ABS ACTA BIOLOGICA SIBIRICA
A journal on the biodiversity of Siberia and the adjacent lands

Acta Biologica Sibirica 11: 1339–1363 (2025)
doi: 10.5281/zenodo.17907296
http://journal.asu.ru

RESEARCH ARTICLE

Ecological and geographical study of *Lasius platythorax* Seifert, 1991 in the Asian part of Russia

Larisa S. Levchenko[1], Bogdan A. Mikhaleiko[1], Andrei S. Babenko[1], Sergey N. Kirpotin[1]

1 *National Research Tomsk State University, 36 Lenin Ave., Tomsk, 634050, Russia*

Corresponding author: Bogdan A. Mikhaleiko (xoxoxanas123@gmail.com)

Academic editor: R. Yakovlev | Received 2 November 2025 | Accepted 25 November 2025 | Published 13 December 2025

http://zoobank.org/5A3F434D-B6F2-4DA8-87AD-F2658A676273

Citation: Levchenko LS, Mikhaleiko BA, Babenko AS, Kirpotin SN (2025) Ecological and geographical study of *Lasius platythorax* Seifert, 1991 in the Asian part of Russia. Acta Biologica Sibirica 11: 1339–1363. https://doi.org/10.5281/zenodo.17907296

Abstract

The present study aims to identify a potential shift in the distribution of *Lasius platythorax* Seifert, 1991, in the context of future climate change using ecological and geographic modeling methods. Climate models from the WorldClim database were used for the years 1970–2000, 2061–2080, and 2081–2100. Three out of four modeled scenarios predict a decrease in available *L. platythorax* habitat by 2100. One scenario predicts an increase in available habitat, where atmospheric temperature increases by a maximum of 4.4 degrees Celsius by 2100. This result is thought to be due to a decrease in limiting factors associated with increased air temperature. During the study, an updated map of known *L. platythorax* distribution was also created.

Keywords

L. platythorax, Asian Russia, climate, distribution, habitats, model, temperature

Introduction

Ecological and geographical modeling techniques allow us to determine the bioclimatic characteristics of species, which are shaped by key climatic factors such as average annual temperature, precipitation levels, temperature conditions during warm and dry periods, and more. These methods help identify suitable areas where the studied species can thrive (Afonin and Sokolova 2018).

Statistical analysis-based bioclimatic models, also known as ecological niche models, are widely used for predicting changes in species distribution (Chiou et al. 2015; Feoktistov and Baiakhmetov 2020). While proponents highlight their predictive power, critics point out some unwarranted assumptions (Chiou et al. 2015). Nevertheless, bioclimatic models often exhibit a high level of correspondence with contemporary species distributions (Jeschke and Strayer 2008).

It should be noted that interpreting the results of ecological and geographical modeling as an indication of the likelihood of a species' presence in a specific area is not a correct approach. Such models are typically based solely on the spatial distribution of abiotic environmental factors (Lisovsky et al. 2020). However, they do not consider either the interactions between living organisms or the dynamics of population numbers over time. Therefore, ecological and geographical models provide only a partial understanding of the distribution of species, disregarding important biological and temporal factors that significantly influence their survival and adaptation to their environment.

Lasius platythorax, described by Seifert in 1991 (Seifert 1991), has many similarities to *Lasius niger*, which was described by Linnaeus in 1758. Therefore, *L. platythorax* was not considered a separate species until 1991. This species is found from Europe up to Eastern Siberia, and it has a distinctive ecological feature compared to *L. niger*: it prefers moist soils (Seifert 1991). Despite its wide distribution in Eurasia, *L. platythorax* remains poorly studied, especially in Asia.

In the Tomsk region of Russia, *L. platythorax* has been observed in floodplain ecosystems. Ants of this species colonize floodplains that have been left fallow due to changes in land use in Russia (Ivanov et al. 2022). At the same time, insects are able to adapt to changing climate and move their habitats to the north, as shown by studies by Callaghan et al. (2021) and Kirpotin et al. (2021).

For example, in one of the previously studied areas (56°31.07'N, 84°52.06'E), with an area of 21.82 ha, 10.228 *L. platythorax* anthills were found (Fig. 1). Therefore, there are an average of 469 anthills per 1 ha of land. A characteristic feature of *L. platythorax* in these areas is aggressive colonization of the entire accessible territory (Fig. 2). We also found similar colonies on the territory of the Tomsk carbon polygon (Kaibasovo research station), which is located in the floodplain of the middle course of the Ob River (57°14.27'N, 84°12.88'E).

Due to the large-scale colonization of floodplain lands, it has been decided to conduct ecological and geographical modeling of *L. platythorax* to assess the impact of future climate change on the distribution of this species in the Asian part of Russia.

The goals of the study are to compile an updated digital map of the species' current locations and identify the climatic niche of *L. platythorax*. Based on this data, a model of a potentially suitable habitat for the species will be created.

Although the concepts of climatic and ecological niches are theoretical, the habitat of a species provides their practical application. The distribution of a species within a certain area is closely linked to its ecological needs, allowing us to predict its range based on its known requirements.

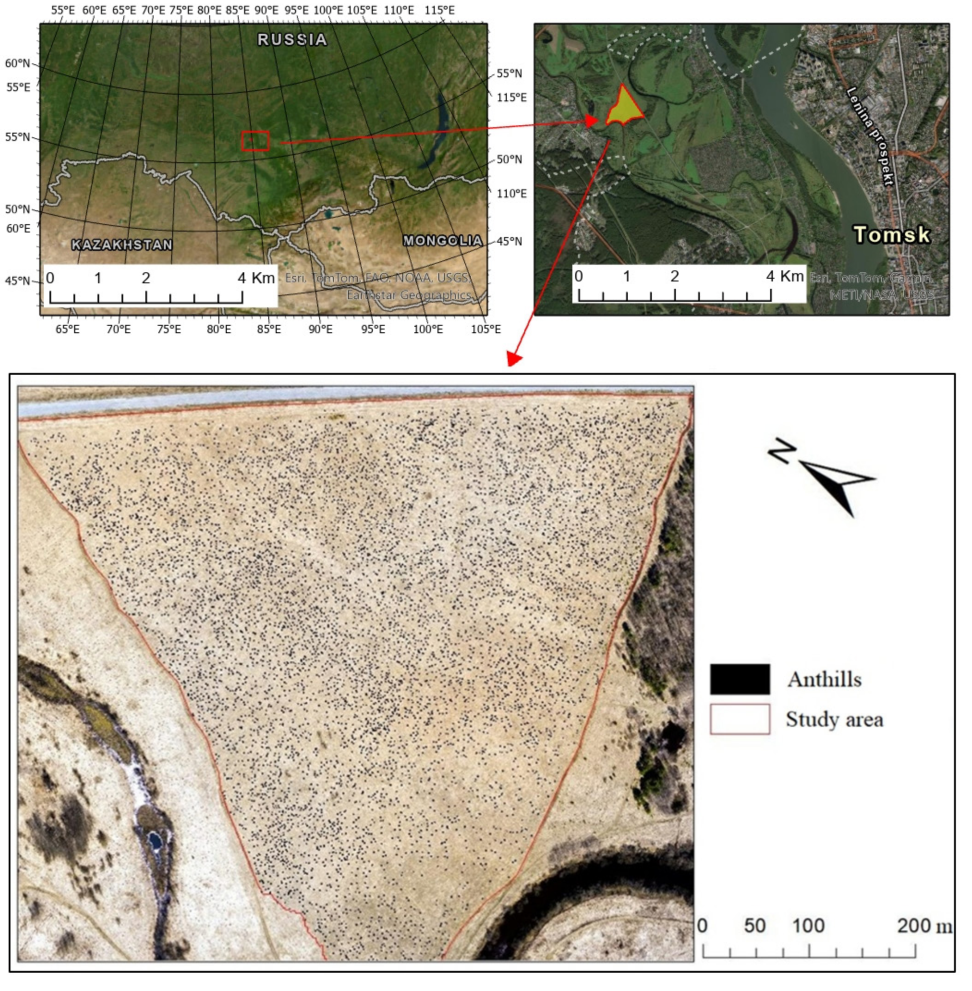

Figure 1. Counted anthills on a site in the floodplain of the Kislovka River (lower channel of the Chipmunk).

It is important to note that information on the distribution of species may be incomplete due to the lack of sufficient study of certain territories. This is particularly true in Siberia, where vast and difficult-to-access areas make it challenging to explore, due to difficult terrain, a small population, and a weak transport network.

This study is based on the concept of niche conservatism, which was developed by Severtsov (1990, 2008) and Peterson et al. (2013).

Figure 2. Numerous anthills in the floodplain of the Kislovka River (lower channel of the Chipmunk).

Materials and methods

Materials

Since ecological and geographical modeling uses information about the distribution of the species and environmental data (bioclimatic variables), in order to establish the known locations of *L. platythorax*, an analysis of scientific publications, materials and conference abstracts was carried out. In addition, the GBIF (Global Biodiversity Information Facility) database was used to expand the data sample and improve the accuracy of determining the detection locations of the species.

