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Investigation of ash stands' health condition in emerald ash borer (*Agrilus planipennis* Fairmaire) infestation: Case study in Holosiivskyi District, Kyiv, Ukraine

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ABSTRACT

The aim of this study is to comprehensively assess the health condition of ash stands in Holosiivskyi National Nature Park, Kyiv, and identify the main biotic and abiotic factors contributing to stand decline, determining damage distribution patterns and the role of individual factors in stand degradation. Field observations were conducted during the peak growing season to ensure accurate assessment of tree health parameters. This research demonstrates the complex interactions between invasive and stem pests, fungal and bacterial pathogens, and abiotic factors in ash stand degradation. Research was conducted in 2023–2024, combining forest pathological surveys, identification sample collection (n > 110), stand assessment by health condition classes, and pest monitoring using pheromone and color-based traps with D-shaped exit hole counts. The weighted average health condition index (HCI = 3.82) indicates severe stand damage and high proportions of dying trees. Most studied trees exhibited dead branches and symptoms of decline. Healthy trees (health class I) comprised only 7%, while declining or dead trees (health classes IV–VI) accounted for over 57%. Trees with 48–88 cm diameters showed the highest vulnerability. Stem pest emergence rates were: *Agrilus planipennis* – 1.1 ± 0.2 holes/dm², *Hylesinus crenatus* – 2.7 ± 1.3, *Hylesinus fraxini* – 2.2 ± 1.3. Root rot and epicormic shoots were widespread, indicating intensive stress factor impacts. The most common damage combination in roadside stands was "rot + bacterial diseases" (3.0±0.98%) and "stem pests + rot" (3.0±0.72%), while in the interior of the park, the leading association was "rot + stem pests" (1.4±0.96%).. Results demonstrate that critical health conditions result from complex interactions among A. planipennis, stem pests, and fungal and bacterial pathogens, particularly affecting larger-diameter trees.

Keywords: *Fraxinus* sp., phytosanitary monitoring, *Agrilus planipennis*, pheromone traps, phytophagous insects, health condition.

INTRODUCTION

In the 21st century, forest ecosystems are facing significant transformations caused by climate change, biological invasions, and increasing anthropogenic pressure.

Of particular concern is the increasing frequency and intensity of disease outbreaks associated with invasive pests and pathogens capable of adapting to new environments faster than native ecosystems can respond. This is facilitated by climate anomalies, such as increasing average annual temperatures, decreasing air humidity, and hydrological instability, which create favorable conditions for the breakdown of biological barriers.

According to Meshkova (2021), modern challenges require fundamentally new approaches to phytopathological monitoring, risk forecasting, and the implementation of adaptive forest landscape management. In this context, research integrating bioindicators, climatic and ecological factors, and innovative digital methods for forest health monitoring is particularly relevant.

As noted by several scientists, including Matsiakh (2022) and Szyniszewska *et al*. (2024), the dynamic spread of invasive pest insects and pathogens is an irreversible natural process that has been significantly intensified by global climate change and anthropogenic environmental transformations. This creates significant challenges for forestry, as the threat of biotic disturbances to forest ecosystems increases. Therefore, the priority task for forestry professionals, both in Ukraine and worldwide, is to develop resilient forest stands that can effectively resist biotic threats. Key elements of the research include systematic monitoring of the health condition of forest areas, which enables identification of early signs of pathological processes and facilitates timely and scientifically sound decisions regarding the implementation of forest protection and preventive control measures. In addition, an important direction is to enhance the natural immunity of trees and preserve physiologically healthy and highly productive tree species, which will help reduce the vulnerability of forest ecosystems to pest insects and pathogens.

Forest pests are an integral part of forest ecosystems and stay in dynamic balance with tree species over many years without causing substantial damage. However, disturbances to this natural balance, caused by both natural and anthropogenic factors, can cause uncontrolled spread of pests, including the development of epidemic die-offs, which can have severe and sometimes irreversible consequences for forest ecosystems. In particular, Warlo and Ravolainen (2024) and Meshkova (2021) emphasize the importance of maintaining ecological balance as a fundamental prerequisite for preventing large-scale pest outbreaks. Therefore, a comprehensive study of the factors causing dieback of woody plants, particularly *Fraxinus excelsior* L. (common ash), requires assessing the health condition of stands, early detection of pathogens, and monitoring of insect population dynamics.

Currently, the priority task is to identify the primary causes of this process in the study region and develop effective measures to mitigate it, which will contribute to maintaining stable functioning of forest ecosystems. This issue is particularly important for urban areas, where urban forests play a key role in maintaining ecological balance and creating a comfortable living environment. The *Fraxinus* genus includes 64 species, of which 10 are distributed in the natural forests of Europe, 31 in Asia, and 23 in North America. As noted by Eyles *et al.* (2009), it represents one of the most widely distributed genera of deciduous trees in the temperate regions of the Northern Hemisphere. In Ukraine, 20 ash species occur in forests and protective plantations, as well as in gardens and parks, of which 16 are introduced and 4 are native: *Fraxinus excelsior* L. (common ash), *F. oxycarpa* Willd. (sharp-fruited ash), *F. angustifolia* Vahl. (narrow-leaved ash) and *F. pallisae* Wilmott (Levchenko *et al*., 2024).

