2. ЛІСОЗНАВСТВО, ЛІСІВНИЦТВО ТА МИСЛИВСЬКЕ ГОСПОДАРСТВО

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Dynamics of Scots pine health after the release of *Thanasimus formicarius* in bark beetle foci

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In Eastern Polissia, a severe decline of Scots pine started in 2015. It was caused by drought and aggravated by outbreaks of Ips acuminatus (Gyllenhal, 1827) followed by Ips sexdentatus (Börner, 1776). The sanitary felling could not mitigate the effects of the bark beetle outbreak. Therefore, there was an attempt to release a predatory beetle, Thanasimus formicarius (Linnaeus, 1758) (Coleoptera: Cleridae) into bark beetle foci. In 2018, the rearing of this predator started in the State Specialized Forest Protection Enterprise "Kharkivlisozahyst", and it was released into the foci of bark beetles in Chernihiv, Sumy, and Kharkiv regions. The study aimed to evaluate the effects of Th. formicarius introduction into the foci of bark beetles. For the purpose of analysing the situation, sample plots in the Forest zone, on the border of the Forest and Forest-Steppe, and in the Forest-Steppe zone have been selected. The analysis shows that the outbreak of bark beetles in north-eastern Ukraine started earliest in Chernihiv region (Forest zone) and latest in Kharkiv region (Forest-Steppe zone). Selyaninov's Hydrothermal index was less than the standard of the corresponding natural zones. This contributed to the development of bark beetle populations. In the year of the predator introduction (2018), the bark beetle outbreak began to decline in Chernihiv, culminated in Sumy, and started in Kharkiv. In all years, the diameter of recently died trees was smaller than the average diameter of the stand, that is, the tree mortality was not pathological, because bark beetles infested trees of different sizes. In 2018, the mortality of trees was the highest in Chernihiv region, where the outbreak began earlier. The health of the trees improved, and the proportion of recently died trees decreased in all the sample plots in 2019. The health of the trees worsened in all the sample plots in the following years, due to the new outbreak of bark beetles. The trend and level of tree health

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worsening were most pronounced in the sample plots in Sumy, where regular sanitary thinning was conducted. Thus, the release of Th. formicarius into the bark beetle foci contributed to tree health improvement the following year. However, a one-time predator release could not restrain the new outbreak and prevent further forest decline. It is possible that additional releases of predators can provide long-lasting and environmentally safe pest control.

Key words: *Ips acuminatus; Ips sexdentatus; predator; tree mortality; health index.*

Introduction.

A deterioration in the health of many forest tree species has been observed in recent years in various regions (Jaime et al., 2019; Liška, Knížek, & Véle, 2021; Bussotti et al., 2024; Knutzen et al., 2025). This is largely due to a decrease in the amount of precipitation against the background of rising temperatures, which leads to increased evaporation, soil and air drought, and an increase in the frequency and severity of catastrophic events (hurricanes, fires, etc.) (Hlásny, & Turčáni, 2009; Hlásny et al., 2019; Singh et al., 2024). The mineral nutrition of trees, photosynthesis, and metabolism are disrupted. Weakened trees become less resistant to xylophages and pathogens (Lantschner & Corley, 2023; Knutzen et al., 2025). In the new climatic conditions, some species of minor importance have advantages for development, survival, and range expansion (Fischbein & Corley, 2022).

The conifers, Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.), the most economically important tree species in Europe, were most affected (Brichta et al., 2023). Spruce forests were infested by *Ips typographus* (Linnaeus, 1758), and pine forests by *Ips acuminatus* (Gyllenhal, 1827) (Colombari et al., 2013; Knížek, Liška, & Véle, 2022).

In Ukraine, pine forest areas subordinated to the State Forest Resources Agency of Ukraine (SFRAU) occupy 2.4 million hectares, including 66.7% in the Forest zone, and 26% in the Forest-steppe zone (Buksha et al., 2021). Since 2010, a sharp deterioration in the health of the Scots pine forests has occurred in Ukraine, which was initially attributed to climatic factors. However, by 2017, *I. acuminatus* had been found to infest weakened stands. This species replaced *Tomicus* sp., due to its ability to colonise almost healthy trees (temporarily weakened, for example, by drought), develop in several generations per year, and successfully reproduce in thin branches and logging debris (Meshkova, 2021).

The foci of bark beetles developed over a larger area in the Forest zone with more pure pine stands of the same age, and relatively slow drying of felling residues (Meshkova & Borysenko, 2018; Meshkova & Bobrov, 2020).

Trees, severely weakened by drought and *I. acuminatus*, are infested by *Ips sexdentatus* (Börner, 1776), which also has several generations (Erdoğan, 2024). As the foci of these species collapsed, the abundance of *Tomicus piniperda* (Linnaeus, 1758) and *T. minor* (Hartig, 1834) increased (Андреєва, Вишневський, Болюх, 2019). However, *Ips acuminatus* again dominated in the new outbreak that began in 2019 (Мартиненко, 2025).

