Investigating butterfly communities in peri-urban areas of Alba Iulia, Romania

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Summary: More than 50% of the human population lives in cities presently, and the expansion of urban areas is more accelerated than ever. This affects natural ecosystems through habitat fragmentation, pollution, degradation of habitats etc. Urban ecology studies increased over the last 20 years to address all problems related to urbanisation, from biodiversity conservation to sustainability and resource management. Studies investigating urban and peri-urban biodiversity are useful for the development of sustainable cities, and are very scarce in Romania. Our study documented the butterfly diversity and community assemblages over two years, of a peri-urban area of the city Alba Iulia, in Romania. We produced a species list and documented the composition of butterfly communities in two habitat types (grassland and park), that are widespread in and around Transylvanian cities.

Key words: peri-urban biodiversity, indices, community composition, ecological profile.

Introduction

As cities worldwide expand to accommodate more people and higher living standards, the questions of size, design, and connectivity of urban, peri-urban and extra-urban green spaces and their contribution to the sustainability of urban living become more important. The transdisciplinary field of urban ecology aims at achieving a higher sustainability of cities, and is already an almost century-old enterprise (Wu 2014). According to Wu's review, urban ecology "may be defined as the study of spatio-temporal patterns, environmental impacts, and sustainability of urbanization with emphasis on biodiversity, ecosystem processes, and ecosystem services" (Wu 2014).

Understanding the ecology of species living in urbanized environments is crucial to designing and developing cities towards sustainability. As cities expand, issues such as habitat fragmentation, pollution, and deterioration of habitats, spread of invasive species, and native species loss become even more aggravated (McKinney 2008). Sustainable healthy cities should offer both healthy living conditions for humans, and allow surrounding nature to permeate its space.

Studies assessing urban biodiversity are almost inexistent for most Romanian cities. Several previous studies addressed aspects connected to sustainable urban development and green spaces (e.g. Badiu *et al.* 2016, Gavrilidis *et al.* 2020, Vîlcea and Şoşea 2020), and very few documented floras and faunas in the surroundings of cities (e.g. Goia and Dincă 2006, Anastasiu *et al.* 2017, Sevianu *et al.* 2021). However, urban biodiversity studies are very scarce in Romania, and they represent the basic knowledge on which a sustainable urban planning should be built.

Our study comes to partly cover the need for baseline biodiversity data for peri-urban areas in a city located in the North-Western part of the country. We used butterfly communities to document the biodiversity, as butterflies are considered good biodiversity and habitat quality indicators (Erhardt 1985). The study we performed is however an exploratory one, intended as a preliminary documentation for a larger project to assess biodiversity around several large cities of Romania. For this preliminary study, we set the following objectives: 1. to assemble a species list of butterflies and day-flying moths present in a peri-urban context and estimate their diversity, 2. to explore the similarities between the butterfly assemblages from two habitat types often found in peri-urban areas of Romania, 3. to see how the ecological profiles of different butterfly species connect to the peri-urban habitats we investigated, and 4. to check for the presence of rare and protected butterfly species.

Materials and methods

1. Study area

We assessed the butterfly diversity, ecological profile and conservation status of butterflies in two peri-urban habitats (Fig. 1), in six linear transects of 200 m each in July and August of the years 2020 and 2022, next to the city of Alba Iulia (Transylvania, Romania). Three transects were situated in an area covered by grasslands (lat. 46.077966 N, lon. 23.543003 E,

