expressed in numbers of species, individuals and basic synecological indices, and whether species

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of faunistic, ecological or other significance occur in addition to pests.

MATERIAL AND METHODS

Research area. The research was carried out in the outskirts of the town of Ivančice, SE part of Czechia (49.0950703N, 16.3610058E). The study area lies in a valley position at 205 m a.s.l., the surrounding landscape is rugged and rises to an altitude of about 270 m. The average annual air temperature is 8.5 °C, and the average annual rainfall is 550 mm (VÚMOP 2022). There is a vegetable garden with individual fruit trees and ornamental plants in the site's immediate vicinity. Extensively farmed fields with islands of ruderal vegetation predominate within a 200 m radius. In the east, at a distance of at least 200 m, this area is bordered by the Jihlava river with riparian stands of wetland plants. Large areas to the east and partly to the south are urbanised; to the north, west and south, there are large intensively farmed agrocenoses (esp. with barley, rape, maise, and wheat). Small forest stands are found in different directions at distances of 1 000–1 600 m, and groups of trees are along the streams and in small islands in the agrocenoses. The nearest localities of xerothermophilous herbaceous and scrub vegetation are located about 900 m to the south and about 1 200–1 600 m west (Figure 1).

Trapping, identification and evaluation. A portable light trap of the standard construction was used (Dykyjová 1989); the light source was an energy-saving UV bulb BeamZ 160.022/023 25 W 230 V (wavelength 320–400 nm, luminosity 850 lm). Chloroform was used as the killing medium. The trap was placed under the roof of a farm building and was in operation every night from dusk to dawn (photo booth) from April 22 to November 15, 2021 (207 nights). The somewhat delayed start of the trapping was due to the very cold spring in 2021. All individuals were determined to species level. Standard determination manuals were used where appropriate, especially for some Gelechiidae and Tortricidae (Elsner et al. 1999; Razowski 2001). Knowledge of trophic requirements and bionomics is based primarily on the comprehensive publication by Patočka and Kulfan (2009). In assessing the harmfulness, we relied both on older and more recent compendia and papers, especially by Miller (1956), Kůdela and Kocourek (2002), and Šefrová (2003). For details on the calculation of basic synecological indices, for example Odum (1971). We used natural logarithms (ln) to calculate the Shannon-Wiener diversity (H') and evenness (e) indices.

We analysed the presence of important and occasional pests, divided into pests of fields and gardens, orchards, ornamental plants and stored materials. Occurrence of semi-natural habitat species and otherwise interesting species was also evaluated. The nomenclature of moth species follows Laštůvka and Liška (2011).

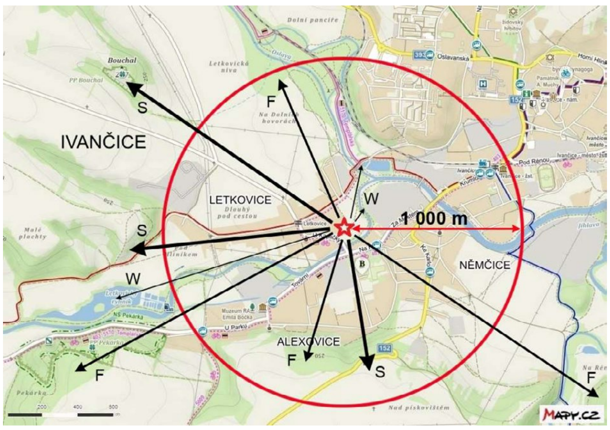

Figure 1. Map of the area

* location of the light trap; F – forest habitats; S – xerothermic herbaceous and scrub habitats; W – small wetlands

Source map: mapy.cz, © Seznam.cz, a.s.

RESULTS

Overall results. During the research, 485 species belonging to 36 families were captured, totalling 5 170 individuals. The most species-rich families were Noctuidae (125 species), Geometridae (81 spp.) and Tortricidae (61 spp.), while the most rich families in terms of number of individuals were Noctuidae (2 285 individuals), Geometridae (766) and Crambidae (752). The most abundant species was *Xestia c-nigrum* (Table 1).

