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Contribution to the diversity of leaf miners of silver birch, *Betula pendula* Roth in North-Eastern Kazakhstan

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ABSTRACT. To date, Kazakhstan is an underexplored territory regarding the study of leaf miners. This article aims to present new data on the defoliators of silver birch (*Betula pendula Roth*) in cultivated plants of North-Eastern Kazakhstan (the Pavlodar Region). Occurrence of *Fenusa pumila* Leach, 1817, as well as additional new data on the previously known leafminer species are presented for the first time for the Pavlodar Region. Groups of birch-defoliating insects were chosen as model objects. The research conducted in the territory of the Pavlodar Region revealed six species of leaf miners belonging to three genera *Stigmella* Schrank, 1802, *Phylloporia* Heinemann, 1870, and *Fenusa* Leach, 1817. All representatives are obligate miners that develop at the larval stage in the mesophyll of birch leaves. This group of insects harmfully affects plants, often causing their death, which in turn proves the importance of studying them.

Keywords: Central Asia, conservation, defoliators, forest, invasive species

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INTRODUCTION

Recurrent large-scale outbreaks of forest defoliators often serve as a factor in the significant reduction of forest stand resistance even in the absence of mass reproduction (Bussotti et al., 2024). This is also accompanied by a decrease in birch resistance to other negative biotic and abiotic factors (Chamard et al., 2024). As a result, temporarily weakened forests are often affected by infectious diseases and leaf miners. Poor knowledge of entomological complexes hinders the prevention and control of forest pests (Isaev, 1981). The silver birch, or warty birch (*Betula pendula* Roth) is a botanical species of the genus *Betula* in the family Betulaceae. It is widespread in the Northern Hemisphere, particularly in northern

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areas of temperate and boreal climates (Ashburner & McAllister, 2013), prevailing in Europe and Southwest and Central Asia; although in southern Europe, it is only found at higher altitudes (Grozdova et al., 1986; Gubanov et al., 2003). Its range extends into Siberia, China, and southwest Asia in the mountains of northern Turkey, the Caucasus, and northern Iran. *Betula pendula* has a wide range in the European part of Russia (from the tundra to the steppes), in the Altai and Caucasus with the eastern border in Lake Baikal. The Pavlodar region is in the northeast part of Kazakhstan, in a place with many open grassy areas called the steppe, where birch trees are found in abundance (Sarsekova, 2021). However, there are few publications devoted to the study of the entire complex of defoliating insects associated with coenopopulations of woody plants in general, and with *Betula pendula* in particular (Kutenkova, 1990, 1991; Turmukhametova & Dorogova, 2014).

In these forests, numerous insect species attack birches and other trees. Among invasive herbivore insects, leaf miners represent an important group (Shvydenko et al., 2021). Many leaf miners are known as economic pests of crops, whereas others threaten forest and urban plants (Lopez-Vaamonde et al., 2021). Leaf miner larvae live inside leaf tissues feeding on the parenchyma or epidermis, building cavities called mines. They are known from four insect orders, i.e., Lepidoptera, Hymenoptera, Coleoptera, and Diptera, accounting for more than 10,000 species worldwide (Dantas et al., 2021). Mines are often species-specific and can provide a diagnostic tool for species identification (Dobrosavljević et al., 2020). Because of their endophagous lifestyle, leaf miners tend to be specific to their host plants, usually at the genus level, although there are many exceptions (Gely et al., 2019). The birch leaf miner, *Fenusa pumila* Leach, 1817, is among the most common insects that affect landscape trees and shrubs in Kazakhstan (Kirichenko et al., 2018). They form blotch mines, where partial or whole areas inside the leaves are consumed. In Kazakhstan, two commercially important tree-like birch species occur naturally: silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.) (Isakov, 2021). In recent years, leaf miners have attracted much attention due to their increasing invasion record (Kobayashi et al., 2020). Biological studies related to insect miners represent a relatively young domain in modern entomology. The presence of birches in the artificial forest belts of the region and their resettlement in natural biocenoses became the reason for our research on organisms associated with this culture (Andersen et al., 2021; van Driesche et al., 2023). To date, Kazakhstan is an understudied territory regarding the research of leaf miners. There is a practical need to understand the principles of leaf miners' introduction and ways of their translocation to the territory of Kazakhstan, the degree of colonization of woody vegetation by new species, and their relationship with species typical of Kazakhstan and its specific regions. Kirichenko et al. (2017) made a valuable contribution to the study of the diversity and distribution of leaf-mining insects on *Betula* species in Siberia (Russia). They used modern molecular genetic tools that allowed them to obtain reliable results regarding taxonomic richness and discover novel species (Kirichenko et al., 2017). Bogacheva and Zamshina (2017) studied the community of birch leaf miners in large cities. These scholars, having investigated defoliators in Yekaterinburg territory, discovered 81 leaf-mining species. The largest taxonomic group was Lepidoptera (37 species), and the ecological groups of gnawing open-living insects (26 species) predominated among the leaf miners. It was shown that species richness and the structure of insect communities differed insignificantly among categories of urban green spaces. However, the species richness of insect communities, species number of open-living insects, and their proportion in insect communities are reduced in the streets of the city center. Three factors were revealed: high pollution of air and food plants dustiness (for biotopes of 6 and 7 categories); high shading of plants (for biotopes of 1–3 categories); and the young age of trees, which reduce the species richness of leaf-mining insect communities and change their structure (Bogacheva & Zamshina, 2017).

