Fauna of Carabidae (Coleoptera: Insecta) in the forest ecosystems of the Sursky state nature sanctuary (European Russia)

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Abstract. An analysis of the fauna and abundance of Carabidae inhabiting small steppe areas within the Sursky State Nature Sanctuary (Ulyanovsk Region, European Russia) has been conducted. The study focused on forest ecosystems within the protected area. A total of 32 forest sites were surveyed. In total, 92 species of ground beetles were recorded, amounting to 6,229 specimens. The most frequently encountered species were *Pterostichus niger*, *P. oblongopunctatus*, *P. melanarius*, *Calathus micropterus*, and *Oxypselaphus obscurus*. *Carabus hortensis* and *Carabus glabratus* were also locally very abundant. Most of the recorded species are widespread and common in the forests of the East European Plain. Among the species listed in the Red Data Book of the Russian Federation, *Calosoma sycophanta* was identified. A reduced abundance of several mesohygrophilous species—typically common in mixed and broadleaf forests of more western regions—was observed. *Carabus glabratus* was associated with a moist alder-dominated site. Forest sites with similar external features of mixed forests differed significantly in their species composition of ground beetles.

1 Introduction

Insect populations and their biodiversity are declining worldwide, despite their critical importance to ecosystem functioning. As a result, significant efforts have been made in recent decades to inventory and study insect ecology, as well as to investigate population dynamics [1,2]. These efforts are essential for developing conservation strategies, monitoring species and populations, and studying rare species. Protected areas play a significant role in biodiversity and ecosystem conservation [3–5].

In Russia, there are several types of protected areas, which together currently cover more than 12% of the country's territory. A State Nature Sanctuary is a type of protected area where specific components of the natural complex are under protection. These may include certain animal or plant species, unique geological formations, or historical landmarks. In complex state sanctuaries, entire ecosystems are conserved. These

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sanctuaries are established not only for preservation but also for the restoration of protected natural features.

The State Nature Sanctuary represents a distinctive form of protected area, characterized by a broad spectrum of regulatory approaches to land use and human activities. Protective measures may range from complete prohibition of economic activities to the protection of specific natural components. However, as with other forms of protected areas, the inventory and monitoring of plant and animal fauna in state nature sanctuaries are recognized as a governmental responsibility [6,7].

The family Carabidae is one of the most well-known and diverse families within the order Coleoptera. The complex dependence of soil invertebrate population structures on soil conditions, microrelief, moisture levels, and the composition of phytocenoses increases the vulnerability of their communities to anthropogenic impacts [8,9]. Ground beetles (Carabidae) are considered reliable indicators of the condition and dynamics of soil and vegetation systems [10,11]. Species diversity on the soil surface, seasonal migrations due to their high activity, and other aspects of ground beetle life cycles serve as indicators of ecosystem health. For these reasons, the Carabidae fauna requires continuous monitoring and research.

The aim of the study was to inventory the Carabidae fauna within one of the largest protected areas by surface area.

2 Materials and methods

The Sursky State Nature Sanctuary (SSNS) is located in the forest-steppe zone of the East European Plain, within the Sursky District of Ulyanovsk Region, in the interfluve of the Sura and Barysh rivers. The total area of the sanctuary is 22,200 hectares. The territory encompasses mixed, coniferous, and floodplain forests, as well as wetlands, lakes, and floodplain meadows. Forests cover approximately 20,270 hectares of the area.

In the northern part of the sanctuary, forest stands characteristic of the European taiga are present. This is the only location in Ulyanovsk Region where pine forests are interspersed with both common and Siberian spruce. The understory features common juniper, while the herbaceous layer includes typical taiga species such as lingonberry, blueberry, and club moss. In addition to forest vegetation, riparian and meadow plant communities are well developed along rivers and streams. Wetlands within the sanctuary support a unique complex of boreal-bog species, which are considered relict elements within the forest-steppe zone of Ulyanovsk Region.

