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CHANGES IN THE COMPLEX OF PHYLLOPHAGOUS LEPIDOPTERA (INSECTA) IN DECIDUOUS TREES OF KHARKIV CITY FOR 50 YEARS

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Abstract

The aim of this work is to compare the species composition of phyllophagous Lepidoptera in deciduous trees of Kharkiv city as of the 1960s and 2017-2020, as well as the distribution of insect species by lifestyle, by the size of individuals, and by the ability to mass propagation. The greatest increase in the number of genera and species was noted in the families Gracillariidae, Tortricidae, and Geometridae, and a decrease in the families Notodontidae and Erebidae. Gracillariidae has been replenished due to 4 alien species: *Cameraria ohridella*, *Macrosaccus robiniella*, *Parectopa robiniella*, and *Phyllonorycter issikii*. Open-living species predominate in both assessments, however, at the second assessment, the number of species with semi-hidden and hidden life-styles increased as well as the number of middle-size and small-size species. The eruptive species from the first assessment became rarer, and alien species more often.

Key words: Lepidoptera, urban deciduous trees, lifestyle, size rank, type of population dynamics

INTRODUCTION

Urban entomofauna was formed first at the expense of the surrounding forests and gardens (Klausnitzer 1987). Later it enriched at the expense of species introduced with plant material, including alien ones, some of which turned out to be invasive, for example, *Cameraria ohridella* Deschka & Dimic, 1986 (Lepidoptera: Gracillariidae) (Kollár 2014, Branco et al. 2019, Frank and Just 2020). As cities developed, environmental conditions began to differ more and more sharply from the surrounding forests or gardens. In particular, in cities, the composition of woody plants is richer, the air temperature is higher, the soil is denser, the air and soil are polluted by industrial and household pollutants (Brown, 2018). This is reflected in the phenology, the health condition of the trees and their resistance to insect damage, as well as the phenology and vitality of the insects (Kirichenko et al. 2018). In recent decades, there has been intense climate change and an increase in anthropogenic load on a global scale (Brown 2018). The health condition of forests in a large area is deteriorating, the area of foci of pests and diseases is increasing (Meshkova 2009). At the same time, outbreaks of once classic defoliators (from the genera *Lymantria*, *Notodonta*, and *Malacosoma*) have become rare in forest stands, but information has appeared about mass propagation of leaf beetles (Coleoptera: Chrysomellidae) (Meshkova et al. 2016, Sokolova 2019), leaf-miners (Lepidoptera: Gracillariidae) (Ermolaev 2014, Akulov et al. 2018, Shvydenko et al. 2020), aphids (Hemiptera: Aphidoidea) and mites (Acari: Eriophyidae) (Brown 2018). In contrast to forest insects, data on the dynamics of the species composition and abundance of urban insects are discrete, often obtained by different researchers at the study of the species composition, individual taxonomic groups, spatial structure, and trophic relationships (Belova and Belov 2004, Tarasova et al. 2004, Prokopovich and Kaplich 2009, Bălăcenoiu et al. 2020, Fedyay et al. 2018, Fedyay and Markina 2020).

In the 1960s, Yu.P. Maksimova studied the entomofauna of green stands in Kharkiv, which included different orders of insects with different lifestyle (Maksimova 1965). In the forest stands of the Kharkiv region, the biology and dynamics of the number of foliage-browsing insects capable of forming outbreaks of mass propagation have been deeply studied (Meshkova and Gamajunova 2000, Meshkova 2009). In 2007-2012 in Kharkiv, alien leaf-miners (Lepidoptera: Gracillariidae) (Meshkova and Mikulina 2012), as well as phyllophages from other taxonomic groups, in particular (Hymenoptera: Tenthredinidae) (Meshkova et al. 2017) and (Coleoptera: Chrysomelidae) (Meshkova et al. 2016, 2018, Sokolova 2019) were studied. In 2017–2020 regular surveys of the street, park, and forest-park stands in Kharkiv have begun, in which 159 species of phyllophagous insects from six orders with different lifestyles have been found (Kardash and Sokolova 2020, Shvydenko et al. 2020, Sokolova et al. 2020).

