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Thirty-Year Dynamics of the Pine Stand Sanitary Conditions of Boyarka Forestry Research Station

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Abstract. The drying up of coniferous forests is a problem for both Europe and Ukraine, where drying area of pine stands covered the Polissia region and spread to other natural areas, therefore, the analysis of pathological factors of the reasons for the weakening and deterioration of the sanitary condition is relevant. The purpose of the study provides for generalisation of the reasons for the deterioration of the sanitary condition of pine stands and pathological processes in dynamics over 30 years. The results are based on data from 12 permanent and 10 temporary sample plots established in a separate subdivision of the National University of Life and Environmental Sciences of Ukraine "Boyarka Forestry Research Station". The study used empirical and systematic methods. The predominance of drying of pine stands due to infection with the pathogen *Heterobasidion annosum* ((F.) Bref.) was revealed, at the same time, with the highest infestation coefficient, the dominant species in the stands under study were ash bark beetles *Tomicus piniperda* L. (54%), *Tomicus minor* Hartig (46%) with high and medium infestation rates and *Monochamus galloprovincialis* Olivier with a tree population ratio of 52% and an average degree of population in trunk areas with transitional and rough bark. In the dynamics of observations since 2011, an increase in the index of sanitary condition of pine stands and deterioration of forests due to changes in weather conditions and climate aridity have been established. After the dry growing seasons of 2015-2017, the drying of pine trees with mass reproduction of stem pests was revealed, the infestation coefficient of which indicates the dominance of the sharp-dentated bark beetle *Ips acuminatus* Gyll. and a large ash bark beetle *Tomicus minor* which are aggressive species. Since 2019, there has been a decrease in the number of bark beetles due to exceeding the long-term precipitation rate due to a decrease in the temperature at the beginning of the growing season and unfavourable weather conditions for wintering of these insect species. The results obtained would become an informational component in the development of a strategy for managing damaged forest areas

Keywords: pathological process, forest pathology monitoring, pine stands, forest drying, xylophagous insects

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INTRODUCTION

Reproduction of biologically stable productive forest stands is an important indicator of sustainable forest development, the decrease in the biotic stability of forests is caused by the violation of established links between the components of forest ecosystems, therefore, the sanitary condition of forests is determined by the influence of anthropogenic factors.

There have been significant changes in hydrological and weather conditions, which, in turn, has led to a sharp depletion of pine stands, weakening of trees, deterioration of sanitary conditions and drying of stands (Jaime *et al*., 2022; Meshkova & Borysenko, 2018; Weather archive, n.d.). An increase in the average temperature and a decrease in precipitation leads to a decrease in the groundwater level and creates optimal conditions for the infestation of harmful insects, in particular, bark beetles (Meshkova *et al*., 2017; Porohniach, 2018).

If in the past years drying was characterised by the death of individual trees or their small groups, now there is a dynamic group drying of pine stands in different types of forest-growing conditions, which is characterised by intense yellowing or reddening of needles, followed by the fall of shoots and bark with the exposure of the wood layer. Davydenko *et al*., 2017, Meshkova & Borysenko, 2018, Meshkova *et al*., 2017, noted that earlier pathological processes were mainly inherent in ripening stands at the age of more than 80 years, now rapid drying is observed in young and middle-aged stands. Consequently, the decline in the resistance of Scots pine to the effects of stress factors associated with climate change, and the mass spread of the populations of xylophagous insects caused a large-scale drying of coniferous forests and Scots pine, in particular, in most European countries, where over the past decade it has been registered in Poland, Italy, Germany, and in the Scandinavian countries – Finland and Sweden (Gómez-Pineda *et al*., 2022; Batllori *et al*., 2022; Pineau *et al*., 2017). According to the scientific publications of European researchers (Hajek *et al*., 2022; Batllori *et al*., 2022), the leading role in the weakening of stands and the formation of foci of mass reproduction of harmful insects is played by unfavourable changes in weather and climatic conditions, among which the main role belongs to the level of moisture and temperature regime.