In Eastern Polissia, a pathological decline of Scots pine trees started in 2015 in the mature pure stands of the State Enterprise "Oster Forestry" (Chernihiv Region) (Жежкун, & Порохняч, 2019). As of the end of 2017, foci were present in the forests of Chernihiv region and the Forest zone of Sumy region. The first dead trees appeared singly or in groups, mainly in the southern and southwestern edges near open areas (clear-cuts, glades, etc.). Later, the foci rapidly expanded and in some cases were continuous (Порохняч, 2018).

In 2017, no significant differences were found in the parameters of *I. acuminatus* outbreak between sample plots in the Forest-Steppe and Forest parts of Sumy region (Meshkova, & Bobrov, 2020). However, in both regions, the average outbreak area, bark beetles' production, the number of infested trees, tree health indices, the proportion of recently died trees, the density of egg galleries, nuptial chambers, and young beetles were higher in pure Scots pine stands than in the mixed ones, and these indicators increased sharply from June to September.

The sanitary felling is the main way of mitigating the effects of the bark beetle outbreak. Doing it timely allows for reducing the bark beetle population and obtaining commercial timber before infested trees are inhabited by longhorn beetles and destroyed by wood-destroying fungi. However, the removal of drying and especially recently died trees leads to a decrease in the number of saproxylic species that contribute to the rapid decomposition of felling residues, and entomophages that can provide long-lasting and environmentally safe pest control (Riddick, 2023; Papek et al., 2025).

Among the entomophages, *Thanasimus formicarius* (Linnaeus 1758) (Coleoptera: Cleridae) is one of the most abundant bark beetle predators in Europe (Kenis et al., 2017; Papek et al., 2025; Schroeder, Knape, & Kärvemo, 2025). It preys on many xylophagous insects, including *I. typographus*, *I. acuminatus, I. sexdentatus*, *T. minor* (Hart.), and *T. piniperda*. Since 2006, *Th. formicarius* has been reared in laboratories and released for the biological control of bark beetles in Turkey (Akyol & Sarikaya, 2017).

In 2018, the rearing of *Th. formicarius* started in the State Specialized Forest Protection Enterprise "Kharkivlisozahyst", and since 2018, this predator has been released into the foci of bark beetles in Chernihiv, Sumy, and Kharkiv regions of Ukraine. According to the 2020 assessment, the density of larval galleries of the bark beetle decreased in all the plots compared to 2018, and forest health improved (Meshkova et al., 2021). However, a new outbreak of bark beetles started in north-eastern Ukraine in 2021. Therefore, it was important to find out whether single introductions of *Th. formicarius* could control bark beetle populations in the long term.

The object of research was the dynamics of Scots pine health in the bark beetle foci. *The subject of research* was the consequences of *Th. formicarius* introduction in the bark beetle foci for Scots pine health. The study *aimed* to evaluate the effects of *Th. formicarius* release into the foci of bark beetles. The tasks included: 1) analysis of long-term dynamics of bark beetle outbreaks' area in the north-east of Ukraine in the period 2015-2024 taking into account weather conditions; 2) assessment of the health of Scots pine (2018-2023) after predator introduction in 2018; 3) assessment of the diameter of dead and living trees in 2019 and 2023.

Material and methods.

Data on the long-term dynamics of bark beetle outbreaks' area were obtained from the archive of the State Specialized Forest Protection Enterprise "Kharkivlisozahyst" (Sumy and Kharkiv regions) and the State Forest Resources Agency of Ukraine (Chernihiv region).

Weather parameters for the years of research were obtained from the website ClimateCharts.Net (Zepner et al., 2021) based on data from Chernihiv meteorological station (51.49111°N; 31.29861°E) – Forest zone; Konotop (51.2403200°N; 33.2026300°E) – border between Forest and Forest-Steppe zones; Kharkiv (49.9808100°N; 36.2527200°E) – Forest-Steppe zone.

Selyaninov's Hydrothermal Index – HTI was calculated by the formula:

$$HTI = 10\frac{\sum P}{\sum t}, \quad (1)$$

where ΣP is the amount of precipitation for the period with mean monthly air temperature over 10°C, mm; Σt is the sum of daily air temperatures for the same period, °C.

For a comparative analysis of pine stands' health after the introduction of the predator, we selected sample plots in the Forest zone (Chernihiv region: Yalyvschina Regional Landscape Park and "Sviate" tract), on the border of the Forest and Forest-Steppe (Sumy region: Konotop), and in the Forest-Steppe (Sumy region: Sumy, Okhtyrka; Kharkiv region: Babai) (Fig. 1).

All the sample plots where the health of Scots pine trees was monitored in the period 2018-2020 and 2023 are located in fresh, relatively poor forest site conditions, in pure stands (100% Scots pine) aged 65-75 years with a relative density of stocking of 0.6-0.8. After predator introduction, no sanitary felling was conducted in these stands to assess the long-term effect of this measure. The exception was the sample plots near Sumy, where selective sanitary felling is regularly conducted, which can serve as a control.