Thus, the reasons for the appearance and development of mass reproduction foci of certain silver birch defoliators, especially in the Pavlodar region, have not been sufficiently studied. Little scientific data has been accumulated regarding the ecological characteristics of some defoliators in various geographical provinces of Kazakhstan. In the present study, defoliating insects that mine birch leaves in the Pavlodar region were studied in detail, and different species of birch miners were identified and classified.

MATERIAL AND METHODS

The study area. Most of the territory of the Pavlodar region is located to the south of the West Siberian Plain in the middle reaches of the Irtysh River and currently occupies an area of 127.5 thousand km² and borders the Russian Federation, Karaganda, East Kazakhstan, Akmola and North Kazakhstan regions. The climate of the Pavlodar region is sharply continental, characterised by cold, long winters (5.5 months) and hot, short summers (3 months). The vegetation in the Pavlodar region is mostly undiversified and homogeneous, steppe. Elm, poplar and birch are common among cultivated plantations. Locations representing different categories of green spaces were selected for the study in cities. Forest parks are plantings that are closest to natural forests. We used six forest parks for our work: 1) plantings adjacent to forest parks; 2) city parks inside continuous buildings – territories of different sizes that can preserve individual trees and bushes (and sometimes fragments of former ecosystems) growing once in these locations; 3) block green belts, including plantings around hospitals and schools; 4) planted vegetation in busy city streets with significant traffic load.

Sampling and rearing the specimens. The areas of leaf sampling collection are in the cities of Pavlodar, Ekibastuz, and Aksu and in the villages of Aktogay, Koktobe, and Zhelezinka (Fig. 1). Leaves were gathered during the growing seasons of 2019–2022 in three rounds: (1) June 25–28, (2) July 30–August 1 (in all four plots), and (3) August 29–30 and September 3 (in two plots) (Fig. 2). Compared with long-term average values, plant phenological dates were delayed by 7 ± 6 days (±SD) in early spring, 11 ± 10 days at the onset of the growing season, 15 ± 3 days at the peak of spring, and 10 ± 9 days in summer. In insects, the overall delay in spring–summer phenological dates was 10 ± 5 days. In each plot, leaves were collected from ten model trees of each species by cutting a branch with 30–40 leaves from each tree at a height of 1.5–2.5 m, regardless of its position in the crown relative to the cardinal points. When possible, branches were cut from trees of different species growing within the same local group. At the points of vegetation of fodder plants, the generative and vegetative organs of the plants were visually inspected to record the wounded points. Standard entomological methods were used: shaking, mechanical capture of individual insects and colonies, mowing with an entomological net (Egorova et al., 1987; Khmelev et al., 2000), and use of stem and soil traps in the trunk part of the tree (Gilyarov, 1975). The methods described by Lopez-Vaamonde et al. (2021) and Hering (1951) were used to rear adult birch leaf miners. Since larvae of miner insects continue their development outside the mines and pupate in the soil, for this purpose, a 2.0–3.0 cm layer of moist soil was placed at the bottom of plastic containers (0.5 litres) on which leaves with mines were placed. The lids of the containers were punctured for air circulation. To avoid wilting of leaves, their petioles were wrapped with moist cotton wool beforehand. Larvae that had finished feeding emerged from the mines and pupated in the soil. The transformation from pupa to adult took about 7–10 days. Due to climatic differences (humidity, temperature, etc.), many larvae did not survive to the adult stage. Therefore, the collection period itself was considerably reduced, which subsequently reduced the possibility of rearing larvae into adults (out of 20–30 larvae only one grew to Adult) (Fig. 3). The collected material is stored and kept by the corresponding author and is their collection.

Identification of species. The identification of leaf mine types was made in the field based on the characteristics of the mines using the catalogues of Johansson et al. (1990) and Kuznetsov (1981), and by living larvae, which we managed to grow. Particular attention was paid to the way the eggs were laid, the shape of the mine, its size and depth, colour, any holes, and the surrounding parts of the leaf. The Plant Parasites of Europe website (Ellis, 2020) was used as an additional source for species identification. The photos were taken using a Nikon® D5600+18-140 VR digital camera.

Evaluation of leaf damage. Birch leaves were examined to assess the taxonomic diversity of leaf miners. The pathological condition of trees was estimated by sight: weak degree – up to 25% of leaves are damaged, insects and mines are rare; medium degree – up to 50% of leaves are damaged; strong degree – more than 50% of leaves are damaged; and mines are abundant (Tuzov, 2004). In the laboratory environment, the affected leaves were placed in the packing plastic bags. One or two dozen leaves from each plant were put into a plastic bag, together with a working (temporary) label containing information about the taxonomy of the plant (each of the plant species was later agreed with specialists), the place and date of collection.

Figure 1. Places of collection of birch leaves mined by insects in the Pavlodar region (compiled by the authors during field studies).

The components of each collection were recorded in a field diary according to the method. The leaves were spread on a clean and dry surface for 12 hours. The leaves were chosen with a small wig, which contributed to the further hatching of adult insects from pupae and larvae (Nahrung & Carnegie, 2020). This procedure increased the life span of leaf miners and increased the chances of the successful development of adult insects. Under laboratory conditions, mines were also carefully opened with a dissected needle to study the preimaginal stages and identify other entomofauna inhabiting them; a stereoscopic microscope and a digital camera were used in this case, while the adult insects were identified using determinants (Valan et al., 2019).

