Entomology and Applied Science Letters
Volume 7, Issue 1, Page No: 1-9

Available Online at: www.easletters.com

ISSN No: 2349-2864

Fauna and Abundance of Ground Beetle (Coleoptera, Carabidae) in Pine Forests

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ABSTRACT

The fauna of various types and ages of ground beetles were studied in pine forests of central Russia. A total of 52 ground beetle species from 21 genera were recorded and the genera *Harpalus, Carabus, Pterostichus,* and *Amara* had the largest number of species. Twenty-five species were recorded in the pine forest near a swamp (with moderate moisture). At the same time, only 10 species were found in drier habitats (pine forests dominated by *Convallaria majalis* and *Calamagrostis arundinacea* in the grass cover). The ground beetle communities of humid pine forests had the highest Shannon-Wiener index values. The species diversity of ground beetles in the young pine forest was lower than in the old-aged pine forest. However, the Shanon-Wiener index was higher in young stands, and the dominance indices were lower compared to the old-growth forests. *Pterostichus oblongopunctatus* was the most common and in some forest mass species.

Keywords: *ground beetle, Carabidae, pine forests, central Russia.*

HOW TO CITE THIS ARTICLE: Sergey K. Alekseev, Alexander B. Ruchin; Fauna and Abundance of Ground Beetle (Coleoptera, Carabidae) in Pine Forests, Entomol Appl Sci Lett, 2020, 7 (1): 1-9.

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Received: 22/10/2019
Accepted: 16/03/2020

INTRODUCTION

Ground beetles (Coleoptera, Carabidae), one of the largest groups among coleopterans, play a significant role in biocenoses as entomophages that regulate the abundance of terrestrial invertebrates. They are considered economically useful, since both adults and larvae destroy some pests of forestry and agriculture, limiting their numbers [1, 2]. They live in many biocenoses, both forest and steppe; they are found in agro landscapes and urbocenoses [3-12]. They occupy one of the leading positions in terms of abundance and biomass in these biocenoses due to the variety of feeding methods and eurybiontism [13-16]. On the other hand, there are many species that are rare and are found in few biotopes [16-19].

The natural zone of coniferous forests is located between the tundra in the north and deciduous forests in the south. They are the largest biome in the world and extend across Eurasia and North America. The main forest-forming species are *Picea, Pinus, Abies sibirica Ldb*. and *Larix sibirica Ldb*. In many places, coniferous forests, especially pine forests, are pyrogenic formations, i.e. formed on the site of burned forests [20]. In Russia, coniferous forests are located in the natural zone of the taiga and occupy about 70% of the total country's forest area. This area is known for low temperature and humid air. In recent decades, coniferous forests have changed because of human activity [21-24]. Tree felling, pollution, fragmentation, fires, climate aridization, and other factors affect the insect fauna of

these forests [11, 12, 25-29]. Being one of the largest families, the ground beetles inhabit the most diverse forest systems [30-34]. When comparing Carabidae communities in deciduous and coniferous forests, certain differences were revealed in terms of species composition, abundance, and distribution [35, 36]. Our studies were aimed to determine the species composition and differences in the fauna of ground beetles in pine forests.

MATERIAL AND METHODS

During April–August 2009, 2012–2014, and 2018, we collected the material using pitfall traps. They were represented by 0.5-liter cups with 4% formalin solution. In each biocenosis, there were 10 traps that had been installed in one line with a distance of two to three meters between them.

Study area

Pine forest No. 1 (pine forest with *Pinus sylvestris, Tilia cordata, Betula pendula*). In such a pine forest, the main forest-forming species is *Pinus sylvestris* L. The second tier of such a forest is well defined. It consists of *Tilia cordata* Mill., Betula pendula Roth, and *Picea abies* (L.) H. Karst partially grows. The shrub layer consists of *Acer platanoides* L., *Euonymus verrucosus* Scop., *Sorbus aucuparia* L., saplings of *T. cordata,* and *B. pendula*. The herb layer is well defined and represented by *Dryopteris carthusiana* (Vill.) H.P. Fuchs, *Pteridium aquilinum* (L.) Kuhn, *Glechoma hederacea* L., *Convallaria majalis* L., *Aegopodium podagraria* L., as well as various cereals. Soil moisture is low.

