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Degradation of *Betula* spp. under the influence of biotic factors in the forests of Ukrainian Polissia

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Abstract: The paper examines the impact of biotic factors – mainly pests and pathogens – on the degradation of *Betula* spp. in the forests of Ukrainian Polissia. The taxonomic structure of the identified mycobiota includes representatives of 9 genera, 8 families, 5 orders, 4 classes, and two divisions (Ascomycota 44.4%, Basidiomycota 55.6%). Xylotrophic Basidiomycetes, particularly *Fomitopsis betulina* and *Fomes fomentarius*, pose the greatest threat due to their ability to destroy wood tissues. The bacterial pathogen *Lelliottia nimipressuralis*, the agent of wetwood, also plays a major role, impairing xylem water transport and causing systemic physiological imbalance in affected trees. Entomofauna significantly contributes to degradation processes. A total of 31 insect species were recorded, belonging to five orders, 24 families, and 29 genera, with Coleoptera being the most numerous (32.3%). The most harmful are xylophagous species (e.g. *Agrilus betuleti*, *Rhagium mordax*) and phytophagous species (e.g. *Geometra papilionaria*, *Parornix betulae*), which cause mechanical tissue damage and facilitate secondary infections. The results indicate that pathogenic complexes intensify under environmental stress, accelerating the decline of *Betula* spp. stands. These findings underscore the necessity for ongoing phytosanitary monitoring and adaptive management measures to mitigate further degradation risks in the birch forests of Polissia.

Keywords: harmfulness; pathogen; pests; symptoms; wood-destroying fungi

Betula spp. (birch) is one of the leading components of natural and artificial forest stands in Ukrainian Polissia, fulfilling important ecological, soil-protective, and biotopic functions. Ukrainian Polissia is characterised by a high forest cover rate (Shvidenko et al. 2017). The dominant tree species in the region's stands are *Pinus sylvestris*, *Quercus robur*, *Alnus glutinosa*, *Betula pendula*,

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and *Betula pubescens*, which collectively account for a significant share of the mixed and pure stands (Shvidenko et al. 2017; Goychuk et al. 2018). Birch is characterised by high ecological plasticity, the ability to colonise various soil types, tolerance to frost and drought, a light-demanding nature, and a crucial role in forming mycorrhizal associations (Goychuk et al. 2023). This makes it a valuable component of Polissia's forest biogeocenoses.

Birch forest dieback represents a serious ecological issue (Gougherty 2023; Shvidenko et al. 2017; Vindstad et al. 2019). Recurrent waves of birch degradation are typical of boreal and subboreal ecosystems, where a combination of stress factors creates favourable conditions for the development of pests and pathogens (Meshkova et al. 2024). Specifically, the rapid dieback of birch in Ukraine is most frequently associated with bacterial infections. Although the species diversity of bacteria infecting forest trees is significantly lower than that of fungal pathogens, bacterial wetwood, despite its harmfulness, is often not categorised separately in forest reports (Figure 1) (Goychuk et al. 2020).

Alongside bacterial pathogens, fungal agents play a significant role in birch degradation. The most damaging include xylotrophic Basidiomycetes, such as *Fomitopsis betulina* and *Fomes fomentarius*, which destroy the wood, disrupt conductive tissues, and accelerate the process of tree degradation (Krynytska et al. 2021; Kunca et al. 2022; Rudawska et al. 2022). Foliar fungi are also capable of disrupting the physiological processes of trees, especially in mixed stands (Nguyen et al. 2017).

Entomofauna constitutes another key factor in birch degradation. The most detrimental are xylophages (*Agrilus betuleti*, *Rhagium mordax*) and phytophages (*Geometra papilionaria*, *Parornix betulae*), which cause mechanical tissue damage, thereby opening entry points for secondary infections (Meshkova et al. 2024). Weakened trees become more vulnerable to colonisation by fungal and bacterial pathogens, which establishes a cycle of progressive stand dieback.

The relevance of studying the biotic factors contributing to birch decline is driven by the need to assess their impact on stand condition, identify the main pests and pathogens, and develop effective monitoring and control measures (Meshkova et al. 2024). To provide the scientific background for the study, a literature review was conducted based on scientific articles, conference proceedings, monographs, and international databases related to the influence of biotic factors on forest woody plants. In total, 31 literature sources were analysed, including Ukrainian publications on the phytosanitary status of forests and international peer-reviewed studies from scientific journals, as well as database materials (EPPO, GBIF, MycoBank) and global reviews of forest health and forest condition.