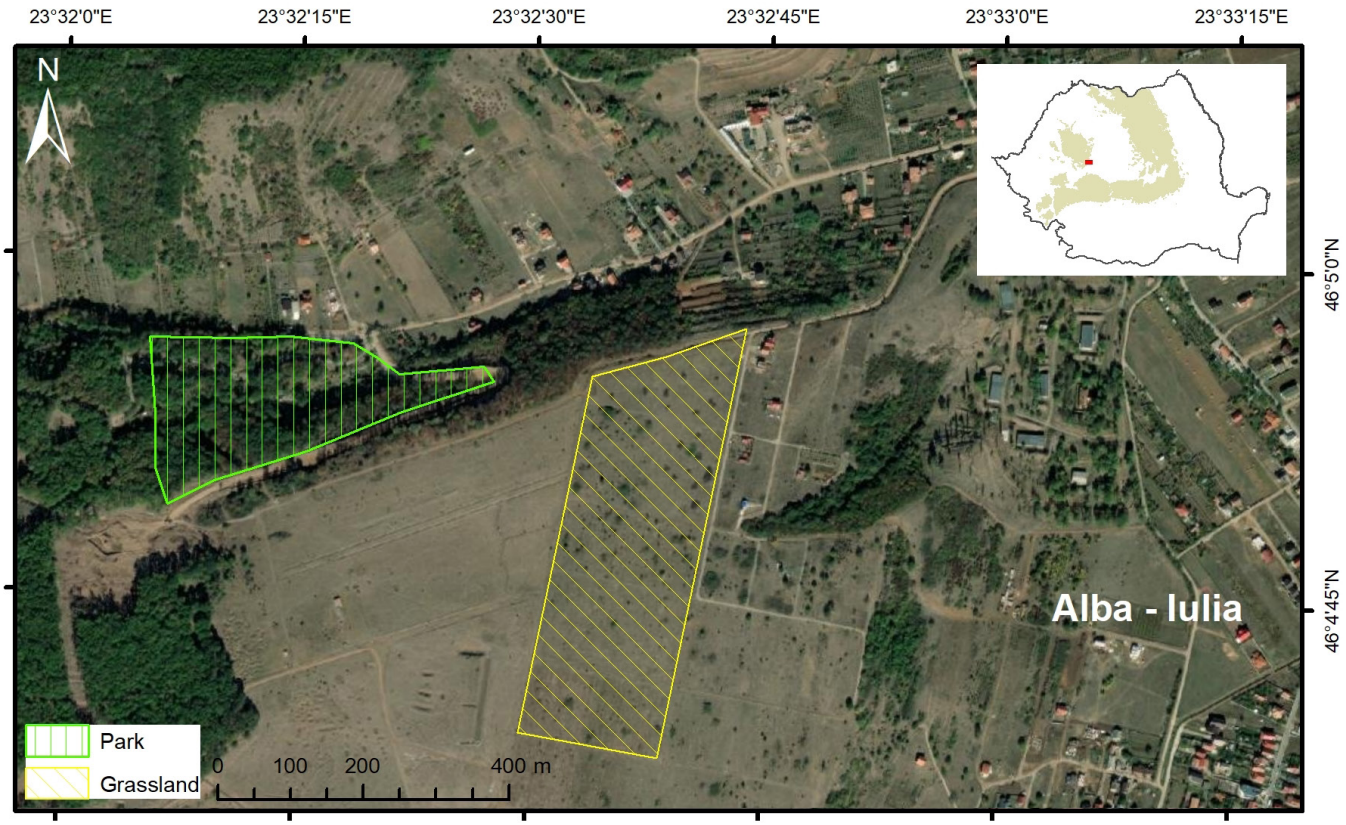

Fig. 1. Map of the study areas where six butterfly transects were recorded in the years 2020 and 2022, located near Alba Iulia City, central Romania.

coded: G1 – G3) and three transects in a park (Dr. Ioan Vlad Dendrological Park, lat. 46.081418 N, lon. 23.536656 E, coded: P1 – P3). The grasslands have a mesophilous character and have scattered shrubs of the species *Crataegus monogyna, Rosa canina*, and *Prunus spinosa*, and are representative for the surroundings of the city. Human leisure activities and sheep grazing shape them. The park is a dendrological sanctuary with a free landscape design. It harbours 1100 plant species from several parts of the world, and is located on a 22-ha plot that includes a hill section and a forest area. The forest comprises a variety of conifers, such as *Picea abies* or *Pinus sp*., as well as deciduous trees from the *Fagaceae* family, fragmented by clearings with herbaceous vegetation representing the target landscape of our butterfly transects.

In the study area, the climate is humid continental with a mean annual temperature of 10.5 °C, mean annual precipitation of 856 mm and maximum precipitation occurring during the summer months (https://en.climate-data.org/).