According to the state agency for forest resources of Ukraine, intensive drying caused by xylophagous insects has covered more than 23% of the area of all foci of harmful insects since 2018, and the area of foci has increased 7.7 times in recent years (Agency of Forest Resources of Ukraine, n.d.). The first foci of drying of pine forests in Ukraine were observed in 2011 in the Zhytomyr Oblast, since 2015, such foci have spread to the north-western direction, in 2017, pine drying was observed in the central regions of Ukraine, and in the spring of 2018 – in the Forest-Steppe. The dry and hot summer of 2018-2019 caused the drying of large areas of stands in Central European forests, but since 2020, a sufficient amount of moisture in the summer period has contributed to the restoration of the hydrological regime and the gradual extinction of drying foci.

The purpose of the study is to investigate the main factors of drying of pine stands with the analysis of the species composition of pathogens, phytophagous insects, and their number over a thirty-year period.

MATERIALS AND METHODS

The study was conducted in pine stands of the National University of Life and Environmental Sciences of Ukraine "Boyarka Forestry Research Station". Field studies and information from the Boyarka FRS scientific database for the period since 1990 were used to determine the dynamics of pathological processes and the volume of drying of pine forests. The results are based on data from 12 constant and 10 temporary sample plots.

In particular, in pine forest stands with signs of the presence of pathological processes and drying, reconnaissance and detailed surveys were carried out on permanent and temporary test areas established in stands of different age groups with foci of drying trees. Within the selected sites, the localisation of drying foci, the type of drying, damage by pathogens, and infestation by harmful insects were determined. The type of drying was determined by its area: up to 10 trees – single (group), up to 0.25 ha – block, over 0.25 ha – continuous.

Detailed forest pathological studies of the dynamics of the spread of drying foci in pine stands since 2011 have also been conducted on temporary test areas established around existing group foci of dying trees, according to generally accepted methods (Methodological guidelines…, 2020; Puzrina *et al*., 2021) and in accordance with regulatory reference materials (Standard of organisations of Ukraine, 2007). The state of forest stands was determined by the average index of sanitary condition of trees (Is), the sanitary condition of each tree was determined in accordance with the Sanitary rules in the forests of Ukraine (Sanitary rules in the forests of Ukraine, 2016).

During field work, biotic and abiotic factors of the pathological process and their manifestations in stands (phytophagous insects and pathogens, forest fires, damage by late frosts, animals, etc.) were recorded in test areas.

Sanitary condition (Is) of stands were calculated using the equation (1):

$$I_S = \frac{\sum ki \cdot ni}{N} \quad (1)$$

where I_S – index of sanitary condition of stands; k_1–k_6 – tree condition category (from 1 to 6); ni – number of examined trees of the corresponding condition category; N – total number of trees surveyed.

The level of damage to stands was determined on the scale of values of sanitary condition indices shown in Table 1.

***Table 1**. Scale of indices of sanitary condition of stands*

Sanitary condition index	Degree of damage	Stand condition
1.00-1.50	Absent	Healthy
1.51-2.50	Weak	Weakened
2.51-3.50	Medium	Severely weakened
3.51-4.50	Strong	Drying
4.51-6.00	Very strong	Dead wood

***Source:** (Methodological guidelines..., 2020; Puzrina et al., 2021)*

The degree of weakening of stands was determined as a weighted average value for estimating the distribution of trees of different conditioned categories. Based on the results of accounting for test areas, the index (average category) of the sanitary condition of the stand as a whole was calculated. Indices of the sanitary condition of stands are characterised by the following indicators: 1.0-1.50 – healthy; 1.51-2.50 – weakened; 2.51-3.50 – severely weakened; 3.51-4.50 – drying; 4.51-6.00 – dead wood.

Population indicators of insects that inhabited trees in drying foci were determined by the pallet method on model Scots pine trees (Methodological guidelines..., 2020; Puzrina, 2020; Puzrina *et al.*, 2021). The state of the population and its impact on forest stands allow assessing the quantitative characteristics of the insect population, in particular: the number, prevalence and harmfulness of insects. In addition, the indicators used to determine the level and dynamics of insect populations include: population, density, and frequency of occurrence.

When studying the species composition of xylophagous insects, each model tree was cleaned of knots, removing a 10 cm wide part of the bark from the base to the top. Within the identified areas of each species, accounting sticks were used, on which the infestation density was determined by the number of uterine passages per 1 dm2 for the subfamily *Scolytinae* and by the number of larvae on the bark-free part of the trunk for families *Cerambycidae* and *Buprestidae* (Table 2).

