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Ecological Mechanisms of *Sus Scrofa* Population Regulation in Modern Conditions

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Abstract. Wild boar population (*Sus scrofa*) has been growing rapidly in most countries of the world over the past decades. The invasive species has high reproduction rates and well-developed adaptive responses, which allows it to successfully expand the boundaries of its habitat, create significant economic losses to agriculture and horticulture, urban ecosystems, and threatens the loss of biological diversity and the spread of zoonotic infections. The purpose of the paper was to analyse the factors that contribute to the expansion of the *Sus scrofa* species in the world, to determine the ecological mechanisms of population regulation against the background of rapid anthropogenic transformation of the habitat and global climatic anomalies; to assess changes in the dynamics of population size in hunting farms of Ukraine for the period from 2010 to 2020 in the Chernihivska oblast, in particular. Conventional methods of retrospective analysis, synthesis, environmental, general biological, and epizootic research were used. The paper analyses the world experience and identifies the main factors of low effectiveness of strategies for controlling the rapidly growing population of wild boar in agroecosystems, mixed forest and urban ecosystems. Due to the unique features of forming a life strategy, the *Sus scrofa* species demonstrate successful development, expansion of the range of available food resources, effective use of daily diversification of ecological niches in the conditions of transformed ecosystems, etc. It is established that the reason for the inefficiency of ecological mechanisms of pressure on the population of the species in the "predator-prey" system is the absence of large predators in the forest ecosystems of Chernihivska oblast. At the same time, the absence of deterrent mechanisms in the predator-prey system ensured the manifestation of next-level mechanisms, namely, the appearance of foci of African swine fever along the forest cycle in the natural biocenoses of the region. Response — the response of populations was manifested by a rapid short-term decrease in the population of *Sus scrofa*, as a temporary deterrent effect with a subsequent recovery trend. The results obtained can be used in the development of practical recommendations for biological monitoring, environmental control, and the development of effective forest management measures to prevent biological safety associated with the uncontrolled distribution of *Sus scrofa* and African swine fever based on universal ecological mechanisms of population regulation

Keywords: invasive species, habitat, African swine fever, epizootics, biotic regulatory mechanisms

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INTRODUCTION

The transformation of natural landscapes, anthropogenic pressure, and climate anomalies have serious implications for the conservation of biological diversity. The response of species to global climate change and anthropogenic pressure has a wide range of manifestations: from rapid population growth, habitat expansion, and establishment of new types of interspecific ties, to a decrease in its number and extinction. Some populations respond positively to changing environmental conditions. They fill free ecological niches, move to new territories, and effectively use the available trophic resource, which contributes to the rapid reproduction of the species and the formation of dominant cells. At the same time, displacement or loss of less adaptable native species can deal damage to agriculture, forestry and the national economy, and cause uncontrolled outbreaks of infectious diseases in a rapidly growing population (Vetter *et al*., 2020).

Factors of influence are divided into external (availability of available resources, population size of predators and parasitic organisms) and internal, associated with density-dependent regulatory mechanisms (changes in gene- and phenotypic composition, biochemical and behavioural reactions). A population responds to external influences with positive and negative feedback, and to internal influences with ecological mechanisms for regulating its own abundance by forming an oscillatory mode of population waves. Adaptive endogenous mechanisms in populations create additional stability in their structural and functional organisation. At the population level, the cyclicity of different species and the ecological features of their spectra as an element of the overall adaptive structure are of prognostic significance and require additional research (Froehly *et al*., 2020).

The leader among the growth rates of the mammalian population of the European continent is the wild boar or wild pig (*Sus scrofa* L., 1758). The species is characterised by adaptability, flexible eating habits, great reproductive potential, high survival rates among young animals under favourable climatic conditions, and in unfavourable conditions — physiological adaptations to low temperatures with the development of alternative thermogenesis, unique survival among females and their fertility. Only one female *Sus scrofa* gives birth to up to 14 piglets in one litter (Ruf *et al*., 2021).

The wild pig is a eurytopic species that poses economic threats and leads to the transformation of ecological systems, and its geographical range has gone far beyond the primary (Southeast Asia, the Far East, and Asia Minor). Nowadays, the species is distributed on all continents except Antarctica. At the same time, over the past century, the wild boar has significantly expanded its range to areas with high winter temperatures (up to –30°C) and has been seen near the Arctic Circle (Ruf *et al*., 2021).

On the territory of European countries, a constant increase in the population of Wild Boars has been recorded since the 1960s and 1970s. In the period from 1980 to 2010, the number of wild boar increased 6-fold in Germany and Slovenia, 5-fold — in Austria and France, 4-fold — in the Czech Republic and Italy, 2.5-fold — in Belgium (Tack, 2018). As of 2017, the number of wild boars in Poland reaches 228 thousand with a constant upward trend. The expansion of the hunting license in the period from 1975 to 2015 and about 3 thousand animal units lost from African swine fever (ASF) did not significantly affect the situation (Pejsak *et al*., 2018). In general, today in Europe the population of wild boars exceeds the figure of 10 million units (ENETWILD, n.d.). In Canada, signs of exponential growth in the wild boar population within 9% per year were recorded mainly in agricultural regions, and in the state of Florida (USA) near freshwater bodies, which is associated with the degradation of 19% of wetlands (Wong, 2021).

The purpose of the study was to analyse scientific developments on the ecological mechanisms of population regulation of an invasive species of *Sus scrofa* and to establish its effectiveness in retrospect in the conditions of Ukraine and Chernihivska oblast, in particular.

To achieve this goal, the following tasks were defined:

- to analyse the current state of investigation of the issue of ecological features of an invasive species of *Sus scrofa* under conditions of anthropogenic pressure on natural biocenoses and the role of biotic mechanisms of population regulation in the global expansion of the species;
- to assess the reasons for changes in the dynamics of the wild boar population in hunting farms of Ukraine for the period from 2015 to 2020, and Chernihivska oblast for the period from 2010 to 2020;
- to evaluate the effectiveness of population regulation mechanisms of *Sus scrofa* on the example of Chernihivska oblast.

The results obtained are aimed at practical solutions to the issue of biological monitoring, environmental control, and the development of effective measures to prevent the biological hazard associated with the spread of African swine fever based on universal environmental mechanisms for population control.

LITERATURE REVIEW

A sharp increase in the population size and expansion of the habitat of wild boar in most countries of the world is associated with high rates of biotic potential and reproduction among ungulates (2.0), as well as adaptation to various habitats (Croft *et al*., 2020). According to D. Liu *et al.* (2022), the reasons for the expansion of the species lie in indirect factors, in particular, the nutritional value of the available food ration, ecological relationships between habitat types, interspecific co-actions, genetic diversity, population structure, etc. Thus, over the past 30 years, American researchers have noticed a rapid increase in mixed populations of wild pigs. The vast majority of the studied livestock had a genotype of oligonucleotide polymorphism of mixed origin, with dominant genetic associations with Western breeds of

domestic pigs and European wild populations (Niedziałkowska *et al*., 2021; Smyser *et al*., 2021).