2. Butterfly survey

Butterflies were surveyed within each transect where we applied the linear transect method (Pollard 1977). Transects were patrolled every week between 6 July and 27 August 2020, and 9 July and 20 August 2022, by the same person (IC) only under good weather conditions (sunny, temperature ≥ 18 °C and wind speed ≤ 16 km/h [Beaufort scale 3]) between 10.00 and 17.00 h. We recorded all species and individuals of the superfamily Papilionoidea and two additional day-flying moths found on transects. Multiple counting of the same individuals is not completely avoidable, however, this error is the same for each transect, and not affecting the comparisons of transects walked by the same person (Cremene *et al*. 2005). The sequence in which transects were surveyed varied in order to avoid biasing the results due to changes in diurnal butterfly behavior during different times of the day (Craioveanu *et al.* 2021). We recorded species richness and individual abundance of butterflies for each study transect. We assigned conservation status (IUCN categories—CR, EN, VU, NT, LC and DD) and ecological profile based on thermal and humidity preferences (HF—hygrophilous, MHF— meso-hygrophilous, MF—mesophilous, U—ubiquitous, MXF—mesoxerophilous, XF—xerophilous and MI—migrant) to each species. Conservation status, ecological profile, as well as species identification followed Rákosy (2013) and Rákosy *et al.* (2021).

3. Data analysis

In order to estimate the diversity of each transect we recorded the following indices: *species richness*, *abundance* of individuals, *Shannon-Wiener's H* diversity index, and *Equitability* (*Shannon's H/ln(N)*). Additionally, we assembled rarefaction curves to check whether our sampling effort was sufficient. The distribution of data for each transect was checked to see whether it was following a normal distribution with the help of Shapiro-Wilk test. We first compared

the diversity indices between years, and since there were no significant differences found, we compiled (summed abundance/species values for each transect) the data for both years, in order to analyse diversity and abundance patterns. Secondly, we compared the diversity indices between habitat types. In order to check for patterns of similarity between transects and habitat types, regarding butterfly communities we used an exploratory Principal Component Analysis (*PCA*). Comparisons of diversity and abundance parameters of butterfly species of different ecological character and conservation status, were computed with the help of *Student's T-test* and *Mann-Whitney tests*. Diversity indices and rarefaction curves were computed in Past version 4.03 (Hammer *et al.* 2001). All other statistical analyses were performed in RStudio 2023.09.1+494 „Desert Sunflower" Release (2023-10-16) for windows (RStudio Team 2020).

Results

1. Diversity

Our study revealed the presence of 27 species of butterflies and two of day-flying moths in the peri-urban habitats investigated around the city of Alba-Iulia. Seventeen species were recorded on grassland transects and 21 on park transects. Table 1 summarises the species list with presence-absence data, ecological profile and IUCN conservation status.

The individual rarefaction curves revealed that our sampling effort per transect was sufficient, and increasing the length of the transect walk, or the time spent sampling would not yield a higher number of species (Fig. 2).

The data of all diversity indices (abundance, *Shannon-Wiener's H*, and *Equitability*), except species richness, were normally distributed according to *Shapiro-Wilk test* (*P>0.05*), and are summarized in table 2.

The comparisons between the diversity indices of the two habitat types (grassland and park, Fig. 3) revealed no significant differences in species richness

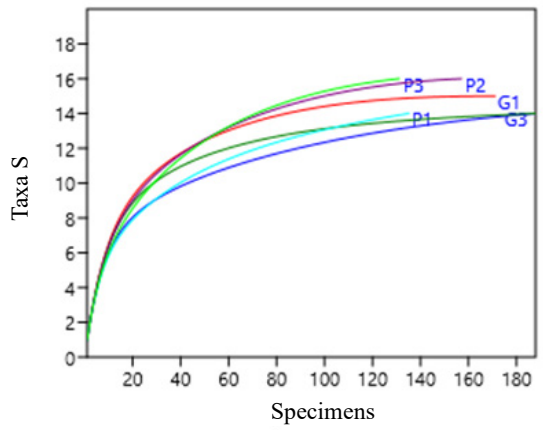

Fig. 2. Individual (specimens) rarefaction curves for the species richness (*Taxa S*) of day-flying Lepidoptera in six transects situated in peri-urban habitats of Alba-Iulia city (G1-G3 – transects in grasslands, P1-P3 – transects in park habitats).