Statistical analysis. In all cases, a model tree was used as a statistical unit (n=300; ten trees of each of the three species in four plots during the first and second sampling rounds and in two plots during the third round) (Kilpeläinen et al., 2022). Parameters of leaf damage in *A. negundo* and native species were compared using linear mixed models (LMMs), where tree species and sampling round were fixed factors and plot number was a random factor. Variables expressed as proportions were arcsine transformed before analysis. The false discovery rate (FDR) in multiple tests was controlled using the Benjamini–Yekutieli procedure (all *p-values* shown in the text and table are FDR-corrected). The calculations were performed using JMP 10.0.0. During the study, common and rare species of defoliating insects were recognized after statistical processing. After collection, the total number of leaves was calculated. From there, more common/rare species for the region were identified by proportion. After the collection of 2000 leaves of silver birch, all mined leaves were herbarized. They have a special label with the following data: date and time of collection, fodder plant, place of collection, and name of the miner pest. This also gives the opportunity to analyze and draw conclusions about which species of miner insect does the most harm depending on the extent to which the leaf plate was damaged, the area of the mine and the general condition of the tree. All these data are entered into the diary during field research.

Figure 2. Places of collection (some of them) of birch leaves mined by insects in the Pavlodar region (photos taken by the authors). **A.** The main river bank street of the Pavlodar City (June 2019); **B.** Bayanaul National Park (mid to late June 2022); **C.** Aqsu City Ecopark (early to mid-July 2021).

RESULTS

A detailed study of birch leaf miners in the Pavlodar Region, Kazakhstan, was conducted, and different leaf miners were identified. All species of Nepticulidae in the Pavlodar region belong to the genus *Stigmella* (Lep., Nepticulidae)(4 species). Species of other leaf miners are less common: *Phylloporia* (Lep., Incurvariidae)(1 species) and *Fenusa* (Hym., Tenthredinidae) (1 species).

Taxonomic hierarchy

Class Insecta

Order Lepidoptera Linnaeus, 1758

Family Nepticulidae Stainton, 1854

Genus *Stigmella* Schrank, 1802

***Stigmella naturnella* (Klimesch, 1936)** (Fig. 3A)

During leaf collection in the Pavlodar Region, 233 mined leaves (*Betula* sp.) were found from the beginning of June to the end of August 2019–2022 in Pavlodar: City Embankment, Victory Public Garden, Shanyrak Public Garden, Constitution Public Garden, Central Public Garden, Gagarin Park, Afghans Park; in Ekibastuz: Miner Park; in Aksu: City Park; and in Koktobe village: Victory Park.

***Stigmella lapponica* (Wocke, 1862)** (Fig. 3B)

During leaf collection in the Pavlodar Region, 267 mined leaves (*Betula* sp.) were found from the beginning of June to the end of August 2019–2022 in Pavlodar: City embankment, Central Public Garden, Gagarin Park, Afghan Park; in Ekibastuz: Miner Park; Aksu: City Park; and in Koktobe village: Victory Park.

***Stigmella luteella* (Stainton, 1857)** (Fig. 3C)

During leaf collection in the Pavlodar region, 58 mined leaves (*Betula* sp.) were found from the beginning of June to the end of August 2019–2022 in Gagarin Park, Pavlodar.

***Stigmella continuella* (Stainton, 1856)** (Fig. 3D)

During leaf collection in the Pavlodar Region, 21 mined leaves (*Betula* sp.) were found from the beginning of June to the end of August 2019–2022 in Pavlodar: Teatralny Public Garden.

Family Incurvariidae Spuler, 1898

Genus: *Phylloporia* Heinemann, 1870

***Phylloporia bistrigella* (Haworth, 1828)** (Fig. 3E)

During leaf collection in the Pavlodar Region, 49 mined leaves (*Betula* sp.) were found from the beginning of June to the end of August 2019–2022 in Pavlodar: Victory Public Garden.

Order Hymenoptera Linnaeus, 1758

Family Tenthredinidae Latreille, 1802

Genus *Fenusa* Leach, 1817

***Fenusa pumila* Leach, 1817** (Figs 3F, 4)

During leaf collection in the Pavlodar Region, 55 mined leaves (*Betula* sp.) were found from the beginning of June to the end of August 2019–2022 in Pavlodar: Teatralny Public Garden, Victory Public Garden, 3/1 Toraigyrov St.

Occurrence of the leafminer species. Within the territory of the Pavlodar region, this study revealed four species of the genus *Stigmella* Schrank, 1802 and two species belonging to the genera *Phylloporia* Heinemann, 1870 *and Fenusa* Leach, 1817. During the research, it was found that *Stigmella lapponica* (Wocke, 1862) and *Stigmella naturnella* (Klimesch, 1936) were predominant among the six species of miner insects. But if we consider them from the viewpoint of damage to the plant, we can say that *Phylloporia bistrigella* (Haworth, 1828) and *Fenusa pumila* Leach, 1817 are more harmful than the other four species (noticeable from the mined leaves). It was noted that most leaf miners belong to the Nepticulidae (*Stigmella* species) and constitute 85% of the total diversity of defoliators. This genus is distributed everywhere, in the immediate vicinity of the Irtysh River, and at a distance from it, closer to the central Kazakhstan region (Ekibastuz). The Nepticulidae comprises four species of birch leaf miners in the region. Analyzing the distribution of leaf miners of this taxon, we found that representatives of *S. naturnella* and *S. lapponica* were most widespread. These types of leaf miners are found everywhere on birches. The exception is the *S. continuella* species, which was found only in Pavlodar and was not found in collections of birch leaves in Aksu, Ekibastuz, and the southern and northern areas of the region.

