NATURAL RESOURCES

DOI: https:/doi.org/10.23649/jae.2021.2.18.4

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Received: 28.05.2021; Accepted: 09.06.2021; Published: 24.06.2021

CARTOGRAPHICAL ANALYSIS OF *FORMICA* S. STR ANTHILLS COMPLEXES` DISPERSAL IN THE MIDDLE VOLGA REGIONS

Research article

Abstract

The current article is devoted to the role of biotic (forest type, forest age and consistence etc.) and abiotic (landscape type) factors affecting the spatial structure of red wood ants` (Formica s. str.) dispersal in several Middle Volga regions. As ants tend to form complexes as well as single anthills, this research in purposed on finding a correlation between complexes formation in certain localities and environmental factors that can further there help to use them as indicators of environmental situation in forests. The research work is based on methods of digital mapping using geographic information systems (GIS) and statistical analysis of the mapped data according to Fisher criterion to determine a possible correlation between complexes` spatial structure and forest conditions.

Keywords: red wood ants, anthills, complexes, geographic information systems, digital mapping.

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Получена: 28.05.2021; Доработана: 09.06.2021; Опубликована: 15.04.2021

КАРТОГРАФИЧЕСКИЙ АНАЛИЗ РАСПРЕДЕЛЕНИЯ КОМПЛЕКСОВ МУРАВЕЙНИКОВ *FORMICA* S. STR В СРЕДНЕМ ПОВОЛЖЬЕ

Научная статья

Аннотация

Статья посвящена влиянию биотических (тип, возраст, состояние леса и т.д.) и абиотических (тип ландшафта) факторов на пространственную структуру расселения рыжих лесных муравьев (*Formica* s. str.) в ряде регионов Среднего Поволжья. Так как муравьи образуют комплексы муравейников наряду с одиночными гнездами, основной задачей текущего исследования является поиск корреляции между образованием комплексов в определённых локалитетах и экологическими факторами, что может позволить использовать их в дальнейшем как индикаторов состояния леса. Настоящее исследование основывается на методах цифрового картографирования с помощью геоинформационных систем (ГИС) и статистической обработке экспортируемых на карту данных с применением точного критерия Фишера для определения потенциальной зависимости пространственной структуры комплексов муравейников от лесорастительных условий.

Ключевые слова: рыжие лесные муравьи, муравейники, комплексы муравейников, геоинформационные системы, цифровое картографирование.

1. Introduction

Forest communities are known as a vulnerable component of the biosphere, suffering from abiotic, anthropogenic and biotic factors and, among them, from pine- and leaf-gnawing pests of woody plants. Since 1960s, red wood ants of the subgenus *Formica* s. str. have been used as a biological method of forest protection.

Nevertheless, red wood ants themselves are acknowledged to be under threat – anthropogenic impact (deforestation, mechanical destruction of anthills, etc.) leads to a significant decrease in their population density. In this regard, the need for regular monitoring of *Formica* s. str. population structure is indisputable. Myrmecological communities in the USSR introduced the operation «Ant», whose main aims were inventory and mapping of significantly large anthills formed by various species. At present, registration and inventory of red wood ants on the territory of Russia are mentioned as principal

assignments of the «Monitoring Formica» project whose participants took into consideration a new unit named an anthill complex. A complex is understood as a group of same or closely related species` anthills having common feeding compartments. The main function of the project was interpreted as inventory of anthills at three levels – registration level (putting general information about the complex in a single register), basic level (obtaining necessary information to assess the conditions of the complex) and monitoring level (obtaining information for use of the complex as a long-term object monitoring) [1, P. 12, 22-23].

While registration and examining of complexes, scientific community raised a question about a correlation between their location and several abiotic, biotic and anthropogenic factors, such as forest growing conditions in the areas where the complexes were discovered. Elucidation of the anthills complexes` dispersal patterns in the Middle Volga regions was determined as the main aim of the current research.

Occupying a significant part of the East European Plain, the Middle Volga includes Nizhny Novgorod, Kirov, Saratov, Samara regions, as well as the republics of Mari El, Chuvashia and Tatarstan. Thus, the total area of the explored regions is 394,000 km^2.

