Journal of Insect Biodiversity and Systematics

ISSN: 2423-8112
2026 | 12 (01), X–XX

Paper in press, Proofed, Available online December 12, 2025

Website: https://jibs.modares.ac.ir
Contents list: https://www.biotaxa.org/jibs
https://doi.org/10.48311/jibs.12.01.97

Original Article

Modeling the potential range for *Lymantria mathura* (Moore, 1865) (Lepidoptera: Erebidae) in Ukraine

Yuriy Klechkovskiy [1] | Lesia Bondareva [2*] | Lyudmila Titova [1] |

1 Quarantine Station for Grape and Fruit Crops, Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine 65049, 49 Fontanska Road, Odesa, Ukraine; oskvpk@te.net.ua; titovalg48@gmail.com

2 National University of Life and Environmental Sciences of Ukraine03041, 15 Heroiv Oborony Str., Kyiv, Ukraine.

Corresponding author: Lesia Bondareva | lnubip69@gmail.com

https://zoobank.org/urn:lsid:zoobank.org:E6610980-5127-43AE-9ABF-4BC3DA164727

Academic Editor
Abbas Ali Zamani

Received
September 28, 2025

Revised
November 25, 2025

Accepted
November 27, 2025

Published online
December 12, 2025

ABSTRACT. The introduction and further spread of the defoliator *Lymantria mathura* (Moore, 1865), a pest of deciduous and coniferous tree species that is currently absent in Ukraine, poses a potential threat to the country's ecosystems. This highlights the necessity for a comprehensive risk assessment, considering Ukraine's favorable climatic conditions, the availability of host plants, and the country's active involvement in global trade. The purpose of this study is to model the potential range of *L. mathura* in Ukraine based on an analysis of the spatial distribution of biological objects, considering environmental and geographical bioclimatic conditions within its current range, and to assess the risk of invasion by this species. Using MapInfo Pro 15.0 (ESTIMap) and IDRISI Selva (Clark Labs) software, it was determined that almost the entire territory of Ukraine is potentially suitable for the acclimatization and settlement of this pest, except for the highlands of the Ukrainian Carpathians, which constitute approximately 1% of the country's total area. The model showed that several of Ukraine's bioclimatic factors, including long-term averages, correspond to those within its current natural range (average annual temperature, temperature of the warmest month, and hydrothermal coefficient). The main limiting factor for the species' spread is the average annual temperature of the coldest month. The invasion risk of *L. mathura* and its potential threat to Ukraine's plant resources were assessed as high. To prevent the pest's invasion, it is proposed that *L. mathura* be included in the A1 List (quarantine pests not present in Ukraine) of the "List of Regulated Harmful Organisms in Ukraine," which would prohibit the potential introduction of the pest. Preventing the invasion of *L. mathura* will support the conservation of Ukraine's plant resources (both forest and agricultural) and minimize potential economic losses caused by this pest.

KEYWORDS: Biological invasions, Pest acclimatization, Quarantine, Rosy gypsy moth, Spatial modeling

Citation: Klechkovskiy, Y., Bondareva, L. & Titova, L. (2026) Modeling the potential range for *Lymantria mathura* (Moore, 1865) (Lepidoptera: Erebidae) in Ukraine. *Journal of Insect Biodiversity and Systematics*, 12 (01), xx–xx.

INTRODUCTION

Establishing the patterns that determine the formation and stabilisation of invasive insect ranges remains one of the fundamental challenges in modern ecology and biogeography. These processes are closely related to the historical development of species within both global and local contexts of biotic and abiotic environmental changes, as well as to the broader dynamics of biodiversity. Identifying such patterns enables forecasting the long-term impacts of insects – particularly polyphagous species with high migration potential – which pose a serious threat to the stability of natural ecosystems. This research direction is essential for addressing a wide range of theoretical and applied problems, including faunagenesis, biogeographical analysis, conservation planning, and the rational use of biological resources (Avtaeva et al. 2021).

ISSN 2423-8112 – **Published by** Tarbiat Modares University | **Owner** The Entomological Society of Iran

The integration of geoinformation technologies with biogeographical approaches provides an effective framework for accurately determining the current distribution of species, analysing the agroclimatic conditions of their existence, and modelling the spatial patterns of biological objects. GIS-based ecological modelling makes it possible to assess environmental suitability for the potential acclimatisation of entomological invaders and to forecast the likelihood of establishment of quarantine pests not yet recorded in a region. Forest insects, especially polyphagous species with high dispersal potential, represent a serious risk to ecosystem stability. Timely prediction of their population dynamics and spread requires integrated approaches, particularly through the application of geographic information systems (GIS), which allow for the identification of risk zones and the development of preventive measures vital for adaptive forest management and biodiversity conservation.

The object of this study was *Lymantria mathura* (Moore, 1865), commonly known as the rosy gypsy moth, a species belonging to the family *Erebidae*. It feeds on a wide variety of deciduous trees, as well as some coniferous species, across a range of climatic zones. This polyphagous defoliator damages leaves, buds, flowers, and young shoots of more than 45 plant genera from 24 families, including *Betula L.*, *Castanea Mill.*, *Juglans L.*, *Malus L.*, *Quercus L.*, *Salix L.*, *Tilia L.*, and *Ulmus L.*, thereby weakening host plants, reducing timber and fruit yields, and, in severe infestations, causing plant mortality (Kaustubh et al. 2022; EPPO 2025).

Adults of *L. mathura* resemble other lymantriine moths but can be distinguished by the pink hind wings of females (Arimoto & Iwaizumi 2014). The species exhibits pronounced sexual dimorphism: females are larger (7.5–9.5 cm, avg. 84 mm) than males (3.5–5 cm, avg. 46 mm). Males possess brown forewings, yellow hindwings, and a yellow thorax with grey spots, while females have a pinkish-white body with grey markings, white forewings, and pink hindwings. Both sexes bear dark grey wing spots and strongly pectinate antennae. Although adults are morphologically recognisable, genitalia dissection is often required for reliable identification, as many *Lymantria* species are externally similar. Consequently, molecular methods – capable of working with as little as 30 pg of genomic DNA – are increasingly important for precise diagnostics (Ji et al. 2023). The larvae of *L. mathura* are defoliators that cause extensive damage to foliage, buds, flowers, and shoots. Outbreaks can severely reduce canopy density: in Asia, defoliation of beech and oak forests has reached several tens of percent, leaving stands vulnerable to secondary pests and diseases, and leading to ecosystem degradation (EPPO 2025). Within its natural range, the species is mainly univoltine or bivoltine: one generation per year is reported in Japan and Korea, two in India, and three in Hong Kong (CABI 2025). In 2005, *L. mathura* was included on the EPPO Alert List as a potentially dangerous pest (EPPO 2005). Approximately 38% of the continental United States has a climate favourable for its establishment (Davis et al. 2005). The spread of the species is facilitated by the movement of bark-covered wood and by its strong dispersal ability (EPPO 2004, 2025). According to EPPO (2025), the range of *L. mathura* has expanded significantly, and by 2025, the species had been granted quarantine status in Morocco (2018), Canada (2019), Chile (2019, List A1), and the United Kingdom (2022).