It occurs in *L. platythorax* and is widespread in Central and Eastern Europe, covering such countries as Poland (Radchenko et al. 1999; Seifert 2019), Germany (Dolle et al. 2011; Seifert 2019; Feldmeyer 2024), Slovakia (Dekoninck et al. 2004), Hungary (Szinetár et al. 2015), Luxembourg (Wegnez et al. 2021), Spain (Espadaler and Prince 2001), Austria (Glaser and Kopf 2018; Tista 2019), Bulgaria (Seifert 2019), the Netherlands (Dekoninck et al. 2004), Switzerland (Schläppi et al. 2020), Romania (Tăuşan et al. 2017; Seifert 2019), Ukraine (Stukalyuk 2015; Stukalyuk 2017a; Stukalyuk 2017b) and Belarus (Ostrovsky 2023; Sinchuk et al. 2024). *L. platythorax* is less frequently observed on the territory of the Balkan Peninsula, but its presence has been confirmed in Croatia (Seifert 2019). The western distribution boundary passes through Great Britain, Ireland, France (Seifert 2019) and Belgium (Dekoninck et al. 2004), while the northern reaches the southern part of the Scandinavian Peninsula, where this species is found in Sweden (Rudolphi, 2007; Seifert

2019). The southern border is represented by countries such as Italy, Greece (Seifert 2019) and the Republic of South Ossetia (Yusupov and Komarov 2017).

L. platythorax can also be found in Russia, mainly in the European part, as well as in some areas of Western Siberia. Thus, *L. platythorax* was found in 27 regions of Russia, mainly in the European part of the country: Nizhny Novgorod Region (Zryanin and Zryanina 2007; Zryanina, 2009; Lisitsyn P. 2020), Mordovia Republic (Ruchin 2015; Popkova et al. 2021), Mari El Republic (Zryanin and Zryanina 2007) and others (Prisny 2003; Sarapiy 2008; Adakhovsky 2009; Larionov and Larionov 2009; Putyatina 2009; Ryabinin and Novgorodova, 2013a, 2013b; Novgorodova and Ryabinin, 2015; Krasilnikov 2017; Tselishcheva 2018; Seifert 2020; Yusupov and Volodchenko 2021; Krasilnikov 2022). In Southwestern Russia, this ant species is found in the Kabardino-Balkarian Republic (Yusupov 2015). In Western Siberia, this ant species was previously found in the Kemerovo Region (Yeremeeva 2004; Blinova 2009a, 2009b, 2012; Blinova and Kauchakova 2022), Novosibirsk Region (Novgorodova and Biryukova 2011; Ryabinin et al. 2017), Tyumen Region (Novgorodova and Ryabinin 2015), Altai Krai (Krugova 2009, 2017; Krugova and Chesnokova 2012) and Altai Republic (Novgorodova and Biryukova 2011; Chesnokova and Omelchenko 2011). In Eastern Siberia, *L. platythorax* was found in 2 regions: the Irkutsk Region (Antonov 2012, 2013a, 2013b, 2014) and the Buryatia Republic (Antonov 2013a, 2014).

Based on the data collected, a database has been created that includes all available records of *L. platythorax*. This database has been mapped onto a digital world map, and it also includes habitats that were discovered by our researchers and previously described (Mikhaleiko et al. 2023).

The distribution map of *L. platythorax*, based on information from 4,044 recorded locations (Fig. 3), shows the fragmentation of its range. This fragmentation can be attributed to both natural factors such as mountain systems and water barriers, as well as human activities such as landscape changes and environmental pollution. It is possible that isolated populations of *L. platythorax* exist outside the main distribution area, indicating the species' ability to adapt to different environmental conditions.

Due to the fragmentation of the habitat and the focus of this study, we decided to concentrate on the points found between the Ural Mountains and Lake Baikal in Asian Russia (Fig. 4).

As previously mentioned, climate parameters important for modeling are needed, such as the average monthly precipitation and temperature extremes (Table 1). From 1970 to 2000, these variables were downloaded in GeoTIFF format from the WorldClim database (Fick and Hijmans 2017), with a resolution of 2.5 arc minutes (approximately 5 km).

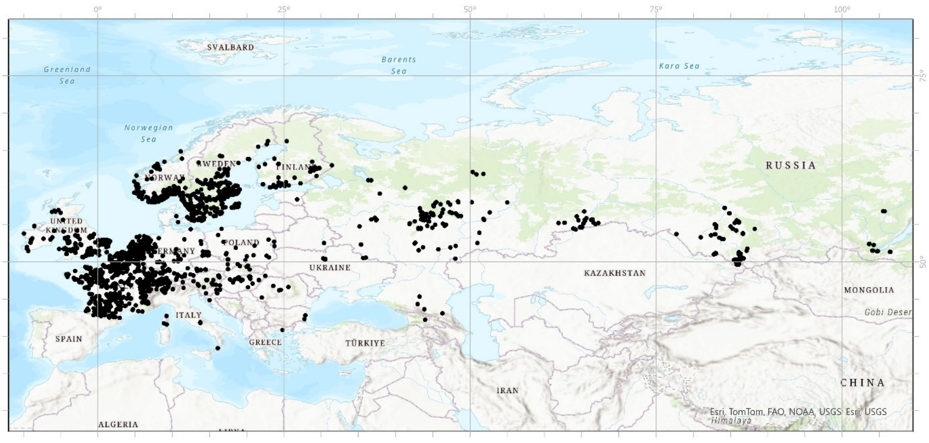

Figure 3. Updated distribution map of *L. platythorax*: black dots indicate known locations (4044).

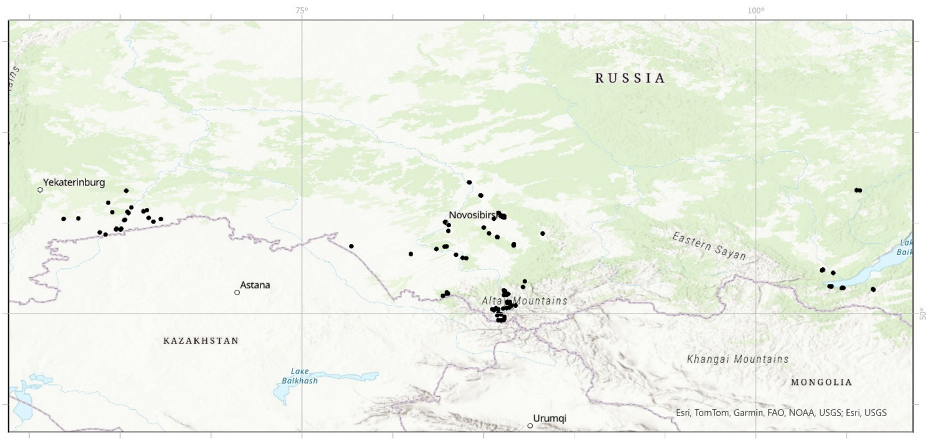

Figure 4. Distribution of *L. platythorax*: black dots represent known locations in Asian Russia (154 sites).

Table 1. WorldClim variables

Bioclimatic Variables:	Monthly Averages		
bio1 Average annual temperature (°C)	**tmax1** Average monthly maximum temperature in January , °C*10	**tmin1** Average monthly minimum temperature in January, °C*10	**prec1** Average monthly precipitation in January, mm
bio2 Temperature range per day (°C)	**tmax2** Average monthly maximum temperature in February , °C*10	**tmin2** Average monthly minimum temperature in February, °C*10	**prec2** Average monthly precipitation in February, mm

Bioclimatic Variables:		**Monthly Averages**	
bio3 Isothermicity	**tmax3** Average monthly maximum temperature in March , °C*10	**tmin3** Average monthly minimum temperature in March , °C*10	**prec3** Average monthly precipitation in March, mm
bio4 Temperature seasonality, standard deviation	**tmax4** Average monthly maximum temperature in April , °C*10	**tmin4** Average monthly minimum temperature in April , °C*10	**prec4** Average monthly precipitation in April , mm
bio5 Maximum temperature of the warmest month (°C)	**tmax5** Average monthly maximum temperature in May, °C*10	**tmin5** Average monthly minimum temperature in May , °C*10	**prec5** Average monthly precipitation in May, mm
bio6 Minimum temperature of the coldest month (°C)	**tmax6** Average monthly maximum temperature in June, °C*10	**tmin6** Average monthly minimum temperature in June, °C*10	**prec6** Average monthly precipitation in June, mm
bio7 Temperature range per year (°C)	**tmax7** Average monthly maximum temperature in July, °C*10	**tmin7** Average monthly minimum temperature in July, °C*10	**prec7** Average monthly precipitation in July,, mm
bio8 Average temperature of the wettest quarter (°C)	**tmax8** Average monthly maximum temperature in August, °C*10	**tmin8** Average monthly minimum temperature in August, °C*10	**prec8** Average monthly precipitation in August, mm
bio9 Average temperature of the driest quarter (°C)	**tmax9** Average monthly maximum temperature in September, °C*10	**tmin9** Average monthly minimum temperature in September, °C*10	**prec9** Average monthly precipitation in September , mm
bio10 Average temperature of the warmest quarter (°C)	**tmax10** Average monthly maximum temperature in October , °C*10	tmin10 Average monthly minimum temperature in October, °C*10	prec10 Average monthly precipitation in October, mm
bio11 Average temperature of the coldest quarter (°C)	tmax11 Average monthly maximum temperature in November, °C*10	tmin11 Average monthly minimum temperature in November, °C*10	prec11 Average monthly precipitation in November, mm
bio12 Annual precipitation (mm/year)	tmax12 Average monthly maximum temperature in December , °C*10	tmin12 Average monthly minimum temperature in December, °C*10	prec12 Average monthly precipitation in December, mm
bio13 Precipitation in the rainiest month (mm/month)	–	–	–
bio14 Precipitation in the driest month (mm/month)	–	–	–

