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ORIGINAL ARTICLE

Adaptive features of the *Phyllonorcyter robiniella* (Clemens, 1859) (Gracillariidae Stainton, 1854) population in urban ecosystems

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The article provides study results of the existence peculiarities of adventitious lepidopteran species of leaf blotch miners (Gracillariidee Steinton, 1854) *Parectopa robiniella* (Clemens, 1863) in the conditions of Dnipro city (Ukraine). In various ecosystems, the invasive leaf miner's invasion degree was estimated with the number of mines visually recorded on the leaves of *Robinia pseudoacacia* Linnaeus (1753) as a forage plant species. The research covered all major park ecosystems various in size within Dnipro city where the forage trees have been planted. Field surveys were conducted during three growing seasons (2018–2020). The adaptive ability to survive in a new environment was evaluated by analyzing the intrapopulation and interpopulation polymorphism on the third stage of insect development (pupae). According to our study results on Robinia trees occupation by miner species, the highest density of mines was found in ecologically cleaner green areas like Oles Honchar Dnipro National University Botanical Garden and Dnieper-Orel Nature Reserve. Different living conditions may cause this; the miners that inhabit the green zones in Dnipro city may be affected by a complex of anthropogenic factors that suppress their populations' development. We can conclude that the most vulnerable Robinia specimens were those located outside the city boundary. Investigation of *P. robiniella* pupae morphometric characteristics showed that both linear characteristics and indices were stable relative to the average value since a significant variation coefficient was observed only in specimens collected in the Pridneprovsky Park. However, skewness and excess coefficients indicate that most studied *P. robiniella* populations showed a trend to displace Poisson distribution. Moreover, in this case, the sample selected in the Dnipro-Orel Nature Reserve also differed significantly: the high coefficient of excess was found for wing length and the ratio of body length to wing length, compared to other ecosystems. The population closest by this parameter was shown in the Peoples' Friendship Park, a pristine ecosystem compared to the city center. The intrapopulation polymorphism of two linear characteristics and three indices was higher than the interpopulation polymorphism. From this, we can conclude that pupae's diversity within a particular population or ecosystem is more significant than pupae's diversity from diverse ecosystems. That is, conditions of ecosystems within the city limits have little effect on pupae's diversity of the black locust miner. However, when comparing pupae samples collected within the city and outside its borders, morphometric characteristics can vary.
Keywords: biological invasion, invasive butterflies, Gracillariidae, urban ecosystems, intrapopulation polymorphism, interpopulation polymorphism.

Introduction

A list of 435 quarantine species has been compiled for European countries (Holoborodko et al., 2016;), these species have different hazard statuses, both environmental and economic because their life activities annually cause economic damage (Sanders et al., 2003). Experts currently estimate the number of potential invasive species entering Ukraine territory at 1,500 species. Disturbances in the natural functioning of ecosystems associated with invasive species activity can cause direct and indirect threats immediately to human health (Voronkova et al., 2018).

Nowadays, among the adventitious forest species on the territory of Ukraine, leaf-mining moths have wide-spread occurrence, and their role increases among other phytophages due to the excellent ability to adapt to a sufficiently high-level contamination, moisture deficiency, insecticide exposure, as well as a large number of generations per year (Meshkova et al., 2014; Shupranova et al., 2019). The history of the adventitious lepidopteran species invasion on the territory of Ukraine dates back more than 25 years. During this period, the most significant concern is caused by four invasive species belonging to the family of leaf blotch miners *Gracillariidae Stainton*, 1854, *Cameraria ohridella* Deschka et Dimić, 1986, *Phyllonorycter issikii* Kumata, 1963, *Parectopa robiniella* Clemens, 1863 and *Phyllonorycter robiniella* Clemens, 1859 (Zerova et al., 2007; Ivinskis and Řimsaité, 2008; Lopez-Vaamonde et al., 2010; Seliutina et al., 2020).