Lymantria mathura is distributed throughout many Asian countries and regions, including Bangladesh, China, India, Japan, Kashmir, Korea, the Kuril Islands, Myanmar, Nepal, Pakistan, the Russian Far East, Sri Lanka, Taiwan, Thailand, and Vietnam. Outbreaks of *L. mathura* typically occur every four years or coincide with those of *L. dispar*, with which it shares similar behaviours and life cycles (EPPO 2025). As a pest closely associated with broadleaf forests, *L. mathura* disrupts trophic relationships within forest ecosystems. The rapid destruction of foliage alters the microclimate and composition of the understorey, leading to a decline in biodiversity. Prolonged defoliation, as observed in other *Lymantria* species, can trigger outbreaks of secondary pests such as bark beetles and promote the dominance of xerophilous vegetation. Even in the absence of widespread tree mortality, *L. mathura* can significantly alter ecological processes in mixed forests (EPPO 2025). So far, the species' range has been restricted to the Eastern Hemisphere; however, there is a growing risk that it could establish in other parts of the world. Phytosanitary risk assessments conducted by EPPO experts indicate that the regions most threatened by invasion and establishment of *L. mathura* include much of central and southern Europe (EPPO 2004). Although the species has not yet been recorded in Europe, it is considered a serious potential threat due to the wide distribution of its host species (mainly oaks) and the facilitation of its spread through global trade. The climatic suitability of Europe and the prevalence of economically important host plants make the timely study and monitoring of *L. mathura* both scientifically and practically relevant.

Modelling the spread of *Lymantria* species, particularly *L. dispar*, has been widely applied to predict potential ranges and invasion risks. Studies by Srivastava et al. (2020) and Régnière (2002) have demonstrated the effectiveness of models such as MaxEnt and seasonal climate approaches in assessing establishment potential under new environmental conditions. A similar approach has been effectively applied in temperate broadleaf forest zones, where climatic conditions resemble the species' natural habitat in Asia. This supports the relevance of using comparable modeling methods for the analysis and management of invasive species in the European context.

To ensure the protection and sustainable use of Ukraine's plant resources, it is necessary to evaluate the risks associated with the possible introduction, acclimatization, and establishment of *Lymantria mathura*, which may become a major defoliator of numerous deciduous and certain coniferous tree species. A comprehensive assessment of the species' invasion potential, environmental impact, and effective measures for its early detection and containment is a critical step in preventing economic and ecological damage. Therefore, this study focuses on GIS-based modelling of the potential distribution of *L. mathura* in Ukraine, taking into account key bioclimatic variables. The model integrates climatic data and draws on previous research of closely related species, highlighting its practical relevance for early-warning and forecasting systems of biological threats.

MATERIAL AND METHODS

The modeling of the spatial distribution of biological objects based on ecological and geographical analysis is used. The algorithm for identifying the potential ecological range of a species using geoinformation technologies includes: identification of environmental factors limiting the distribution of the species; quantitative determination of the ecological amplitude of the species in relation to each limiting factor by comparing available information on the locations of objects and ecological maps of these locations (layer overlay and data extraction operations); identification of ecologically suitable areas (ESA) on ecological maps in relation to each factor limiting the species' distribution (reclassification operations); mapping the potential ecological range of the species as an area suitable for the species' existence for each of the entire set of EATs (overlay and raster algebra operations) (Afonin & Li 2011).

The probability of acclimatization and the potential range of *L. mathura* in Ukraine were studied using the computer software AgroAtlas (Shumilin & Li 2009), MapInfo Pro 15.0 (ESTIMap®), and IDRISI Selva (Clark Labs®). The IDRISI Selva program (Clark Labs) is GIS software that allows you to extract numerical values of environmental factors from each cell of the environmental map raster within the territory where the species (*Lymantria mathura*) occurs. This allows you to determine the environmental amplitudes of the species in relation to each significant environmental factor. In the AgroAtlas program (Shumilin & Li 2009), the ecological map of the territory being analyzed for the acclimatization of a new species (Ukraine) was used to determine the ecologically suitable territory for the species' existence for each factor. By combining maps of ecologically suitable areas for all predictors, a generalized raster map is determined, showing the area potentially suitable for the existence of the species based on the total sum of predictors. AgroAtlas GIS software [Online], which contains sets of climate maps of Russia and neighboring countries, was used to model the potential range of the pest in Ukraine. The climate maps of Ukraine are an excerpt from the general map. Long-term monthly averages based on data from 1981–2017, version 5.01, were used.

The potential distribution range was obtained through an overlay GIS operation that combined three layers representing different temperature indicators across Ukraine (mean annual temperature, average temperatures of the warmest and coldest months). The resulting layer contains a comprehensive set of spatial baseline data. To complete the task, a series of the following operations was performed: creation of a vector map of the *L. mathura* range in MapInfo Pro 15.0. Exporting the obtained vector map of the *L. mathura* range to the IDRISI Selva program. Exporting of world climate maps from AgroAtlas to IDRISI Selva. Finding values of average multi-annual indicators of climatic factors in different parts of the range using the "Cursor Inquiry Mode" function on climate maps of the world (average annual temperature, sum of active temperatures - SAT (>10°C), temperatures of the warmest and coldest months, hydrothermal coefficient (HTC). Determination of maximum and minimum values of each limiting climatic factor in different parts of the *L. mathura* range. Evaluation of the suitability of the climatic conditions of the territory of Ukraine for the species for each of the individual climatic indicators. Construction of raster maps of ecologically suitable areas for *L. mathura* for each limiting factor on the AgroAtlas climate maps. Mapping of the potential range of *L. mathura* in Ukraine by overlaying raster maps of areas suitable for different climatic indicators in IDRISI Selva (Afonin & Li 2011). The result is a cartographically defined area suitable for the species based on a set of climatic factors.

The IDRISI SELVA program automatically excludes areas that do not meet the necessary climatic requirements of the species, allowing for the systematization of all data to clearly predict the possibility of regions in acclimatization and spread of the pest, and to present the results cartographically. Areas suitable for the species, according to each of the analyzed climatic factors and its potential range, are colored in one color, and unsuitable regions are colored in another (white).

RESULTS

In different parts of the pest's current range, as shown on global climate maps (Fig. 1A–E), the long-term average values of key climatic indicators (mean annual temperature, the temperatures of the warmest and coldest months, SAT,> 10°C, and hydrothermal coefficient) were identified. Additionally, the maximum and minimum values of the quantitative amplitudes were determined for each of the limiting factors. The long-term average climatic indicators within the current range of *L. mathura*, determined using the "Cursor Inquiry Mode" function on global climate maps, are presented in Table 1.