(*Mann-Whitney test: W=2, P=0.346*), *Shannon's H* (*two-sample t-test: t=0.61, df=4, P=0.58*), and *Equitability* (*Mann-Whitney test: W=0.86, P=0.20*). Only abundance of Lepidoptera differed significantly between the two habitat types (*two-sample t-test: t=4.19, df=3.58, P=0.02*), with grasslands having a higher abundance of individuals (Fig. 3).

2. Butterfly assemblages

The Principal Component Analysis explained 75% of data variability, and revealed that butterfly assemblages were grouped rather according to habitat type, and not according to ecological profile of the species. For the *PC1 axis* (55% of data variability), the most opposite effects of species on data distribution were recorded between *Coenonympha pamphilus* and *Plebejus argus*, both mesophilous species. On the other hand, on the *PC2 axis* (which explains only 20% of data variability) data are not clearly grouped based on habitat type. The most opposite effects were recorded between *Coenonympha pamphilus* and *Maniola jurtina*. The ecological profile of the species did not seem to play a very important role in the distribution of species in the investigated communities.

3. Ecological profile and conservation status

The average number of species of different ecological profile varied significantly between the two investigated habitat types, except for the ubiquitous species. There were less mesophilous and xerophilous species and more meso-hygrophilous and meso-xerophilous species in the grassland transects, compared to the park habitats (Fig. 4, Table 3).

The average abundance of species of different ecological profile did not vary significantly between the two habitat types, except for mesophilous species (Table 3). Grassland transects had a higher abundance of mesophilous species than park transects.

The Lepidoptera species found were classified either in the least concern category (LC - 25 taxa,86%), or in the near threatened category (NT – 4 taxa, 14%). Three NT species were found in park habitats, whileonly one NT species was found in the grassland transects (Fig. 5.). Four species found in most transects (*Coenonympha pamphilus, Lasiommata megera, Maniola jurtina,* and *Polyommatus icarus*) are found among the 17 indicator species used to compute the European Butterfly Indicator for Grassland butterflies (Van Swaay *et al.* 2015).

Discussion

Studies assessing urban and peri-urban biodiversity are very scarce in Romania, while their importance is crucial as basic knowledge for sustainable urban planning. Our study partly covers the need for baseline biodiversity data for a peri-urban area near Alba Iulia city, Alba County. Our study aimed at investigating the Lepidoptera fauna from two habitat types frequently found in peri-urban areas in the North-Western part of Romania.