The Middle Volga is mainly characterized by a flat relief with a slope from the Valdai upland in the north of the territory to the Caspian lowland in the south. The right bank of the Volga is occupied by uplands, the average height of which is measured up to 200-250 m. The highest elevations of the relief in the Zhiguli mountains do not exceed 400 m. The slopes of these mountains abruptly break down to the Volga. The left bank includes flat terraces above the floodplain, Their average heights range from 100 to 150 m.

Climatically the Middle Volga region is known for its sharp weather contrasts: rapid transition from a cold winter to a rather hot summer, low humidity, dryness of atmospheric air, winds, a significant evaporation rate and a wealth of sunlight. This is due to the fact that Cis-Ural forest-steppe and Trans-Volga steppe territories are getting under influence of the Asian baric maximum, as a result of which significantly cooled air enters here in winter, and gets overheated in summer.

The landscape structure of the researched area is heterogeneous. The northern part of the Middle Volga belongs to boreal moderately continental East European landscape zone – these are southern taiga upland or lowland landscapes with a relatively low diversity. In the southern part of the Middle Volga, landscapes vary from forest-steppe weakly dissected lowlands to upland plains with mature erosional relief and a dense network of river valleys [2, P. 56] (Figure 1).

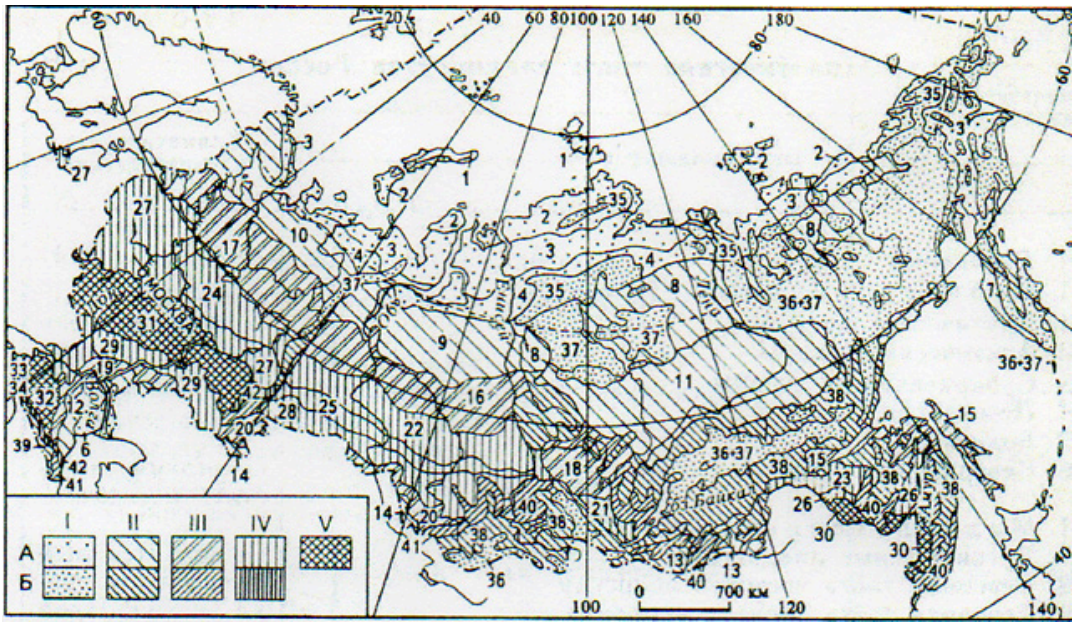

Figure 1 – Landscape zonation of Russia (Isachenko, 1998)

Conventionally, it is possible to classify the Middle Volga landscapes into «opolie» (including several localities of the Chuvash republic and the Samara region) and «polesie», forming a zone elongated in meridional direction which captures the predominant part of the researched area.

According to the forest zonation, phytocenoses Middle Volga can be classified into four zones: coniferous forests (central and southern subzones of the taiga), mixed (coniferous-deciduous) forests, deciduous forest zone with northern and southern subzones and forest-steppes [3, P. 21-22] (Figure 2).

