Foliage-browsing Lepidoptera (Insecta) in deciduous forests of Ukraine for the last 70 years

V. L. Meshkova

As insect development depends on temperature, so the change in biology, behavior habits, frequency, and severity of outbreaks of foliage-browsing insects considered pests can follow the climate change. The reactions of species to the same climate changes can be specific; therefore, an unpredictable change in their ratio in the community will affect the consequences of climate change.

The details of such changes must be studied to quantitatively assess future trends and the threats to deciduous forests. The aim of this research was to evaluate the representation in deciduous forests the foliage-browsing lepidopterous insects if different groups of size, lifestyle, voltinism, trophic relations, and ability to mass propagation in different periods of assessment for recent 70 years.

In the analysis, we used a list of 118 lepidopterous species of foliage-browsing insects of deciduous forests, compiled on the basis of archival data from 1940–1975, and in the course of our own field research from 1975 to the present in the forests of Ukraine. Following trends were expected to be confirmed for these time intervals: to increase the number of species of small size, the number of species with hidden lifestyle, multivoltine species, polyphagous species, and so-called indifferent species. For each species, all these parameters were identified and proportions of species of each category for certain time intervals (1940–1950, 1960–1970, 1980–1990, and 2010–2020). Their distribution for size, voltinism, lifestyle, trophic features, and outbreak potential at these time intervals was compared using \( \chi^2 \)-test.

Among lepidopterous foliage-browsing insects of deciduous forests of Ukraine, the increase for recent 70 years was proved for the proportion of indifferent species (do not able to mass propagation), small species (with wingspan below 20 mm), as well as species with hidden lifestyle (leaf-miners) and semi-hidden lifestyle (leaf-rollers). All trends are expressed the most obviously in 1940–1950 and further periods. The hypothesis about decrease the proportion of the univoltine and monophagous species for this period is not supported statistically.

**Key words:** size; voltinism; lifestyle; trophic features; outbreak.

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**Introduction.** Climate change brings to forest weakening and increases its susceptibility to insect damage (Frank, & Just, 2020; Halsch et al., 2021). At the same time, insects under new climate conditions accelerate development, change their behavior, and hibernation habits (Branco et al., 2019; Jactel, Koricheva, & Castagneyrol, 2019). Such changes must be studied in detail to determine threats to forests.

Some phytophagous insects are able to cause considerable damage to tree foliage in the forest, protective, and urban stands during particular periods, so-called outbreaks when the number of these pests increases drastically (Iсаев, Пальникова, Суховольский, Тарасова, 2015). The incidence, severity, duration, and intervals between such outbreaks were analyzed for different periods to find the algorithm for predicting the following increase outbreaks were analyzed for different periods to find the algorithm for predicting the following increase outbreaks of outbreaks for different foliage-browsing insects is studied in detail to determine threats to forests.  

One can see the change of its dates and rates, depending on size, lifestyle, voltinism, trophic relations, and ability to mass propagation. 

The aim of the research was to evaluate the representation of the foliage-browsing lepidopterous insects of different groups by size, lifestyle, voltinism, trophic relations, and ability to mass propagation in different periods of assessment for recent 70 years in deciduous forests of Ukraine.

In the analysis, we used a list of 118 species of foliage-browsing insects of deciduous forests, compiled on the basis of archival data from 1940–1975, and in the course of our own field research from 1975 to the present.

Five hypotheses considered concerning trends in structure change of foliage-browsing insects of deciduous forests.

According to the first hypothesis, there is a trend to increase the number of species of small size. For analysis, all species were divided into 3 groups by wingspan: large (over 40 mm), middle (21-40 mm), and small (below 20 mm).

According to the second hypothesis, there is a trend to increase the number of species with hidden lifestyles. All detected insect species were divided into 3 groups by lifestyle: open-living caterpillars feed on foliage without shelters, cobwebs, leaves held together, etc. Hidden-living insects feed under leaf cuticles (leaf-miners, for example). Semi-hidden-living insects most of the life cycle feed in the shelters, for example, cobwebbed, glued, or folded leaves (Соколова, Швиденко, Кардаш, 2020).