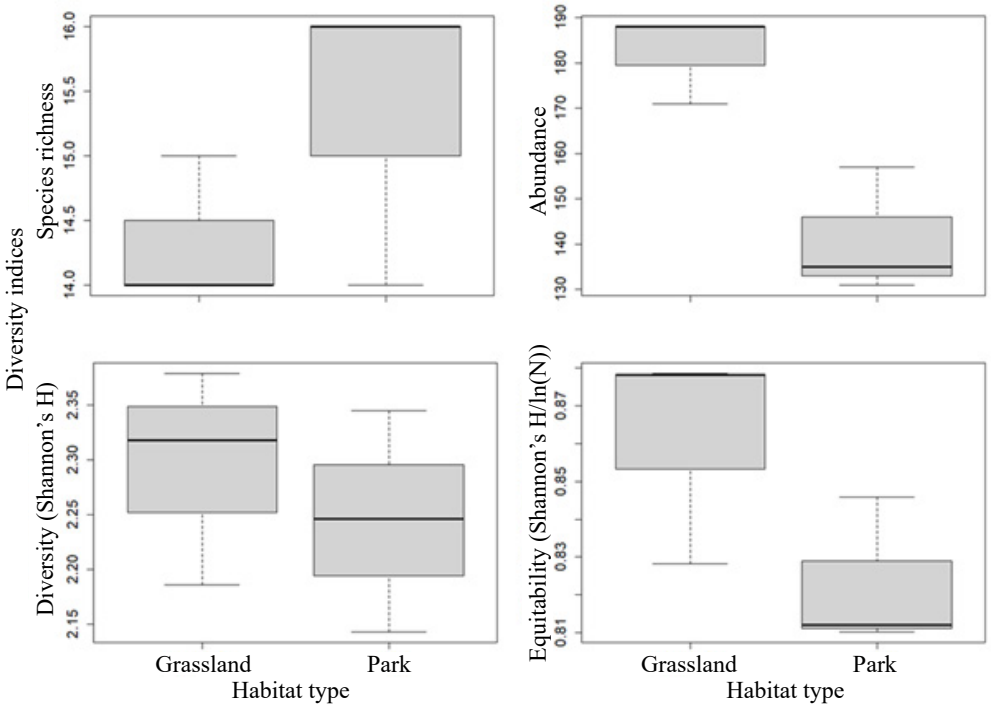

Fig. 3. Butterfly and day-flying moth diversity indices compared from transects in peri-urban grassland and park habitats of Alba-Iulia city.

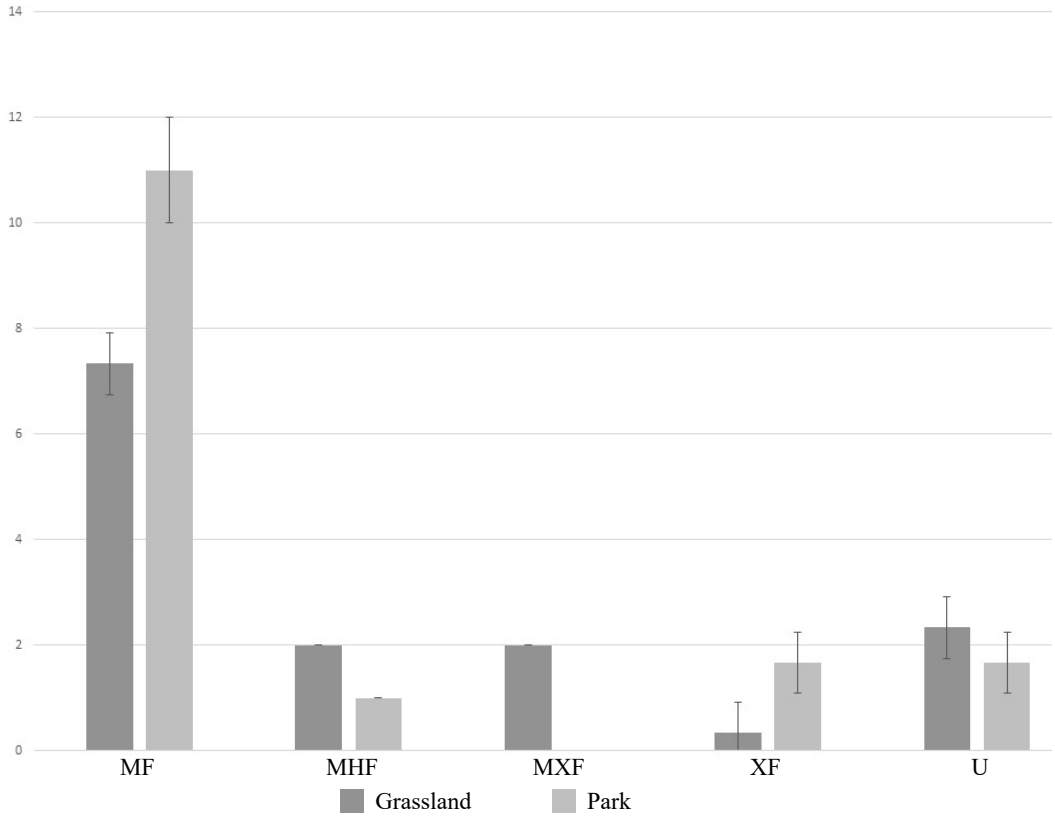

Fig. 4. Biplot of the PCA indicating data grouping according to habitat type (Grassland and Park) of the butterfly species. Latin names of species were abbreviated with the first two letters of each word (see Table 1).