The aim of this work is to compare the species composition of phyllophagous Lepidoptera in deciduous trees of Kharkiv city as of the 1960s and 2017-2020, as well as the distribution of insect species by lifestyle, by the size of individuals, and by the ability to mass propagation.

MATERIAL AND METHODS

The analyzed lists of insects were compiled during the survey of forest parks, parks, and street plantings in Kharkiv, which is located in the northeastern part of Ukraine on the border of the forest-steppe and steppe (50º00 ‘N, 36º10’ E). In the first assessment period (the 1960s), studies were carried out by Maksimova (1965), in the second (2017–2020) with participation of author: Kardash and Sokolova (2020), Shvydenko et al. (2020), Sokolova et al. (2020).

Nomenclature of taxa was aligned to current status (Karsholt and Nieukerken 2013, Sinev 2019).

Insect distribution according to the degree of dominance was estimated by calculating the proportion of each genus or species in individual families from the total number of genera or species in the list of each assessment period. The calculated percentages were distributed according to the W. Tischler scale (Tishler 1965): eudominant – > = 10 %, dominant – 5–9.99 %, subdominant – 2–4,99 %, recedent – 1–1.99 %, subrecedent <1 %.

According to lifestyle, Lepidoptera species were divided into open-living, semi-hidden-living and hidden-living ones (Tarasova et al. 2004). Open-living insects at the caterpillar stage skeletonize or gnaw leaves. Hidden-living insects (leaf-miners) feed in the middle of leaf tissues. Semi-hidden-living insects most of the life cycle are found in shelters like folded, glued, cobwebbed leaves.

Considering that the size of caterpillars is usually proportional to the wingspan of an adult, all detected species were divided into 3 groups by wingspan: large (over 40 mm), middle (21–40 mm) and small (below 20 mm).

Lepidoptera species were classified into indifferent, prodromal and eruptive according to their ability to mass propagation. In accordance with the classification of Isaev et al. (2015), the abundance of indifferent species in the long-term dynamics slightly deviates from the background values. The prodromal and eruptive species are capable of a multiple increase in abundance, which varies in prodromal species near the lower stationary state, while in eruptive species it can remain at the level of the upper stationary state of the phase portrait for several generations without losing the ability to regulate the population size.

Statistical analysis of the data obtained was performed by employing the mean ± standard error of the mean. All variables were tested for normal distribution using the Shapiro-Wilk test ($p > 0.05$). The lists of species were compared using the nonparametric Kruskal-Wallis test and chi2 test (Atramentova and Utevskaya 2008). The statistical significance was tested at $p=0.05$. The similarity in the insect composition of two assessments was also evaluated by Sorensen similarity coefficient (C_{sc}) (Leontyev 2007). Microsoft Excel software and statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer et al. 2001) were used.

RESULTS AND DISCUSSION

The list of the 1960s assessment is represented by 20 families, 48 genera and 63 species of Lepidoptera, and the list 2017–2020 by 11 families, 48 genera and 82 species (Table 1).

Differences in species composition are significant ($Chi^2 = 38.92$; $df = 20$; $p = 0.0068$). The similarity in the composition of the lists decreases from families to species (C_{sc} = 1.82, 0.78, and 0.42 respectively).