Green ash, or downy ash (*Fraxinus pennsylvanica* Marsh. = *Fraxinus pubescens* L.), and narrow-leaved ash (*F. angustifoli*a Vahl.) also occur in shelterbelts, parks, and street plantings. According to Tkach *et al.* (2021) and Lotytskyi (2023), ash grows successfully in various ecological conditions, except on acidic soils, and often dominates in areas less favourable for beech, oak, or alder. It is capable of growing in relatively dry areas, rocky mountain slopes, and ravine forests. In the absence of competition, it establishes well on gley soils, chalk deposits, and peatlands.

Common ash (*Fraxinus excelsior* L.), together with common oak, forms the canopy layer in forest stands and is also found in shelterbelts, arboretums, parks, and streets of settlements. In recent years, deterioration in the health condition of ash stands has been observed in many countries. According to Stroheker *et al.* (2021), the causes of this phenomenon include climatic factors, damage by pest insects, bacterial diseases, wood-decaying fungi, and chalara necrosis caused by the invasive fungus *Hymenoscyphus fraxineus*. The researchers confirm the significant impact of this pathogen on the health condition of ash trees in parks and urban stands, while emphasising the possible involvement of other fungi of the genus *Diplodia*.

Due to various stress factors, trees undergo natural weakening and mortality. However, in some cases, this process takes on a pathological character, which can lead to stand disruption, resulting in only partial survival to maturity. Therefore, it is important to analyse the age structure of ash stands in the study region, taking into account the type of forest site conditions, stocking, composition, and site index of the stands. This will allow for differential determination of rotation age while maintaining wood quality.

The first mentions of pathological processes associated with dieback and mortality of shoots and trees of *Fraxinus americana* L. and *Fraxinus pennsylvanica* Marsh. appeared in the late 1950s and early 1960s in the northeastern United States.

Among the possible causes of this phenomenon, researchers identified a combination of climatic and biotic factors, particularly air pollution, water stress, fungal infections (*Fusicoccum* sp., *Cytophoma pruinosa* (Fries) von Höhnel, *Gloeosporium aridum* Ell. & Holw.), as well as viruses and nematodes (*Xiphinema americanum* Cobb) (Malek and Smolik, 2001).

In recent research, Meshkova and Borysova (2019) and Goychuk *et al.* (2021) concur that ash stand degradation results not from a single factor, but from a complex of interrelated stressors that vary with environmental conditions and have long-term effects. Without effective protection, restoration, and health improvement measures for these stands, the loss of ash forests becomes a real threat. Researchers consider invasive insects, disease pathogen outbreaks, wildlife damage, and livestock grazing to be the biotic factors that most negatively affect the productivity and resilience of forest ecosystems. All of these are powerful catalysts for transformational changes in forest ecosystems.

Invasive insects and disease pathogens can have catastrophic economic and environmental consequences for the structure and functioning of forest ecosystems. They cause mass tree mortality, leading to biodiversity loss, changes in forest composition, and disruption of natural ecosystem processes (Bradshaw *et al.*, 2016; Cuthbert *et al.*, 2022). According to scientific estimates, total global economic losses from invasive species have reached approximately US$1.3 trillion, and this figure is expected to continue growing (Diagne *et al*., 2021). In response, the scientific community is intensifying efforts to develop effective management strategies that involve early detection of invasions and minimizing their impact on ecosystems.

Recently, the problem of ash dieback, caused by the pathogen *Hymenoscyphus fraxineus* and the invasive pest emerald ash borer, *Agrilus planipennis*, has become increasingly urgent. This has become a serious environmental problem for many countries. The suburban forests of Kyiv, where ash is one of the dominant tree species, have become the latest area affected by this dangerous pest. Suburban forests perform important ecological functions, including air pollution reduction, carbon sequestration, oxygen production, microclimate improvement, water balance regulation, and soil erosion prevention.

The phenomenon of forest dieback is becoming increasingly widespread, affecting additional tree species. This, in turn, leads to an increase in hypotheses regarding weakening triggers and mortality risk factors in trees. Simultaneously, scientific approaches for describing dieback models and mechanisms in forest ecosystems are being actively developed and refined.

Among current concepts explaining the causes of forest decline, leading factors include extreme drought stress, increased frequency of forest fires, widespread pathogen proliferation, and population outbreaks of pests from various trophic groups. Researchers (Anderegg *et al.*, 2015) emphasise the importance of a comprehensive understanding of these factor interactions in the context of climate change for developing effective adaptation strategies.