Bioclimatic Variables:	Monthly Averages		
bio15 Seasonality of precipitation (coefficient of variation)	–	–	–
bio16 Precipitation in the wettest quarter (mm/quarter)	–	–	–
bio17 Precipitation in the driest quarter (mm/quarter)	–	–	–
bio18 Precipitation in the warmest quarter (mm/quarter)	–	–	–
bio19 Precipitation in the coldest quarter (mm/quarter)	–	–	–

To predict the potential habitats of *L. platythorax* in the future, we used the MIROC 6 model (Tatebe et al. 2019), which was based on the WorldClim data. This model includes various Shared Socio-Economic Pathways (SSPs) that take into account different levels of carbon dioxide emissions. The scenarios were developed by international experts and are presented in the IPCC's 6th assessment report. All scenarios predict an increase in temperature over the period 2081–2100 (Pörtner et al. 2022). The range of projected increases in temperature is from 1.8°C (SSP1-2.6) to 4.4°C (SSP5-8.5), depending on the level of emissions (Table 2).

Table 2. Common socio-economic pathways published in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Shared Socio-Economic Pathways	Brief description of the scenario	Estimated warming (2081–2100)
SSP1-2.6	CO_2 emissions will decrease to net zero around 2075	1.8°C
SSP2-4.5	CO_2 levels will be around current levels until 2050, then start to decline, but will not reach net zero by 2100	2.7°C
SSP3-7.0	By 2100 CO_2 emissions will have doubled	3.6°C
SSP5-8.5	By 2075 they will have tripled	4.4°C

Methods

The paper compared models of potential *L. platythorax* habitats, based on all the SSP scenarios presented for 2061–2080 and 2081–2100, but it should be noted that these scenarios do not account for rising sea levels or changes in the cryosphere.

To prepare the data for modeling, we used the ArcGIS Pro (ESRI) software (version 3.0.1). The Analyst Tools integrated into ArcGIS allowed us to convert GeoTIFF raster layers into ASCII and GRID formats, making them more suitable for analysis. Additionally, we converted tabular data in Excel format into vector layers, simplifying their use in further analysis.

To randomize and remove duplicate *L. platytorax* points, as well as points that are within 30 kilometers of each other, the SDMtoolbox PRO application (version 0.9.1), operating in the ArcGIS Pro environment was used (Brown 2014). This process was necessary to optimize the data and reduce correlation during model construction. Therefore, the identification of a climatic niche and the creation of a model was based on 54 presence points out of the 154 initially identified (Fig. 5).

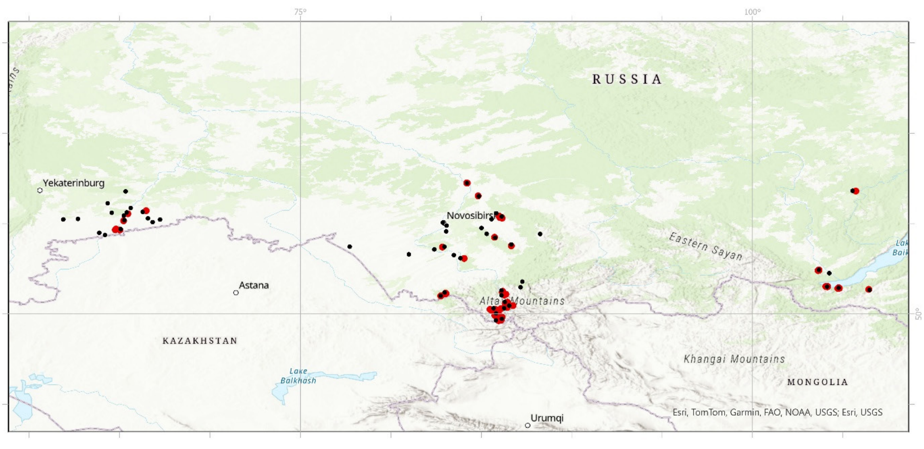

Figure 5. Distribution of *L. platythorax*: the red dots represent 100 points that were excluded from the analysis after thinning to obtain a more accurate assessment of the ecological niche. The black dots represent the 54 points that were included in the analysis.

The BIOCLIM algorithm, which was developed by Hijmans et al. (2005), was used to determine the climatic requirements of the species, taking into account its adaptation to specific climatic conditions. This method allows us to visualize the climate niche of the species using 19 histograms and climate envelopes (Nix 1986).

As part of the preliminary data preparation for modeling in the R statistical environment (version 4.4.0), out of 55 variables (Table 1), the Pearson correlation analysis (Nettleton 2014) method was used to exclude strongly correlated climatic factors (> 0.8). This process allows us to create a more accurate model of the territory and correctly assess the contribution of each variable to the model.

After excluding variables with a correlation coefficient greater than 0.8, the analysis included the following: bio2 (average daily temperature range, °C), bio7 (average annual temperature range, °C), bio14 (average precipitation in the driest month, mm/month), bio15 (coefficient of variation for precipitation seasonality), bio18 (average precipitation in the warmest quarter, mm/quarter), bio19 (average precipitation in the coldest quarter, mm/quarter), prec1 (monthly average precipitation in January, mm), and prec8 (monthly average precipitation in August), as well as tmax1 (monthly maximum temperature average in January) and tmin8 (monthly minimum temperature average in August).

The maximum entropy method, or MaxEnt (Phillips et al. 2004), was used to create models of suitable territories for the *L. platythorax* habitat. This algorithm is based on training a sample using one part of the data (75%), and then testing the results using the other part (25%). A threshold of 10 percentiles was also set, indicating that 10% of edge points were excluded from the analysis and considered random. As a result, values that exceeded the threshold value in their climatic parameters were considered atypical and displayed on the model as unsuitable territories for this species habitat.

The predictive ability of the model is assessed using the AUC (Area Under the Curve): the area under the Receiver Operating Characteristic (ROC) curve. This curve is used to evaluate the quality of binary classification models. AUC measures the ability of the model to distinguish between cells with and without a view. AUC ranges from 1 to 0, with higher values indicating better performance. Values between 1 and 0.9 are considered excellent, 0.9–0.8 are good, 0.8–0.7 are acceptable, 0.5–0.7 is bad, and 0–0.5 is unacceptable, indicating that the model performs worse than a random predictor (Araujo et al. 2005).

At the same time, MaxEnt allows us to estimate the contribution of variables in model construction using three independent methods: the percentage contribution, the permutation method (Scheldeman and van Zonneveld 2010), and the Jackknife (Fard et al. 2013). However, according to the developers (Phillips et al. 2006), the use of the first method is not recommended, as the percentage contribution can vary depending on the "path taken" by the algorithm and the degree of correlation between variables.

Unfortunately, MaxEnt does not provide other statistical criteria for assessing the accuracy of obtained models, which can be seen as a limitation (Lobo et al. 2008; Jiménez-Valverde 2012).

Results and discussion

Identification of the Climatic Niche of *L. platythorax*

Using the BIOCLIM algorithm, we obtained histograms reflecting the frequencies of various values of climatic characteristics, bio1-19 (only 19 out of 55 variables were used due to limitations of the method), observed in the species. The limits of variability for each factor and optimal values for *L. platythorax* were obtained (Fig. 6). Arrows show maximum and minimum values. For example, for bio1, the range of values is -4.8 to 2.6, with optimal values between 1.1 and 2.6.

An analysis of the histograms of climatic variables for *L. platythorax* showed that the frequency of bio9, which represents the average temperature of the driest quarter, was closest to a normal distribution. Graphs bio17 and bio19, which represent the precipitation for the driest and coldest quarters, were found to be sharply asymmetrical and similar in configuration, indicating that the species distribution may be limited by climatic factors.

On the other hand, graphs bio8, bio10, bio16, and bio18, which represent average temperatures and precipitation amounts for wettest and warmest quarters, as well as driest month, were all found to be similar in both configuration and limiting and optimal values, indicating a strong correlation between these variables. The similarity between graphs bio14 and 19, representing precipitation amounts in the driest month and coldest quarter, can be attributed to the high correlation between season and precipitation.

Two-vertex graphs (bio2, bio3, bio5, bio8, bio10) suggest that the species may be sensitive to seasonal temperature variations, as its range covers areas with different temperature ranges. This may also indicate ecological heterogeneity within *L. platythorax* and divergence in ecological and climatic niches.

