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Expected harmfulness of gnawing phyllophagous insects in urban stands of Kharkiv city

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Abstract

Urban stands are becoming increasingly important in improving the environmental health and liveability of cities. However, they weaken as a result of technogenic air pollution and become vulnerable to pests, particularly to non-native forest insects. The aim of this research was to assess potential harmfulness (bionomically determined harmfulness [BDH]), environmentally determined harmfulness (EDH) and generally expected harmfulness (GEH) of the gnawing phyllophagous lepidopterous insects in the green stands of Kharkiv (Ukraine). All supplementary parameters were assessed by analysis of publications and the own experience of authors. BDH was evaluated as a product of the duration of larvae nutrition (p1) and an index of larvae nutrition (p2). An index of larvae nutrition (p2) was considered being proportional to their imago wingspan. EDH was evaluated as a product of the value of damaged tree species (p3), location of plant damage (p4), the period of loss decorative effect (p5) and the prevalence of certain insect species in the stands (p6). GEH was estimated as a product of BDH, EDH and the ability of insect species to the outbreaks (p7).

A modified approach for evaluation BDH, EDH and GEH was suggested and implemented, considering phyllophagous leaf miner insects and phyllophagous insects with open lifestyle in the deciduous stands of streets, parks, and Forest Park of Kharkiv city. EDH of insects with an open lifestyle depends on their size and prevalence in the stand. EDH and GEH of all revealed insects with an open lifestyle increase from streets to Forest Park. Among the insects with an open lifestyle, Lymantriidae and Notodontidae had the highest BDH due to the large size and long feeding period of larvae. Among the insects with hidden lifestyle, *Cameraria ohridella* had the highest BDH due to the highest prevalence and the large duration of feeding period with its several generations.

Key words

larvae size, prevalence, duration of nutrition, ability to outbreaks

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Introduction

Urban stands provide great benefits for environment, climate change mitigation and dust and gas retention (Tarasova et al. 2004). At the same time, such stands weaken under the influence of technogenic pollution and become vulnerable to insect pests and pathogens, particularly to non-native forest insects (Branco et al. 2019; Frank and Just 2020). The species composition of insects in urban, park and forest stands varies depending on suitable habitats and sensitivity to pollutants (Langellotto and Hall 2020).

Certain biological features of insects are constant, in particular, the lifestyle, type and duration of feeding (Isaev et al. 2015; Berryman 2020). Thus, it is possible to conditionally distinguish open-living, semi-hidden-living and hidden-living species with gnawing or sucking mouthparts (Tarasova et al. 2004). On exploiting insects' features, assessment of their potential impact on the condition of trees becomes possible (Kollár and Hrubík 2009). With a low population number, this effect is almost imperceptible and with a higher one, the decorative and ecological features of urban stands deteriorate. With very high population numbers, for instance, during outbreaks of mass propagation, defoliation can lead to a significant weakening of trees and increase their susceptibility to infestation by stem pests and pathogens (Isaev et al. 2015).

The potential harmfulness of certain insect species and groups of urban insects must be evaluated in order to monitor and, if necessary, prevent or overcome their negative impact. Due to differences in the features of individual insects, it is difficult to unify the methods of assessment of their harmfulness, even for members of the same ecological group.

Thus, an approach to assess the harmfulness of stem insects has been developed on pine (Mozolevskaya 1974), and in other regions, it has been developed in relation to other tree species, taking into account the number of insects and the health condition of trees (Meshkova 2017; Skrylnik et al. 2019).

Later, different approaches to assessing the harmfulness of foliage-browsing insects (Mozolevskaya and Dolzhenko 1979), sucking insects on the example of coccids (Kulikova 1987), gall-making insects (Petrov and Buga 2008) and miners (Roginsky and Buga 2020) have been suggested. The last two approaches were used to assess the harmfulness of miners, sucking gall-making and sucking insects with an open lifestyle in urban stands (Glyakovskaya 2018). It was assumed that the potential harmfulness of each insect is determined by its lifestyle and the intensity and duration of the feeding period. At the same time, the expected harmfulness of insects is influenced by external conditions, in particular, the value of the damaged plant, the selectivity of crown damage and the possibility of its regeneration, and, to the greatest extent, by the prevalence of certain insect species in the stand. That is, the species can be potentially harmful, but at low prevalence, safe for stands (Roginsky and Buga 2020).