To construct vector maps of ecologically suitable areas and determine the acceptable climatic conditions in Ukraine for the existence of *L. mathura*, the maximum and minimum values of ecological amplitudes for each limiting factor within the pest's range were used. The long-term average annual temperature in the range of *L. mathura* varies from -9.8°C to +26.5°C (Table 1). The average annual air temperature in Ukraine ranges from +11°C to +13°C in the south to +5°C to +7°C in the north. The temperature regime in Ukraine falls within the natural range of the pest, and the conditions for its existence and development are met (Fig. 2A). The average multi-annual temperatures of the warmest month (July) in the range of *L. mathura* vary from 7.5°C to 29.3°C (Table 1). In the warmest month, the average monthly temperature in Ukraine varies from +17°C to +19°C in the north and northwest of the country to +22–23°C in the southern regions and up to +25°C on the south coast of Crimea. Fluctuations in the average temperature in July are within the limits of the temperature fluctuations in the pest range, indicating that the territory of Ukraine, according to this factor, meets the conditions required for *L. mathura* survival and growth (Fig. 2B).

The amplitude of fluctuations of SAT, >10, T0°C in the pest's range is significant and ranges from 727°C to 10219°C (see Table 1). In Ukraine, the largest sum of active temperatures exceeding 100°C is observed on the southern coast of Crimea (36000°C). In the plains, it decreases to 24000C in the north and to 16000C in the upper Carpathians. The limits of fluctuations of average SAT, >10, T0°C in Ukraine are within the limits of amplitudes of fluctuations in the pest's range. The constructed vector map demonstrates that the above-mentioned climate indicator in Ukraine fully satisfies the conditions of existence and development of the pest (Fig. 2C). The multi-annual average temperature of the coldest month (January) in the range of *L. mathura* varies from -24.5°C to -20.9°C (Table 1). In Ukraine, the multi-annual average temperature of the coldest month varies from -7–8°C in the northeast of the country and up to +2°C to +4°C on the southern coast of Crimea. In some years, there is a decrease in average monthly temperatures to -15°C. On the highest peaks of the Ukrainian Carpathians, temperatures can fall to -25°C and below. Absolute minimum temperatures in mountain valleys can reach -37°C and even -42°C (Slavske weather station). The built map clearly showed the area where the temperature regime in January does not meet the pest requirements. This area is located on the border between Zakarpattia, Ivano-Frankivsk, and Lviv Regions in the Ukrainian Carpathians.

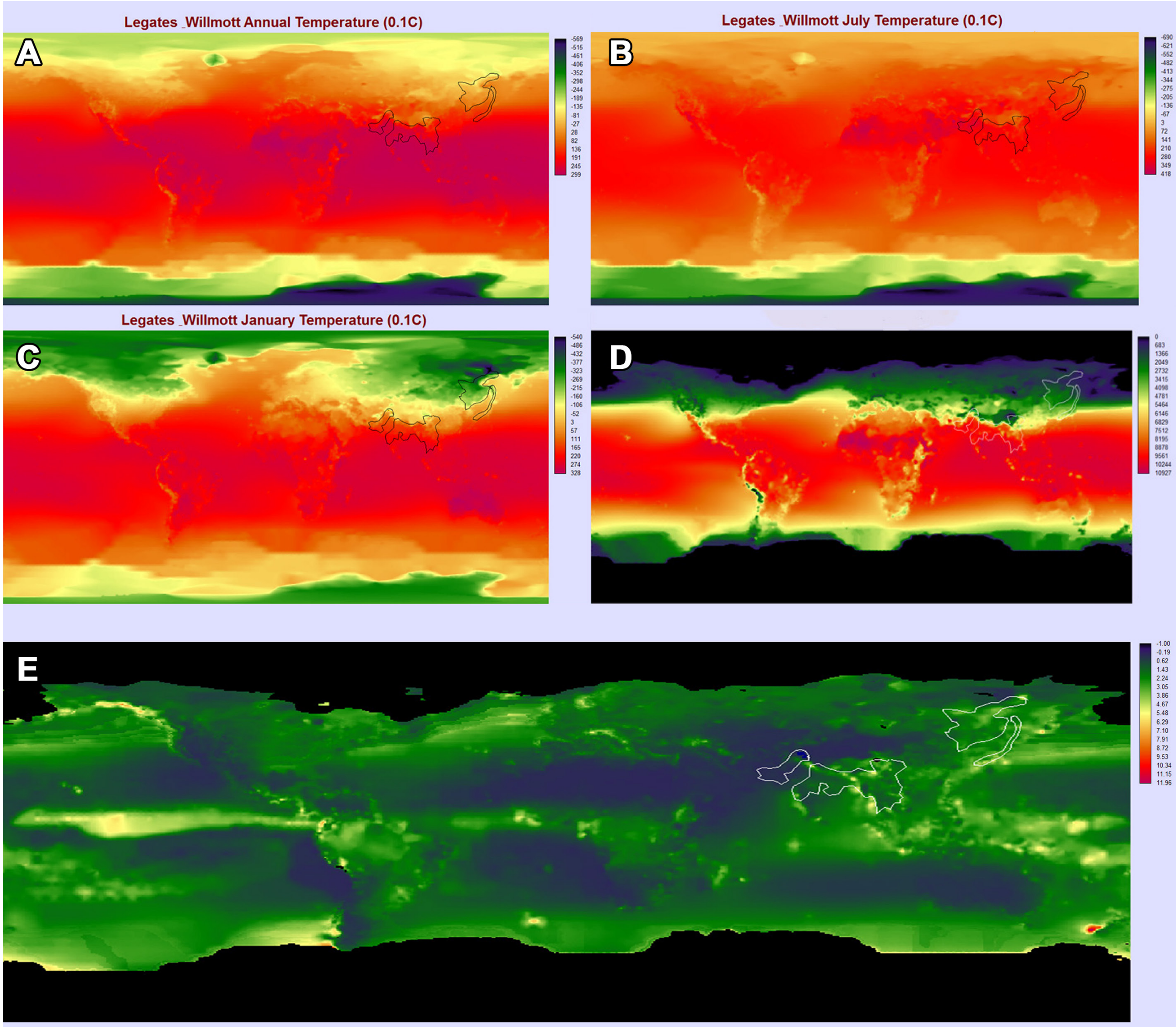

Figure 1. Indicators of temperature fluctuations in various areas where *L. mathura* is distributed: **A.** Average annual temperature (T°C); **B.** Temperatures of the warmest month (T°C); **C.** Temperatures of the coldest month (T°C); **D.** Sum of active temperatures (SAT, >10, T°C); and **E.** Hydrothermal coefficient (HTC). Area boundaries are marked in black for A, B, C, and in white for D and E.

Thus, the multi-annual average temperature of the coldest month (January) is a factor that limits the possibility of pest development in Ukraine (Fig. 2D). The average long-term hydrothermal coefficient (HTC) values in the range of *L. mathura* range from 0.1016 to 4.6721. The HTC indicator values in Ukraine vary considerably by location. In the west of Ukraine, the maximum HTC values are observed: in the foothills of the Carpathians, values range from 2.4495 to 2.4744, while in the mountainous zone, they range 3.0014 to 4.1760. In the north, in Polissia, the HTC ranges from 1.1647 to 1.8029, and in the Forest-Steppe zone, it is between 1.0774 and 1.5269. As one moves south into the Steppe zone, the indicators decrease to 0.6799–1.0046.

The limits of fluctuations in the HTC in Ukraine are also within the limits of the amplitudes of fluctuations in the pest's range. The constructed vector map showed that the hydro-temperature regime of Ukraine fully satisfies the conditions of existence and development of the pest (Fig. 2E). The integration of vector maps of ecologically suitable areas into a single map using a GIS overlay operation that combined three layers containing data on average air temperatures for the warmest and coldest months, as well as HTCs across Ukraine, allowed us to determine the potential range of *L. mathura*.