Habitat requirements. Eurytopic species (both harmful and harmless) dominated the area (72%), with 89% of their individuals (Figures 2 and 3). Natural dry and wet habitat species also made up somewhat larger proportions (7%) but with only 2% of individuals. Ornamental woody planting and orchard species had low proportions, with an even lower proportion of individu-

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Table 1. The most numerous species (ordered by abundance)

Species	No.	(%)
Xestia c-nigrum (Linnaeus)	295	5.73
Ochropleura plecta (Linnaeus)	219	4.26
Axylia putris (Linnaeus)	195	3.79
Peribatodes rhomboidaria (Den. & Schiff.)	180	3.50
Luperina testacea (Den. & Schiff.)	126	2.45
Catoptria falsella (Den. & Schiff.)	119	2.31
Chiasmia clathrata (Linnaeus)	117	2.27
Agrotis exclamationis (Linnaeus)	94	1.83
Mythimna pallens (Linnaeus)	90	1.75
Timandra comae (Schmidt)	89	1.73
Hoplodrina ambigua (Den. & Schiff.)	85	1.65
Hoplodrina octogenaria (Goeze)	80	1.56
Ostrinia nubilalis (Hübner)	78	1.52
Hoplodrina blanda (Den. & Schiff.)	71	1.38
Phragmatobia fuliginosa (Linnaeus)	63	1.23
Xestia xanthographa (Den. & Schiff.)	59	1.15
Pediasia contaminella (Hübner)	57	1.11
Agriphila inquinatella (Den. & Schiff.)	55	1.07
Plutella xylostella (Linnaeus)	54	1.05
Agriphila tolli (Bleszyński)	51	0.99

als. Synanthropic species' representation was the same at the species and individual level. The assessment of forest species should be considered as only indicative because some of them can also develop on solitary woody plants in the landscape or settlement and thus may not have come to light from relatively remote forest habitats; for species of individual habitats, see Electronic Supplementary Material (ESM).

The records of several rare species associated with warm ruderal and ornamental plantings

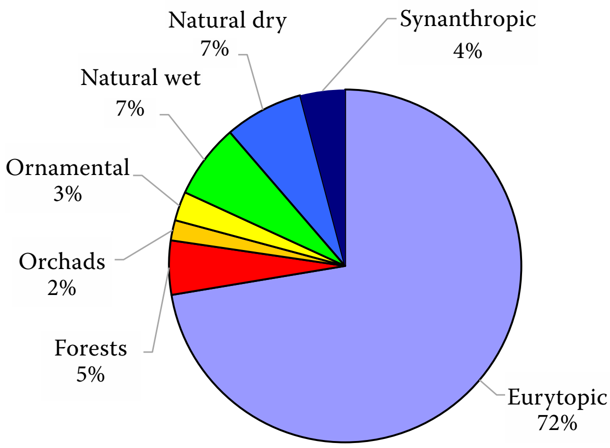

Figure 2. Habitat requirements – species; the categories 'eurytopic', 'orchard', 'ornamental' and 'synanthropic' include both harmful and harmless species

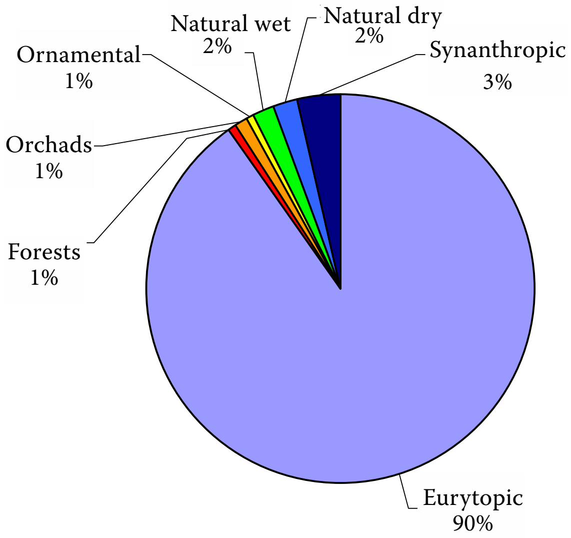

Figure 3. Habitat requirements – individuals

are also noteworthy, esp. *Crocidosema plebejana* Zeller (1♂, August 3, 2021), *Gelechia sabinellus* (Zeller) (1♂, June 19, 2021), *Agrotis bigramma* (Esper) (2♂♂, August 12 and 15, 2021), and *Spaelotis ravida* (Den. & Schiff.) (1♂, September 25, 2021).

