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Changes in Population Densities and Species Richness of Pollinators in the Carpathian Basin during the Last 50 Years (Hymenoptera, Diptera, Lepidoptera)

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Abstract: Temporal changes of population densities and species richness of three main pollinator groups: moths and butterflies (Lepidoptera), bees, wasps and sawflies (Hymenoptera) and hoverflies, horse-flies, tachninids and bee flies (Diptera) were investigated in the Carpathian Basin. Maintaining pollinator diversity is a crucial factor for preserving our biodiversity and ecosystems, furthermore several pollinator species has strong economic role in maintaning crop and fruit cultures. Our conclusions are based on our three or four decades of faunistic surveys in various regions of the Carpathian Basin. Analyzing and comparing our data with the historical data of the last 50 years, we concluded, densities of some pollinators were declined during the past decade and the half (Symphyta, hoverflies), although populations of several species of Mediterranean-origin were grown (Aculeata) and even new species were migrated from the warmer regions. In numerous cases, this decrease was dramatic: more than 90% decrease of certain butterfly species were detected. On the other hand, the composition of pollinator fauna significantly changed due to the disappearance of some montaneous or mesophyle species. The main reason of decrease of pollinator communities is partly the climatic change and partly anthropogenic factors. Our conclusion: in our region, the pollinator crisis is present, but moderate; however, there is clear sign of the gradual transition of our pollinator fauna towards the Mediterranean type.

Keywords: pollinators 1; Hymenoptera 2; Diptera 3; Lepidoptera 4; Carpathian Basin; 5; population density 6; species richness 7; climate change 8; global warming 9;

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1. Introduction

> "*The apple trees were coming into bloom but no bees droned among the blossoms, so there was no pollination and there would be no fruit. The roadsides, once so attractive, were now lined with browned and withered vegetation as though swept by fire. These, too, were silent, deserted by all living things. Even the streams were now lifeless.*" (Rachel Carson: Silent Spring)

In 1962, Carson predicted the future quiet spring, when neither the noise of bumblebees nor the song of birds would disturb the peaceful growth of green vegetation. The very beginnings of social environmental movements are linked to this iconic work. Today, after 62 years, we have reached a point where the nightmare of silent spring has come within reach. The gradual disappearance of pollinators threatens to become an ecological catastrophe, since pollinators play fundamental role in maintaining our ecosystem. The reproduction the vast majority of cultivated and wild plants depends on the pollination activity of various animals (mainly insects). In recent years, we have seen a significant decline of various pollinator groups. Although the causes of this decline are not yet fully understood, the consequences are commonly referred as a pollination crisis [1]. This pollination crisis goes far beyond the reproductive biology of plants, as Rhodes [2] writes: "The decline in the health and abundance of pollinators may significantly threaten the integrity of global biodiversity, the inclusion of food webs, and risks to the health of humans and other animals". Ultimately, the pollination crisis may cause a global food crisis and a social crisis at the same time. It draws attention to the vulnerability of food chains. Here in our region, we can see this, particularly in the decline of several songbirds (e.g., swallows), since pollinators play role not only in pollination, but they are essential food source for many bird species through their biomass [3]. According to the IPBES report [4], pollinator-dependent plants contribute to 35 per cent of global crop production. According to Dicks et al. [5], the pollination crisis primarily affects the Global South. The risk of pollination crisis in our region is moderate, but at the same time, the decline in diversity of certain groups seems to be truly tragic, as our results show. Of the 8 reasons analyzed, they cited changes in land use, climate change, pollution and the spread of invasive species. Other scientists [6,7], also emphasize habitat fragmentation and degradation, as well as the excessive and inappropriate use of pesticides and herbicides as the main causes of the pollinator crisis. All other reasons are listed as 'other factors'.

The 2021 EU directive on the protection of pollinators, entitled: "Protecting pollinators in the EU" [8], is a response to the current situation, which includes the development of action plans and monitoring programs, the provision of resources, and extension of the ban on certain pesticides such as imidacloprid and all neonicotinoid-based pesticides containing clothianidin and thiamethoxam.

In our work, we monitor the changes in population densities and species richness of different groups of wild pollinators in Hymenoptera, Diptera and Lepidoptera during the last half century. We also study pollinators at the species level either. In this study, only those species were selected that were once common or widespread, but now, they are less common or sporadic; or conversely, those species that are winners of the changes and whose populations are increasing due to recent climatic circumstances. We have also compiled a list of sporadic species of several groups that we had not been able to collect in the last 20 years, even though, they were not rare at all earlier. We have also included species that their populations were increased in the recent decades. These newly spreading species may have arisen due to the expansion of their range (as a result of global warming) or introduced by humans from distant regions of the Earth.

2. Materials and Methods

Our results are based on regular faunistic surveys carried out over the past 50 years in diverse areas of the Carpathian Basin (Pannonian Basin). This kind of tradition of faunistic investigation can be documented back to the time of Scopoli (Observartionis Zoologicae). This time, we compare quantitative and qualitative faunistic data from the 1970s and 1980s with our own recent and sub-recent data from the last 2-4 decades. Statistical analysis of these data determine various trends. These trends either confirm or reject our initial hypothesis regarding the pollination crisis and as a final result, figures out the direction of pollinator changes and point out those pollinator groups and species that suffer from the recent changes or have benefit from these. Finally, we attempt the explanation for these changes based on our field experiences.

Data Selection

Our present work has two main sources: unpublished databases from diverse areas of the Carpathian Basin spanning 4 or 5 decades. Voucher specimens are deposited in various natural science collections of the region (Zoological Institute at Bratislava, Rippli-Rónai Museum at Kaposvár, Natural History Museums at Zirc and Budapest). The second source is the published faunistic papers.

Majority of our data are original, results of 50 or 40 years of continuous collections covering the Pannonian biogeographical region. These databases contain circa 100 000 Aculeata data, 45,000

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Diptera data, and 40,000 Lepidoptera data. These databases, wherever possible (Hymenoptera, Diptera), are results of the work done by one-one specialist over several decades (Dr. Sándor Tóth, Zsolt Józan, Dr. Ladislav Roller and Dr. Attila Haris), consistently using the same methods. To supplement these databases, we used the following publications dominantly from the precvious authors: Symphyta: Zombori [9–13], Haris [14–23], Haris et al. [24] and Roller [25,26]; Aculeata: Józan [27–40]; Diptera: Tóth [41–44]; Lepidoptera: Ábrahám [45–48], Ábrahám et. al. [49], Ábrahám and Uherkovich [50], Uherkovich [51], Pillich [52], Sáfián1 [53], Ács et al. [54], Čanády [55], Dietzel [56], Sarvašová [57], Gergely [58], Gór [59], Schmidt [60], Németh [61], Szabóky et al., 2014[62], Hudák [63], Varga et al. [64], Árnyas et al. [65] and Kovács [66].

We selected those data only (in Hymenoptera and Diptera) which were results by comparable and regular field recordings, 30-35 field days per year, and we omitted results of non regular collections and scattered data, as these data cannot be processed statistically.

The analyzed species were selected according to the following criteria: they should have important role in pollination (i.e., rare species were excluded) and we highlighted those species whose change proved to be the strongest. In case of light trap data series, we checked the beginning and the end of time series to see which species occurred in the largest number in the beginning and at the end of the studied 50 years period from 1970 till 2022. After this, we analyzed those species, that provided the most significant changes over the past 50 years. Since the scope of our work does not allow the analysis of circa 2,500 Hymenoptera, Diptera and Lepidoptera species, and due to lack of space and opportunity, we restricted it to 15–40 species from each group, especially for those species where the changes were outstanding or for those which we found characteristic for the total group or play important role in pollination due to their population densities.

Changes in Methods and Their Statistical Balancing

In nocturnal lepidoptera, methodological changes had to be taken into account. From 2014, UV Led light trap used which replaced the black light UV 20 W (between 1990 and 2010) and Jermy type light trap with 125W mercury vapor lamp (used between 1970 and 2010). These different light sources had different selectivity according to Infusino et al., and Pan et al. [67,68]. This is the reason, that we calculated trends from 1970 and a separate trend from 2014 to draw reliable conclusions. From light-trap data, we selected only those data-series, which span 6 months of intensive, daily collections generally from April to October, in few cases from May to November. Light-traps worked continuously during these periods. Other, shorter or incomplete light trap data were excluded from the analysis.

Regarding diurnal lepidoptera, we have minimal original data. Regular butterfly monitoring started only in the last decade in our region, Therefore we have to rely on processing of previously published datasets. We analyzed the earlier commonest pollinator species (but not all), where, (according to our field experiences), we noticed the greatest changes.

In absence of reliable quantitative data, we used the method followed by Ábrahám [47] as follows: 0: the species is not present or has disappeared:, 1: rare, 2: sporadic, 3: occasionally frequent, 4: generally frequent, 5: common. Other methods, finally, had to be rejected: database of the European Butterfly Monitoring Scheme - eBMS contains different amounts of observations from various years. For example, we have approximately 600 observations from Transdanubia in 2018, and 2 280 from the same region in 2023. We also attempted to compare the amount of diurnal butterflies collected during an average collecting day. These data have high standard deviation, without showing any trend, e.g., Csombárd 2015: [60] 330 individuals per day on average, Zvolen between 2009 and 2011: 143 individuals per day on average [57], Tapolca between 1977 and 1990 approximately 28 individuals per field-day [61]. In other words, these butterfly surveys proved to be completely useless. In this way, the firstly mentioned approach with its many subjective elements remained the only one possibility for us.

Data processing

At Hymenoptera and Diptera, we formed our data into 5 or 6 years batches (providing even time-intervals). After plotting these data-groups on bar graph, we added trend lines including trend equation and coefficient of determination (r^2 value). In nocturnal Lepidoptera, instead of creating batches, we analyzed separate data-series of each location (5,000-15,000 specimens per location per 1 year) throughout the various ecosystems of the Carpathian Basin. These data series are dating back to 50 years except 90s (period of changing the political system in this region) when the light trap network was suspended and we have 10 years gap this time. After arranging these data series in chronological order and creating the bar charts, trend-lines wer drawn (mostly linear trends) and the trend-parameters were recorded. These parameters are the slope of trend (linear x coefficient) and the coefficient of determination. The linear x coefficient indicates the direction of the trend (minus: decrease, plus increase), and its value indicates the slope of the trend line, i.e., the intensity of change (for some Syrphidae species, this trend is exponential). Coefficient of determination indicates how strong is the trend and in how our data fit to the trend-line i.e., in case of high proportion of continuous temporal changes (real trend: high r^2 value) and r^2 value is low, when spatial or cyclical variables has main role in the changes of populations or species richness.

Sampling Sites

Diptera and Hymenoptera (except Symphyta) collected from approximately 1 200 various locations from all parts of the Pannonian biogeographic region. These are smaller samples (1-50 specimens) from ech location.

Lepidoptera and Symphyta specimens are from separate and significantly lower number of locations (circa 50 locations sampled in different years), as listed below. These are larger samples, between 500 and 30 000 specimen from each location (Symphyta samples are smaller, between 500 - 4 000 per location, Lepidoptera samples are larger, 5 000 - 30 000 specimen per location per 1 year).

Collecting sites: Symphyta: Nagykovácsi and its surroundings, Aggtelek National Park, Fertő-Hanság National Park, Zselic Hills, Keszthelyi Hills, Cserhát Hills, Vértes Hills, Southern Transdanubia at River Drava, North Somogy, Börzsöny Mountains, Szeged and its surroundings, South Somogy, Ivanka pri Dunaji, Javorina, Mošovce, Pernek, Devin, Hriňová, Stefanova, Horša, Bokroš, Tvrdošovce, Virt and Malacky regions. Applied methods were sweeping net and Malaise trap.

Collecting sites:: Lepidoptera: Felsőtárkány, Tompa, Gilvánfa, Magyarszombat, Mike, Vásárosbéc, Almamallék, Palé, Lipótfa, Aggtelek, Tompa, Répáshuta, Sopron, Plain of River Dráva, Bakonynána, Boronka, Tapolca, Keszthelyi Hills, Aggtelek National Park, Biatorbágy, Pomáz, Székesfehérvár, Őrség, Csombárd, a Sliač in Zvolenská kotlina and surroundings of Košice. Applied methods were light trap and sweping net.

