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Ecological and Faunistic Structure of Ground Beetle Population (Coleoptera, Carabidae) of Forest Belts in The Tambov Region (Russia)

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Abstract: ***The article presents the analysis of ground beetle population in forest belts of different types. The ecological structure of ground beetle complexes of forest belts is determined by soil and moisture conditions. Differences in the diversity of ground beetle populations depending on a complex of soil and plant conditions and the nature of anthropogenic impact are found. The increase in steppe formation and xerophytism conditions in forest belts leads to a decrease in species diversity of the genera Carabus, Poecilus, Pterostichus, Calathus, Amara and Harpalus.***

Keywords: ***artificial forests, species diversity, dominance structure, community stability, ecological structure, life form.***

I. INTRODUCTION

Artificial forests are especially attractive for ground beetles; their conditions are favourable for the development and wintering of many insects, including ground beetles. Since forest belts are less exposed to agrotechnical influence and a lot of insects gather here in winter, forest belt coenoses act as buffers and have the status of agrobiocenoses [1-4].

The study of the structure of ground beetle population of forest belts in the Tambov region in anthropogenically transformed territory of forest-steppe zone of the Central Black Earth Region has begun relatively recently [4-6].

At present, there is a lot of data on ground beetle population of forest belts, which requires new approaches of understanding. These approaches can be associated with the study of the diversity of their organization, as well as the complexity of spatial and biotic relationships between various species [2, 7-10].

In scientific literature, there is no data about the generalization of the species composition and ecological structure of ground beetle population of various forest belts in the Tambov region.

The aim of the work is to study the ecological and faunistic structure of ground beetle population of forest belts in the Tambov region.

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II. PROPOSED METHODOLOGY

A. General description

The material for this work was data collected in the territories of forest belts in the Tambov region in 1996-2015. Forest belts of different types (birch, poplar and mixed oak) differ in their location, soil type and moisture coefficient [5, 6]. The age of model forest belts is more than 40 years.

The capture and account of adult ground beetles in biotopes were carried out using Barber soil traps [11] – glass jars with a volume of 0.5 l. A 4%-formalin solution was used as a fixative.

The capture index (dynamic density) was expressed in the unit of capture (specimens per 10 trap-days).

The dominants were species, the number of which was more than 5%, subdominants – from 2% to 5%.

B. Algotitm

To assess the species diversity of ground beetles in grassy areas of the city, the Margalef (Dmg) and Menkhinik (Dmn) indexes of diversity were used [12, 13]:

$Dmg = \frac{S-1}{\ln N}$, where S – total number of species; N – total number of specimens of all identified species, ln –natural logarithm.

$Dmn = \frac{S}{\sqrt{N}}$, where S – total number of identified species; N – total number of specimens of all species.

The even distribution of species in the community by their richness was characterized using the Shannon index (Hr):

$H = -\sum pi\ln$, where pi – proportion of specimens of i-species, ∑– sum sign, ln – natural logarithm.

The evenness index was determined using the Pielou method (e):

$e = \frac{H}{\log S}$, where H – the Shannon index and S – the number of species.

The Berger-Parker index (d) was used to assess the dominance of ground beetles in grassy areas. By many indicators, the Berger-Parker index is not demanding in terms of sample number [12].

$d = \frac{N_{max}}{N}$, where N_{max} – the number of specimens of the most abundant species in the biotope; N – the total number of specimens of all species in the biotope.

A five-point logarithmic scale of relative richness was used [14] to summarize the quantitative structure of the ground beetle population.

The characterization of the ecological structure of ground beetles was carried out according to the biotopic species preferendum.

III. RESULTS ANALYSIS

Forest belts of varying complexity affect the microclimate and the distribution of insects. The main factor regulating the dynamics of species composition of soil entomofauna of forest belts is the degree of crown closure and conditions depending on it [2, 9, 10, 15-18]. In forest belts (birch, poplar, oak and mixed), 57 species of ground beetles belonging to 25 genera of 14 tribes were registered. In birch forest belts, 37 species of ground beetles belonging to 16 genera were found, in poplar – 38 species belonging to 21 genera, in oak – 31 species belonging to 15 genera and in mixed – 32 species belonging to 13 genera.

The species diversity of ground beetles in the studied forest belts varies greatly: in birch forest belts – from 13 to 27 species, in poplar – from seven to 27 species; in oak – from 13 to 22 species, and in mixed – from 12 to 24 species (Table 1).

The total average capture index of ground beetles in the forest belts of the region amounted to 7.4 specimens per 10 trap-days. The highest capture index was in poplar forest belts (13.8 specimens per 10 trap-days), the lowest index was in mixed (three specimens per 10 trap-days). In birch and oak forest belts, it amounted to 7.1 specimens per 10 trap-days and 5.5 specimens per 10 trap-days, respectively (Table 1).