***Table 2**. Estimation of xylophagous insect settlement density*

Species	Settlement density, units*dm^{-2} (uterine passages for bark beetles; number of larvae per 1 tree – for sawyer beetles and jewel beetles)		
	Low	Average	High
Phaenops cyanea	0.4 or less	0.5-0.8	0.9 or more
Monochamus galloprovincialis	0.3 or less	0.4-0.8	0.9 or more
Tomicus piniperda	0.7 or less	0.8-1.5	1.6 or more
Tomicus minor	2.9 or less	3.0-5.0	5.1 or more
Ips sexdentatus	0.5 or less	0.6-1.2	1.3 or more
Ips acuminatus	2.0 or less	2.1-5.0	5.1 or more

***Source:** (Methodological guidelines..., 2020; Puzrina et al., 2021)*

The relative density was determined by the ratio of the number of individuals of a certain species per unit of accounting (the number of trees surveyed) using the equation (2):

$$Vd = \frac{k}{n}, \quad (2)$$

where Vd – relative density; k – the sum of all individuals of a certain species on the examined trees, units; n – the number of trees surveyed, units.

The density of individuals of a particular species of xylophagous insect is a significant indicator of the accounting of forest biocenosis components; when determining the density it is mandatory to consider data from sample plots where no individuals of that species have been found infesting.

Infestation rate (K_I), which calculates the proportion of trees with the presence of xylophagous insect populations, is calculated by the equation (3):

$$K_I = \frac{m * 100\%}{n}, \quad (3)$$

where m – number of trees with the presence of xylophagous insect settlements, units; n – total number of test areas.

The degree of climate humidity (De Morton aridity index) is calculated to assess the impact of changes in weather conditions for the period 2010-2020 using the equation:

$$V = \frac{R}{t + 10'} \quad (4)$$

where R – amount of precipitation per year, cm; t – average annual temperature, °C.

The complex of methodological approaches provided objective information on the specific features of the dynamics of the sanitary condition of pine stands of the Boyarka Forestry Research Station over a thirty-year period.

RESULTS AND DISCUSSION

The drying of pine stands is chronic, and during the observation period from 1991 to 2020, pathological processes and, as a result, deterioration of the sanitary condition of the studied forest stands occurred unevenly.

As a result of the conducted research, reflecting the generalised research data on the sanitary condition of pine stands of the National University of Life and Environmental Sciences of Ukraine "Boyarka Forestry Research Station" for the period from 1990 to 2010, according to the data of 12 permanent sample plots and according to the author's research for the period 2011-2020, dynamic trends in changes in the index of their sanitary condition were established. The dynamics of the weighted average index of the sanitary condition of pine stands for the period 1991-2000 is shown in Figure 1.

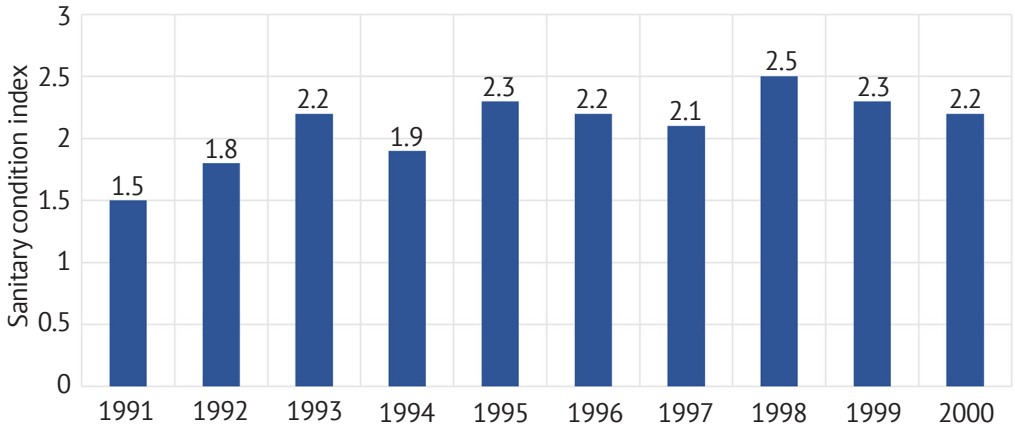

Figure 1. *Dynamics of the weighted average index of the sanitary condition of pine stands for the period 1991-2000*
Source: *compiled by the authors*

Comparison of the obtained generalised data on the sanitary condition of the studied pine stands shows that the sanitary condition index (Is) varies between 1.5-2.5 and increases with age (Fig. 2).