Table 1. Indicators of the amplitudes of oscillations of climate predictors in various areas where *Lymantria mathura* occurred. (Data compiled by the authors)

Bioclimatic factors	Values
Average annual temperature, T°C	-9.8; -9.1; -8.1; -7.9; -7.6; -5.0; -2.6; -1.9; 1.7; 1.8; 2.3; 2.8; 4.3; 4.9; 5.2; 6.1; 9.8; 10.5; 12.5; 13.7; 13.9; 15.8; 17.2; 20.1; 20.5; 21.1; 21.3; 22.4; 24.3; 26.5
Temperatures of the warmest month, T°C	7.5; 10.5; 11.5; 12.2; 12.3; 13.2; 14.4; 14.6; 14.9; 15.9; 16.1; 17.3; 18.0; 18.4; 19.8; 20.4; 21.0; 21.6; 22,1; 22.1; 23.1; 23.2; 24.5; 24.5; 26.5; 27.2; 27.5; 27.6; 28.7; 29.3
Temperatures of the coldest month, T°C	-24.5; -23.9; -23.1; -23.1; -19.3; -18.9; -17.1; -16.1; -15 9; -15.7; -15.5; -15.4; -12.3; -11.2; -9.2; -9.0; -3.4; -2.5; -2.2; 1.1; 3.1; 3.8; 5.2; 7.3; 7.8; 8.7; 9.1; 11.6; 13.1; 20.3; 20.9
The sum of active temperatures, SAT, >10, T°C	727; 730; 804; 1253; 1451; 1771; 2069; 2097; 2732; 2904; 2920; 2978; 3694; 4147; 4508; 5033; 5112; 5178; 6123; 6780; 6810; 7528; 7767; 7820; 8363; 9318; 9480; 9798; 9896; 10219.
Hydrothermal coefficient (HTC)	0.1016; 0.1804; 0.2752; 0.7639; 1.1175; 1.2365; 1.2665; 1.2817; 1.3411; 1.6256; 1.7305; 1.8115; 1.8889; 2.3029; 2.6929; 2.8465; 2.9771; 4.0721; 4.0893; 4.2092; 4.6721

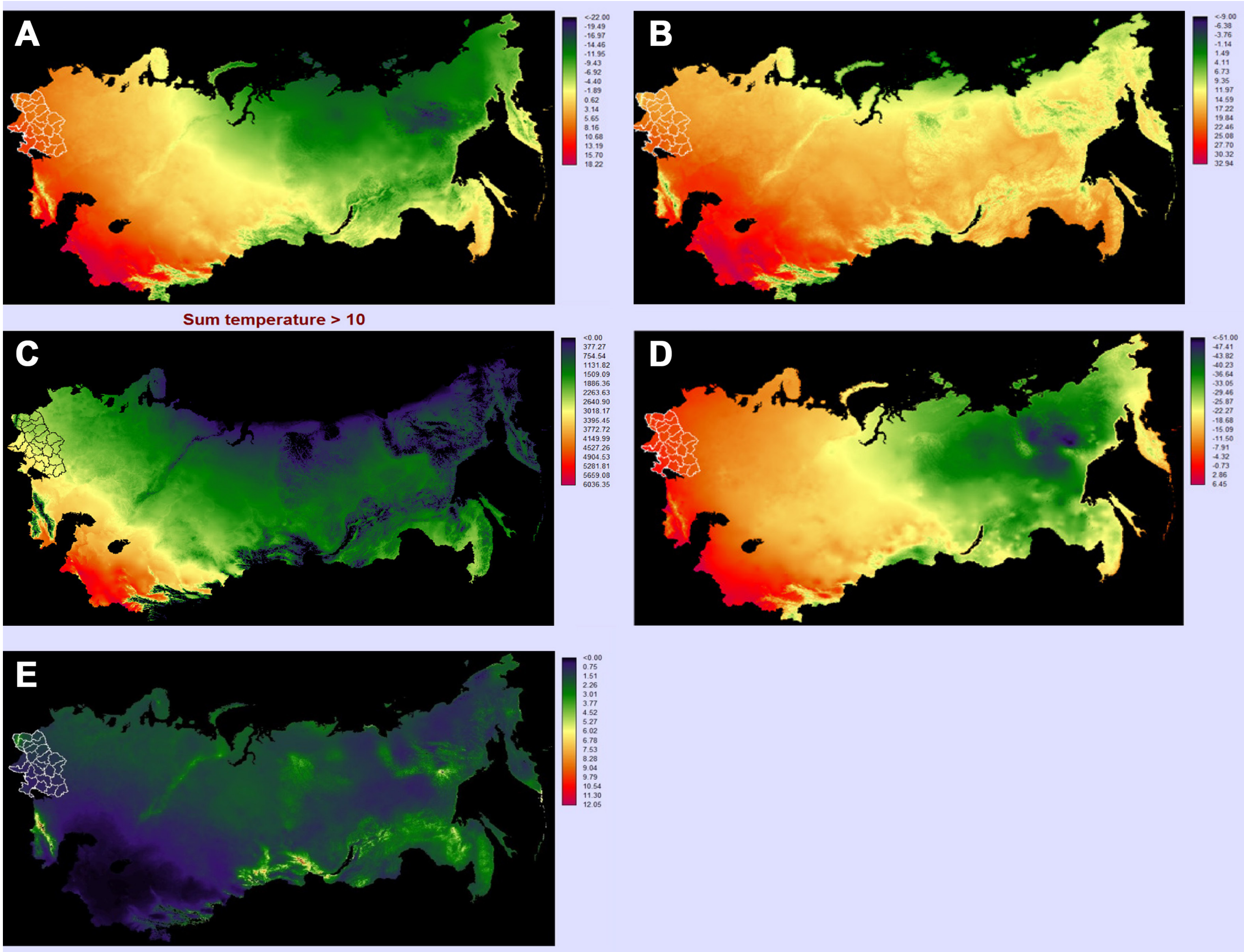

Figure 2. Ecologically suitable areas in Ukraine for the development of *L. mathura,* based on: **A.** Mean annual temperature; **B.** Mean long-term temperature of the warmest month; **C.** Sum of active temperatures above 10°C (SAT, >10, T°C); **D.** Mean long-term temperature of the coldest month, and **E.** GTC indicator.

It was found that almost the entire territory of Ukraine is potentially suitable for acclimatization and settlement of this peof the foothills and highlands of the Ukrainian Carpathians (Fig. 3). An important factor contributing to the emergence and spread of this invasive species is the availability of food resources, particularly host plants. *L. mathura* exhibits broad host plant preferences: within its current range, the rosy gypsy moth is a major pest of deciduous forests and fruit trees across various genera.