Table 1

Number of Lepidoptera genera and species in two periods of assessment

Families	1960s		2017–2020	
	Genera	Species	Genera	Species
Nepticulidae	1	5	1	5
Bucculatricidae	1	1	1	1
Tischeriidae	1	1	1	1
Gracillariidae	3	6	6	13
Yponomeutidae	1	3	–	–
Ypsolophidae	1	2	–	–
Lyonetiidae	1	1	–	–
Coleophoridae	1	1	–	–
Gelechiidae	2	2	–	–
Tortricidae	5	7	11	28
Papilionidae	1	1	–	–
Nymphalidae	2	2	–	–
Pieridae	1	1	–	–
Pyralidae	1	2	1	1
Lasiocampidae	1	1	1	1
Sphingidae	3	3	–	–
Geometridae	6	**7**	14	20
Notodontidae	5	5	3	3
Erebidae	10	11	8	8
Nolidae	–	–	1	1
Limacodidae	1	1	–	–
Total	48	63	48	82

There are 10 common families, and all of them are found in the list of the 1960s. Only one family Nolidae is on the list of 2017–2020. The greatest increase in the number of genera and species was noted in Gracillariidae, Tortricidae, and Geometridae, and a decrease in the number of genera and species was noted in the families Notodontidae and Erebidae (Table 1).

In terms of genera participation in the entomofauna, subdominants predominated; the number of families with the presence of eudominant genera decreased over 50 years from 14 to 6 (from 70 to 54.5 %) (Fig. 1).

Dominant genera in the compared samples were represented in 2 and 1 families, eudominants - in 4 families in each period, but their composition was different. In both lists, eudominants were found in the families Tortricidae, Geometridae, and Erebidae. In the list of 1960s, eudominants present in the Notodontidae family, which became dominants in the second assessment period. The Gracillariidae were eudominants by genera in the second list and were dominants in the first list.

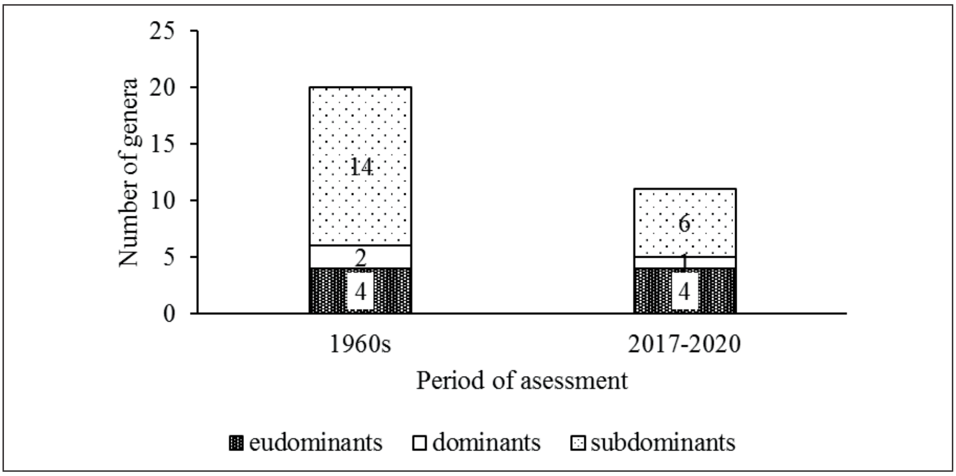

Fig. 1. Number of Lepidoptera genera with different dominance in two periods of assessment

In terms of species participation in both periods, the number of eudominant families was the same (3 each), but their proportion in the lists differed, amounting to 15 and 27.3 %, respectively (Fig. 2). These are the same families (Tortricidae, Geometridae, and Erebidae) that were present in the list of genera for the first period. The first two families remained eudominants in the second period of assessment, and Erebidae became dominants. The third eudominant family in the second period was Gracillariidae.