One of the hypotheses regarding the promotion of the species to new territories is associated with the liberation of ecological niches by other species of wild animals and adaptation to a wide range of climates. The researchers suggest that wild boar infestation on all continents does not show signs of an evolutionary niche, and the innovative potential of the species is associated with reproductive, trophic and morphological characteristics combined with behavioural thermoregulation (Sales *et al*., 2017).

At the same time, the development of an adaptive complex was recorded, which manifested itself as the response of the species to an increase in average annual temperatures, precipitation, relative humidity, availability and caloric content of food (Brivio *et al*., 2017). As a result of a decrease in the body's need for energy expenditure, a tendency to reduce body weight in adult animals and a smaller number of newborns in Central European wild boar populations were observed (Vetter *et al*., 2020; Ruf *et al*., 2021).

Spatial strategy of *Sus scrofa*, the size and shape of the habitat depend on the landscape characteristics, the size of the area, meteorological conditions, and access to water and food. Cases of migration of the species to megacities and suburban areas in the autumn-winter period are associated with attractive warm locations and the search for easily accessible food resources (human food residues) (Amendolia *et al*., 2019), and moving to nature reserves is associated with feeding of wild animals (Brogi *et al*., 2020). Increasing population density in certain areas (along water bodies, in nature reserves, in urban areas) is important for monitoring species and predicting foci of zoonotic infections (Amendolia *et al*., 2019; Clontz *et al*., 2021).

Due to its high adaptive property, the species easily switch to nocturnal activity under increased anthropogenic pressure, while increasing the size of their population. In addition, phenotypic plasticity allows the species to quickly adapt to local conditions, which indicates behavioural adaptation of *Sus scrofa* to the circadian rhythm. There is a temporary diurnal diversification of ecological niches between humans and wild boar in the absence of other mechanisms of interaction. This fact poses new challenges to find effective methods to counteract species and protect them from entering undesirable territories (Brivio *et al*., 2017; Johann *et al*., 2020).

Mechanisms of artificial containment of epizootics, in particular, species-specific African swine fever (ASF), today in 80% of cases are focused on depopulation of wild boars (Vetter *et al*., 2020). Thus, the study of the "Reserve effect" by J. Colomer *et al.* (2021) showed the effectiveness of wild boar population control, mitigation of conflict caused by the species, and localisation of ASF foci in areas with hunting bans. The results obtained by E. Jori *et al.* (2020), confirm the effectiveness of the buffer and transition zones in the elimination of ASF foci with subsequent culling of animals. According to A. Yang (2021), there is an effective culling zone within a radius of 2 kilometres around the epizootic focus, while high culling pressure threatens to intensify interpopulation contacts and spread the disease to large areas. Studies by Jo & Gortázar (2021) confirmed an increase in the risk of spreading the disease when moving people and vehicles in the area of ASF focus, in particularm natural biogeocenoses (Jo & Gortázar, 2021; Gortázar, 2019).

Conventional methods of controlling the number of wild boars are shooting, trapping, and the use of toxicants. At the same time, hunting is declining in most countries, and in some regions, there is a direct ban on hunting and trapping animals. The use of toxic substances to control the species contradicts animal welfare regulations and threatens the environment. This is the situation, against the background of a rapid increase in the population size of *Sus scrofa*, it is necessary to review effective means of reducing them quickly. In this regard, individual researchers focus their efforts on developing mathematical models for population reduction using fertility controls in combination with culling. According to the researchers, this would allow achieving the target reduction in the number of animals by half. The use of birth control alone has a threat of the "placeholder effect" when infertile animals occupy areas inaccessible to fertile ones (Croft *et al*., 2020).

A whole complex of adaptive advantages and opportunities for uncontrolled growth of the species population invariably triggers regulatory mechanisms based on the principle of reverse feedback. These mechanisms are poorly understood, especially in the context of the transformation of the climate system and anthropogenic pressure on natural biocenoses, which opens up wide opportunities for researchers for analytical, fundamental, and applied research.

Thus, the analysis of available sources indicates the urgency of the problem of controlling a rapidly growing population of *Sus scrofa* in many countries of the world and the search for ways of effective management based on the study of the ecology of the species and favourable environmental factors of abiotic, biotic, and anthropogenic origin.

MATERIALS AND METHODS

A systematic approach was used to determine the ecological prerequisites and mechanisms for regulating the population size *Sus scrofa,* including manifestations of emerging infections in the population on the territory of Ukraine and Chernihivska oblast, in particular. Conventional methods of retrospective analysis, synthesis, environmental, general biological, and epizootic research were used.

The analysis of the dynamics of the wild boar population in hunting farms in Ukraine covered the period from 2010 to 2020. Registration of outbreaks of African swine fever in Ukraine covers the period from 2012 to 2022.

As basic materials for analytical generalisations about the population of *Sus scrofa* in Ukraine, the study

used the reporting data of the Environmental passport of the regions of Ukraine for the period 2016-2020 and the Environmental passport of the Chernihivska oblast for 2012-2020 (Ministry of Environmental Protection and Natural Resources of Ukraine, 2021), data of the Chernihiv Regional Department of Forestry and Hunting (Chernihiv Regional Department of Forestry and Hunting, 2016), the report on the state of the natural environment in the Chernihivska oblast for 2020 (Chernihiv Regional State Administration, 2020) and open data from the website "African swine fever" of the State Service of Ukraine for Food Safety and Consumer Protection (The official website of the African swine fever, 2021).

A bibliographic review of classical and modern literature on the adaptive mechanisms of wild boar, their behavioural reactions, containment mechanisms, and methods of artificial population control adopted in international practice was conducted.

RESULTS AND DISCUSSION

Nowadays, human activity has become the driving force that affects the transformation of landscapes and, consequently, changes in the structural and functional organisation of biocenoses and biological diversity. Key factors contributing to the population growth of *Sus scrofa* include: forest restoration, increasing the availability of food resources for the species in the form of crops, feeding in winter in forestry, and mitigating climatic conditions (Croft *et al*., 2020).

Uncontrolled growth of the wild boar population is accompanied by the transformation of natural ecosystems and the impact on biological diversity, economic damage to agriculture and farms, colonisation of settlements and urban neighbourhoods, damage to public parks, sports grounds, cemeteries, collisions with vehicles on roads, the spread of zoonotic infectious diseases among companion species.

Manifestation of species-specific adaptive reactions inherent in *Sus scrofa,* in combination with favourable climatic conditions and wide access to food, has led to the low effectiveness of measures aimed at controlling the wild boar population. In some regions, farmers independently struggle with attacks by wild boars on livestock and raids on fields with agricultural crops.

Researchers study and use a variety of strategies to control the rapidly growing wild boar population to develop effective management mechanisms that would slow down this process and prevent potential environmental threats and conflicts conditioned by the penetration of animals into urban ecosystems and agrocenoses (Vetter *et al*., 2020).