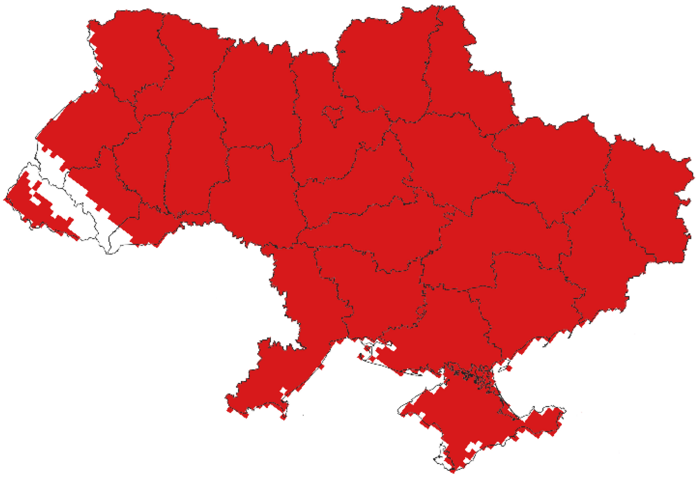

Figure 3. Potential range of *Lymanthria mathura* in Ukraine. (source data compiled by the authors)

Research on the species' ability to utilize both deciduous and coniferous trees in North America and Europe has confirmed its capacity to develop, at varying levels of intensity, on plant species belonging to the families Fagaceae, Juglandaceae, Betulaceae, Oleaceae, Aceraceae, and Pinaceae (Zlotina et al. 1998). Many representatives of these families are native to Ukraine, including species of the genera *Quercus, Juglans, Malus, Ulmus, Tilia, Salix, Betula*, and *Castanea* (Los et al. 2014).

DISCUSSION

Among the abiotic factors affecting the development of leaf-feeding insects, particularly members of the family *Lymantriidae*, the carbon-to-nitrogen (C:N) ratio in host plant foliage plays a decisive role. Numerous studies have demonstrated that leaves with a lower C:N ratio – indicating higher nitrogen content – are more nutritious and attractive to caterpillars. Milanović et al. (2014) showed that *L. dispar* larvae exhibited higher growth rates and shorter developmental periods when feeding on *Quercus cerris* leaves with a low C:N ratio. Similar findings by Lindroth et al. (1997) and Hunter (2001) confirm a strong positive relationship between leaf nitrogen concentration and larval growth and survival. This relationship highlights the key role of nitrogen availability in determining the foraging quality of host plants for defoliating pests.

One of the major mechanisms ensuring polyphagy in *L. mathura* is the species' ability to metabolize a wide spectrum of plant secondary compounds, particularly polyphenols. According to Volf et al. (2024), *L. mathura* larvae exhibit substantial intraspecific variability in the metabolism of polyphenolic compounds, even when feeding on the same host plant. Most polyphenols are excreted unchanged, suggesting that the caterpillars possess an effective biochemical mechanism to neutralize phytochemical defenses. Previous feeding experience also influences subsequent metabolic responses and feeding rates, indicating a capacity for physiological adaptation. Together, these traits contribute to the broad host range and potential invasiveness of *L. mathura*. Assessing areas suitable for pest establishment through ecological modeling is a key tool in modern invasion biology (Penjor et al. 2021). Species distribution models (SDMs) such as MaxEnt are widely applied to predict potential species ranges by correlating known occurrence data with environmental and climatic variables (Naimi & Araujo 2016; Melo-Merino et al. 2020).

Successful applications of SDMs in Ukraine demonstrate their reliability. For instance, the MaxEnt model developed for *Agrilus planipennis* (Fairmaire, 1888) predicted the potential distribution of this pest with high accuracy (AUC = 0.988), showing substantial invasion risk in the Luhansk, Kharkiv, and Donetsk regions (Meshkova et al. 2023). Similarly, Bondareva et al. (2023) modeled the potential spread of the *Metcalfa pruinosa* (Say, 1830), identifying almost the entire territory of Ukraine as climatically suitable, particularly Transcarpathia, Crimea, and forest-steppe zones. Field studies (Kushnir &

Bondareva 2022) later confirmed rapid establishment and northward expansion of the species, validating the accuracy of SDM predictions. Borzykh et al. (2018) used GIS technologies to model the acclimatization zones of *Oemona hirta* (Fabricius, 1775) (Col., Carambycidae) and *Thaumatotibia leucotreta* (Meyrick, 1913) (Lep., Tortricidae) in Ukraine, identifying limited potential ranges primarily in southern coastal regions and Crimea. These examples emphasize that while predictive modeling is powerful, it should be complemented by continuous field monitoring, pest control, and inclusion of species in national quarantine lists. This integrated approach ensures that predictive tools translate into practical phytosanitary management strategies. Given the potential threat posed by *L. mathura*, identifying sustainable and ecologically safe control measures is a high priority. In its native range, chemical treatments are recommended only in cases of high population density and are generally similar to those used against *L. dispar* and *L. monacha*. Diflubenzuron has shown efficacy against *Lymantria* spp., although data on its specific effects on *L. mathura* remain limited (Roychoudhury et al. 2020). However, reliance on chemical insecticides is no longer considered an optimal strategy. Preference is increasingly given to biological control and integrated pest management practices (Boukouvala et al. 2022).

Worldwide, at least ten natural enemies are known to parasitize or infect *L. mathura*, including parasitoid insects (Hymenoptera, Diptera), parasitic nematodes, entomopathogenic fungi, and viruses affecting larvae and pupae (CABI 2025). In Korea, *Brachymeria lasus*, *Cotesia melanoscela*, *Carcelia gnava*, *Compsilura concinnata*, and *Winthemia sumatrana* have been successfully employed for biological control (Lee & Lee 1996). Nevertheless, the recorded parasitism rate (3.89%) for *L. mathura* is considerably lower than for *L. dispar* (27–99%) (Fuester et al. 1983; Gould 1990), suggesting that the diversity of natural enemies of *L. mathura* remains underexplored. In the biological control of *Lymantriidae* insects, numerous studies confirm the high efficacy of *Bacillus thuringiensis* (Bt), particularly the kurstaki strain, against *Lymantria dispar* larvae. Field experiments (Ruiu et al. 2012) have shown that Bt formulations effectively reduce pest populations in oak forests. However, Bt performance varies depending on host tree species and leaf nutritional quality (Farrar et al. 1996), highlighting the need for a comprehensive assessment of environmental factors affecting biocontrol efficiency. Beyond lethal effects, sublethal impacts—such as developmental disruption, altered lifespan, and interactions with natural enemies – have been reported (Erb et al. 2001). Molecular studies (Sparks et al. 2013) reveal complex immune and physiological responses of *L. dispar* larvae to Bt, underscoring potential adaptation mechanisms and the need for resistance monitoring. Therefore, integrating Bt into forest protection systems requires consideration of ecological, biochemical, and molecular aspects, particularly when managing invasive or potentially hazardous species such as *L. mathura*.