Table 1: Characteristics of species diversity of ground beetle communities in different types of forest belts in the Tambov region

Types of forest belts	Number		Number of species (S)	Capture index (specimen per 10 trap-days)
	biotopes	specimen		
Birch	7	888	37 (13-27)	7.1 (2.2-3.9)
Poplar	8	3,526	38 (17-27)	13.8 (5.2-26.7)
Oak	4	843	31 (13-22)	5.5 (3.7-4.9)
Mixed	6	794	32 (12-24)	3.0 (1.5-5.7)

The calculations of species diversity using the Shannon index (H') showed that the highest index was in poplar forest belts (2.45) and the lowest – in oak forest belts (1.43). In mixed and birch forest belts, the index was 1.78 and 1.45, respectively (Table 2).

The calculations of the evenness index according to Pielou (E) showed that the highest index was in poplar forests (0.67) and the lowest – in birch forests (0.40). In oak and mixed forests, it amounted to 0.41 and 0.51, respectively (Table. 2).

The calculations of species richness using the Margalef index (Dmg) showed that the highest index was in birch forests (5.29) and the lowest – in oak forests (3.88). In poplar forests, it amounted to 4.39 and in mixed forests – to 4.18 (Table 2).

The calculations of species richness using the Menkhinik index (Dmn) showed that the highest index was in birch forests (1.24) and the lowest – in poplar forests (0.62). In oak and mixed forests, it was approximately the same (0.93 and 1.0, respectively) (Table 2).

Table 2: Values of main indexes of species diversity and species richness in forest belt communities of different types

Indexes	Forest belts			
	Birch forests	Poplar forests	Oak forests	Mixed forests
Shannon (H’)	1.45	**2.45**	*1.43*	1.78
Pielou (E)	*0.40*	**0.67**	0.41	0.51
Berger-Parker (d)	**0.69**	*0.40*	0.49	0.53
Margalef (D_{Mg})	**5.29**	4.39	*3.88*	4.18
Menkhinik (D_{Mn})	**1.24**	*0.62*	0.93	1.0
Number of species	37	38	31	32
Number of dominants	2	5	3	5

Note: bold font indicates the value with the maximum diversity, italics – with the minimum diversity

Ground beetle communities in both congeneric and mixed forest belts can be monodominant or include several dominants. In forest belts, two-five species of ground beetles dominate, which account from 77.6% to 84.6% in different biotopes. The composition of the dominant species of forest belts varies depending on the type of trees and soil, as well as plant conditions. The numerosity of permanent dominant of model forest belts H. rufipes is from 15.9% to 69.0%. Pt. melanarius as a part of dominants is recorded in three forest belts (birch, poplar, oak) with the numerosity from 6.7% to 49.1%. In two forest belts (poplar and mixed), Poecilus cupreus prevail with the numerosity 39.9% and 7.8%, respectively, and Harpalus affinis – 15.9% and 7.7%, respectively. In poplar forests, Anisodactulus signatus is a part of the dominants (10.1%), in mixed forests – Carabus granulatus (7.6%) and C. marginalis (5.0%).

In the model forest belts of various types in the Tambov region, seven dominants were identified. The dominant species included Harpalus rufipes (30.8%), Poecilus cupreus (24.8%), Pterostichus melanarius (2.2%), Harpalus affinis (8.3%) and Anisodactulus signatus (6.3%). The general dominant species for all types of forest belts in the region was H. rufipes. (Table 4).

The distribution of ground beetle species by richness score in the studied forest belts is characterized by the predominance of rare species. Only in birch forest belts, Harpalus rufipes (69.0%) was numerous. This species became a part of dominants with the fourth richness score. The average numerosity was recorded in Pterostichus melanarius (49.1%) and Harpalus rufipes (53.0%) in oak and mixed forest belts, respectively, amounting to three scores of richness. Poecilus cupreus (39.9%) in poplar forest belts and Harpalus rufipes (15.9%) in oak forest belts had two scores each.

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The value of the Berger-Parker dominance index (d) was the highest in birch forest belts (0.69) and the lowest – in poplar (0.40). In oak and mixed forest belts, it was 0.49 and 0.53, respectively (Table 2).

These studies show that structurally stable and fluctuating communities of ground beetles can be distinguished. In the first case, the number of dominant species and the spectra of biotopic groups and life forms are constant. In the second case, they change in time. Under mesophytic conditions of birch forest belts, ground beetle communities belong to the stable type; in water-logged poplar and mixed forest belts, ground beetle communities are fluctuating (Table 3).