Special attention was paid to studies describing the diversity, ecological role, and harmfulness of insect pests and phytopathogens associated with *Betula* spp. This analysis made it possible to iden-

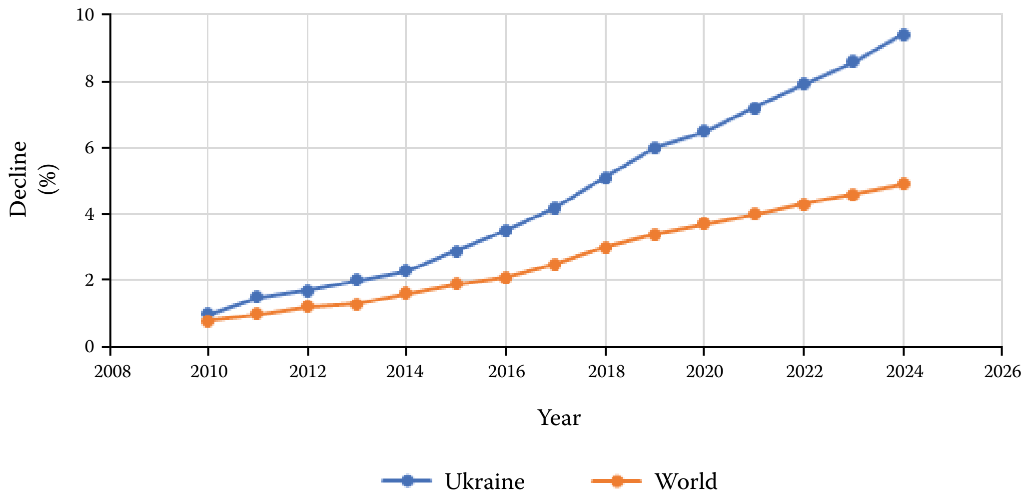

Figure 1. Conceptual model of birch health decline and associated biotic risks in Ukraine and globally (2010–2024), based on literature review (Goychuk et al. 2018; Hammond et al. 2022; Hartmann et al. 2022; Meshkova et al. 2024)

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tify the main groups of biotic agents potentially affecting birch stands and to define their role in the weakening and decline of birch forests in Europe and Ukraine.

In this context, the objective of the research is to conduct a comprehensive assessment of the influence of biotic factors, including insect-phytophages and xylophages, as well as fungal and bacterial pathogens, on the degradation of *Betula* spp. in the forests of Ukrainian Polissia. The study focuses on identifying the taxonomic structure of the pathogenic complexes, determining the dominant groups of causative agents and pests, and establishing their role in the processes leading to the weakening and dieback of birch stands.

MATERIAL AND METHODS

Study location and period. The study was conducted in the Zhytomyr region (northern Ukraine), within the Ukrainian Polissia physiographic zone (approximately 50°N, 28°E). Investigations into the actual sanitary condition of forests containing *Betula* spp. and the factors contributing to its deterioration were conducted in the Baranivske, Zviahelske, and Korostyshivske Forestry Management Units of the 'Stolychnyi Forest Office' branch of the State Enterprise 'Forests of Ukraine' during June–August 2024–2025, through forest pathological monitoring. The survey period corresponds to the peak vegetation and biological activity season, when symptoms of pest damage and pathogen infection are most clearly expressed and can be reliably detected during forest pathological monitoring.

Selection of trial plots. In each stand compartment where the proportion of birch in the stand composition was not less than 30%, a total of 10 sample plots were established, with the average number of birch trees being 200 trees. The sample plots were established within forest compartments according to standard forest pathological monitoring procedures. Forest stands of varying species composition, age, and fullness that formed under different forest-growing conditions were examined. The age of the studied trees ranged from 20 to 119 years. *Betula pendula* grew in dry and fresh conditions, predominantly in high-site quality (I, Ia) and high-density stands (average stocking – 0.8) within mixed-composition stands. According to the Ukrainian forest site classification, the majority of the studied stands belong to high productivity site classes (I–Ia). In each plot, the following were determined: sanitary status categories of the trees (from I – no signs of weakening, to VI – old dead standing wood), typical symptoms of pest damage, and signs of birch disease infection (Cabinet of Ministers of Ukraine 2020). In total, 2 073 birch trees were surveyed across the sample plots in 9 compartments of the Korostyshivske Forestry Management Unit.

Entomological methods. The identification of insect species was based on the presence of live or dead individuals, their exuviae (shed skins), and characteristic feeding traces. Systematic and structural analysis of representatives of the class Insecta was performed using the GBIF (Global Biodiversity Information Facility) database. To facilitate comparison between plots with different numbers of examined trees, the occurrence of pests and pathogens was expressed as a percentage of the total number of trees surveyed. To characterise the pest complex of silver birch (*Betula pendula*), two indicators were used across the sample plots: species frequency of occurrence (%) and mean damage intensity (scores). Species frequency of occurrence (%) was calculated as the proportion of trees exhibiting damage signs caused by a specific species, expressed as a percentage of the total number of examined trees. Mean damage intensity (0–3 scores) is an indicator of the damage level, determined by a scale where 0 represents no damage, 1 – slight, 2 – moderate, and 3 – severe damage. The mean value was obtained by averaging the scores for all examined trees.

Such scoring systems are widely used in forest health monitoring for rapid stand-level assessment of pest and disease damage (Meshkova et al. 2020).

For a general assessment of the phytosanitary condition of forest stands involving *B. pendula*, a sanitary condition index was applied. This index is calculated based on the number of trees in various categories according to the degree of damage by pests and disease agents, allowing for a quantitative evaluation of the overall stand health and the identification of the most affected areas.

Descriptive statistical indicators (mean values and standard deviation) were used to summarise the obtained data.

This approach aligns with standard forest pathological monitoring methods used for a rapid assessment of a stand's condition.