The last but not least aspect that is taken into account when assessing the harmfulness of an insect is its population dynamics, that is, ability to outbreaks. The abundance of indifferent species in the long-term dynamics slightly deviates from the background values. The prodromal and eruptive species are capable of multiple increases 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 (Isaev et al. 2015; Berryman 2020).

Therefore, generally expected harmfulness (GEH) of any insect species depends on its ability to damage the plant during feeding, the influence of the environmental conditions and the type of dynamics of the insect population – its ability to form foci of mass propagation (Glyakovskaya 2018).

The aim of this research was the assessment of potential (bionomically determined harmfulness [BDH]), environmentally determined harmfulness (EDH) and GEH of the gnawing phyllophagous lepidopterous insects in the green stands of Kharkiv (Ukraine).

Material and methods

The list of insects for analysis was compiled during the survey of broadleaved street stands, parks and Forest Park in Kharkiv, which is located in the northeastern part of Ukraine on the border of the forest-steppe and steppe (50°00'N, 36°10'E). The survey was carried out with the participation of authors (Kukina and Zinchenko 2017; Shvydenko et al. 2020; Sokolova et al. 2020).

Only lepidopterous insects were included in analysis. In this research. 53 open-living and semi-hidden species and 12 hidden insect species (leaf miners) were analysed (Tab. 1 and 2).

Table 1. Prevalence of gnawing Lepidoptera with open lifestyle in urban stands of Kharkiv (2017–2020) (Sokolova et al. 2020)

Insect species	Prevalence (points)*		
	streets	parks	forest park
1	2	3	4
Arctiidae			
Hyphantria cunea (Drury, 1773)	0	1	2
Lymantriidae			
Calliteara pudibunda (Linnaeus, 1758)	0	0	1
Leucoma salicis (Linnaeus, 1758)	0	0	1
Lymantria dispar (Linnaeus, 1758)	0	0	1
Orgyia (Orgyia) antiqua (Linnaeus, 1758)	0	0	1
Euproctis (Euproctis) chrysorrhoea (Linnaeus, 1758)	0	1	1
Geometridae			
Abraxas (Calospilos) sylvata (Scopoli, 1763)	1	1	1
Agriopis leucophaearia (Denis & Schiffermüller, 1775)	1	1	1
Agriopis marginaria (Fabricius, 1776)	0	1	1
Agriopis aurantiaria (Hübner, 1799)	0	1	1
Alsophila aescularia (Denis & Schiffermüller, 1775)	0	0	1
Apocheima hispidaria (Denis & Schiffermüller, 1775)	0	0	1
Biston betularia (Linnaeus, 1758)	1	1	1
Biston strataria (Hufnagel, 1767)	0	1	1
Ennomos alniaria (Linnaeus, 1758)	0	1	1
Ennomos autumnaria (Werneburg, 1859)	0	0	1
Ennomos quercinaria (Hufnagel, 1767)	0	1	1
Erannis defoliaria (Clerck, 1759)	1	1	2
Hypomecis roboraria (Denis & Schiffermüller, 1775)	0	0	1
Lycia hirtaria (Clerck, 1759)	0	1	1
Operophtera brumata (Linnaeus, 1758)	0	1	2
Peribatodes rhomboidaria (Denis & Schiffermüller, 1775)	0	0	1
Phigalia pedaria (Fabricius, 1787)	0	0	1
Selenia lunularia (Hübner, 1788)	0	1	1
Selenia tetralunaria (Hufnagel, 1767)	0	0	1
Synopsia sociaria (Hübner, 1799)	0	0	1
Lasiocampidae			
Malacosoma (Clisiocampa) neustria (Linnaeus, 1758)	0	1	1
Notodontidae			
Notodonta dromedarius (Linnaeus, 1767)	0	0	1
Peridea anceps (Goeze, 1781)	0	1	1
Phalera bucephala (Linnaeus, 1758)	0	0	1
Tortricidae			
Acleris ferrugana (Denis & Schiffermüller, 1775)	0	1	1
Acleris hastiana (Linnaeus, 1758)	0	0	2
Acleris logiana (Clerck, 1759)	0	1	1
Acleris roscidana (Hübner, 1799)	0	0	1
Acleris scabrana (Denis & Schiffermüller, 1775)	0	1	1
Acleris variegana (Denis & Schiffermüller, 1775)	0	0	1
Adoxophyes orana (Fischer v. Röslerstamm, 1834)	1	1	1
Aleimma loeflingiana (Linnaeus, 1758)	1	1	1
Ancylis achatana (Denis & Schiffermüller, 1775)	0	1	1
Ancylis geminana (Donovan, 1806)	0	0	1
Ancylis laetana (Fabricius, 1775)	0	0	1
Ancylis tineana (Hübner, 1799)	0	0	1
Ancylis upupana (Treitschke, 1835)	0	1	1
Apotomis betuletana (Haworth, 1811)	1	1	1
Apotomis lineana (Denis & Schiffermüller, 1775)	0	0	1