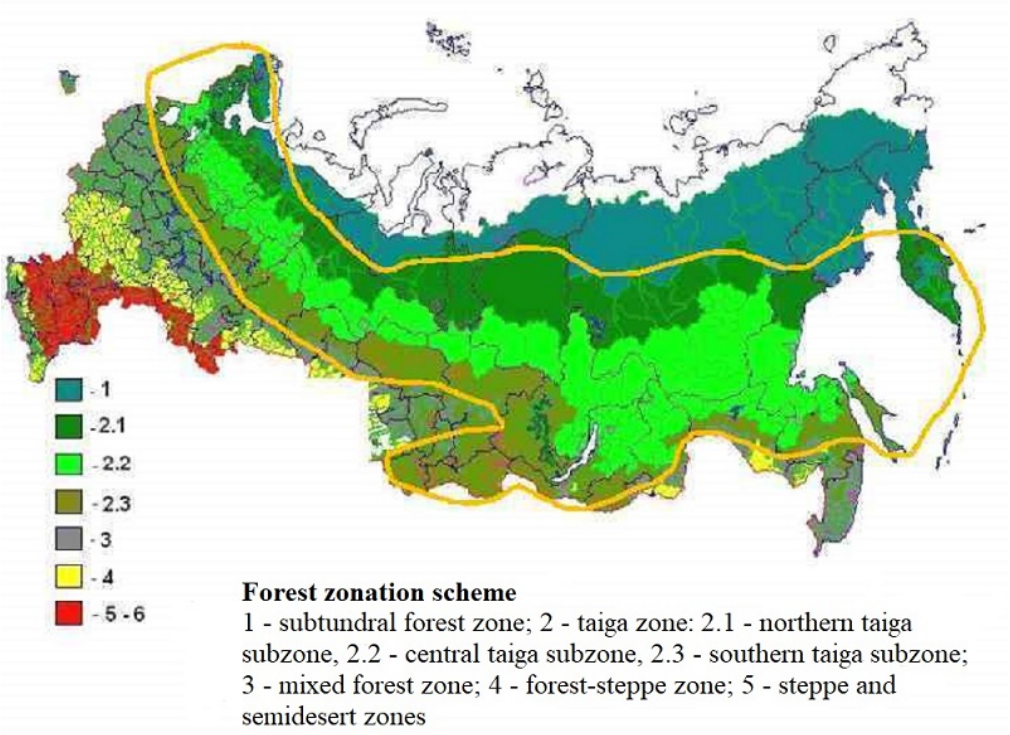

Figure 2 – Forest zonation of Russia (Kashpor et al., 2011)

The current research also considers the division of the Middle Volga into district and inter-district forestries whose territorial boundaries in the overwhelming majority of cases coincide with the administrative division of regions into districts.

2. Methods

2.1. Materials (results of field explorations)

Materials used in the current research are essentially represented by results of field exploration on the territory of the Middle Volga and adjacent regions. Most results were gathered in 2007 [4, P. 227-229] and further transformed into a regularly renewable geodatabase in 2016-2018 [5, P. 162]. Fragmented information about registrations of *Formica* s. str. anthills complexes is compensated by the detailed phenotypic characteristics of the samples. A significant predominance of any ant phenomorph allows concluding that ants tend to form a large complex in the given locality. If the shares of different phenomorphs correlate approximately in the same proportion, the complex is formed by mixed families.

In total, 88 samples of 6 ant species were collected on the territory of the Nizhny Novgorod and Samara regions and the Chuvash republic. 15 localities among them belong to complex-forming ant families, 73 – to single anthills (Table 1). This data was converted into *xls format for further export to the ArcGIS platform [6, P. 23, 35-37] and digital mapping. The statistical processing was based on StatTech platform.

Table 1 – Samples of the Formica s. str. ants in the Middle Volga by species

Parameter	Category	Absolute value	%
Ant species	*Formica aquilonia*	15	17.0
	Formica lugubris	2	2.3
	Formica polyctena	18	20.5
	Formica pratensis	19	21.6
	Formica rufa	22	25.0
	Formica truncorum	8	9.1
	*Formica polyctena*Formica rufa*	4	4.5
Colony type	complex	15	17.0
	single anthill	73	83.0

Besides that, the current research included operations with the open access data about the forest conditions (prevailing tree species, their age, density and quality of the forest) in the Middle Volga (forms №2 and №5 of the State Forest Register). This information was used to assess the qualitative and quantitative indicators potentially affecting the complexes distribution over the explored area. Analytical operations with this data were also carried out on the StatTech platform.