The study was conducted from April to August 2023. Several forest sites, representing the most widespread forest types within the Sursky State Nature Sanctuary (SSNS), were selected for the installation of pitfall traps. At five of these forest sites, pitfall traps were in place continuously from April through August. A brief description of these biotopes is provided below:

Biotope No. 1 (N 54.5141, E 46.8982). A mixed forest site. Among the deciduous tree species, linden and birch dominate. The understory is dense, consisting of bird cherry, rowan, and young birch and linden trees.

Biotope No. 2 (N 54.5088, E 46.8909). A mixed forest site. Differs from Biotope No. 1 by a lower canopy cover of the first tree layer. Birch dominates among the deciduous trees, with linden and aspen present to a lesser extent. The understory includes aspen, bird cherry, rowan, and young birch and linden trees.

Biotope No. 3 (N 54.5115, E 46.8908). A moist forest site dominated by alder and aspen. The understory includes bird cherry, aspen, and willows.

Biotope No. 4 (N 54.5178, E 46.8940). A mixed forest site. Similar in structure and species composition to Biotope No. 2.

Biotope No. 5 (N 54.5199, E 46.8953). A mixed forest site. Structurally and floristically similar to Biotope No. 1.

The remaining pitfall trap lines were set for a duration of one month. In total, 32 trap lines were established across the forest sites. Each line consisted of 10 plastic cups, buried in the ground at intervals of 2–3 meters. Each cup was a 0.5-liter container filled to one-third of its volume with 6% formalin solution.

Species identification of Carabidae was performed following the keys by Müller-Motzfeld [12] and Isaev [13]. Modern nomenclature was adopted according to I. Lobl and D. Lobl [14]. The species list is currently presented in alphabetical order. A total of 6,229 specimens from all sampling sites were studied.

The life forms of Carabidae imagines were classified according to Sharova [15]. Ecological groupings were assigned based on species distributions in better-studied regions of the forest zone. Statistical analyses were conducted using the software package PAST 4.03.

3 Results

A total of 92 Carabidae species were recorded within the territory of the Sursky State Nature Sanctuary during the study period (Table 1).

Table 1. Abundance and occurrence of Carabidae in the forests of the Sursky State Nature Sanctuary (summary data for 2023).

Species	Number of individuals	Number of plots
Agonum fuliginosum (Panzer, 1809)	2	2
Agonum gracilipes (Duftschmid, 1812)	3	3
Agonum lugens (Duftschmid, 1812)	1	1
Agonum sexpunctatum (Linnaeus, 1758)	1	1
Amara aenea (De Geer, 1774)	2	2
Amara aulica (Panzer, 1796)	2	2
Amara brunnea (Gyllenhal, 1810)	1	1
Amara communis (Panzer, 1797)	107	18
Amara consularis (Duftschmid, 1812)	3	2
Amara convexior Stephens, 1828	10	5
Amara eurynota (Panzer, 1796)	26	13
Amara familiaris (Duftschmid, 1812)	2	1
Amara gebleri Dejean, 1831	15	3
Amara ingenua (Duftschmid, 1812)	1	1
Amara littorea C.G. Thomson, 1857	1	1
Amara lunicollis Schiødte, 1837	2	2
Amara montivaga Sturm, 1825	2	2
Amara ovata (Fabricius, 1792)	11	4
Amara plebeja (Gyllenhal, 1810)	1	1
Amara similata (Gyllenhal, 1810)	8	5
Amara spreta Dejean, 1831	2	1
Amara tibialis (Paykull, 1798)	2	2
Asaphidion flavipes (Linnaeus, 1761)	1	1
Badister bullatus (Schrank, 1798)	8	5
Badister lacertosus Sturm, 1815	57	7
Badister sodalis (Duftschmid, 1812)	1	1
Bembidion lampros (Herbst, 1784)	3	2
Bembidion neresheimeri J. Müller, 1929	2	2
Bembidion properans (Stephens, 1828)	1	1
Calathus erratus (C.R. Sahlberg, 1827)	3	3
Calathus fuscipes (Goeze, 1777)	2	2
Calathus micropterus (Duftschmid, 1812)	540	25
Callistus lunatus (Fabricius, 1775)	14	1