In accordance with Order No. 837 of the Kyiv City Military Administration dated July 31, 2024, a quarantine regime has been implemented in Kyiv following the detection of emerald ash borer *Agrilus planipennis* Fairmaire, and a list of phytosanitary measures for localising and eliminating quarantine pest foci in Kyiv for 2024–2028 has been approved. In this study, it is important to analysis the scale of invasion, its causes and consequences for suburban forest ecosystems, and to develop possible methods for emerald ash borer population control. This analysis will form the basis for developing effective measures for forest protection and restoration, preserving their ecological stability, and ensuring the provision of ecosystem services they provide.

The aim of the study is to comprehensively assess the health condition of ash stands, particularly emerald ash borer *Agrilus planipennis* Fairmaire, Coleoptera: Buprestidae infestation in stands of the Holosiivskyi district of Kyiv, evaluate its ecosystem impact, and develop effective measures to minimize negative consequences. *The study object* is common ash (*Fraxinus excelsior* L.) stands. *The study subject* is the health condition of ash stands in the Holosiivskyi district of Kyiv and factors contributing to their deterioration.

MATERIALS AND METHODS

To achieve this goal, the following main research tasks were identified: to determine the health condition of stands based on health condition index calculation; to identify factors contributing to decline and direct impact factors affecting common ash trees that weaken ash stands.

Tree health condition was determined in accordance with generally accepted methods (State Forestry Committee of Ukraine, 2005). The health condition of each tree was assessed considering the overall condition according to the following classes: I – healthy trees, II – weakened trees, III – severely weakened trees, IV – dying trees, V – recently dead trees, VI – old dead trees. Based on survey results, the average health condition class of the stand was calculated using a weighted average indicator (HCI), which allowed for quantitative assessment of the overall community condition, and is calculated using the formula:

$$HCI = \frac{(n1 \cdot 1 + n2 \cdot 2 + n3 \cdot 3 + n4 \cdot 4 + n5 \cdot 5 + n6 \cdot 6)}{(n1 + n2 + n3 + n4 + n5 + n6)} \quad (1)$$

where: $n1$, $n2$, $n3$, $n4$, $n5$, and $n6$ are the number of trees in health classes I, II, III, IV, V, and VI, respectively.

Additionally, comprehensive tree measurements were performed to analyse changes in forest plot attributes of the stand.

In total, the area of all types of urban forests within Kyiv city reaches 57.2 thousand hectares. Within the city limits, there are 23.0 thousand hectares of urban forests, with 186.3 hectares dominated by common ash.

The largest areas of forest stands of all tree species within the Holosiivskyi district of Kyiv are managed by Holosiivskyi National Nature Park, Koncha-Zaspa Forest Park Management Municipal Enterprise, Feofaniya Park (a national garden and park art monument), Expocenter of Ukraine National Complex, Separate Subdivision of the National University of Life and Environmental Sciences of Ukraine «Boyarka Forest Research

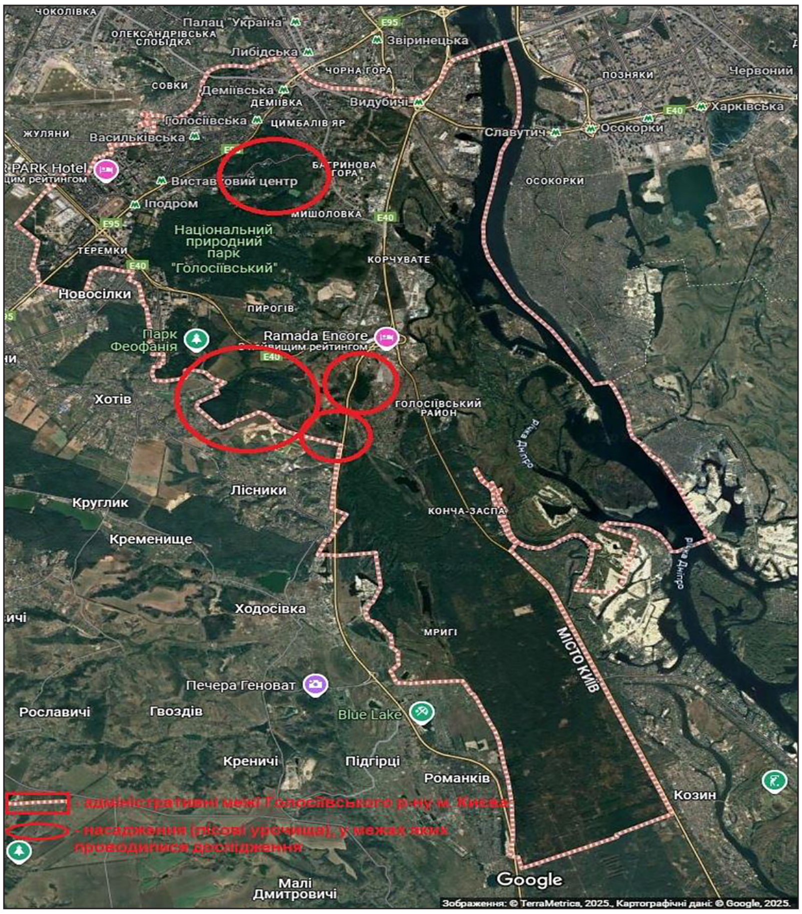

Figure 1. Surveyed stands with common ash

Station», and Lysa Hora Regional Landscape Park. In the surveyed urban forests and forest tracts of the Holosiivskyi district of Kyiv, forest pathological survey routes were established, covering stands containing common ash (Figure 1).