Biological invasion is the second most crucial threat to conserving natural biological diversity after habitat destruction (Vitousek et al., 1996). The entry of invader species can often result in irreversible environmental consequences (Holoborodko et al., 2016), leading to significant biological disturbances in the vital activity of entire ecosystems, as a result of which significant economic damages are caused in various sectors of the economy (Marenkov et al., 2017).

One of the main prerequisites for the successful invasion of phytophagous insects in new territories is suitable forage plants in the local flora, less often native but more often introduced (Parker et al., 1999). The black locust (*Robinia pseudoacacia* Linnaeus 1753) is a typical representative of introduced fraction in the dendroflora of many Central European countries. This arboreal plant of North American origin has been widely cultivated in Europe since the end of the XIX century (Gritsan et al., 2019). The black locust was

actively used in the forest belt formation along highways and railways in the south of Ukraine in the 50s and 60s of the last century (Lakyda et al., 2019). The black locust is widely used for strengthening slopes, including ravines and quarries. Later, it was used as an ornamental plant for planting roads and streets, in gardens, parks, in the alley, and single plantings (Sytnyk et al., 2018). One of the black locust's specialized phytophagous pests is leaf miner *Phyllonorycter robiniella* Clemens, 1859; Lepidoptera: Gracillariidae. This species of North American origin is currently widely distributed in Europe (Fauna Europaea, 2013; Kirichenko et al., 2018).
Under the influence of the vital activity of adventitious lepidopteran species on local ecosystems and economic regimes, there was a need to monitor their populations. Due to the rate of invasion and ecological plasticity shown by invasive species of the leaf blotch miner family (Gracillariidae), observations of their populations' state are of particular importance (Holoborodko et al., 2020).

Methodos

The black locust leaves damaged by the leaf miner were collected at the end of the growing season in 2020 within Dnipro city and in the Dnipro-Orel Nature Reserve.

Fig. 1. Locations of the test sites: 1 -Pridneprovsky Park; 2 – Oles Honchar Dnipro National University Botanical Garden; 3 – Peoples' Friendship Forest Park; 4 – Park of the 40th anniversary of the liberation of the Dnieper; 5 – T. G. Shevchenko Park; 6 – Dnipro-Orel Nature Reserve

Fig. 1 shows a map with areas where the material was collected and *P. robiniella*. mines were counted.
1. Pridneprovsky Park – 48°24'N 35°07'E
2. Oles Honchar Dnipro National University Botanical Garden – 48°26'N 35°02'E
3. Peoples' Friendship Forest Park – 48°31'N 35°05'E
4. Park 40th anniversary of the liberation of Dnipropetrovsk – 48°25'N 35°01'E
5.Park named after T.G. Shevchenko – 48° 27′ N 35° 04′ E
6. Dnipro-Orel Nature Reserve – 48°30'N 34°46'E

The model branch recorded the number of mines on trees. A tree and a random branch with a length of at least 1 M were selected by randomization. After that, the number of leaves and the number of mines formed by *P. robiniella* individuals were counted. After that, the number of compound leaves on the model branch was counted to determine the mine density, that is, the number of mines per compound leaf.
R. pseudoacacia leaves sampled from various ecosystems were sorted, the mines were found, the number of damages (mines) on compound leaves was recorded, after which the mine was dissected, and pupae were pulled out. Pupae were placed in numbered tubes for fixation with an ethyl solution. The test tube number corresponded to the ecosystem number.
In total, measurements were made on 140 specimens of *P. robiniella* pupae. Insects were photographed using MBS–10 binoculars with a 5 MP digital camera. An object micrometer was applied to the insects to calibrate the measured parameters.
Measurements were made from digital photos using ToupView software. 3 linear characteristics were measured: body length (Lb), elytra length (Le), and body height (Hb); 3 indices were calculated: body-length-to-wing-length ratio (Lb/Le), wing-length-to-body-height ratio (Le/Hb), and body-length-to-body-height ratio (Lb/Hb). Primary data processing was performed in MS Excel 2019, and subsequent data processing was performed in the Statistica 13 software package.
The univariate variance analysis method was used to compare the density of formed mines on a compound sheet, depending on the ecosystem. Excess (Ex) and asymmetry (As) indicators were used to compare the detection of deviations in pupae's morphometric