2.2. Method of web-mapping

Information about the complexes was exported on a digital map of the Middle Volga created on the ArcGIS platform. This service is a program allowing to upload information in *csv or *shp format and convert it into layers of point, line or polygonal elements displayed on the map [7, P. 414-417], [8, P. 172].

This system includes software, an interactive cloud infrastructure, professional tools, customizable resources such as application templates, ready-to-use web- or mobile applications and basemaps. ArcGIS Online also contains a wide range of spatial analysis tools, including those used in the current research in terms to analyze the territorial distribution of *Formica* s. str. anthill complexes in the Middle Volga regions.

Another source of information about the forest conditions in the explored regions was represented by forest zoning plans of the relevant territorial subjects and schematic maps of forestries provided in the public domain by regional ministries and departments [9], [10], [11]. These maps include administrative territorial boundaries of district and interdistrict forestries as well as State Forest Register data forms containing information about forest conditions (the area of forest lands occupied by certain species, forests of a certain age, belonging to various groups of density and quality etc.).

2.3. Statistical analysis (F-Test)

As the main purpose of current research was determined as analysis of correlation between forest conditions and location of *Formica* s. str. anthills complexes, the main method used while analysis was the F-Test whose essential function in this particular case was to find a correspondence between the theoretical and empirical (real, obtained during field explorations) dispersal of complexes and to determine its regularity or randomness in the regions of the Middle Volga. In the current research the analysis was based on Fisher's exact criterion, since expected values did not exceed 10 due to the sample size. However, in cases with a number of expected values more than 10 it is necessary to use «chi-square» method [12, P. 51].

Statistical analysis was based on the StatTech platform [13]. The main hypothesis put forward was that the type of landscape and forest-forming tree species prevailing in a given locality affect the tendency of ants to form complexes: *Formica* ants prefer to inhabit «polesie» landscapes rather than «opolie». It is also assumed that anthill complexes are formed mainly by northern and small wood ants (*Formica aquilonia* and *F. polyctena* correspondantly).

The analysis was processed using "indicator-category" matches, where the indicator denoted an independent argument and the category denoted a dependent function. In this research the matches were formed by following parameters:

- landscape type – ant species;
- landscape type – colony type (single anthill or complex);
- prevailing tree species – ant species;
- prevailing tree species – colony type;
- ant species – colony type.

The program determined the difference between the highest and lowest indicator values for each category. This value is characterized by the *p*-criterion of significance (if *p* is less than the critical value, then the difference is statistically significant). In the current research the critical *p*-value for all variables was determined as $p < 0.05$.

3. Results

3.1. Cartographical visualization

At the first stage of the current research, the results of field explorations were uploaded on a digital ArcGIS map as a point layer in which each point contained information about a single anthill or a complex formed by ants of a certain species. (Figure 3).