In the event of *L. mathura's* introduction to Ukraine, entomophagous insects would likely form the first line of natural defense. Complementary tools, including bioinsecticides based on microorganisms and pheromone-based mating disruption technologies, have been successfully implemented for *L. dispar* (Roychoudhury et al. 2020; Boukouvala et al. 2022). Novel nucleic acid-based biotechnological insecticides (Oberemok et al. 2019) represent a promising direction but require rigorous environmental risk assessment (Heinemann & Walker 2019; Hu et al. 2024). The results of ecological modeling suggest that *L. mathura* could easily adapt to Ukrainian climatic conditions, as they closely correspond to those within its current range. The availability of suitable host plants and the insect's high dispersal potential further increase the risk of successful establishment. Hence, *L. mathura* poses a significant phytosanitary threat across most of Ukraine, with only high-altitude regions of the Carpathians being relatively less suitable for its survival. The experience of the United States provides a model for proactive management. As noted by Mastro et al. (2021), the U.S. has implemented a comprehensive monitoring and inspection system targeting *Lymantria* species, which includes risk assessment, surveillance at ports, ship certification by the National Plant Protection Organization (NPPO), and coordinated eradication efforts. The success of this program lies in its multi-tiered integration of regulatory agencies, inspection services, and the shipping industry – a model that could be adapted for Eastern Europe.

Invasive insects impose substantial economic burdens globally, estimated at USD 70 billion annually, including USD 25 billion spent on research and management (Bradshaw et al. 2016). Seebens et al. (2023) emphasized that these figures are likely underestimated due to underreporting, especially in developing countries. Financial analyses indicate a threefold increase in costs each decade, reflecting both the escalating scale of biological invasions and the limited effectiveness of current containment strategies. Management of invasive species is typically based on a hierarchy of measures, which includes: prevention as the primary strategy; early detection and rapid response as supplementary actions; and long-term management, which is applied in cases where complete eradication is no longer feasible. These principles underscore the urgent need for proactive phytosanitary monitoring and ecological modeling as essential tools for national biosecurity planning. Thus, the present findings confirm that *L. mathura* possesses a combination of biological, physiological, and ecological traits that promote adaptability and invasiveness. GIS-based modeling demonstrates that Ukraine's territory provides favorable climatic conditions for its potential establishment. Therefore, integrating ecological modeling with biological control, phytosanitary monitoring, and international collaboration is essential for preventing the introduction and spread of this species. Proactive management, supported by continuous field validation and adaptive biosecurity measures, will be key to mitigating the ecological and economic impacts of potential *L. mathura* invasion.

For the first time in Ukraine, the threat of the acclimatization of *L. mathura* was detected, and the potential area of the pest was evaluated. The factors contributing to this phenomenon are the similarity of climatic conditions to those of the modern range and the presence of a wide spectrum of host plants. The suitability of the territory of Ukraine for *L. mathura* in modern climatic conditions was evaluated. The potential range of the pest covers almost the whole country except for the highlands of the Ukrainian Carpathians. The main bioclimatic factors favouring the establishment of the species are long-term climate indicators: the average annual temperature and the temperature of the warmest month, the sum of active temperatures above 10°C, as well as the hydrothermal coefficient indicator. The factor limiting the presence of the species is the long-term average temperature of the coldest month. The distribution of *L. mathura* is determined by several factors: the high risk of introduction of the species, its ability to survive in a broad spectrum of climatic conditions, its ability to acclimatize and disperse in new areas through migration of the imago and transport by air masses, and the existence of a broad spectrum of host plant species in Ukraine. The modelling results indicated that almost the entire territory of Ukraine, except for a small part of the Carpathian highlands, meets the climatic requirements for *L. mathura*. The identified suitable areas largely coincide with the distribution of economically important broadleaf species, such as *Quercus*, *Tilia*, *Betula*, *Juglans*, *Malus*, *Ulmus*, *Salix*, and *Castanea*, which serve as host plants for the pest.

An effective control system for *L. mathura* should be developed to prevent its introduction and further spread. One of the most effective risk management measures could be the inclusion of *L. mathura* in List A1 (absent) of the List of Regulated Pests in Ukraine. This would strengthen national biosecurity and prevent significant economic losses.

AUTHOR'S CONTRIBUTION

The authors confirm their contribution to the paper as follows: Y. Klechkovskiy: Research project management and task setting; L. Bondareva: writing and editing a manuscript; L. Titova: GIS analysis. The authors read and approved the final version of the manuscript.

FUNDING

Research work was carried out within the framework of PND 12 'Scientific foundations of modern technologies for forecasting and managing the phytosanitary status of agrocenoses' ('Plant Protection'). Subprogramme 06. 'Scientific basis for monitoring regulated harmful plant organisms in accordance with international requirements' ('Plant Quarantine'). 12.06.00.17.P Phytosanitary risk analysis (PRA) for Ukraine of pests limited in distribution in EEC countries: *Lymantria mathura* Fabricius (pink gypsy moth), *Thaumatotibia leucotreta* Meyrick (false codling).

AVAILABILITY OF DATA AND MATERIAL

Data is available through UkrINTEI 03150, Kyiv, Antonovycha Street, 180. E-mail: uintei@uintei.kiev.ua.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study only included arthropod material, and all required ethical guidelines for the treatment and use of animals were strictly adhered to in accordance with international, national, and institutional regulations. No human participants were involved in any studies conducted by the authors for this article.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

ACKNOWLEDGMENTS

Our sincere thanks to the anonymous reviewers for their constructive comments, which have greatly enhanced the quality of our manuscript.

REFERENCES

Arimoto, M. & Iwaizumi, R. (2014) Identification of Japanese *Lymantria* species (Lepidoptera: Lymantriidae). Based on morphological characteristics of adults. *Research Bulletin of the Plant Protection Service Japan,* 50, 89–110.

Avtaeva, T.A., Sukhodolskaya, R.A. & Brygadyrenko, V.V. (2021) Modeling the bioclimatic range of *Pterostichus melanarius* (Coleoptera, Carabidae) in conditions of global climate change. *Biosystems diversity*, 29 (2), 140–150. https://doi.org/10.15421/012119

Afonin, A.N. & Li, Yu.S. (2011) An ecological-geographical approach based on geographic information technologies in the study of ecology and distribution of biological objects. *BioGIS Journal* 1, 115.

Bondareva, L.M., Kaliuzhna, M.O., Titova, L.G., Klechkovskiy, Yu.E. & Perkovsky, E.E. (2023) Potential distribution of the invasive species *Metcalfa pruinosa* (Hemiptera, Flatidae) and perspectives of its classical biocontrol in Ukraine. *Zoodiversity,* 57 (6), 545–562. https://doi.org/10.15407/zoo2023.06.545

Borzykh, O.I., Klechkovskyi, Yu.E., Titova, L.G. & Palahina, O.V. (2018) Use of modern computer technologies to determine the possibility of acclimatization of adventitious phytophages in Ukraine during the analysis of phytosanitary risk (PRA). *Interdepartmental thematic scientific collection Plant protection and quarantine,* 64, 3–10. https://doi.org/10.36495/1606-9773.2018.64.3-10 [In Ukrainian with English summary].