3. Results

Symphyta

Of the 797 species living in the Carpathian Basin, 376 are rare, 277 sporadic and 144 frequent or common. The last 3 categories (sporadic, frequent and common) can be considered as important pollinators. Similar to Aculeata species, we can observe an increase of species are predominant in the Mediterranean region (Tables 1 and 2). On the other hand, we found significant decrease in most of sawfly species, which is clearly evident from the Malaise trap data (Table 2 and Figure 1). In two countries, we measured changes in individual numbers and species richness over 5 and 3 decades, respectively, using two different methods. We have Malaise trap data from Slovakia and sweeping net data from Hungary, which are shown in Tables 1 and 2 and in Figure 1. Although there are differences between the two areas and the two methods, the similarities are: increase of Mediterranean sawfly species and gradual decline in number of individuals of most sawfly species. Species that are tolerant to climatic changes are: Tenthredo distinguenda (Stein, 1885), Arge nigripes

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(Retzius, 1783), Arge ochropus (Gmelin, 1790), Arge cyanocrocea (Forster, 1771). These species mainly dominate the fauna of the Mediterranean region and Anatolia. Strongest decline has been observed in moisture-loving species such as Tenthredo mesomela Linné, 1758. However, as suborder Symphyta reaches its maximum species richness and abundance in northern Europe, the negative trends appear realistic and are indication of the Mediterranean transformation of our pollinator fauna. As a matter sporadic species (regularly collected, but in low 1-3 number per year), we have listed in Table3 those species that have not been collected in the Carpathian Basin in the last 20 years. These species were not rare in the middle of the 20th century (until the 1970s), but despite our efforts, we have not succeeded to collect them in the area of the Pannonian biogeographical region. It seems, these species haven't been disappeared but their populations have fallen below the detection limit. Of the 41 species listed, 9 were not found in the entire Carpathian Basin, while 32 species were found in the high-altitude regions (alpine and subalpine) of Slovakia. The list shows that Tenthredo species and several Nematinae species (genera Pristiphora and Pteronidea) have become rare. The decline of the northern Nematinae subfamily is explained by global warming. The reasons for the rarity and disappearance of the Tenthredo species are still unclear. As for the Tenthredo species, similar observations were made by Goulet in Canada [69]. We can say: sporadic species listed in Table 3 are now rare. So far, we have not detected any species spreading from south to north that have appeared in recent decades, although the occurrence of some southern species such as Macrophya superba Tischbein, 1852 can be expected in the near future. In addition, the population densities of Tenthredo bifasciata ssp. bifasciata O. F. Müller, 1776 and Tenthredo costata Klug, 1817 are expected to increase. M. superba reaches its distribution area at the very southern border of the Carpathian Basin [70]. T. costata has the northernmost limit of its distribution range in our region, this is the reason, that its populations are subject of fluctuation in our region. Several specimens of T. costata were captured in the 70s and after long disappearance, it was captured again 2 years ago in Nagybajom, Southern Transdanubia. T. bifasciata ssp. bifasciata was recently recorded in Slovakia [70]. It reaches its highest density in the Anatolian region [71], we can expect its increase in our region as well. In the fauna of the Carpathian Basin, an invasive species, Aproceros leucopoda Takeuchi, 1939, appeared in the early 2000s. Overall, based on our Malaise trap data series, we have observed a strong decline in sawflies over the last 3 decades, which is not surprising if one knows the ecological needs of this group (Table 2 and Figure 1).

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Table 1. Number of individuals of sawflies between 1971 and 2022, netsweeping method.

Taxon	1971-75	1986-98	1990-92	1996-99	2009-12	2019-22	lin x coef.	r^2
Tenthredo mesomelas	27	32	11	2	9	0	-6.09	0.75
Tenthredo atra	57	0	7	0	32	5	-4.88	0.16
Temethredopsis tarsata	29	7	2	0	18	1	-3.11	0.25
Macrophya blanda	21	20	0	0	17	1	-3.11	0.31
Athalia glabricollis	20	0	0	0	3	0	-2.60	0.37
Tenthredo solitaria	28	3	1	2	22	0	-2.34	0.13
Tenthredopsis nassata	24	0	6	10	11	1	-2.20	0.23
Pachyprotasis rapae	25	39	16	10	47	13	-1.20	0.02
Macrophya ribis	6	2	18	10	6	0	-0.74	0.05
Tenthredo campestris	0	23	9	0	11	5	-0.57	0.02
Tenthredo omissa	3	0	8	1	5	0	-0.20	0.01
Arge enodis	2	0	15	8	56	26	-0.20	0.01
Pachynematus rumicis	1	0	0	0	6	0	0.37	0.08
Ametastegia glabrata	0	1	1	8	2	2	0.57	0.14
Temethredopsis literata	3	0	6	2	8	4	0.71	0.21
Athalia lugens	1	0	4	21	4	1	0.82	0.04
Pristiphora pallidiventris	0	4	0	0	7	4	0.82	0.27
Allantus cinctus	4	3	2	7	8	6	0.85	0.46
Tenthredo zonula	1	21	9	0	34	2	1.00	0.02
Tenthredo „arcuata”	2	4	7	0	22	1	1.20	0.08
Tenthredopsis ornata	0	0	0	0	8	4	1.25	0.49
Macrophya duodecimpunc	18	8	18	13	46	5	1.26	0.03
Arge berberidis	1	2	2	0	12	5	1.37	0.24
Arge pagana	1	1	3	0	16	3	1.49	0.21
Tenthredo vespa	0	0	17	0	20	2	1.51	0.09
Arge nigripes	1	6	2	0	12	10	1.74	0.43
Megalodontes plagiocephal	1	4	0	1	18	5	1.80	0.25
Arge ochropus	2	0	0	0	16	9	2.37	0.45
Tenthredo temula	16	10	6	0	44	14	2.45	0.09
Tenthredo amoena	0	0	4	0	30	0	2.45	0.15
Tenthredo rossii	9	5	12	0	31	13	2.46	0.19
Stethomostus fuliginosus	1	6	4	27	17	7	2.46	0.22
Tenthredo distinguenda	0	0	4	0	21	8	2.83	0.41
Temethredopsis stigma	3	4	6	0	19	19	3.40	0.58
Tenthredo marginella	0	2	9	0	14	19	3.49	0.67
Monophadnus pallescens	1	36	6	8	41	25	3.90	0.19
Tenthredopsis sordida	19	9	12	2	37	42	5.40	0.4
Eutomostethus ephippium	31	34	31	18	62	82	9.31	0.53
Aglaostigma aucupariae	5	13	12	10	56	49	9.90	0.7
Arge cyanocrocea	6	3	6	0	37	58	10.17	0.64
Arge melanochra	9	8	12	0	101	40	12.06	0.35
Aglaostigma fulvipes	6	28	11	68	74	113	20.86	0.86

Table 2. Population densities of sawflies between 1991 and 2021, Malaise trap.

Taxon	1992	1992	1992	1994	1994	1995	1996	2017	2017	2018	2018	2021	lin x coef.	r^2
Pachyprotasis rapae	112	111	1154	12	6	10	617	0	0	0	1	0	-34.16	0.12
Empria klugi	29	220	0	14	0	0	0	0	0	0	0	0	-8.28	0.22
Cladius pectinicornis	174	0	12	85	86	36	38	31	40	57	0	2	-6.87	0.25
Tenthredella mesomela	0	60	205	0	0	0	22	0	0	0	0	0	-6.83	0.17
Pteronidea myosotidis	79	1	71	112	72	108	180	1	3	1	18	6	-6.38	0.15
Ametastegia carpini	27	4	95	171	8	0	0	25	0	0	4	3	-6.06	0.17
Claremontia tenuicornis	0	195	0	0	0	0	80	0	0	0	0	1	-5.82	0.13
Ametastegia tenera	7	0	10	267	6	271	0	2	1	0	34	1	-5.04	0.03
Birka cinereipes	1	94	71	6	0	0	0	0	0	0	1	0	-4.81	0.28
Tenthredopsis tarsata	115	0	0	4	16	0	2	0	0	0	1	0	-4.62	0.26
Aglaostigma aucupariae	106	0	10	23	61	2	7	2	1	24	6	0	-4.53	0.26
Macrophya alboannulata	135	0	0	9	14	1	1	0	0	19	32	0	-4.02	0.14
Dolerus aeneus	1	110	26	1	0	3	52	0	0	0	0	0	-3.98	0.18
Tenthredopsis ornata	73	0	0	16	66	35	12	4	5	3	5	0	-3.50	0.24
Athalia cordata	31	0	12	114	121	568	163	38	40	18	21	13	-3.47	0.01
Allantus cinctus	151	0	2	14	36	5	36	46	46	49	14	1	-3.41	0.09
Tenthredopsis sordida	60	5	0	31	39	4	0	3	5	0	0	1	-3.27	0.35
Empria liturata	32	60	4	33	3	5	18	0	0	0	4	29	-2.54	0.23
Tenthredo campestris	0	2	84	0	0	1	7	0	0	0	0	0	-2.10	0.10
Pristiphora pallidiventris	3	18	15	85	2	54	27	2	1	3	2	10	-2.09	0.08
Allantus didymus	1	0	0	0	5	3	17	78	30	0	24	0	-2.06	0.10
Pareophora pruni	63	0	3	10	43	7	2	10	6	18	11	4	-1.99	0.14
Tenthredopsis nassata	8	1	78	20	11	0	133	1	4	4	4	0	-1.94	0.03
Nematus oligospilus	0	83	1	0	0	0	1	0	0	0	1	28	-1.52	0.05
Aglaostigma fulvipes	51	0	4	5	16	1	86	0	2	18	2	0	-1.48	0.04
Allantus cingulatus	29		10	31	47	5	121	40	14	28	10	1	-1.47	0.02
Pristiphora armata	18	0	11	56	11	89	10	2	10	12	16	0	-1.34	0.03
Halidamia affinis	47	0	9	10	26	0	10	3	12	10	17	4	-1.27	0.12
Tenthredopsis stigma	18	0	0	4	131	0	0	58	2	0	8	0	-1.24	0.01
Dolerus gonager	24	9	25	31	4	2	3	3	0	26	20	0	-1.10	0.11
Tenthredopsis litterata	4	0	0	1	111	0	16	4	4	3	2	0	-1.03	0.01
Monophadnus pallescens	4	5	33	5	0	2	7	0	1	0	1	9	-0.79	0.10
Tenthredella atra	0	14	16	1	1	1	24	2	1	0	0	0	-0.74	0.11
Eutomostethus ephippium	19	0	13	3	0	0	5	0	0	0	0	10	-0.70	0.15
Euura mucronata	0	16	9	0	0	0	0	0	0	0	0	2	-0.64	0.21
Ametastegia glabrata	11	0	5	8	4	0	0	0	0	0	0	4	-0.57	0.30
Claremontia alternipes	28	12	5	1	0	2	16	1	0	10	3	17	-0.54	0.05
Arge berberidis	9	0	6	0	1	0	0	0	0	0	0	0	-0.50	0.38
Tenthredo solitaria	4	0	10	1	0	0	3	0	0	0	0	0	-0.41	0.23
Tenthredo „arcuata”	0	0	18	1	0	2	22	0	0	0	0	0	-0.39	0.03
Macrophya annulata	23	0	7	4	3	5	2	5	27	11	0	1	-0.34	0.02
Athalia lugens	0	0	3	4	1	12	1	1	0	0	0	0	-0.18	0.04
Athalia bicolor	8	0	14	14	0	0	21	2	11	1	17	0	-0.05	0.00
Arge melanochra	2	0	1	3	0	0	0	2	6	0	5	0	0.13	0.05
Macrophya duodecimpunctata	1	0	0	1	0	0	4	0	6	0	0	4	0.22	0.14
Tenthredo zonula	0	0	0	0	4	9	9	3	1	9	1	0	0.26	0.06
Dolerus puncticollis	6	0	1	3	8	2	0	4	0	0	20	0	0.27	0.03
Ardis sulcata	0	0	1	0	0	1	0	2	0	13	16	0	0.81	0.28
Stethomostus fuliginosus	3	0	11	2	2	0	0	0	0	1	0	37	1.01	0.12
Sawflies Total	**2315**	**3033**	**4203**	**2532**	**1929**	**2184**	**2894**	**637**	**1311**	**953**	**795**	**1236**	**-223.89**	**0.57**

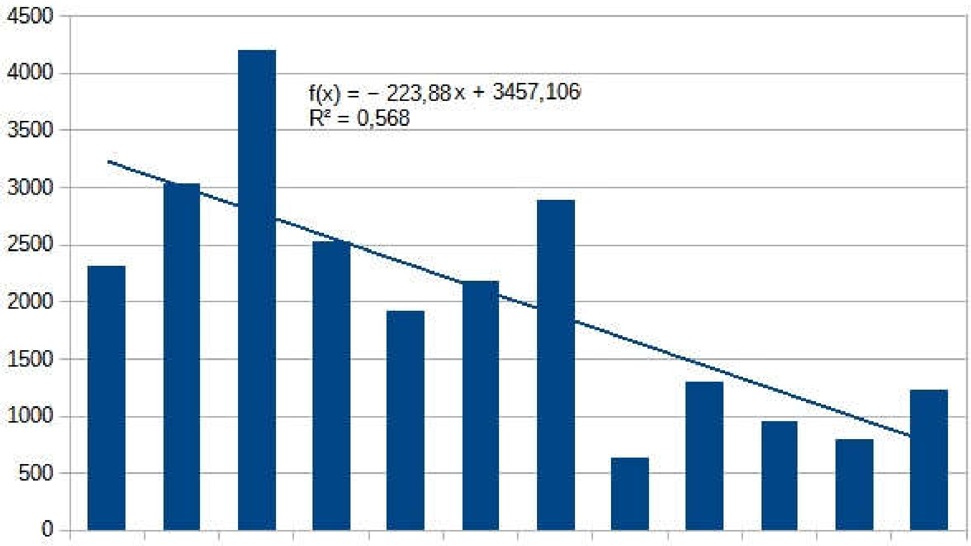

Figure 1. Changes of sawfly populations between 1991 and 2021 with trend line and equation (based on Table 2).