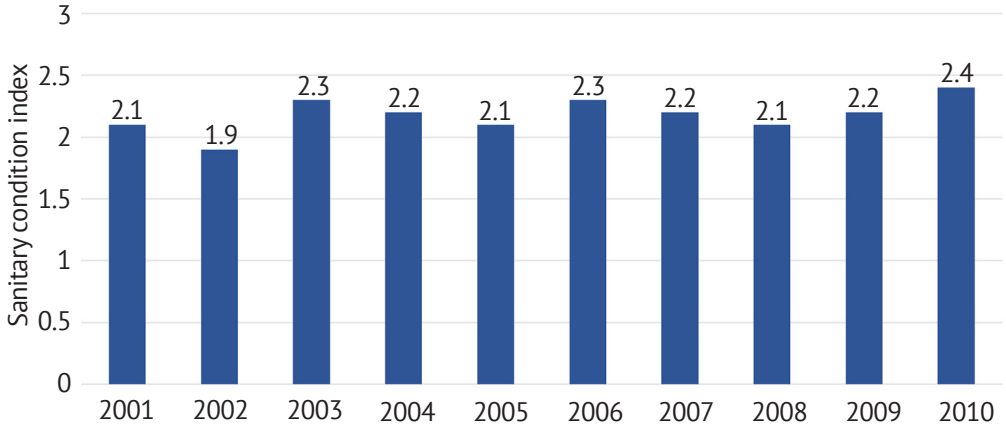

Figure 2. *Dynamics of the weighted average index of the sanitary condition of pine stands for the period 2001-2010*
Source: *compiled by the authors*

According to the analysis of information from the database of the Boyarka Forestry Research Station during this period, the main pathological factors of the weakening of pine stands in the region under study were the pine fungus *Heterobasidion annosum* (Fr.) Bref. (detection rate was 60%) and a complex of stem pests (Table 2). Four species of bark beetles (family *Curculionidae*, subfamily *Scolytinae*) most often inhabited viable Scots pine trees: large and small ash bark beetles *Tomicus piniperda* and *T. minor*, pine bark beetle

Ips sexdentatus. A jewel beetle *Phaenops cyaneus* (family *Buprestidae*) and sawyer beetle *Monochamus galloprovincialis* (family *Cerambycidae*) were also found.

The analysis of pine stands damaged by pine fungus indicated that temperature conditions and soil moisture favourable for the development of *Heterobasidion annosum* were formed in pine forests on sandy loamy and sandy soils mainly with the roots in the litter and with the established surface root system. Artificially created pine stands under these growing conditions were in ecological optimum, were highly productive, and were characterised by slow differentiation of trees during growth. Spread of the pathogen *Heterobasidion annosum* contributed to the creation of monocultures of Scots pine on old arable, agricultural, or unsuitable for agriculture lands and the formation of high-growth young trees. Due to the infection with the pathogen *Heterobasidion annosum*, changes in external morphological features were observed in Scots pine trees due to the deterioration of physiological functions. Negative impact of *Heterobasidion annosum* consisted in the accumulation of fresh and old dead wood and deterioration of the sanitary and, as a result, fire safety conditions of pine stands. In the absence of forest fires, pine crops affected by the pine fungus pathogen formed mixed stands with pine fungus-resistant specimens of Scots pine in the first tier and soft-leaved tree species and self-seeding of pine in the second. Analysis of the phytosanitary state of pine forest stands in dynamics indicates that the foci of *Heterobasidion annosum* under favourable conditions for the pathogen, become potential reserves of pathogens and phytophagous insects and can pass into active foci.

The areas and density of xylophagous insect settlements were determined by comparing the number of uterine passages of stem pests (per 1 dm^2) and the number of larvae (per 1 tree) on the rootless side of the trunk with tabular indicators (Table 3), which were used to determine the degree of tree infestation in the test areas.