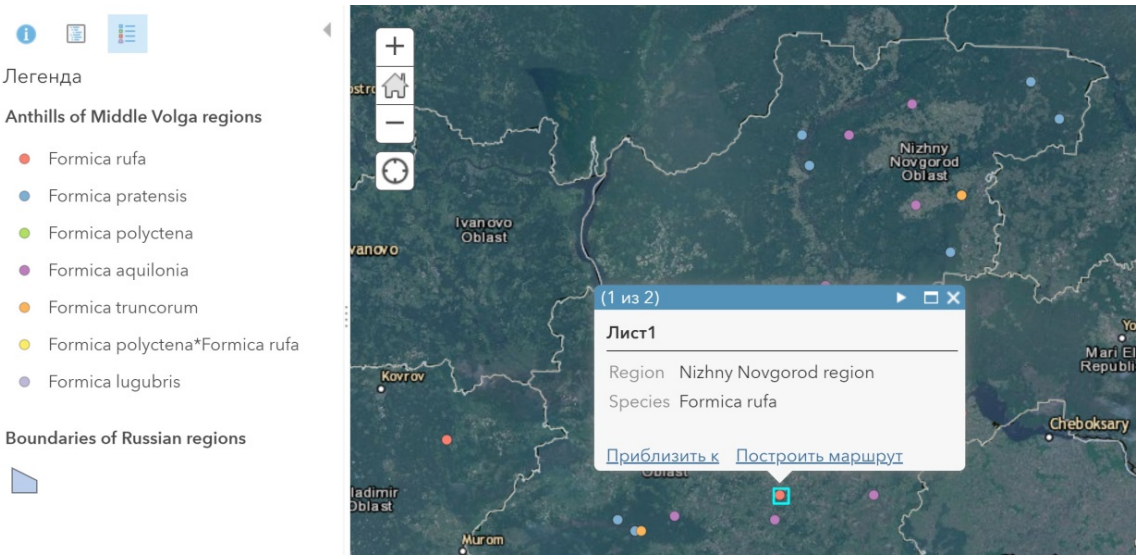

Figure 3 – Diversity of red wood ants (*Formica* s. str.) in the Middle Volga

Observing the ants` location on the map, it is possible to remark that most complexes were actually formed by *Formica polyctena* and *F. aquilonia*. They are located rather sparsely, mainly in the north and north-east of Nizhny Novgorod region. Single anthills forming the most part of the sample are inhabited mainly by the red wood ant (*F. rufa*) and meadow ant (*F. pratensis*), what may be explained by forest conditions in the explored regions.

Besides that, an intensity map created as a next stage demonstrates ant-inhabited areas within the Middle Volga. Here it is possible to observe evident clusters in Arzamassky, Krasnobakovsky, Tonkinsky, Varnavinsky and Vetluzhsky districts of Nizhny Novgorod region, as well as in the city area of Togliatti in Samara region, what indicates that the most anthill complexes are grouped in the above-mentioned areas (Figure 4).

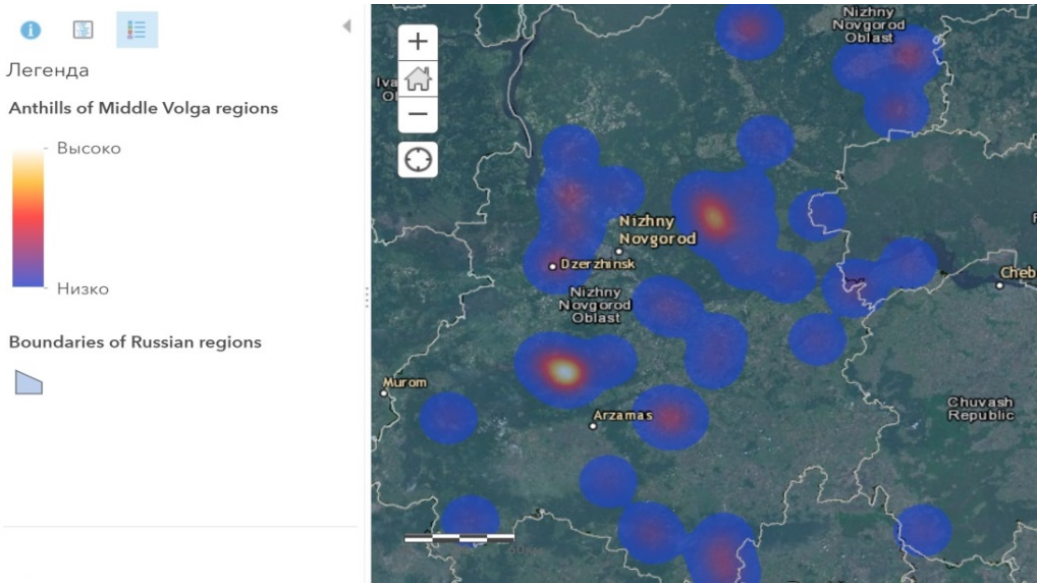

Figure 4 – Intensity map of the ant-inhabited areas with clusters

3.1. Statistical analysis

To determine the randomness or regularity of the anthills localization observed on the map, a statistical analysis of the data contained in the mapped layer was carried out. A geodatabase displaying qualitative and quantitative characteristics of landscape and forest conditions in the explored territory was uploaded to the StatTech platform. While calculating the Fisher's criteria it was determined that a direct dependence of the ants` colony type on the landscape in the territory really exists in explored regions (the p value for this category amounted to $p = 0.042$). Thus, it was possible to observe the preference of «polesie» landscapes for the *Formica* ants. This can be explained by a specific taxis of this ants group to forests, outskirts and edges on which most anthills were registered. Open steppe and forest-steppe spaces are less inhabited and characterized by prevalence of single anthills. However, a correlation between the dominant tree species and the complex-formation tendency has not been proven (p-value = 0.245, $p > 0.05$) (Table 2).