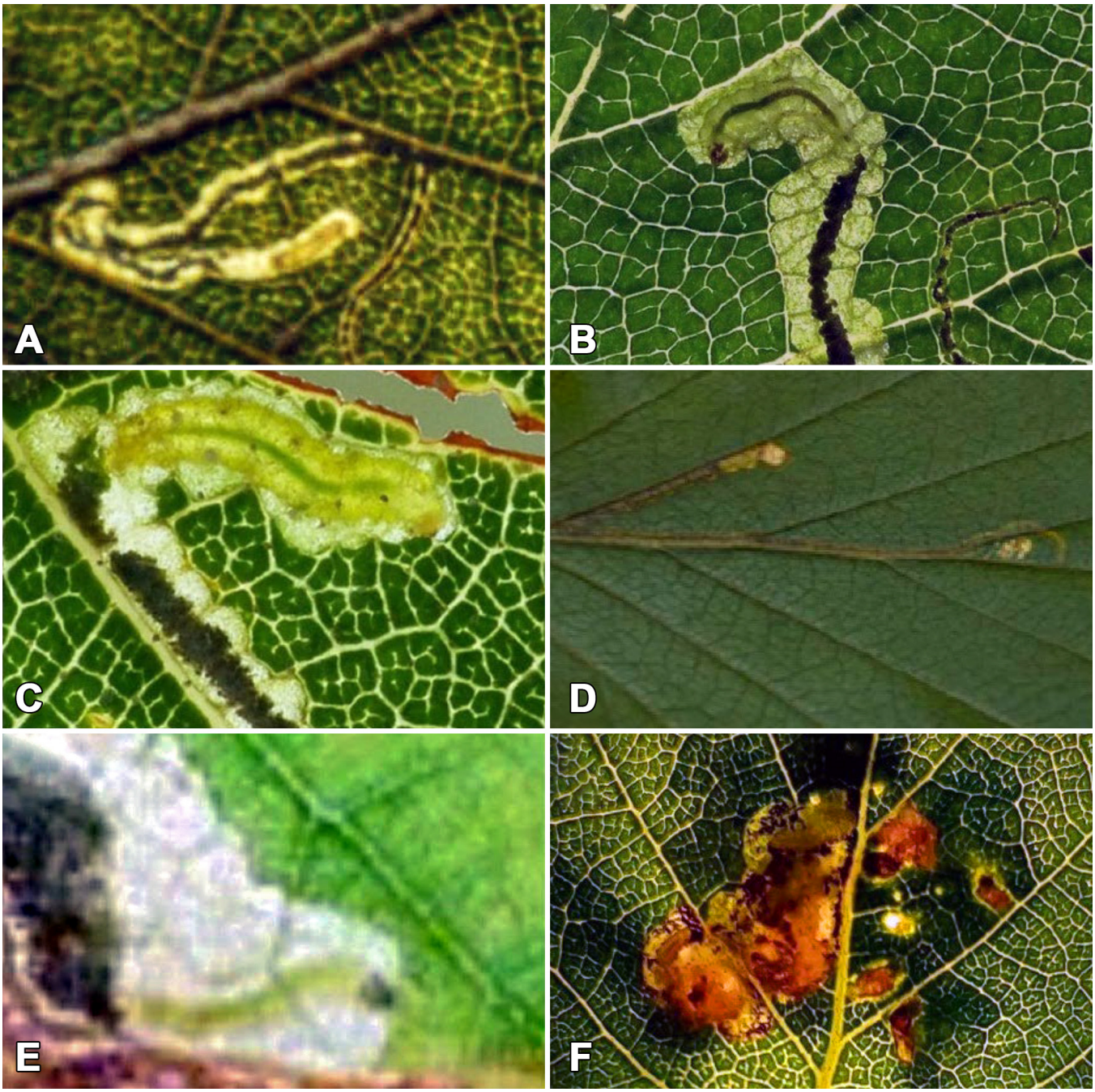

Figure 3. Mining insects in the larval stage on birch leaves. **A.** *Stigmella naturnella* (Klimesch, 1936); **B.** *Stigmella lapponica* (Wocke, 1862); **C.** *Stigmella luteella* (Stainton, 1857); **D.** *Stigmella continuella* (Stainton, 1856); **E.** *Phylloporia bistrigella* (Haworth, 1828); **F.** *Fenusa pumila* Leach, 1817 (photos by M. Zhussip).

In general, the identified species are characterized by thriving in environments that are rich in trees and confinement to fodder plants of certain species, i.e., monophagy. Potentially harmful pests are *S. lapponica*, *P. bistrigella,* and *F. pumila* because they form a large mine on the leaf blade, in some cases several mines, which leads to plant suppression and defoliation. *Fenusa pumila* is one of the factors that significantly worsens the condition of silver birch. Unfortunately, chemical treatments are ineffective against these defoliating insects; therefore, further study of these species is required to determine the most effective way to combat them.