Table 3. Earlier sporadic species, not recorded in the Pannonian biogeographic region in the last 20 years.

Species under detection level (Pannon biogeographic region)	Detected in the high altitudes	Species under detection level (Pannon biogeographic region)	Detected in the high altitudes
Abia candens	+	Nematus pavidus	+
Aglaostigma lichtwardti	+	Nematus ribesii	+
Amauronematus histrio	+	Nematus vicinus	+
Arge fuscipennis		**Pamphilius betulae**	
Arge gracilicornis	+	Pikonema pallescens	+
Cephalcia abietis	+	Pontania bridgmani	+
Cephalcia arvensis	〃	Pontania pedunculi	+
Cephalcia erythrogaster	+	**Pristiphora geniculata**	
Claremontia tenuicornis	+	**Pristiphora maesta**	
Dolerus pratensis	+	Rhogogaster punctulata	+
Empria longicornis	+	Siobla sturmi	+
Empria pumila	+	Tenthredo bipunctula	+
Euura testaceipes		Tenthredo crassa	+
Gilpina polytoma	+	Tenthredo ferruginea	+
Hoplocampa brevis		Tenthredo koehleri	+
Janus femoratus		Tenthredo olivacea	+
Janus luteipes	+	Tenthredo rubricoxis	+
Megalodontes cephalotes	+	**Tenthredo sulphuripes**	
Monostegia cingulata		Tenthredo trabeata	+
Nematus leucotrochus	+	Tenthredo velox	+
Nematus melanaspis	+		

Aculeata

Population densities of most Aculeata groups have intensively increased in the last 40 years (Figure 2). In Table 4, we listed those species which have changed the most in number of individuals. In wild bees, the most intense increase was observed at Nomiapis diversipes (Latreille, 1806),

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Nomada distinguenda Morawitz, 1874 and Halictus sexcinctus (Fabricius, 1775) (Table 6). Since the main distribution area of these species is in the Mediterranean biogeographic region, they are excellent indicators of global warming. In other groups of Aculeata, Priocnemis perturbator (Harris,1780), Scolia hirta (Schrank 1781) and Ancistrocerus gazella (Panzer, 1798) also produced outstanding growth (Table 6).

In terms of proportions, the average population-increase of these species compared to the first half of the 80s are between 1.6 and 3.8x. In the Carpathian Basin, Nomiapis diversipes (Latreille, 1806), Nomada distinguenda Morawitz, 1874, Coelioxys conoidea (Illiger,1806), Andrena symphyti Schmiedeknecht, 1883, Lasioglossum villosulum (Kirby,1802), Melitta nigricans Alfken 1905 and Stelis breviuscula (Nylander,1848) were rare till the 1980s,,but now, they are sporadic or even frequent species.

In contrast, certain moisture-loving or mountainous species became particularly rare, or their populations are decreased from frequent to sporadic such as Anthophora plumipes (Pallas,1772), Ceratina cyanea (Kirby, 1802), Dasypoda hirtipes (Fabricius,1793) and Andrena limata Smith, 1853.

Decline of bumble bees are discussed separately in the next entry. In other non bee groups of Aculeata (Crabronidae, Philanthidae, Scoliidae, Pompilidae, Chrysididae, etc.), this increase was between 1.5 and 3.4x. Some species of Crabronidae associated with the wet conditions of marshy meadows, such as Ectemnius continuus (Fabricius,1804), or saprophilic Hymenoptera which are associated with old trees and forests, like Xylocopa valga Gerstaecker 1872 or Crossocerus elongatulus (Vander Linden,1829), became significantly rarer.

At generic level, we have obviously experienced similar changes. The most striking increase (3-4x) was observed in genera Priocnemis, Oxybelus, Gorytes, Cerceris, Sceliphron and Megascolia (Table 4). Decline of the moisture-loving and saproxyl species observed only at species level.

According to our observations, certain xerotolerant, Mediterranean species are gradually spreading north. These species are: Cerceris rubida (Jurine, 1807) (Philantidae), Chrysis taczanovskii Radoszkowski, 1876 (Chrysididae), Megascolia maculata (Drury, 1773) (Scoliidae), Colletes hederae Schmidt & Westrich , 1993 (Colletidae). Nomiapis bispinosa (Brullé, 1832) (Halictidae) Pasites maculatus Jurine, 1807, Scolia galbula (Pallas, 1771), and Scolia hirta (Schrank 1781) (Scoliidae) (Table 5). The last one was recently discovered in Slovakia. Until now the northern border of its distribution was Hungary, inside the Carpathian Basin. Furthermore, 2 species with originally Mediterranean-distribution, namely Lasioglossum griseolum. (Morawitz 1872) and Heriades rubicola Pérez, 1890 were subrecently captured in Slovakia [80,82] in 2014 and 2009.

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Table 4. Number of individuals of various Aculeata genera and families collected between 1988 and 2023.

genera	1988-93	1994-99	2003-08	2012-17	2018-23	lin. x coef.	r²	changes
Sceliphron	15	18	28	17	64	9.7	0.56	4,3
Cerceris	287	367	536	548	1084	177.5	0.81	3,8
Gorytes	72	74	180	247	209	44.7	0.78	2,9
Oxybelus	245	250	348	447	659	102.5	0.89	2,7
Priocnemis	33	33	127	68	83	13.5	0.26	2,5
Hedychrum	157	162	207	287	372	56.5	0.91	2,4
Crossocerus	195	1430	1064	288	370	-79.2	0.06	1,9
Chrysis	481	496	758	1089	903	143.7	0.75	1,9
Scolia	68	65	49	107	126	15.8	0.60	1,9
Diodontus	316	541	883	503	552	43.4	0.11	1,7
Ectemnius	241	245	540	305	255	8.8	0.01	1,1
Crabro	32	32	35	17	34	-1.1	0.07	1,1
Ammophila	87	78	101	106	82	1.8	0.06	0,9
Megascolia	0	0	0	1	3	0.7	0.72	NA
families	**1988-93**	**1994-99**	**2003-08**	**2012-17**	**2018-23**	**lin. x coef.**	**r²**	**changes**
Philanthidae	338	419	581	600	1163	183.1	0.80	3,4
Bembicidae	82	124	250	324	278	59.2	0.82	3,4
Psenidae	89	357	280	196	274	20.9	0.11	3,1
Halictidae	2225	3320	4524	4122	6633	961.8	0.86	3,0
Chrysididae	612	954	1454	1824	1707	306.0	0.89	2,8
Sphecidae	130	157	220	308	345	58.1	0.97	2,7
Colletidae	1132	1538	1817	1834	2660	335.2	0.89	2,3
Anthophoridae	837	838	1401	1301	1927	264.3	0.85	2,3
Crabronidae	2110	5235	5503	3698	4405	305.3	0.13	2,1
Pemphredonidae	190	441	396	232	309	2.9	0.00	1,6
Andrenidae	1447	1518	2615	1573	2295	175.1	0.27	1,6
Megachilidae	1234	1421	1237	1522	1860	135.3	0.69	1,5

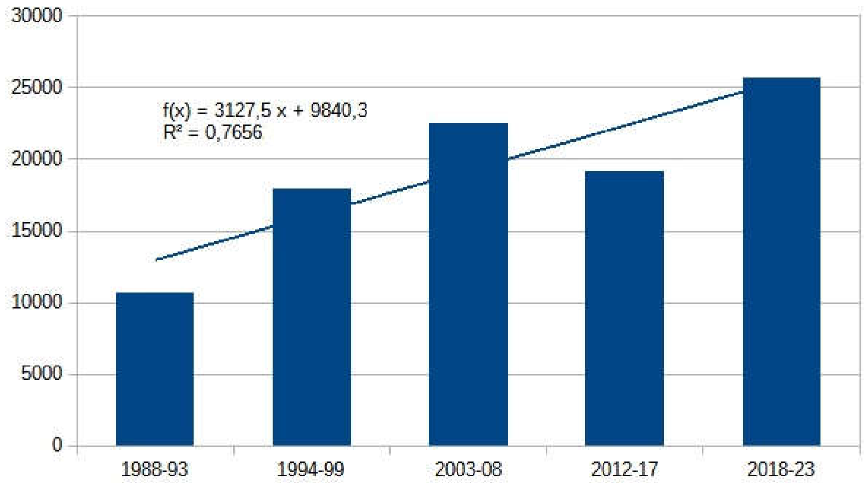

Figure 2. Changes of Aculeata populations between 1988 and 2023 with trend line and equation (based on Table 4).

Non native species are also enriched our pollinator fauna. This enrichment has 2 ways: one is the expansion of the area of certain species due to climatic change or introducing species from distant

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regions by human activity. The following species reached the Carpathian Basin from the Mediterranean region (Table 5): Sceliphron madraspatanum (Fabricius, 1781) (Sphecidae), Diodontus brevilabris Beaumont, 1967 (Pemphedronidae), and Chelostoma styriacum M.Schwarz & Gusenleitner, 1999 (Megachilidae). On the other had, Sceliphron curvatum (F. Smith 1870), Sceliphron caementarium (Drury, 1773), Isodontia mexicana (Saussure, 1867) (Sphecidae), Megachile sculpturalis Smith, 1853 (Megacjilidae) and Vespa velutina (Lepeletier, 1836) (Vespidae) were introduced from distant regions of the Earth (Table 5). Among these, Sceliphron curvatum (F. Smith 1870), Sceliphron caementarium (Drury, 1773) and Isodontia mexicana (Saussure, 1867) were succeed to be frequent (Table 5). We managed to collect only 4 specimens of Megachile sculpturalis near Harta (Bács-Kiskun County). These invasive species expanded quickly in the southern and moderately quickly in the northern area of the Panonian biogeographic region (comapre Hungarian and Slovak data in Table 5). As a matter of the rest, only the voucher specimens were captured.

Table 5. Invasive and recently appeared expansive Aculeata species between 1988 and 2023 (Hungarian data above, Slovak data below).

Taxon	**1988-93**	**1994-99**	**2003-08**	**2012-17**	**2018-23**	**linear x coef f**	**r^2**
Chrysis taczanovskii	0	1	0	42	110	26.10	0.74
Cerceris rubida	1	6	45	116	276	66.00	0.83
Diodontus brevilabris	9	100	177	107	209	40.70	0.69
Colletes hederae	0	0	0	0	5	NA	NA
Nomiapis bispinosa	0	0	0	0	11	NA	NA
Pasites maculatus	1	0	13	18	58	13.20	0.78
Scolia hirta	6	21	18	35	53	10.80	0.9
Megascolia maculata	0	0	0	1	3	0.70	0.72
Sceliphron curvatum	0	8	10	6	13	2.40	0.62
Sceliphron caementqrium	0	0	0	0	47	NA	NA
Isodontia mexicana	0	0	2	37	89	21.50	0.77
Taxon	**2000- 04**	**2005-09**	**2010-14**	**2015-19**	**2020-3**	**linear x coef f**	**r^2**
Colletes hederae	0	0	0	77	25	**5.52**	**0.34**
Sceliphron caementarium	0	1	0	4	15	**1.22**	**0.45**
Sceliphron curvatum	0	4	75	4	8	**3.30**	**0.14**
Isodontia mexicana	0	1	0	5	2	**0.40**	**0.42**
Megascolia maculata	0	1	1	5	7	**0.72**	**0.59**

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Table 6. Number of individuals of various Aculeata species between 1988 and 2023.