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Mycological and bacteriological methods. For mycological and bacteriological methods, current names of fungi and their systematic affiliation were aligned with the MycoBank nomenclature database (Westerdijk Fungal Biodiversity Institute 2023) and the International Code of Nomenclature for Algae, Fungi, and Plants (Turland et al. 2018). Bacterial names were aligned with the List of Prokaryotic Names with Standing in Nomenclature (LPSN Database, Leibniz Institute DSMZ 2025). All pathogens detected on the examined trees were classified according to their taxonomic groups for subsequent analysis of their distribution and harmfulness.

Identification of the collected phytopathological material was carried out using light microscopy in the Educational and Scientific Laboratory of Biotechnology and Cell Engineering of the National University of Life and Environmental Sciences of Ukraine.

Samples of infected plant tissues were collected during field surveys and examined under laboratory conditions to confirm pathogen identification.

Lelliottia nimipressuralis was subsequently identified using bacteriological analysis, specifically by assessing morphological, cultural, and biochemical properties in accordance with established protocols (Patyka et al. 2017). Additionally, we utilised the API 20E and NEFERMtest24 test systems (MikroLaTEST®, ErbaLachema, Czech Republic) at the Department of Phytopathogenic Bacteria, D.K. Zabolotny Institute of Microbiology and Virology of the National Academy of Sciences of Ukraine.

RESULTS AND DISCUSSION

In Ukraine, *Betula pendula* Roth. and *B. pubescens* Ehrh. account for a relatively small proportion of the forest fund – averaging 5–6% of the total area covered by forest vegetation.

This constraint limits the availability of centralised annual reports on their vitality, separate from other deciduous species (Meshkova, Koshelyaeva 2019). At the national level, official data records the total area of weakening and dieback foci in deciduous stands, but without division by species. Therefore, regional studies are primarily used to assess the dynamics of birch dieback. According to scientific studies conducted in Polissia, the Forest-Steppe, and on degraded plots in urban areas, birch dieback is local but periodically intensive, correlating with climatic and biotic factors (Goychuk et al. 2018; Meshkova, Koshelyaeva 2019, Skrylnik et al. 2019). Problems are most frequently registered under the following conditions: post-drought periods – marked by a sharp increase in the proportion of weakened trees and the appearance of symptoms atypical for the species (loss of turgor, bark necrosis, and reduced annual ring growth); phytopathogen damage, involving species such as *Phytophthora* spp., *Nectria galligena*, and *Lelliottia nimipressuralis*, which are exacerbated after soil waterlogging; damage by xylophagous (wood-boring) insects, which is accompanied by the secondary dieback of skeletal branches (Goychuk et al. 2018; Meshkova et al. 2024).

The decline of birch stands is often associated with the combined influence of biotic and abiotic stress factors. Mechanical damage caused by wind, glaze ice, or frost cracks may facilitate the penetration of pathogenic fungi into woody tissues. In addition, hydrothermal conditions, particularly drought periods or excessive moisture, may influence the susceptibility of birch trees to pathogen infection and pest attacks. However, the detailed assessment of abiotic factors was beyond the scope of the present study, which focused primarily on the identification of biotic agents affecting *Betula* spp. stands.

On sandy and degraded soils of Polissia, birch is often a well-regenerating species, but exhibits a rapid decline in vitality at the middle-aged stand stage (Goychuk et al. 2018; Meshkova et al. 2019).

Most regional studies indicate that the proportion of dead trees can range from 3–5% in areas with moderate disturbance to 15–20% in zones of intensive stress, particularly following extreme weather events (Goychuk et al. 2018; Meshkova et al. 2019). However, these values vary sharply across space: conditions can differ severalfold over just a few kilometres due to microtopography, water regimes, and soil type. At the global level, the dynamics of birch dieback align well with the general trend of increasing background tree mortality in boreal and temperate forests over the past 30–40 years. In Europe and North Asia, the *Betula* genus shows heightened sensitivity to prolonged summer droughts, anomalously high temperatures, spring frosts after early vegetation onset, and pathogenic complexes of root rot (such as *Armillaria* and *Heterobasidion*), mycoses, and other types of biotic agents, especially in dense young stands (Petter et al. 2020; González de Andrés et al. 2023). In Northern European countries, the annual tree

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mortality in mature birch stands averages 1–3%, but this figure can increase to 5–7% in specific years following drought. In the mountainous regions of Central Europe, cases of rapid degenerative decline in some birch stands were recorded after the 2018–2020 period (the 'European mega-drought') (Hammond et al. 2022).

The situation is particularly critical in North America, where the introduced pest *Agrilus anxius* causes the almost complete mortality of susceptible birch species, locally resulting in up to 80–100% of trees within a few years after the pest's establishment (*Agrilus anxius* added to the EPPO Alert List). European researchers assess the potential risk posed by this pest as 'high,' as *Betula pendula* exhibits the same susceptibility as North American species (Evans et al. 2020).