The bioclimatic variable graph shows that the average annual temperature suitable for *L. platythorax* habitat is 1.1–2.6°C. The average daily temperature varies 10.4–11.4°C, and the precipitation in the warmest quarter varies 170–210.6 mm per quarter. The indicators for precipitation levels for *L. platythorax* include: 10.2–15.4 mm in the driest month, and 56–72.4 mm during the precipitation season.

The two-dimensional climate envelope for *L. platythorax* (Fig. 7) is plotted in the coordinates of average annual temperature (Bio1) and average annual precipitation (Bio12). The graph shows the distribution of values and the number of individuals that fall outside the 5–95 percentile range for their climatic parameters.

The upper left corner of the graph, which represents cold and humid habitats, is almost empty when considering average annual temperature and precipitation. In contrast, there is a noticeable presence in the lower right corner, which corresponds to the warmest and least humid habitats.

The red dots extending beyond the climatic envelope indicate the number and location of individuals in atypical habitats. The graph showing the spread of 54 objects with respect to bio1 and bio12 revealed that 34 points of presence were outside the 5–95 percentile range. As mentioned previously, this finding can be explained by special environmental conditions, such as micro-relief and microclimate (Scheldeman and van Zonneveld 2010).

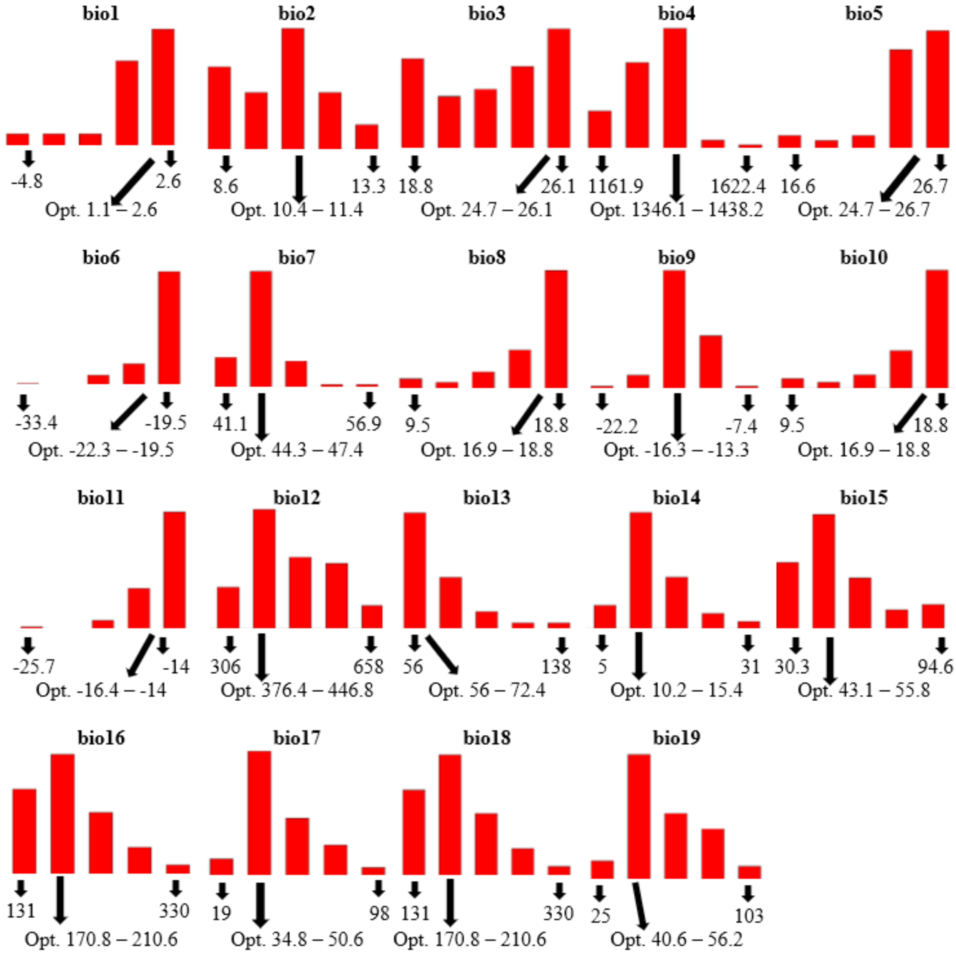

Figure 6. Frequency graphs of climatic parameters for *L. platythorax*.

Modeling favorable habitats for *L. platythorax* in 1970–2000

The model of territories suitable for the habitat of *L. platythorax* based on climatic parameters was constructed using 10 independent variables (bio2, bio7, bio14, bio15, bio18, bio19, prec1, prec8, tmax1, and tmin8) and taking into account 75% of the training sample (Fig. 5).

Based on the results of predicting suitable habitats for *L. platythorax* between 1970 and 2000, and using a logistic threshold of 0.390 (Table 3), the model of suitable territories is classified as: areas with average suitability (0.4–0.8) and areas with high suitability (0.8–1) (Fig. 8). The locations used to build the model are indicated by dots on the diagram.

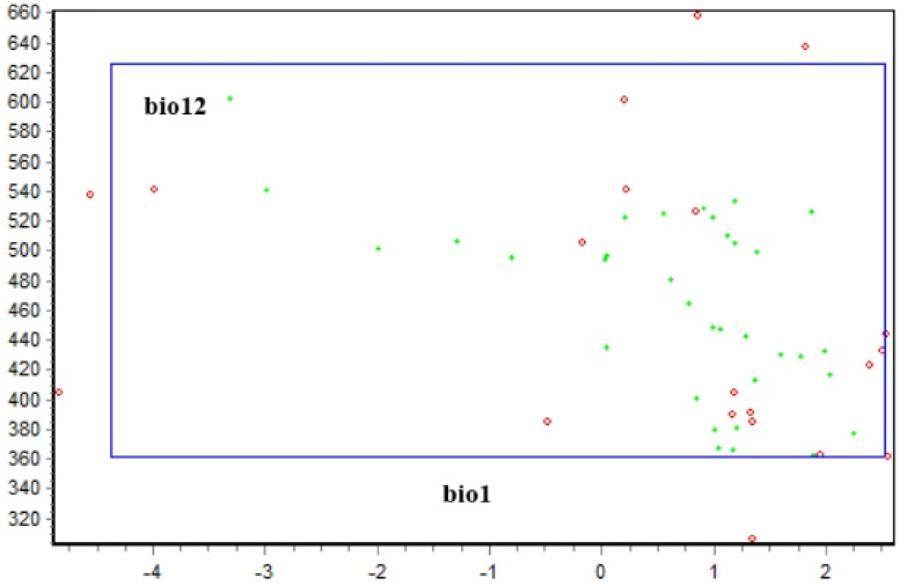

Figure 7. Graphs of the distribution of *L. platythorax* depending on the average annual temperature and average annual precipitation.

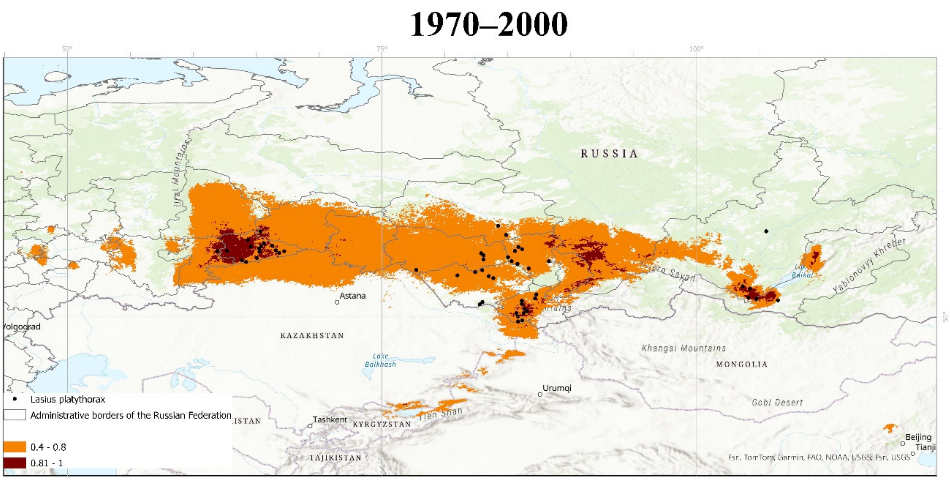

Figure 8. Model of Suitable Habitats for *L. platythorax* in Modern Climatic Conditions (1970–2000): 0.4–0.8, 0.81–1 – territories that are suitable for the species by 40–80% and 81–100%, respectively.

However, some locations are in areas with unsuitable habitat conditions. This indicates that they are located in atypical climates for the species, as confirmed by the graph of the climate envelope.

The model for *L. platythorax* habitats in the modern climate has a high degree of predictive reliability. The main factors contributing to its construction, according to a permutation test, are: tmax1 (average monthly maximum temperature in January), bio14 (precipitation in the driest month), and prec1 (average monthly precipitation in January) (Table 3).