According to the third hypothesis, proportion of multivoltine species tends to increase. We considered as multivoltine ones those species which are known to have more than one generation per year.

According to the fourth hypothesis, the proportion of polyphagous species tends to increase. We considered as polyphagous those species which can feed on more than one plant genus.

According to the fifth hypothesis, the proportion of eruptive species tends to decrease. We considered the prodromal and eruptive species those ones which are capable of a multiple increase in abundance. However, in prodromal species, the abundance remains at the
lower stationary state, while in eruptive species it can remain at lower or upper stationary level (Исаев, Пальникова, Суховольский, Тарасова, 2015).

For each species, all these parameters were identified and proportions of species of each category for certain time periods (1940-1950, 1960-1970, 1980-1990, and 2010-2020) were evaluated.

Descriptive statistics of the data obtained were performed by employing the mean ± standard error of the mean. The proportions of species inside each analyzed characteristic were compared using the chi² test (Атраментова, Утевская, 2008). Microsoft Excel software and statistical software package PAST: Paleontological Statistics Software Package for Education and Data Analysis (Hammer, Harper, & Ryan, 2001) were used.

Results and discussion. The comparison of the lepidopterous insects supports the trend of increase the proportion of small species (Fig. 1).

![Fig. 1. The proportion of Lepidoptera species with different size level in certain periods (bars – standard error; the number of species in parentheses)](image)

The difference in the ratio of small, middle and large insects is the most pronounced between 1940–1950 and further periods (χ² – 18.0–20.3; p < 10⁻⁵) than between 1960-1970 and 1980-1990, 1980-1990 and 2010-2020, and other periods (χ² – 0.1–2.3; p > 0.1).

On some objects, the functional relationship between body size, development duration, and temperature of animals has been proven (Chown, & Nicolson, 2004). It was shown that against the background of the current climate warming, the size of the insect body decreases. At the same time, in regions with lower average annual temperatures, the increase in beetle size is statistically significant.

The proportion of open-living lepidopterous foliage-browsing insect species tends to decrease, semi-hidden species tends to increase, and hidden species tends to increase and then to decrease again (Fig. 2). The difference is the most pronounced between 1940–1950 and further periods (χ² – 24.4–38.5; p < 10⁻⁴) than between these periods (χ² – 0.2–1.8; p > 0.1). The increase of the proportion of hidden species, particularly miners, is registered also in urban stands (Kirichenko, Augustin, & Kenis, 2019; Branco, Nunes, Roques, Fernandes, Orazio, & Jactel, 2019; Kardash, & Sokolova, 2020), but they seem not to be dangerous for a forest.

![Fig. 2. The proportion of Lepidoptera species with different lifestyle in certain periods (bars – standard error; the number of species in parentheses)](image)

The trend of increase the proportion of bivoltine species and decrease the proportion of the univoltine species is rather slight (Fig. 3), and the difference is not statistically proved (χ² < 0.4; p >0.1). So this hypothesis is rejected, however, it may be due to an insufficient dataset.

![Fig. 3. The proportion of Lepidoptera species with different number of generations in certain periods (bars – standard error; the number of species in parentheses)](image)

Most of the papers are devoted to an increase in the number of generations, this is logical since an earlier start and a later end of the growing season and an increase in the sum of temperatures during this period are favorable for the development of a larger number of generations (Knell, & Thackeray, 2016; Meshkova, 2019; Teder, 2020). An increase in the proportion of multivoltine species has recently been reported in Finland (Pöyry, Leinonen, Söderman, Nieminen, Heikkinen, & Carter, 2011). However, in some cases the last generation does not enter the diapause before winter, contrary to expectations, but dies (Invasive stink bugs, 2017).
The shift under the warming the phases of the food plant and the caterpillars can bring to the earlier hatch than the available food appears, and entomophages will appear earlier or later than the phytophages hatch. In this case, those phytophages and entomophages that can adapt to feeding on a large number of hosts will gain advantages, that is, polyphages will receive advantages over monophages (Robinet, & Roques, 2010).