Harmful species. Of the total number of species captured, 59 are considered harmful at least occasionally (12% of the total). These 59 species were represented by 1 292 individuals (25% of the total). However, 26, i.e. almost half of these species, were captured in a maximum of 3 individuals (15 in only one) and were of no importance as pests in the area that year.

Field and garden pests were represented by 25 species and 942 individuals (Table 2). These species reached, on average, distinctly higher abundances than other detected species (18% of individuals to only 5% of species). About half of these species were recorded in greater numbers. Still, they are often broad polyphagous, develop mainly on wild plants, and infestation of production plants is minimal (*Agrotis exclamationis, Cnephasia* spp., *Noctua pronuba, Peribatodes rhomboidaria, Xestia c-nigrum*). Thus, based on the observed abundances and trophic requirements, only a few species could cause minor damage, particularly *Ostrinia nubilalis* to maise and *Lacanobia oleracea* to beet and vegetables.

Of the orchard pests, 17 species were recorded in 95 individuals (Table 3) (only 1.8% of individuals to 3.5% of species). None of these reached abundance which would indicate significant damage. Minor damage may have been caused by *Cydia pomonella* to apples in that year.

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Table 2. Pests of agricultural and horticultural crops with numbers of individuals (ordered by abundance)

Species	No.
Xestia c-nigrum (Linnaeus)	295
Peribatodes rhomboidaria (Den. & Schiff.)	180
Agrotis exclamationis (Linnaeus)	94
Ostrinia nubilalis (Hübner)	78
Plutella xylostella (Linnaeus)	54
Lacanobia oleracea (Linnaeus)	43
Noctua pronuba (Linnaeus)	34
Cnephasia stephensiana (Doubleday)	30
Mamestra brassicae (Linnaeus)	25
Tholera decimalis (Poda)	21
Agrotis segetum (Den. & Schiff.)	18
Autographa gamma (Linnaeus)	14
Cnephasia pumicana (Zeller)	11
Mesapamea secalis (Linnaeus)	9
Triodia sylvina (Linnaeus)	9
Lacanobia suasa (Den. & Schiff.)	6
Cnephasia asseclana (Den. & Schiff.)	5
Acrolepiopsis assectella (Zeller)	3
Euxoa tritici (Linnaeus)	3
Euxoa aquilina (Den. & Schiff.)	2
Helicoverpa armigera (Hübner)	2
Hydraecia micacea (Esper)	2
Mesapamea secalella (Remm)	2
Agrotis ipsilon (Hufnagel)	1
Noctua fimbriata (Schreber)	1
Σ	942

Similarly, pests of ornamental plants were relatively under-represented (no pests of ornamental herbaceous plants were recorded), with a total of 8 species and 51 individuals (Table 4) (1% individuals to 1.6% of species). Only 3 of them were recorded in more individuals and may have caused some aesthetic degradation to ornamental woody plants.

Table 3. Pests of fruit trees with numbers of individuals (ordered by abundance)

Species	No.
Cydia pomonella (Linnaeus)	29
Archips xylosteana (Linnaeus)	19
Hedya nubiferana (Haworth)	12
Euproctis chrysorrhoea (Linnaeus)	8
Spilonota ocellana (Den. & Schiff.)	8
Anarsia lineatella (Zeller)	4
Adoxophyes orana (Fischer v. R.)	2
Cossus cossus (Linnaeus)	2
Grapholita funebrana (Treitschke)	2
Lyonetia clerkella (Linnaeus)	2
Archips podana (Scopoli)	1
Grapholita molesta (Busck)	1
Lymantria dispar (Linnaeus)	1
Malacosoma neustria (Linnaeus)	1
Operophtera brumata (Linnaeus)	1
Pandemis cerasana (Hübner)	1
Pandemis heparana (Den. & Schiff.)	1
Σ	95

Table 4. Pests of ornamental plants with numbers of individuals (ordered by abundance)

Species	No.
Yponomeuta evonymella (Linnaeus)	21
Cydalima perspectalis (Walker)	19
Cameraria ohridella (Deschka & Dimić)	6
Argyresthia trifasciata (Staudinger)	1
Coleophora laricella (Hübner)	1
Epinotia tedella (Clerck)	1
Exoteleia dodecella (Linnaeus)	1
Phalera bucephala (Linnaeus)	1
Σ	51

During the study period, nine species of warehouse pests were captured, with a total number of 80 individuals (Table 5) (1.5% individuals to 1.9% of species). The vast majority of them develop on organic residues in farm buildings without apparent harmfulness. Only *Galleria mellonella* could cause more or less damage to near bee colonies.