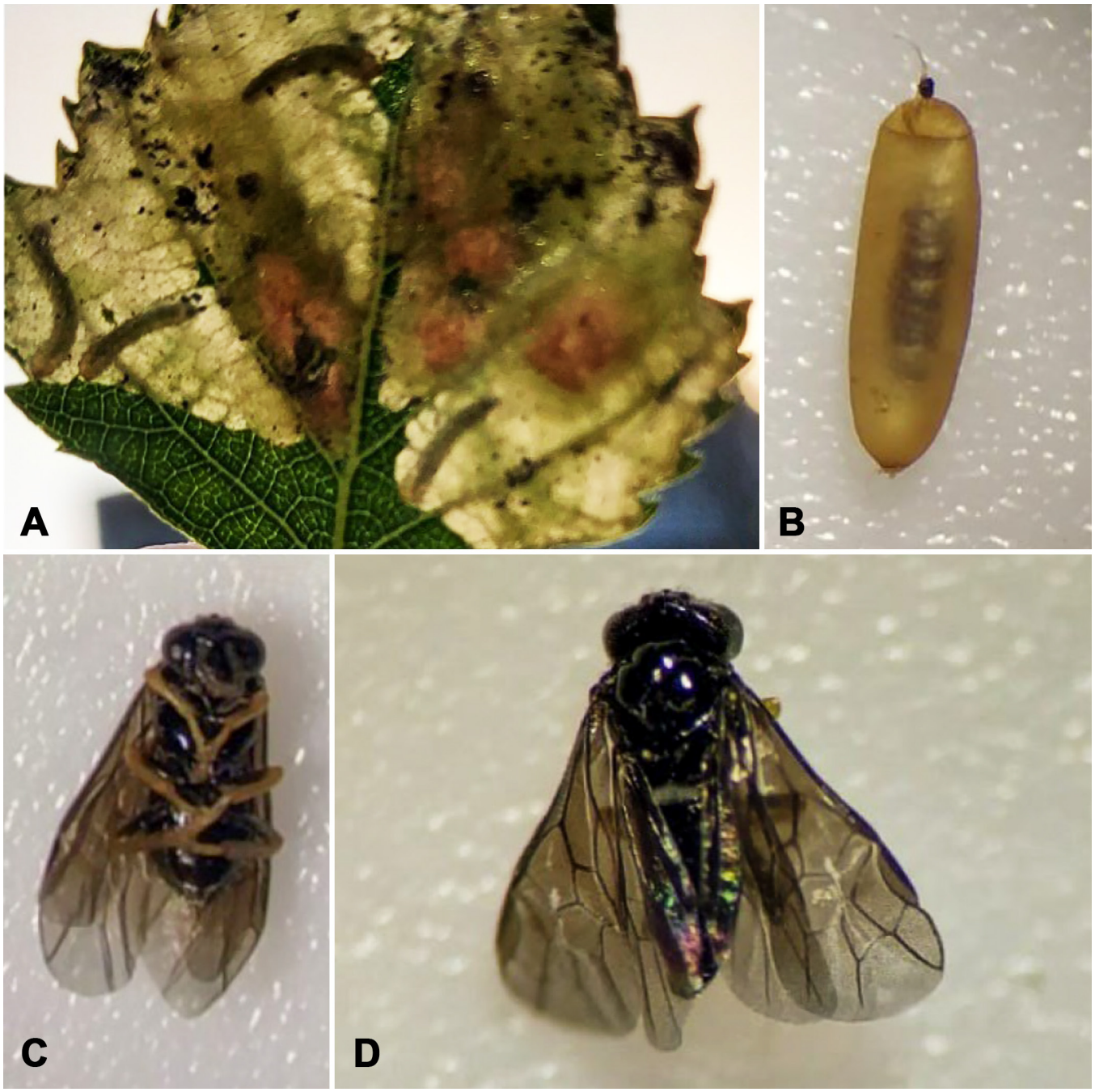

Figure 4. The life cycle of *Fenusa pumila* Leach, 1817 in birch leaves. **A.** Infested leaf with miner larvae; **B.** Pupa; **C.** Adult sawfly (photos by M. Zhussip).

Leaf damage. More than 2000 birch leaves were examined in this study, and six species of the Nepticulidae, Incurvariidae, and Tenthredinidae families belonging to three genera were identified in the region: *Stigmella*, *Phylloporia*, and *Fenusa*. Each leaf miner consumes only a relatively small amount of leaf matter during its life; comparing miners with free-living species, one would assume that miners could never cause real damage to trees and plants cultivated by man. However, some species should be treated as separate pests. They appear either in excessive numbers when there are no leaves left on some trees or when they appear very early, which causes significant damage to the development of very young plants. Numerous small lesions accumulate and cause great harm to the development of the

