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THE INFLUENCE OF CLIMATIC AND ANTHROPOGENIC FACTORS ON THE COMMUNITY OF GROUND BEETLES (*COLEOPTERA, CARABIDAE) OF AGRICULTURAL LANDSCAPES OF THE NORTHERN FOREST-STEPPE ZONE OF THE OB REGION*

Research article

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Abstract

The species composition and abundance of ground beetles (Coleoptera, Carabidae) were investigated on grain crop fields cultivated using low-intensity and high-intensity technologies, and on adjacent plots of natural vegetation. The community of carabid beetles was most diverse and abundant on wheat fields treated with low-intensity technology. Conversely, the community was least diverse and least abundant on corn fields using intensive cultivation technology. Analysis of potential factors influencing the species composition and abundance of carabid beetle communities in agrocenoses and adjacent natural areas revealed a high statistical significance of the cultivated crop, year of observation, and degree of anthropogenic pressure on the territory (GLZ analysis, Wald test, $p<0.001$ in all cases). The abundance of the beetle community in 2019 was significantly lower (Kruskal-Wallis H test, $p<0.0001$) than in 2020 and 2021. Interannual fluctuations in ground beetle abundance were presumably influenced by the thermal and moisture conditions of the territory. The obtained data indicate the absence of a consistently negative impact of the level of agricultural technology intensification on the community of carabid beetles in the agro-landscapes of the Western Siberian forest-steppe.

Keywords: ground beetles, species richness, abundance, agrolandscape, intensive agriculture.

ВЛИЯНИЕ КЛИМАТИЧЕСКИХ И АНТРОПОГЕННЫХ ФАКТОРОВ НА НАСЕЛЕНИЕ ЖУЖЕЛИЦ (*COLEOPTERA, CARABIDAE*) АГРОЛАНДШАФТОВ СЕВЕРНОЙ ЛЕСОСТЕПИ ПРИОБЬЯ

Научная статья

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Аннотация

Исследованы видовой состав и численность жужелиц (*Coleoptera, Carabidae*), отловленных на посевах зерновых культур, возделываемых с использованием малоинтенсивной и интенсивной технологий, и на сопредельных участках естественной растительности. Наиболее богатым видами и многочисленным было население жужелиц на посевах пшеницы, обрабатываемой по малоинтенсивной технологии. Самым бедным видами и малочисленным – население посевов кукурузы с интенсивной технологией возделывания. Анализ возможных факторов, определяющих видовой состав и численность сообществ жужелиц агроценозов и сопредельных с ними участков естественной растительности, выявил высокую статистическую значимость влияния возделываемой культуры, года наблюдения и степени антропогенной нагрузки на территорию (GLZ анализ, тест Вальда, во всех случаях $p<0.001$). Численность сообщества в 2019 году была достоверно (Тест Краскела — Уоллиса, $p<0.0001$) ниже, чем в 2020 и 2021 гг. Межгодовые колебания численности жужелиц были обусловлены, очевидно, тепло- и влагообеспеченностью территории. Полученные данные свидетельствуют об отсутствии однозначно негативного влияния уровня интенсификации агротехнологии на население жужелиц в агроландшафтах лесостепи Западной Сибири.

Ключевые слова: жужелицы, видовое богатство, обилие, агроландшафт, интенсивное сельское хозяйство.

Introduction

Conservation of natural biodiversity is one of the key challenges in modern ecology [1], [2], [3]. The decline in population numbers and reduction of habitats for many species across different taxonomic groups are primarily linked to environmental pollution and the destruction of natural ecosystems during their transformation into agricultural landscapes [4], [5], [6], [7]. In addition to the destruction of natural trophic interactions and the mechanical impact on soil cover, agricultural land cultivation involves the use of fertilizers and pesticides that can have detrimental effects on biodiversity [5], [7], [8], [12]. Even with modern technologies that aim to minimize the risks to non-target organisms during treatments, representatives of various ecological groups become victims – from non-specialized phytophagous insects to pollinators and insectivorous birds [6], [13], [14], [16]. While the presence of any species other than the cultivated one is considered undesirable for plants in agroecosystems, maintaining natural biodiversity of invertebrates, represented by a wide range of life forms, can be a crucial factor in enhancing the productivity of agrocenoses and improving the quality of agricultural produce. Transitioning to organic farming in countries with advanced agricultural practices is associated with an increase in the abundance and species richness of various groups of organisms, including insectivorous and predatory birds, pollinating insects, terrestrial, and soil-dwelling arthropods, not only within agrocenoses but also in neighboring territories [15], [17], [18].