Currently, birch in Ukraine exhibits a trend toward increased stress, similar to other countries in the temperate zone. However, the absence of an invasive pest complex and the relatively small proportion of the species in the forest structure make the dieback processes less catastrophic than those observed in North America. Globally, there is a consistent trend of increasing mortality in *Betula* spp. in response to changing climatic conditions, which suggests the genus's high sensitivity to hydrothermal anomalies (Hammond et al. 2022; Hartmann et al. 2022). It should be noted that the data in Figure 1 are modelled and reflect generalised trends recorded in European and global forest status assessments. The values for Ukraine demonstrate an almost twofold acceleration in the rate of dieback compared to the global average for the period 2010–2024, highlighting the need for a detailed study of the factors causing such rapid deterioration in the condition of birch stands.

A total of 2 073 trees were inventoried across the ten sample plots, of which 51.7% (1 072) were healthy, 18.0% (374) weakened, 13.3% (276) severely weakened, 8.6% (178) dying, and 8.3% (173) deadwood (fresh and old) (Table 1). It should be noted that a significant difference in the sanitary condition index is observed across the various sample plots, indicating the heterogeneity of the phytosanitary situation in the forest stands of the Korostyshivske Forestry Management Unit 'Stolychnyi Forest Office'. The mean condition index for all sample plots is 2.06, which generally suggests an unsatisfactory condition of the forest stands. The lowest calculated index value was recorded at sample plot No. 9, meaning the forest stands there are characterised by good vitality indicators and the absence of weakening signs (being effectively healthy).

On most sample plots, a significant proportion of trees fall into categories II (weakened) and III (severely weakened). This indicates a general trend of deterioration in forest health. The presence of a substantial number of trees in categories V (fresh deadwood) and VI (old deadwood) suggests prolonged processes of tree dieback and mortality. The worst phytosanitary situation was observed in sample plots No. 5, No. 6, and No. 10.

Table 1. Forest stand condition index with the participation of silver birch Korostyshivske Forestry Management Unit 'Stolychnyi Forest Office'

Trial plot number	Total trees (pcs)	Tree condition category						Sanitary index
		I – healthy	II –weakened	III – severely weakened	IV – dying	V – fresh dead wood	VI – old dead wood	
1	208	119	40	25	20	1	3	1.81
2	215	104	44	19	13	30	5	2.24
3	210	109	48	23	12	10	8	2.00
4	197	147	16	21	6	5	2	1.54
5	208	89	40	25	30	18	6	2.36
6	209	75	31	45	39	14	5	2.53
7	199	112	24	39	18	5	1	1.91
8	209	76	54	35	23	21	0	2.33
9	215	151	40	18	1	4	1	1.47
10	203	90	37	26	16	28	6	2.37
Total	2 073	1 072	374	276	178	136	37	2.06

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In these specific plots, signs of tree damage caused by various species of phytopathogenic organisms, including infectious disease agents and pests, were recorded.

As a result of detailed sanitary monitoring of the forests in Polissia, Ukraine, the species composition of pests and pathogens that significantly weaken (and, consequently, lead to degradation) trees of the genus *Betula* spp. was established. In total, 31 species of insects belonging to 5 orders, 24 families, and 29 genera were identified (Figure 2).

Analysing the systematic position of pests, it was found that the largest share in the birch entomocomplex is occupied by representatives of the Coleoptera order (32.3%), which indicates long-term degradation processes in the surveyed forests, since such conditions are favourable for the development of xylophagous insects (for example, bark beetles and beetles-barbels), which settle on weakened (sometimes dying or withered) trees, damaging trunks and branches (Figure 3). The department includes representatives of the families Attelabidae (*Deporaus betulae* L., 1758), Brentidae (*Apion simile* Kirby, 1811), Buprestidae (*Agrilus betuleti* Ratz., 1837 and *Agrilus anxius* Gory, 1841), Cerambycidae (*Rhagium mordax* De Geer, 1775), Curculionidae (*Phyllobius argentatus* L., 1758, *Orchestes rusci* Herbst, 1795 and *Scolytus ratzeburgi* Janson, 1856), Lymexylidae (*Elateroides dermestoides* L., 1760) and Scarabaeidae (*Homaloplia ruricola* F., 1775).

Rhagium mordax is generally considered a secondary species colonising weakened or dying trees. Its presence in the studied stands therefore reflects the ongoing weakening processes rather than acting as a primary cause of stand decline.

A smaller share is occupied by representatives of the order Lepidoptera (25.8%), among which leaf-eating pests that can cause mass defoliation of birch trees prevail. Within the department, representatives of the families Drepanidae (*Falcaria lacertinaria* L., 1758), Endromidae (*Endromis ver-*

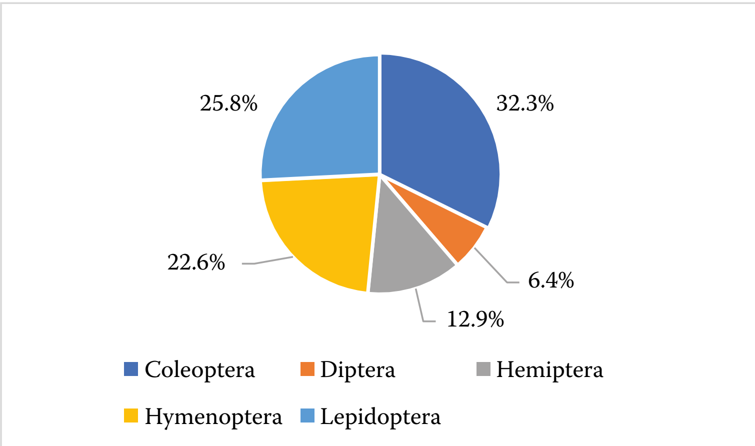

Figure 2. Systematic position of the birch entomological complex in the section of departments