Table 3: Characteristics of ground beetle community organization (on the example of forest belts in the central part of the forest-steppe zone)

Index	Stable	Fluctuating
Set of dominants	Constant	Variable in time
Number of potential dominants	2	Up to 5
Spectra of life forms and biotopic groups	Constant	Variable in time
Predominant biotopic group	By species richness – meadow field By numerical richness – field	Variable in time
Main environmental factors affecting the population of ground beetles	A lot of light, the soil dries quickly	Less light, the soil dries more slowly
Habitat	Birch forest belts	Poplar, oak and mixed forest belts

In the ecological structure of ground beetle population of the forest belts in the Tambov region, we distinguished nine ecological groups of ground beetles (forest, forest-marsh, marsh, meadow, meadow-field, field, meadow-marsh, steppe-field, steppe).

In the complex of ground beetles of forest belts (birch, poplar and mixed), by species (50.0-62.2%) and numerical (82.6-87.2%) richness, the open space species (meadow, meadow-field and field groups) dominate. In oak forest belts by species (48.3%) and numerical (63.6%) richness, the forest complex of ground beetles dominates (forest, forest-marsh and marsh species). Among the ecological groups of ground beetles of open spaces, the insects of the field group (71.8%) in birch forest belts and ground beetles of the meadow-field group (60.7%) in poplar forest belts are of the greatest importance in terms of their numerical richness. The greatest species richness in forest belts was recorded in meadow-field species of ground beetles (32.5-43.3%). The core of ground beetles of the meadow-field group were Poecilus cupreus and Harpalus affinis and the field group – Harpalus rufipes. The greatest richness of meadow-field species was in poplar forest belts, the field species – in birch forest belts. The meadow group (Cylindera germanica, Amara similata, Ophonus rufibarbis) of ground beetles is present only in poplar and birch forest belts. The species richness of meadow species was 2.6% and 8.1%, respectively, and the numerical richness was insignificant.

In the forest complex of ground beetles, forest species ere of importance (23.7-38.7% of species richness and 8.8-65.2% of numerical richness). The most significant richness among forest species was observed in Pterostichus melanarius; its proportion increases in oak forest belts. The species richness of forest-marsh species in the forest belts was 2.7-18.4% and numerical richness – 0.1-8.5%. Only in birch forest belts, the largest numerosity was found in Pterostichus strenuus. The species and numerical richness of marsh ground beetles (Sericoda quadripunctatum, Agonum gracilipe) increased from birch and poplar forest belts towards oak. In mixed forest belts, marsh species of ground beetles were not registered. The meadow-marsh group in artificial forests was represented by the species Badister bullatus. The species richness of ground beetles of this group increased from poplar forest belts (2.6%) towards oak (3.2%). Ground beetles of this group were absent in birch forest belts.

Steppe-field (Ophonus stichus) and steppe (Harpalus zabroides, Cymindis macularis) species in the model forest belts accounted to 2.6-5.4% of the species richness and the numerical richness of ground beetles of these groups was insignificant.

The similar tendency for changes in biotopic groups is also characteristic of the spectra of carabid complexes of dominant species. Towards oak forest belts, the richness of dominant forest species increases. Xerophilization of conditions in birch forest belts contributes to an increase in the richness of ground beetles in open spaces and a decrease in the richness of ground beetles in the forest complex.

IV. CONCLUSION

The analysis of the diversity of ground beetles in different types of forest belts has shown that the greatest species richness calculated using the Margalef and Menkhinik indexes is observed in birch communities. The indexes of relative species richness and evenness (the Shannon and Pielou indexes), as well as dominance indexes (the Simpson and the Berger-Parker indexes) in general identically assess the evenness of communities and show the greatest biodiversity in poplar forests.

In birch forest belts, the dominance of two species was stable over the years; in the remaining forest belts, the number of dominates was up to five species. The value of the Berger-Parker dominance index (d) was the highest in birch forest belts (0.69) фтв the lowest – in poplar forest belts (0.40). In oak and mixed forest belts, it amounted to 0.49 and 0.53, respectively. The value of the Simpson index (D) in forest belts was similar to the Berger-Parker dominant index (d). The highest index value was in birch forest belts (0.49) and the lowest – in poplar forest belts (0.22). In oak and mixed forest belts, it amounted to 0.35 and 0.30, respectively.

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In the dominance structure of ground beetles of forest belts of different types, there are changes associated with the transition from multidominant (poplar and mixed forest belts) to oligodominant (birch forest belts). The general dominant species in all types of forest belts of the region was Harpalus rufipes (45.0%).

In the ecological structure of ground beetles population of the forest belts in the Tambov region by species and numerical richness, open space ground beetles dominate, among which the richness of the field group (71.8%) increases towards birch forest belts and meadow-field (60.7%) towards poplar. The forest complex of ground beetles is also of importance in artificial forests. The forest species are the most abundant in oak forest belt (62.5%).

The distribution of soil invertebrates under the formed forest belts is influenced by the hydrothermal regime of soils. With the change in microclimatic conditions (temperature, moisture) in oak forest belts, there is a decrease in the species and numerical richness of ground beetles of open spaces and an increase in the richness of ground beetles of the forest complex.

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