Calosoma inquisitor (Linnaeus, 1758)	2	2
Calosoma sycophanta (Linnaeus, 1758)	1	1
Carabus cancellatus Illiger, 1798	93	9
Carabus coriaceus Linnaeus, 1758	4	1
Carabus glabratus Paykull, 1790	297	13
Carabus granulatus Linnaeus, 1758	53	11
Carabus hortensis Linnaeus, 1758	644	12
Carabus stscheglowi Mannerheim, 1827	2	2
Carabus convexus Fabricius, 1775	23	3
Cychrus caraboides (Linnaeus, 1758)	12	6
Cymindis vaporariorum (Linnaeus, 1758)	24	5
Elaphrus cupreus Duftschmid, 1812	1	1
Harpalus calceatus (Duftschmid, 1812)	2	1
Harpalus distinguendus (Duftschmid, 1812)	6	3
Harpalus laevipes Zetterstedt, 1828	115	16
Harpalus latus (Linnaeus, 1758)	71	15
Harpalus luteicornis (Duftschmid, 1812)	33	4
Harpalus progrediens Schauberger, 1922	21	5
Harpalus rubripes (Duftschmid, 1812)	2	2
Harpalus rufipes (De Geer, 1774)	26	8
Harpalus signaticornis (Duftschmid, 1812)	4	3
Harpalus tardus (Panzer, 1796)	66	3
Harpalus xanthopus winkleri Schauberger, 1923	17	4
Harpalus zabroides Dejean, 1829	1	1
Leistus terminatus (Panzer, 1793)	3	2
Licinus depressus (Paykull, 1790)	23	5
Limodromus assimilis (Paykull, 1790)	11	1
Limodromus krynickii (Sperk, 1835)	3	2
Loricera pilicornis (Fabricius, 1775)	16	3
Microlestes minutulus (Goeze, 1777)	4	1
Notiophilus aquaticus (Linnaeus, 1758)	3	2
Notiophilus germinyi Fauvel, 1863	4	3
Notiophilus palustris (Duftschmid, 1812)	27	6
Olisthopus rotundatus (Paykull 1790)	1	1
Oxypselaphus obscurus (Herbst, 1784)	311	19
Panagaeus bipustulatus (Fabricius, 1775)	16	6
Panagaeus cruxmajor (Linnaeus, 1758)	2	1
Patrobus atrorufus (Strøm, 1768)	3	3
Platynus livens (Gyllenhal, 1810)	1	1
Poecilus cupreus (Linnaeus, 1758)	3	3
Poecilus lepidus (Leske, 1785)	71	7
Poecilus versicolor (Sturm, 1824)	31	6
Pterostichus anthracinus (Illiger, 1798)	1	1
Pterostichus diligens (Sturm, 1824)	13	5
Pterostichus gracilis (Dejean, 1828)	7	1
Pterostichus melanarius (Illiger, 1798)	872	20
Pterostichus minor (Gyllenhal, 1827)	21	5
Pterostichus niger (Schaller, 1783)	924	30
Pterostichus nigrita (Paykull, 1790)	25	10
Pterostichus oblongopunctatus (Fabricius, 1787)	1281	29
Pterostichus quadrifoveolatus Letzner, 1852	8	4
Pterostichus rhaeticus Heer, 1837	4	1
Pterostichus strenuus (Panzer, 1796)	72	10
Pterostichus vernalis (Panzer, 1796)	9	4
Stomis pumicatus (Panzer, 1796)	6	5
Syntomus foveatus (Geoffroy, 1785)	2	1
Synuchus vivalis (Illiger, 1798)	19	5
Trechus secalis (Paykull, 1790)	75	11
Total	**6229**	**32**