Figure 3. (A) Holes of xylophagous insects, (B) larvae of leaf-eating pests, and (C) adult (female) *Tremex fuscicornis*

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sicolora L., 1758), Geometridae (*Geometra papilionaria* L., 1758 and *Biston betularia* L., 1758), Gracillariidae (*Caloptilia betulicola* Hering, 1928 and *Parornix betulae* Stainton, 1854), Notodontidae (*Furcula bicuspis* Borkh., 1790) and Sesiidae (*Synanthedon scoliaeformis* Borkh., 1789) are distinguished. The consequences of their vital activity are a decrease in growth, weakening of photosynthesis, stress on trees, and increased vulnerability to the influence of other factors.

The share of the order Hymenoptera is 22.6%, which indicates the presence of sawflies, leafhoppers, and other species of phytophagous insects of this order, capable of damaging leaves and young shoots of birch. Within the department, representatives of the families Argidae (*Arge pullata* Zaddach, 1859), Cimbicidae (*Cimbex femoratus* L., 1758), Siricidae (*Tremex fuscicornis* Fabr., 1787), and Tenthredinidae (*Emphytus cingillum* Klug, 1818, *Nematus latipes* Villaret, 1832, *Scolioneura betuleti* Klug, 1816, and *Scolioneura betuleti* Klug, 1816) are distinguished.

The order Hemiptera (12.9%) mainly unites sucking pests, which, by sucking the juice from leaves and shoots, inhibit growth processes, and also act as potential carriers of viruses. Within the department, representatives of the families Aphididae (*Hormaphis betulae* Mordvilko, 1901), Acanthosomatidae (*Elasmucha grisea* L., 1758), Psyllidae (*Psylla betulae* L., 1758), and Lygaeidae (*Kleidocerys resedae* Panzer, 1797) are distinguished. The impact on the sanitary condition of birch consists of chronic depletion and reduction of the tree's immunity. The impact of these pests can be attributed to the second line of biotic pressure, which significantly weakens trees and promotes secondary infection.

The smallest share in the birch entomological complex is occupied by representatives of the Diptera order (6.4%), while the harmfulness of individual species can be locally high, especially in young trees. Within the department, representatives of the Agromyzidae (*Agromyza alnibetulae* Hendel, 1931) and Cecidomyiidae (*Plemeliella betulicola* Kieffer, 1889) families are distinguished.

All these insects form a complex biotic interaction, which should be taken into account when developing sanitary and health measures in the forests of Polissia.

The trophic specialisation of birch pests unites the group of phytophages, xylophages, and pests of generative organs. The most numerous group is that of leaf pests (67.7%), followed by xylophages (25.5%), and the fewest species are attributed to the group of seed-eating insects (6.5%) (Table 2).

A high proportion of leaf-eating species causes the annual weakening of trees and reduces their overall viability, especially in conditions of increasing average annual air temperature and hydrological stress, which is currently typical of the climatic conditions in Polissia. At the same time, the presence of a significant proportion of xylophagous insects indicates intense secondary biotic pressure on weakened trees, as most pests become active after primary stress has occurred. Seed-eating insects, although less numerous, affect the reproductive function of birch, reducing the quality and quantity of seeds, which is critical for the natural regeneration of stands. Thus, the structure of the trophic groups of birch pests reflects the complex nature of the entomological load on forest phytocenoses, which require an integrated approach to monitoring and protecting natural and artificial stands.

For a comprehensive assessment of the impact and spread of *Betula pendula* pests, key indicators were analysed, including the frequency of species occurrence and the average intensity of damage to vegetative and reproductive organs. Additionally, the typicality of species for the forests of Polissya was taken into account, which allows us to determine the main factors of biotic pressure on birch stands and identify species with the greatest ecological and harmful significance (Table 3).

Special attention should be paid to *Agrilus anxius*, which is included in the EPPO lists of regulated quarantine pests (A1 and A2). In the studied stands, this species was recorded with relatively low frequency of occurrence and low damage intensity, which does not indicate outbreak development under the current conditions.

The results indicate that most insect species recorded in the studied stands are background components of the birch entomocomplex, causing relatively low damage intensity. However, several species exhibit higher prevalence and damage potential, particularly *Agrilus betuleti* and *Rhagium mordax*. These species can act as key drivers of local decline in birch stands, especially under conditions of physiological stress. Therefore, the degradation of birch stands in the studied region should be considered a result of the combined action of multiple biotic agents rather than the impact of a single dominant pest.

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Table 2. Taxonomic structure of the entomocomplex associated with the phytocenoses of *Betula* spp.