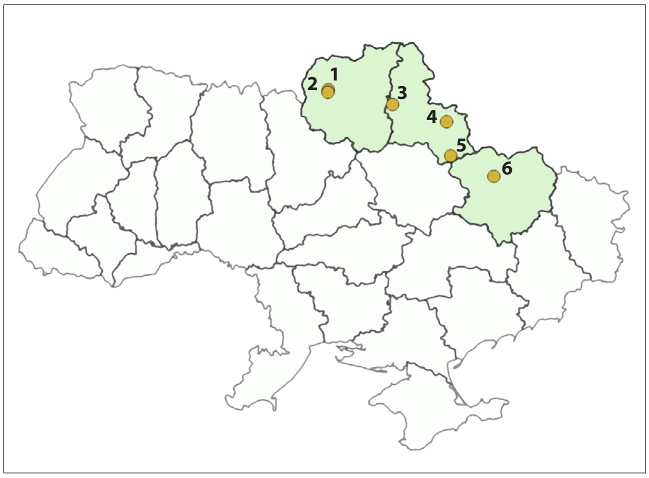

Fig. 1. Location of sample plots in the map of Ukraine.
Chernihiv region: 1 – Regional Landscape park "Yalivshchyna"; 2 – "Svyate" tract.
Sumy region: 3 – Konotop; 4 – Sumy; 5 – Okhtyrka.
Kharkiv region: 6 – Babai

At the sample plots, the diameter at breast height (DBH) of all trees was measured with an accuracy of 1 cm. In the period 2018-2020, and then in 2023, each tree was assigned to one of six classes of health condition: 1st – healthy; 2nd – weakened; 3rd – severely weakened; 4th – drying-out; 5th – recently died; 6th – died over a year ago (Sanitary Forests Regulations in Ukraine, 2016).

Health indices for all living and dead trees (HI_{1-6}) and for living trees (HI_{1-4}) have been calculated. The use of HI_{1-4} reflects the real health condition of stands, especially those where sanitary felling has not been conducted for a long time (Meshkova, Bobrov, 2020).

Tree mortality for each sample plot was calculated as the proportion of recently died trees (5th health class) of the number of trunks in 2018.

Normality of data on tree health condition was not confirmed by the Shapiro-Wilk test ($p > 0.05$), and the samples of dead trees were too small to use parametric tests for analysis. Therefore, we compared the groups of trees using non-parametric methods (Kruskal-Wallis test). Tukey's honest significant difference test was used to compare all possible pairs of means from a set of groups (Peck, Short, & Olsen, 2020).

Spearman's coefficient was evaluated for the correlation between Scots pine decline area and Selyaninov's Hydrothermal index.

Microsoft Excel (2019, Microsoft Corporation, Redmond, WA, USA, 2019) and the statistical software package PAST (54.5.12, Øyvind Hammer, Natural History Museum, University of Oslo, Oslo, Norway, 20253 (Hammer, Harper, & Ryan, 2001) were used for data analysis and visualization. QGIS 3.40.5 was used for map building (QGIS 3.40.5).

Results.

An analysis of archival data showed that Scots pine decline caused by bark beetles in the northeast of Ukraine began in 2016. It was most severe in Chernihiv region (Forest zone), and less severe in Sumy region, located partly in the Forest zone and partly in the Forest-Steppe zone (Fig. 2).

In Kharkiv region area, located partly in the Forest-Steppe and partly in the Steppe, bark beetle outbreaks were recorded later, and over a smaller area. After the outbreaks collapsed in 2019-2020, a new increase in bark beetles populations and the area of Scots pine dieback has begun, which was most severe in Chernihiv region (see Fig. 2). We must note, however, the data on bark beetle outbreaks in Kharkiv and Sumy regions in recent years are incomplete due to military actions and limited access to forests contaminated with explosive devices.

During the analyzed period, Selyaninov's Hydrothermal Index (HTI) in Chernihiv was lower than the standard value for the Forest zone (HTI = 1.3). It was higher than the standard for the Forest-Steppe zone (HTI = 1.0) only in 2021 (Fig. 3).

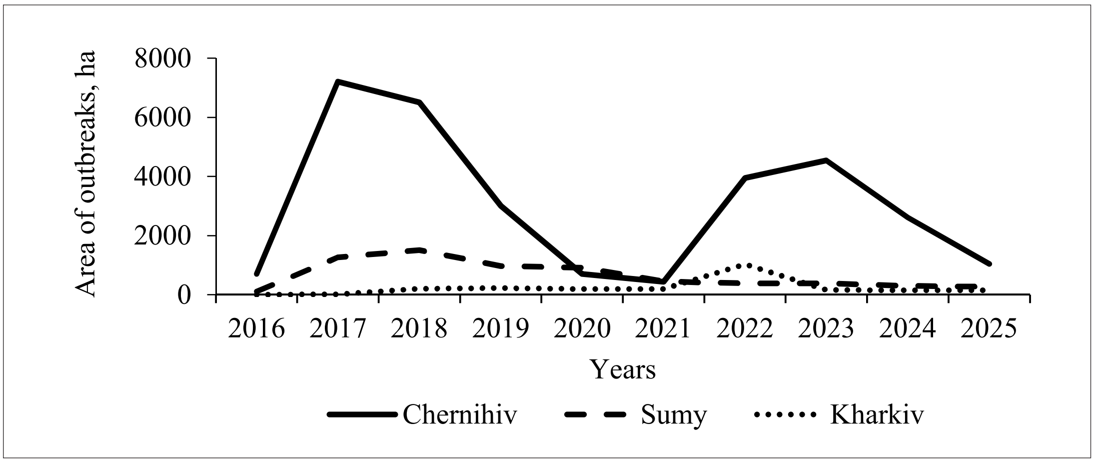

Fig. 2. Dynamics of the area of Scots pine decline caused by bark beetles in the northeast of Ukraine (by regions)