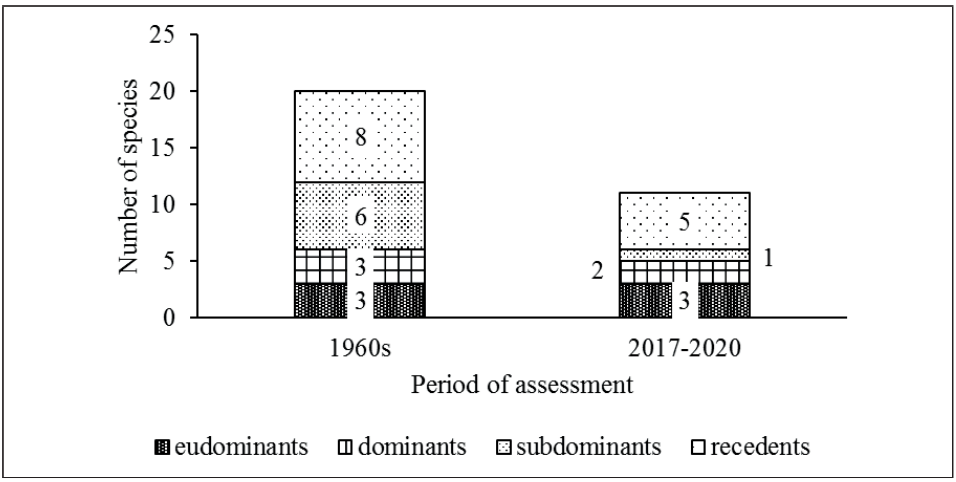

Fig. 2. Number of Lepidoptera species with different dominance in two periods of assessment

The families of Nepticulidae, Gracillariidae, and Notodontidae were the dominants in the number of Lepidoptera species in the first period of assessment, and in the second period of assessment, Gracillariidae moved to the rank of eudominants, and Notodontidae to the rank of subdominants. Of the six subdominant families of the first period of assessment (Yponomeutidae, Ypsolophidae, Gelechiidae, Nymphalidae, Pyralidae, and Sphingidae), in the second period, five families were absent in the list, and Pyralidae species became the recedents.

Of the eight families of recedents of the first period of assessment (Bucculatricidae, Tischeriidae, Lyonetiidae, Coleophoridae, Papilionidae, Pieridae, Lasiocampidae, Limacodidae), only three retained the status in the second period of assessment (Bucculatricidae, Tischeriidae, and Lasiocampidae).

The ranking showed that five families account for 60.4 and 87.5% of Lepidoptera genera detected in the first and second periods of assessment, respectively (Fig. 3). At the same time, a significant increase in the number of genera in the second period of assessment was noted for Geometridae ($t = 2.05$; $t_{0.05}=1.99$). The increase in the number of genera of Tortricidae ($t=1.67$; $t_{0.05}=1.99$) and Gracillariidae ($t=1.06$; $t_{0.05}=1.99$), as well as the decrease in respective numbers of Erebidae and Notodontidae is not proved statistically.

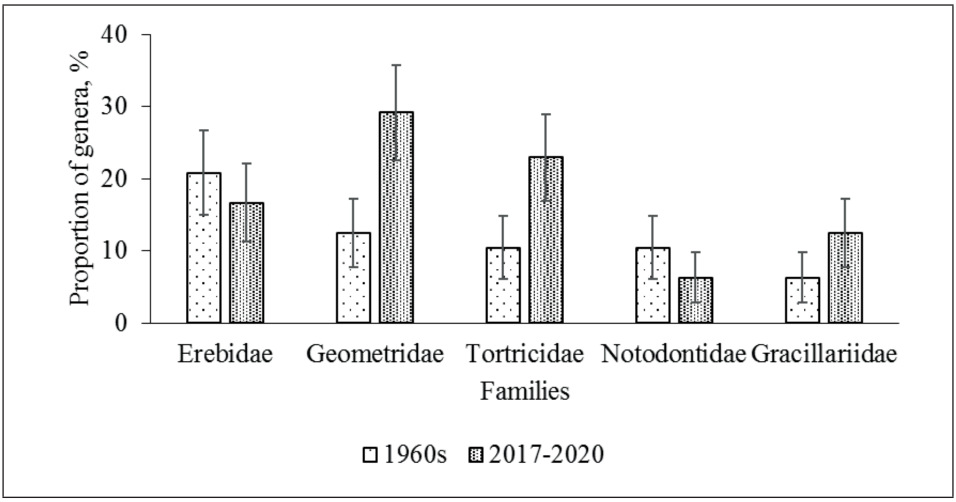

Fig. 3. The proportion of genera in the most represented families of Lepidoptera in two periods of assessment (bars – standard error)

One-way ANOVA Kruskal-Wallis test (H χ^2(df 1) = 3.65; p = 0.04) proves the differences in species composition of Lepidoptera in two periods of assessment.