species	1988-93	1994-99	2003-08	2012-17	2018-23	linear x coeff.	r^2	change
Nomada bifasciata	18	15	123	172	305	73	0.92	4.1
Lasioglossum politum	122	365	878	424	436	68.7	0.16	3.6
Hylaeus brevicornis	221	265	274	347	481	60.2	0.87	2.2
Nomada goodeniana	21	4	50	137	232	55.5	0.85	11,0
Andrena minutuloides	95	110	179	177	333	54.3	0.83	3,5
Lasioglossum marginatum	210	360	349	423	370	38.3	0.58	1,8
Andrena flavipes	161	176	188	198	320	34	0.71	2,0
Megachile pilidens	28	39	31	86	151	29.3	0.78	5.4
Hylaeus communis	136	151	186	157	263	26	0.67	1.9
Heriades truncorum	110	100	63	89	236	24.1	0.32	2.1
Sphecodes ephippius	39	38	110	46	150	23	0.51	3.8
Halictus sexcinctus	10	37	29	47	117	22.4	0.75	11.7
Halictus subauratus	60	53	84	85	153	21.8	0.76	2.6
Nomiapis diversipes	1	7	66	91	66	21.4	0.72	66,0
Andrena ovatula	78	73	82	121	154	20.2	0.82	2,0
Colletes daviesanus	14	14	38	85	70	18.3	0.8	5,0
Megachile ericetorum	58	35	40	100	117	18.3	0.62	2,0
Nomada distinguenda	3	21	56	73	62	17	0.82	20.7
Hylaeus confusus	122	105	73	44	97	11	0.33	0.8
Andrena nitidiuscula	34	53	22	14	107	10.7	0.21	3.1
Lasioglossum leucozonium	34	55	55	44	90	10.1	0.57	2.6
Andrena proxima	43	29	51	35	89	9.9	0.43	2.1
Colletes similis	15	14	23	31	54	9.5	0.84	3.6
Sphecodes albilabris	31	28	44	72	56	9.4	0.66	1.8
Sphecodes monilicornis	83	98	85	89	134	9.3	0.49	1.6
Panurgus calcaratus	53	55	83	50	99	9.2	0.41	1.9
Coelioxys afra	31	51	54	48	76	8.7	0.73	2.5
Anthidium manicatum	20	17	28	34	51	7.9	0.85	2.6
Coelioxys conoidea	3	8	18	18	30	6.4	0.94	10
Osmia aurulenta	44	31	56	57	59	5.6	0.56	1.3
Amegilla salviae	17	22	35	14	47	5.2	0.36	2.8
Anthidium oblongatum	57	20	26	57	63	4.9	0.15	1.1
Andrena hattorfiana	19	7	13	35	29	4.8	0.44	1.5
Hylaeus annularis	31	36	25	39	53	4.7	0.5	1.7
Andrena bimaculata	13	54	84	49	37	4.3	0.07	2.8
Andrena haemorrhoa	78	64	103	18	61	4.3	0.07	0.8
Andrena symphyti	1	15	11	17	20	4	0.74	20
Andrena nitida	22	17	26	32	33	3.8	0.71	1.5
Tetralonia malvae	25	32	25	25	47	3.7	0.38	1,9
Lasioglossum villosulum	4	25	32	25	20	3.2	0.23	5,0
Melitta nigricans	2	8	24	9	12	2.1	0.16	6,0
Eucera nigrescens	35	48	72	35	48	1.8	0.03	1,4
Stelis breviuscula	1	18	13	14	12	1.8	0.2	12,0
Stelis punctulatissima	3	9	25	10	10	1.5	0.08	3,3
Tetraloniella salicariae	3	10	8	4	1	1	0.18	0,3
Andrena labialis	3	5	19	2	2	-0.5	0.01	0,6
Andrena labiata	13	13	12	8	10	-1.1	0.65	0,8
Chelostoma campanularum	17	23	16	7	19	-1.2	0.1	1,1
Megachile centuncularis	61	39	29	31	57	-1.6	0.03	0,9
Andrena subopaca	49	13	24	16	35	-2.2	0.5	0,7
Chelostoma florisomne	26	55	13	25	30	-2.2	0.05	1,2
Xylocopa valga	13	20	6	4	6	-3	0.51	0,5
Lasiogloosum calceatum	48	63	57	46	40	-3.3	0.32	0,8
Hylaeus variegatus	55	75	54	29	57	-4.2	0.16	1,0
Andrena limata	35	38	30	18	13	-6.4	0.87	0,4
Colletes cunicularius	52	104	139	52	45	-6.6	0.06	0,9
Dasypoda hirtipes	51	44	29	39	18	-7.1	0.75	0,4
Hoplitis adunca	52	14	21	29	6	-7.7	0.48	0,1
Lasioglossum morio	78	149	131	64	81	-7.9	0.11	1,0
Andrena minutula	88	84	172	83	48	-8.1	0.07	0,5
Ceratina cyanea	71	71	49	10	43	-11.7	0.54	0,6
Osmia rufa	54	138	49	32	44	-12.6	0.23	0,8
Anthophora plumipes	36	95	14	18	8	-13.3	0.35	0,2
Lasioglossum malachurum	59	163	82	31	36	-17.8	0.28	0,6
Crossocerus elongatulus	21	319	174	90	48	-17.5	0.05	2,2
Ectemnius continuus	128	106	135	91	80	-11.1	0.56	0,6
Polistes nimpha	68	45	11	21	57	-4.6	0.09	0,8
Auplopus carbonarius	50	103	95	63	53	-3.4	0.05	1,0
Sceliphron destillatorium	15	11	18	11	4	-2.2	0.44	0,3
Vespula germanica	44	15	23	30	29	-1.5	0.05	0,7
Diodontus minutus	259	366	503	315	229	-1.1	0.03	0,9
Tiphia femorata	103	177	134	122	152	4.3	0.06	1,5
Ancistrocerus gazella	4	26	61	21	28	4.3	0.11	7,0
Ammophila sabulosa	36	28	46	56	50	5.6	0.63	1,4
Psenulus pallipes	82	309	187	129	201	5.8	0.01	2,5
Cerceris arenaria	94	143	143	111	145	7	0.27	1,5
Anoplius viaticus paganus	7	28	56	37	39	7.3	0.42	5,6
Chrysis ignita	39	49	96	57	72	7.4	0.27	1,8
Bembecinus tridens	90	106	72	172	94	7.4	0.09	1,0
Priocnemis perturbator	1	10	25	32	34	8.8	0.94	34,0
Scolia hirta	6	21	18	35	53	10.8	0.9	8,8
Pseudomalus pusillus	34	58	98	74	88	12.4	0.6	2,6
Pemphredon lethifera	166	275	212	184	274	12.5	0.15	1,7
Tachysphex tarsinus	0	0	51	120	70	26	0.66	NA
Gorytes quinquecinctus	63	41	102	136	146	26.1	0.83	2,3
Hedychrum nobile	66	66	82	120	189	30	0.83	2,9
Lestica clypeata	100	88	110	135	229	30.5	0.72	2,3
Cerceris sabulosa	88	110	179	187	322	54.5	0.89	3,7
Oxybelus quatordecimnotatu	90	105	69	216	310	55.1	0.73	3,4
Philantus triangulum	51	52	45	52	79	5.6	0.44	1,5

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Bumblebees (*Bombus* spp.)

Trend of population densities are strikingly different from the majority of other Aculeata species, this is the reason that we discuss separately the true bumblebees and also their social parasites the cuckoo bumblebees (Table 7). Their trends are opposite to other Aculeate species. Almost all bumblebee species have experienced significant decline. According to our data, only Bombus argillaceus (Scopoli, 1763) went through a moderate and Bombus haematurus Kriechbaumer, 1870 an intensive increase in populations. Numerous bumblebee species such as Bombus confusus Schenck, 1859, Bombus subterraneus (Linnés, 1758) and Bombus (Thoracobombus) pomorum fall below the detection limit in the Pannonian biogeographic region. Particularly interesting are those species that were common in the middle of the last century, but showed considerable decrease in frequency in the last 20 years: Bombus lapidarius (Linné, 1758), Bombus pascuorum (Scopoli, 1763), Bombus hortorum (Linné,1761) and Bombus ruderarius (Mueller,1776) suffered the strongest decline. Data from longer time window (1980 – 2023) provide more realistic, and even optimistic picture about the above named bumble bees (Table 7, sum of historical and more recent data). Here the trend in overal abundance increase is observable. As a conclusion, we may say that the population of these common and widespread species increased.

Especially interesting species are Bombus haematurus Kriechbaumer, 1870 and Bombus argillaceus Scopoli, 1763. These two species were historically very sporadic [27,99–102]. Due to the changed climatic condition, they are spreading to newer territories situated North-West of their original area of distribution [94,103–106]. The center of distribution of these 2 species is the Western Palearctic, Ponto-Mediterranean region. Their increase is strong indication of ongoing climatic change. According to projections of Rasmont et al. [106], these species can benefit from the climate change and potentially enlarge their current distribution in Europe in the upcoming decades.

Cuckoo bumblebees were never been frequent but for now, they became even rarer as they were before. They didn't disappear (since time by time they are observed by various entomologists and reporting the observation on the net) but they fall below our detection limit (Table 7).

Table 7. Number of individuals of various bumblebee and cuckoo bumblebee species between 1980 and 2023.

Taxon/ data of the last 2 decades	2005 - 2009	2010 - 2014	2015 - 2019	2020 - 2023	linear x coeff	r²
Bombus (Bombias) confusus	2	0	0	0	recently under detection limit	
Bombus (Subterraneobombus) subterraneus	0	0	0	0		
Bombus (Thoracobombus) pomorum	0	0	0	0		
Bombus (Bombus) terrestis	944	888	479	205	-262.6	0.94
Bombus (Melanobombus) lapidarius	835	291	481	45	-218.0	0.72
Bombus (Thoracobombus) pascuorum	692	944	401	284	-176.7	0.60
Bombus (Megabombus) hortorum	173	357	106	11	-73.7	0.42
Bombus (Thoracobombus) ruderarius	174	151	56	13	-57.8	0.95
Bombus (Thoracobombus) humilis	75	7	32	16	-15.2	0.42
Bombus (Bombus) lucorum	41	104	31	7	-17.5	0.30
Bombus (Pyrobombus) hypnorum	31	18	12	7	-7.8	0.95
Bombus (Megabombus) ruderatus	18	11	0	0	-6.5	0.90
Bombus (Thoracobombus) sylvarum	77	98	24	65	-1.7	0.39
Bombus (Thoracobombus) muscorum	6	1	1	2	-1.2	0.42
Bombus (Pyrobombus) pratorum	1	28	18	2	-0.7	0.00
Bombus (Pyrobombus) haematurus	80	93	103	116	11.8	1.00
Bombus (Megabombus) argillaceus	4	28	8	31	61.0	0.33
Bombus (Psithyrus) vestalis	60	49	55	13	-13.5	0.67
Bombus (Psithyrus) rupestris	12	56	6	0	-8.6	0.19
Bombus (Psithyrus) bohemicus	3	29	21	0	-1.7	0.02
Bombus (Psithyrus) barbutellus	4	1	0	0	-1.3	0.79
Bombus (Psithyrus) campestris	2	4	1	0	-0.9	0.46
Bombus (Psithyrus) maxillosus	1	0	0	0	under detection limit	
Taxon/ historic data	**1980 - 1984**	**1985 - 1989**	**1990 - 1994**	**1995 - 1999**	**2000 - 2004**	
Bombus (Bombias) confusus	71	45	1	0	0	
Bombus (Subterraneobombus) subterraneus	38	3	0	0	0	
Bombus (Thoracobombus) pomorum	25	0	0	0	0	
Bombus (Megabombus) argillaceus	0	0	0	0	0	
Bombus (Megabombus) ruderatus	NA	NA	NA	NA	6	
Bombus (Megabombus) hortorum	26	NA	NA	NA	16	
Bombus (Thoracobombus) muscorum	27	0	27	0	50	
Bombus (Thoracobombus) ruderarius	33	NA	NA	NA	54	
Bombus (Thoracobombus) sylvarum	129	NA	NA	NA	145	
Bombus (Thoracobombus) humilis	NA	NA	NA	NA	7	
Bombus (Thoracobombus) pascuorum	71	NA	NA	NA	42	
Bombus (Pyrobombus) haematurus	0	0	0	0	1	
Bombus (Pyrobombus) hypnorum	7	NA	NA	NA	1	
Bombus (Pyrobombus) pratorum	3	NA	NA	NA	NA	
Bombus (Bombus) terrestis	349	NA	157	96	134	
Bombus (Bombus) lucorum	2	NA	NA	NA	4	
Bombus (Melanobombus) lapidarius	103	NA	NA	NA	188	
Bombus (Psithyrus) rupestris	NA	NA	0	0	NA	
Bombus (Psithyrus) campestris	NA	NA	0	0	NA	
Bombus (Psithyrus) vestalis	1	NA	2	1	1	
Bombus (Psithyrus) bohemicus	NA	NA	NA	NA	NA	
Bombus (Psithyrus) barbutellus	NA	NA	2	2	1	
Bombus (Psithyrus) maxillosus	NA	NA	NA	NA	1	

Diptera

Syrphidae (Hoverflies)

Being a moisture-loving group of insects, it is not surprising that their number shows decreasing trend Tables 8 and 12). The surprising is the intensity of this trend. At family level, the decrease compared to the beginning of the 80s is about 80%. Some species, namely Sphaerophoria scripta (Linné, 1758), Cheilosia variabilis (Panzer, 1798) and Syrphus torvus (Osten Sacken, 1875) suffered drastic decrease in numbers (96-97%) (Table 8). We didn't find any species in the family whose population density would have been positively affected by the climatic conditions of recent decades.

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No invasive species were detected in this group. The northern expansion of a Mediterranean species, Chalcosyrphus pannonicus (Ooldengberg, 1916), was detected in Poland and Slovakia in 2010 and in 2011: Poland, Carpathians, Lower Beskid, Magura NP, Żydowskie, 530 ma.s.l., 24. 07. 2011, 1 male; Slovakia, Carpathians, Lower Beskids, Ondavskie Foothills (Slov. Ondavská vrchovina), district. Chalcosyrphus pannonicus (Ooldenberg, 1916) is a rare species, so far it has been caught in Croatia, Romania, Bulgaria, Greece and the Caucasus [83]. According to our experience, the strong decline of hoverflies is independent of their ecological type: whether the insect is eurytherm or mesophyl. This decline also affects all hoverfly groups independently of their lifestyle: if the species develops in water, compost, plant parts, fungi or even aphidophage or nest parasite, all of them have suffered serious decline in their population density. Decline of some species is so strong, that itcan be modeled by exponential trend (ln x coeff. value) instead of linear trend, Table 8). Fifty, earlier regularly collected, sporadic species became so rare, that they fell below the detection limit in the last 2 decades (Table 13).