Boukouvala, M., Kavallieratos, N., Skourti, A. & Pons, X. (2022) *Lymantria dispar* (L.) (Lepidoptera: Erebidae): current status of biology, ecology, and management in Europe with notes from North America. *Insects*, 13 (9), 854. https://doi.org/10.3390/insects13090854

Bradshaw, C.J., Leroy, B., Bellard, C., Roiz, D., Albert, C., Fournier, A., Barbet-Massin, M., Salles, J.-M., Simard, F. & Courchamp, F. (2016) Massive yet grossly underestimated global costs of invasive insects. *Nature Communications*, **7** (1), 12986. https://doi.org/10.1038/ncomms12986

CABI (2025) *Lymantria mathura* (pink gypsy moth). Datasheet (10 December 2020). *CABI Compendium*, 31809. https://doi.org/10.1079/cabicompendium.31809 [Accessed June 20, 2025]

Davis, E., French, S. & Venette, R. (2005) Mini risk assessment pink gypsy moth, *Lymantria mathura* Moore [Lepidoptera: Lymantriidae]. USDA: CAPS PRA, 1–31.

EPPO (2004) Report of a pest risk assessment for *Lymantria mathura.* Doc 05/11593 Available from https://gd.eppo.int/download/doc/1304_pra_rep_LYMAMA.pdf. [Accessed June 20, 2025]

EPPO (2005) *Lymantria mathura*. Datasheets on pests are recommended for regulation, 2005: *EPPO Bulletin*, 35 (3), 464–467. [Accessed June 20, 2025]

EPPO (2025) *Lymantria mathura.* EPPO data on pests recommended for regulation. https://gd.eppo.int [Accessed June 16, 2025] https://doi.org/10.1111/j.1365

Erb, S.L., Bourchier, R.S. & van Frankenhuyzen, K. (2001) Sublethal effects of *Bacillus thuringiensis* Berliner subsp. *kurstaki* on *Lymantria dispar* (Lepidoptera: Lymantriidae). *Environmental Entomology*, 30 (6), 1174–1181. https://doi.org/10.1603/0046-225X-30.6.1174

Farrar, R.R., Kennedy, G.G. & Laing, J.E. (1996) Host plant effects on activity of *Bacillus thuringiensis* against gypsy moth *(Lymantria dispar*). *Environmental Entomology,* 25 (5), 1215–1220. https://doi.org/10.1093/ee/25.5.1215

Fuester, R.W., Drea, J.J., Gruber, F., Hoyer, H. & Mercadier, G. (1983) Larval parasites and other natural enemies of *Lymantria dispar* (Lepidoptera: Lymantriidae) in Burgenland, Austria, and Würzburg, Germany. *Environmental Entomology,* 12 (3), 724–737. https://doi.org/10.1093/ee/12.3.724

Gould, J.R., Elkinton, J.S. & Wallner, W.E. (1990) Density-dependent suppression of experimentally created gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), Populations by Natural Enemies. *Journal of Animal Ecology*, 59 (1), 213–233. https://doi.org/10.2307/5169

Heinemann, J.A. & Walker, S. (2019) Environmentally applied nucleic acids and proteins for purposes of engineering changes to genes and other genetic material. *Biosafety and Health,* 1 (3), 113–123. https://doi.org/10.1016/j.bsheal.2019.09.003

Hu, X., Xu, B., Chen, M., Li, K., Xiao, Y., Liang, S., Zhang, C., Ma, H. & Song, H. (2024) Development and assessment of cutting-edge biotechnologies. *Journal of Biosafety and Biosecurity*, 6, 51–63. https://doi.org/10.1016/j.jobb.2024.03.001

Hunter, M.D. (2001) Effects of elevated atmospheric carbon dioxide on insect-plant interactions. *Agricultural and Forest Entomology*, 3 (3), 153–159.

Ji, W., Dou, F., Zhang, C., Xiao, Y., Yin, W., Yu, J., Kurenshchikov, D.K., Zhu, X. & Shi, J. (2023) Improvement in the identification technology for Asian spongy moth, *Lymantria dispar* Linnaeus, 1758 (Lepidoptera: Erebidae) based on SS-COI. *Insects*, 14 (1), 94. https://doi.org/10.3390/insects14010094

Kaustubh, K., Joshi, R. & Hassan, S.M.M. (2022) Report of occurrence of *Lymantria mathura* (Lepidoptera: Erebidae) from Saranda Forest Division, Jharkhand, India. *Acta Entomology and Zoology*, 3 (1), 30–33. https://doi.org/10.33545/27080013.2022.v3.i1a.61

Kushnir, N.V. & Bondareva, L.M. (2022) Propagation, trophic connection, and phenology of *Metcalfa pruinosa* (Say, 1830) (Auchenorrhyncha: Hemiptera) in N. N. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine. *Russian Journal of Biological Invasions*, 13 (1), 74–80 https://doi.org/10.1134/S207511172201009X

Lee, J.H. & Lee, H.P. (1996) Parasites and phenology of *Lymantria mathura* Moore (Lymantriidae: Lepidoptera) in Kyonggi Province, Korea. *Korean Journal of Entomology*, 26 (4), 393–401.

Lindroth, R.L., Klein, K.A., Hemming, J.D. C. & Feuker, A.M. (1997) Variation in temperature and dietary nitrogen affect performance of the gypsy moth (*Lymantria dispar* L.). *Physiological Entomology*, 22 (1), 55–64. https://doi.org/10.1111/j.1365-3032.1997.tb01140.x

Los, S.A., Tereshchenko, L.I., Gayda, Y.I., Ustimenko, P.M., Yatsyk, R.M., Chernyavsky, M.V., Neyko, I.S., Torosova, L.O., Dutka, M.M., Polakova, L.V. et al. (2014) *State of forest genetic resources in Ukraine.* Kharkiv, Ukraine: Planeta-Print, 138 p. [In Ukrainian]

Mastro, V.C., Munson, A.S., Wang, B., Freyman, T. & Humble, L.M. (2021) History of the Asian *Lymantria* species program: A unique pathway risk mitigation strategy. *Journal of Integrated Pest Management,* 12 (1), 1–10. https://doi.org/10.1093/jipm/pmab023

Melo-Merino, S.M., Reyes-Bonilla, H. & Lira-Noriega, A. (2020) Ecological niche models and species distribution models in marine environments: A literature review and spatial analysis of evidence. *Ecological Modelling*, 415, 108837. https://doi.org/10.1016/j.ecolmodel.2019.108837

Meshkova, V., Borysenko, O., Kucheryavenko, T., Skrylnyk, Y., Davydenko, K. & Holusa, J. (2023) Potential westward spread of emerald ash borer, *Agrilus planipennis* Fairmaire, 1888 (Coleoptera: Buprestidae) from eastern Ukraine. *Forests*, 14 (4), 736. https://doi.org/10.3390/f14040736

Milanović, S., Lazarević, J., Popović, Z., Kostić, M. & Stojanović, D. (2014) Preference and performance of the larvae of *Lymantria dispar* (Lepidoptera: Lymantriidae) on three species of European oaks. *European Journal of Entomology,* 111 (3), 341–347. https://doi.org/10.14411/eje.2014.037

Naimi, B. & Araujo, M.B. (2016) SDM: a reproducible and extensible R platform for species distribution modelling. *Ecography,* 39, 368–375. https://doi.org/10.1111/ecog.01881