Today, the following options for managing the wild boar population are used:

1) recreational hunting, with a transition to targeting certain age groups (1-2 years), longer or year-round hunting periods;

2) culling and use of traps;

3) measures in the long term, namely reducing the capacity of the habitat, that is, restricting access to a food resource (stopping feeding animals and fencing fields, using electric fencing and other means to restrict access to crops) (Tack, 2018; Gortázar, 2019).

At the same time, the issue of artificial species control is quite controversial. On the one hand, some researchers suggest that for the structural and functional organisation of biocenoses, significant reduction or removal of *Sus scrofa* is harmful. This is conditioned by a violation of the balance in the predator-prey system, since the wild boar is an important element of the trophic chain, an ecosystem engineer, and is able to influence soil properties, soil processes, and the cycle of nutrients in the forest floor through digging activities. In addition, the species plays a sanitary role, especially valuable in reforestation. On the other hand, according to D.R. Risch *et al.* (2021) and Johann *et al.* (2020) the large distribution and high population density of wild boar poses a threat to rare species of flora and fauna. Thus, studies conducted in 54 countries revealed a threat to 672 taxa of vulnerable populations caused by the transformation of the wild boar habitat, including 345 plant species (out of 59 families), 123 representatives of herpetofauna (out of 25 families), 96 birds (out of 38 families), 84 invertebrates (out of 22 families), and 24 mammals (out of 11 families), including their natural habitats (Risch *et al*., 2021).

In natural conditions, the regulation of the number of species is provided by multiple types of regulating interspecific and intraspecific relationships. Biotic mechanisms of population regulation include functional and numerical responses (predator-prey regulation), outbreaks of infectious and parasitic diseases, and intraspecific competition.

In the case of the *Sus scrofa* population, environmental regulatory mechanisms are not of decisive importance and are temporary. This is associated with a whole range of factors, namely, the complete absence or an insignificant number of natural predators. In particular, in the predator-prey system, the main regulator of the wild boar population is the wolf *(Canis lupus)* (Tack, 2018).

C. Nores *et al.* (2008) proved that the wolf predator provides a key ecosystem service in forest ecosystems by influencing populations of *Sus scrofa*, and one wolf can kill about 50-80 wild boars a year. Studies conducted in Spain during 2000-2014 show a significant role of wolves in regulating the number of wild boars. In areas where wolves live, the population density increased from 1.65 to 2.55 individuals per km^2, while without them — from 1.2 to 3.6.

According to Resolution 6 of the Bern Convention on the Conservation of European Wildlife and Natural Habitats, the wolf is under strict protection. In the European habitat, the diet of wolves consists mainly of wild ungulates (wild boar, deer, roe deer) and agricultural animal species (goats and sheep). In some European regions (Italy, Spain), wild boar is the dominant prey of wolves and accounts for 3 to 31% of their diet, mainly piglets (up to 75%) (Nores *et al*., 2008). According to experts, wolf predation affects 4.5% of the wild boar population and reaches 12% in terms of causes of death (Nores *et al*.,

2008; Petridou *et al*., 2019). Studies conducted in 2018-2021 in Belgium found that wild ungulates make up about 69 %, and wild boar — almost 23% of the wolf's diet (Van Der Veken *et al*., 2021). The restoration of the wolf population in Greece in 1980-1990 has led to an increase in their population and an expansion of their habitat. At the same time, easy access to livestock for grazing in agricultural landscapes and low population density of wild ungulates in natural biocenoses led to a substitution of up to 25% in the wolf's diet for domestic animals (Petridou *et al*., 2019).

Some researchers suggest that predation does not depend on the population density of wild boars, but is inversely related to the availability of alternative prey species and has a non-significant impact on the population of wild ungulates compared to factors such as low winter temperatures, availability of food resources, and hunting (Nores *et al*., 2008).

In a sense, in ecosystems with a low density of the species *Canis lupus,* the hunters took over the role of the predator. At the same time, interest in hunting in many countries decreases every year and often hunting licenses remain unused. For example, as of 2017 in Poland, the number of wild boars reached 228 thousand units with a constant growth trend. The expansion of the hunting license in the period from 1975 to 2015 and about 3 thousand animal units lost from ASF did not significantly affect the situation (Pejsak *et al*., 2018).

The ineffectiveness of the predator-prey system and hunting led to the start of epizootics as the next stage of the population regulation mechanism. As a rule, infectious diseases in wild animal populations occur when the victim population reaches such a high number that it goes beyond the influence of predators. In the case of *Sus scrofa*, a highly contagious viral disease, African swine fever (ASF), has manifested itself in European countries (Croft *et al*., 2020).

The body of wild boar is a source and carrier of a large number of pathogens of infectious and parasitic diseases (zoonotic, species-specific, and with a wide range of hosts). Among them: tuberculosis, trichinosis, African swine fever, and others that lead to significant economic losses.

African swine fever (ASF) or Montgomery's disease is a viral emergent infection of wild and domestic pigs included in List A of the World Organization for Animal Health (WOAH). Due to its rapid cross-border spread and high mortality rates among patients (mortality in 98-100% of cases), there is a real threat to human health, animal welfare, and food security (Agricultural Research Service, 2021). At the same time, despite proactive measures to control the population size of *Sus scrofa* in agroecosystems and ecosystems of mixed forests and the ASF epidemic, in some countries, the wild boar population does not stop increasing (Khwarahm *et al*., 2022).

ASF is a difficult process to control in the wild boar population. The measures used for mass depopulation, removal of wild boar carcasses, poisoning, and construction of fences turned out to be ineffective and unethical. The creation and development of predictive models of the spread of ASF showed that the determining prognostic risk factor in the models is the population size and the availability of a suitable environment for its habitat. At the same time, the population density in the transmission and spread of the disease is contradictory. The experience of the Czech Republic and Belgium in countering ASF shows the positive impact and reality of integrated efforts to eliminate ASF using individual approaches (Sauter-Louis *et al*., 2021).

Today, in the epidemiology of ASF, there are 4 models of the virus transmission mechanism: "wild boar-wild boar", "wild boar-environment", "corpse-wild boar", and "wild boar-argass ticks of genus Ornithodoros", which are independent, although inter-cyclical transmission of the disease periodically occurs. The prevalence of ASF in the population remains at the same level <5% with characteristic local persistence. In the Baltic states, the virus was recorded in about 85% of corpses, while in captured animals the proportion of detected cases of damage was low (up to 3%) (Chenais *et al*., 2018).

Penetration of any new type of pathogen or its strain into the biocenosis can affect not only the population itself, but also the trophic network, various types of coactions, and overall stability of the biocenosis, while compensating for mortality from the absence of predation (Voloshyn *et al*., 2022).

In Ukraine, studies of the dynamics of changes in the wild boar population are fragmentary. Data on the population size of wild animals are presented in the environmental passports of regions, which is an analytical collection on the state of the natural environment and its components, including the animal world, in particular, the retrospective dynamics of the number of the main species of hunting animals and their extraction (Voloshyn *et al*., 2022; Pavlenko, 2018).