1	2	3	4
Apotomis semifasciana (Haworth, 1811)	0	0	1
Apotomis sororculana (Zetterstedt, 1839)	0	1	1
Archips podana (Scopoli, 1763)	1	1	1
Archips rosana (Linnaeus, 1758)	1	1	1
Archips xylosteana (Linnaeus, 1758)	1	1	1
Archips crataegana (Hübner, 1799)	1	1	1
Choristoneura diversana (Hübner, 1817)	0	0	1
Pandemis cerasana (Hübner, 1786)	0	1	1
Pandemis corylana (Fabricius, 1794)	0	1	1
Pandemis heparana (Denis & Schiffermüller, 1775)	1	1	1
Ptycholoma lecheana (Linnaeus, 1758)	1	0	1
Syndemis musculana (Hübner, 1799)	0	0	1
Tortrix viridana Linnaeus, 1758	0	1	2
Pyralidae			
Acrobasis consociella (Hübner, 1813)	1	2	2

Note: * – a prevalence of certain insect species: 0 – absent; 1 – single (below 0.1%); 2 – rare (0.1%–1%) (Palij 1966)

Table 2. Prevalence of phyllophagous miners in urban stands of Kharkiv (2017–2020) (Sokolova et al. 2020)

Insect species	Prevalence (points)*		
	streets	parks	forest park
1	2	3	4
Bucculatricidae			
Bucculatrix thoracella (Thunberg, 1794)	0	1	1
Gracillariidae			
Acrocercops brongniardella (Fabricius, 1798)	0	1	2
Cameraria ohridella Deschka & Dimic, 1986	3	3	1
Macrosaccus robiniella (Clemens, 1859)	0	1	1
Phyllonorycter issikii (Kumata, 1963)	1	1	2
Phyllonorycter populifoliella (Treitschke, 1833)	1	1	1
Phyllonorycter quercifoliella (Zeller, 1839)	0	1	1
Parectopa robiniella Clemens, 1863	0	1	1
Nepticulidae			
Stigmella atricapitella (Haworth, 1828)	0	1	1
Stigmella basiguttella (Heinemann, 1862)	0	1	1
Stigmella tiliae (Frey, 1856)	1	1	2
Tischeriidae			
Tischeria ekebladella (Bjerkander, 1795)	1	2	2

Note: * – a prevalence of certain insect species: 0 – absent; 1 – single (below 0.1%); 2 – rare (0.1%–1%); 3 – common (1%–5%), (Palij 1966).