Species of 6 families (Erebidae, Tortricidae, Geometridae, Gracillariidae, Nepticulidae, Notodontidae) accounted for 65.1 and 93.9 % of Lepidoptera species found in the first and second periods of assessment, respectively (Fig. 4).

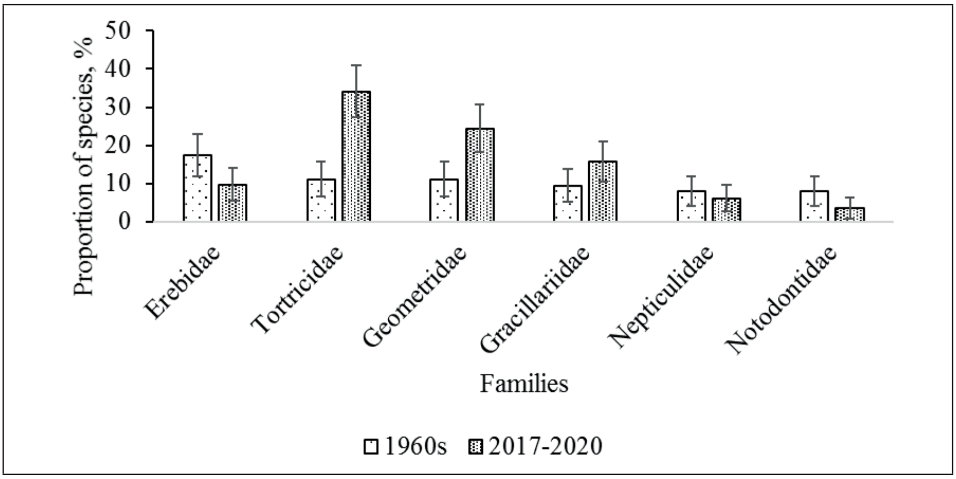

Fig. 4. The proportion of species in the most represented families of Lepidoptera in two periods of assessment (bars – standard error)

At the same time, a significant increase in the number of species in the second period of assessment was proved for Tortricidae ($t=2.81$; $t_{0.05}=1.99$). However, a noticeable increase in the number of Geometridae species was insignificant.

The increase in Tortricidae and Geometridae species number may be related to the cessation of insecticide use in surrounding deciduous forests in the past 30 years (Meshkova 2009).

The species composition of Gracillariidae has been replenished in comparison with the first assessment due to 4 alien species: *Cameraria ohridella* Deschka & Dimic, 1986, *Macrosaccus robiniella* (Clemens, 1859), *Parectopa robiniella* Clemens, 1863, and *Phyllonorycter issikii* (Kumata, 1963).

When analyzing the distribution of the detected Lepidoptera species in three groups depending on the lifestyle, it turned out that open-living species predominate in both lists of assessments (Fig. 5).

At the same time, in the first list, the number of open-living species is more than twice that of semi-hidden and hidden ones. In the second list, the number of open-living species has remained unchanged (although their composition has changed), the number of semi-hidden species has almost doubled, and the number of hidden ones increased by almost a third. These changes were confirmed statistically ($Chi^2 = 7.54$; $df = 2$; $p = 0.023$).