***Table 3**. Species composition of xylophagous insects (for the period 1991-2010)*

Species	Settlement area	Infestation rate, %	Settlement density, units*dm^{-2} (uterine passages for bark beetles; number of larvae per 1 tree – for sawyer beetles and jewel beetles)	Degree of infestation
Phaenops cyanea	Rough, transitional, thin bark	45	0.3 ± 0.2	Low
Monochamus galloprovincialis	Rough, transitional bark	52	0.7 ± 0.5	Medium
Tomicus piniperda	Rough bark	54	1.9 ± 0.8	High
Tomicus minor	Thin bark	46	3.6 ± 0.7	Medium
Ips sexdentatus	Rough bark	36	1.0 ± 0.4	Low

***Source:** compiled by the authors*

It was found that at the highest rate of infestation, the dominant species in the stands under study were ash bark beetles *Tomicus piniperda* (54%) and *Tomicus minor* (46%) with high and medium infestation rates, respectively, and *Monochamus galloprovincialis* with a tree infestation rate of 52% and an average degree of infestation, mainly in areas of the trunk with transitional and rough bark. Moreover, during additional nutrition of ash bark beetles, intensive damage to annual and biennial shoots is noted in the crowns of Scots pine. During the period of monitoring studies since 2011, pine stands on temporary test areas were examined and their sanitary condition was established (Fig. 3).

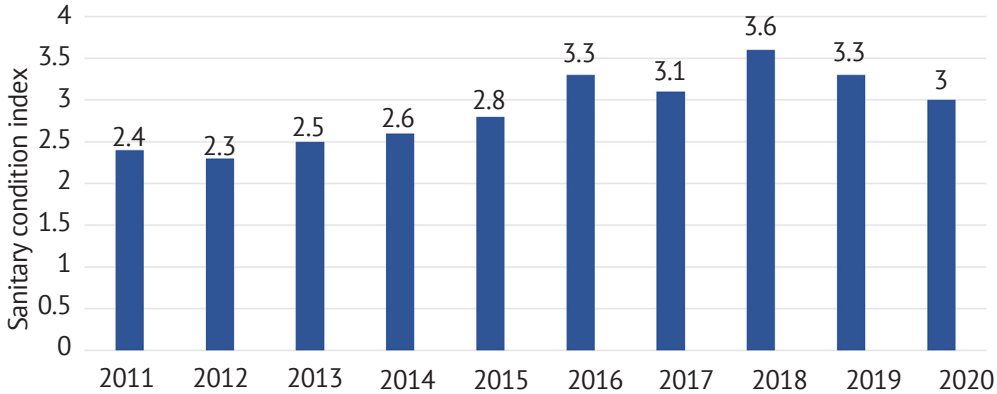

***Figure 3**. Dynamics of the weighted average index of the sanitary condition of pine stands for the period 2011-2020*
***Source:** compiled by the authors*

Calculated as the proportion of the distribution of annual precipitation and average annual air temperature, the De Morton aridity index allowed estimating the degree of climate humidity and changes in climatic conditions over the studied years (Fig. 4). The gradual increase in the sanitary conditions index of pine stands, and, consequently, the deterioration of the state of forests during the study period, depended on weather conditions and arid climate.

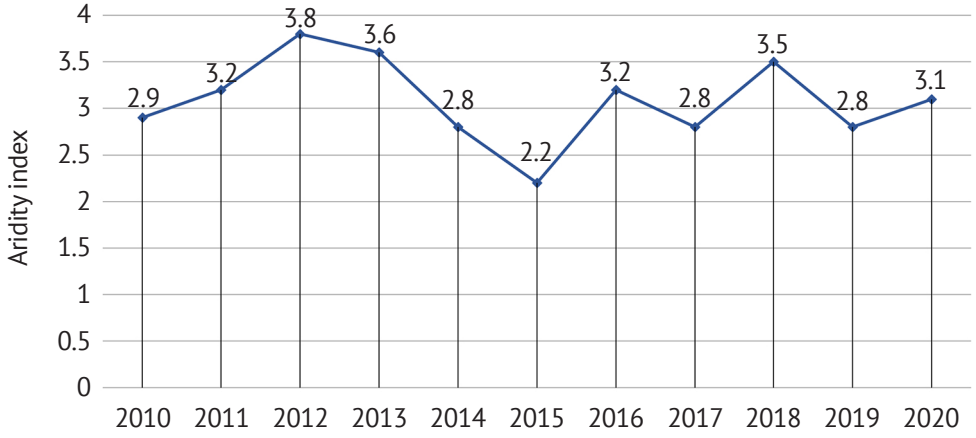

***Figure 4**. Climate aridity index of Kyiv Polissia*
***Source:** developed by the authors based on the weather archive*