characteristics from the normal distribution. The coefficient of variation (CV) and standard deviation (SD) were used to analyze intrapopulation diversity. Univariate analysis of variance (ANOVA) was used to compare linear characteristics and indices to detect interpopulation polymorphism. To compare the distribution of linear characteristics and pupal indices *P. robiniella* collected from diverse ecosystems, box graphs were built indicating the numbers of ecosystems in which pupae were collected along the abscissa axis and the characteristic values or index the ordinate axis. The differences between the samples for $P < 0.05$ were considered reliable.

Results

Table 1. One-way analysis of variance of *P. robiniella* population in different green areas of the city. Dnipro (*n* = 226).

Eco	n	x ± SD	SS	MS	F	P
1	36	2.22 ± 1.33	685.3254	137.0651	14.9876	$<1*10^{-12}$
2	30	5.27 ± 5.10				
3	39	1.46 ± 0.94				
4	56	2.46 ± 2.03				
5	39	2.44 ± 1.86				
6	26	6.88 ± 5.67				

Note: Eco – ecosystem number, n – sample size, x ± SD – standard deviation, SS – the sum of squares, MS-value of squares, F – Fisher value, P – degree of confidence.

Fig. 2 shows that the number of mines per black locust compound leaf found in Oles Honchar Dnipro National University Botanical Garden and the Dnieper-Orel Nature Reserve differs significantly. Simultaneously, other ecosystems within the of Dnipro city do not differ in this indicator from each other (Table 1).

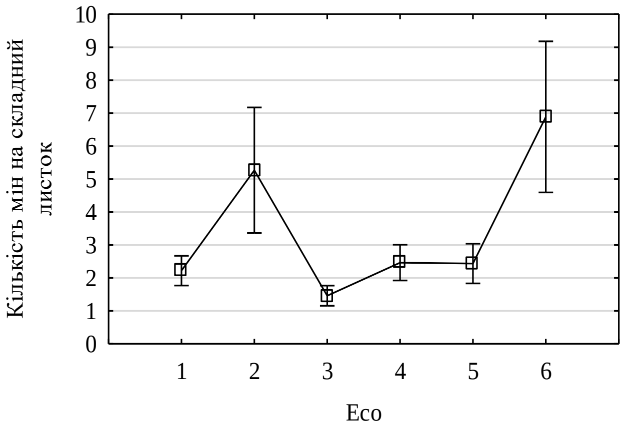

Fig. 2. Population variability *P. robiniella* on *R. pseudoacacia* model branches: the ecosystem number (Eco) on the OX axis, the characteristic's value on the ordinate axis.

According to our study results, the distribution of P. robiniella pupae selected in the Pridneprovsky Park (Table 2) shows among linear characteristics a significant asymmetry in body height (Hb, As = 1.33) and wing length (Hb, As = 0.76), as well as among indices body length-to-body height ratio (Lb/Hb, As = -1.09), and wing length-to-body height ratio (Le/Hb, As = -0.97). The excess values were reliable for body height (Hb, ex = 0.82) and body length-to-elytra length ratio (Lb/Le, Ex = -1.11). Body length (Lb) and elytra length (Le) did not show significant asymmetry or excess. A significant coefficient of variation of CV is also observed in body height (Hb), body length-to-body height ratio (Lb/Hb), and wing length-to-body height ratio (Le/Hb).

Among the pupae selected in Oles Honchar Dnipro National University Botanical Garden, a reliably significant asymmetry was observed only in body height (Hb, As = 0.66), in wing length-to-body height ratio (Le/Hb, As = -0.73). In contrast, a significant excess was observed in body length (Lb, Ex = -1.15), elytra length (Le, Ex = -1.03), and in wing length-to-body height ratio (Le/Hb, Ex = 0.74). Body-length-to-body-height ratio (Lb/Hb) and body-length-to-wing-length ratio (Lb/Le) did not show significant asymmetry or excess. None of the characteristics studied showed a significant coefficient of variation.