infected tree (Pálsson et al., 2023). Among the examined leaves, 683 were damaged by miners. Hand calculation (the process of performing mathematical operations using only pen and paper, without the aid of electronic devices) was used as the method for counting (Fig. 5). Many mine characteristics are most easily recognized from a fresh leaf that has not yet had time to dry. The bulk of leaf damage was inflicted by leaf chewers (chewed-off or skeletonized leaves). This type of damage was the only one in *A. negundo* because leaf mines and galls in this species were recorded in single cases and only during the first and second sampling rounds (in only 1–3 out of 1280–1360 leaves examined). During the third round, the proportion of leaves with mines in *B. pendula* and *S. caprea* was 6.2%–6.9% and that of leaves with galls was 0.6%–4.3%. Damages categorized as "other" (leaves with blotches, spots, necrotic areas, etc.) occurred with similar frequencies in all three species. In some cases, it appeared that they were inflicted by leaf-sucking insects or resulted from fungal infection; however, their origin usually remained unclear. The frequencies of such damage in *B. pendula* ranged between 25–53% during the first sampling round, 67–87% during the second round, and 94–99% during the third round. The total proportion of leaf area removed by the leaf mining proved to differ significantly between tree species ($p<0.0001$) and between sampling rounds ($p<0.0001$). On average, this proportion was the lowest in *A. negundo* (<1% during all rounds), intermediate in *B. pendula* (5.8% during the third round), and highest in *S. caprea* (7.5% during the third round). Moreover, the loss of leaf area due to leaf miners markedly increased during the growing season in *B. pendula* and *S. caprea* but remained unchanged in *A. negundo* (Fig. 6). The seasonal dynamics of this trait in *B. pendula* and *S. caprea* and its absence in *A. negundo* are confirmed by the high statistical significance of the interaction of the factors "tree species" and "sampling round" ($p=0.0008$). Figure 6 presents the shares of species of each genus from their total number. Figure 4 presents mining insects in the larval stage on birch leaves.

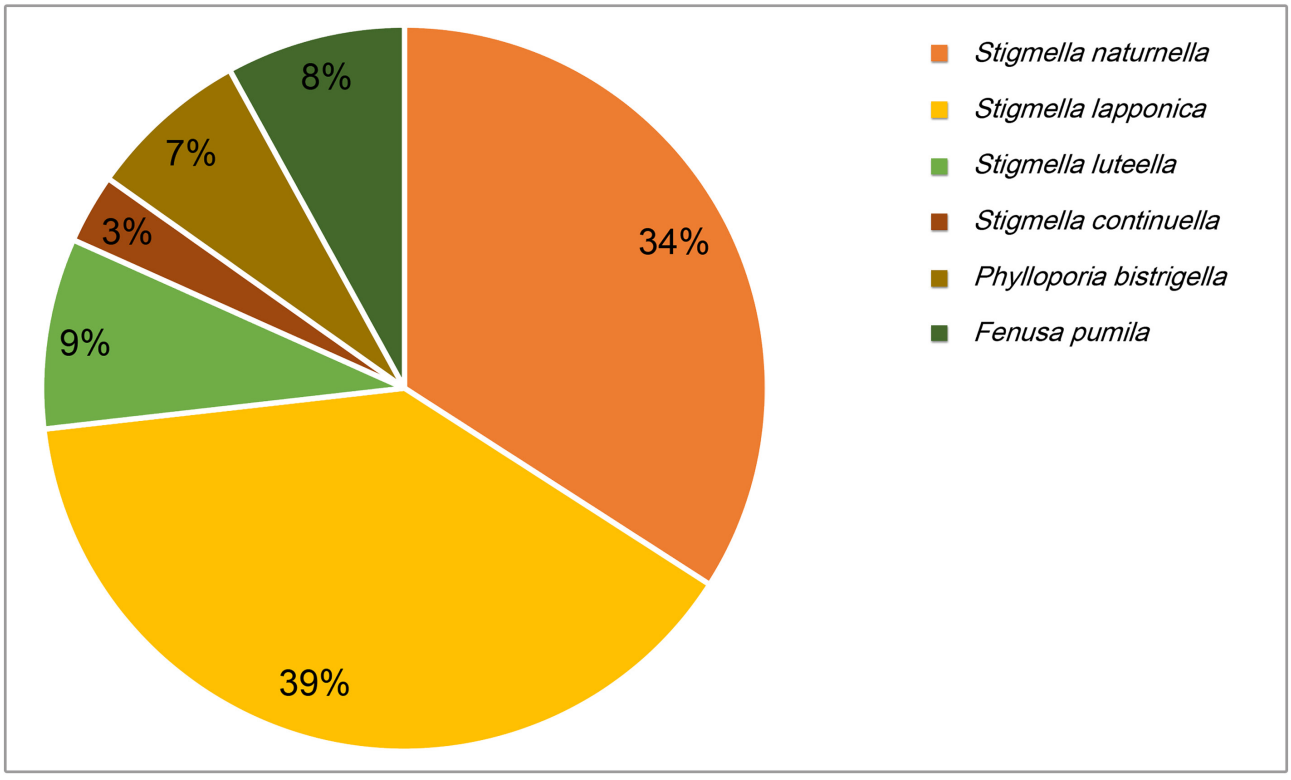

Figure 5. The percentage of the silver birch leaves damaged by the various leafminers in the Pavlodar region.