BDH, EDH and GEH were evaluated. All supplementary indices were assessed by expert estimation considering publications (Mozolevskaya and Dolzhenko 1979; Petrov and Buga 2008; Glyakovskaya 2018) and our own experience.

BDH was evaluated as a product of duration of larvae nutrition (number of 10 days) (p1) and an index of larvae nutrition (p2).

An index of larvae nutrition (p2) was considered being proportional to their imago wingspan. Therefore, all detected species were divided into three groups by wingspan: large (over 40 mm), middle (21–40 mm) and small (below 20 mm). This index is also higher if the insect deeply deforms the leaf.

$$BDH = p1 \times p2$$

EDH was evaluated as a product of the value of damaged tree species (p3), location of plant damage (p4), the period of loss ornamentation (p5) and the prevalence of certain insect species in the stands (p6).

$$EDH = p3 \times p4 \times p5 \times p6$$

For ‘p3’, we assumed all trees as valuable and evaluated them with 3 points. Location of plant damage (p4) was evaluated as 0.5 or 1 point (from selective to total).

Duration of the period of loss ornamentation (p5) was 1–3 points and depended on the time of plant damage and the remaining time until the end of the growing season (Glyakovskaya 2018).

A prevalence of certain insect species in the stands (p6) was estimated according to the following scale:

0 – absent; 1 – single (below 0.1%); 2 – rare (0.1%–1%); 3 – common (1%–5%) and 4 – abundant (over 5%) (Palij 1966). It was evaluated for stands in streets, parks and Forest Park.

GEH was estimated as a product of BDH, EDH and the ability of the insect species to outbreaks (p7).

$$GEH = BDH \times EDH \times p7$$

A parameter p7 was accepted as 1, 2 or 3 to indifferent, prodromal and eruptive species according to their ability to mass propagation (Isaev et al. 2015).

Statistical analysis of the data obtained was performed as mean ± standard error of the mean. Microsoft Excel software and the statistical software package Paleontological Statistics (PAST) Software Package for Education and Data Analysis (Hammer et al. 2001) were used.

Results

An analysis of the potential harmfulness of phyllophagous insects of deciduous trees in the green stands of Kharkiv showed the necessity to differential consideration of leaf miners and insects with an open lifestyle. Among the insects with an open lifestyle, Lymantriidae and Notodontidae had the highest BDH due to the large size and long feeding period of larvae (Fig. 1).

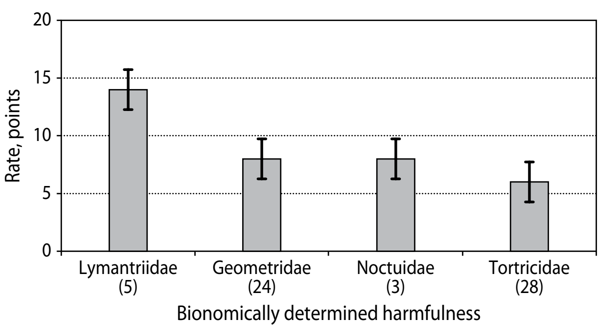

Figure 1. Bionomically determined harmfulness (BDH) for different families of open-living Lepidoptera (bars – standard error; the number of insect species in parentheses; a value of trees 3 points)

The effect of an insect with an open lifestyle on the plant is proportional to the size of the insect. However, EDH also depends on the prevalence of insects in the stands of streets, parks and Forest Park. Comparison of Figs 1 and 2 shows that BDH of Lymantriidae is the highest (14 points), but EDH is the highest only for Forest Park (9 points). BDH of Geometridae is 8 points, and its EDH increases from 1.1 in streets through 3.1 in parks to 6.4 in the Forest Park (Fig. 2).