Significant asymmetry was observed among a sample of pupae from the Peoples' Friendship Park: body length (Lb, As = –0.91), body height (Hb, As = 0.79), body length-to-elytra ratio (Lb/Le, As = -1.49), body length-to-height ratio (Lb/Hb, As = -1.37), and wing length-to-body height ratio (Le/Hb, As = 0.65).

A reliably positive excess was observed in (Hb, Ex = 0.73) body length-to-elytra length ratio (Lb/Le, Ex = 1.35) and body length-to-body height ratio (Lb/Hb, Ex= 1.75); a negative excess was observed in body length-to-body height ratio (Lb/Hb, Ex = –1.08).

There was no significant asymmetry or excess in wing length (Le). The studied characteristics do not show significant indicators in the coefficient of variation.

In pupae collected from the Park 40th anniversary of the liberation of Dnipropetrovsk, none of the studied characteristics shows a reliable asymmetry, except for the wing length (Le, As = 0.62). However, a significant negative excess was observed for body length (Lb, Ex = –0.80), body length-to-wing length ratio (Lb/Le, Ex = –0.76), and in body-length-to-heigh ratio (Lb/Hb, Ex = –1.14). Significant asymmetry and excess were not shown in body height (Hb) and wing length-to-body height ratio (Le/Hb). The coefficient of variation was significant in terms of body height (Hb), body length-to-wing length ratio (Lb/Le), and body length-to-height ratio (Lb/Hb).

Table 2. Morphometric variability of *P. robiniella* within populations (n = 140).

Eco	n	Characteristics	x ± SD	CV	As	Ex
Pridneprovsky Park	16	Lb, mm	3.48 ± 0.17	0.05	-0.20	0.12
		Hb, mm	0.79 ± 0.16	0.20	1.33	0.82
		Le, mm	2.12 ± 0.12	0.06	0.76	0.31
		Lb / Le	1.64 ± 0.11	0.07	0.18	-1.11
		Lb / Hb	4.55 ± 0.86	0.19	-1.09	0.05
		Le / Hb	2.76 ± 0.45	0.16	-0.97	0.02
Oles Honchar Dnipro National University Botanical Garden	34	Lb, mm	3.34 ± 0.28	0.08	-0.31	-1.15
		Hb, mm	0.82 ± 0.08	0.10	0.66	0.52
		Le, mm	1.88 ± 0.20	0.10	0.01	-1.03
		Lb / Le	1.79 ± 0.17	0.09	0.18	-0.43
		Lb / Hb	4.11 ± 0.42	0.10	0.08	-0.46
		Le / Hb	2.30 ± 0.20	0.09	-0.73	0.74
Peoples' Friendship Park	18	Lb, mm	3.30 ± 0.19	0.06	-0.91	-0.32
		Hb, mm	0.81 ± 0.09	0.11	0.79	0.73
		Le, mm	1.73 ± 0.15	0.09	0.25	-0.17
		Lb / Le	1.92 ± 0.13	0.07	-1.49	1.35
		Lb / Hb	4.10 ± 0.37	0.09	-1.37	1.75
		Le / Hb	2.14 ± 0.18	0.08	0.65	-1.08
Park 40th anniversary of the liberation of Dnipropetrovsk	22	Lb, mm	3.46 ± 0.16	0.05	-0.23	-0.80
		Hb, mm	0.76 ± 0.09	0.12	0.28	-0.17
		Le, mm	1.96 ± 0.12	0.06	0.62	0.07
		Lb / Le	1.76 ± 0.08	0.05	0.27	-0.76
		Lb / Hb	4.60 ± 0.51	0.11	0.38	-1.14
		Le / Hb	2.61 ± 0.28	0.11	0.47	-0.58
Park named after T.G. Shevchenko	22	Lb, mm	3.44 ± 0.20	0.06	-1.17	0.37
		Hb, mm	0.78 ± 0.05	0.07	0.65	-0.37
		Le, mm	1.87 ± 0.15	0.08	-0.57	-0.83
		Lb / Le	1.85 ± 0.10	0.05	0.53	0.45
		Lb / Hb	4.40 ± 0.33	0.07	0.51	-0.22
		Le / Hb	2.38 ± 0.17	0.07	0.11	-1.21
Dnipro-Orel Nature Reserve	28	Lb, mm	2.79 ± 0.09	0.03	0.37	-0.95
		Hb, mm	0.67 ± 0.06	0.09	0.03	-0.88
		Le, mm	1.68 ± 0.16	0.10	2.19	4.82
		Lb / Le	1.67 ± 0.10	0.06	-2.32	5.39
		Lb / Hb	4.23 ± 0.36	0.08	0.40	-0.44
		Le / Hb	2.54 ± 0.27	0.11	0.51	-0.80