Seasonal dynamics of selected harmful species. Individual pest species show various seasonal dynamics (number of generations, time of adults, overwintering stage) and were recorded throughout the growing season – in spring, summer, and autumn. We present here the seasonal dynamics of seven selected pest species that responded to seasonal changes and peculiarities of 2021 in a diverse and species-specific manner: *Plutella xylostella, Cydalima perspectalis, Ostrinia nubilalis, Lacanobia oleracea, Peribatodes rhomboidaria, Agrotis exclamationis*, and *Xestia c-nigrum* (Figures 4–10).

Ecological indices. The value of the Shannon-Wiener index for the entire taxocenosis assessed, H' = 5.03, is relatively high (H'max = 6.18 for the

Table 5. Warehouse pests with numbers of individuals (ordered by abundance)

Species	No.
Niditinea fuscella (Linnaeus)	48
Endrosis sarcitrella (Linnaeus)	7
Nemapogon granella (Linnaeus)	5
Sitotroga cerealella (Olivier)	5
Galleria mellonella (Linnaeus)	4
Pyralis farinalis (Linnaeus)	4
Tineola bisselliella (Hummel)	4
Tinea pellionella (Linnaeus)	2
Haplotinea insectella (Fabricius)	1
Σ	80

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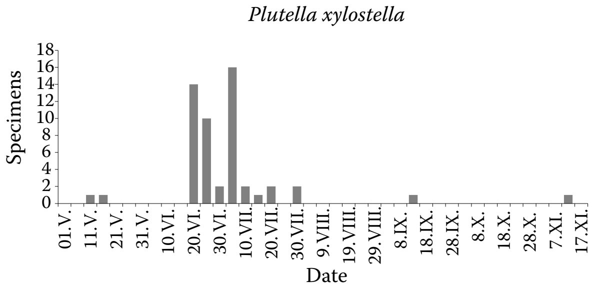

Figure 4. Seasonal dynamics of *Plutella xylostella* adults; sums at five-day intervals (in all Figures 4–10)

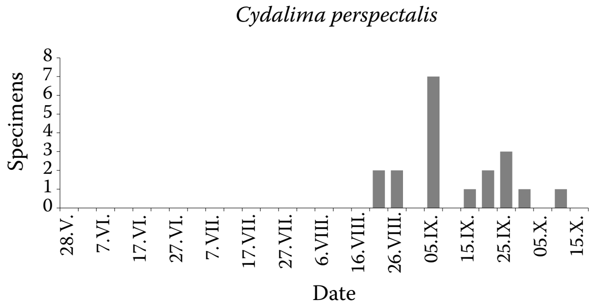

Figure 5. Seasonal dynamics of *Cydalima perspectalis* adults

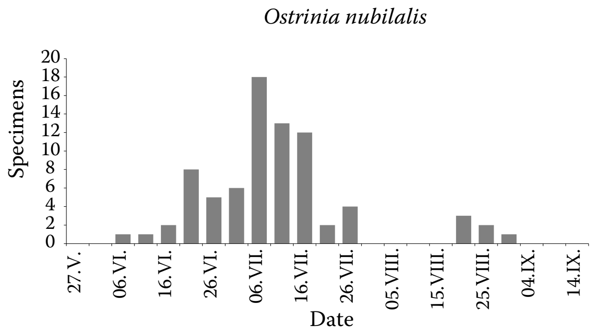

Figure 6. Seasonal dynamics of *Ostrinia nubilalis* adults

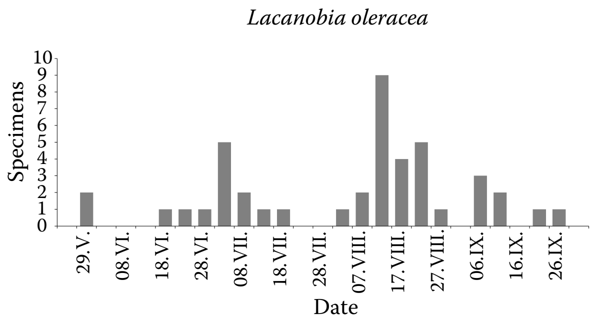

Figure 7. Seasonal dynamics of *Lacanobia oleracea* adults

number of species recorded). This corresponds to the high value of evenness e = 0.81. If only groups of large moths (which are usually evaluated) are considered in the calculation, the values are H' = 3.30 and e = 0.59.