The jackknife analysis (Fig. 9) confirmed the statistical estimates of the contributions of tmax1 (the average monthly maximum temperature in January) and bio7 (the temperature range for the year) to the model. The tmin8 factor (the average monthly minimum temperature in August) came in third, pushing bio14 (the amount of precipitation in the driest month) down to fourth. The graph also showed that tmax1, bio14, bio18, and prec1 carry the largest shares of unique information (see Table 3).

Table 3. The main characteristics of the distribution model of *L. platythorax*, constructed by Seifert in 1991 using the MaxEnt algorithm

	L. platythorax n = 54			
n tr/n test	41 / 13			
AUCtr/AUCtest	0.983/ 0.974			
Standard deviation	0.009			
Logistical threshold	0.390			
Evaluation	**Percentage contribution, %**	**Permutation, %**	**Jackknife**	
			Rating of the contribution of variables	Rating of variables with unique properties
	tmax1 = 50.9	tmax1 = 48.3	1 – tmax1	1 – tmax1
	bio14 = 18.6	bio14 = 17.2	2 – bio7	2 – bio14
	bio18 = 9.4	prec1 = 13.2	3 – tmin8	3 – bio18
	prec1 = 6.5	bio18 = 9.3	4 – bio14	4 – prec1
	bio15 = 6.2	prec8 = 6.8	–	–
	prec8 = 3.6	bio15 = 2	–	–
	bio2 = 1.8	bio7 = 1.3	–	–
	tmin8 = 1.7	tmin8 = 1.1	–	–
	bio7 = 1.3	bio2 = 0.8	–	–
	bio19 = 0	bio19 = 0	–	–

Note: n tr – the size of the training sample, n test – the size of the testing sample, AUCtr is the AUC of the training sample, and AUCtest is the AUC of the testing sample.

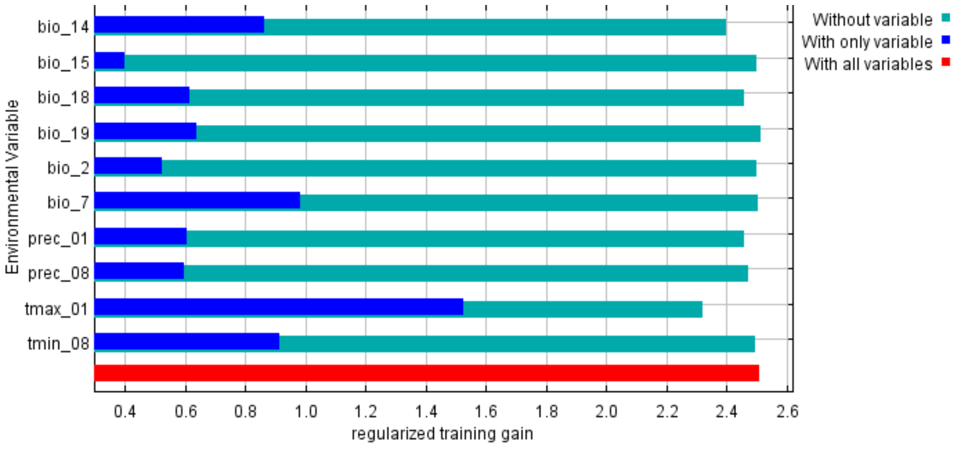

Figure 9. Jackknife test results.

According to the permutation and Jackknife tests, the average monthly maximum temperature in January and the amount of precipitation in the driest month are the most significant factors for the distribution of *L. platythorax*.

Modeling favorable habitats for *L. platythorax* under scenarios of predicted climate change

To create models of favorable habitats under scenarios of future climate change, we used the same 10 bioclimatic variables as for the current period (bio2, bio7, bio14, bio15, bio18, bio19, precip1, precip8, tmax1, and tmin8). Based on the relationship between ecological niche and geographical range, as well as the concept of niche conservatism, we assumed that sites identified as suitable for *L. platythorax* now will likely remain suitable in the future (Table 4).

To identify possible changes in the distribution of *L. platythorax*, we correlated the ecological needs of this species with projected climate changes in 2061–2080 and 2081–2100. According to the future climate scenario SSP1-2.6 (Fig. 10A–C), which assumes a 1.8°C increase in the Earth's total temperature by 2100, we constructed models of territories suitable for *L. platythorax* in new conditions. Based on these models, the most suitable territories (range 0.8–1) are expected to decrease by 62.5% by 2100 under this scenario.

Under the SSP2-4.5 scenario, which predicts a 2.7°C increase in global temperature by 2100, simulation results (Fig. 10D–F) show that the optimal range for *L. platythorax* will decrease by 91.06% under this scenario compared to the present.

For the SSP3-7.0 scenario, which envisions an increase in average global temperature by 3.6°C by the year 2100, the models (Fig. 10G–I) suggest that the most suitable territories for *L. platythorax* currently will also experience a 98.2% decrease by the end of the century, similar to the SSP1-2.6 and SSP2-4.5 scenarios.

Table 4. Changes in habitat area under different scenarios

Scenario/period	Area, ha			Area, %		Area change, %	
	0.4–0.8	0.8–1	Sum	0.4–0.8	0.8–1	0.4–0.8	0.8–1
1970–2000	179889063	11788960	191678023	100.0	100.0	0.00	0.00
SSP1-2.6 2060–2080	172623120	8578725	181201845	95.96	72.77	-4.04	-27.23
SSP1-2.6 2080–2100	167248065	4421314	171669379	92.97	37.50	-7.03	-62.50
SSP.2-4.52060–2080	166271701	1173002	167444703	92.43	9.95	-7.57	-90.05
SSP.2-45 2080–2100	183371249	1053686	184424935	101.94	8.94	1.94	-91.06
SSP.3-70 2060–2080	180490976	3084579	183575555	100.33	26.16	0.33	-73.84
SSP.3-70 2080–2100	164528043	211697	164739740	91.46	1.80	-8.54	-98.20
SSP.5-85 2060–2080	205878445	5553322	211431767	114.45	47.11	14.45	-52.89
SSP.5-85 2080–2100	187664612	16031424	203696036	104.32	135.99	4.32	35.99

Note: 0.4–0.8, 0.81–1 territories that are suitable for the species by 40–80% and 81–100%, respectively.

According to the future climate scenario SSP5-8.5, which forecasts an increase in global temperature of 4.4°C by 2100, models have been developed to assess territories suitable for this species to thrive in new conditions (Fig. 10J–L). Based on these models, the territories currently most suitable for *L. platythorax* are projected to decrease by 52.89% by 2080, similar to what was observed with SSP1-2.6 and SSP2-4.5.

Nevertheless, by the year 2100 there was an expansion of a zone by 35.99% (compared to the range during the period 1970–2000) that is most favorable for *L. platythorax* existence within the Asian region of Russia.

The result may be linked to the fact that by 2080, one or more of the factors considered (for example, precipitation) may fall within a range that is unsuitable for *L. platythorax*. In contrast, by 2100 suitable habitats are increasing, which could be due to the largest increase in temperature compared to previous scenarios. It is assumed that the increase in temperature will counteract the limiting effect of changing environmental factors in 2100, leading to an expansion of *L. platythorax* habitat.

It should be noted, however, that in addition to climate factors, the specific distribution of *L. platythorax* in Asia is also determined by other environmental factors such as microtopography, soil properties, and the position of the species within an ecosystem. Therefore, to obtain a more accurate prediction for a given area, it will be necessary to identify additional locations of the species and consider these factors in more detail. This includes not only climate variables but also features such as relief, soil composition, vegetation cover, and position within communities.

An important environmental factor in the region under consideration is the change in land use patterns. Numerous agricultural lands are being abandoned and converted to fallow land. Fallow land is a favorable habitat for ants, but this issue was not taken into account in the study. The possible transformation of former agricultural land by biological factors in the region is poorly understood due to the recent large-scale changes in land use in the Asian part of Russia, highlighting the need for further research.