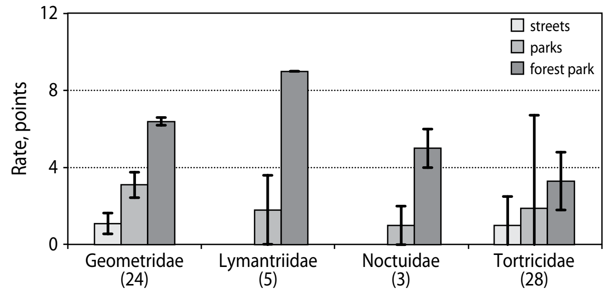

Figure 2. Environmentally determined harmfulness (EDH) of open-living Lepidoptera of different families depending on the place of assessment (bars – standard error; the number of insect species in parentheses; a value of trees 3 points)

Data analysis showed that the EDH of all revealed insects with an open lifestyle increased from streets (1.0 ± 0.24) to parks (2.9 ± 0.42) and the Forest Park (5.3 ± 0.33) (Fig. 3).

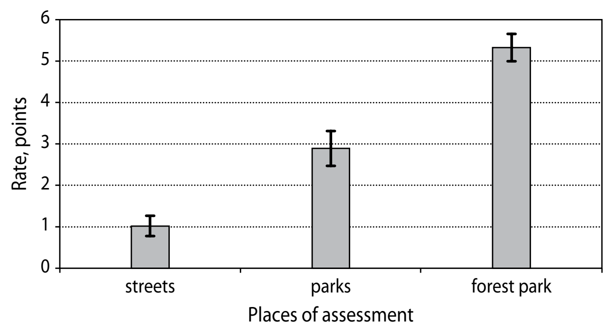

Figure 3. Environmentally determined harmfulness (EDH) of open-living Lepidoptera in different places of assessment (bars – standard error; the number of insect species in parentheses; a value of trees 3 points)

GEH, which considers BDH, EDH and the ability of insects to initiate outbreaks, also increased from streets (11.7 ± 2.81) to parks (42.4 ± 0.42) and the Forest Park (88.6 ± 13.68) (Fig. 4).

Considering certain families with an open lifestyle also showed increase in GEH from streets to the Forest Park (Fig. 5).

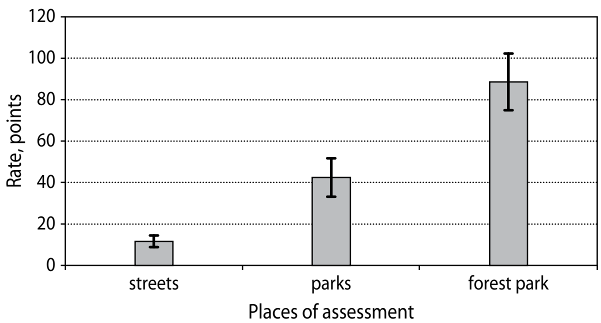

Figure 4. Generally expected harmfulness (GEH) of open-living Lepidoptera in different places of assessment (bars – standard error; the number of insect species in parentheses; a value of trees 3 points)

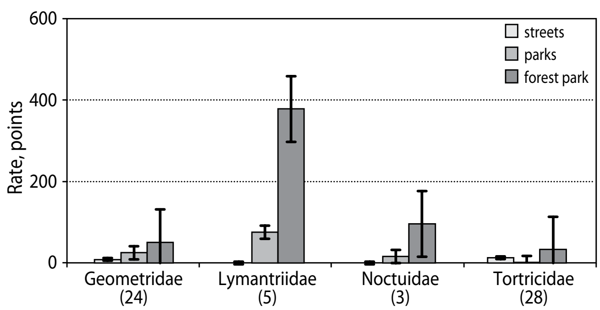

Figure 5. Generally expected harmfulness (GEH) of open-living Lepidoptera of different families depending on the place of assessment (bars – standard error; the number of insect species in parentheses; a value of trees 3 points)

Table 3. Supplementary parameter (K = p3 × p4 × p5) for the calculation of GEH for certain miner species