More than 110 samples of damaged individual tissues and organs parts of tree were collected from trees showing visual signs of damage by pathogens and pest insects, particularly emerald ash borer (*Agrilus planipennis*).

To determine the species composition of pest insects, a set of specialised research methods was used, including macroscopic, microscopic, and mycological approaches, which enabled accurate identification of pathogenic organisms and determination of their role in the disruption of forest ecosystem functioning. The research was conducted in accordance with the 'Methodological guidelines for monitoring, recording and forecasting the spread of forest pests and diseases for the flat part of Ukraine' (Methodological guidelines…, 2020).

Based on the results of health monitoring of stands to determine their overall health condition (including calculation of the health condition index) and pest identification, it was found that the vast majority of stands with common ash in the study region are experiencing dieback (Figure 2) and are severely degraded.

Detailed forest pathological surveys in *Fraxinus* dieback areas (Figure 3) were conducted in accordance with generally accepted methods (Goychuk *et al.*, 2012). The approaches used enabled a comprehensive assessment of tree health conditions, identification of typical damage symptoms, and determination of probable causes of pathological changes.

This involved visual observations and recording of main damage symptoms, including the presence of dead branches, epicormic shoots, stem damage, and effects of pests and pathogens. In addition, sampling of bark, bast, and wood was conducted for mycological and entomological analysis.

Figure 2. Determination of the health condition of the surveyed stands

Figure 3. Defoliation and dry-topped crowns of *Fraxinus excelsior* in the surveyed areas

Pheromone traps (sticky traps) with artificially synthesised *Agrilus planipennis* pheromone and color-based traps (green) without pheromone were used to determine the abundance and distribution of *Agrilus planipennis* imagoes.

The pheromone traps were placed at a height of 1.3–1.5 m above the ground (Figure 4), attaching them to the first live branch of common ash trees. When setting the traps, weather conditions and the flight period of the emerald ash borer, *Agrilus planipennis*, were taken into account. Barrier traps were used to catch *Agrilus planipennis* imagoes by attaching a pheromone dispenser to the stem of living trees in the transition zone between living and dead shoots. The number of imagoes was monitored every 14 days.

During trap placement, weather conditions and developmental phenophases were taken into account, particularly the flight period of emerald ash borer imagoes (*Agrilus planipennis*). Monitoring of imago populations was carried out at 14-day intervals. Quantitative assessment of population characteristics of insects inhabiting trees in dieback areas was conducted using the following key indicators: abundance, prevalence, emergence of young beetles (based on the number of exit holes), and population density per unit area or volume of wood. All studies were conducted in accordance with current methodological guidelines for monitoring, assessing, and forecasting the spread of forest pests and diseases in Ukraine (Meshkova, 2020).

The study was conducted using the grid sampling method on model common ash trees. Within the identified infestation sites, counting grids were used (Figure 5) to determine settlement density and production of young beetles based on the number of characteristic D-shaped exit holes per 1 dm². The average number of exit holes was calculated by counting three sides of each tree within the study area. The obtained results were used to calculate average population density indicators of *Agrilus planipennis* in the designated area.

The processing of collected materials and analysis of the obtained results were conducted under laboratory conditions.

Experimental studies of plants complied with national and international guiding principles. The authors adhered to the standards of the Convention on Biological Diversity (1992).

RESULTS AND DISCUSSION

Based on forest pathological monitoring results of stands containing common ash, conducted to assess overall health condition and identify factors causing dieback, it was established that common ash stands are experiencing intensive dieback and have high damage levels.

We observed that trees without damage exhibited superior growth compared to trees showing pathological signs of decline and wood decay indicators. Tree mortality in dieback areas affected specimens of different diameters according to their distribution by diameter classes. Comparing tree distribution by health condition classes across different diameter classes with stand averages, the most vulnerable trees were those in the largest diameter classes (Figure 6).