Table 8. Number of individuals of various hoverfly species between 1980 and 2010.

Syrphidae (Hoverflies)	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2010	linear x coeff	r2	ln x coeff	r2	change
Sphaerophoria scripta	3509	2049	557	581	39	109	-657.31	0.81	-2008.23	0.95	0.03
Cheilosia variabilis	392	5	21	1	20	13	-53.43	0.41	-187.76	0.64	0.03
Syrphus torvus	359	43	14	14	10	15	-51.97	0.49	-178.25	0.72	0.04
Syrphus vitripennis	846	176	210	121	24	48	-129.57	0.63	-417.9	0.82	0.06
Episyrphus balteatus	1587	909	652	2050	85	94	-243.97	0.33			0.06
Melanostoma mellinum	1168	1257	420	321	73	75	-260.45	0.85			0.06
Pipizella viduata	364	426	97	82	48	33	-80.11	0.75			0.09
Eristalis arbustorum	1259	767	411	156	86	116	-228.94	0.85	-691.94	0.96	0.09
Myathropa florea	93	132	45	20	17	9	-22.57	0.73			0.10
Eristalis pertinax	160	41	15	25	5	19	-22.94	0.54	-76.95	0.77	0.12
Syritta pipiens	501	588	415	109	36	78	-116.48	0.82			0.16
Scaeva pyrastri	210	85	106	17	16	34	-33.6	0.71			0.16
Platycheirus albimanus	162	46	33	121	33	27	-17.89	0.34			0.17
Volucella zonaria	6	0	7	1	36	1	2.2	0.09			0.17
Eristalis tenax	1115	509	270	89	122	196	-169	0.67			0.18
Syrphus ribesii	344	114	32	156	23	63	-44.4	0.48			0.18
Volucella pellucens	64	8	15	8	9	12	-7.54	0.4			0.19
Eupeodes luniger	36	16	21	58	7	8	-3.71	0.13			0.22
Eupeodes luniger	40	16	22	59	7	15	-3.28	0.1			0.38
Cheilosia impressa	74	89	81	11	20	28	-14.49	0.62			0.38
Cheilosia soror	26	59	55	7	19	23	-5.23	0.22			0.88

Tabanidae (Horse-flies)

At family level, the number of individuals shows an increase about 1.89x compared to the beginning of the 80s (Table 12). Certain xerotolerant, warm-loving species, namely Therioplectes gigas (Herbst, 1787), Chrysops caecutiens (Linné, 1758), Haematopota italica Meigen, 1804 and Tabanus bovinus Linnaeus, 1758 increased remarkably, taking the early 1980s as a base, this increase is 3-5x (Table 9). We have (so far) caught neither Mediterranean newcomers nor invasive species. Decline of Haematopota pluvialis (Linné, 1758) moorland and silvícole species and Atylotus rusticus (Linné, 1761) mesophile species shade the overall picture (Table 9). Only the Mediterranean *Pangonius pyritosus* (Loew, 1859) can be assumed to have been able to expand to the north due to climate change. In 1991, it appeared for the first time in the Carpathian Basin near Homorúd [84], but its population density hasn't expanded so far. Till this time, invasive species hasn't been detected either.

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Table 9. Number of individuals of various horse-fly species between 1980 and 2014.

Tabanidae (Horse-flies)	1980-84	1985-89	1990-94	1995-99	2005-09	2010-14	lin. x coeff..	r^2	change
Tabanus bromius	212	128	187	134	116	62	-23,97	0,71	0,3
Haematopota pluvialis	189	228	205	760	161	70	-6,88	0,03	0,4
Atylotus rusticus	116	13	13	40	72	61	-2,03	0,01	0,5
Chrysops viduatus	74	20	29	59	90	48	3,24	0,05	0,6
Heptatoma pellucens	16	4	4	11	42	21	4,17	0,3	1,3
Tabanus autumnalis	29	18	14	28	67	41	6,31	0,38	1,4
Silvius alpinus	5	0	1	1	31	9	3,22	0,26	1,8
Therioplectes gigas	5	1	3	5	34	14	4,17	0,3	2,8
Chrysops caecutiens	14	16	13	33	83	41	10,17	0,05	2,9
Haematopota italica	19	114	227	42	85	58	-2,2	0	3,1
Tabanus bovinus	8	13	20	14	81	40	10,23	0,38	5,0

Bombyliidae (Bee Flies)

We experienced intensive increase in population densities in family (Table 12) and in species level as well (Table 10). Taking the beginning of the 80's as the base period, this increase is about 80%. It makes this group one of the winners of climate change. The following species produced outstanding growth: Bombylius discolor Mikan, 1796, Conophorus virescens (Fabricius, 1787), Bombylius fimbriatus Meigen, 1820, Bombylius cinerascens Mikan, 1796, Villa hottentotta (Linné, 1758), Bombylius canescens Mikan, 1796, Bombylius fulvescens Meigen & Wiedemann, 1820, Bombylius major Linné, 1758, Anthrax anthrax (Schrank, 1781), Anthrax leucogaster Meigen & Wiedemann, 1820, Bombylius pictus Panzer, 1794 and Hemipenthes morio (Linné,1758) (Table 10). The extreme 10-18x increase of density of Exoprosopa jacchus (Fabricius, 1805), Lomatia sabaea (Fabricius 1781) and Bombylius medius Linné, 1758 is associated with the intensive expansion of these species. The reasons for this expansion is unknown, it is likely their hosts are warm-loving insect (for instance antlions [85,86], and other xerotolerant gorups like Acrididae, Tenebrionidae, Aculeata etc. [87]). We haven't detected any invasive species so far.

Table 10. Number of individuals of various bee fly species between 1980 and 2020.

Bombyliidae (Bee flies)	1980-84	1985-89	1990-94	1995-99	2000-04	2005-09	2010-14	2016-20	ln. x oeff..x	r^2	change
Apolysis szappanosi **	0	1	0	0	1	0	5	0	0.25	0.13	NA
Exoprosopa jacchus	1	2	7	1	8	27	23	18	3.46	0.67	18,0
Lomatia sabaea	3	0	15	3	18	13	23	38	4.39	0.73	12,7
Bombylius medius	7	7	9	14	10	34	34	70	7.7	0.73	10,0
Bombylius discolor	13	14	8	41	41	23	31	91	8.04	0.55	7,0
Conophorus virescens	9	32	19	45	38	57	72	60	7.9	0.83	6,7
Bombylius fimbriatus	8	31	18	40	41	13	26	52	3.2	0.27	6,5
Bombylius cinerascens	13	33	19	24	28	51	27	79	6.33	0.53	6,1
Villa hottentotta	20	6	72	33	36	70	73	99	10.54	0.65	5,0
Bombylius canescens	8	6	15	27	13	32	19	33	3.29	0.59	4,1
Bombylius fulvescens	7	20	15	21	9	23	27	27	2.23	0.51	3,9
Bombylius major	54	156	105	160	63	26	28	199	0.49	0	3,7
Anthrax anthrax	5	1	9	0	1	9	10	18	1.63	0.43	3,6
Anthrax leucogaster	5	2	12	20	6	21	15	17	1.93	0.43	3,4
Bombylius pictus	2	5	3	4	3	10	21	4	1.36	0.27	2,0
Hemipenthes morio	67	42	90	254	31	78	89	124	4.46	0.02	1,9
Bombylella atra	23	39	22	53	3	45	36	7	-1.28	0.03	0,3

Tachinidae (Tachinids)

They suffered significant decline similar to that of Syrphidae (Tables 11 and 12). However, this decrease is not strong trend, the average r^2 value is around 0.2. For hoverflies, it is 0.5. Probably, thanks to their endoparasitoids way of life, they are less exposed to external influences than moisture-loving Syrphidae. No species has population density increased, however some previously common species, such as Phasia pusilla Meigen, 1824 or Gymnosoma dolycoridis Dupuis 1961, have suffered

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so strong decline in populations that their numbers have fallen below detection limit. We have not detected any invasive species till this time. Twenty-seven, earlier regularly collected, sporadic species became so rare, that they fell below the detection limit in the last 2 decades (Table 13).

Table 11. Number of individuals of various Tachinid species between 1980 and 2014.

Tachinidae (Tachinids)	1980-84	1985-89	1990-94	1995-99	2000-04	2005-09	2010-2014	lin. x coeff..	r^2	change
Blondelia nigripes	52	29	69	12	NA	12	NA	-9.7	0.37	0,2
Chetogena filipalpis	4	0	18	5	NA	0	NA	-0.3	0	0,0
Compsilura concinnata	29	44	216	13	NA	3	NA	-8.3	0.22	0,1
Exorista larvarum	29	33	80	5	NA	7	NA	-7.2	0.14	0,2
Gymnosoma clavatum	15	5	30	7	NA	4	NA	-2	0.06	0,3
Gymnosoma dolycoridis	31	10	71	19	NA	0	NA	-5.3	0.09	0,0
Gymnosoma rotundatum	28	29	125	10	NA	7	NA	-6.1	0.04	0,3
Linnaemya frater	11	75	11	1	NA	7	NA	-8.2	0.18	0,6
Phasia pusilla	53	45	39	0	NA	1	NA	-14.9	0.87	0,0
Tachina fera	55	19	232	42	NA	26	NA	-3.5	0	0,5

Table 12. Changes of frequency of vEarious Diptera families between 1980 and 2019.

Families	1980-84	1985-89	1990-94	1995-99	2000-04	2005-09	2010-14	2014-19	lin. x coeff	r^2	change
Syrphidae	11602	9226	4415	5365	2587	2708	NA	NA	-1812.49	0.86	0.2
Bombilidae	530	533	569	615	452	701	928	980	63.79	0.65	1.8
Tabanidae	978	1046	977	1387	NA	1614	571	NA	136.93	0.84	0.6
Tachinidae	2473	1826	4477	725	233	516	NA	NA	-523.31	0.37	0.2

Table 13. Earlier sporadic Diptera species not colelcted in the last 20 years.

Bombyliidae	**Syrphidae**
Bombylosoma unicolor (Loew, 1955)	*Brachyopa panzeri* Goffe, 1945
Bombylius fuliginosus Wiedemann in Meigen, 1820	*Brachyopa vittata* Shummel, 1834
Bombylius quadrifarius Loew, 1855	*Brachypalpus chrysites* Egger, 1859
Heteralonia dispar (Loew, 1869)	*Callicera macquarti* Rondani, 1944
Spogostylum aethiops (Fabricius, 1781)	*Callicera rufa* Schummel, 1842
	Callicera spinolae Rondani, 1844
Tabanidae	*Chalcosyrphus curvipes* (Loew, 1854)
Pangonius pyritosus (Loew, 1859)	*Cheilosia bracusi* Vujic & Claussen, 1994)
Hybomitra arpadi Szilády,1923	*Cheilosia brunnipennis* (Becker, 1894)
Hybomitra aterrima (Meigen, 1820)	*Cheilosia hypena* (Becker, 1894)
Hybomitra expollicata (Pandellé, 1883)	*Cheilosia insignis* (Loew, 1857)
Hybomitra montana (Meigen, 1820)	*Cheilosia melanopa* (Zetterstedt, 1843)
Hybomitra nigricornis (Zetterstedt, 1842)	*Cheilosia melanura* (Becker, 1894)
Hybomitra tarandina (Linnaeus, 1758)	*Cheilosia pictipennis* Egger, 1860
	Cheilosia sahlbergi (Becker, 1894)
Tachinidae	*Cheilosia subpictipennis* (Claussen, 1898)
Amelibaea tultschensis (Brauer & Bergenstamm, 1891)	*Chrysogaster basalis* (Loew, 1857)
Anthomyiopsis nigrisquamata (Zetterstedt, 1838)	*Cliorhina pachymera* (Egger, 1858)
Anthomyiopsis plagiodera Mesnil, 1972	*Epistrophe obscuripes* (Strobl, 1910)
Aphria xyphias Pandellé, 1896	*Eristalis vitripennis* (Strobl, 1893)
Besseria dimidiata (Zetterstedt, 1844)	*Eumerus hungaricus* (Szilády, 1940)
Besseria melanura (Meigen, 1824)	*Eumerus longicornis* (Loew, 1855)
Bithia acanthophora (Rondani, 1861)	*Eumerus ruficornis* (Meigen, 1822)
Blepharomyia pagana (Meigen, 1824)	*Eumerus sabulosum* (Fallén, 1817)
Cadurciella tritaeniata (Rondani, 1859)	*Eumerus tauricus* (Stackelberg, 1952)
Campylochaeta latigena Mesnil, 1974	*Eupeodes lucasi* (Marcos-García & Láska, 1983)
Catharosia albisquama (Villeneuve, 1932)	*Hammersmidtia ferruginea* (Schummel, 1834)
Ceranthia tristella Herting, 1966	*Helophilus affinis* (Wahlberg, 1844)
Chetoptilia puella (Rondani, 1862)	*Lejota ruficornis* (Zetterstedt, 1843)
Conogaster pruinosa (Meigen, 1824)	*Melanogaster curvistylus* (Vujić-Stuke, 1998)
Elfia abnormis (Stein, 1924)	*Melanostoma dubium* (Zetterstedt, 1837)
Eloceria delecta (Meigen, 1824)	*Milesia crabroniformis* (Fabricius, 1775)
Estheria acuta (Portschinsky, 1881)	*Orthonevra tristis* (Loew, 1871)
Gonia bimaculata Wiedemann, 1819	*Paragus medeae* Stanescu, 1991
Heraultia albipennis Villeneuve, 1920	*Paragus punctulatus* (Zetterstedt, 1938)
Ligeriella aristata (Villeneuve, 1911)	*Pipiza fenestrata* (Meigen, 1822)
Minthodes pictipennis Brauer & Bergenstamm, 1889	*Pipizella pennina* (Goeldlin de Tiefenau, 1974)
Psalidoxena transsylvanica (Villeneuve, 1929)	*Platycheirus complicatus* (Becker, 1889)
Siphona confusa Mesnil, 1961	*Platycheirus immarginatus* (Zetterstedt, 1849)
Siphona ingerae Andersen, 1982	*Platycheirus jaerensis* (Nielsen, 1971)
Therobia leonidei (Mesnil, 1965)	*Platycheirus nielseni* (Vockeroth, 1990)
Vibrissina debilitata (Pandellé, 1896)	*Platycheirus perpallidus* (Verrall, 1901)
Winthemia bohemani (Zetterstedt, 1844)	*Rhingia austriaca* (Meigen, 1830)
	Scaeva albomaculata (Macquart, 1842)
	Sphaerophoria shircan (Violovits, 1957)
	Sphiximorpha binominata (Verrall, 1901)
	Syrphus nitidifrons (Becker, 1921)
	Syrphus sexmaculatus (Zetterstedt, 1838)
	Trichopsomyia joratensis (Goeldlin de Tiefenau, 1997)
	Xylota coeruleiventris (Zetterstedt, 1838)