The analysis of the dynamics of the number of wild boars in the hunting grounds of Ukraine and the volume of their withdrawal under the license for 2015-2020 is shown in Figure 1 (Ministry of Environmental Protection and Natural Resources of Ukraine, 2021).

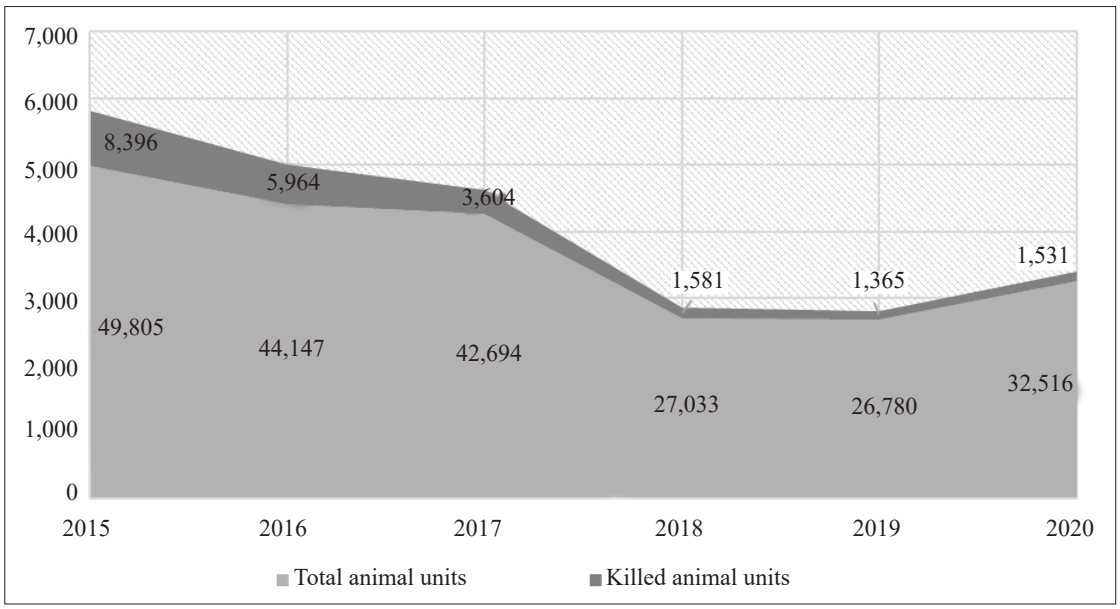

Figure 1. *Dynamics of the number of wild boars in hunting grounds of Ukraine and the volume of withdrawal under the license for 2015-2020*

The decline in the population size by more than six times in the period from 2015 to 2019 is associated with the epizootic ASF in Ukraine (the first cases began to be registered in 2012).

The analysis of changes in the dynamics of the wild boar population on the example of Chernihivska oblast of Ukraine is presentable from the standpoint of optimal conditions for the existence of the population, since the forest fund of the region reaches 31,903.0 km^2, with a forest cover index of 20.9%. The area of forest plots is 708,063.7 hectares, of which almost 15% are under environmental protection. Chernihivska oblast accounts for 8.75% of the state's territory in terms of the total volume of nature reserves (7.86) and the number of territories and objects of the nature reserve fund (667). 2,733,224 hectares (more than 85%) are allocated for hunting and economic activities, where the main ungulates for hunting are deer, roe deer, and wild boar (Ministry of Environmental Protection and..., 2021).

According to A.V. Pavlenko (2018), trends in the population density of wild boar in Chernihivska oblast were +4.4%, with the volume of withdrawal in the range of 10-12%, which indicates the well-being of the population. The loss of livestock in the range of 46% occurred in 2014-2015 is conditioned by the occurrence of an epizootic of African swine fever in the region. At the same time, during the study period, 0.6-1.3% of the forest area of Chernihivska oblast was lost due to deforestation and forest fires, which led to a decrease in the forest cover indicator by 24.7% from the original value and had no negative consequences for the number and density of the wild boar population. The abrupt decline in the number of wild boar in hunting farms of Chernihivska oblast almost by five times in the period 2015-2017 coincides with the outbreak of ASF in the region, and trends toward population recovery in 2019 and 2020 are associated with the high biotic potential of the species (Pavlenko, 2018).

A favourable factor for population recovery of *Sus scrofa* in Chernihivska oblast is a large number of objects of the nature reserve fund and objects of the Emerald Network, of which there are 16 in the region. The presence of populations within these territories provides them with access to food and protection due to the European Environment Agency (n.d.).

At the same time, the dynamics of the wild boar population and the volume of withdrawal under the license in Chernihivska oblast (according to the Environmental passport of Chernihivska oblast for 2012-2020) (Fig. 2) show an abrupt decrease in the wild boar population almost five times in the period 2015-2017, which coincides with the outbreak of ASF in the region. 2019 and 2020 are marked by the same rapid trend toward population recovery, which is explained by the high biotic potential of the species (Chernihiv Regional State Administration, 2020).

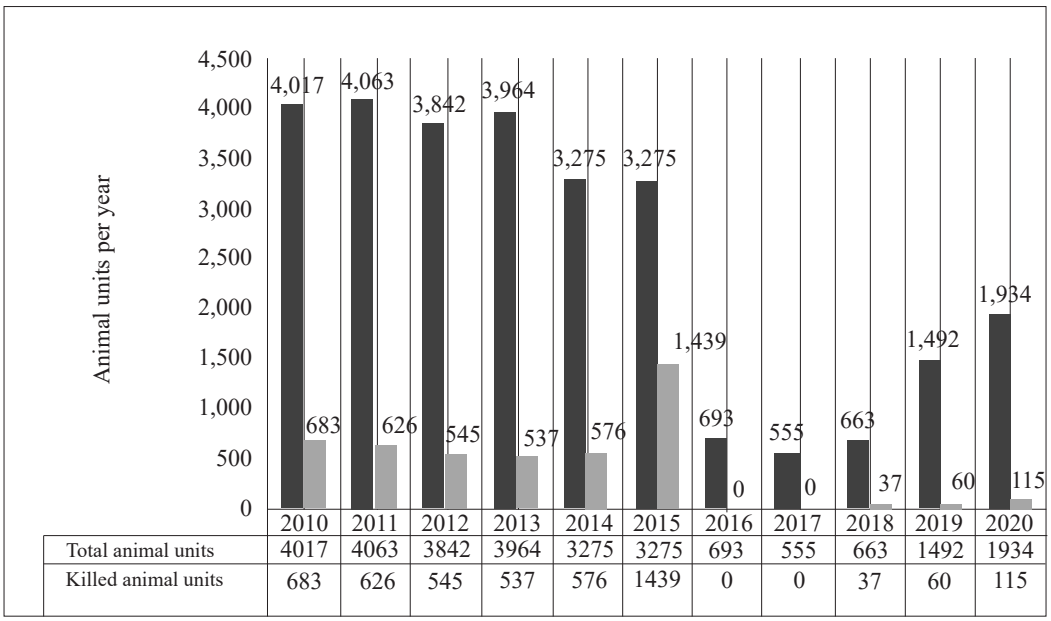

Figure 2. *Dynamics of the wild boar population in hunting farms of Chernihivska oblast*

According to A.V. Pavlenko, interspecific competition and predator-prey interactions in the faunal complex of Chernihivska oblast do not function, but there are unrelated changes in the population density of large mammals in the ecosystem. According to the findings, conservation activities to preserve in-situ biodiversity are environmentally effective for the wild boar population and allow it to recover quickly. In addition, a positive effect is manifested from ploughing land for corn (R_{emp}=0.824), oilseeds (R_{emp}=0.682) and sunflower (R_{emp}=0.760), which is a food resource for the species, and unfavourable — from ploughing agricultural land for cereals (R_{emp}=–0.664), fodder grasses (R_{emp}=–0.841) (Pavlenko, 2018).