Division	Family	Genus	Species
Hymenoptera	Cimbicidae	*Cimbex* Olivier, 1790	*Cimbex femoratus* (Linnaeus, 1758)
	Argidae	*Arge* Schrank, 1802	*Arge pullata* (Zaddach, 1859)
	Tenthredinidae	*Allantus* Panzer, 1801	*Emphytus cingillum* (Klug, 1818)
		Craesus Leach, 1817	*Nematus latipes* (Villaret, 1832)
		Scolioneura Konow, 1890	*Scolioneura betuleti* (Klug, 1816)
	Siricidae	*Tremex* Jurine, 1807	*Tremex fuscicornis* (Fabricius, 1787)
Lepidoptera	Geometridae	*Geometra* Linnaeus, 1758	*Geometra papilionaria* (Linnaeus, 1758)
		Biston Leach, 1815	*Biston betularia* (Linnaeus, 1758)
	Notodontidae	*Furcula* Lamarck, 1816	*Furcula bicuspis* (Borkhausen, 1790)
	Drepanidae	*Falcaria* Haworth, 1809	*Falcaria lacertinaria* (Linnaeus, 1758)
	Endromidae	*Endromis* Ochsenheimer, 1810	*Endromis versicolora* (Linnaeus, 1758)
	Gracillariidae	*Caloptilia* Hübner, 1825	*Caloptilia betulicola* (Hering, 1928)
		Parornix Spuler, 1910	*Parornix betulae* (Stainton, 1854)
	Sesiidae	*Synanthedon* Hübner, 1819	*Synanthedon scoliaeformis* (Borkhausen, 1789)
Coleoptera	Curculionidae	*Phyllobius* Germar, 1823	*Phyllobius argentatus* (Linnaeus, 1758)
		Orchestes J.C.W. Illiger, 1798	*Orchestes rusci* (Herbst, 1795)
		Scolytus Geoffroy, 1762	*Scolytus ratzeburgi* (Janson, 1856)
	Scarabaeidae	*Omaloplia* Schönherr, 1817	*Homaloplia ruricola* (Fabricius, 1775)
	Attelabidae	*Byctiscus* C.G. Thomson, 1859	*Deporaus betulae* (Linnaeus, 1758)
	Lymexylidae	*Hylecoetus* Latreille, 1806	*Elateroides dermestoides* (Linnaeus, 1760)
	Buprestidae	*Agrilus* Curtis, 1825	*Agrilus betuleti* (Ratzeberg, 1837)
			Agrilus anxius (Gory, 1841)
	Cerambycidae	*Rhagium* Fabricius, 1775	*Rhagium mordax* (De Geer, 1775)
	Brentidae	*Betulapion* Ehret, 1994	*Apion simile* (Kirby, 1811)
Hemiptera	Aphididae	*Hormaphis* Osten-Sacken, 1861	*Hormaphis betulae* (Mordvilko, 1901)
	Acanthosomatidae	*Elasmucha* Stål, 1864	*Elasmucha grisea* (Linnaeus, 1758)
	Psyllidae	*Psylla* Geoffroy, 1762	*Psylla betulae* (Linnaeus, 1758)
	Lygaeidae	*Kleidocerys* Stephens, 1829	*Kleidocerys resedae* (Panzer, 1797)
Diptera	Cecidomyiidae	*Plemeliella* Seitner, 1908	*Plemeliella betulicola* (Kieffer, 1889)
	Agromyzidae	*Agromyza* Fallén, 1810	*Agromyza alnibetulae* (Hendel, 1931)

Source: GBIF 2026

As presented in Table 4, of the 30 insect species identified, 21 are typical of Polissya forests, including key species with high harmfulness: *Agrilus betuleti* (42% frequency of occurrence, 2 damage intensity scores) and *Rhagium mordax* (37% frequency, 2 scores). These species form localised foci of severe damage and can significantly contribute to the degradation of birch. Most other species are characterised by moderate frequencies of occurrence (5–20%) and low damage intensity (1 score), which indicates their relatively weak impact on the overall condition of the stands. Rare species (6 species) were generally found locally and had virtually no effect on the overall health of the trees; however, their presence may indicate structural changes in the pest composition. The mean frequency of occurrence across all species was 12.6%, the mean intensity was 1.07 scores, and the standard deviation for intensity was 0.26, which demonstrates low variability for most species and highlights the role of specific highly harmful insects in the degradation of forest trees.

The obtained results indicate that the weakening of birch stands in the studied region is asso-

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Table 3. Frequency of occurrence, intensity of damage, and typicality of pests of European birch in the forests of Polissia, Ukraine (based on analysis of data from sample plots)