Lepidoptera

Nocturnal macrolepidoptera

Considering the beginning of the 70's as the base period, population-decrease of moths is relatively strong (Figure 3), but with low determination coefficient, which means the long term,

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tendentious changes (for example: climate change, habitat changes), are only partly the cause of their decline; other cyclical temporal variables, and their spatial distribution pattern are also significant and strongly influence their populations. According to our observations and our available data, decline-trend lasted till the 2010s. After this time, the trend reversed and we may consider a certain increase in the number of individuals: (linear x coefficient from -157 up to 147 , Table 15, moths total). The low r^2 value (0,04) indicates some influence of different method of light trapping (see methods and material part). Taking a closer look at the various groups, owlet moths, sphinx moths and Drepanids suffered the most drastic changes. In family level, the trend is continuously declining in these groups. Nolidae and Notodontidae species show an increasing trend in number of individuals during the last decade (only UV LED portable light traps were applied in this decade). In terms of species richness, negative trend is experienced. In each year, light traps catch fewer and fewer species, till 2014 when this trend stopped (Table 16 and Figure 4). At Geometridae, we observed the strongest decline in species diversity. This decrease in species richness of this group has not stopped till this day (Table 16), while in other families, this trend has stopped and turned into slight increase (Table 16). During this phase, there was no change of methodology. In last decade, we noticed some changes in the order of the 10 most frequent species: relative proportion of Mythimna turca, Athetis furvula and Mythimna pallens declined and proportion of Eilema lurideola and Colocasia coryli increased. For details, see Table 14.

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Table 14. Changes in frequency of various moths in the last 50 years.

Taxon	1970	1970	1970	1970	1973	1976	1977	1978	1979	1979	1980	1980	1981	1981	1986	1987	2019	2019	2020	2020	2021	2021	2021	2021	2022	lin. x coeff (1970)	r^2	lin. x coeff (1981)	r^2
Phragmatobia fuliginosa	0	13	0	207	1028	261	221	193	145	110	121	407	116	472	315	428	0	20	45	7	10	22	11	34	23	-9.28	0.09	-28.44	0.42
Xestia c-nigrum	1049	309	132	532	186	674	189	230	7	7	14	189	248	273	224	147	2	55	49	21	14	61	62	70	5	-20.52	0.38	-17.64	0.52
Mythimna pallens	16	35	18	41	139	229	62	96	11	0	8	34	27	216	113	90	0	0	0	0	0	1	0	0	0	-3.13	0.12	-10.77	0.40
Eilema lurideola	64	0	112	24	0	2	6	0	16	53	59	218	471	7	11	3	2	581	3	181	0	228	2	121	2	4.07	0.04	-9.14	0.03
Diachrysia chrysitis	59	35	18	39	111	143	103	45	9	118	16	113	19	61	89	59	0	9	0	13	1	8	0	11	0	-3.18	0.27	-6.42	0.52
Spilosoma lubricipeda	0	85	0	156	303	369	151	27	68	47	85	88	26	86	57	130	33	9	18	22	27	7	0	2	8	-5.88	0.21	-6.25	0.41
Melanchra pisi	0	0	0	3	8	65	46	18	12	3	7	19	2	171	44	24	0	0	0	0	0	0	0	0	0	-0.52	0.01	-6.12	0.25
Arctia caja	5	2	20	11	121	72	13	22	30	32	12	51	37	32	32	21	0	1	0	0	0	0	0	0	1	-1.66	0.19	-3.14	0.67
Lacanobia oleracea	13	25	0	37	38	226	22	13	3	7	5	27	25	73	34	28	0	14	3	14	0	40	30	1	2	-1.34	0.14	-2.01	0.17
Melanchra persicariae	0	0	1	25	27	132	9	16	0	2	1	26	35	15	21	19	0	9	34	29	15	0	0	1	2	-0.64	0.03	-2.00	0.35
Smerinthus ocellata	14	0	8	12	16	52	23	5	0	0	1	29	11	36	15	12	0	0	1	2	0	6	0	1	0	-0.65	0.13	-1.70	0.41
Macdunnoughia confusa	3	3	0	46	27	50	73	39	3	4	1	15	27	27	22	17	0	9	8	4	1	10	12	5	1	-0.90	0.12	-1.68	0.47
Mythimna turca	2	210	3	118	461	833	75	44	1	4	3	65	85	36	34	14	8	42	48	55	26	10	85	4	17	-8.61	0.12	-1.53	0.05
Abrostola triplasia	1	21	0	6	14	25	5	4	0	26	16	7	2	12	30	14	0	43	9	42	3	22	0	1	3	0.15	0.01	-0.77	0.04
Abrostola tripartita	1	16	2	32	8	11	3	7	9	20	22	9	16	11	3	5	0	0	0	1	6	3	3	5	2	-0.47	0.19	-0.59	0.24
Drymonia obliterata	0	0	0	2	0	0	3	6	0	1	1	13	1	7	4	13	0	114	5	301	19	1	0	1	26	2.37	0.08	1.19	0
Protodeltote pygarga	3	899	10	200	431	127	41	25	6	28	20	61	115	53	61	64	209	225	444	375	95	95	331	10	99	-2.12	0.01	5.07	0.02
Eilema depressa	2	0	24	0	0	1	0	0	2	0	1	1	0	1	99	35	0	79	20	38	0	31	1	315	1	3.78	0.18	8.1	0.13
Colocasia coryli	3	7	20	253	155	42	35	45	9	9	16	74	18	25	16	29	50	217	17	1034	52	142	0	105	69	5.96	0.05	10.12	0.02
Athetis furvula	0	1654	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	371	1	0	-10.82	0.06	10.31	0.15
Zanclognatha lunalis	5	986	2	51	8	0	2	0	6	4	1	1	2	0	1	1	0	108	268	171	30	17	433	21	92	-1.45	0	15.05	0.19
Earias vernana	0	87	0	7	2	0	0	0	0	1	0	0	0	0	1	2	0	0	18	0	21	0	546	0	0	4.04	0.07	15.1	0.15
Paracolax tristalis	48	2049	29	28	33	13	8	11	14	3	5	5	7	4	3	3	0	365	210	777	210	167	1594	342	277	9.1	0.02	67.41	0.35
Eilema sororcula	0	13	1	2923	5151	1	0	0	0	0	0	0	0	0	0	0	69	0	1352	0	414	1243	1860	24	184	-16.26	0.01	86.13	0.27

Table 15. Changes in frequency of various moths families in the last 50 years.

Families	1970	1970	1970	1970	1971	1971	1973	1973	1975	1976	1976	1977	1978	1979	1979	1980
Geometridae	2999	11723	1409	10538	5853	909	4513	7299	901	1749	1378	1013	1217	2853	2954	1669
Noctuidae	2192	5431	1169	7987	2009	1305	5897	7599	3301	6560	5872	3481	3077	1032	3560	1059
Lasiocampidae	37	15	115	269	65	21	211	393	126	206	81	94	45	42	43	54
Saturniidae	2	0	0	4	0	0	4	12	56	75	16	29	25	1	2	0
Sphingidae	16	5	38	182	2	0	218	161	237	570	205	142	81	15	202	12
Drepanidae	14	7	15	660	42	2	141	674	108	153	119	28	47	34	43	22
Notodontidae	51	321	64	1828	106	282	485	2160	319	598	278	99	191	50	233	22
Erebidae	579	7020	785	6150	1604	909	4845	12153	989	2864	3259	884	735	1501	1668	1498
Nolidae	6	158	153	1031	12	55	185	529	30	151	142	20	43	91	153	109
Thyatridae	13	545	18	543	29	103	92	502	18	109	151	57	40	66	26	62
Total	**5896**	**25228**	**3770**	**28830**	**9824**	**4828**	**16606**	**31002**	**6115**	**13104**	**11501**	**5847**	**5533**	**5693**	**8901**	**4511**

Families	1980	1981	1981	1986	1987	2000	2001	2014	2015	2016	2017	2018	2019	2019	2019	2020
Geometridae	1088	2552	1398	2573	1831	3924	2217	570	1073	838	693	1105	1021	525	3578	984
Noctuidae	2488	1065	1990	3605	4094	NA	NA	4619	2053	2587	2359	2862	5236	459	1972	1874
Lasiocampidae	35	42	47	221	55	364	471	18	6	34	60	104	160	3	31	96
Saturniidae	1	8	2	24	11	1	0	2	0	2	6	3	22	0	29	5
Sphingidae	87	10	95	215	85	288	353	78	73	169	193	164	213	2	18	103
Drepanidae	18	31	39	74	29	158	115	NA	NA	NA	NA	NA	NA	36	195	47
Notodontidae	85	35	92	376	96	102	77	197	153	182	134	184	166	36	284	144
Erebidae	1283	1709	1409	2415	1939	NA	NA	1313	3240	2527	1899	3552	2694	683	3355	1363
Nolidae	71	135	73	143	110	NA	NA	7	58	52	24	8	14	58	94	18
Thyatridae	25	235	31	76	39	53	38	NA	NA	NA	NA	NA	NA	46	205	36
Total	**5191**	**5839**	**5203**	**9786**	**8308**	**12732**	**11422**	**6914**	**6876**	**6450**	**5488**	**8121**	**9638**	**1842**	**9761**	**4675**

Families	2020	2020	2020	2020	2021	2021	2021	2021	2022	lin x coef 1970	r^2	lin x coef 2014	r^2	AVG	MD
Geometridae	2050	1047	1951	5336	1996	1386	3838	1056	2053	-79.7	0.15	113.94	0.22	1908	2301
Noctuidae	4842	1818	1127	3142	715	3219	7099	1664	1103	-45.45	0.08	-26.44	0	2633	3391
Lasiocampidae	110	56	49	84	34	49	100	23	52	-1.8	0.04	0.76	0.01	67	73
Saturniidae	27	13	28	60	18	5	3	10	5	NA	NA	NA	NA	16	3
Sphingidae	130	111	70	18	81	88	147	113	35	-0.54	0	-3.13	0.07	99	111,5
Drepanidae	69	52	106	152	208	93	43	53	36	-1.77	0.02	-2.35	0.02	91	42,5
Notodontidae	292	208	106	659	208	159	341	226	223	-8.64	0.06	8.06	0.11	225	255,5
Erebidae	6623	1271	2891	3486	1402	2928	5369	1423	1252	-17.86	0.01	16.73	0	2679	1552,5
Nolidae	335	77	195	142	129	35	708	36	56	-1.91	0.01	12.47	0.15	129	125,5
Thyatridae	133	85	113	262	59	33	165	58	104	-2.33	0.04	-0.74	0.01	108	64
Total	**14755**	**4757**	**6613**	**13341**	**4750**	**8123**	**17911**	**5676**	**5020**	**-156.7**	**0.08**	**146.83**	**0.04**	**9424**	**6876**

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Table 16. Changes in species richness of various moths families in the last 50 years.