Note: Eco – ecosystem number, n – number of measured pupae, Characteristics – studied parameters and indices, x ± SD – mean ± standard deviation, CV – coefficient of variation, As – asymmetry coefficient, Ex – excess coefficient.

Significant asymmetry among pupae collected in the Taras Shevchenko Park was evident in body length (Lb, As = –1.17) and body height (Hb, As = 0.65). A significant harmful excess was observed in wing length (Le, Ex = –0.83) and wing length-to-body height ratio (Le/Hb, Ex = –1.21). Significant asymmetry and excess are not shown in the body length-to-body height ratio (Lb/Hb). Pupae collected in the Dnipro-Orel Nature Reserve significantly show positive asymmetry in wing length (Le, As = 2.19) and body length-to-wing length ratio (Lb/Le, As = –2.32). The excess is reliably seen by all the studied characteristics, except for body length-to-body height ratio (Lb/Hb): for body length (Lb, Ex = –0.95), body height (Hb, Ex = –0.88), wing length (Le, Ex = 4.82). Significant asymmetry and excess are not shown in the body length-to-body height ratio (Lb/Hb).

Based on the results of one-way analysis of variance based on linear characteristics, there is a significant (P < 1*10-6) difference between samples from diverse ecosystems (Table 3). The intergroup sum of squares by body length (Lb) was more significant than the squares' intragroup sum. According to the remaining linear characteristics, squares' intragroup sum was higher than the squares' sum between the studied groups.

Table 3. One-way analysis of variance ANOVA of interpopulation variability of *P. robiniella* linear characteristics (n = 140).

Characteristics	Eco	n	x ± SD	SSi	SSb	F	P
Lb	1	16	3.48 ± 0.17	5.1718	8.6013	44.5716	$<1*10^{-6}$
	2	34	3.34 ± 0.28				
	3	18	3.30 ± 0.19				
	4	22	3.46 ± 0.16				
	5	22	3.44 ± 0.20				
	6	28	2.79 ± 0.09				
	1	16	0.79 ± 0.16				
	2	34	0.82 ± 0.08				
	3	18	0.81 ± 0.09				
Hb	4	22	0.76 ± 0.09	1.0361	0.4321	11.1777	$<1*10^{-6}$
	5	22	0.78 ± 0.05				
	6	28	0.67 ± 0.06				
	1	16	2.12 ± 0.12				
	2	34	1.88 ± 0.20				
	3	18	1.73 ± 0.15				
Le	4	22	1.96 ± 0.12	3.4067	2.5767	20.2707	$<1*10^{-6}$
	5	22	1.87 ± 0.15				
	6	28	1.68 ± 0.16				

Note: Eco – the ecosystem number, x ± SD, SSi – the sum of squares within the studied populations, SSb – the sum of squares between the studied populations, F – the Fisher value, P – the degree of confidence.

Based on the results of one-way analysis of variance ANOVA of interpopulation variability of index characteristics *P. robiniella*, as in the case of linear characteristics, shows a significant (P < 0.001) difference between ecosystems (Table 4) for all the studied indices. The intragroup sum of squares was more significant than the intergroup sum of squares for all the indices studied.