The main factors influencing the static distribution and dynamics of wild boar population density in Chernihivska oblast are: demographic indicators (density and volume of withdrawal) and dominant external influences (concern factor due to deforestation and forest fires, agricultural activities) (Pavlenko, 2018).

In the absence of natural predators in the area, it is logical to manifest the mechanism of epizootic development in fast-growing animal populations. Thus, since 2012, the first isolated cases of the disease have been registered in Ukraine, and in 2014, out of 16 recorded cases, 12 were found in wild pigs (The official website of the African swine fever, 2021).

In total, 553 cases of ASF were registered in Ukraine from 2012 to 2022, 120 of them were wild pigs. Analysis of the dynamics of ASF epizootology development in Ukraine confirmed the existence of a direct link between ASF cases in different sectors of the economy. The presence of a correlation between the number of cases in private farms of the population and in the wild (R=0.8, P-value=0.045, R^2=0.6, n=7) indicates the synchronicity of a single infectious process and a decrease in cases of the disease in constant proportions on farms, private farms, and the population of wild pigs in the period 2017-2018 (Fig. 3) (The official website of the African swine fever, 2021).

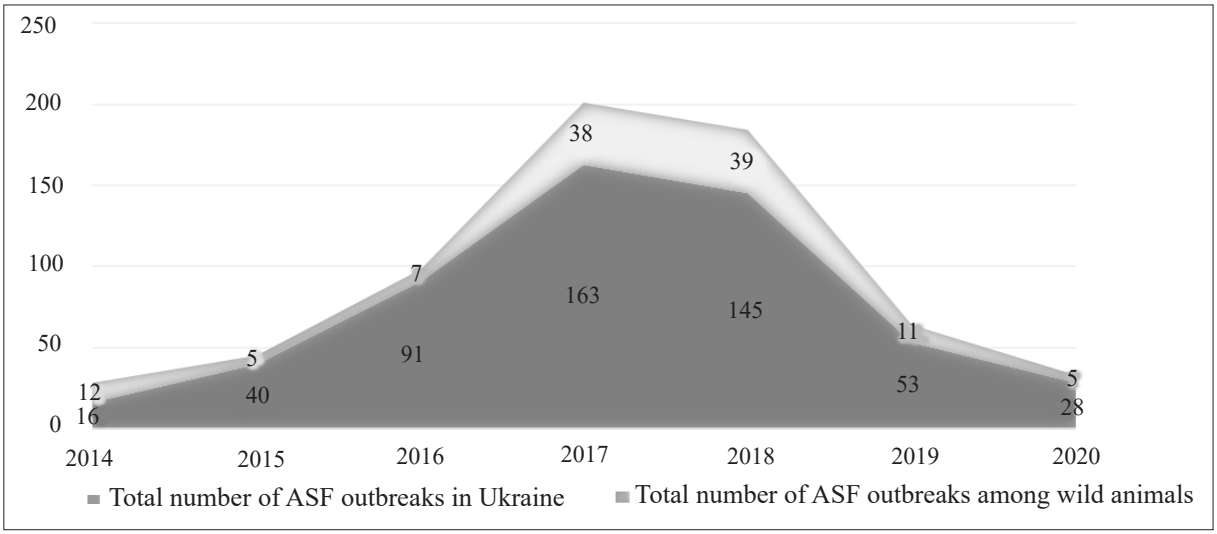

Figure 3. *Total number of ASF outbreaks in Ukraine and number of cases among wild animals in 2014-2020*

Cases of ASF outbreaks among wild boars were recorded mainly in regions with high forest cover and border areas (Fig. 4). 34 outbreaks of ASF were detected in Chernihivska oblast for the period from 2012-2021, 11 of them in wild animals (32%), the pathogen attack rate was 0.0015 among wild boars and 0.0028 in the region in general. Most ASF outbreaks were recorded in areas bordering Belarus (Fig. 5) (The official website of the African swine fever, 2021).

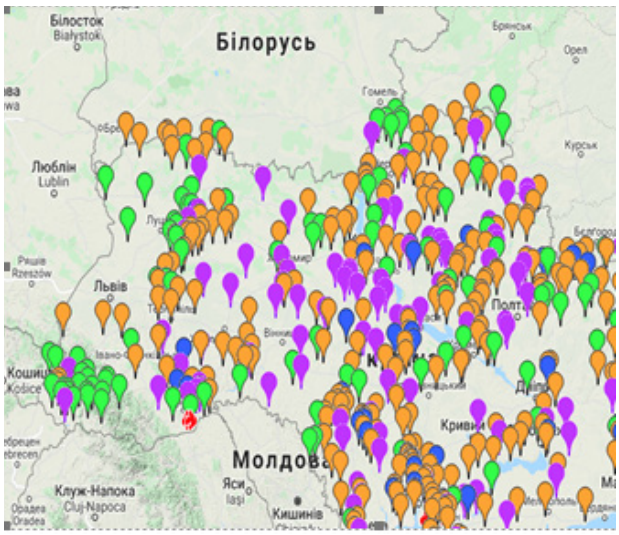

***Figure 4**. Map of ASF outbreaks in Ukraine for the period from 2012-2021*
***Note**: green — detected sick wild pigs; orange — in the private sector, lilac — at the enterprise*

***Figure 5**. Map of ASF outbreaks in Chernihivska oblast for the period from 2012-2021*
***Note**: green — detected sick wild pigs; orange — in the private sector, lilac — at the enterprise*

In officially registered epizootic units of various types in the time spectrum in the period from 2014 to 2020, most cases of ASF were registered in 2017 (163 cases) and 2018 (145 cases). The risk assessment model with geographical visualisation of attack rates for wild pigs has an indicator of 83 %, with a high probability of the highest risk of ASF outbreaks in remote areas with low rural population densities. The areas marked on the map (Fig. 6) in red are areas with the maximum risk of ASF spread, which allows timely measures to be taken in hunting farms, namely: to raise awareness of hunters about biosafety when hunting, conduct diagnostic studies, and ensure an appropriate level of passive monitoring of the wild boar population.