family	1970	1970	1970	1970	1971	1971	1971	1973	1976	1977	1978	1979	1979	1980
Geometridae	114	107	147	176	120	68	143	139	105	120	124	126	134	109
Noctuidae	106	102	120	163	118	61	156	151	133	164	160	98	150	103
Lasiocampidae	6	3	7	13	5	2	11	13	9	10	10	9	9	8
Saturniidae	1	0	0	1	0	0	2	3	3	2	2	1	2	0
Sphingidae	2	1	5	10	2	0	11	10	9	11	9	6	10	5
Drepanidae	3	2	4	5	3	1	5	5	13	12	12	9	10	8
Notodontidae	11	11	10	25	9	14	24	20	24	25	25	9	21	9
Erebidae	37	33	39	57	42	24	54	54	49	47	44	47	52	49
Nolidae	3	8	5	8	4	2	7	7	5	5	4	5	6	5
Thyatiridae	4	4	5	6	4	2	6	6	7	6	7	4	6	3
Moths total	**287**	**271**	**342**	**464**	**307**	**174**	**419**	**405**	**356**	**401**	**396**	**309**	**393**	**294**

family	1980	1981	1981	1986	1987	2000	2001	2014	2015	2016	2017	2018	2019	2019
Geometridae	122	122	125	148	144	117	121	115	143	127	127	149	134	61
Noctuidae	136	96	132	163	165	NA	NA	73	75	72	79	91	89	36
Lasiocampidae	7	6	9	11	9	12	9	8	3	9	9	10	9	1
Saturniidae	1	1	2	4	1	1	0	1	0	1	2	2	2	0
Sphingidae	7	5	9	10	8	10	8	9	8	9	9	9	10	5
Drepanidae	10	8	11	12	15	5	5	7	11	7	9	10	10	1
Notodontidae	19	10	14	23	23	15	17	17	17	17	17	17	19	10
Erebidae	44	42	44	55	54	NA	NA	29	34	33	33	43	43	27
Nolidae	7	5	7	9	8	NA	NA	3	3	2	2	3	1	2
Thyatiridae	5	3	5	6	8	NA	NA	NA	NA	NA	NA	NA	NA	5
Moths total	**350**	**293**	**349**	**435**	**428**	**377**	**378**	**266**	**300**	**281**	**288**	**337**	**321**	**142**

family	2019	2020	2020	2021	2021	2021	2021	2022	lin x coef 1970	r^2	lin x coef 2014	r^2	AVG	MD
Geometridae	103	101	113	110	91	74	77	107	-0.89	0.15	-3.50	0.38	124	122
Noctuidae	108	86	113	89	153	128	125	95	-0.98	0.1	4.01	0.40	128	127
Lasiocampidae	7	7	9	7	8	4	3	6	-0.05	0.04	-0.16	0.07	8	9
Saturniidae	1	1	1	1	2	1	4	2	NA	NA	NA	NA	1	1
Sphingidae	2	6	6	4	9	9	8	3	0.04	0.01	-0.23	0.16	7	8
Drepanidae	5	3	5	3	5	2	4	3	-0.04	0.01	-0.50	0.50	7	5
Notodontidae	15	11	14	14	16	17	22	14	-0.02	0.00	-0.04	0.00	17	17
Erebidae	48	42	48	39	50	39	39	52	-0.06	0.01	1.08	0.40	45	47
Nolidae	10	10	9	11	5	7	2	6	0.01	0.00	0.35	0.21	5	5
Thyatiridae	4	5	5	4	5	4	5	4	NA	NA	NA	NA	5	6
Moths total	**304**	**268**	**324**	**277**	**344**	**285**	**289**	**295**	**-1.91**	**0.09**	**1.19**	**0.01**	**326**	**315**

Table 17. Invasive, expansive and introduced moths species in the last 50 years.

species	1970	1970	1970	1970	1973	1976	1977	1978	1979	1979	1980	1980	1981	1981	1986
Tarachidia candefacta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hyphantria cunea	4	1265	0	14	4	199	0	2	0	0	0	0	0	0	0
Antheraea yamamai	0	0	0	0	1	9	20	18	1	1	0	0	0	1	15
Helicoverpa armigera	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

species	1987	2019	2019	2020	2020	2020	2020	2020	2021	2021	2021	2021	2022	lin x coef f	r2
Tarachidia candefacta	0	0	0	0	0	0	17	0	0	0	51	2	0	1,31	0,08
Hyphantria cunea	2	1	0	0	2	0	8	0	0	0	43	0	0	-9,41	0,1
Antheraea yamamai	11	0	29	28	60	0	0	3	18	0	0	4	3	0,28	0,03
Helicoverpa armigera	0	0	63	36	18	13	360	5	7	38	1380	13	6	10,88	0,11

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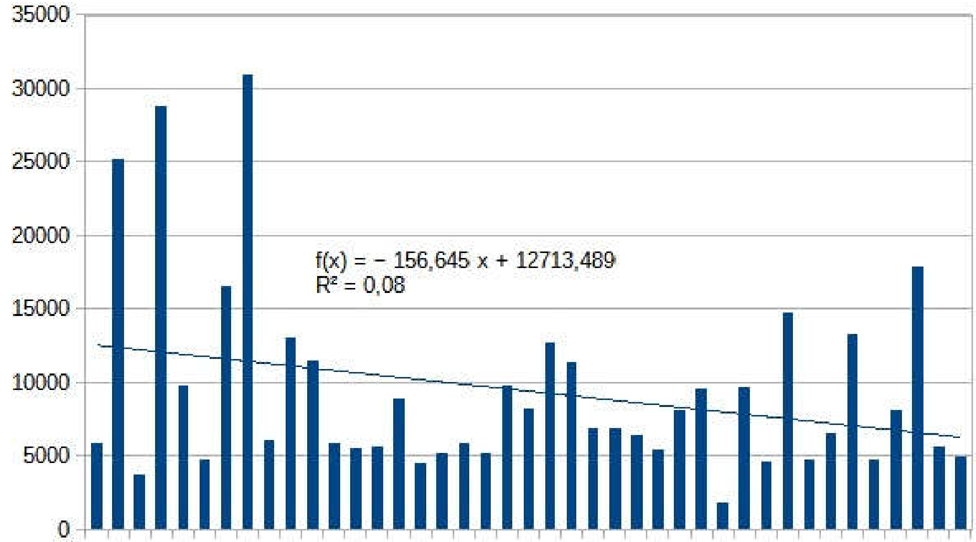

Figure 3. Changes of moth populations between 1970 and 2023 with trend line and equation (based on Table 15).

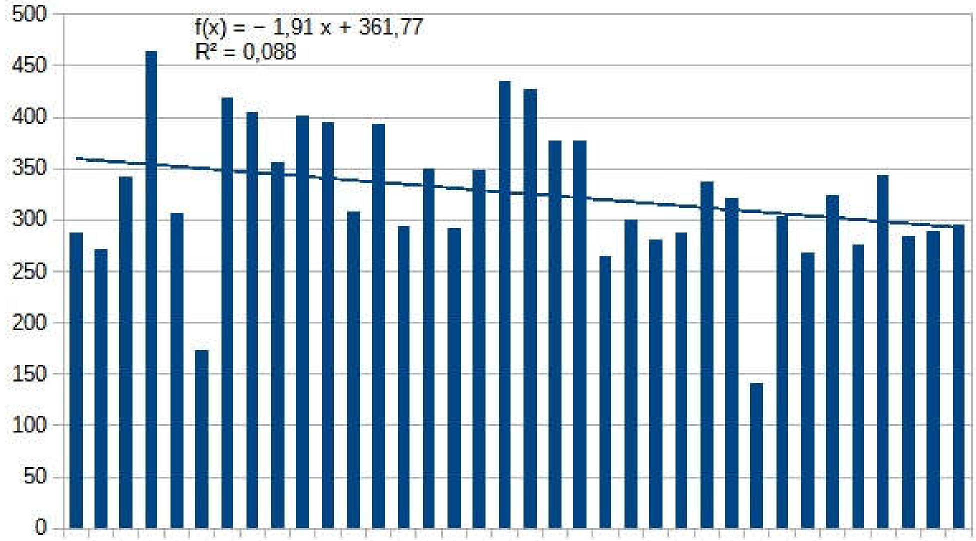

Figure 4. Changes of moth species richness 1970 and 2023 with trend line and equation (based on Table 16).

Our macrolepidoptera fauna is enriched by two imported species (Antheraea yamamai. Guérin-Méneville, 1861 and Tarachidia candefacta (Hübner, 1831)), one accidentally introduced species (Hyphantria cunea (Drury, 1773)) and one expansive species (Helicoverpa armigera (Hübner, 1808)). Hyphantria cunea (Drury, 1773) is very likely not a pollinator and this species has strong tendency to gradation, so its occasional erruptions (such as in the 70s) makes difficult to determine its population trend. Our data, show declining trend, which can easily be overwritten by a population eruption (gradation) at any time. The trend of the other 3 species shows slight increase (Table 17).

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Butterflies (Rhopalocera)

Scheme 60. but in some groups even up to 90% (compared to 1970s). The estimated relative changes in populations of some important butterflies are displayed in Table 18. Certain species, especially Aglais urticae (Linné, 1758), were once among the most common species, but for now, almost completely disappeared. Species of Pieridae, Lycaenidae, Nymphalidae and Hesperiidae show strong decrease either. Species of family Paplionidae seem to be stable. Population densities of some species tend to opposite direction. Increase of Iphiclides podalirius (Linnaeus, 1758) is the strongest. Our data in Table 18, indicate the expansion of Euphydryas aurinia Rottemburg, 1775 and Libythea celtis (Laicharting, 1782) either.

Recent re-investigation of the 40 years or even earlier researched areas were carried out in three regions: Dráva Plain (border region between Hungary and Croatia), Bátorliget Nature Reserve (NE Hungary, close to Ukraine) and the area around Simonfa town. Decline in species richness in these regions shows strong change. Compare data of Table 19 .

Table 18. Relative frequency of some butterfly species in the last 40 years.

species	1980	1984	1990	1991	1994	1997	1997	2007	2011	2011	2013	2013	2015	2016	2018	2018	2020
Nymphalidae																	
Vanessa atalanta	4	2	4	4	3	4	4	4	3	4	4	4	2	2	4	4	4
Inachis io	5	4	4	4	3	4	4	4	5	4	4	4	3		4	5	4
Vanessa cardui	4	3	4	3	4	4	3	4	4	4	3	3	3	3	4	5	3
Polygonia c-album	5	2	4	3	3	3	4	4	2	4	3	4	0	2	4	4	6
Arachina levana	5	5	4	5	5	4	5	4	3	4	0	4	4	3	5	5	2
Argynnis paphia	4	5	4	3	3	4	3	4	2	4	3	3	0	4	4	4	4
Issoria lathonia	4	4	4	4	3	3	2	4	3	3	2	3	0	2	3	5	4
Melitaea athalia	5	5	4	4	5	5	5	4	3	4	2	4	4	2	0	2	4
Nymphalis urticae	4	5	4	3	3	4	1	2	0	3	0	2	0	0	2	1	1
Euphydryas aurinia	0	0	2	0	0	3	0	3	0	2	0	0	0	0	0	0	0
Libythea celtis	1	0	0	0	0	2	0	0	0	0	0	0	2	0	4	4	4
Pararge aegeria	5	5	4	3	3	4	4	3	3	4	4	3	3	0	4	3	4
Maniola jurtina	5	5	5	5	4	5	5	4	5	4	3	3	5	5	4	4	4
Lasiommata megera	4	2	4	3	3	4	3	4	3	3	3	3	0	0	4	4	4
Neptis hylas	3	0	3	0	3	1	3	0	0	4	0	3	0	0	4	0	4
Pierodae																	
Colias hyale	5	5	5	2	3	4	2	3	3	2	0	0	0	3	4	3	4
Colias croceus	4	1	4	3	3	4	3	3	2	3	0	2	3	0	4	4	4
Anthocharis cardamines	5	4	4	3	4	3	4	4	3	4	0	3	3	0	4	4	4
Leptidea sinapis	5	4	4	4	5	3	5	4	4	4	0	3	3	0	4	4	4
Lycaenidae																	
Polyommatus icarus	5	5	5	4	4	4	5	4	5	4	3	5	4	4	4	4	4
Lycaena dispar rutilus	4	3	4	3	3	2	3	3	3	4	0	2	0	2	3	3	4
Lycaena phlaeas	4	4	4	3	3	3	3	2	4	0	3	3	3	0	3	3	4
Papilionidae																	
Iphicledes podalirius	2	2	3	2	3	2	4	4	3	4	3	3	2	2	4	4	2

Table 19. Changes of butterfly species richness in various regions after 40, 50 and 100 years.

family	Bátorliget 1950	Bátorliget 1990	Dráva-valley, 1966-74	Dráva-valley 2019-22	Simon-tornya 1914	Simon-tornya 2014
Nymphalidae	26	19	35	18	40	20
Lycaenidae	14	8	19	4	27	9
Papilionidae	2	2	4	3	3	4
Pieridae	11	5	10	5	10	12
Hesperiidae	8	6	10	2	11	6
Riodinidae	1	1	1	1	1	0
Total	**62**	**41**	**79**	**33**	**92**	**51**

4. Discussion

Symphyta

We have only small amount of literature data on the changes in population densities of sawflies. In the Pannonian biogeographic region, the decline in the diversity of certain localities and the number of individuals of the Nematinae group is logical, as this subfamily typically reaches its maximum diversity and number of individuals in Scandinavia and the north [70]. The decline of Tenthredo species is somewhat incomprehensible. Goulet [69], found the same trend in Canada. Goulet attributes the decline in Tenthredo species to the use of pesticides. However, the spread of beekeeping is also having an unfavorable effect on the this group [72].