Species	BDH (p1 × p2)	Tree value (p3)	Level of crown damage (p4)	Duration of the period of decreasing ornamentality (p5)	K = p3 × p4 × p5
Bucculatrix thoracella	5.0	3.0	0.5	1.0	1.5
Acrocercops brongniardella	4.0	3.0	0.5	2.0	3.0
Cameraria ohridella	10.0	3.0	1.0	3.0	9.0
Macrosaccus robiniella	5.0	3.0	0.5	1.0	1.5
Phyllonorycter issikii	10.0	3.0	0.5	1.0	1.5
Phyllonorycter populifoliella	5.0	3.0	0.5	1.0	1.5
Phyllonorycter quercifoliella	5.0	3.0	0.5	1.0	1.5
Parectopa robiniella	5.0	3.0	0.5	1.0	1.5
Stigmella atricapitella	5.0	3.0	0.5	1.0	1.5
Stigmella basiguttella	5.0	3.0	0.5	1.0	1.5
Stigmella tiliae	5.0	3.0	0.5	1.0	1.5
Tischeria ekebladella	10.0	3.0	0.5	2.0	3.0

BDH – bionomically determined harmfulness; GEH – generally expected harmfulness.

Hidden-living Lepidoptera species were mainly found in the Forest Park and parks, with the exception of *Cameraria ohridella*. This insect damages only *Aesculus* sp., which is represented in the streets and parks only (Tab. 2; Sokolova et al. 2020).

Since the prevalence of miners varied in different types of stands, we evaluated a supplementary parameter K as p3 × p4 × p5 for the calculation of GEH for each miner species (Tab. 3).

The lowest BDH values were found for *Acrocercops brongniardella* and the highest for *C. ohridella* and *Tischeria ekebladella*. The degree of crown damage and duration of the period of decreasing ornamentation were also the highest for *C. ohridella*. Duration of the period of decreasing ornamentation was rather high for *A. brongniardella* and *T. ekebladella* too. The values of these parameters were reflected in the K value, which was the maximum (K = 9) for *C. ohridella*. For *A. brongniardella* and *T. ekebladella*, K = 3 and for other miner species, K = 1.5 (Tab. 3). Since the prevalence of leaf miners varies in the streets, parks and the Forest Park, the order of species according to the EDH and GEH values differed from that evaluated according to the BDH (Tab. 4).

Table 4. EDH and GEH of certain miner species in different types of stands

Species	EDH*			GEH = K × p7		
	streets	parks	forest park	streets	parks	forest park
1	2	3	4	5	6	7
bucculatrix thoracella	0	1.5	1.5	0	7.5	7.5
Acrocercops brongniardella	0	3.0	6.0	0	36.0	72.0
Cameraria ohridella	27.0	27.0	9.0	810.0	810.0	270.0

1	2	3	4	5	6	7
Macrosaccus robiniella	0	1.5	1.5	0	22.5	22.5
Phyllonorycter issikii	1.5	1.5	3.0	45.0	45.0	90.0
Phyllonorycter populifoliella	1.5	1.5	1.5	22.5	22.5	22.5
Phyllonorycter quercifoliella	0	1.5	1.5	0	15.0	15.0
Parectopa robiniella	0	1.5	1.5	0	15.0	15.0
Stigmella atricapitella	0	1.5	1.5	0	7.5	7.5
Stigmella basiguttella	0	1.5	1.5	0	7.5	7.5
Stigmella tiliae	1.5	1.5	3.0	7.5	7.5	15.0
Tischeria ekebladella	3.0	6.0	6.0	24.0	48.0	48.0

Note: EDH = * – prevalence from Table 2 × K from Table 3; GEH = BDH × EDH × p7. BDH – bionomically determined harmfulness; EDH – environmentally determined harmfulness; GEH – generally expected harmfulness.

In street stands, only five species of miners were identified with the dominance of *C. ohridella*. The EDH of this species was also the highest in parks and the Forest Park, although the absolute value of EDH in the Forest Park was three times lesser than in streets and parks.