Species name	Frequency of occurrence (%)	Average damage intensity, score	Typicality for the forests of Polissia
Cimbex femoratus (Linnaeus, 1758)	12	1	typical
Arge pullata (Zaddach, 1859)	10	1	typical
Emphytus cingillum (Klug, 1818)	8	1	typical
Nematus latipes (Villaret, 1832)	7	1	typical
Scolioneura betuleti (Klug, 1816)	6	1	typical
Tremex fuscicornis (Fabricius, 1787)	5	1	rare/local
Geometra papilionaria (Linnaeus, 1758)	28	1	typical
Biston betularia (Linnaeus, 1758)	15	1	typical
Furcula bicuspis (Borkhausen, 1790)	9	1	typical
Falcaria lacertinaria (Linnaeus, 1758)	8	1	typical
Endromis versicolora (Linnaeus, 1758)	6	1	typical
Caloptilia betulicola (Hering, 1928)	7	1	rare/local
Parornix betulae (Stainton, 1854)	15	1	typical
Synanthedon scoliaeformis (Borkhausen, 1789)	5	1	rare/local
Phyllobius argentatus (Linnaeus, 1758)	18	1	typical
Orchestes rusci (Herbst, 1795)	10	1	typical
Scolytus ratzeburgi (Janson, 1856)	12	1	typical
Homaloplia ruricola (Fabricius, 1775)	7	1	typical
Deporaus betulae (Linnaeus, 1758)	6	1	typical
Elateroides dermestoides (Linnaeus, 1760)	5	1	typical
Agrilus betuleti (Ratzeberg, 1837)	42	2	typical
**Agrilus anxius* (Gory, 1841)	20	1	typical
Rhagium mordax (De Geer, 1775)	37	2	typical
Apion simile (Kirby, 1811)	6	1	typical
Hormaphis betulae (Mordvilko, 1901)	10	1	typical
Elasmucha grisea (Linnaeus, 1758)	8	1	typical
Psylla betulae (Linnaeus, 1758)	8	1	typical
Kleidocerys resedae (Panzer, 1797)	5	0	rare/local
Plemeliella betulicola (Kieffer, 1889)	4	1	rare/local
Agromyza alnibetulae (Hendel, 1931)	3	1	rare/local

*The species is included in the List of Regulated Harmful Organisms, Lists A1 and A2 of the European and Mediterranean Plant Protection Organization

ciated with the combined action of several biotic agents rather than the dominance of a single pest or pathogen. Xylophagous insects, defoliators, and phytopathogenic fungi together form a complex of factors that may accelerate the decline of birch stands under conditions of environmental stress. An equally important role in the degradation of birch belongs to myco- and microorganisms, pathogens of infectious diseases. The species composition of phytopathogens includes representatives of the kingdoms of fungi and bacteria. Analysis of the taxonomic structure of the detected mycobiota showed that the species belong to 9 genera, 8 families, 5 orders, 4 classes, and 2 divisions. In particular, 44.4% of the species are representatives of the Ascomycota division and 55.6%, respectively, of Basidiomycota. The species of the Ascomycota division are represented by representatives of the classes Leotiomycetes and Sordariomycetes. The class Leotiomycetes is rep-

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Table 4. Taxonomic characterisation of mycobiota associated with phytocenoses of *Betula* spp.

Division	Class	Order	Family	Genus	Species
Ascomycota	Leotiomycetes	Helotiales	Erysiphaceae	*Erysiphe*	*Erysiphe betulina* U. Braun & S. Takam., 2000
			Dermateaceae	*Marssonina*	*Marssonina betulae* (Libert) Magnus, 1909
			Sclerotiniacea	*Ciboria*	*Ciboria betulae* (Woronin) W.L. White, 1941
	Sordariomycetes	Hypocreales	Nectriaceae	*Nectria*	*Nectria cinnabarina* (Tode) Fr., 1849
Basidiomycota	Pucciniomycetes	Pucciniales	Pucciniastraceae	*Melampsoridium*	*Melampsoridium betulinum* (Pers.) Kleb., 1899
	Agaricomycetes	Polyporales	Fomitopsidaceae	*Fomitopsis*	*Fomitopsis betulina* (Bull.) B.K. Cui, M.L. Han & Y.C. Dai, 2016
			Polyporaceae	*Fomes*	*Fomes fomentarius* (L.) Fr., 1849
				Daedaleopsis	*Daedaleopsis tricolor* (Bull.) Bondartsev & Singer, 1941
		Auriculariales	Exidiaceae	*Exidia*	*Exidia glandulosa* (Bull.) Fr., 1822

Source: MycoBank (Westerdijk Fungal Biodiversity Institute 2023)

resented by 3 species (*Erysiphe betulina* U. Braun & S. Takam., 2000, *Marssonina betulae* (Libert) Magnus, 1909, and *Ciboria betulae* (Woronin) W.L. White, 1941), which infect leaves, shoots, and seeds. One species belongs to the Sordariomycetes [*Nectria cinnabarina* (Tode) Fr., 1849], known as a secondary necrotroph, colonising weakened tree tissues. The species of the Basidiomycota division are represented by representatives of the classes Pucciniomycetes and Agaricomycetes. The class Agaricomycetes is represented by 4 species that mainly cause trunk diseases and are necrotrophs – *Fomitopsis betulina* (Bull.) B.K. Cui, M.L. Han & Y.C. Dai, 2016, *Fomes fomentarius* (L.) Fr., 1849, *Daedaleopsis tricolor* (Bull.) Bondartsev & Singer, 1941, and *Exidia glandulosa* (Bull.) Fr., 1822.