Pine forest No. 2 (pine with well-defined moisture due to the nearby swamp). It is characterized by the dominance of *Pinus sylvestris* with an admixture of *Alnus glutinosa* (L.) Gaertn., *Populus tremula* L., *Betula pendula*. The shrub layer is represented by *Sorbus aucuparia*, *Frangula alnus*, juvenile *Picea abies, Populus tremula*. *Urtica dioica* L., *Vaccinium myrtillus* L., *Impatiens nolitangere* L., *Carex pilosa*, *Athyrium filix-femina* (L.) Roth grow in the herb layer. It is considered a mesophytic type with a transition to hygrophytic.

Pine forest No. 3 (pine forest with *Pinus sylvestris, Tilia cordata, Betula pendula,* and a developed herb layer). The second tier consists of *Tilia cordata* Mill., *Betula pendula*. Shrubs are represented by *Corylus avellana* L., *Euonymus verrucosus*, and *Sorbus aucuparia*. The herb layer is well defined. Various types of cereals, *Vaccinium vitisidaea*, *Convallaria majalis*, *Impatiens nolitangere, Athyrium filixfemina* grow in it. Reforestation is a good subject for litter mineralization. Mesophytic type. Humidity is less than in pine forest No. 2

Pine forest No. 4 (pine forest with *Convallaria majalis* dominance in herb layer). *Pinus sylvestris* predominates with negligible involvement in the *Betula pendula* stand. The shrub layer is represented by *Sorbus aucuparia, Frangula alnus*, juvenile *Picea abies,* and *Tilia cordata*. A distinctive feature of this forest type was the herb layer, whose significant part consisted of *Convallaria majalis*. In addition, there were found separate plants of the following species: *Polygonatum odoratum* (Mill.) Druce, *Calamagrostis arundinacea, Pulsatilla patens* (L.) Mill., *Geranium sanguineum* L., *Vaccinium vitisidaea, Antennaria dioica* (L.) Gaertn., *Campanula rotundifolia* L., *Viola canina* L. s. str. The biotope was xerophytic.

Pine forest No. 5 (pine forest with *Calamagrostis arundinacea* dominance in herb layer). *Betula pendula* is included in a small amount in the stand with *Pinus sylvestris*. The shrub layer is sparse, represented by *Sorbus aucuparia, Frangula alnus*. The grass-shrub layer is well developed. A feature of this forest type was the herb layer, whose significant part consisted of *Calamagrostis arundinacea* and *Calamagrostis arundinacea* (L.) Roth. *Vaccinium vitisidaea*, *V. myrtillus, Antennaria dioica, Rubus saxatilis, Viola rupestris* were also presented. The biotope was xerophytic.

Pine forest No. 6 (pine forest with *Carex pilosa* dominance in herb layer). It was characterized by the dominance of *Pinus sylvestris* mixed with *Betula pendula*. The second tier was represented by *Tilia cordata*, with the inclusion of *Quercus robur, Populus tremula*. *Sorbus aucuparia, Frangula alnus, Acer platanoides* grew in a shrub layer. A feature of this forest type was the herb layer, whose significant part consisted of *Carex pilosa Scop*. Separate trees *Mercurialis perennis, Pulmonaria obscura, Rubus saxatilis, Convallaria majalis, Asarum europaeum*, and *Viola rupestris*

also grew in this tier. The biotope was xerophytic.

We have installed several studied sites in pine forests of different ages. Young pine forests (pine forest No. 7) of 25-35 years old were characterized by the dense tree stands formed by man. Shrub and herb tiers were usually poorly shown. The grass practically did not grow due to a significant amount of needles that fell from young pine trees. Over 70 years old pine forests (pine forest No. 8) were characterized by a well-defined second tier, consisting of *Sorbus aucuparia, Frangula alnus* Mill., *Euonymus verrucosus* and sometimes young trees *Tilia cordata* and *Betula pendula*. The herb layer was also well shown and represented by various cereals, *Pteridium aquilinum,Convallaria majalis*, and other common herbs. Soil moisture was moderate at all sites.