OBLAST	Wild pigs
Zakarpatska	0.0114
Luhanska	0.0034
Rivnenska	0.0033
Odeska	0.0027
Kharkivska	0.0027
Volynska	0.0026
Ivano-Frankivska	0.0018
Mykolaivska	0.0018
Chernivetska	0.0015
Khersonska	0.0013
Sumska	0.0011
Khmelnytska	0.0011
Chernihivska	0.0011
Kyivska	0.0009
Vinnytska	0.0009
Zaporizka	0.0007
Cherkaska	0.0006
Dnipropetrovska	0.0005
Zhytomyrska	0.0004
AR Krym	0.0004
Kirovohradska	0.0004
Lvivska	0.0003
Poltavska	0.0001
Ternopilska	-0.0004
Donetska	-0.0004

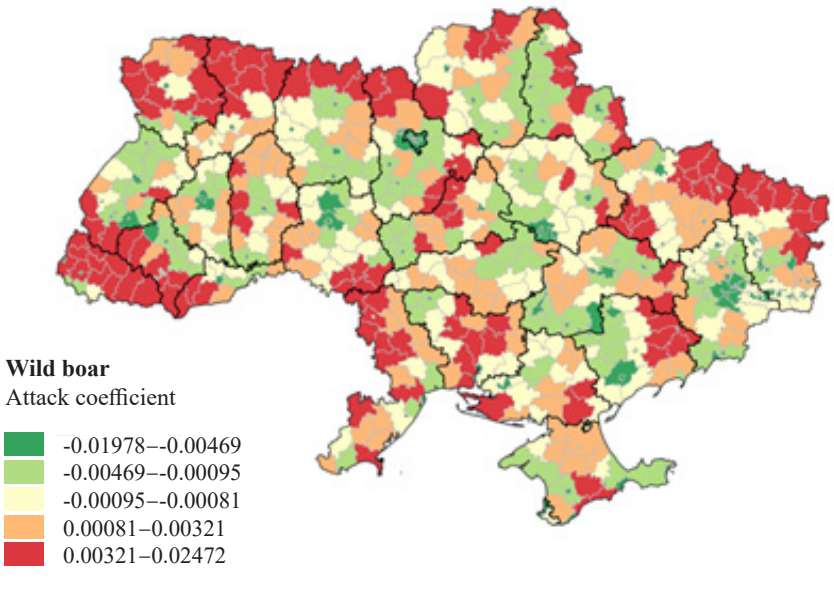

***Figure 6**. Model for assessing the risk of ASF introduction in wild pig populations with an average annual attack rate (AR*100=% of localities where ASF can be detected per year)*
***Note**: red — in the wild; orange — in the private sector, green — at the enterprise, blue — average*

Analysing the collected statistical data, it can be noted that the biotic mechanisms of regulation of the wild boar population on the example of Chernihivska oblast indicate a temporary effect of the ASF pathogen on the population of the species with a tendency to its rapid recovery. The manifestation of the effect of "unexpected increase in pathogenicity", complication of immune mechanisms, and synchronisation of behavioural programmes stimulate the development of adaptive processes in partners in the "parasite-host" system and reflect the acceleration of the rate of evolution in parasitic systems characteristic of transformed ecosystems, which is confirmed by the resumption of growth in the wild boar population in the conditions of Ukraine.

The lack of regulatory environmental mechanisms will lead to a transition to the next level in the future and will manifest itself in acute competition for available resources and the development of stressful manifestations in the population (aggressive behaviour, endocrine response of mammals, etc.).

The outbreak of hostilities throughout Ukraine since February 2022 has become an uncontrolled factor affecting ecosystems and populations of wild animals in particular. The experience gained on the dynamics of wild animal populations in the period 2014-2022 in the temporarily occupied territories of Ukraine in Donetska and Luhanska oblasts, in particular, in the National Nature Park "Sviati Hory", shows an increase in the number of wild boars and foxes, despite aerial shelling and explosions, flights of air transport. Mass migration of the species was not recorded. This was facilitated, according to the researchers, by the reduction of anthropogenic impact after the end of the intensive phase of hostilities, the restriction of hunting and forestry activities (Ukrainian Helsinki Human Rights Union, 2017).

As of 04/01/2022, due to military operations, 1/3 of the nature reserve fund of Ukraine is in danger, which includes 900 territories and almost 200 territories of objects of the Emerald Network (Ministry of Environmental Protection and Natural Resources of Ukraine, 2020). Chernihivska oblast was at the epicentre of active military operations. In particular, in forest ecosystems, through forest fires and active hostilities, irreparable damage to valuable natural objects and natural monuments is already registered, including the destruction of natural dwellings, rare and endangered plant and animal species, a decrease in biological diversity, loss of biological stability of forests, an increase in damage to stands by stem pests. In the forests of the region, wild animals were "in the line of fire", and a large number of detonated missiles and unexploded ordnance pose a potential threat to people and animals (Ministry of Environmental Protection…, 2022).

Part of the wild boar population is likely to be destroyed, while the other is forced to temporarily migrate to safer territories due to the alarm factor from explosions, artillery attacks and bombardments, forest fires, loss of habitat, formation of belligerent landscapes, expansion of areas unsuitable for the habitation of the species. Restoring ecosystems, returning populations, and keeping records of wild animals in such areas will be difficult over a long period of time.

An effective tool for restoring unique natural objects and biodiversity in the natural ecosystems of the state is the creation of a unified state environmental monitoring system for monitoring at 4 levels — from national to object. The Draft Law of Ukraine "On Amendments to Certain Legislative Acts of Ukraine Concerning the State Environmental Monitoring System" was approved on 04/28/2022 (2022).

CONCLUSIONS

The rapid increase in the wild boar population in many countries is of concern for several reasons: first, damage to livestock and crop production and urbanised landscapes; second, the spread of African swine fever and other zoonotic diseases. Retrospective analysis of population dynamics of *Sus scrofa* in Ukraine, in particular, in Chernihivska oblast, allows the study to establish classical mechanisms of biotic regulation of the population size of the species and the influence of concomitant factors associated with anthropogenic activities. The rapid decrease in the population size in Chernihivska oblast in the period from 2015-2017 is associated with a temporary manifestation of the effect due to the mechanism of population regulation in the absence of predators on the considered territory and the manifestation of species-specific zoonotic infection — African swine fever. At the same time, the influence of regulatory mechanisms tends to coadaptation in the "parasite-host" system and move on to the next stage — aggravation of intraspecific competition, which is confirmed by this study and the recovery of the wild boar population is noted.

Investigation of natural mechanisms for controlling the dynamics of the wild boar population and the causal relationships of the epizootic process in the natural and climatic conditions of Ukraine requires a thorough scientific search based on a systematic approach to preserve the structure and function of natural biocenoses and biological diversity in the future.

During the preparation of the material, the war on the territory of Ukraine and active hostilities in the Chernihivska oblast began. The consequences of military operations for wild animals in the coming years will be unpredictable, which encourages the author to investigate the above issue in unpredictable conditions.