Discussion

Phyllophagous insects penetrate the urban stands from the surrounding forests or with planting material, including the exotic plants for arboretums (Langellotto and Hall 2020). The populations of phyllophages in the city do not reach the outbreak level, but individual trees lose their decorative effect. Plant damage depends on the prevalence of insects with different lifestyles and feeding modes. According to lifestyle, phyllophagous insects are divided into open-living, semi-hidden and hidden ones (Tarasova et al. 2004). Open-living Lepidoptera at the caterpillar stage skeletonise or gnaw leaves. Hidden insects (leaf miners) feed in the middle of leaf tissues. Semi-hidden insects for most of the life cycle are found in shelters like folded, glued cobwebbed leaves.

Our study was focused on only phyllophagous species with gnawing mouthparts. The analysis used actual data on the prevalence of 53 species of open-living phyllophages and 12 species of leaf miners from the order Lepidoptera, obtained during the survey of urban stands in Kharkiv. These data were analysed using a modified methodological approach from publications (Mozolevskaya and Dolzhenko 1979; Petrov and Buga 2008; Glyakovskaya 2018), expert estimation of parameters and experience of authors.

The approach reveals that BDH depends on the intensity of larval nutrition. However, EDH of the same insect can be, for example, high for *Fraxinus excelsior* L. and low for *Acer negundo* L. and increases with a greater prevalence of the insect species.

GEH depends on BDH, EDH and the ability of insects to initiate outbreaks.

In our analysis, open-living insects with the largest larval size (particularly, Lymantriidae) had the highest BDH. However, their prevalence in the urban stands was rather low. The size of open-living insects affected their EDH also. The data obtained show that all species capable of outbreaks of mass propagation have a high GEH, but publications mention that such outbreaks can occur no more than once in every 10 years (Meshkova 2009; Berryman 2020). Smaller insects (in particular, Tortricidae) have lower BDH and EDH values. However, several species are able to form joint (complex) foci of mass propagation and cause defoliation of trees for several consecutive years with a change in the dominant species (Meshkova 2009; Isaev et al. 2015).

In the region of our research, the last outbreak of foliage-browsing insects in broadleaved stands was registered in 2012 (Meshkova et al. 2018). In 2017–2020, representatives of eight families, indicated in Table 1, were found in the Forest Park, seven in parks, and only Geometridae, Tortricidae and Pyralidae were occasionally found in street stands.

Unlike open-living phyllophages, leaf miners were found more often in urban stands, where they got both as a result of flight and with planting material of exotic plants (Branco et al. 2019). So, since 2007, in the urban stands of Kharkiv, the presence and specifics of the seasonal development and dynamics of alien species *C. ohridella* Deschka and Dimic, 1986, *Macrosaccus robiniella* (Clemens 1859), *Parectopa robiniella* Clemens, 1863, and *Phyllonorycter issikii* (Kumata 1963) were registered (Meshkova and Mikulina 2012).

In contrast to the identified free-living phyllophages, many miners are confined to certain tree species and are not found in their absence (Meshkova and Mikulina 2012). *C. ohridella* had the highest BDH due to the highest prevalence and large duration of feeding with its several generations.

Tree value is also of great importance in assessment of the potential harmfulness of miners. So, *Robinia pseudoacacia* L., 1753 can be considered a weed in some stands and an ornamental or soil-protective species in others. In such cases, the potential harmfulness of insects in prevailed and valuable stands is higher than in less-prevailed and low-value stands by six times, in widespread, low-value stands by 3 times and in low-spreading stands by 1.5 times (see Tab. 3 and 4).

Conclusions

A modified approach for evaluation of BDH, EDH and GEH is suggested and implemented, considering phyllophagous leaf miner insects and phyllophagous insects with open lifestyle in the deciduous stands of streets, parks and the Forest Park of Kharkiv city.

EDH of insects with an open lifestyle depends on their size and prevalence in the stand. EDH and GEH of all revealed insects with an open lifestyle increase from streets to Forest Park.

Among the insects with an open lifestyle, Lymantriidae and Notodontidae had the highest BDH due to the large size and long feeding period of larvae. Among the insects with hidden lifestyle, *C. ohridella* had the highest BDH due to the highest prevalence and the large duration of feeding period with its several generations.

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