Data analysis

The diversity analysis among the ecosystems was evaluated by the following diversity indexes: Shannon-Wiener (H'), which consider equal weight to the rare and abundant species and Simpson's index (1-D), which is characterized by being sensitive to changes in the most abundant species composition [37] were employed. The uniformity among the coleopterans caught in the five sampling areas was calculated with the Berger and Parker index. Mathematical processing was carried out in Microsoft Excel.

In total, about 1,500 specimens were collected and processed during the research. To characterize the numerical abundance of species, the following classification was adopted: dominant species were species with a numerical abundance exceeding 5%, subdominant species were species with a numerical abundance from 2% to 5%, small species from 1% to 2%, and for rare species, less than 1%. The dynamic density of the beetles was represented as a number of beetle specimens caught per 100 traps per day (ex./100 trap-days).

For research, we adopted the Carabidae system, corresponding to that on the website of the Zoological Institute of the Russian Academy of Sciences [38] and based on the well-known catalog [39]; The nomenclature is given in the catalog of Palearctic beetles [40].

RESULTS AND DISCUSSION

In total, 52 ground beetles species from 21 genera were caught. The largest number of species is represented in the genera *Harpalus, Carabus, Pterostichus,* and *Amara*. In various pine forests, species diversity varied (Table 1). Twenty-five species were collected in pine forest No. 1 near the swamp (with moderate moisture). At the same time, only 10 species were found in drier habitats (pine forest No. 4 and pine forest No. 6).

Table 1. The fauna and dynamic density (ex./100 trap-days) of species collected in different pine forests (in May - June)

Species	Pine forest № 1	Pine forest № 2	Pine forest № 3	Pine forest № 4	Pine forest № 5	Pine forest № 6
Leistus terminatus **(Hellwig in Panzer, 1793)**			0,45			
Notiophilus aquaticus **(Linnaeus, 1758)**		0,74	0,45			
Notiophilus germinyi **Fauvel, 1863**						0,87
Notiophilus palustris **(Duftschmid, 1812)**		0,37				
Loricera pilicornis **(Fabricius, 1775)**			1,82			
Calosoma inquisitor **(Linnaeus, 1758)**	1,58			5,21		
Calosoma investigator **(Illiger, 1798)**					0,43	
Calosoma sycophanta **(Linnaeus, 1758)**	0,26					
Carabus cancellatus **Illiger, 1798**					1,74	3,91
Carabus coriaceus **Linnaeus, 1758**			0,91	0,43		0,87
Carabus glabratus **Paykull, 1790**	3,42		1,82	0,43	2,17	2,61
Carabus granulatus **Linnaeus, 1758**	9,47		12,27		3,04	22,17
Carabus hortensis **Linnaeus, 1758**			2,73			
Cychrus caraboides **(Linnaeus, 1758)**			0,91			