Analysis of the diagram reveals that the weighted average health condition index for the

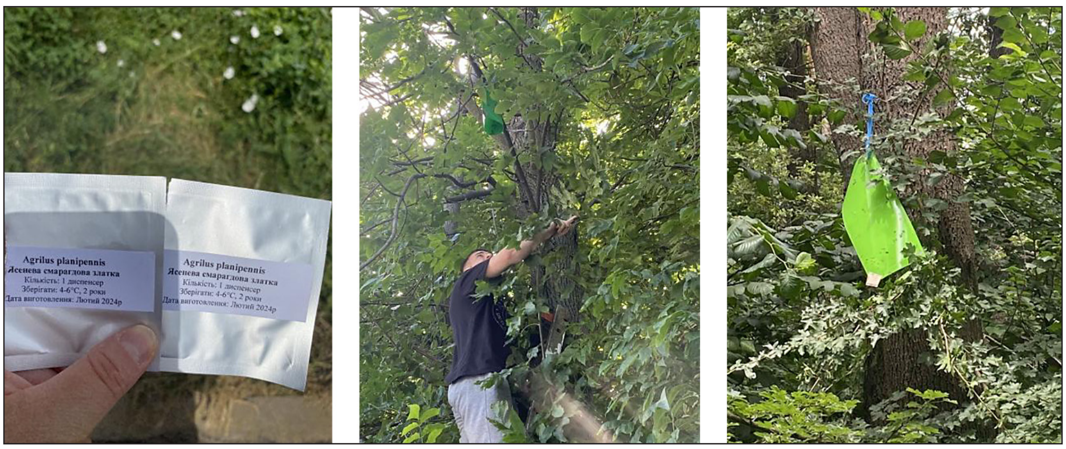

Figure 4. Placement of sticky traps using artificially synthesised pheromone

Figure 5. Assessment of abundance and average number of *Agrilus planipennis* exit holes

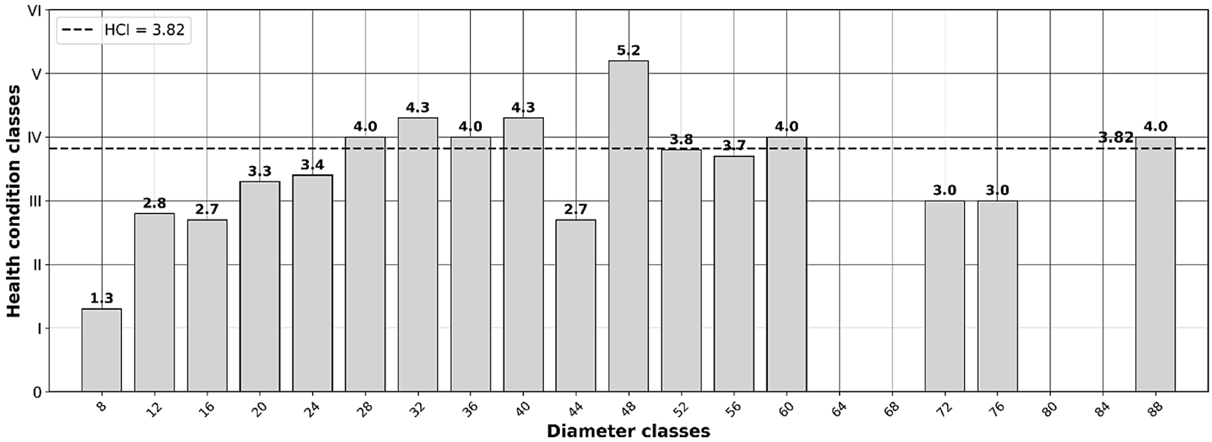

Figure 6. Distribution of common ash trees of various diameter classes by health condition classes

Figure 7. Overall health condition of the stand in the surveyed sample plots

sample plots (HCI = 3.82) characterises the degree of stand damage as severe, with the stand condition classified as declining (Figure 7). In dieback areas, ash trees of various diameters died, with larger specimens predominating.

Overall, during 2023–2024, in stands showing dieback symptoms due to the spread of pathological mortality areas, total stem mortality increased, and the condition of severely weakened trees progressed to dieback. It was found that trees with diameters of 48–88 cm were most susceptible to pathological factors. This indicates that trees with larger diameters are significantly affected by *Agrilus planipennis* infestation. Conversely, trees with smaller diameters (8–44 cm) were found to be least vulnerable. In general, there is a tendency for health condition classes to increase with diameter, which may indicate the accumulation of damage in older trees. We conducted a study of the health condition of stands with common ash in the Holosiivskyi district of Kyiv, particularly in areas affected by emerald ash borer infestation. Analysis of the obtained results allows assessment of the level of stand damage, classification of health condition classes, and determination of necessary measures for stand protection and restoration (Figure 8).

It has been established that tree distribution by health condition classes is uneven. Trees in health class I account for the smallest share (7%), indicating a small number of completely healthy trees. Trees in health classes II and III account for 18% each, indicating a significant proportion of trees with moderate signs of decline. The largest share is occupied by trees in health class IV (24%), which may indicate widespread tree decline or initial stages of mortality. Health class V trees represent 11%, indicating the presence of partially dead trees. A significant proportion (22%) falls into health class VI, indicating a substantial number of standing dead trees that require removal measures.