Large-size and small-size species (27 and 31 species or 42.9 and 49.2% respectively) are represented almost equally in the list of the first assessment (Fig. 6). In the list of the second assessment, the number of large-size species has significantly decreased ($t = 2.70$; $t_{0.05} = 2.36$), while the number of middle-size and small-size species has increased. As a result, small-sized species (49 species, or 59.8%) prevail in the list of the second assessment period, middle-size and large-size species are represented by 15 and 18 species with proportions 18.3 and 22.0 % respectively. These changes were confirmed statistically (Chi^2=28,77; df=2; 5,668E-07)

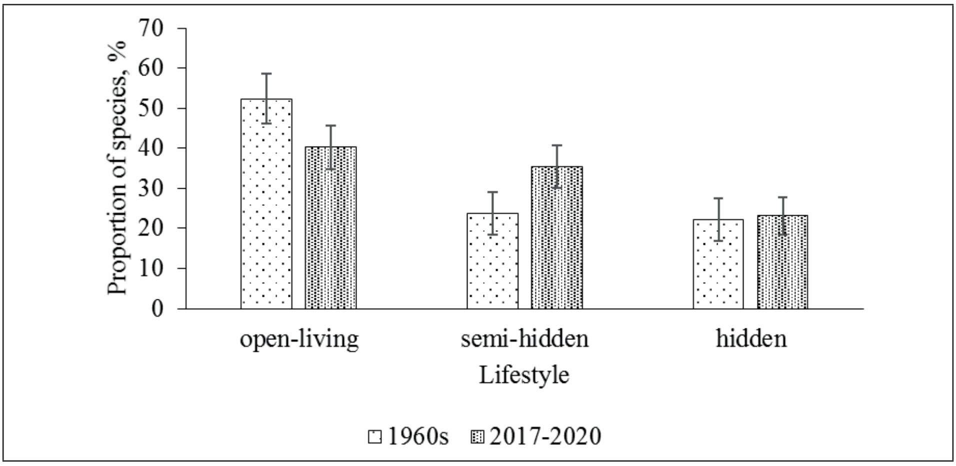

Fig. 5. The proportion of Lepidoptera species with different lifestyle in two periods of assessment (bars – standard error)

Smaller insects are more likely to survive when there is a lack of food and unfavorable environmental conditions. The increase in the number of small-sized insect species is accompanied by an increase in the number of species with a semi-hidden and hidden mode of life.

Of the Lepidoptera species found in the 1960s, the majority (38 species, or 55.6 %) are indifferent, while prodromal and eruptive species account for 13 and 15 species, or 20.6 and 23.8 % (Fig. 7). According to the 2017–2020 assessment data, the number of indifferent species significantly decreased to 28 and amounted to 34.1% ($t = 2.62$; $t_{0.05} = 2.31$).

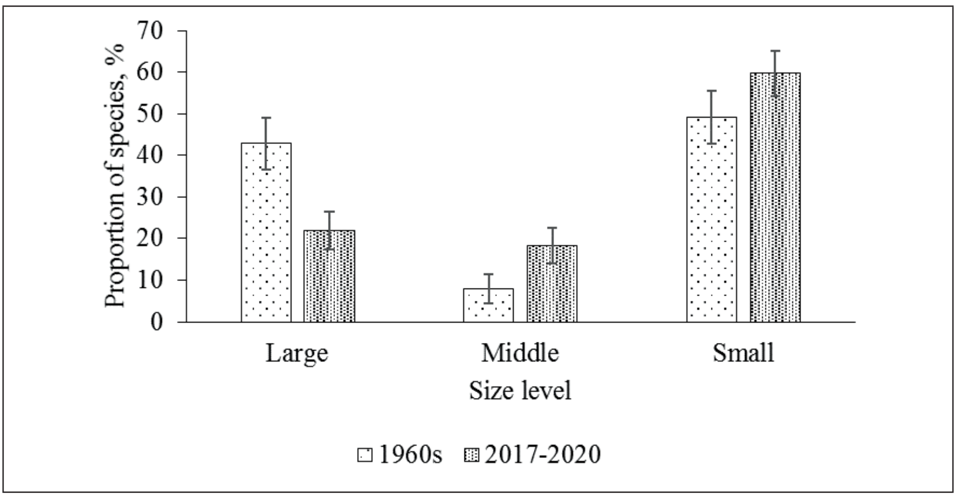

Fig. 6. Proportion of Lepidoptera species with different size level in two periods of assessment (bars – standard error)