Discussion

The rate of invasion and ecological plasticity shown by invasive species of the leaf blotch miners (Gracillariidae) attach great importance to observations of their populations' state (Holoborodko et al., 2018). Studies of trophic relationships of invasive lepidopteran miners will help develop a modern strategy for managing the number of these species, therefore protecting *R. pseudoacacia* as the leading forest and reclamation woody plant in the steppe zone of Ukraine.

Table 4. One-way analysis of variance ANOVA of interpopulation variability of *P. robiniella* linear characteristics (n = 140).

Characteristics	Eco	n	x ± SD	SSi	SSb	F	P
Lb / Le	1	16	1.64 ± 0.11	2.064	1.0733	13.9359	$<1*10^{-6}$
	2	34	1.79 ± 0.17				
	3	18	1.92 ± 0.13				
	4	22	1.76 ± 0.08				
	5	22	1.85 ± 0.10				
	6	28	1.67 ± 0.10				
	1	16	4.55 ± 0.86				
	2	34	4.11 ± 0.42				
	3	18	4.10 ± 0.37				
Lb / Hb	4	22	4.60 ± 0.51	30.7168	5.3343	4.6541	0.0006
	5	22	4.40 ± 0.33				
	6	28	4.23 ± 0.36				
	1	16	2.76 ± 0.45				
	2	34	2.30 ± 0.20				
	3	18	2.14 ± 0.18				
Le / Hb	4	22	2.61 ± 0.28	9.14	4.9003	14.3685	$<1*10^{-6}$
	5	22	2.38 ± 0.17				
	6	28	2.54 ± 0.27				

Note: Eco – the ecosystem number, x ± SD, SSi – the sum of squares within the studied populations, SSb – the sum of squares between the studied populations, F – the Fisher value, P – the degree of confidence.

According to our study results on Robinia trees occupation by miner species, the highest density of mines was found in ecologically cleaner green areas – Oles Honchar Dnipro National University Botanical Garden and the Dnieper-Orel Nature Reserve. The reason may be different living conditions; the miners inhabiting the green zones of Dnipro city may be affected by a complex of anthropogenic factors that suppressed miner populations' development. Thus, Robinia in urban areas is less likely to become infected with miners compared to trees in cleaner ecosystems. We can conclude that the most vulnerable Robinia specimens were those located outside the city boundary.

Morphological variability is one of the instances of adaptations that develop living organisms' accommodation to changes in environmental conditions (Komlyk and Brygadyrenko, 2019). Factor effects can accumulate in biological objects over a specific time. Morphological features of living organisms largely depend on their habitat. This is due to the diet's peculiarities, the breeding season, adaptation to a particular ecosystem. Morphological variability is characterized by changes in weight and linear indicators; this results from the influence of environmental factors.

Morphological variability of the population is an instance of general genetic polymorphism and an indicator of population potential stability under high anthropogenic load conditions on natural ecosystems (Komlyk and Brygadyrenko, 2020). The study of morphological variability in invertebrates allows us to assess the ability of the population to maintain constancy, the changes possible within the same species and deviations from the average size (Brygadyrenko and Korolev, 2015), as well as to assess the environment quality (Hodgkinson and Jackson, 2005). Morphological changes are most often assessed using morphometric indices (Komlyk and Brygadyrenko, 2020). Specimens not sufficiently adapted to their specific living conditions are eliminated by selection carried out at the individual level. This selection leads to changes in the average values of characteristics or indices and the parameters of statistical distribution, variability of characteristic range reflecting the optimal level of adaptation of the living organism to the environment. The abundance of insects determines their significant role in the functional support of ecosystems (Chen et al., 2004), and it is an essential component in the energy flow of both consumers and prey for insectivores (Cohen, 1978). Representatives of certain ecological groups give mixed response to urbanization, the number, and density of forest species decrease, while the indicators of ground beetles in open biotopes increases. The number of myxophytophages in urbanized areas is increasing.