We obtained a species list of Lepidoptera that added a missing faunistic record for this geographic area. Furthermore, we assembled two butterfly community profiles of the two investigated peri-urban habitat types. Our results indicated that these butterfly communities were similar from the diversity perspective, and different regarding community composition. Diversity indices like species richness,

Table 1: Species list of butterflies and day-flying moths recorded in the summer of 2020 and 2022 in peri-urban habitats of Alba-Iulia. Ecological profile was defined as follows: U – ubiquitous, MHF – meso-hygrophilous, MF – mesophilous, XF – xerophilous, MXF – meso-xerophilous; present IUCN categories: LC – least concern, NT – near threatened. The first two letters of each Latin name are underlined to indicate abbreviations used in the PCA analysis.

Families and Species	Habitat type: Grassland	Habitat type: Park	Ecological profile	IUCN conservation status
Fam. Hesperiidae				
Thymelicus sp.	x		U	LC
Thymelicus lineola	x		U	LC
Fam. Pieridae				
Pieris brassicae	x	x	U	LC
Pieris napi	x	x	MHF	LC
Leptidea sinapis	x		MF	LC
Colias hyal/alfacariensis	x		XF	LC
Fam. Riodinidae				
Hamearis lucina		x	MF	LC
Fam. Lycaenidae				
Favonius quercus		x	MF	LC
Plebejus argus	x	x	MF	LC
Polyommatus icarus	x	x	MF	LC
Celastrina argiolus		x	MF	LC
Fam. Nymphalidae				
Lasiommata megera	x		MXF	LC
Pyronia tithonus		x	MF	NT
Maniola jurtina	x	x	MF	LC
Melanargia galathea	x	x	MF	LC
Melitaea cinxia	x		MF	LC
Melitaea didyma	x		MXF	LC
Neptis sappho		x	MF	NT
Aphantopus hyperantus		x	MF	LC
Argynnis paphia		x	MF	LC
Argynnis aglaja		x	MF	LC
Boloria selene	x		MHF	NT
Brintesia circe		x	XF	NT
Brenthis hecate		x	MF	LC
Coenonympha glycerion	x	x	MF	LC
Coenonympha pamphilus		x	MF	LC
Vanessa atalanta		x	U	LC
Fam. Zygaenidae				
Zygaena filipendulae	x		MF	LC
Fam. Erebidae				
Amata phegea		x	XF	LC

Table 2: Values of butterfly and day-flying moth diversity indices from six transects (G1-G3, P1-P3) in grassland (G) and park (P) habitats around Alba-Iulia city.

Index\Transect	G1	G2	G3	P1	P2	P3
Species richness	15	14	14	14	16	16
Abundance	171	188	188	135	157	131
Shannon's H	2.38	2.19	2.32	2.14	2.35	2.25
Equitability	0.88	0.83	0.88	0.81	0.85	0.81

Table 3: Results of the comparison tests between average species and abundances of Lepidoptera of different ecological profile in grassland (G) and park (P) habitats around Alba-Iulia city. (Abbreviations: U – ubiquitous, MHF – meso-hygrophilous, MF – mesophilous, XF – xerophilous, MXF – meso-xerophilous).

Comparison G vs. P	Test	Degrees of freedom	Test statistic	P-value
MF-Species	*Student's t-test*	3.2	*t = -5.5*	*P = 0.010*
MHF-Species	*Mann-Whitney U-test*		*W = 9.0*	*P = 0.047*
MXF-Species	*Mann-Whitney U-test*		*W = 9.0*	*P = 0.047*
XF-Species	*Student's t-test*	4	*t = -2.8*	*P = 0.047*
U-Species	*Student's t-test*	4	*t = 1.4*	*P = 0.230*
MF-abundance	*Student's t-test*	3.9	*t = 2.8*	*P = 0.049*
MHF-abundance	*Student's t-test*	2.6	*t = -0.7*	*P = 0.551*
MXF-abundance	*Student's t-test*	2	*t = 4.2*	*P = 0.053*
XF-abundance	*Student's t-test*	4	*t = -1*	*P = 0.386*
U-abundance	*Student's t-test*	3.6	*t = 1.5*	*P = 0.211*