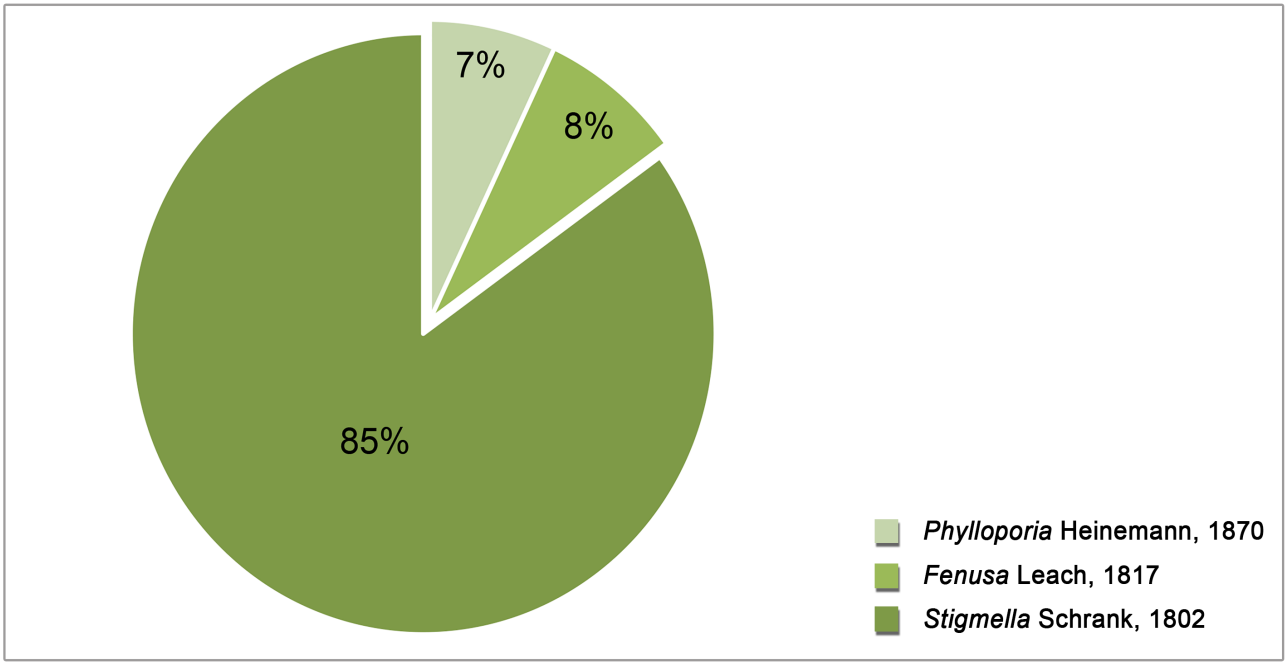

Figure 6. Proportion (%) of leaf miners by genera in forests of the Pavlodar region.

DISCUSSION

Table 1 shows the distribution of birch in Kazakhstan and other countries where it is abundant (Dubois et al., 2020). In the Nordic countries, the proportion of birch out of the total volume of the growing stock varies between 11% and 16% and between 17% and 28% in the Baltic countries (Table 1). Birch is also a very important commercial tree species in Russia and Kazakhstan. Most of the birch resources occur in mixed stands dominated by conifers; however, in Kazakhstan, silver birch is also grown in pure even-aged artificially regenerated stands. When studying approximately 1000 birch trees in the Pavlodar region from six settlements (Pavlodar, Ekibastuz, Aksu, Bayanaul village, Koktobe village, and Zhelezinka village), leaves were sampled in more than 40 locations, and six species of birch defoliating insects were found. Lepidoptera (5 species) predominate among taxonomic groups, and openly living defoliators (6 species) dominate among ecological groups. *Stigmella naturnella* is widespread in Central and Western Europe, namely in Austria, Belgium, Croatia, Czech Republic, France, Germany, Hungary, Italy, the Netherlands, Poland, Slovakia, Switzerland, Ukraine, and Russia (van Nieukerken, 2023), and Japan (Hirano, 2013), except the Balkan Peninsula and islands of the Mediterranean Sea (van Nieukerken, 2023). *Stigmella lapponica* is distributed almost throughout Europe, except for the Balkan Peninsula and the islands of the Mediterranean Sea (van Nieukerken, 2023). In the United States, more than 1,148 *Coccoidea* species have caused damage to ornamental plants and fruit trees. Cochineals are either pests or pose a potential threat. They spread in different ways (Miller et al., 2005). Several exotic *Coccoidea* species have been introduced to North America and Europe through the ornamental plant and fruit trade (Pellizzari & Porcelli, 2014). Major encyclopedic studies were also conducted on the sawfly in North America, which provided the basis for subsequent ecological research. Foreign experts studied the biology of five species of birch mining sawflies that were unintentionally imported in the 20th century from Europe: *Profenusa thomsoni* (Konow, 1886), *Fenusa pumila* Leach, 1817, *Heterarthrus nemoratus* (Fallen, 1808), *Fenusella nana* (Klug, 1816), and *Scolioneura vicina* Konow, 1894 (Baran, 2013). Leaf pests belonging to the leaf miner group are a taxonomically diverse association of endophagous insects. Taxa represented by important invasive species are of particular importance in the leaf miner group (Dantas et al., 2021; Steyn et al., 2020).

Table 1. Birch growing stocks in different countries.