The class Pucciniomycetes is represented by one species [*Melampsoridium betulinum* (Pers.) Kleb., 1899], which causes leaf rust. Thus, the pathogens of birch diseases cover a wide range of ecological niches and taxonomic groups. They cause chronic weakening of trees, a decrease in the phytosanitary condition, and productivity of stands (Krynytska et al. 2021; Rudawska et al. 2022). A significant part of them are secondary pathogens or necrotrophs, which are activated against the background of a general weakening of trees under conditions of climate change, anthropogenic load, or the complex action of other biotic and abiotic factors (Vasaitis 2024; Kunca et al. 2022).

It has been established that phytopathogens of various etiologies (fungi, bacteria) form a complex infectious pressure, which is a background factor in the degradation of birch stands. The greatest threat is posed by the causative agent of bacterial wetwood – *Lelliottia nimipressuralis*, which is characterised by systemic damage, i.e. the ability to penetrate the vascular system of the tree and cause disruption of water metabolism and transport of substances. Infection of birch causes massive formation of water shoots, destruction and rot of the core, formation of mucous secretions (bacterial exudate) and progressive weakening of the tree, which often ends with dieback within 3–5 years. Unlike fungal phytopathogens, which affect local tissues, *L. nimipressuralis* causes systemic bacteriosis, the manifestations of which can be difficult to diagnose in the early stages. This complicates the timely detection and control of lesions in natural stands. It has been recorded that the bacterium is activated in conditions of increased humidity

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Figure 4. Leakage of exudate is a typical symptom of (A) bacterial wetwood, (B) basidioma *Fomitopsis betulina*, and (C) *Inonotus obliquus*

and mechanical damage to the bark, which makes it especially dangerous in young trees, in clearings, and in conditions of a disturbed hydrological regime. In addition, *L. nimipressuralis* can act as a factor in the secondary colonisation of trees by pests, in particular xylophagous, which actively penetrate the tissues of weakened trees. Thus, the bacterial infection plays the role of a 'trigger of degradation', initiating a chain of pathological changes, which in the conditions of Polissia have a clear tendency to spread over significant areas (Goychuk et al. 2020, 2022). No less dangerous agents of influence are wood-destroying fungi *Fomitopsis betulina*, *Fomes fomentarius*, and *Inonotus obliquus* (Figure 4), which cause deep structural damage to wood and can affect the condition of birch for decades. Their activity causes the decomposition of cellulose and lignin, which significantly weakens tree trunks, making them potentially wind-resistant and wind-broken as a result.

The occurrence of some pests and wood-decaying fungi may also be influenced by stand age. Older birch stands are often more susceptible to colonisation by secondary xylophagous insects and saproparasitic fungi. In the studied stands, the age range varied from 20 to 119 years, which may partially explain the presence of species associated with weakened or ageing trees. In addition, natural ageing processes typical for birch stands may contribute to the gradual decline of tree vitality, which increases the susceptibility of trees to secondary pests and pathogens.

It is assumed that phytopathogenic organisms (fungi, bacteria, and pests), which form consortial relationships with trees of the genus *Betula* spp. in the forests of Polissia of Ukraine, have a systemic negative impact on the viability of tree stands due to damage to the assimilation apparatus, generative organs and the conductive system (Goychuk et al. 2017; Skrylnik et al. 2019). Such an impact creates a chronic infectious background, which not only causes direct physiological weakening of trees but also contributes to the secondary colonisation of birch by xylophagous insects (Meshkova et al. 2019, 2021). As a result, a synergy of biotic factors occurs, which accelerates the degradation of stands and worsens their sanitary condition. All these factors not only weaken birch stands but also make them vulnerable to natural disasters, such as storms, droughts, or frosts. If timely measures are not taken to combat pests and diseases, this can lead to significant losses of the forest fund.

CONCLUSION

The Sanitary Condition Index calculated for 2 073 birch trees across ten sample plots in the Korostyshivske Forestry Management Unit indicated an overall unsatisfactory state of the stands (mean index = 2.06). More than half of the trees (51.7%) were healthy, while the remaining proportion showed various stages of weakening, dieback, or were classified as deadwood. The best condition was recorded at sample plot 9, whereas plots 5, 6, and 10 were the most affected, reflecting strong pressure from pests and pathogens.

The degradation of *Betula* spp. in Polissia is driven by a complex interplay of biotic factors. Xylophagous insects, primarily Coleoptera, were the most numerous and caused significant mechanical damage that facilitated secondary infections. Leaf-eating Lepidoptera and Hymenoptera contributed to assimilation loss through repeated defoliation, while Hemiptera exerted chronic stress through sap feeding.

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Phytopathogenic fungi were dominated by representatives of Basidiomycota and Ascomycota, ranging from foliar pathogens (*Erysiphe betulina*, *Melampsoridium betulinum*) to xylotrophic necrotrophs (*Nectria cinnabarina*, *Exidia glandulosa*). Their activity disrupts photosynthesis, reproductive processes, and the integrity of wood. The most dangerous pathogen identified was the bacterium *Lelliottia nimipressuralis*, the agent of bacterial wetwood, which causes systemic vascular dysfunction and rapid decline of infected trees. Overall, the combined influence of pests and pathogens – intensified by climatic and hydrological stress – accelerates birch dieback. These findings highlight the need for continuous monitoring and integrated adaptive forest health management to mitigate further degradation.

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