Indexes of natural biodiversity in agrocenoses depend on various factors, primarily on the complex of agrotechnical measures used for cultivating a particular crop and its type [6], [19], as well as the presence of natural refugia [17], [20], [21], [23]. Specific microclimatic conditions within different agrolandscapes, such as soil surface temperature, humidity, and insolation, also significantly influence the abundance of surface-dwelling invertebrates [24], [25], [26]. The effect of cultivated crops can either neutralize or amplify the influence of the local climate and its extreme manifestations in specific years [25], [27], [28]. Considering the above, it is evident that research on assessing the abundance and species richness of specific animal groups inhabiting agrocenoses and the influence of anthropogenic and climatic factors on them is of utmost importance. This is particularly relevant for those groups that are not the primary targets of pesticide treatments but are affected due to the non-specific toxic effects of agrochemicals and improper application.

One of the most convenient model groups of invertebrates inhabiting agrocenoses is the family *Carabidae*, comprising numerous species and exhibiting a wide range of life forms [24], [26], [29]. Beetles of this family are generally active, moving across the soil surface, and can be effectively captured using soil traps, providing representative data through standard methods. Their high abundance and wide distribution, along with their ground-dwelling habits, make them one of the most suitable indicators of the state of agroecosystems [23], [30], [31], [32]. Despite the wealth of literature, the general patterns of how the above-mentioned factors influence the species composition and abundance of ground beetles, considering the zoogeographic, ecological, and economic specificities of the studied regions, remain insufficiently explored.

The aim of this study was to evaluate the influence of a complex of climatic factors (temperature and moisture conditions) and anthropogenic factors (crop type and cultivation techniques) on the species richness and abundance of *Carabidae* communities in agroecosystems of the forest-steppe zone of Southwest Siberia (northern forest-steppe of the Ob River).

Research methods and principles

The material was collected during the growing season 2019-2021 at the sowing areas of the experimental station “Elitnaya” and stock farm Plemzavod “Uchkhoz Tulinskoye” (Novosibirsk region, Novosibirsk district). This geographic area belongs to the subzone of the Northern Forest-Steppe, which is characterized by a moderately dissected plain on the left bank of the Ob River. The studied territory had a flat and gently sloping relief, with linear erosion forms. The sampling sites were mainly located on slopes with a gradient of 0-3°, predominantly facing north and east exposition. The capture of imago invertebrates was carried out using standard methods in the fields of two crops – spring wheat and corn, treated with agro-technologies of varying intensities, as well as on adjacent (control) areas with natural vegetation. The levels of intensification were primarily determined by the frequency and quantity of chemical treatments, and were described in more detail in previous works [23]. The area of each experimental plot was 150×150 m (2.25 ha). To assess the influence of climatic factors, meteorological data obtained from the agrometeorological station “Ogurtsovo”, located at a distance of 10 km from the study areas, were used. The conditions of heat and moisture supply of the territory were evaluated based on the sum of active air temperatures above 5°C (SAT) and the amount of precipitation during the vegetation period from May to August. The data presented in Fig. 1 indicate that the most favorable agrometeorological conditions for vegetation were observed in the year 2020 when both the sum of effective temperatures above 5°C and the amount of precipitation exceeded the long-term average values.

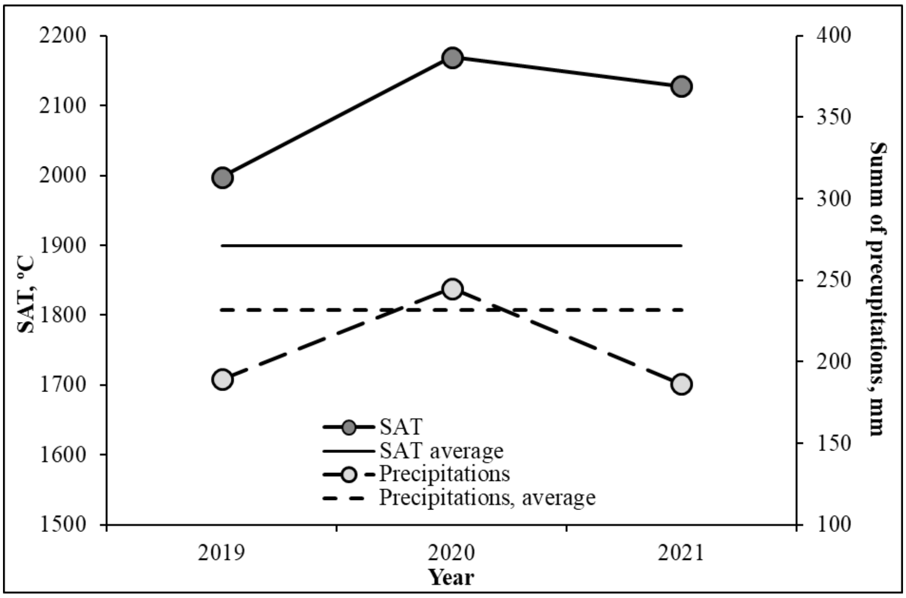

Figure 1 - Meteorological conditions (the sum of active air temperatures (t > 5°C, SAT) and the sum of precipitation during the vegetation period) in the years of observation according to the data of agrometeorological station "Ogurtsovo"