Table 2 – Dispersal of single anthills and anthill complexes of *Formica* s. str. in different landscape and forest types

Parameter	**Category**	**Colony type**		***p***
		complex	**single anthill**	
Landscape type	«opolie»	4 (44.44%)	5 (55.56%)	0.042
	«polesie»	11 (13.92%)	68 (86.08%)	
Prevailing tree species	deciduous	3 (10.34%)	26 (89.66%)	0.245
	coniferous	12 (21.43%)	44 (78.57%)	

As a result of distribution analysis of anthills formed by different species on the territory of the Middle Volga, it was determined that several species demonstrate selectivity to the forest type (the p-value for the parameter «forest type» amounted to $p = 0.001$). There are reasons to suppose that this dependence has a climatic nature – coniferous forests in the north and north-east of the Nizhny Novgorod region are included in the southern taiga zone on podzolic and sod-podzolic soils favorable for the northern wood ant *Formica aquilonia* [14, P. 562-563], whereas the meadow ant *F. pratensis* is confined to deciduous forests in the south of the European mixed forests zone and its border with the forest-steppe zone. However, it was not possible to evaluate any unambiguous preference of certain species to certain landscape types (p-value = 0.115, $p > 0.05$) (Table 3).

Table 3 – Dispersal of various *Formica* s. str. species anthills in connection with landscape and forest type

Parameter	**Category**	**Species**							***p***
		F. aquilonia	***F. lugubris***	***F. polyctena***	***F. pratensis***	***F. rufa***	***F. truncorum***	***F. polyctena* F. rufa***	
Landscape type	«opolie»	–	–	3 (33.33%)	1 (11.11%)	3 (33.33%)	–	2 (22.22%)	0.115
	«polesie»	15 (18.99%)	2 (2.53%)	15 (18.99%)	18 (22.78%)	19 (24.05%)	8 (10.13%)	2 (2.53%)	
Prevailing tree species	deciduous	1 (3.45%)	–	5 (17.24%)	13 (44.83%)	8 (27.59%)	1 (3.45%)	1 (3.45%)	0.001
	coniferous	14 (25%)	2 (3.57%)	12 (21.43%)	5 (8.93%)	13 (23.21%)	7 (12.5%)	3 (5.36%)	

The final stage of the analysis was to determine the correlation between the number of complexes and ant species inhabiting anthills. A direct dependence of the ability to complex formation on the species was revealed (the *p*-value amounted to $p < 0.001$). The northern wood ant (*Formica aquilonia*) and small wood and (*F. polyctena*) were admitted as the most complex-forming species; *F. polyctena* also tends to form mixed colonies with the red wood ant *F. rufa*. Presumably, this can be explained by the selectivity of *F. aquilonia* to climatic and soil factors, as well as by the high hybridization ability of *F. rufa* (this hypothesis requires a more detailed analysis of samples including molecular-genetic research in order to estimate the proportion of *F. rufa* phenomorph in mixed families) (Table 4).

Table 4 – Tendency to complex formation among various *Formica* s. str. ant species

Parameter	**Category**	**Colony type**		***p***
		complex	**Single anthill**	
Species	*Formica aquilonia*	5 (33.33%)	10 (66.67%)	< 0.001
	Formica lugubris	1 (50%)	1 (50%)	
	Formica polyctena	4 (22.22%)	14 (77.78%)	
	*Formica polyctena*Formica rufa*	4 (100%)	–	
	Formica pratensis	–	19 (100%)	
	Formica rufa	1 (4.55%)	21 (95.45%)	
	Formica truncorum	–	8 (100%)	

4. Conclusions

After having analyzed all the results of the current research, it can be concluded that several environmental factors directly influences *Formica* ants` locality preference for single anthills and complexes formation.

The most significant factor in this regard is the belonging of the territory to a specific landscape type, as well as climatic and soil conditions. According to the research results, ants demonstrate an evident preference to «polesie» landscape type (11 of 15 complexes and 68 of 73 single anthills were registered in the «polesie» zone, the *p*-value between maximal and minimal sample values amounts to $p = 0142$, what can be estimated as a statistical significance of the landscape criterion for complex formation). Although, the forest type factor doesn`t seem to affect evidently on the ants` dispersal (the *p*-criterion $p = 045$ tends to be statistically insignificant, the proportion of complexes and single anthills is apparently similar in both coniferous and deciduous forests).