At the same time, in our set of data, the hypothesis of increase the proportion of polyphagous species and decrease the proportion of the monophagous species is not supported ($\chi^2 < 0.4; p > 0.1$) (Fig. 4).

It is possible that when considering a particular outbreak, conclusions regarding the ratio of polyphages to monophages will change. So, according to our research in the 80s in the focus of the Archips crataegana (Hübner, 1799), the caterpillars of all foliage-browsing species that lived there preferred to feed on oak leaves, but after severe defoliation of trees, the insects moved to other tree species and successfully completed their development (Мєшкова, 2002). In the years when the outbreak was collapsed, the largest populations of all species were again recorded in oak trees. That is, in the years of high insect population density and lack of oak foliage, these species became polyphagous.

The trend of decrease the proportion of eruptive species and increase the proportion of indifferent species is expressed the most obviously in 1940–1950 ($\chi^2 = 32.7–41.2; p < 10^{-5}$) than between these periods ($\chi^2 = 0.5–3.0; p > 0.1$).

Thus, the data obtained confirm that the reactions of species even to the same climate changes are species-specific. Therefore, an unpredictable change in their ratio in the community (Wagner, Fox, Salcido, & Dyer, 2021) will affect the consequences of climate change (Gilman, Urban, Tewksbury, Gilchrist, & Holt, 2010).

**Conclusions.** Among lepidopterous foliage-browsing insects of deciduous forests of Ukraine, the increase for recent 70 years was proved for the proportion of indifferent species (do not able to mass propagation), small species (with wingspan below 20 mm), as well as species with hidden and semi-hidden lifestyle. An increase in the proportion of small-sized species as well as for species with a hidden and semi-hidden lifestyle is known also for other groups of insects. Small size and hidden and semi-hidden lifestyle allow survival under high anthropogenic pressure.

The hypothesis about decrease the proportion of the univoltine and monophagous species for this period is not supported statistically.

However, both hypotheses should be tested in the future again, taking into account that polyphagia helps species that have lost the advantages of feeding on one host plant, in particular, as a result of a shift of the synchronicity of development, and multivoltine development allows a rapid increase in population number.

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Зміна клімату приводить до ослаблення лісів і збільшення їхньої сприйнятливості до пошкоджень комахами. Водночас комахи в нових умовах клімату пришвидшують розвиток, змінюють кількість поколінь, поведінку, місця зимівлі, а також частоту і інтенсивність спалахів масового розмноження. Такі зміни потрібно детально вивчати, щоб оцінити тенденції та загрози лісам з бoku комах. Метою цього дослідження було оцінити представництво у листяних лісах листогризних лускокрилих комах різних груп за розміром, спосо- бом життя, кількість поколінь (вольтинізмом), трофічними зв'язками, спроможність утворювати осередки масового розмноження в різні періо- ді впродовж останніх 70 років.

Для аналізу використано перелік 118 видів лус- кокрилих листогризних комах листяних лісів, складений за архівними даними 1940-1975 рр. та матеріалами власних польових досліджень, здійснених від 1975 р. до 1990 р. Намір перевірити декілька гіпотез стосовно тенденцій, що виявлені в комплексі листогризних луско- крилих за цей інтервал часу. Перша полягало в тому, що у міру потепління збільшується частка ви- дів невеликого розміру (з розмахом крил до 20 мм). Друга гіпотеза полягало в тому, що в нових умовах більша кількість видів комах веде потаємний і на- півтаємний способи життя (розвиваються в мі- нах, згорнуті або сплетені навпаки листах та інших укриттях). Також припускали, що в умо- вах зміни клімату посилюється загроза насадженням від мультивольтинних видів, гусениці яких пошко- джують листя впродовж усього сезону (третя гіпо- теза). Четверта гіпотеза полягало у збільшенні кіль- кості видів, спроможних до життя на широкому асортименті кормових рослин (комах-поліфагів), а п’ята – у збільшенні частки видів комах, що не- спроможні формувати осередки масового розмно- ження (інідиферентних). Для кожного з розглянутих видів визначено всі названі параметри та співвідно- шення кількості видів кожні категорії для чис- вих інтервалів 1940-1950 pp., 1960-1970 рр., 1980-1990 рр. та 2010-2020 роки. Розподіл видів за роз- міром, спроможністю до утворення додаткових по-