The most frequently encountered species were *Pterostichus niger, P. oblongopunctatus, Calathus micropterus, P. melanarius, Oxypselaphus obscurus,* and *Amara communis*. The dominant species in terms of total abundance were *P. oblongopunctatus, P. niger, P. melanarius, Carabus hortensis, Calathus micropterus, O. obscurus,* and *Carabus glabratus*. A significant proportion of species (26 species, or 28%) were recorded at only one of the sampled trap lines, and 15 species were represented by a single individual in the entire collection.

Most of the recorded species are widespread throughout the forest zone of European Russia, both to the west and to the east of the study area. Among the species restricted to the forest-steppe zone, *Carabus stscheglowi* should be noted. Also of particular interest is the finding of *Calosoma sycophanta*, a species listed in the Red Data Book of the Russian Federation.

In terms of biotopic preference, the majority of recorded species inhabit a wide range of forested or open habitats. The number of species associated with forest habitats and open habitats is nearly equal, comprising 43% and 40% of the total species richness, respectively. However, in terms of total abundance, forest-dwelling species clearly dominate, accounting for 88% of all specimens collected. Species restricted to specific habitats include wetland and bog specialists such as *Agonum lugens*, *Limodromus krynickii*, *Platynus livens*, and *Pterostichus rhaeticus*.

Regarding the spectrum of life forms, the most abundant categories were stratobiont soil-burrowing zoophages (18%), large epigeobiont walkers (18%), and litter-dwelling stratobionts (13%). Mixophytophagous species accounted for only 9% of total abundance, though they represented 33% of the total species diversity.

At the individual biotopes surveyed throughout the entire season, between 29 and 41 species were recorded (Table 2). Notably, despite a shared set of dominant species, the sites exhibit substantial differences in species composition (Figs. 1, 2). Of the 72 species found across these five plots, only 9 were detected at all of them.

Plot 4 is characterized by the dominance of *Poecilus lepidus* (23%), a species typical of open habitats, along with a significant presence of other open-habitat carabids such as *Harpalus latus, H. signaticornis,* and *H. rufipes*. This site exhibited the highest species richness, the lowest overall abundance, minimal dominance, and the highest values for equitability and the Shannon diversity index.

In contrast, the remaining sites were dominated by forest species, primarily *Pterostichus oblongopunctatus* and *Carabus hortensis.* Plot 2 stood out for its reduced abundance of *P. oblongopunctatus* (11% of specimens) and lower total beetle abundance. Plot 3 was distinguished by a high relative abundance of *Carabus glabratus* (18%).

Plots 5 and 1 were very similar in terms of dominant species, but Plot 5 was enriched with several meadow-steppe species and was the only site where *Carabus stscheglowi* was recorded. Along the gradient from Plot 1 to Plot 4 (Fig. 1), the proportion of open-habitat species increases, while the abundance of *P. oblongopunctatus* and *C. granulatus decreases*.

Table 2. Abundance and occurrence of Carabidae in the forests of Sursky State Nature Sanctuary (summary data for 2023).

Feature	plot 1	plot 2	plot 3	plot 4	plot 5
Number of species	29	33	37	41	36
Number of individuals	850	413	833	274	856
Berger-Parker	0.32	0.28	0.30	0.23	0.31
Simpson_1-D	0.80	0.86	0.84	0.92	0.82
Shannon_H	2.01	2.49	2.33	3.17	2.18
Equitability_J	0.60	0.71	0.64	0.85	0.61