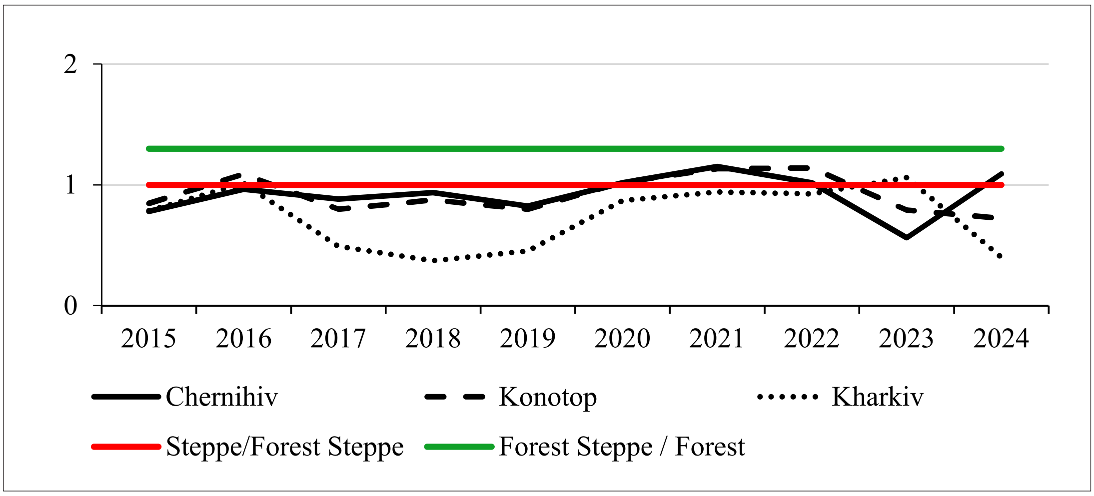

Fig. 3. Dynamics of Selyaninov's Hydrothermal index (HTI) for some points in the study area (Chernihiv – Forest zone; Konotop – border between Forest and Forest-Steppe zones; Kharkiv – Forest-Steppe zone). The standard HTI=1.3 for the Forest zone (green) and HTI=1.0 for the Forest-Steppe zone (red) are shown

The HTI values in Konotop, which is located on the border of the Forest and Forest-Steppe zones, were lower than the standard value for the Forest zone in all years and exceeded its value for the Forest-Steppe zone only in 2016 and 2021. The HTI values in Kharkiv were lower than the standard value for the Forest-Steppe in all years, and in the period 2017-2019, they were only 37.7, 28.5, and 34.9% of it (see Fig. 3). The next period of the HTI decrease in Chernihiv began in 2021, but in 2023, it increased to 1.1. The HTI decreased from 2022 to 2024 in Konotop and from 2023 to 2024 in Kharkiv (see Fig. 3).

The Spearman correlation between HTI and foci area was low and nonsignificant for all regions (r_s – 0.2; 0.003, and 0.46 for Chernihiv, Konotop, and Kharkiv, respectively; $r_{s0.05} = 0.648$). An increase in the outbreak area in Chernihiv region began in 2016, the next year after the low HTI. However, after the low HTI in 2023, the outbreak area decreased in subsequent years. An increase in the outbreak area in Sumy region also began in 2016, the next year after the low HTI. However, the growth of HTI after 2019 was accompanied by a decrease in the outbreak area. In Kharkiv region, despite the HTI decrease in the period 2016-2018, the outbreak area increased only in 2022, with a subsequent decrease. However, the outbreak area in Kharkiv region might be underestimated because of the military actions and limited accessibility to forests.

Thus, the predator was introduced in 2018 into all the sample plots which are considered here. However, as can be seen from Fig. 2, in 2018, in Chernihiv region the outbreak passed its culmination, in Sumy it was at its peak, and in Kharkiv it began to increase.

The mortality of Scots pine trees in 2018 in the sample plots ranged from 1 to 5.6% (Fig. 4) and was the highest in the northern part of the study area (Forest zone), where the bark beetle population has increased since 2015 (see Fig. 2).

In 2019 (see Fig. 4), a sharp decrease in mortality occurred in all the sample plots, except for Konotop and Sumy. The tree mortality continued decreasing in 2020 in Yalivshchyna and Konotop; mortality remained unchanged in "Svyate" and increased in Sumy, Babai, and, most noticeably, in Okhtyrka (8.8%). In 2023, tree mortality continued to grow because of a new outbreak of bark beetles and an increase in the area of Scots pine decline in north-eastern Ukraine (see Fig. 2).