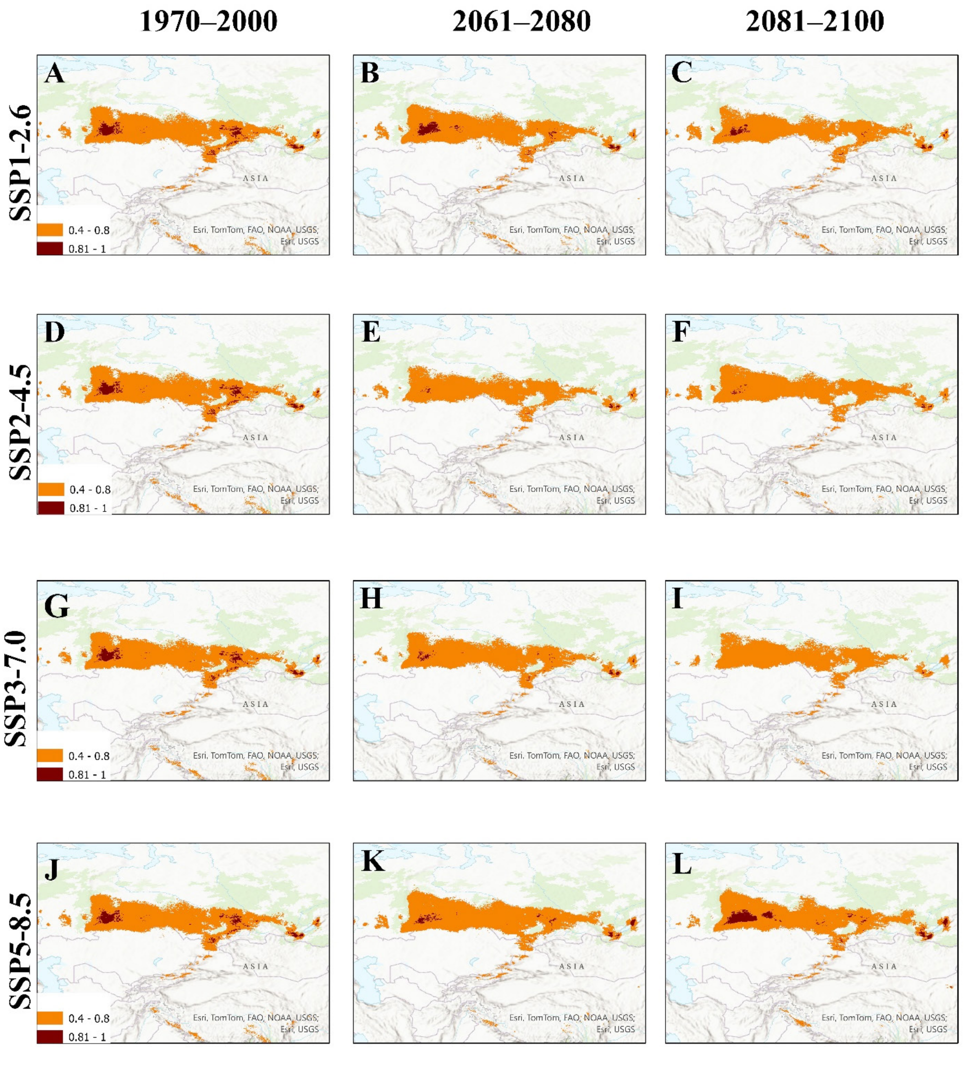

Figure 10. Probable dynamics of territories suitable for *L. platythorax* due to projected climate change from 1970 to 2100 according to scenarios SSP1-2, SSP2-4.5, and SSP3-7.0: 0.4–0.8, 0.81–1 – territories that are suitable for the species by 40–80% and 81–100%, respectively.

Conclusions

According to the study, the scenarios SSP5-2.6, SSP2-4.5, and SSP3-70, which all predict an increase in global temperature of 1.8°C, 2.7°C, and 3.6°C, respectively, will result in a decrease of 62.5%, 91.06%, and 98.2%, respectively, in the most favorable areas for the habitat of the L. platythorax by 2100.

The most positive scenario for the future expansion of the *L. platythorax* habitat is the SSP5–8.5 scenario, which predicts a 4.4°C increase in global temperature by 2100 and a 35.99% increase in habitat. It is likely that this increase in temperature will offset the negative effects of changing environmental factors, leading to an expansion of *L. platythorax* habitat. In other words, warming may neutralize the negative impacts of other environmental changes and contribute to the spread of this species.

It is important to note that the distribution of *L. platythorax* in the Asian part of Russia is influenced not only by climate, but also by specific environmental factors, such as microforms of relief, soil properties, and the role of the species in the ecosystem. A more accurate prediction of its distribution in the region would require the discovery of new habitats and a thorough analysis of a wider range of environmental factors, including climatic parameters as well as characteristics of the terrain, soil, vegetation, and position of the species within communities.

During the course of our work, we have created an updated map of known habitats for *L. platythorax*. This map shows that there is a low level of research on this species in Asian Russia, compared to the European part of the continent. This emphasizes the importance of studying ants in this region.

Considering the potential for further expansion of *L. platythorax* and its ability to colonize new territories, additional research is necessary. This research should include studies on the environment-forming role of ants, as well as other aspects of their biology and ecology.

Acknowledgements

The study was supported by Russian Science Foundation within the framework of project 23-16-00218 "Carbon balance and increasing the sequestration potential of agricultural land in the floodplain of the middle Ob" (conceptualization, modeling), State Assignment project № FSWM-2023-0005 “Assessment total flow of CO_2 within terrestrial and aquatic ecosystems in the conditions of high individuality of the landscapes of the Tomsk carbon polygon” (statistical analysis, writing).

References

Adakhovsky DA (2009) Myrmecocomplexes of the south of the Vyatka-Kama interfluve forest zone. In: Zryanin VA (Ed.) Ants and forest protection. Proceedings of the XIII All-Russian Myrmecological Symposium (September 2009, Novgorod, Russia). Nizhny Novgorod State University Publishing House, Nizhny Novgorod, 113–117. [In Russian]

Afonin AN, Sokolova YV (2018) Ecological and Geographical Analysis and Modeling of the Distribution of Biological Objects Using GIS. Publishing House of the Russian Academy of Sciences, Saint Petersburg, 121 pp. [In Russian]

Antonov IA (2012) Myrmecocomplexes of the city of Baikalsk. The Bulletin of Irkutsk State University. Series Biology and Ecology 5(4): 144–147. [In Russian]

Antonov IA (2013a) Supplement to the myrmecofauna (Hymenoptera, Formicidae) of Baikal Siberia. Zoological Journal 92(8): 991–993. [In Russian]

Antonov IA (2013b) Ant assemblages (Hymenoptera: Formicidae) of cities of the temperate zone of Eurasia. Russian Journal of Ecology 44: 523–526. https://doi.org/10.1134/S1067413613050020

Antonov IA (2014) The use of GIS technologies for the study of the myrmecocomplexes of the Baikal region. Science and Modernity 29: 25–28. [In Russian]

Araujo MB, Pearson RG, Thuiller W, Erhard M (2005) Validation of species-climate impact models under climate change. Global Change Biology 11(9): 1504–1513. https://doi.org10.1111/j.1365-2486.2005.01000.x

ArcGIS. Esri's enterprise geospatial platform. https://www.esri.com/en-us/arcgis/geospatial-platform/overview

Blinova SV (2009a) Structure of myrmecocomplexes of the Kuznetsk Alatau. News of Higher Educational Institutions of the North Caucasus Region 4(152): 82–85. [In Russian]

Blinova SV (2009b) The influence of a lead-zinc enterprise on ants. In: Zryanin VA (Ed.) Ants and forest protection. Proceedings of the XIII All-Russian Myrmecological Symposium (Nizhny Novgorod, Russia, September 2009). Novgorod State University Publishing House, Nizhny Novgorod, 203–206. [In Russian]

Blinova SV (2011) Changes in the myrmecocomplex of the pine-birch forest during the removal of nests of dominant species. Ecology 6: 158–160. [In Russian]

Blinova SV (2012) Ecological and faunal structure of myrmecomplexes of the Salair Ridge. Bulletin of Kemerovo State University 31: 7–11. [In Russian]

Blinova SV, Kauchakova TA (2022) Myrmecocomplexes of ash and slag dumps of the Kemerovo Thermal Power Station. In: Fedoseeva EV (Ed.) Ants and forest protection. Proceedings of the XVI All-Russian Myrmecological Symposium (Moscow, August 2022). Limited Liability Company Association of Scientific Publications of the KMC, Moscow, 66–69. [In Russian]

Brown JL (2014) SDMtoolbox: a Python-based GIS toolkit for landscape genetic, biogeographic and species distribution model analyses. Methods in Ecology and Evolution 5: 694–700. https://doi.org/10.1111/2041-210X.12200

Callaghan TV, Shaduyko O, Kirpotin SN, Gordov E (2021) Siberian environmental change: synthesis of recent studies and opportunities for networking. Ambio 50: 2104–2127. https://doi.org/10.1007/s13280-021-01626-7

Chesnokova SV, Omelchenko LV (2011) Ants of the Central Altai: spatial and typological structure and classification of the population. Zoological Journal 90(2): 162–173. [In Russian]

Chiou CR, Hsieh TY, Chien CC (2015) Plant bioclimatic models in climate change research. Botanical Studies 56: 26. https://doi.org/10.1186/s40529-015-0104-8

Dekoninck W, Boer P, Maelfait JP (2004) *Lasius platythorax* Seifert, 1991 as a host of several Chthonolasius species, with remarks on the colony foundation of the parasites (Hymenoptera: Formicidae). Myrmecological News 6: 5–8.

Dolle P, Buchholz S, Sonnenburg H (2011) Ant pitfall catches in dry ecosystems of North Rhine-Westphalia. Drosera 2010: 55–62.

Espadaler X, Prince A (2001) *Lasius platythorax* Seifert, 1991 (Hymenoptera, Formicidae) in Spain. Orsis 16: 189–192.