REFERENCES

[1] Agricultural Research Service (2021). *African Swine Fewer/GAP Analysis Report.* Retrieved from https://www.ars.usda.gov/ARSUserFiles/np103/SymposiumWorkshopsMeetings/GARA%20Gap%20Analysis%20Report%202018%2011-11-18.pdf.

[2] Amendolia, S., Lombardini, M., Pierucci, P., & Meriggi, A. (2019). Seasonal spatial ecology of the wild boar in a peri-urban area. *Mammal Res*earch, 64, 387-396. doi: 10.1007/s13364-019-00422-9.

[3] Brivio, F., Grignolio, S., Brogi, R., Benazzi, M., Bertolucci, C., & Apollonio, M. (2017). An analysis of intrinsic and extrinsic factors affecting the activity of a nocturnal species: The wild boar. *Mammalian Biology*, 84, 73-81.

[4] Brogi, R., Grignolio, S., Brivio, F., & Apollonio, M. (2020) Protected areas as refuges for pest species? The case of wild boar. *Global Ecology and Conservation*, 22, article number 00969. doi: 10.1016/j.gecco.2020.e00969.
[5] Chenais, E., Stahl, K., Guberti, V., & Depner, K. (2018). Identification of wild boar–habitat epidemiologic cycle in african swine fever epizootic. *Emerging Infectious Diseases*, 24(4), 810-812. doi: 10.3201/eid2404.172127.
[6] Chernihiv Regional Department of Forestry and Hunting. (2016). Retrieved from https://chernigivlis.gov.ua/%d0 %b1 %d0 %b5 %d0 %b7-%d1 %80 %d1 %83 %d0 %b1 %d1 %80 %d0 %b8 %d0 %ba%d0 %b8/mislivstvo/
[7] Chernihiv Regional State Administration. (2020). *Report on the state of the environment in the Chernihiv region for 2012-2020.* Retrieved from https://eco.cg.gov.ua/index.php.
[8] Clontz, L.M., Pepin, K.M., Ver Cauteren, K.C., & Beasley, J.C. (2021). Influence of biotic and abiotic factors on home range size and shape of invasive wild pigs (*Sus scrofa*). *Pest Management Science*, 78(3), 914-928.
[9] Colomer, J., Rosell, C., Rodriguez- Teijeiro, J.D., & Massei, G. (2021). 'Reserve effect': An opportunity to mitigate human-wild boar conflicts. *Global Ecology and Conservation,* 795, article number 148721. doi: 10.1016/j.scitotenv.2021.148721.
[10] Croft, S., Franzetti, B., Gill, R., & Massei, G. (2020). Too many wild boar? Modelling fertility control and culling to reduce wild boar numbers in isolated populations. *PLOS ONE*, 15(9), article number 15392.
[11] Draft Law No. 7328 "On Amendments to Certain Legislative Acts of Ukraine Concerning the State Environmental Monitoring System" (April 2022). Retrieved from https://cutt.ly/SLsZo98.
[12] ENETWILD. (n.d.). *Complete census of European Wildlife Species presence data bases, following a standardized protocol*. Retrieved from https://enetwild.com/.
[13] European Environment Agency. (n.d.). *Emerald network viewer*. Retrieved from https://emerald.eea.europa.eu/.
[14] Froehly, J.L., Beane, N.R., Evans, D.E., Cagle, K.E., & Jachowski, D.S. (2020). Using multi-scale behavioral investigations to inform wild pig (*Sus scrofa*) population management. *PLoS ONE*, 15(2), article number 0228705. doi: 10.1371/journal. pone.0228705.
[15] Gortázar, C. (2019). Is it possible to control the population of wild boar? Retrieved from https://www.pig333.com.
[16] Jo, Y., & Gortázar, C. (2021). African Swine Fever in wild boar: Assessing interventions in South Korea. *Transboindary and Emerging Deceases*, 68(5), 2878-2889. doi: 10.1111/tbed.14106.
[17] Johann, F., Handschuh, M., Linderoth, P., Dormann, C.F., & Arnold, J. (2020). Adaptation of wild boar (*Sus scrofa*) activity in a human-dominated landscape. *BMC Ecology*, 20, article number 4. doi: 10.1186/s12898019-0271-7.
[18] Jori, F., Chenais, E., Boinas, F., Busauskas, P., Dholllander, S., Fleischmann, L., Olsevskis, E., Rijks, J.M., Schulz, K., Thulke, H.H., Viltrop, A., & Stahl, K. (2020). Application of the World Café method to discuss the efficiency of African swine fever control strategies in European wild boar (*Sus scrofa*) populations. *Preventive Veterinary Medicine*, 185, article number 105178. doi: 10.1016/j.prevetmed.2020.105178.
[19] Khwarahm, N.R., Ararat, K., HamadAmin, B.A., Najmaddin, P.M., Rasul, A., & Qader, S. (2022). Spatial distribution modeling of the wild boar (*Sus scrofa*) under current and future climate conditions in Iraq. *Biologia,* 77, 369-383. doi: 10.1007/s11756-021-00936-1.
[20] Liu, D., Li, Z., Hou, Z., Bao, H., Luan, X., Zhang, P., Liang, X., Gong, S., Tian, Y., Zhang, D., She, W., Yang, F., Chen, S., Roberts, N.J., & Jiang, G. (2022). Ecological relationships among habitat type, food nutrients, parasites and hormones in wild boar *Sus scrofa* during winter. *Wildlife Biology*, 3, article number 01020.
[21] Ministry of Environmental Protection and Natural Resources of Ukraine. (2021). *Ecological passports of regions*. Retrieved from https://mepr.gov.ua/news/37742.html.
[22] Ministry of Environmental Protection and Natural Resources of Ukraine. (2020). *Report on strategic environmental assessment of the state forest management strategy of Ukraine until 2035*. Retrieved from https://mepr.gov.ua/files/docs/Proekt/23022021/%D 0 %A1 %D 1 %82 %D 1 %80 %D 0 %B 0 %D 1 %82D 0 %B 5 %D 0 %B 3 %D 1 %96 %D 1 %8F%D 0 %A4 %D 1 %96 %D 0 %BD%D 0 %B 0 %D 0 %BB 2.pdf.
[23] Ministry of Environmental Protection and Natural Resources of Ukraine. (2022). *Due to the military actions of the occupier, 900 protected areas of Ukraine are in danger today.* Retrieved from https://mepr.gov.ua/news/39149.html.
[24] Niedziałkowska, M., Tarnowska, E., Ligmanowska, J., Jędrzejewska, B., Podgórski, T., Radziszewska, A., Ratajczyk, I., Kusza, S., Bunevich, A.N., Danila, G., Shkvyria, M., Grzybowski, T., & Woźniak, M. (2021). Clear phylogeographic pattern and genetic structure of wild boar *Sus scrofa* population in Central and Eastern Europe. *Scientific Reports,* 11, article number 9680. doi: 10.1038/s41598-021-88991-1.
[25] Nores, C., Llaneza, L., & Alvare, A. (2008). Wild boar *Sus scrofa* mortality by hunting and wolf *Canis lupus* predation: An example in northern Spain. *Wildlife Biology*, 14 (1), 44-51. doi: 10.2981/0909-6396(2008)14[44:WBSSMB]2.0.CO;2.
[26] Pavlenko, A.V. (2018). *Substantiation of ecological efficiency of nature protection activity on biodiversity conservation (on the example of Chernihiv region)* (Doctoral thesis, Kyiv, National University of Life and Environmental Sciences of Ukraine.
[27] Pejsak, Z., Niemczuk, K., & Frant, M. (2018). Four years of African swine fever in Poland. New insights into epidemiology and prognosis of future disease spread. *Polish Journal of Veterinary Sciences*, 21(4), 835-841.
[28] Petridou, M., Youlatos, D., Lazarou, Y., Selinides, K., Pylidis, C., Giannakopoulos, A., Kati, V., & Iliopoulos, Y. (2019). Wolf diet and livestock selection in central Greece. *Journal Mammalia,* 83(6), 530-538.
[29] Risch, D.R., Ringma, J., & Price, M.R. (2021). The global impact of wild pigs (*Sus scrofa*) on terrestrial biodiversity. *Scientific Reports*, 11, article number 13256. doi: 10.1038/s41598-021-92691-1.
[30] Ruf, T., Vetter, S.G., Painer, J., Stalder, G., & Bieber, C. (2021). Atypical for northern ungulates, energy metabolism is lowest during summer in female wild boars (*Sus scrofa*). *Scientifc Reports*, 11, article number 18310.