In 2018, the HCI_{1-6}, considering living and dead trees, characterized the stands as severely weakened (within 2.51-3.5 according to Sanitary Forests Regulations in Ukraine, 2016) in Babai, Okhtyrka, Konotop, and "Svyate", as drying up (within 3.51-4.5) in Sumy and RLP Yalivshchyna (Fig. 5).

The following year after the introduction of predators into the bark beetle foci, the health condition of the stands improved in all the sample plots, except Sumy, where selective sanitary felling was conducted. The HI_{1-6}, decreased in 2019 by 0.1-0.4 points. However, in 2020, a new outbreak of bark beetles started in the northeast of Ukraine. In 2020, the HI_{1-6} increased compared to 2019 in all the sample plots, but was lower than in 2018 in RLP Yalivschyna and "Svyate", similar to 2018 in Konotop, and exceeded the values of previous years in Sumy, Okhtyrka, and Babai. As of 2023, the Scots pine stands in Babai, Konotop and "Svyate" were significantly weakened (HI_{1-6} – 2.51-3.5), and RLP Yalivschyna, Okhtyrka, and Sumy are drying out. At the same time, the selective sanitary felling in Sumy did not contribute to a decrease in the weakening of trees.

Considering only living trees in HI_{1-4}, the health of the stands improved the year after the predator's introduction, although the stands remain very weakened (Fig. 6).

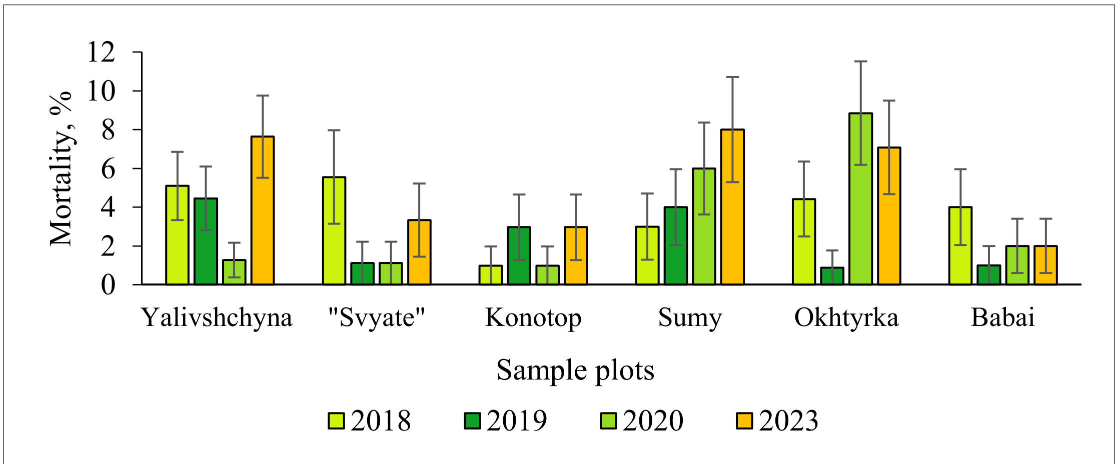

Fig. 4. Tree mortality in sample plots as a percentage of the total tree number in 2018 (bars – St. error)

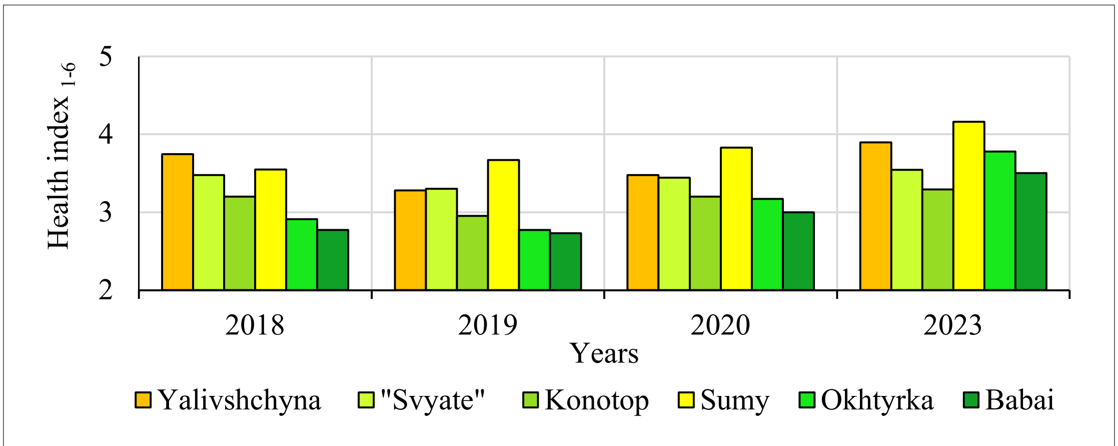

Fig. 5. Health index considering all living and dead trees (HI_{1-6}) in the sample plots in the period 2018-2023