Country	Total volume of birch (Mm^3 - Megameters)	Proportion of the total volume (%)
Russia	11,023	14
Finland	357	16
Sweden	334	11
Kazakhstan	233	24
Latvia	154	28
Norway	126	16
Estonia	101.6	22
Poland	76.7	4.3
Ukraine	75	4
Lithuania	69.4	17

The average number of species per location (species richness) was the lowest in the biotopes of the forest park category. However, the total number of species found in the biotopes of this category is quite large. In terms of the species composition of defoliating insects, biotopes of different categories differ quite strongly from each other: there are many openly living gnawing species in categories 0-1 that are not found closer to the city center; in category 2, the number of species of sucking insects sharply increases. In busy streets, the proportion of openly living gnawing species is lowest. It was found that the communities of defoliating insects in urban biotopes are most similar in composition to those in urban parks. Locations of different categories and even of the same category of biotopes can differ significantly in species richness. The reasons for the decrease in species richness may be a significant decrease in illumination in biotopes 1–3, high pollution of the air and the plantings themselves, high temperature and low humidity of air and soil in biotopes 6 and 7, and young age of trees in any category of biotopes. While moving from the outskirts to the city centre, some species are replaced by others; however, species richness and the structure of insect communities change slightly. Only in the central city streets did the detected species show a slight decrease in overall richness and the number and proportion of openly living gnawing insects. Biological invasions of alien species into cenoses are recognized as a significant agent of global environmental changes because they affect biodiversity and ecosystems through various mechanisms, such as interspecific competition for resources or space and habitat change. According to the researchers, the above leads to a significant loss of economic value, biological diversity, and functions in the invaded ecosystems. It also affects taxonomy at different trophic levels (Péré et al., 2009; Sinchuk et al., 2020).

This study had some limitations. The results of the research are aimed only at determining the species diversity of miner insects of silver birch in the Pavlodar region. A herbarium was collected during the field research. Larvae were grown from the leaves and preserved in alcohol (although there were left few of them because many of the larvae died or became unsuitable for research in the process (mould, etc.). No photographs of the larvae were taken because there was no microscope at hand. The research materials make a certain theoretical and practical contribution to the study of the biodiversity of insect miners. The results provide a holistic view of the formation of leaf miners of silver birch in the Pavlodar region. The obtained data make a significant contribution to the study of entomofauna. It can be valuable and used by biologists, ecologists, and plant protection specialists, for the development of recommendations and preventive measures against green plant pests in the Pavlodar region. The results can be implemented in the courses of the university curriculum for ecology and biology students.

As aforementioned, the topic of the present article has not been touched upon yet and all the results obtained are novel and unique for the Pavlodar region. It was observed that the number of mining insects decreased in 2022 compared to 2019–2021. On the one hand, this may be caused by changes in climate and ecology. On the other hand, it may be related to the intensification of measures taken by the country against insects in the spring and summer periods. The information reflected in the article can be used to create a regional database on insect pests. This is crucial for monitoring changes in populations and biodiversity in the region. These data can serve as a basis for the development and implementation of programs on biodiversity conservation and nature protection. This in turn can interest not only Kazakhstanians but also foreign scientists, as the information on leaf miners of silver birch in the Pavlodar region has not been described anywhere yet and is unique for today. It should be noted that the materials of this study are especially significant for scientists from bordering countries, as the migration of leaf miners occurs accidentally, for example, through the import/export of products. Timely awareness will help in the management, control and development of measures to prevent invasions of harmful species.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: M. Zhussip: Conceptualization, methodology, validation, investigation, data curation, writing—review and editing, project administration, funding acquisition; K. Akhmetov: Conceptualization, methodology, formal analysis, writing—review and editing, supervision; U. Burkitbaeva: Software, formal analysis, writing—original draft preparation, visualization; G. Amanova: Formal analysis, investigation, writing—original draft preparation; L. Mazhenova: Resources, writing—original draft preparation. The authors read and approved the final version of the manuscript.

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AVAILABILITY OF DATA AND MATERIAL

The voucher specimens listed in this study are deposited in the personal collection of the authors, and are available from the curator, upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included plants and arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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مطالعهٔ تنوع مینوزهای برگ درختان توس، *Betula pendula* Roth در شمال شرق قزاقستان

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چکیـــده: قزاقستان، تاکنون به عنوان یک کشور کمتر بررسی شده به لحاظ مطالعه کنندگان برگ مطرح بوده است. هدف این مقاله، ارایه داده‌های جدید در مورد حشرات برگخوار درختان توس (*Betula pendula* Roth) در منطقه شمال شرق قزاقستان (منطقه پاولودار) است. حضور زنبور *Fenusa pumila* Leach, 1817 و همچنین اطلاعات جدید در مورد گونه‌های مینوز قبلا شناخته شده، برای اولین بار از منطقه پاولودار ارایه شد. در این تحقیق، گروه حشرات مینوز به‌عنوان مدل‌های برگ‌خوار انتخاب شدند. بر اساس مطالعه انجام شده، شش گونه مینوز متعلق به سه جنس شامل *Stigmella* Schrank, 1802، *Phylloporia* Heinemann, 1870، *Fenusa* Leach, 1817 در منطقه پاولودار انتشار داشتند. همهٔ گونه‌ها، مینوز اختصاصی بوده و مرحله لاروی آنها در مزوفیل برگ‌های توس فعالیت دارند. این گروه از حشرات به گیاه آسیب زده و نهایتا منجر به زوال آن می‌شود و به همین لحاظ مطالعه آنها اهمیت زیادی دارد.

واژگـــان کلیدی: آسیای مرکزی، حفاظت، برگ‌خوارها، جنگل، گونه‌های مهاجم