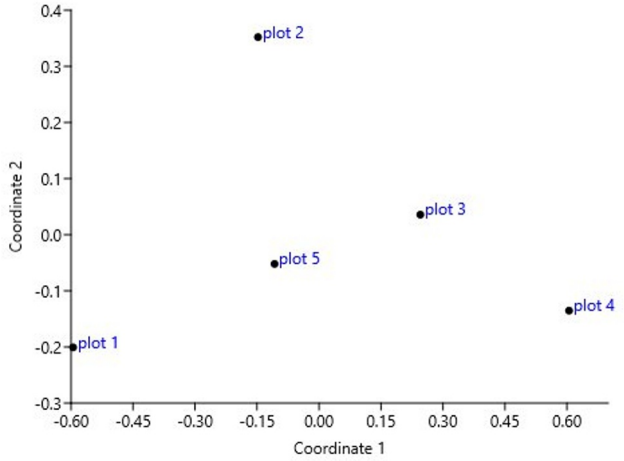

Fig. 1. NMDS ordination of carabid assemblages in Sursky State Nature Sanctuary. Jaccard index.

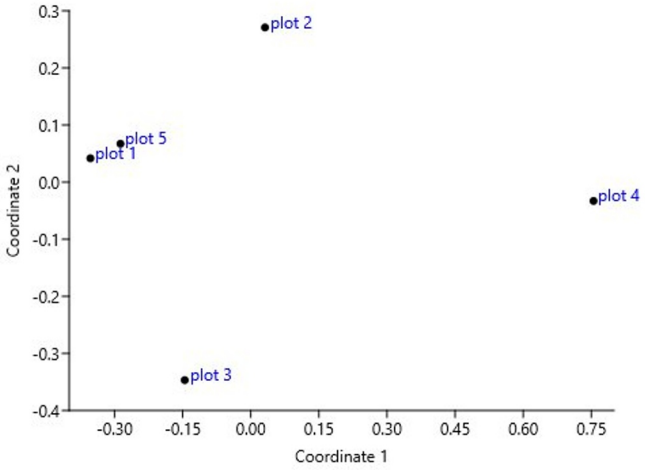

Fig. 2. NMDS ordination of carabid assemblages in Sursky State Nature Sanctuary. Bray – Curtis index.

4 Discussion

When comparing the obtained results with data on Carabidae from natural complexes of comparable size in adjacent regions, it can be assumed that the species count for the Sursky State Nature Sanctuary is likely to increase with continued research. This particularly applies to dendrobionts and geobionts, which are poorly represented in pitfall trap samples, as well as species inhabiting non-forested environments, especially riverbanks. Nevertheless, the collected material has made it possible to identify the main characteristics of the Carabidae fauna and population structure within the study area.

In terms of life-form spectrum, ecological group composition, dominant species, and diversity indices, the studied biotopes are typical of forest habitats on the East European Plain [10,11]. However, compared to more western regions, the forests examined here show a notably lower abundance of mesohygrophilous species that typically dominate in

broadleaf forests – such as *Carabus coriaceus*, *C. granulatus*, and *Limodromus assimilis*. The registration of *Carabus coriaceus* in this study represents one of the species' easternmost known occurrences. Wetland and moist forest specialists were extremely scarce.

Likewise, the community of dry pine forest inhabitants was poorly represented. Of these, *Cymindis vaporariorum* was the most frequently encountered, *Amara brunnea* was rare, and *Carabus arvensis* (Herbst, 1784) was entirely absent. Notably, *Carabus glabratus*, which is typically associated with well-drained upland forests in boreal and boreo-nemoral zones, was found to prefer the wettest alder-dominated site in a topographic depression within SSNS. This pattern may reflect a zonal shift in habitat associations along a longitudinal gradient moving eastward.

5 Conclusion

The Carabidae assemblages in the Sursky State Nature Sanctuary are composed of species that are widespread and typical of forest ecosystems on the East European Plain. In terms of structural characteristics, these assemblages are also representative of forest habitats within this region. At the same time, they are of particular interest and merit conservation attention, as they are situated along the southeastern boundary of the boreo-nemoral forest range. Forest-steppe species also warrant continued monitoring and protection.

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