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For each of the experimental plots, the Normalized Difference Vegetation Index (NDVI) was calculated based on the ratios of the sum to the difference of the reflection coefficients of electromagnetic radiation in the infrared and red regions of the spectrum, determined from satellite images for the corresponding territory. Satellite images from Landsat-8 (with a spatial resolution of 30 meters per pixel) were obtained from the U.S. Geological Survey website (https://earthexplorer.usgs.gov) and processed using open-access Quantum GIS (QGIS) software (https://qgis.org/ru/site/). For capturing imago ground beetles, soil traps (plastic containers with a volume of 0.5 liters and a diameter of 9.5 cm) were used. A 10% solution of ethylene glycol was used as a fixative. Five traps were set up in a line with a 10-meter interval on each sampling site, located at least 50 meters away from the field border to eliminate edge effects. Material sampling was conducted once every 7 days. Over the 3-year study period, a total of 3780 trap-days were conducted (210 trap-days per season on each plot). The mean seasonal dynamic density of imago ground beetles was calculated as the number of individuals per 100 trap-days (hereafter, inds./100 t-d). Statistical analysis of the data was performed using the STATISTICA software package, version 12. To assess the influence of a complex of discrete (cultivated crop, technology intensity, year, vegetation activity index) and continuous (species affiliation) factors on the dynamic density of ground beetles, generalized linear-nonlinear models (GLZ module) were used. Since the data distribution deviated from normality (Shapiro-Wilk test, $p < 0.05$), a Poisson log-linear model was applied. Rare and singly occurring species were excluded from the analysis. Non-parametric criteria were used for paired and multiple comparisons of samples differing in the gradation of the studied factors.

Main results

Over the three years of studies, 11566 specimens of 42 ground beetle species belonging to 16 genera were captured [22], [23].

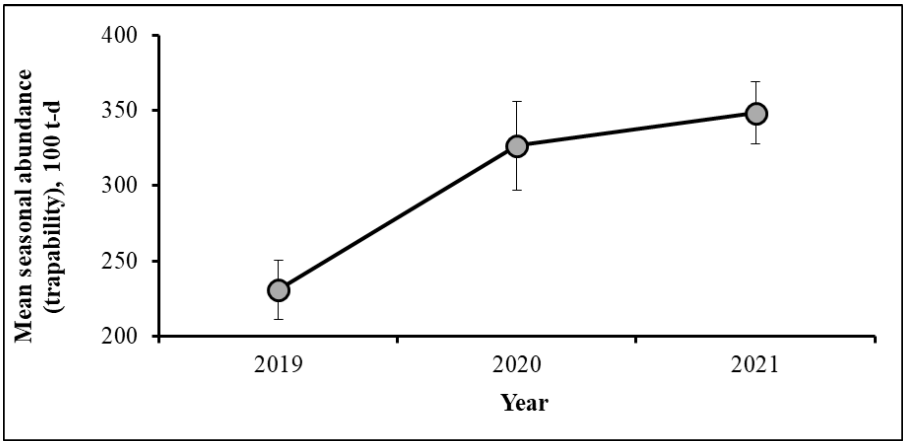

Figure 2 - Dynamics of ground beetle community abundance over three years of observation (mean ± S.E.)

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The analysis of potential factors influencing the species composition and abundance of ground beetle communities in agrocenoses and adjacent natural vegetation areas revealed a high statistical significance of the cultivated crop, the year of observation, and the degree of anthropogenic pressure on the territory (GLZ analysis, Wald test, all cases $p < 0.001$). The influence of NDVI and the position of the crop in the crop rotation were not significant (both cases $p > 0.05$). The abundance of the community in 2019 was significantly lower (Kruskal-Wallis H test, $p < 0.0001$) than in 2020 and 2021 (fig. 2). The highest species richness and maximum abundance of beetles were detected in all years of observation on wheat crops treated with low-intensity technology, while the lowest values were recorded on corn crops treated with high-intensity technology (table 1).

Table 1 - Species richness and abundance of ground beetles in habitats with different degrees of anthropogenic pressure

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Year	Natural vegetation		Low-intensity technology		High-intensity technology	
	Wheat	Corn	Wheat	Corn	Wheat	Corn
2019	25	27	27	23	24	20
	233.3	226.7	341.0	225.7	261.4	174.8
2020	31	34	35	27	29	22
	327.6	331.4	483.3	258.6	364.8	212.4
2021	33	32	34	28	32	25
	379.0	304.3	429.5	302.9	410.0	268.1
Mean	313.3	287.5	417.9	262.4	345.4	218.4

Note: top row – number of recorded species, bottom row – total mean seasonal abundance for all species (inds./100 t-d)

Both on corn crops and on adjacent natural vegetation plots, the abundance of ground beetles was generally lower than on wheat crops and neighboring untreated areas (Mann-Whitney test, $p < 0.01$). On wheat crops, both species richness and abundance were not lower and, when treated with low-intensity technology, even higher (paired Wilcoxon test, $p < 0.001$) than on the adjacent natural vegetation area. On corn crops treated with high-intensity technology, the abundance, on the contrary, was lower than on the adjacent untreated area (paired Wilcoxon test, $p < 0.05$).