Листогрізні Lepidoptera (Insecta) у листяних лісах України за останні 70 років

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Листогрізущі Lepidoptera (Insecta) в листяних лесах України за послідовності 70 літ

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Изменение климата приводит к ослаблению лесов и увеличению их восприимчивости к поврежде- нию насекомыми. В то же время насекомые в новых условиях климата ускоряют развитие, изменяют количества поколений, поведение, места зимовки, а также частоту и интенсивность вспышек массового размножения. Такие изменения должны быть изучены детально, чтобы определить тенденции и угрозы лесам со стороны насекомых. Целью данного исследования было оценить представительство в листяных лесах листогрызущих чешуекрылых насекомых разных групп по размерам, образу жизни, количеству поколений (вольтинизму), трофическому взаимодействию, способности образовывать орды массового размножения в разные периоды года за последние 70 лет.

В данном анализе использован перечень 118 видов чешуекрылых лиственных насекомых лиственных лесов, составленный по архивным дан-
nym 1940-1975 гг. и материалам собственных полевых исследований, проведенных с 1975 года до настоящего времени в лесах Украины. Мы предполагали проверить несколько гипотез по поводу тенденций, отмечаемых в комплексе листогрызащих чешуекрылых насекомых за данный интервал времени. Первая заключалась в том, что по мере потепления возрастает доля видов небольшого размера (с размахом крыльев до 20 мм). Вторая гипотеза состояла в том, что в новых условиях большее количество видов насекомых ведет скрытый и полускрытый образ жизни (развиваются в минах, свернутых или сплетенных паутиной листьях и других укрытиях). Также предполагалось, что в условиях изменения климата возрастает угроза насаждениям от мультивольтинных видов, гусеницы которых повреждают листву в течение всего сезона (третья гипотеза). Четвертая гипотеза заключалась в увеличении числа видов, способных к питанию на широком ассортименте кормовых растений (полифагов), а пятая – в возрастании доли видов, не способных формировать очаги массового размножения (индифферентных). Для каждого из рассмотренных видов определены все названные параметры и соотношения количества видов каждой категории для временных интервалов 1940-1950 гг., 1960-1970 гг., 1980-1990 гг. и 2010-2020 годы. Распределение видов по размеру, способности к вольвинизму, по образу жизни, трофическим связям и способности к образованию очагов массового размножения в соответствующие периоды времени сравнивали с помощью критерия $\chi^2$. Проведенный анализ показал, что среди чешуекрылых листогрызащих насекомых лиственных лесов Украины за последние 70 лет увеличилась доля индифферентных видов (неспособных к массовому размножению), видов малого размера (с размахом крыльев до 20 мм), со скрытым (листовые минеры) и полускрытых формами жизни (листовертки). Все выявленные тенденции наиболее очевидно проявлялись при сравнении с 1940-1950 гг. и последующих периодов. Гипотеза о снижении доли видов, развивающихся всегда лишь в одном поколении, и видов, пытающихся на растениях одного рода, статистически не подтверждалась. Таким образом, в связи с специфической реакцией насекомых на один и те же изменения климата, трудно представить, как изменяются соотношение отдельных видов в сообществе и их роль в лесной экосистеме после изменения климата.

**Ключевые слова:** размер; вольвинизм; образ жизни; трофические особенности; вспышка.