According to our study results, there are significant differences in all linear characteristics and indices between groups of *P. robiniella* pupae. Each group corresponds to the ecosystem in which the leaves affected by the black locus miner were collected. However, on the constructed box graphs shown in Fig. 3, it can be noted that the distribution and values of both linear characteristics and indices in the initial five ecosystems is very different from the sixth ecosystem. Since the sixth ecosystem is the Dnipro-Orel Nature Reserve, located at a considerable distance from the city center and industrial areas, it can be considered a control is comparing its characteristics with ecosystems within the city limits. These differences may be caused by significantly different ecosystem conditions (Fig. 3a).

Pupae collected in the Dnieper-Orel Nature Reserve show less polymorphism than pupae collected in the city in terms of body length, body height, wing length, and body length-to-elytra-length ratio (Figs. 3 a, b, c, d). The intrapopulation polymorphism of two linear characteristics and three indices was more significant than the interpopulation polymorphism. From this, we can conclude that pupae's diversity within a particular population or ecosystem is more significant than pupae's diversity from diverse ecosystems. That is, conditions of ecosystems within the city limits have little effect on pupae's diversity of the black locust miner. However, when comparing samples of pupae collected within the city and that collected outside its borders, morphometric characteristics can vary quite a lot. Thus, for future research on this topic, it is important to carefully compare the Interpopulation polymorphism of *P. robiniella*to identify factors that may be responsible for differences in the morphology of pupae of this species.

Studies of pupae's morphometric characteristics of the black locust miner have shown that both linear characteristics and indices of pupae in the population are stable relative to the average value since a significant coefficient of variation is observed only in pupae collected in the Pridneprovsky Park. This may be due to insufficient sample size, so it is worth performing a similar analysis for a larger sample for further studies. However, skewness and excess coefficients indicate that most studied P. robiniella populations showed a trend to displace Poisson distribution. Moreover, in this case, the sample selected in the Dnipro-Orel Nature Reserve also differed significantly: the high coefficient of excess was found for wing length and the ratio of body length to wing length, compared to other ecosystems. The population closest by this parameter was shown in the Peoples' Friendship Park, a pristine ecosystem compared to the city center. A high excess coefficient indicates a tendency to reduce the number of specimens with characteristics that differ significantly from the average.

However, on the contrary, there is an increase in the number of individuals in other populations, which can potentially be very different from the average. This may be because, within the city limits, the black locust populations were affected by more stringent living conditions, so individuals who cannot adapt were eliminated from the population. The asymmetry coefficient also indicates similar processes in populations: specimen living in urban conditions tend to deviate in various indicators, while in the Dnipro-Orel Nature Reserve, the tendency to deviate is manifested only in elytra length, but the rest of the studied indicators are relatively stable. Such processes in populations indicate that pupae P. robiniella are influenced to a certain extent by stressful factors, in particular, anthropogenic factors.