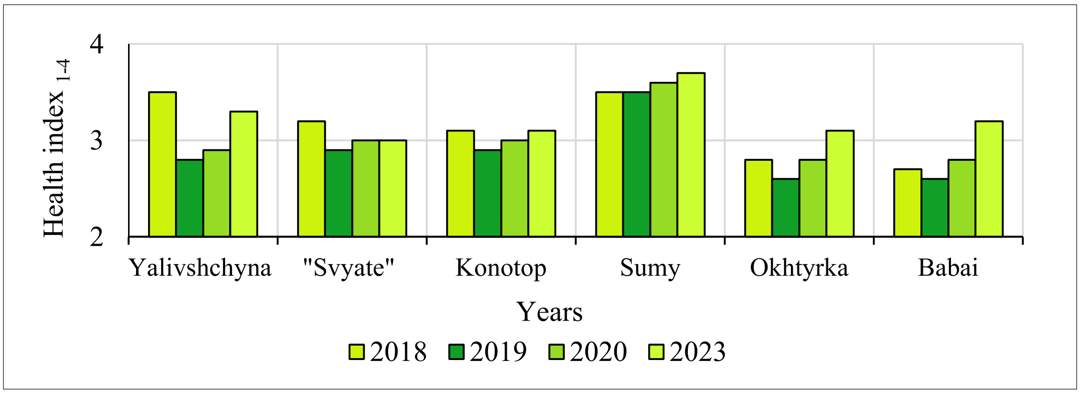

Fig. 6. Health index considering only living trees (HI_{1-4}) in sample plots in the period 2018-2023

In 2020, the HI_{1-4} increased compared to 2019, but was less than in 2018, and even in 2023, exceeding the 2018 value only in Okhtyrka and Babai, although the stands remain very weakened. The Shapiro-Wilk test showed that the distribution of trees by health condition is not normal ($p < 0.05$). Therefore, the data on tree health were compared using nonparametric methods. The Kruskal-Wallis test for equal medians showed significant differences between sample plots by HI_{1-4} in all years of the study, with the H (chi2) decreasing from 93.05 in 2018 to 85.5 in 2019, 56.8 in 2020, and 40.6 in 2023. According to the Tukey criterion, in 2023, HI_{1-4} in Sumy significantly differed from all the other sample plots ($p < 0.001$).

In 2019, the diameter of recently died trees (5th health class) was smaller than the average diameter of the stand in all the sample plots (Fig. 7). However, the differences were significant only in RLP Yalivshchyna and “Svyate” (H (chi2) = 14.83; $p < 0.001$; and H (chi2) = 15.26; $p < 0.001$, respectively). That is, the mortality was not pathological in these sample plots. The Kruskal-Wallis test for equal medians for other sample plots showed no significant differences between recently died trees and the average diameter of the stand (H (chi2) – 0.68-4.15; p – 0.1-0.7).

In 2023, the diameter of recently died trees was the same as the average diameter of the stands in RLP Yalivshchyna, Sumy, and Okchtyrka (H (chi2) – 3.99-4.15; $p>0.1$).

In 2023, in Konotop, the diameter of recently died trees (34 cm) was less than the average diameter of the stand (36 cm). In “Svyate” and Babai, the diameter of recently died trees (36 cm) was greater than the average diameter of the stand (32 and 28 cm, respectively). However, such differences were insignificant (H (chi2) – 0.68-1.93; p – 0.37-0.7).