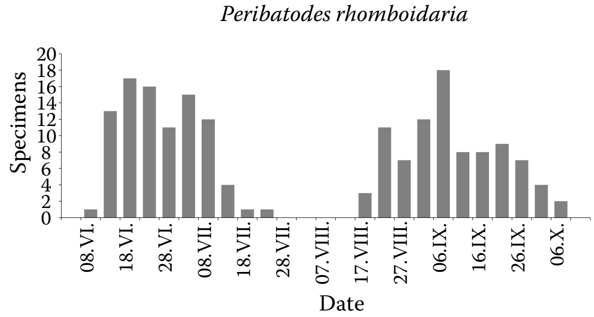

Figure 8. Seasonal dynamics of *Peribatodes rhomboidaria* adults

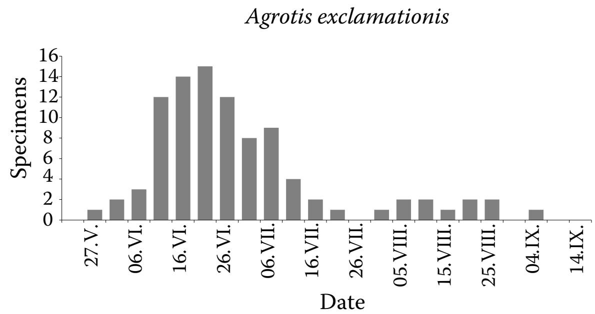

Figure 9. Seasonal dynamics of *Agrotis exclamationis* adults

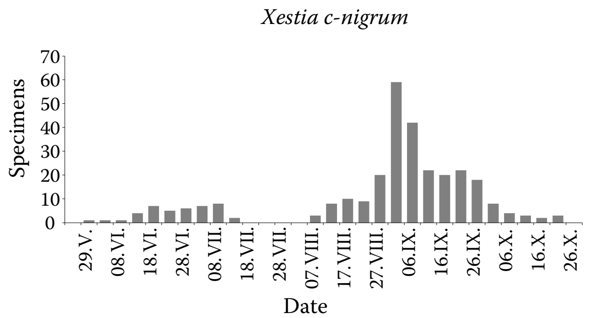

Figure 10. Seasonal dynamics of *Xestia c-nigrum* adults

DISCUSSION

The observed species composition is a reflection of the habitat and its surroundings. The abundance of species was more or less influenced by the weather of 2021 (or even of 2020) and by the long-term population dynamics of some species. The results supported the assumption that less specialised species distinctly dominate the agricultural landscape, but Kadlec et al. (2009) found a much smaller pro-

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portion of non-specialists. The proportion of at least occasional pests (12%) was significantly higher than at the country level, about 3.5% (Šefrová 2003). The representation of saprophagous species was approximately equal to their proportion in the Central European fauna (about 4%, own assessment) and was not higher despite the proximity of farm buildings. Species of dry and wet semi-natural habitats were represented in a comparable number as pests (14%) but at significantly lower numbers of individuals (4%). This corresponds to the considerable distance and small size of these habitats.

The weather more or less influenced the developmental cycles of species in 2021. The spring months of March and April were very cold, causing a significant phenological shift in many species, which gradually levelled off during May and June, when temperatures were already in the normal range (average air temperature in March was 0.7 °C and in April 2.9 °C below the long-term average – CHMI 2023). In addition, the data obtained by a light trap may be biased by the varying activity of adults, especially depending on temperature, and also by the phases of the moon, and the numbers of individuals captured may not fully correspond to the actual abundance and dynamics of a species. Because of this bias, the data obtained by the light trap are variously sufficient for example signalling the occurrence of adults, determining critical numbers, forecasting abundance trends, and timing plant protection interventions. These data have limited predictive value for migrants, e.g. in *Plutella xylostella*. This species was captured irregularly between early May and mid-November, only with significant increases during July. This is because adults are transmitted anemochorically over considerable distances, and the abundance does not reflect population dynamics in a particular area but may result from overbreeding hundreds to thousands of km away (Figure 4).