The number of prodromal species increased almost 3 times (t = 3.43; $t_{0.02}$ = 3.00). The number of eruptive species remained almost unchanged, and the decrease in their proportion is statistically insignificant (t = 0.62; t0.1 = 1.94). At the same time, the changes in the distribution of species by type of population dynamics were confirmed statistically (Chi^2 = 27.64; df = 2; $9.93E^{-07}$): indifferent species prevailed in the first assessment period, and prodromal ones in the second assessment period.
In the first period, the eruptive species included the semi-hidden Tortricidae, mainly *Tortrix viridana* Linnaeus, 1758, and other species of this family – *Archips rosana* (Linnaeus, 1758), *Archips crataegana* (Hübner, 1799), *Archips xylosteana* (Linnaeus, 1758). The so-called early spring complex of defoliators also included species of the Notodontidae – *Phalera bucephala* (Linnaeus, 1758), *Dicranura ulmi* (Denis & Schiffermüller, 1775), Geometridae – *Lycia hirtaria* (Clerck, 1759), *Biston betularia* (Linnaeistus, 1758), *Biston strataria* (Hufnagel, 1767), *Operophtera brumata* (Linnaeus, 1758), *Ennomos alniaria* (Linnaeus, 1758), Lasiocampidae – *Malacosoma (Clisiocampa) neustria* (Linnaeus, 1758), Erebidae (then still Lymantriidae) – *Euproctis (Euproctis) chrysorrhoea* (Linnaeus, 1758), *Lymantria dispar* (Linnaeus, 1758), *Leucoma salicis* (Linnaeus, 1758).

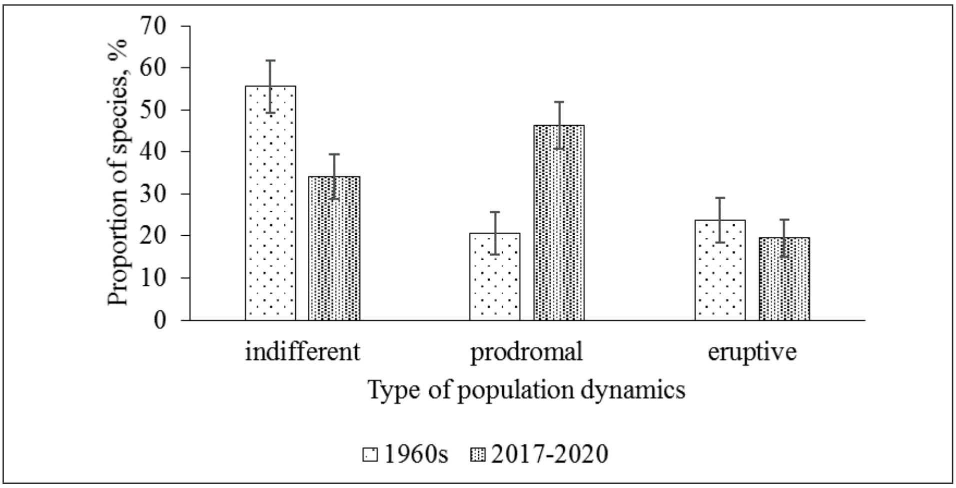

Fig. 7. Proportion of Lepidoptera species with different type of population dynamics in two periods of assessment (bars – standard error)

In the list of species of the second period of assessment, almost all eruptive species from the list of the first period are present, although the outbreaks of these species have been observed quite rarely in recent years. At the same time, the list was supplemented by the open-living alien species *Hyphantria cunea* (Drury, 1773) (Erebidae) and several hidden species of Gracillariidae, capable of significantly increasing the number and causing noticeable damage to tree leaves. Unlike the polyphage *Hyphantria cunea*, the named miners are confined to plants of a certain genus. For example, *Acrocercops brongniardella* (Fabricius, 1798) feeds the *Quercus* L. foliage, *Cameraria ohridella* on the foliage of *Aesculus* L., *Phyllonorycter issikii* (Kumata, 1963) on *Tilia* L., *Phyllonorycter populifoliella* (Treitschke, 1833) on the foliage of *Populus* L. Outbreaks of these species are known in different parts of their new ranges (Ermolaev 2014, Kollár 2014, Bălăcenoiu et al. 2020). During the years of our research in the green spaces of Kharkiv, *Cameraria ohridella* is permanently present in high numbers (Shvydenko et al. 2020).