According to the study results, the main factor in the deterioration of the health condition of ash stands was emerald ash borer *Agrilus planipennis* infestation. This species causes intensive tree damage, leading to tree decline, mortality, and the formation of a significant proportion of standing dead trees.

The emerald ash borer *Agrilus planipennis* Fairmaire, 1888, Coleoptera: Buprestidae is classified as an invasive species originating from East Asia. It is included in the list of 20 most dangerous quarantine pests of forest trees. Under natural conditions in China, Japan, Korea, and Mongolia, this species primarily colonizes weakened *Fraxinus* trees, causing limited damage to vigorous specimens. At the same time, in several regions of China, including Tianjin, Beijing, and Heilongjiang Province, cases of ash damage have been recorded in suburban areas where North American ash species were introduced in the 1990s as ornamentals. Observations show that these introduced trees proved extremely vulnerable to *Agrilus planipennis* infestation (Wang *et al.*, 2010).

The emerald ash borer (*Agrilus planipennis*) was first detected in 2002 in Detroit, Michigan, USA, where it caused massive dieback of *Fraxinu*s trees (family *Oleaceae*) in natural, riparian, and urban ecosystems (Herms and McCullough, 2014). Despite the implementation of active quarantine measures, this invasive species has already spread to at least 35 US states as of 2022, causing the death of more than one billion ash trees (Poland and McCullough, 2006; Kovacs *et al.*, 2010). In recent decades, there has been a rapid expansion of the *A. planipennis* range, posing a threat not only to North America but also to the European continent. Ukraine has also been affected by this pest, with the first damage cases recorded in 2019 in eastern regions. Given the high invasiveness of this species, there is a real threat of its further westward spread toward European Union countries.

Agrilus planipennis is capable of colonizing virtually all available trees of the genus *Fraxinus*, with the exception of young specimens with thin trunks that lack sufficient phloem area for larval development. As population density increases, extensive damage to the tree's vascular tissues occurs, leading to gradual crown thinning, weakening of physiological functions, and complete tree mortality. Under extreme conditions, the population reaches peak levels, followed by

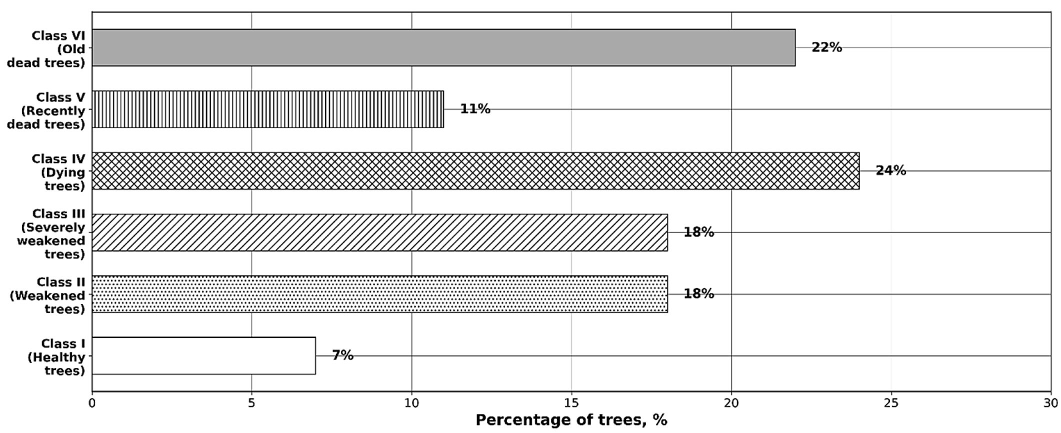

Figure 8. Tree distribution by health condition classes, %

a sharp decline due to depletion of available host trees (Smith *et al.*, 2010).

One of the key diagnostic features of *Agrilus planipennis* infestation is the presence of D-shaped exit holes in tree bark through which imagoes emerge. Despite the difficulty of detecting them in early stages, these holes remain a reliable indicator of active pest spread (Lindgren and Raffa, 2013). According to Duan *et al*. (2011), natural enemies of the beetle in its native range include woodpeckers, which actively destroy larvae, thereby limiting species reproduction.

As established by Mercader *et al*. (2013), *A. planipennis* populations fluctuate significantly depending on invasion stage, environmental conditions, and the level of stand damage.

In natural ecosystems, populations are usually in equilibrium, but in invasive ranges, in the absence of natural regulators, they can grow rapidly. Population density determination is based on pheromone monitoring results, larval infestation analysis, and the number of exit holes in bark (Francese *et al.*, 2014). Uncontrolled emerald ash borer reproduction can cause mass dieback of ash stands, indicating a high threat level to forest ecosystems.

In addition to the emerald ash borer, the studied stands contained xylophagous insects of the subfamily *Scolytinae* of the family Curculionidae. In particular, three species of ash bark beetles were found to dominate: the large ash bark beetle (*Hylesinus crenatus* F., 1787) and the variegated ash bark beetle (*Hylesinus fraxini* Panzer, 1779) (Coleoptera: Scolytinae) (Figure 9).