In terms of taxonomic diversity, several species, such as *Formica aquilonia* (33,33% of all complex samples) and *F. polyctena* (22,22%) were determined as the most complex-forming species in comparison with *F. rufa* (only 4,55% of all complex samples) and *F. pratensis* (no complexes registered, 0% of the samples) which were majorly discovered in single anthills. The *p*-value amounted to $p < 0.01$ that demonstrates a high statistical importance of the taxonomic criteria. This selectivity does presumably have a climatic nature.

In general, landscape, forest and soil factors tend to be strictly connected and their influence on red wood ants' population structure should be estimated inseparably to get an objective picture for environmental monitoring in regional forest phytocenoses.

Acknowledgement

The author expresses gratitude to her scientific advisor – Vladimir Alexandrovich Zryanin, candidate of biological sciences, associate professor of the Department of Botany and Zoology of Nizhny Novgorod Lobachevsky State University – for the data provided and assistance in the current research.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

References

1. Захаров А. А. Мониторинг муравьев Формика / Захаров А. А., Длусский Г. М., Горюнов Д. Н. и др. – М.: КМК. 2013. – 99 с.

2. Исаченко Г. А. Методы полевых ландшафтных исследований и ландшафтно-экологическое картографирование (курс лекций) / Исаченко Г. А. – СПб.: Изд-во С.-Петерб. ун-та, 1998. – 112 с.

3. Кашпор Н. Н. Схема лесного районирования Российской Федерации / Кашпор Н. Н., Мартынюк А. А., Желдак В. И. и др. // Лесной вестник, 2011. № 3. – С. 17-24.

4. Зрянин В. А. Новые данные о фауне муравьев (Hymenoptera, Formicidae) Среднего Поволжья / Зрянин В. А., Зрянина Т. А. // Успехи современной биологии, 2007. Т. 127, № 2. – С. 226-240.

5. Зрянин В. А. База геоданных по комплексам муравейников Formica s.str. Среднего Поволжья / Зрянин В. А., Козлова А. А. // «Муравьи и защита леса»: XV Всероссийский мирмекологический симпозиум. Екатеринбург. 2018. – С. 161-165.

6. David W. Allen. Focus on Geodatabases in ArcGIS Pro. / David W. // ESRI Press, 2019. – 260 P.

7. Chapman A. D. Quality control and validation of point-sourced environmental resource data in Spatial Accuracy Assessment / Chapman A. D. // Land Information Uncertainty in Natural Resources. – Lowell K. and Jaton A. eds. 1999. P. 409 – 418.

8. Лебедев П. П. Теория и методы кадастрового картографирования с применением географических информационных систем (ГИС) / Лебедев П. П. – М.: ГУЗ. 2001. – 128 с.

9. Лесной план Нижегородской области, 2019-2028 гг. [Электронный ресурс]. – URL: https://minles.government-nnov.ru/documents/active/918/ (дата обращения: 28.05.2021)

10. Лесной план Самарской области, 2019-2028 гг. [Электронный ресурс]. – URL: https://priroda.samregion.ru/category/lesnoe_hozyaistvo/ les_plan_i_org_lesopolzovaniya/lesnou_plan/ (дата обращения: 28.05.2021)

11. Лесной план республики Чувашия, 2019-2028 гг. [Электронный ресурс]. – URL: http://minpriroda.cap.ru/action/activity/lesnoj-plan-chuvashskoj-respubliki-i-lesohozyajstv/otkritie-dannie (дата обращения: 28.05.2021)

12. Белюченко И.С. Анализ данных и математическое моделирование в экологии и природопользовании / Белюченко И.С., Смагин А.В., Попок Л.Б. – Краснодар: КубГАУ, 2015. – 313 с.

13. Статистическая обработка данных [Электронный ресурс]. – URL: https://stattech.ru/ (дата обращения: 28.05.2021)

14. Корочкина Н. И. Популяционная структура Formica aquilonia (Hymenoptera, Formicidae) на границе бореальных и суббореальных ландшафтов в Поволжье / Корочкина Н. И., Коноплева Е. Е., Зрянина Т. А. // Зоологический журнал. 2014. Т. 93, № 4. – С. 559 – 569.