***Elaphrus cupreus* Duftschmid, 1812**			0,45			
***Trechus secalis* (Paykull, 1790)**	0,79			2,17	5,21	
***Bembidion quadrimaculatum* (Linnaeus, 1761)**		0,37				
***Patrobus assimilis* Chaudoir, 1844**		1,11				
***Poecilus cupreus* (Linnaeus, 1758)**	1,05					
***Poecilus lepidus* (Leske, 1785)**	0,26	0,74				
***Poecilus versicolor* (Sturm, 1824)**	0,26		0,45		0,43	
***Pterostichus diligens* (Sturm, 1824)**			3,64			
***Pterostichus melanarius* (Illiger, 1798)**	4,76		4,09			2,17
***Pterostichus minor* (Gyllenhal, 1827)**			2,27			
***Pterostichus niger* (Schaller, 1783)**	1,32	0,37	12,73		0,43	9,13
***Pterostichus nigrita* (Paykull, 1790)**		0,37	4,09			
***Pterostichus oblongopunctatus* (Fabricius, 1787)**	2,11	1,85	25,00	6,09	5,21	13,48
***Pterostichus rhaeticus* Heer, 1837**			7,73			
***Pterostichus vernalis* (Panzer, 1796)**			1,82			
***Calathus melanocephalus* (Linnaeus, 1758)**	0,53					
***Calathus micropterus* (Duftschmid, 1812)**			1,82	2,61	3,48	
***Limodromus assimilis* (Paykull, 1790)**			0,45			
***Agonum duftschmidi* Schmidt, 1994**			0,45			
***Agonum fuliginosum* (Panzer, 1809)**	0,26		2,27			
***Agonum obscurum* (Herbst, 1784)**			2,73	0,87	1,74	
***Agonum sexpunctatum* (Linnaeus, 1758)**		0,37				
***Synuchus vivalis* (Illiger, 1798)**					0,87	0,43
***Amara bifrons* (Gyllenhal, 1810)**		0,37				
***Amara brunnea* (Gyllenhal, 1810)**	0,53					
***Amara communis* (Panzer, 1797)**	2,11					
***Amara erratica* (Duftschmid, 1812)**		0,37				
***Amara similata* (Gyllenhal, 1810)**	0,26					
***Harpalus calathoides* Motschulsky, 1844**				0,43		
***Harpalus latus* (Linnaeus, 1758)**	1,32				3,48	
***Harpalus picipennis* (Duftschmid, 1812)**		1,11				
***Harpalus progrediens* Schauberger, 1922**		0,37				
***Harpalus rubripes* (Duftschmid, 1812)**						0,43
***Harpalus rufipes* (DeGeer, 1774)**		0,74	0,45			
***Harpalus tardus* (Panzer, 1796)**		0,37				
***Harpalus laevipes* Zetterstedt, 1828**			1,37	1,74	2,61	
***Ophonus subquadratus* (Dejean, 1829)**				0,43		
***Microlestes maurus* (Sturm, 1827)**		0,74				
Total number of exemplars	115	28	205	47	71	129
Shannon-Wiener index	2,26	2,61	2,53	1,88	2,32	1,66
1-D	0,16	0,09	0,13	0,19	0,11	0,25
Berger and Parker index	0,31	0,18	0,29	0,30	0,17	0,40
Number of species	17	16	25	10	13	10

Pterostichus oblongopunctatus was the only common species for all pine forest types. *Pterostichus niger* and *Carabus glabratus* were found in four of five biotopes.

Ground beetle communities of pine forest No. 2 and pine forest No. 3 had the highest Shannon-Wiener index values. Moreover, we found not only common pine forest species but also species that live in moist biotopes. As we know, an increase in the Simpson index and the Berger-Parker index means a decrease in community diversity and an increase in the dominance of any one species [41]. According to Table 1, the maximum values of these indices were obtained for ground beetle communities in pine forest No. 6, pine forest No. 4 and pine forest No. 1. The

following species were the dominant species in those communities: *Carabus granulatus, Pterostichus oblongopunctatus* and *Pterostichus niger* in the first community, in the second community - *Pterostichus oblongopunctatus* and *Calosoma inquisitor*, in the third community - *Carabus granulatus*

Table 2. The fauna and dynamic density (ex./100 trap-days) of species collected in pine forests of different ages (young and old ones)