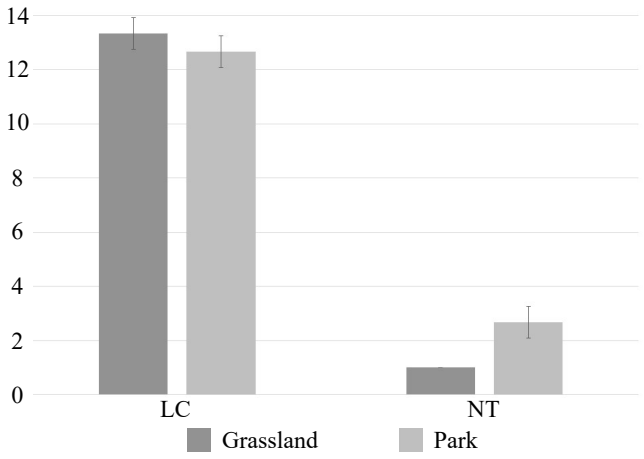

Fig. 5. Average number of Lepidoptera species (±SD) of different conservation status found in peri-urban grassland and park habitats in the years 2020 and 2022, near Alba-Iulia city. (Abbreviations: NT – near threatened, LC – least concern).

Shannon-Wiener index, and equitability did not differ between the two community types; however, abundance of individuals was much higher in the grassland habitat. This result was expected as open habitats generally are more flower-rich, and is in line with several other studies (e.g. Cremene *et al.* 2005, Berg *et al.* 2011, Robinson *et al.* 2012) performed in semi-natural grasslands that found open habitats much more abundant in butterflies than other habitats with more closed structures (e.g. shrubs or forest edges). The differences we found between communities were mostly based on abundances of several dominant species (*Maniola jurtina, Melanargia galathea, Pieris napi, Polyommatus icarus*), and not based on the species' ecological profile. The dominant species were those most commonly found in grasslands across Transylvania, with several generations per year and a high mobility. Other studies also found an important effect of dominant species on butterfly communities e.g.: Berg *et al.* 2011, Robinson *et al*. 2012 *etc*. A similar study by Konvicka and Kadlec (2011) however, found stronger associations between ecological profiles of butterflies and community assemblage. The study however, took into consideration a large number of sites and a large variety of landscape, habitat, urbanisation and other species-associated factors. In our study these tendencies were not detectable, most likely due to the small number of transects sampled, and to the small timeframe of sampling. Additionally, we did not take into consideration variables like urbanisation gradient or larger landscape patterns. Therefore, for future studies some of these factors should be taken into consideration for a better understanding of the butterfly community assemblages.

Most recorded species belonged to the LC conservation category, indicating that the peri-urban habitats we investigated were populated by rather widespread and ecologically tolerant species. Three of the four NT classified species were found in park habitats, indicating that these might be good refuges for more sensitive species within cities. Of all species found, several were among those classified as indicator species for the butterfly grassland indicator (Van Swaay *et al.* 2015). Their abundant presence in most transects and their high detectability (e.g. slow flyers, many generations/year, easily identifiable patterns etc.) can be used for future monitoring purposes, with public involvment. Monitoring directed towards specific indicators can be a useful and easy-to-use tool in evaluating habitat quality in peri-urban areas.

Conclusion

Our results showed that urban butterfly communities from park and grassland habitats do not differ much in terms of diversity, but species tend to group after habitat type. Our study was meant to be an exploration of peri-urban butterfly fauna in the city of Alba-Iulia. It included only two months of sampling, which is usually insufficient for a complete set of data. This was partly due to the exploratory purpose of this study, and to the restrictions implemented during the Covid-19 pandemic. However, we managed to assemble a species list of a peri-urban area, little

studied until now, and gives us a glimpse into the butterfly communities and their assemblages in such urbanized areas from Romania. Furthermore, our results pave the way for several future approaches to estimating biodiversity and habitat quality in peri-urban areas.

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