The 42 beetle species recorded over 3 years represent about 10% of the known species composition of the carabid fauna of the Novosibirsk region [33], [34] and about 80% of the beetle species previously captured in cereal and oilseed crop agrocenoses of the northern forest-steppe of the Ob River region [30], [35], which indicates the sufficient representativeness of our data.

Discussion

Ground beetles are a widely distributed and ecologically diverse group. Their species composition and abundance are influenced by a wide range of climatic, biocenotic and anthropogenic factors [24], [26], [29], [31]. The interannual variability in the quantitative characteristics of the ground beetle community revealed in our study was apparently influenced by weather and climatic conditions, which affect significant parameters of agroecosystems such as primary biological production, physical soil structure, soil moisture, etc. In southwestern Siberia, the most favorable conditions for all these indicators occurred in 2020, characterized by an anomalously early spring that shifted all vegetation periods (fig. 1). However, even a slight decrease in the indexes of heat and moisture supply in 2021 (remaining at the level of long-term average values) did not lead to a significant decrease in ground beetle abundance (fig. 2). This may be attributed to both cumulative effects of favorable climatic years (enhanced survival of pre-imaginal stages compared to other years) and the resilience of this community, responding to worsening climatic conditions only when they exceed long-term average norms.

The lack of statistically significant influence of NDVI on the characteristics of the ground beetle community may also be related to the relatively favorable agrometeorological conditions during the observation period, with no extreme climatic events. The consistent precipitation in May and June contributed to high crop germination and the formation of relatively uniform vegetative biomass.

The influence of such a significant factor of anthropogenic landscape transformation as the cultivation of agricultural crops on the natural biodiversity of various organism groups has been extensively studied. Most of these studies, except for specialized phytophagous insects ("pests" of a particular crop), report a reduction in natural biodiversity proportional to the intensity of agro-technological use [1], [6], [10], [11] et. al. Since a significant portion of agrochemicals comprises broad-spectrum insecticides, non-target insect species become the most vulnerable components of agroecosystems. Nevertheless, the negative effects of insecticide treatments can be reduced through the judicious use of technologies (pre-seeding treatment, systemic pesticides, proper dosage, application method) and depend on the size of crop areas and the presence of natural refugia [15], [21], [22]. Studies conducted in countries with advanced agriculture show that the effects of adopting “organic” technologies depend on the studied taxonomic group and are manifested differently depending on the level of diversity considered (alpha, beta, or gamma diversity) [6], [14], [19].

Since the majority of ground beetle species belong to stratobionts and are active predators or polyphagous, insecticide treatments have a relatively weak toxic effect on them and may even provide additional food in the form of deceased target species [37]. In our study, we found differences in the effects of treatments depending on the cultivated crop: a positive effect with low intensity wheat agro-technological practices and, albeit weak, statistically significant negative effect with intensive corn treatment. These differences may be related to the specifics of the applied cultivation technologies (soil treatment system, plant protection measures, fertilizers, crop species, predecessor) as well as the various ecological conditions prevailing in the different crop areas (vegetation biomass, lighting and moisture regimes) [38]. The similarity between the ground beetle communities on cereal crops and adjacent areas of natural vegetation may be due to the wide utilization of these areas by the ground beetles as natural refugia and overwintering sites [17], [20], [21], [22], [23].

Conclusion

The obtained data indicate that agricultural landscape transformation, when following the regulations for the application of chemical treatments, may not have a significant influence on the natural biodiversity of an ecologically important group like ground beetles. The significant but not consistent influences on the species composition and abundance of ground beetles are exerted by the climatic conditions of the year and the cultivated crop type. Negative effects of agricultural activities in our study were only detected for ground beetles inhabiting corn crops when using intensive technologies, which involve the application of contact insecticides in combination with repeated inter-row treatments.

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Конфликт интересов

Не указан.

Conflict of Interest

None declared.

Рецензия

Все статьи проходят рецензирование. Но рецензент или автор статьи предпочли не публиковать рецензию к этой статье в открытом доступе. Рецензия может быть предоставлена компетентным органам по запросу.

Review

All articles are peer-reviewed. But the reviewer or the author of the article chose not to publish a review of this article in the public domain. The review can be provided to the competent authorities upon request.

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