Oberemok, V.V., Laikova, K.V., Gal'chinsky, N.V., Useinov, R.Z., Novikov, I.A., Temirova, Z.Z., Shumskykh, M.N., Krasnodubets, A.M., Repetskaya, A.I., Dyadichev, V.V. et al. (2019) DNA insecticide developed from the *Lymantria dispar* 5.8 S ribosomal RNA gene provides a novel biotechnology for plant protection. *Scientific Reports*, 9 (1), 6197. https://doi.org/10.1038/s41598-019-42688-8

Régnière, J. & Nealis, V. (2002) Modelling seasonality of gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), to evaluate probability of its persistence in novel environments. *The Canadian Entomologist,* 134 (6), 805–824. https://doi.org/10.4039/n02-041

Penjor, U. Kaszta, Z., Macdonald, D.W. & Cushman, S.A. (2021) Prioritizing areas for conservation outside the existing protected area network in Bhutan: the use of multi-species, multi-scale habitat suitability models. *Landscape Ecology*, 36, 1281–1309. https://doi.org/10.1007/s10980-021-01225-7

Roychoudhury, N., Singh, R.B. & Kumar, R.M. (2020) Occurrence of *Lymantria mathura* in sal forests of Odisha. *Van Sangyan,* 7 (10), 27–31.

Ruiu, L., Satta, A., Floris, I. & Delrio, G. (2012) Comparative applications of *Bacillus thuringiensis* formulations against *Lymantria dispar* in Sardinian forests. *Bulletin of Insectology*, 65 (2), 251–257.

Seebens, H., Meyerson, L.A., Rahlao, S.J., Lenzner, B., Tricarico, E., Aleksanyan, A., Courchamp, F., Keskin, E., Saeedi, H., Tawake, A. et al. (2023) Chapter 2: *Trends and status of alien and invasive alien species.* In: Roy, H.E., Pauchard, A., Stoett, P., Renard Truong, T. (eds) *Thematic Assessment Report on Invasive Alien Species and their Control of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* IPBES Secretariat, Bonn, Germany, pp. 76–200.

Shumilin, V.P. & Li, Yu.S. (2009) AgroAtlas GIS software. [Online]. http://www.agroatlas.ru [Accessed September 10, 2025]

Sparks, M.E., Blackburn, M.B., Kuhar, D., Gundersen-Rindal, D.E. (2013) Transcriptome response of gypsy moth (*Lymantria dispar* L.) larvae infected with *Bacillus thuringiensis kurstaki*. *PLoS ONE*, 8 (4), e61190. https://doi.org/10.1371/journal.pone.0061190

Srivastava, V., Kaur, R. & Mehta, R. (2020) Assessing the potential distribution of Asian gypsy moth in North America using species distribution models. *Scientific Reports,* 10 (1), 1–10. https://doi.org/10.1038/s41598-019-57020-7

Volf, M., Fontanilla, A.M., Vanhakylä, S., Abe, T., Libra, M., Kogo, R., Lilip, R., Kamata, N., Murakami, M., Novotny, V., Salminen, J.-P. & Segar, S.T. (2024) High intraspecific variability and previous experience affect polyphenol metabolism in polyphagous *Lymantria mathura* caterpillars. *Ecology and Evolution,* 14, e10973. https://doi.org/10.1002/ece3.10973

Zlotina, M.A., Mastro, V.C., Leonard, D.E. & Elkinton, J.S. (1998) Survival and development of *Lymantria mathura* (Lepidoptera: Lymantriidae) on North American, Asian, and European tree species get access arrow. *Journal of Economic Entomology,* 91 (5), 1162–1166. https://doi.org/10.1093/jee/91.5.1162

مدل‌سازی دامنهٔ انتشار بالقوهٔ شب‌پرهٔ کولی صورتی *Lymantria mathura* (Moore, 1865) (Lepidoptera: Erebidae) در اوکراین

یوری کلچکوفسکی [۱]، لزیا بانداروا [۲*]، لودمیلا تی‌تووا [۱]

۱ ایستگاه قرنطینه میوه‌جات، موسسه گیاهپزشکی، آکادمی ملی علوم کشاورزی اوکراین، اودسا، اوکراین
۲ دانشگاه ملی علوم زیستی و محیطی اوکراین، کی‌یف، اوکراین.

نویسندهٔ مسئول: لزیا بانداروا | lnubip69@gmail.com

ویراستار علمی
عباسعلی زمانی

دریافت: ۰۶ مهر ۱۴۰۴
ویرایش: ۰۴ آذر ۱۴۰۴
پذیرش: ۰۶ آذر ۱۴۰۴
انتشار: ۲۱ آذر ۱۴۰۴

چکیـده: ورود و انتشار روزافزون پروانه برگخوار *Lymantria mathura* (Moore, 1865)، آفت گونه‌های درختی برگ‌ریز و مخروطی که در حال حاضر در اوکراین غایب است، تهدید بالقوه‌ای برای اکوسیستم‌های این کشور محسوب می‌شود. این موضوع ضرورت ارزیابی جامع ریسک را با توجه به شرایط اقلیمی مطلوب اوکراین، در دسترس بودن گیاهان میزبان و مشارکت فعال کشور در تجارت جهانی برجسته می‌سازد. هدف این مطالعه مدل‌سازی دامنه انتشار بالقوهٔ شب‌پرهٔ *L. mathura* در اوکراین بر اساس تحلیل توزیع فضایی اشیاء بیولوژیک، مبتنی بر شرایط بیوکلیمایی محیطی و جغرافیایی در دامنه انتشار فعلی و ارزیابی ریسک تهاجم این گونه است. با استفاده از نرم‌افزارهای MapInfo Pro 15.0 (ESTIMap) و IDRISI Selva (Clark Labs)، مشخص شد که تقریباً تمام سرزمین اوکراین، به جز نواحی مرتفع کارپات‌های اوکراین که تقریباً ۱ درصد از مساحت کل کشور را تشکیل می‌دهد، به‌طور بالقوه برای سازگاری و سکونت این آفت مناسب است. مدل نشان داد که چندین عامل زیس‌اقلیمی در اوکراین، از جمله میانگین‌های بلندمدت (دمای سالانه، دمای گرم‌ترین ماه و ضریب آب‌گرمایی)، با عوامل موجود در دامنه طبیعی فعلی آن مطابقت دارد. عامل محدودکننده اصلی برای گسترش این گونه، میانگین دمای سالانه سردترین ماه است. ریسک تهاجم *L. mathura* و تهدید بالقوه آن برای منابع گیاهی اوکراین بسیار بالا ارزیابی شد. برای جلوگیری از حمله آفت، پیشنهاد می‌شود که *L. mathura* در بخش A1 (آفات قرنطینه‌ای که در اوکراین وجود ندارند) مربوط به فهرست موجودات زیان‌آور قانونی در اوکراین قرار گیرد که ورود بالقوه آفت را ممنوع می‌کند. جلوگیری از تهاجم *L. mathura* به حفظ منابع گیاهی اوکراین (هم جنگلی و هم کشاورزی) کمک کرده و خسارات اقتصادی بالقوه ناشی از این آفت را به حداقل می‌رساند.

واژگـان کلیدی: تهاجم زیستی، سازگاری آفت، قرنطینه، شب‌پره کولی صورتی، مدل‌سازی سه‌بعدی