[31] Sales, L.P., Ribeiro, B.R., & Hayward, M.W. (2017). Niche conservatism and the invasive potential of the wild boar. *Journal of Animals Ecology*, 86(5), 1214-1223. doi: 10.1111/1365-2656.12721.
[32] Sauter-Louis, R.C., Conraths, F.J., Probst, C., Blohm, U., Schulz, K., Sehl, J., Fischer, M., Forth, J.H., Zani, L., Depner, K., Mattenleiter, T.C., Beer, M., & Blome, S. (2021). African swine fever in wild boar in Europe — A review. *Viruses,* 13(9), article number 1717. doi: 10.3390/v13091717.
[33] Smyser, T.J., Tabak, M.A., & Slootmaker, C. (2020). Mixed ancestry from wild and domestic lineages contributes to the rapid expansion of invasive feral swine. *Molecular Ecology*, 29(6), 1103-1119. doi: 10.1111/mec.15392.
[34] Tack, J. (2018). *Wild Boar (Sus scrofa) populations in Europe. A scientific review of population trends and implications for management.* Retrieved from https://cutt.ly/GLsKM25.
[35] The official website of the African swine fever. (2021). *State service of Ukraine for food safety and consumer protection.* Retrieved from https://cutt.ly/RLsLs7y.
[36] Ukrainian Helsinki Human Rights Union. (2017). *On the verge of survival: Destruction of the environment during the armed conflict in eastern Ukraine*. Kyiv: KIT.
[37] Van Der Veken, T., Van Den Berge, K., Gouwy, J., Berlengee, F. & Schamp, K. (2021). Diet of the first settled wolves (*Canis lupus*) in Flanders, Belgium. *Lutra (Leiden)*, 64(1), 45-56.
[38] Vetter, S.G., Puskas, Z., Bieber, C., & Ruf, T. (2020). How climate change and wildlife management affect population structure in wild boars. *Scientific Reports*, 10(1), article number 7298. doi: 10.1038/s41598-020-64216-9.
[39] Voloshyn, O., Voloshyna, N., Karpenco, U., Dubinskyi, D., & Sushko, D. (2022). Ecological features of the spread of emergency infections in the natural biocenoses of Ukraine. *Journal Environmental sciences,* 1(40), 90-94.
[40] Wong, A. (2021). *Developing population control strategies for wild boar management in Canada*. Retrieved from https://scholars.wlu.ca/cgi/viewcontent.cgi?article=3493&context=etd.
[41] Yang, A., Schlichting, P., Wight, B., Anderson, W.M., Chinn, S.M., Wilber, M.Q., Miller, R.S., Beasley, J.C., Boughton, R.K., Ver Cauteren, K.C., Wittemyer, G., & Pepin, K.M. (2021). Effects of social structure and management on risk of disease establishment in wild pigs. *Journal for Animal Ecology*, 90, 820-833. doi: 10.1111/1365-2656.13412.

Екологічні механізми регуляції чисельності популяції *Sus scrofa* в сучасних умовах

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Анотація. Популяція дикого кабана виду (*Sus scrofa*) збільшується стрімкими темпами в більшості країн світу упродовж останніх десятиліть. Інвазивний вид володіє високими показниками відтворення та добре розвиненими адаптивними реакціями, що дозволяє йому успішно розширювати межі свого ареалу, створювати значні економічні збитки сільському і садовому господарствам, урбоекосистемам, загрожує втраті біологічного різноманіття та поширенню зоонозних інфекцій. Метою статті було проаналізувати чинники, які сприяють експансії виду *Sus scrofa* у світі, визначити екологічні механізми регуляції чисельності популяції на фоні стрімкої антропогенної трансформації середовища існування та глобальних кліматичних аномалій; оцінити зміни динаміки чисельності популяції в мисливських господарствах України за період з 2010 по 2020 роки і Чернігівської області, зокрема. Застосовували традиційні методи ретроспективного аналізу, синтезу, екологічних, загально-біологічних, епізоотичних методів дослідження. Проаналізовано світовий досвід та визначено основні чинники низької ефективності стратегій контролю за швидко зростаючою популяцією кабана дикого в агроекосистемах, екосистемах мішаних лісів та урбоекосистемах. За рахунок унікальних особливостей формування життєвої стратегії вид *Sus scrofa* демонструє успішний розвиток, розширення ареалу та спектру доступних харчових ресурсів, ефективне використання добової диверсифікації екологічних ніш в умовах трансформованих екосистем тощо. Встановлено, що причиною неефективності екологічних механізмів тиску на популяцію виду в системі «хижак-жертва» є відсутність великих хижаків в лісових екосистемах Чернігівської області. Водночас, відсутність стримуючих механізмів в системі «хижак-жертва» забезпечило маніфестацію механізмів наступного рівня, а саме формування осередків африканської чуми свиней за лісовим циклом в природних біоценозах регіону. Реакція-відповідь популяцій проявилася стрімким короткочасним зниженням чисельності популяції *Sus scrofa*, як тимчасовий стримуючий ефект з наступною тенденцією до відновлення.Отримані результати можуть бути використані у розробці практичних рекомендацій щодо біологічного моніторингу, екологічного контролю та розробки ефективних заходів менеджменту лісового господарства щодо запобігання біологічній безпеці, пов'язаній з неконтрольованим поширенням виду *Sus scrofa* та африканської чуми свиней на основі універсальних екологічних механізмів регуляції чисельності популяції

Ключові слова: інвазивний вид, ареал, африканська чума свиней, епізоотія, біотичні механізми регуляції