It is revealed that a typical sign of climate change is a persistent tendency to sharp fluctuations in the amount of precipitation. This was especially evident in recent years, as the average amount of precipitation for the growing seasons of 2012-2013 exceeded the norm, and in 2015, 2017, and 2019 there was a sharp shortage of atmospheric moisture. Deviation of the average air temperature for the year from the norm is proof of gradual changes in the thermal regime and climate warming, so the main factor of epiphytotic drying of Scots pine and forest woody plants in Ukraine is hydrothermal stress. Thus, in the last decade, with an annual amount of precipitation in the range of 491-625 mm, up to 115 mm of precipitation fell during the growing season, which is typical for the region under study. Therefore, the deterioration of the sanitary condition of pine stands is associated with their ecological features, in particular, the attitude to humidity and soil fertility. Evidently, under such conditions, there are droughts (atmospheric and soil), and sometimes temperature indicators have abnormally high values throughout the year. There is also a certain deformation of hygrotopes with an increase in the dryness index of forest-growing conditions, which leads to a weakening and deterioration of the condition of pine stands.

During monitoring studies since 2018, a dynamic drying of pine stands has been noted. The largest number of new drying foci in pine stands occurred in 2017-2018, and the predominance of group and single types of drying of pine trees was established. In the resulting foci of drying out, a sharp increase in the population size of *Ips acuminatus* was recorded, including a rapid expansion of existing foci and the establishment of new ones. Notably, an increase in the number of sharp-dentated bark beetles was recorded during 2018, and since 2019, the population has gradually decreased due to unfavourable conditions for wintering in the young beetle phase and climatic indicators, in particular, low temperatures and excessive precipitation at the beginning of the growing season.

During the examination of drying foci and detailed analysis of model trees of the 4th and 5th categories of sanitary condition, chronic damage by the pine fungus pathogen was established according to the characteristic symptoms of root system rot. Notably, the volume of drying of pine stands from the pine fungus has significantly decreased, the degree of damage is weak, but the drying processes have not stopped.

It was also found that a complex of xylophagous insects acts in the focus, which infected the pine tree with fungi of the genus *Ophiostoma* with a predominance of the apical type of lesion, followed by the spread of pathogens along the trunk. The population indicates the dominance of the sharp-dentated bark beetle (inhabiting thin bark) and the large ash bark beetle (inhabiting weakened pines in the zone of thick and transitional bark), which are aggressive species. Most of the identified insect species tended to inhabit weakened trees, preferring trees of category 6 of sanitary condition, pine bark beetle and ash bark beetle also caused damage to trees during additional feeding in the crowns, weakening them (Fig. 5), which increased the susceptibility of trees to infestation by other trunk insects.

***Figure 5**. Additional nutrition of ash bark beetles ("crown cutting")*
***Source:** photographed by the authors*

Big ash bark beetles *Tomicus piniperda* and pine tree beetles *Ips sexdentatus* populated the trunk in the lower part in areas with rough bark (Table 4). In the foci of the sharp-dentated bark beetle, the needles of inhabited trees changed colour from green to light green, and then to reddish within 4-6 weeks.

***Table 4**. Species composition of xylophagous insects (for the period 2011-2020)*

Species	Settlement area	Infestation rate, %	Settlement density, units per 1 dm^2	Degree of infestation
Ips acuminatus	Thin bark	68	6.4 ± 1.4	High
Tomicus piniperda	Rough bark	58	0.6 ± 0.5	Medium
Ips sexdentatus	Rough bark	45	1.5 ± 0.9	High
Tomicus minor	Thin bark	52	4.2 ± 1.1	Medium
Phaenops cyanea	Rough, transitional bark	44	0.6 ± 0.5	Medium
Monochamus galloprovincialis	Rough, transitional bark	37	0.8 ± 0.4	Medium

***Source:** compiled by the authors*

The frequency of detection on the trunk of the surveyed trees was dominated by the sharp-dentated bark beetle (68% of the analysed trees), to a slightly lesser extent there was big ash bark beetle (58%), pine tree beetle (45%), the lowest infestation coefficient of the small ash bark beetle (32%), which does not stand up to the competition with the sharp-dentated bark beetle.