Fard SS, Sarafrazi A, Moeini M, Ahadiyat A (2013) Predicting habitat distribution of five heteropteran pest species in Iran. Journal of Insect Science 13: 1–16. https://doi.org/10.1673/031.013.11601

Feldmeyer B, Guiglielmoni N, Kirangwa J, Menzel F, Salces-Ortiz J, Fernández R, Atienza EB, Ciofi C, Diroma MA, Iannucci A, Natali C, McCartney AM, Riess O, Casadei N, Waldvogel AM (2024) Reference genome of the ant *Lasius platythorax*. bioRxiv: 2023.07.18.549505. https://doi.org/10.1101/2023.07.18.549505

Feoktistov DS, Baiakhmetov EZh (2020) Species distribution modelling of the genus *Equisetum* subgenus *Equisetum* for the territory of Russia. Ukrainian Journal of Ecology 10(1): 333–338. https://doi.org/10.15421/2020_52

Fick SE, Hijmans RJ (2017) WorldClim 2: New 1 km spatial resolution climate surfaces for global land areas. International Journal of Climatology 37(12): 4302–4315.

GBIF – the Global Biodiversity Information Facility. https://doi.org/10.15468/dl.qrvw5c

Glaser F, Kopf T (2018) Ameisen (Hymenoptera, Formicidae) im Wildnisgebiet Samina- und Galinatal (Vorarlberg, Österreich/Fürstentum Liechtenstein). Inatura – Forschung online 61: 32. [In German]

Hijmans RJ, Guarino L, Jarvis A, O’Brien R, Mathur P, Bussink C, Cruz M, Barrantes I, Rojas E (2005) DIVA-GIS version 5.2 Manual. www.diva-gis.org

Ivanov V, Loiko S, Milyaev I, Konstantinov A (2022) Land-Use Changes on Ob River Floodplain (Western Siberia, Russia) in Context of Natural and Social Changes over Past 200Years. Land 11(12): 2258. https://doi.org/10.3390/land11122258

Jeschke JM, Strayer DL (2008) Usefulness of bioclimatic models for studying climate change and invasive species. Annals of the New York Academy of Sciences 1134(1): 1–24. https://doi.org/10.1196/annals.1439.002

Jiménez-Valverde A (2012) Insights into the area under the receiver operating characteristic curve (AUC) as a discrimination measure in species distribution modeling. Global Ecology and Biogeography 21(4): 498–507. https://doi.org/10.1111/j.1466-8238.2011.00683.x

Kirpotin SN, Callaghan TV, Peregon AM, Babenko AS, Berman DI, Bulakhova NA, Byzaakay AA, Chernykh TM, Chursin V, Interesova EA, Gureev SP, Kerchev IA, Kharuk VI, Khovalyg AO, Kolpashchikov LA, Krivets SA, Kvasnikova ZN, Kuzhevskaia IV, Merzlyakov OE, Nekhoroshev OG, Popkov VK, Pyak AI, Valevich TO, Volkov IV, Volkova II (2021) Impacts of environmental change on biodiversity and vegetation dynamics in Siberia. Ambio 50: 1926–1952. https://doi.org/10.1007/s13280-021-01570-6

Krasilnikov VA (2017) Materials on the fauna of ants (Hymenoptera, Formicidae) of the Prisursky Reserve (Chuvash Republic). Scientific Works of the Prisursky State Nature Reserve 32: 159–163. [In Russian]

Krasilnikov VA (2022) On the fauna of ants (Hymenoptera, Formicidae) of the Chuvash Republic and its rare elements. In: Fedoseeva EV (Ed.) Ants and forest protection. Proceedings of the XVI All-Russian Myrmecological Symposium (Moscow, August 2022). Limited Liability Company Association of Scientific Publications of the KMC, Moscow, 147–151. [In Russian]

Krugova TM (2009) Post-fire changes in the density of distribution of ant nests in the pine forests of the Priobsky Plateau. In: Zryanin VA (Ed.) Ants and forest protection. Proceedings of the XIII All-Russian Myrmecological Symposium (Nizhny Novgorod, Russia, September 2009). Publishing House of the Novgorod State University, Nizhny Novgorod, 216–218. [In Russian]

Krugova TM (2017) The population of ants of the Cherny taiga of the Tigiretsky Ridge (North-Western Altai). Proceedings of the Tigirek Nature Reserve 9: 68–77. [In Russian]

Krugova TM, Chesnokova SV (2012) Ants of the Tigirek River Valley in the Northwestern Altai. Eurasian Entomological Journal 11(6): 546–552. [In Russian]

Larionov MV, Larionov NV (2009) Biogeocenotic level of ecotoxicological effects in the communities of living organisms of the Saratov region. Bulletin of the Volga 1: 238–243. [In Russian]

Lisitsyn PA (2020) The population of ants (Hymenoptera: Formicidae) at different stages of wood destruction in the Nizhny Novgorod region. In: Musolin DL, Kirichenko NI, Selikhovkin AV (Eds) Dendrobiont invertebrates and fungi and their role in forest ecosystems (XI Readings in memory of O.A. Kataev). Proceedings of the All-Russian Conference with international participation (Saint Petersburg, Russia, November 2020). Publishing House of Saint Petersburg State University, Saint Petersburg, 195–196. [In Russian].

Lisovsky AA, Dudov SV, Obolenskaya EV (2020) Advantages and limitations of using methods of ecological modeling of habitats: 1. General approaches. Journal of General Biology 81(2): 123–134. [In Russian]

Lobo JM, Jiménez-Valverde A, Real R (2008) AUC: a misleading measure of the performance of predictive distribution models. Global Ecology and Biogeography 17(2): 145–151. https://doi.org/10.1111/j.1466-8238.2007.00358.x

Mikhaleiko B, Kirpotin SN, Babenko AS (2023) Development and transformation of floodplain territories by ants. Acta Biologica Sibirica 9: 943–952. https://doi.org/10.5281/zenodo.10101342

Nettleton D (2014) Commercial Data Mining: Processing, Analysis and Modeling for Predictive Analytics Projects. Elsevier, Waltham-USA, 304 pp.

Nix HA (1986) A biogeographic analysis of Australian elapid snakes. In: Snakes: atlas of elapid snakes of Australia. Australian Flora and Fauna 7: 4–15.

Novgorodova TA, Biryukova OV (2011) Some ethological aspects of the trophobiotic interrelations between ants (Hymenoptera: Formicidae) and larvae of the sawfly *Blasticotoma filiceti* (Hymenoptera: Blasticotomidae). European Journal of Entomology 108: 47–52. https://doi.org/10.14411/eje.2011.006

Novgorodova TA, Ryabinin AS (2015) Trophobiotic relationships between ants (Hymenoptera, Formicidae) and aphids (Hemiptera, Aphidomorpha) in the Southern Trans-Ural Mountains. Izvestiya of Saratov University. Chemistry. Biology. Ecology 15(2): 98–107. [In Russian]

Ostrovsky AM (2023) Materials on the fauna of terrestrial orthopteroid insects (Insecta, Orthopteroidea) in the south-east of Belarus. Amur Zoological Journal 15(1): 50–68. [In Russian]

Peterson AT, Soberón J, Pearson RG, Anderson RP, Martínez-Meyer E, Nakamura M, Araújo MB (2013) Ecological niches and geographic distributions. Journal of Mammalogy 94(1): 241–242. https://doi.org/10.1644/1545-1542-94.1.241

Phillips SJ, Dudík M, Schapire RE (2004) A maximum entropy approach to species distribution modeling. Proceedings of the Twenty-First International Conference on Machine Learning, 655–662. https://doi.org/10.1145/1015330.1015412

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. Ecological Modeling 190(3–4): 231–259.

Popkova TV, Zryanin VA, Ruchin AB (2021) Fauna of ants (Hymenoptera: Formicidae) of the Mordovia Nature Reserve, Russia. Nature Conservation Research 6(3): 45–57. [In Russian]

Pörtner HO, Roberts DC, Adams H, Adelekan I, Adler C, Adrian R, Aldunce P, Ali E, Ara Begum R, Bednar-Friedl B, Bezner Kerr R, Biesbroek R, Birkmann J, Bowen K, Caretta MA, Carnicer J, Castellanos E, Cheong TS, Chow W, Cissé G, Clayton S, Constable A, Cooley SR, Costello MJ, Craig M, Cramer W, Dawson R, Dodman D, Efitre J, Garschagen M, Gilmore EA, Glavovic BC, Gutzler D, Haasnoot M, Harper S, Hasegawa T, Hayward B, Hicke JA, Hirabayashi Y, Huang C, Kalaba K, Kiessling W, Kitoh A, Lasco R, Lawrence J, Lemos MF, Lempert R, Lennard C, Ley D, Lissner T, Liu Q, Liwenga E, Lluch-Cota S, Löschke S, Lucatello S, Luo Y, Mackey B, Mintenbeck K, Mirzabaev A, Möller V, Moncassim Vale M, Morecroft MD, Mortsch L, Mukherji A, Mustonen T, Mycoo M, Nalau J, New M, Okem A, Ometto JP, O'Neill B, Pandey R, Parmesan C, Pelling M, Pinho PF, Pinnegar J, Poloczanska ES, Prakash A, Preston B, Racault MF, Reckien D, Revi A, Rose SK, Schipper ELF, Schmidt DN, Schoeman D, Shaw R, Simpson NP, Singh C, Solecki W, Stringer L, Totin E, Trisos CH, Trisurat Y, Van Aalst M, Viner D, Wairiu M, Warren R, Wester P, Wrathall D, Zaiton Ibrahim Z (2022) Technical Summary. In: Pörtner HO, Roberts DC, Tignor M, Poloczanska ES, Mintenbeck K, Alegía A, Craig M, Landgsdorf S, Löschke S, Möller V, Okem A, Rama B (Eds) Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, 37–118. https://doi.org/10.1017/9781009325844.002