To date, the negative effects of climate change on the Symphyta group have been studied in Andalusia [73]: "While some species were frequently found in the same areas as 50 years ago, climate changes affected the vertical displacement of other studied sawfly species to higher altitudes. The main results of this study showed that in the 21st century, four species (Megalodontes bucephalus, Macrophya militaris, Strongylogaster multifasciata, Dolerus (Poodolerus) puncticollis) were not observed in any location or sampling area, which means that these species (important specialized pollinators) have disappeared from the Andalusia region." This "vertical shift" can be observed in the higher areas of the Carpathian Basin either (Table 3). High altitudes, like surrounding mountains of the Carpathian Basin, help us to save the diversity of the sawfly fauna for a while longer.

Aculeata

Scientific papers don't discuss the change of Aculeata in total, however our results are supported by scientific publications on specific genera and species. These results are consistent with our experiences. Olszewski et al. [74] reported the increase of population density of Philanthus triangulum (Fabricius,1775) and Eickermann et al. [75] wrote about the increasing population of Polistes spp. in Europe. Similar tendencies are took place in North America either, as indicated by the proliferation of several Sphex species [76]. Also, in South America, from where, the northern expansion of Centris nigrescens Lepeletier, 1841 was reported in connection with global warming [77]. Zimmerman et al. [78] published their similar experiences about the gradual increase and expansion of wild bee populations in Eastern Austria: "Among the newly recorded species, Ceratina nigrolabiata, Icteranthidium laterale, Lithurgus chrysurus, L. cornutus, Osmia bidentata, O. spinulosa, Pseudapis diversipes, and its parasite Pasites maculatus currently expand their distribution from warmer, more southern and eastern regions to Austria, probably as a response to climatic warming". Data on the decline of Ectemnius and Crossocerus species are provided by Bogusch and Jakub, also Pearce-Higgins et al. [79,80]. Reasons for their decline, one is the general decline of saprophilic Hymenoptera due to the disappearance of old forests (energy crisis) and the climatic change: some of Ectemnius species are mesophile, and they are characteristic species of marshy meadows. Finally, these marshy meadow are threatened not only by the global warming but also by the non native Golden rod (Solidago spp.) expansion which kill the original vegetation.

Bumblebees (*Bombus* spp.)

Data of international scientific papers confirm the same that we experienced in the Pannonian Basin: slighter or similar decrease in the population densities and diversity was observed in many other European countries [88]. At the same time, in Western Europe, originally common species (e.g., B. lapidarius, B. pascuorum, B. terrestris) became rare [89]. In England, this decline was so strong in the 1980s that only six bumblebee species were collected in those regions where 19 species had been captured before 1960 [90].

According to Plowright et al. [91]: between 1977 and 1994, Bombus muscorum (Linné,1758) disappeared from many habitats in northern England and they were replaced by B. pascuorum. Our observation may confirm this conclusion, although, in our region, the Mediterranean B. haematurus has more significant role in replacing other bumblebee species. Regarding Bombus terrestis, B.

hortorum, B. lapidarius, B. pascuorum, B. haematurus, B. ruderarius and B. argillaceus our long term data confirm the results of Jakab et. al. [92]. Our data from period of 2000 – 2003 are well in line with the results of Sárospataki et. al. [93], According to this paper: '36% of the bumblebee fauna can be considered rare and 24% moderately rare, i.e., over half of the total number of species can be classified into these two categories. Almost half (47%) of the species still living in the Pannonian biogeographic region of the Carpathian Basin, showing decreasing trend starting from the 1950s and 1960s'. However, montaneous regions of Western Carpathians situated north of Pannonicum (Carpaticum occidentale and Carpaticum orientale), could show different trends. Bumble bee communities of Outer and Inner Western Carpathians are apparently still rich in diversity and relative abundance. Rare and infrequent species, such as e.g., Bombus distinguendus, B. subterraneus, B. pomorum, B. confusus, B. veteranus, B. quadricolor and B. norvegicus are still present in this area [96–98]. Moreover, sub recently, a new species, Bombus semenoviellus. Skorikov, 1910, appeared in our region [95]. For the more precise knowledge on status of the bumble bee fauna of the Pannonian basin, we would strongly advice to continue in systematic and frequent monitoring of all members of bumble bee fauna in the entire area of interest.

Diptera

We have limited information available from the scientific papers therefore our research brings original and new results. Available literature published in the neighboring regions agrees that certain groups, especially hoverflies, suffer significant decline in numbers of individuals similar to our results [107]. According to an IUCN study [108]: "Hoverflies generally ensure better pollination than bees at higher altitudes, under Nordic climatic conditions, or in cool microclimate or weather situations.". Sommagio et al., [109] in addition to the catastrophic decline in number of hoverflies, mention that mountainous regions are able to provide shelter for them, but this is not true for bumble bees: "The two taxa show different distribution patterns: hoverflies have a unimodal distribution (richness and abundance) with peak at middle altitude (1500 m), while bees have a monotonic decline (richness and abundance) with increasing altitude."

The experienced increase of populations of horse-flies is explained by their need for warmth. Herczeg et al. [110] did not manage to collect even a single Tabanid specimen below 18 °C. At the same time, they note that variability in moisture requirements per species is high, which explains the often opposite trends in populations of various species, similar to our experiences. Also interesting the opposite trend of 2 similar and closely related large horse-fly species, namely Tabanus bromius Linné, 1758 and Tabanus bovinus Linné, 1758 (Table 9). Probably there is niche competition between these 2 species as Dörge et al. [111] write:"Tabanus bovinus and T. bromius have similarly large niches which are mostly overlapping." In case of Tachinids, climatic factors have strong, but indirect and very diverse effect. The most important effect is the optimization of the synchronicity between the presence of host and the parasitoid's egg-laying time: an optimally developed host animal larva should be available at the time of reproduction. Climatic conditions can improve this, but it can also shift it in an unfavorable direction [112], which could also be the reason of the fluctuation shown in Tables 11 and 12. For Bombyliidae, Boesi et al., [113] provide good explanation for their increased reproduction:"Bee flies (Diptera: Bombyliidae) have a virtually cosmopolitan distribution and are commonly found in warm arid to semi-arid habitats, where they can form a conspicuous part of the flower-visiting insect fauna [113].

Lepidoptera

Nocturnal macrolepidoptera

Only 3 papers study and discuss temporal changes of various moths species during the last 3-4 decades. Far the most important comparative study available is the PhD. thesis of Fox [114]. Fox investigated changes of about 600 moth species between 1970 and 2010. Our trend for many species is opposite to the tendencies set in Great Britain by Fox. These are Phragmatobia fuliginosa (Linnaeus, 1758), Xestia c-nigrum (Linnaeus, 1758), Eilema lurideola (Zincken, 1817), Spilosoma lubricipeda

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(Linnaeus, 1758), Lacanobia oleracea (Linnaeus, 1758) and Mythimna turca (Linnaeus, 1761) (Table 14). Their decrease in the south and their expansion in the north may indicate that they find better living conditions in the northern and humid Atlantic areas due to the gradually warming climatic conditions in their original habitats. Major proportion of the declined or rare species from the South (including the Carpathian Basin) are usually mesophile, silvicol species. Their typical habitats are meadows, swamps, tall sedges, mesophile forests, groves, and alder forests. The opposite movement can be observed at warm-loving species: their populations in England declined, while in the Carpathian Basin, according to our data, their individual density increased, for instance Paracolax tristalis (Fabricius, 1794). Other xerotolerant, warm-loving species, like Macdunnoughia confusa (Stephens, 1850), Drymonia obliterata (Esper, 1785), Athetis furvula (Hübner, 1808), Zanclognatha lunalis (Scopoli, 1763) and Earias vernana (Fabricius, 1787).are not on the British list, since they are Mediterranean species. These species expand their territories and population densities in the Carpathian Basin These are eurytherm and/or polyphagous species, adapted better to more extreme conditions. Those species which prefer cold and moisture ecosystems are strongly declined like Diachrysia and Abrostola species (Table 14).

Otherpapers, like Conrad et. al., [115] treating 337 species from Britain and Mikkola's work [116] discussing 54 species from Finnland, howver those species which are discussed in these monographs are hardly overlap the fauna of the Carpathian Basin, therefore we don't discuss these works in details.

The reasons behind the above described trends can be traced back to many influencing factors that act in very complex way: global warming, frequent extreme temperature maximums, changed temporal distribution of precipitation: droughts, torrential rains, improper forest management, degradation of habitats, large-scale clear-cutting that affect microclimate, intensive lawn management, fertilization of lawns, incorrect selection of lawn-mowing dates. groundwater depletion, underground piping etc. Internal factors also may influence population densities: just an example: according to Hill et.al .[117], Xestia c-nigrum (Linné, 1758) can produce a so called heat shock protein, Hsp70: "Another molecular marker that is likely to be important in the response to climate change is the heat shock protein (Hsp70). Hsp70 genes play a critical role in helping insects survive exposure to extreme temperatures by increasing heat tolerance". In this aspect, Xestia c-nigrum population shall increase, however: "We found that grazing and mowing/fertilization (in Germany) had largely opposing effects on the moth assemblages: species characteristic for meadows such as Agriphila straminella, Agriphila tristella and Crambus perellus declined under more intense livestock grazing and were replaced by other species such as Anerastia lotella, Mythimna pallens and Xestia c-nigrum" [118]. In our region, livestock grazing has declined and the trend is opposite than in Germany. Finally, there is still an open discussion, which moths, or even which insects are pollinators [119]. We may say, pollinators are those moths (and even those animals), which have at least minimal parts of their life-cycle is temporarily or regularly connected to flowers and in this way, they transport pollen, helping the fertilization of plants. These insects could be predators: hunting for their prey on flowers, insects attracted to various colors and wavelengths emitted by flowers, insects attracted to various odors and pheromone-like chemicals of flowers, or attracted to special appearance of flowers, animals feeding on nectar or consuming various parts of flowers, or those which find temporary shelter or place for warming up themselves on the surfaces of flowers etc.

Butterflies (Rhopalocera)

Population increase of Euphydryas aurinia is described by Dietzel, Ábrahám and Ács et al. [48,54,56]. Euphydryas aurinia has two ecotypes. Wet meadow ecotype has been drastically decreased, while the dry meadow ecotype has been spreading since the 90s. Other results confirm the expansion of Libythea celtis (Laicharting, 1782) [56,120]. Libythea celtis is a migratory species, reaches the Carpathian Basin from South. Its population is increasing step by step as a result of global warming. Also, its food plant (Celtis occidentalis) is planting in parks and also in forests. Bury et al., [121] observed the population increase of Iphiclides podalirius (Linné, 1758) in Poland, the same that we experienced in the Carpathian basin (Table 18). Its gradual population increase caused by the expansion of blackthorn (Prunus spinosa) in the abandoned areas. Neptis hylas (Linné, 1758) was frequent in Southern and Western Transdanubia only. In recent years, it has appeared in areas where it hasn't bred before. Fuirthermore this species started to feed on locust tree (Robinia pseudoacacia). Till recently, only Lathyrus spp. were its host-plants [56,120]. Decline of populations of other rare butterfly species like Nymphalis antiopa. (Linné, 1758), Apatura and Maculinea spp. is rather a nature conservation problem.

In terms of population-densities of butterflies, Hill et al., [117] came to a similar conclusion:: "In most cases, oligo- or polyphagous species (diet generalists) have an advantage because they have a wider breadth of host plants, allowing for easy colonization of new sites during range expansion. By contrast, diet and habitat specialists typically have poor dispersal ability and may not be able to track environmental changes when suitable habitat patches are reduced and fragmented, resulting in local extinctions and range declines.".

5. Conclusions

Our results support the conclusion of Dicks et al. [5] "Europe was the region where human well-being was considered at the lowest risk from pollinator declines overall (mean risk score = 19.6), with no 'high' risks, and only two 'serious' risks (pollination deficit and wild pollinator diversity)."

Beyond the above mentioned pollinator decline, most important is the gradual transition of our Continental type pollinator towards Mediterranean type.

Population densities of warm-loving and drought-tolerant species, and species groups are increasing, while those of northern, silvicole species are declining.

Butterflies (Rhopalocera), hoverflies (Syrphidae), tachinids (Tachinidae), Symphyta and bumblebees (Bombus spp.) suffered decline in the last 2 decades. Meanwhile, population densities of Aculeata, Bombyylidae, Tabanidae are increasing.

High altitudes may provide shelter and help to keep diversity for some moisture-loving group. We provided evidence for this at sawflies (Table 3). Probably it is true for other pollinator groups which prefer moderate climatic and moisture conditions.

Decline of bumblebees started around 2015, Syrphidae around 2000, Tachinidae around 1995 and butterflies around 2000 (the latest is indicated by disappearance of the so far common Aglais urticae).

The influx of Mediterranean species into the Carpathian Basin was the strongest at Aculeata. Introduced species also enriched local pollinator fauna, especially in Aculeata and Lepidoptera (in Symphyta only 1 species are introduced recently).

The Mediterranean transformation of our pollinator fauna is a response to the gradual aridification of the Carpathian Basin [122] .

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