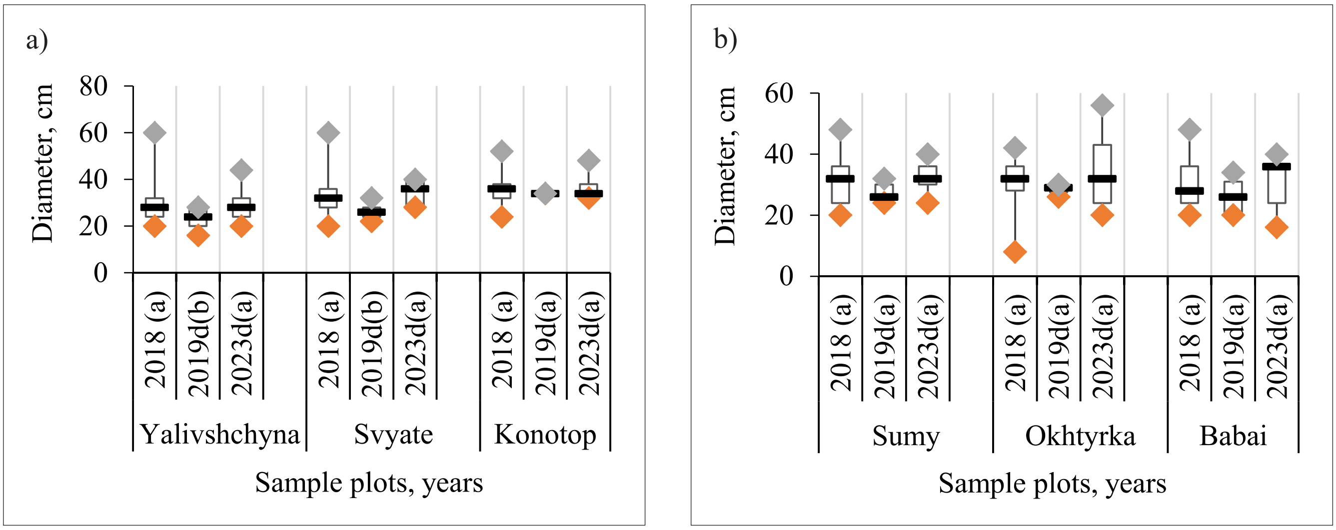

Fig. 7. Diameters of living (2018) and dead (2019, 2023) trees in sample plots (box – 25-75 percentiles with a median inside (dark line); whiskers are max-min; letters in the parentheses show the significant differences at p<0.05) (a – three northern points; b – three southern points)

Discussion.

Classical biocontrol aims to keep pest populations below a damage threshold and to maintain an ecological equilibrium at lower population levels between the pest and its natural enemies (Kenis et al., 2017; Goundar et al., 2025). Coleopteran predators are often released to control bark beetle populations (Khobakhidze, Tvaradze, & Kraveishvili, 1970; Klapwijk et al., 2016; Vasadze, Dumbadze, & Gatenadze, 2024). Predators are mass-produced and released to the foci of bark beetles (Riddick, 2023). Two predators were successfully used in bark beetle outbreaks. *Rhizophagus grandis* Gyllenhal, 1827 (Coleoptera: Monotomidae) is an effective specific predator of *Dendroctonus micans* (Kugelann, 1794) (Coleoptera: Curculionidae: Scolytinae) (Alkan Akıncı, & Grégoire, 2025). Mass rearing programs of this predator and its releases in bark beetle foci have been known from Georgia since 1963 (Kobakhidze et al. 1970; Beridze et al., 2024; Vasadze et al., 2024). Later, such programs started in France, Türkiye, and the UK (Büyükterzi, Özcan, & Sakici, 2022). Unlike *R. grandis*, *Th. formicarius* preys on many bark beetle species in spruce, pine, and broadleaf trees. However, it is most abundant in pine stands. Fecundity of *Th. formicarius* is higher than that of bark beetles (Weslien, 1994). Adults live for several months, prey on numerous species with different phenologies (Schroeder et al., 2025).

The outbreak of bark beetles in the north-east of Ukraine developed later than in Zhytomyr Polissya (Андреєва та ін., 2019). Within the three regions considered, the outbreak began earlier, was most severe in Chernihiv region (Forest zone), and less severe in Kharkiv region (Forest-Steppe) (see Fig. 2). Within Chernihiv region, the bark beetle outbreaks had spread from the west and northwest to the east (Порохняч, 2018).

An analysis of data from 16 European countries shows forest decline in northern, central, Alpine, and southern regions due to drought and elevated temperatures (Knutzen et al., 2025). In our studies, the Hydrothermal index in northeastern Ukraine was less than the standard for the corresponding natural zones (see Fig. 3). High temperatures and drought were confirmed as the main causes of the forest decline in Europe. This created conditions for outbreaks of bark beetles and fires. Forests in the southern regions of Europe revealed greater resilience, likely due to historical drought exposure (Knutzen et al., 2025). In the Forest zone of Ukraine, Scots pine also suffered more, since its root system was adapted to the high level of ground waters (Meshkova, 2021).

In Poland, a significant correlation between drought and *I. acuminatus* outbreaks was confirmed (Jabłonski, Tarwacki, & Sukovata, 2019). The absence of significant correlation between the hydrothermal index and bark beetle foci area in this study is due to the various timing of population growth in the highly mosaic forest sites and structure, or with a relatively short observation period.

The predator was released in 2018 in all the sample plots considered in this paper. However, the outbreaks were at different phases: the beginning of decline in Chernihiv, culmination in Sumy, and growth in Kharkiv (see Fig. 2). Usually, the release of entomophages is most effective after the culmination (Kenis et al., 2017), i.e., like in Chernihiv region.

The mortality of trees in 2018 was highest in Chernihiv region, where the outbreak began earlier (Fig. 4). The diameter of recently died trees was smaller than the average diameter of the stand (Fig. 7). This is consistent with the fact that the mortality was not pathological because bark beetle inhabited trees of different sizes (Meshkova & Borysenko, 2018; Jaime et al., 2019).

In 2019, the proportion of recently died trees decreased sharply in all the sample plots. During the new outbreak of bark beetles, the health of the trees worsened in all the sample plots being most pronounced in Sumy, where regular sanitary thinning was carried out (Fig. 4). It can be assumed that drying and recently died trees, which hosted both bark beetle larvae and their entomophages, were removed due to sanitary felling.

Thus, the release of *Th. formicarius* into the bark beetle foci contributed to tree health improvement the following year. However, a one-time predator release could not restrain the new outbreak and prevent further forest decline. It is possible that additional releases of predators could stabilize the bark beetle population at a low level, as is the case in Georgia using *Rh. grandis* to control *D. micans* (Vasadze et al., 2024).