Prisny AB (2003) Myrmecofauna of the Belgorod Region, Russia. Eurasian Entomological Journal 2(2): 125–134. [In Russian]

Putyatina TS (2009) Communities of ants in the Ugra National Park (Kaluga region). In: Zryanin VA (Ed.) Ants and forest protection. Proceedings of the XIII All-Russian Myrmecological Symposium (Nizhny Novgorod, Russia, September 2009). Publishing House of the Novgorod State University, Nizhny Novgorod, 171–175. [In Russian]

Radchenko A, Czechowska W, Czechowski W, Siedlar E (1999) *Lasius niger* (L.) and *Lasius platythorax* Seifert (Hymenoptera, Formicidae) – a revolution in Polish myrmecological faunistics and zoocoenology? Fragmenta Faunistica 42(10): 103–113.

Ruchin AB (2015) Additional materials to the entomofauna of the Mordovia State Nature Reserve. Proceedings of the Mordovia State Nature Reserve Named After P. G. Smidovich 13: 351–398. [In Russian]

Rudolphi J (2007) Bryophytes, lichens and dead wood in young managed boreal forests. Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden, 32 pp.

Ryabinin AS, Novgorodova TA (2013a) Zoogeographical characteristics of ants (Hymenoptera: Formicidae) from the Southern Urals. Proceedings of the Saratov State University. Chemistry. Biology. Ecology 13(4): 49–58. [In Russian]

Ryabinin A, Novgorodova T (2013b) The ant fauna (Hymenoptera, Formicidae) of South Zauralye of Russia 12: 161–166.

Ryabinin AS, Chesnokova SV, Novgorodova TA (2017) A preliminary review of the ant fauna (Hymenoptera: Formicidae) of the Novosibirskaya Oblast, Russia. Euroasian Entomological Journal 16(6): 566–576. [In Russian]

Sarapiy MI (2008) Fauna and Ecology of Ants of the Genus *Lasius* (Hymenoptera: Formicidae) in the Central Ciscaucasus. Natural Sciences (3): 75–78. [In Russian]

Scheldeman X, van Zonneveld M (2010) Training manual on spatial analysis of plant diversity and distribution. Biodiversity International Rome, Italy, 180 pp.

Schläppi D, Chejanovsky N, Yañez O, Neumann P (2020) Foodborne Transmission and Clinical Symptoms of Honey Bee Viruses in Ants *Lasius* spp. Viruses 12(3): 321. https://doi.org/10.3390/v12030321

Seifert B (1991) *Lasius platythorax* n. sp., a widespread sibling species of *Lasius niger* (Hymenoptera: Formicidae). Entomologia Generalis 16(1): 69–81.

Seifert B (2019) *Lasius nigroemarginatus* Forel 1874 is a F1 Hybrid between *L. emarginatus* (Olivier, 1792) and *L. platythorax* Seifert, 1991 (Hymenoptera, Formicidae). Contributions to Entomology 69(2): 291–300. https://doi.org/10.21248/contrib.entomol.69.2.291-300

Seifert B (2020) A taxonomic revision of the Palaearctic mem bers of the subgenus *Lasius* s. str (Hymenoptera Formicidae). Soil Organisms 92(1): 15–86. https://doi.org/10.25674/so92iss1pp15

Severtsov AS (1990) The direction of evolution. Publishing House of Moscow State University, Moscow, 270 pp. [In Russian]

Severtsov AS (2008) Evolutionary stasis and microevolution. Comradeship Scientific Publishing House, Moscow, 176 pp. [In Russian]

Sinchuk OV, Yudchits TS, Kolbas AP, Arkhipova NV (2024) Species composition of hymenopteran insects trophically related to fruit and berry crops in horticultural agroecosystems of the Brest region. In: Vitchenko AN (Ed.) Modern Problems of Landscape

Science and Geoecology. Proceedings of the VII International Scientific Conference (Minsk, Belarus, November 2024). Belarus State University, Minsk, 632–635. [In Russian]

Stukalyuk S (2015) Structure of the ant assemblages (Hymenoptera, Formicidae) in the broad-leaved forests of Kiev. Entomological Review 95: 370–387. https://doi.org/10.1134/S0013873815030094

Stukalyuk SV (2017a) Interaction of Three Dominant Ant Species, *Lasius Emarginatus* (Ol.), *Formica Ruful* L., and *Lasius Fuliginosus* (Latreille) (Hymenoptera: Formicidae) Among Themselves and with Subordinate Ant Species in Broad-Leaved Forests. Entomological Review 96(3): 451–478. [In Russian]

Stukalyuk S (2017b) Stratification of the ant species (Hymenoptera, Formicidae) in the urban broadleaf woodlands of the city of Kiev. Entomological Review 97: 320–343. https://doi.org/10.1134/S001387381703006X

Szinetár C, Kovács P, Eichardt J (2015) A kisalföldi meszes homokpuszta katonai használatú gyepterületeinek hangyafaunája (Formicidae). The ant fauna (Formicidae) of the Gönyű military shooting range. Rence 1: 261–282. [In Hungarian]

Tatebe H, Ogura T, Nitta T, Komuro Y, Ogochi K, Takemura T, Sudo K, Sekiguchi M, Abe M, Saito F, Chikira M, Watanabe S, Mori M, Hirota N, Kawatani Y, Mochizuki T, Yoshimura K, Takata K, O'Ishi R, Kimoto M (2019) Description and basic evaluation of simulated mean state, internal variability, and climate sensitivity in MIROC6. Geoscientific Model Development 12(7): 2727–2765. https://doi.org/10.5194/gmd-2018-155

Tăușan I, Dauber J, Trica M, Markó B (2017) Succession in ant communities (Hymenoptera: Formicidae) in deciduous forest clear-cuts – an Eastern European case study. European Journal of Entomology 114: 92–100. https://doi.org/10.14411/eje.2017.013

Tista M (2019) Die Ameisenfauna (Hymenoptera: Formicidae) des Naturdenkmals «Trockenrasen» in Tattendorf. Biodiversität und Naturschutz in Ostösterreich – BCBEA 4(2): 130–138. [In German]

Tselishcheva LG (2018) Soil mesofauna of broad-leaved forests in the Nurgush Nature Reserve. In: Shikhmina TYa (Ed.) Biodiagnostics of the State of Natural and Man-Made Systems. Proceedings of the 16th All-Russian Scientific and Practical Conference with International Participation (Kirov, Russia, December 2018). Vyatka State University, Kirov, 189–194. [In Russian]

Wegnez P, Ignace D, Morro C (2021) Atlas des fourmis luxembourgeoises (Hymenoptera, Formicidae). Ferrantia 84, Musée national d'histoire naturelle, Luxembourg, 130 pp. [In French]

Yeremeeva NI (2004) Ecological and faunal studies of herpetobia in an urbanized area. Izvestiya TRTU 5(40): 194–197. [In Russian]

Yusupov ZM (2015) Fauna and altitude distribution of ants of the genus *Lasius* (Hymenoptera, Formicidae) Kabardino-Balkaria (Central Caucasus). Proceedings of the Samara Scientific Center of the Russian Academy of Sciences 17(4–2): 433–437. [In Russian]

Yusupov ZM, Komarov YuE (2017) Preliminary data on the fauna of ants (Hymenoptera, Formicidae) of the Southern macroslope of the Central Caucasus. Proceedings of the Mordovian State Nature Reserve named after P. G. Smidovich 19: 205–214. [In Russian]

Yusupov ZM, Volodchenko AN (2021) New finds of ants (Hymenoptera, Formicidae) in the Voroninsky Nature Reserve. In: Zanina MA (Ed.) Biodiversity and anthropogenic transformation of natural ecosystems. Proceedings of the IX All-Russian Scientific and Practical Conference (Saratov, Russia, April 2021). Saratov Source Publishing House, Saratov, 164–167. [In Russian]

Zryanina TA (2009) The importance of green areas in the formation of urban myrmecocomplexes. In: Zryanin VA (Ed.) Ants and forest protection. Proceedings of the XIII All-Russian Myrmecological Symposium (Novgorod, Russia, September 2009). Nizhny Novgorod State University Publishing House, Nizhny Novgorod, 209–212. [In Russian]

Zryanin VA, Zryanina TA (2007) New data on the ant fauna (Hymenoptera, Formicidae) Of the Middle Volga region. Successes of modern biology 127(2): 226–240. [In Russian]