References in English

1. Zakharov A. A. Monitoring murav'ev Formika [Monitoring of the Formica ants] / Zakharov A. A., Dlussky G. M., Goryunov D. N. et al. – Moscow: KMK. 2013. 99 P. [in Russian]

2. Isachenko G. A. Metody polevyh landshaftnyh issledovanij i landshaftno-ekologicheskoe kartografirovanie (kurs lekcij) [Field landscape research methods and landscape-ecological mapping (course of lectures)] / Isachenko G. A. – St. Petersburg: State University, 1998. – 112 P. [in Russian]

3. Kashpor N. N. Skhema lesnogo rajonirovaniya Rossijskoj Federacii [Forest zoning scheme of Russian Federation] / Kashpor N. N., Martynyuk A. A., Zheldak V. I. // Forest Bulletin, 2011. № 3. – P. 17-24. [in Russian]

4. Zryanin V. A. Novye dannye o faune murav'ev (Hymenoptera, Formicidae) Srednego Povolzh'ya [New Data on the fauna of ants (Hymenoptera, Formicidae) of the Middle Volga] / Zryanin V. A, Zryanina T. A. // Successes of modern biology. 2007. Vol. 127, № 2, P. 226–240. [in Russian]

5. Zryanin V. A. Baza geodannyh po kompleksam muravejnikov Formica s.str. Srednego Povolzh'ya [Geodatabase of the Formica s. str. anthills` complexes in the Middle Volga] / Zryanin V. A., Kozlova A. A. // Ants and forest protection: Materials of the XV All-Russian myrmecological symposium. Ekaterinburg, 2018. P. 161–165. [in Russian]

6. David W. Allen. Focus on Geodatabases in ArcGIS Pro. / David W. // ESRI Press, 2019. – 260 P.

7. Chapman A. D. Quality control and validation of point-sourced environmental resource data in Spatial Accuracy Assessment / Chapman A. D. // Land Information Uncertainty in Natural Resources. – Lowell K. and Jaton A. eds. 1999. P. 409 – 418.

8. Lebedev P. P. Teoriya i metody kadastrovogo kartografirovaniya s primeneniem geograficheskih informacionnyh sistem (GIS) [Theory and methods of cadastral mapping using geographic information systems (GIS)] / Lebedev P. P. – Moscow: State University of Land Management. 2001. – 128 P. [in Russian]

9. Lesnoj plan Nizhegorodskoj oblasti, 2019-2028 gg. [Forest zoning plan of the Nizhny Novgorod region, 2019-2028] [Electronic resource]. – URL: https://minles.government-nnov.ru/documents/active/918/ (accessed: 28.05.2021) [in Russian]

10. Lesnoj plan Samarskoj oblasti, 2019-2028 gg. [Forest zoning plan of the Samara region, 2019-2028] [Electronic resource]. – URL: https://priroda.samregion.ru/ category/lesnoe_hozyaistvo/ les_plan_i_org_lesopolzovaniya/lesnou_plan/ (accessed: 28.05.2021) [in Russian]

11. Lesnoj plan respubliki CHuvashiya, 2019-2028 gg. [Forest zoning plan of the Chuvash republic, 2019-2028] [Electronic resource]. – URL: http://minpriroda.cap.ru/action/activity/lesnoj-plan-chuvashskoj-respubliki-i-lesohozyajstv/otkritie-dannie (accessed: 28.05.2021) [in Russian]

12. Belyuchenko I. S., Smagin A. V., Popok L. B., Popok L. E. Data analysis and mathematical modeling in ecology and environmental management.– Krasnodar: Agricultural State University, 2015. – 313 P. [in Russian]

13. Statisticheskaya obrabotka dannyh [Statistical data processing] [Electronic resource]. – URL: https://stattech.ru/ (accessed: 28.05.2021) [in Russian]

14. Korochkina N. I., Konopleva E. E., Zryanina T. A. Population structure of Formica aquilonia (Hymenoptera, Formicidae) on the border of boreal and subboreal landscapes in the Volga region // Zoological Journal, 2014.Vol. 93, № 4. P. 559–569. [in Russian]