On model trees, the presence of numerous passages of sharp-dentated bark beetles and pine tree beetles was clearly traced, the sharp-dentated bark beetle formed several generations per year, therefore, some individuals overwintered in the adult stage in the litter and under the bark, some – in the larval stage. This explains the long period of departure of adult generations from May to September, since after wintering, imagos that overwintered under the bark first fly out, then imagos that overwintered in the litter and those that overwintered at the larval stage. Notably, with such a rapid increase in the number of natural entomophages, they cannot regulate bark beetle populations, which also contributes to an increase in the number and expansion of the boundaries of existing tree drying foci.

Of particular importance in forest biogeocenoses now are the issues of protecting pine stands from pathogens and phytophagous insects. Global climate change makes research on the biological stability and productivity of Scots pine stands relevant, especially in the context of investigating outbreaks of mass reproduction of xylophagous insects and fungal associations, which is confirmed by the presence of a number of publications (Davydenko *et al.*, 2017; Meshkova & Borysenko, 2018; Gómez-Pineda *et al.*, 2022).

Ustskyi (2011) found that the period 2001-2006 was characterised by a significant deterioration in the sanitary condition of forest stands of Ukraine and scots pine, in particular, the area of pine stands in which pathological processes were recorded, as of 2006, compared with the records as of 1994 and 1997, increased by 1.3-1.4 times, therefore, a steady trend of deterioration of the sanitary condition was also traced in the

monitoring observations of the presented study of pine stands in the Boyarka Forestry Research Station. Zhezhkun *et al.* (2021) for the period 2017-2019 in pine stands of Eastern Polissya analysed the dynamics of drying of *Ips acuminatus* foci and noted the apical drying with the mass spread of the sharp-dentated bark beetle, which is consistent with the results of forest pathological monitoring of the dynamics of the number of foci in the sample areas. Based on the conducted studies, the pattern of occurrence of foci of drying of Scots pine was established, and a clear synchronisation of the distribution areas of xylophagous insects with the weakening of pine stands. In the studies by Borodavka *et al.* (2017) in the stands of the Volyn Polissia, rapid drying of Scots pine was diagnosed, namely, the spread of aggressive associations of ash bark beetles in stands aged from 40 years with the presence of active, growing foci of drying with a rapid course of pathological decline, that is, the above-mentioned processes were observed in all regions of Ukraine.

Most natural forest biocenoses have a disturbed structure as a result of forestry activities, so the determining factors for regulating the number of phytophagous insects are health-improving forestry measures, considering the methods of logging and the time of its implementation. According to the authors' observations, drying was observed mainly in middle-aged, ripe and over-mature pine stands of artificial origin of low fullness, clean in composition in all types of forest, which is consistent with studies of the sanitary condition of pine stands in the Rivne Polissia by Andreieva *et al.* (2018), where it is statistically proved that bark beetle foci are confined to pure medium-high pine stands of 5-8 age classes. Meshkova & Borysenko (2018) also note that the age and proportion of Scots pine in the forest are of the greatest importance for the threat of the spread of xylophagous insect populations. However, after continuous logging is carried out in the drying foci due to the restriction of the food supply, bark beetles can later populate young trees. Yukhnovskyi *et al.* (2018), investigating the drying of pine trees on reclaimed land, note that the timely application of the system of measures in young trees will reduce the natural fall and excessive sampling of trees by sanitary condition and, accordingly, will allow compliance with the standards for reducing the fullness and number of trees per unit area. Therefore, conducting selective sanitary logging in the autumn-winter period is a fairly effective forestry measure, since its terms coincide with the period of winter dormancy of insects.

Notably, the adaptation of Scots pine to the so-called "bark beetle drying" under conditions of high ecological plasticity of its genotype can lead to the appearance of stress-resistant specimens (Vysotska *et al.*, 2020), so further monitoring studies would allow tracking dynamic changes in the complex system "environment-plant-pathological factors".