The large ash bark beetle primarily colonized the lower parts of ash trunks, while the variegated bark beetle preferred the middle and upper parts of the trunks. This indicates different ecological niches and distribution patterns for each species, which may be important for the effectiveness of their control and their impact on ash tree health condition (Table 1).

Identified xylophagous insect populations (Figure 10) demonstrated varying degrees of infestation, with *Agrilus planipennis*, *Hylesinus crenatus*, and *Hylesinus fraxini* populations showing low infestation densities. Emergence rates of these stem pest species were as follows: *Agrilus planipennis* – 1.1 ± 0.2 exit holes per dm², *Hylesinus crenatus* – 2.7 ± 1.3 exit holes per dm², *Hylesinus fraxini* – 2.2 ± 1.3 exit holes per dm².

According to Puzrina *et al*. (2025), rapid deterioration in the health condition of ash trees *Fraxinus* sp. was observed on the territory of the National University of Life and Environmental Sciences of Ukraine during 2024. This was confirmed by crown defoliation and dieback

Figure 9. Galleries of insects of the subfamily *Scolytinae* of the family *Curculionidae*

Table 1. Infestation levels of ash trees by stem pest entomocomplex

Pest species	Population density	Stem pest emergence (average number of exit holes and standard error per 1 dm⁻²)
Agrilus planipennis	low	1.1±0.2
Hylesinus crenatus	low	2.7±1.3
Hylesinus fraxini	low	2.2±1.3

Figure 10. Pest complex in the studied ash stand

compared to 2023 (when 66% of trees were in good condition). The study also revealed emerald ash borer *Agrilus planipennis* imagoes with characteristic D-shaped exit holes, with a maximum density of 4.2±1.8 per dm². This difference in indicators can be explained by emerald ash borer's preference for open-grown host trees, although with extensive distribution, the insect can colonize trees within forest stands.

During the study of common ash stand condition, a significant level of tree decline was found, which contributed to the development of various damages and disease pathogens. Analysis of the health condition of trees in the surveyed areas showed that approximately half of the trees had a small number of dead branches, while the remaining trees were significantly affected, with more than 50% dead branches. Particular attention should be paid to the fact that virtually no healthy trees were found in the surveyed stands, with most trees in weakened or severely weakened condition, creating prerequisites for further damage. In addition to dead branches, epicormic shoots and root rot also became characteristic signs of tree damage. Since these symptoms can result from various pathogenic processes, such as bacterial diseases, fungal diseases, and bracket fungi, detailed analysis allows for a deeper understanding of the relationships between factors contributing to tree decline and mortality (Table 2).

Among the studied trees, a significant proportion (84.5%) had dead branches, which may indicate various physiological disturbances. In particular, in 14.5±1.74% of trees, the proportion of dead branches exceeded 50%.

Assessment of the health condition of the stands showed that 49.6% of trees were severely weakened (health condition class III), while 43.1% were weakened (health class II). At the same time, no healthy trees (health class I) were recorded.

Table 2. Average values of indicators characterizing the health condition of ash trees on experimental plots

Experimental site	Trees with dead branches, %	Trees with epicormic shoots, %	Trees with insect infestations, %	Trees with frost cracks, %	Trees with root rot, %	Trees with mechanical damage, %
1	93.7	62.2	0.0	25.3	77.9	0.0
2	90.4	79.0	33.3	0.0	73.3	0.0
3	66.5	64.0	31.5	1.5	69.0	0.0
4	79.8	62.5	14.4	0.9	77.8	0.0
5	77.6	56.1	27.6	8.5	72.8	3.8
6	93.4	68.4	0.0	0.0	71.2	0.0
7	74.8	83.8	9.6	0.0	35.4	0.0
8	81.4	63.9	9.8	0.0	47.6	0.0
9	90.7	86.5	36.5	3.2	49.0	0.0
10	96.6	77.6	25.2	0.0	22.8	0.0
Average	84.5	70.4	18.6	3.4	59.7	0.4
Minimum	66.5	56.1	0.0	0.0	22.8	0.0
Maximum	96.6	86.5	36.5	25.3	77.9	3.8

Among the weakened and severely weakened trees, those with a relatively small number of dead branches prevailed (59.2% and 56.1%, respectively). In the group of dying trees (health class IV), 36.5% were specimens with 10–50% dead branches, and the proportion of trees with more than 50% dead branches was even higher.

Analysis of epicormic shoots showed that 52.4% of trees in health class III had only isolated epicormic shoots, while 28.7% had a significant number of them. Among trees in health class IV, 49% had isolated epicormic shoots, 24% had numerous epicormic shoots, and another 24% had their trunks completely covered with epicormic shoots. Root rot ranked third among the main types of ash tree damage, occurring on average in 59.7% of trees, with a maximum proportion of 77.9%. This pathology was most often recorded among trees belonging to health classes II–III.