Conclusions.

1. The outbreak of bark beetles in the north-east of Ukraine started the earliest in Chernihiv region (Forest zone), and the latest in Kharkiv region (Forest-Steppe). The Hydrothermal index in northeastern Ukraine was less than the standard for the corresponding natural zones. This contributed to the development of bark beetle populations.
2. In the year of predator introduction (2018), the bark beetle outbreak began to decline in Chernihiv, culminated in Sumy, and started in Kharkiv.
3. In all years, the diameter of recently died trees was smaller than the average diameter of the stand, that is, the tree mortality was not pathological, because bark beetles inhabited trees of different sizes.
4. In 2018, the mortality of trees was highest in region, where the outbreak began earlier. The health of the trees improved, and the proportion of recently died trees decreased in all the sample plots in 2019. The health of the trees worsened in all the sample plots in the following years, due to the new outbreak of bark beetles.
5. The trend and level of tree health worsening were most pronounced in the sample plots in Sumy, where regular selective sanitary thinning was conducted.
6. A one-time release of *Thanasimus formicarius* into the bark beetle foci is not enough to prevent further forest decline.

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Conflicts of Interest.

The authors declare no conflicts of interest.

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Динаміка стану сосни звичайної після випуску *Thanasimus formicarius* в осередки короїдів

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З 2010 року відбулося різке погіршення стану соснових лісів в Україні. Такий стан спровокований посухою та посиленими спалахами масового розмноження короїдів *Ips acuminatus* (Gyllenhal, 1827), а пізніше – *Ips sexdentatus* (Börner, 1776).

У Східному Поліссі всихання сосни розпочалося у 2015 році. До кінця 2017 р. осередки короїдів було виявлено у Чернігівській обл. та лісовій зоні Сумської області. Оскільки вибіркові санітарні рубки не змогли запобігти поширенню осередків короїдів, було застосовано класичний біометод. Хижого жука *Thanasimus formicarius* (Linnaeus, 1758) (*Coleoptera: Cleridae*) з 2018 р. вирощували у Державному Спеціалізованому лісозахисному підприємстві «Харківлісозахист» і випускали в осередки короїдів у Чернігівській, Сумській і Харківській областях. Впродовж 2019-2020 рр. щільність популяцій короїдів зменшилася, а стан дерев покращився. Водночас у 2021 р. розпочався новий спалах масового розмноження короїдів на північному сході України. Мета досліджень полягала в оцінюванні тривалості ефективного впливу внесення хижака *Th. formicarius* в осередки короїдів. Для порівняльного аналізу стану насаджень після внесення хижака ми вибрали пробні площі у лісовій зоні (Чернігівська область: Регіональний ландшафтний парк Ялівщина та урочище «Святе»), на межі лісової та лісостепової зон (Сумська область: Конотоп) та в лісостепу (Сумська область: Суми, Охтирка; Харківська область: Бабаї). Усі пробні площі, на яких здійснювали моніторинг стану сосни у 2018-2020 та 2023 рр., розміщені у свіжому суборі, в чистих соснових насадженнях віком 65-75 років та з відносною повнотою 0,6-0,8. Після випуску хижака санітарних рубок на цих площах не проводили, за винятком пробних площ поблизу Сум, які слугують контролем. Аналіз свідчить, що спалах короїдів на північному сході України розпочався найраніше у Чернігівській, а найпізніше – у Харківській областях. Гідротермічний коефіцієнт Г. Т. Селянінова у період досліджень був меншим, ніж вважається нормою для відповідних природних зон. Це створило умови для ослаблення дерев і поширенню популяцій короїдів. У рік внесення хижака (2018), спалах короїдів починав згасати у Чернігівській, був у фазі кульмінації – у Сумській і на фазі росту – у Харківській областях. В усі роки діаметр свіжого сухостою був меншим, ніж середній діаметр насадження, тобто відпад не був патологічним, оскільки короїди заселяли дерева різного розміру. У 2018 р. відпад дерев був найвищим у Чернігівській області, де спалах короїдів розпочався раніше. Стан дерев покращився, а частка свіжого сухостою зменшилася на всіх пробних площах у 2019 році. Водночас у наступні роки стан дерев погіршився на всіх пробних площах у зв'язку з новим спалахом розмноження короїдів. Тренд погіршення стану насаджень був виражений найбільше на пробних площах у Сумській області, де регулярно проводили вибіркові санітарні рубки з вилученням дерев 4 і 5 категорій стану, в яких переважно перебували хижаки. Отже, внесення *Th. formicarius* в осередки короїдів сприяло поліпшенню стану дерев наступного року. Водночас одноразове внесення хижака не змогло стримати розвиток нового спалаху та запобігти подальшому всиханню насаджень. Можливо, що додатковий випуск хижака сприяв би стабілізації популяції короїдів на низькому рівні.

Ключові слова: *Ips acuminatus*; *Ips sexdentatus;* хижак; відпад дерев; індекс стану.

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