Weather in 2021 significantly affects the development and flight activity of *C. perspectalis*. Although this species usually develops two generations in Central Europe (Nacambo et al. 2014), the trap did not register the first generation, and the start of the 2nd generation was delayed by at least ten days. In addition, even the 2nd generation (usually numerous) was recorded only in single individuals, with a slight increase only in early September (Figure 5). Temperature and precipitation may also cause occurrence in waves, and thus difficulty in signalling, which is typical, e.g. *O. nubilalis*. This species' temporal shift in adult occurrence due to the cool and rainy spring was not as pronounced as for other species in 2021. This may be because the mature overwintering caterpillar is stimulated to pupate by higher humidity, and long-term lower temperature may not be as limiting as in other species. The first generation was clearly defined, with a peak in early July. The few individuals captured after mid-August may represent a partial 2nd generation (Figure 6).

Protracted occurrence of adults and their unpredictable seasonal dynamics may pose a problem in signalling and forecasting *L. oleracea* (e.g., inability to use the sum of effective temperatures). The generations of this species were not clearly separate; they were protracted with several peaks that did not correlate with temperatures or moon phases. More pronounced increases in abundance in late June and mid-August could represent peaks of the first and second generations (Figure 7).

In a positive contrast, the results for, e.g. *Peribatodes rhomboidaria*, *A. exlamationis* and *X. c-nigrum* are well applicable among the species evaluated. The larva of *P. rhomboidaria* completes its development in spring, and the onset time of the 1st generation of adults is thus influenced by spring temperature. The cold spring of 2021 did not affect abundance but caused a significant delay in the onset of the 1st generation, resulting in a shift in phenology throughout the year. In contrast to the usual situation (Patočka & Kulfan 2009), adults of the 1st generation were registered until the end of July. The two generations were clearly separate, and the small drops in the numbers of individuals captured in late June and late August can be attributed to the full moon period with a concomitant decrease in night temperatures in both cases (Figure 8). *A. exclamationis* develops 1–2 generations in Central Europe (Patočka & Kulfan 2009). The 1st generation was clearly defined, with one distinct peak, without any fluctuations caused by lower temperatures or a full moon. Assuming that individuals captured during August were not stragglers of the 1st generation, the partial 2nd generation was very few and without a distinct peak (Figure 9).

In contrast to *A. exclamationis*, the 1st generation of *X. c-nigrum* was very weak, captured over a long period from about late May to mid-July, with no clear culmination. This is consistent with the usual seasonal dynamics of this species (Patočka & Kulfan 2009). The 2nd generation was significantly

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more numerous, with a clear peak in late August and early September (Figure 10).

The numbers of species and individuals recorded and the values of the Shannon-Wiener diversity and evenness indices can be only very roughly compared with the results obtained in similar studies, e.g., inconsistent methodology, different light sources and number of captures. Kadlec et al. (2009) recorded 424 species in a suburb of Prague in 23 years of research, but with values of only $H' = 1.73$ and $e = 0.32$ (cf. also Hluchý & Dobšík 1984; Šafář 2010). The distinctly higher actual values were due to the relatively high number of species recorded with a more or less even distribution of individuals, i.e. to the absence of species with a distinct dominance (maximum dominance 5.7% in *X. c-nigrum)* (Table 1). Despite the somewhat lower values of basic ecological indices compared to natural habitats (own observations), it can be concluded that the studied taxocenosis is relatively species-rich. This is indicated by the assessed indicators and the higher number of faunistically, habitat-wise or zoogeographically remarkable species.

CONCLUSION

The results show that local monitoring provides important data for plant protection (proportion of species with a negative impact, abundance, forecasts) applicable at the regional level. As expected, the fauna of the study area is significantly dominated by eurytopic species, including agricultural pests (72%). The representation of species with a negative impact from a plant protection point of view was higher than the national average (12% compared to 3.5%). Still, the proportion of these species was comparable to the proportion of species considered faunistically, zoogeographically or bioindicatively remarkable. The results thus show that a predominantly agricultural landscape with a certain proportion of natural habitats can (even with the presence of species with negative importance) provide conditions for occurrence of a greater number of "valuable" species and relatively high biodiversity.

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Received: April 5, 2023
Accepted: October 2, 2023
Published online: November 13, 2023