Dead branches can be a symptom of collar necrosis, although their presence can also be caused by other factors. Epicormic shoots developing on viable areas of the crown or stem from adventitious buds were found in 70% of trees, with a maximum proportion of 87%. Among weakened trees (health class II), 43% had no epicormic shoots, while 50.3% had isolated epicormic shoots (Figure 11).

In a sample of ash stands surveyed in 2023–2024, the number and proportion of trees impacted by several factors simultaneously were calculated (Table 3). During the study, mixed infections and damage were recorded among ash trees in various locations in the Holosiivskyi National Nature Park. Five main combinations of two factors were identified: "rot + bacterial diseases," "fungal diseases + rot," "rot + stem pests," "bacterial diseases + stem pests," and "bacterial diseases + rot." Among the associations involving three factors, the combination of rot, stem pests, and bacterial diseases was noted. The highest proportion of affected trees in roadside ash stands was recorded for the combinations "rot + bacterial diseases" (3.0±0.98%) and "rot + stem pests" (3.0±0.72%), which indicates their significant prevalence. In the park interior, maximum damage was observed for the combination "rot + stem pests" (1.4±0.96%), which also indicates significant weakening of trees.

At the present stage, forest ecosystems in Ukraine, as in other regions worldwide, are

Figure 11. Symptoms of common ash damage caused by bacterial and fungal pathogens

Table 3. Prevalence of damage factor associations in common ash trees, %

Decline factors	Ash stands in Holosiivskyi National Nature Park (along roads)	Ash stands in Holosiivskyi National Nature Park (park interior)
Rot + bacterial diseases	3.0±0.98	0.3±0.39
Fungal diseases + rot	2.0±0.72	1.0±0.88
Rot + stem pests	2.0±0.72	1.4±0.96
Bacterial diseases + rot	1.0±0.41	0.0
Bacterial diseases + stem pests	0.2±0.68	0.2±0.68
Stem pests + rot	3.0±0.72	0.6±0.78
Stem pests + bacterial diseases + rot	1.0±0.41	0.0
Bacterial diseases + rot + stem pests	0.0	0.0
Rot + stem pests + fungal diseases	0.0	0.0

experiencing large-scale mortality of major tree species, including Pinus sylvestris L., *Fraxinus excelsior* L., *Picea abies* (L.) Karsten, *Quercus robur* L., *Abies alba* Mill., *Betula pendula* Roth, and others. As noted by researchers including Maurer and Pinchuk (2019) and Dragan and Galkin (2020); Lyalyin and Meshkova (2022) state that this phenomenon is complex in nature and results from the combined action of several factors, including global climate change, hydrothermal regime disruption, pest and pathogen spread, natural biotope transformations, and increasing anthropogenic pressure. Matsiakh (2021) notes that global climate change significantly affects the spread of invasive organisms and weakens host plants, which is a favorable prerequisite for the spread of invasive species to new territories. Anderegg *et al.* (2015) note the need for a comprehensive approach that takes into account tree physiology, insect population dynamics, and interactions between them to more accurately predict the response of forest ecosystems to climate change.

Despite certain differences in the interpretation of causes, scientists are unanimous in their assessment of the scale of degradation processes that threaten the stability of forest ecosystems and their ecosystem functions. The results obtained demonstrate significant variability in the health condition of trees depending on growing conditions. This underscores the need for further monitoring and the development of preventive measures for the conservation of ash stands in the Holosiivskyi National Nature Park.

CONCLUSIONS

As a result of the research, a comprehensive assessment of the health condition of ash stands in Holosiivskyi National Nature Park, Kyiv, was conducted, and the main biotic and abiotic factors causing stand degradation were identified.

Among stem pests, the largest populations are represented by *Agrilus planipennis*, *Hylesinus crenatus*, and *Hylesinus fraxini*. The populations of xylophagous insects showed varying degrees of colonization, with *Agrilus planipennis*, *Hylesinus crenatus*, and *Hylesinus fraxini* characterized by low density. Exit hole density of stem pests was: 1.1 ± 0.2 holes/dm² for *Agrilus planipennis*, 2.7 ± 1.3 holes/dm² for *Hylesinus crenatus*, and 2.2 ± 1.3 holes/dm² for *Hylesinus fraxini*. Monitoring of *Agrilus planipennis* populations demonstrated the effectiveness of color-based traps (green), as imagoes were found exclusively in such traps.

The largest share in the stands is occupied by weakened (health classes II–III) and severely weakened trees (health class IV – 24%), and the proportion of dead trees (health class VI – 22%) indicates the need for urgent forest health measures. It has been established that trees in the largest diameter classes (48–88 cm). During the research, the main combinations of damage factors were identified, among which the most common are rot in combination with stem pests and bacterial diseases.

The study demonstrated key risk indicators and dominant combinations of decline factors, and revealed prospects for further forecasting of urban forest ecosystem degradation and evaluating the effectiveness of forest health measures.

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