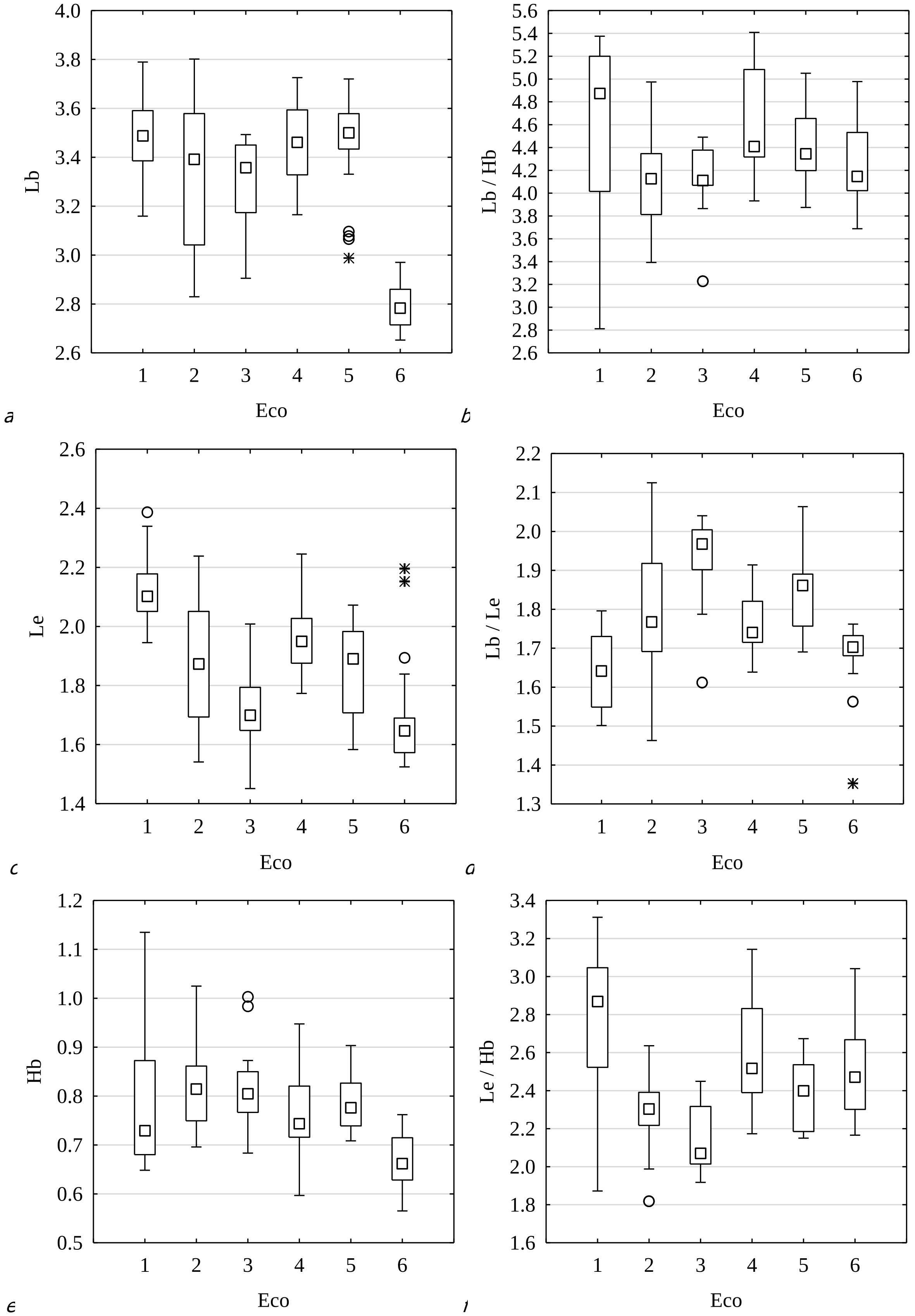

Fig. 3. Box-and-whiskers plots of *P. robiniella* variability: *a* – body length*, b* – body length-to-body height ratio*, c* – wing length*, d* body length-to-wing length ratio*, e* – body heigh*t, f* – wing length-to-body height ratio; on the abscissa axis: the ecosystem number, on the ordinate axis: parameter value.

Conclusions

There were significant differences between groups of *P. robiniella* pupae collected from different ecosystems according to the level of anthropogenic load for all linear characteristics and indices. The intrapopulation polymorphism of two linear characteristics and three indices of the six characteristics studied is higher than the interpopulation polymorphism. From this, we can conclude that pupae's diversity within a particular population or ecosystem is greater than the diversity of pupae from diverse ecosystems. Thus, ecosystem conditions within the city limits have little effect on black locust miner pupae's diversity. However, when comparing samples of pupae collected within the city and that collected outside its borders, morphometric characteristics can vary quite a lot. Thus, for future research on this topic, it is important to carefully compare the Interpopulation polymorphism of *P. robiniella* to identify factors that may be responsible for differences in the morphology of pupae of this species.

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