CONCLUSIONS

In the deciduous trees of Kharkiv, 20 families, 48 genera, and 63 species of Lepidoptera were found in the 1960s, and 11 families, 48 genera, and 82 species in 2017–2020. The similarity in the two lists decreases from families to species. The greatest increase in the number of genera and species was noted in the families Gracillariidae, Tortricidae, and Geometridae, and a decrease in the families Notodontidae and Erebidae.

Five families (Erebidae, Tortricidae, Geometridae, Gracillariidae, Notodontidae) account for 60.4 and 87.5% of Lepidoptera genera detected in the first and second assessment, respectively. A significant increase in the number of genera in the second assessment was noted for Geometridae, the trend of increase for Tortricidae and Gracillariidae, and the trend to decrease for Erebidae and Notodontidae.

Species of 6 families (Erebidae, Tortricidae, Geometridae, Gracillariidae, Nepticulidae, Notodontidae) accounted for 65.1 and 93.9 % of Lepidoptera species found in the first and second assessment, respectively. At the same time, a significant increase in the number of species in the second assessment was proved only for Tortricidae.

The species composition of Gracillariidae has been replenished due to 4 alien species: *Cameraria ohridella*, *Macrosaccus robiniella*, *Parectopa robiniella*, and *Phyllonorycter issikii*.

Open-living species predominate in both lists of assessments, however, at the second assessment, the number of semi-hidden species has almost doubled, and the number of hidden ones increased by almost a third.

In the list of the second assessment, the number of large-size species has significantly decreased, while the number of middle-size and small-size species has increased.

Indifferent species prevailed in the first assessment and prodromal ones in the second assessment. In the list of species of the second period, almost all eruptive species from the list of the first period are present, although their outbreaks have been observed quite rarely in recent years. The list of eruptive insects was supplemented by the open-living alien polyphagous species *Hyphantria cunea* (Erebidae) and several hidden monophagous species of Gracillariidae, (*Acrocercops brongniardella*, *Cameraria ohridella*, *Phyllonorycter issikii*, and *Phyllonorycter populifoliella*).

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ZMIANY W KOMPLEKSIE MOTYLI FILOFAGICZNYCH (INSECTA, LEPIDOPTERA) DRZEW LIŚCIASTYCH W CHARKOWIE NA PRZESTRZENI 50 LAT

Streszczenie

Celem pracy było porównanie składu gatunkowego motyli filofagicznych na drzewach liściastych w latach sześćdziesiątych XX wieku oraz w latach 2017–2020 w Charkowie. Analizowano tryb życia, wielkość osobników i zdolność do gradacji. Największy wzrost liczby rodzajów i gatunków odnotowano w rodzinach Gracillariidae, Tortricidae i Geometridae, a spadek w rodzinach Notodontidae i Erebidae. Rodzina Gracillariidae została uzupełniona czterema adwentywnymi gatunkami: *Cameraria ohridella*, *Macrosaccus robiniella*, *Parectopa robiniella* i *Phyllonorycter issikii*. W obu okresach czasowych przeważały gatunki żyjące otwarte, jednak w latach 2017–2020 zwiększyła się liczba gatunków częściowo ukrytych i ukrytych, a także gatunków małych i średnich. Gatunki u których obserwowano gradacje w latach sześćdziesiątych XX wieku, stały się rzadsze, a gatunki adwentywne zaczęły występować częściej.

Słowa kluczowe: Motyle, Lepidoptera, miasto, drzewa liściaste, tryb życia, ranga wielkości, typ dynamiki populacji