In the conditions of leaving trees freshly populated by xylophagous insects after selective sanitary logging during the current year, they may dry out, which, in turn, will lead to the need for repeated logging. If trees are properly assigned to selective sanitary logging and regularly carried out at the appropriate time, the drying area of pine stands will significantly decrease, and their sanitary condition will improve.

CONCLUSIONS

The drying of pine stands in previous years occurred mainly due to pine fungus damage and covered more than 30% of their total area. Due to changes in weather conditions during 2011-2020, pine stands weakened and stem pests, mainly bark beetles, spread. Artificial pine stands were not always created in accordance with forest-growing conditions, especially in areas after agricultural use, as a result of which significant areas of pine forests were created in unsuitable environments and were unstable to the action of pine fungus and xylophagous insects. With the mass spread of phytophagous insects and pathogens, the death of trees intensified and acquired an epiphytotic character with infectious or pathological disappearance.

In general, the analysis of materials of the forest pathological state of pine stands in the region indicates the establishment of a forest pathological situation cyclically to changes in the age and species structure of forests, the establishment of which is determined by the forestry strategy; the most susceptible to damage by phytophagous insects and pathogens are pure Pine stands created by homogeneous massifs, which are also the most dangerous in terms of fire. Nowadays, in the conditions of martial law, there is a negative impact of the anthropogenic factor on the forest; in particular, partial mining of woodlands, the termination of regular care and economic activities in stands due to military operations will lead to the activation of natural regulatory processes and structural and functional changes in tree stands. Due to the lack of care and sanitary logging in artificial stands, there will be a gradual accumulation of dead wood, and, as a result, disruption of pine stands due to their damage by harmful insects and pathogens. Therefore, to stabilise the ecological and sanitary condition of pine stands, it is necessary to further study the sanitary condition of pine forests in the region, constantly monitor and forecast the dynamics of the development of xylophagous insect populations, considering the current difficult conditions that have developed in the region.

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Тридцятирічна динаміка санітарного стану соснових насаджень Боярської лісової дослідної станції

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Анотація. Всихання хвойних лісів є проблемою як для Європи, так і для України, де площа всихання соснових насаджень охопила регіон Полісся й поширилася на інші природні зони, відтак, аналіз патологічних чинників причин ослаблення та погіршення санітарного стану є актуальним. Мета дослідження передбачає узагальнення причин погіршення санітарного стану соснових насаджень та патологічних процесів в динаміці за 30 років. Результати базуються на даних 12 постійних та 10 тимчасових пробних площ, закладених у відокремленому підрозділ Національного університету біоресурсів і природокористування України «Боярська лісова дослідна станція». В дослідженні було використано емпіричні та системний методи. Виявлено переважання усихання соснових насаджень внаслідок інфікування збудником *Heterobasidion annosum* ((F.) Bref.), водночас, за найвищого коефіцієнту заселення домінуючими видами в досліджуваних насадженнях були лубоїди *Tomicus piniperda* L. (54 %), *Tomicus minor* Hartig (46 %) з високим і середнім ступенем заселення та *Monochamus galloprovincialis* Olivier з коефіцієнтом заселення дерев 52 % та середнім ступенем заселення на ділянках стовбура із перехідною та грубою корою. В динаміці спостережень з 2011 року встановлено збільшення індексу санітарного стану соснових насаджень та погіршення стану лісів за рахунок зміни погодних умов та аридності клімату. Після посушливих вегетаційних періодів 2015–2017 рр. виявлено всихання сосняків за верховим типом із масовим розмноженням стовбурових шкідників, коефіцієнт заселення якими свідчить про домінування короїда верхівкового *Ips acuminatus* Gyll. та великого соснового лубоїда *Tomicus minor*, які є агресивними видами. З 2019 р. відмічено зменшення чисельності короїдів внаслідок перевищення багаторічної норми опадів за зниження температури початку вегетаційного сезону та несприятливих для зимівлі комах зазначених видів погодних умов. Отримані результати стануть інформаційною складовою формування стратегії поводження з пошкодженими ділянками лісу

Ключові слова: патологічний процес, лісопатологічний моніторинг, соснові насадження, всихання лісів, комахи-ксилофаги