Species	Pine forest № 7	Pine forest № 8
Notiophilus aquaticus (Linnaeus, 1758)	0,07	0,49
Carabus arcensis Herbst, 1784	3,95	3,24
Carabus cancellatus Illiger, 1798	0,26	
Carabus convexus Fabricius, 1775	0,07	0,20
Carabus coriaceus Linnaeus, 1758	0,39	0,10
Carabus hortensis Linnaeus, 1758	0,99	0,88
Carabus glabratus Paykull, 1790	0,53	1,18
Carabus granulatus Linnaeus, 1758		0,10
Cychrus caraboides (Linnaeus, 1758)	0,13	
Elaphrus cupreus Duftschmid, 1812		0,20
Poecilus cupreus (Linnaeus, 1758)	0,53	0,49
Poecilus lepidus (Leske, 1785)	0,07	
Poecilus versicolor (Sturm, 1824)	0,26	0,20
Pterostichus anthracinus (Illiger, 1798)	0,39	0,78
Pterostichus gracilis (Dejean, 1828)		0,10
Pterostichus melanarius (Illiger, 1798)	0,86	0,10
Pterostichus minor (Gyllenhal, 1827)	0,53	0,78
Pterostichus oblongopunctatus (Fabricius, 1787)	8,03	28,04
Pterostichus nigrita (Paykull, 1790)	0,66	0,29
Pterostichus niger (Schaller, 1783)	0,20	0,10
Pterostichus strenuus (Panzer, 1796)	0,07	0,78
Pterostichus quadrifoveolatus Letznner, 1852	0,33	0,59
Calathus micropterus (Duftschmid, 1812)	1,64	3,53
Agonum gracilipes (Duftschmid, 1812)		0,20
Agonum lugens (Duftschmid, 1812)		0,78
Agonum obscurum (Herbst, 1784)	0,39	
Agonum sexpunctatum (Linnaeus, 1758)		0,20
Synuchus vivalis (Illiger, 1798)		0,10
Amara aenea (De Geer, 1774)	0,07	
Amara communis (Panzer, 1797)	0,07	
Amara familiaris (Duftschmid, 1812)		0,10
Amara ovata (Fabricius, 1792)		0,20
Amara similata (Gyllenhal, 1810)	0,13	
Amara tibialis (Paykull, 1798)		0,29
Anisodactylus binotatus (Fabricius, 1787)		0,10
Anisodactylus nemorivagus (Duftschmid, 1812)	0,13	0,10

Harpalus latus (Linnaeus, 1758)	0,53	0,78
Harpalus laevipes Zetterstedt, 1828	0,79	1,37
Harpalus progrediens Schauberger, 1922		0,20
Harpalus rubripes (Duftschmid, 1812)	0,07	0,10
Harpalus rufipes (DeGeer, 1774)		0,20
Harpalus xanthopus winkleri Schauberger, 1923	0,13	
Panagaeus bipustulatus (Fabricius, 1775)		0,10
Chlaenius tristis (Schaller, 1783)		0,10
Licinus depressus (Paykull, 1790)	0,07	
Badister bullatus (Schrank, 1798)	0,13	
Badister lacertosus Sturm, 1815	0,13	0,49
Microlestes minutulus (Goeze, 1777)		0,10
Total number of exemplars	343	486
Shannon-Wiener index	2,43	1,90
1-D	0,17	0,36
Berger and Parker index	0,34	0,54
Number of species	33	39

The ground beetles species diversity was lower in young pine forest (pine forest No. 7) than in old-aged one (pine forest No. 8). However, the Shannon-Wiener index was higher in young stands, and the dominance indices were lower compared to old-growth forests. This means that in the community of ground beetles, there are no special dominant species in young stands. *Pterostichus oblongopunctatus* was dominant in both types of forests. Its numerical abundance was 57.8% in old-growth forests, while in young forests, its numerical abundance was 34.1%. This is a trans-Palaearctic, non-moral species with a spring type of reproduction, a mesophile, a stratobiont burrowing, quite common in the forests of the temperate zone [12, 42-45]. *Calathus micropterus* and *Carabus arcensis* were subdominant in old forests. The second species was subdominant in young forests, and the first one belonged to small species (the abundance of *Calathus micropterus* was twice lower than in old forests). The *Carabus arcensis* abundance was almost identical in both types of forests. *Carabus arcensis* is a trans-arctic forest species with spring breeding. This species is found in different habitats, but at the same time, a decrease in its abundance was previously observed in many habitats [46]. In the pine forests of Central Russia, this species is quite common.

Thus, the ground beetles fauna of pine forests in the studied area includes the usual composition of species. Certain differences were revealed in the fauna of different biotopes; they may indicate specific preferences of certain species groups, in particular, preference for mesophytic and hygrophytic habitats. The species abundance and ground beetles abundance was lower in forests with high xerophytization compared to mesophytic biotopes. *Pterostichus oblongopunctatus* was the most common and in some forest mass species. The revealed differences in pine forests of different ages related to species diversity, species dominance, and the spectrum of dominant species.

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