Eurasia Specialized Veterinary Publication

Entomology Letters

ISSN:3062-3588

2022, Volume 2, Issue 1, Page No: 1-11

Available online at: www.esvpub.com/

The Fauna and Diversity of Ground Beetles (Coleoptera, Carabidae) in Meadow Ecosystems

Alexander Ruchin[1]*, Sergei Alekseev[2], Anatoliy Khapugin[1], Mikhail Esin[1]

[1]Joint Directorate of the Mordovia State Nature Reserve and National Park «Smolny», Saransk, Republic of Mordovia, Russia.
[2]Ecological club «Stenus», Kaluga, Kaluga region, Russia.

***E-mail** ✉ ruchin.alexander@gmail.com

ABSTRACT

The diversity of ground beetles (Carabidae) was analyzed in meadow ecosystems within central European Russia, focusing on the Nizhniy Novgorod region and the Republic of Mordovia. 17 sites were investigated, with the meadows categorized into 4 types: wet floodplain meadows, dry meadows, dry meadows near forest shelter-belts, and floodplain meadows impacted by livestock grazing. The highest species diversity was observed in dry meadows near forest shelter belts (65 species) and wet floodplain meadows (62 species), while floodplain meadows affected by grazing had the lowest species (24 species). A total of 40 ground beetle species were recorded in dry meadows. Wet floodplain meadows showed the highest Shannon index and the lowest Simpson index. In contrast, dry meadows showed high values for the Simpson and Berger-Parker indices. In these meadows, only 2 species were dominant, while other habitats had 4 to 7 dominant species. Based on the Jaccard similarity index, dry meadows and those adjacent to forest shelter belts had the most similar ground beetle species composition. Livestock trampling was found to significantly reduce the number and diversity of ground beetles, especially in floodplain meadows affected by grazing.

Keywords: Species, Abundance, Ground beetle, Fauna, Meadows

Received: 09 January 2022
Revised: 28 February 2022
Accepted: 03 March 2022

How to Cite This Article: Ruchin A, Alekseev S, Khapugin A, Esin M. The Fauna and Diversity of Ground Beetles (Coleoptera, Carabidae) in Meadow Ecosystems. Entomol Lett. 2022;2(1):1-11.
https://doi.org/10.51847/xiIPPVCe56

Introduction

Meadows are vegetative landscapes dominated by perennial herbaceous plants, primarily grasses, and sedges, typically thriving in areas with adequate or abundant moisture. These ecosystems are defined by the presence of turf and plant stands. Meadows can be grouped into three primary categories based on their geographic location. Continental meadows, found in plains outside river floodplains, are further classified into dry and lowland types. Floodplain meadows, which occur in river valleys, are periodically flooded during seasonal high waters. Mountain meadows are located above the forest's upper boundary. Across various regions globally, meadows support a diverse array of perennial plant species [1], including those that are endangered [2] and invasive [3]. These habitats serve as crucial environments for numerous species, including birds [4], mammals [5, 6], reptiles [7], invertebrates [8-10], and more. The recovery potential of different meadow types after disturbances varies, with carbon stock levels playing a significant role in this process [11, 12]. Over the centuries, human activities such as uncontrolled grazing, agricultural practices, afforestation, and urban expansion have severely impacted meadows, leading to a reduction in their natural coverage [13].

Recent modifications in open biocenoses, such as meadows, steppes, and pastures, have been observed across various regions globally [14-18]. The transformation of vegetation cover increasingly affects the ground beetle fauna in these biocenoses, which serve as bioindicators of ecosystem health [19-22]. These ground-dwelling organisms are found in large numbers across diverse landscapes (both open and closed), including areas with varying degrees of disturbance. Over the past few decades, human activities have significantly altered meadow ecosystems, with high rates of destruction caused by factors like annual grass fires, excessive land plowing, overgrazing, uncontrolled haying, and afforestation of meadows and fields [23-26]. These environmental impacts disrupt natural habitats, foster the development of secondary forest communities, and lead to shifts in the geographic distribution and population structures of some ground beetle species [16, 27-32]. This research focuses on the ground beetle fauna in meadow ecosystems located in central European Russia.

Materials and Methods

Description of biotopes

All biotopes were categorized into four groups based on moisture levels, proximity to forests or afforestation (within 100 meters), and anthropogenic influences such as grazing by livestock.

I – Dry meadows. These habitats consist of grazed meadows and abandoned fields found on dry, sandy soils, exhibiting a noticeable level of aridity. Common plant species in these areas include *Calamagrostis epigejos*, *Achillea millefolium*, *Bromus inermis*, *Trifolium arvense*, *Trifolium pratense*, *Artemisia vulgaris*, *Lathyrus pratensis*, *Leucanthemum vulgare*, *Matricaria matricarioides*, *Dactylis glomerata*, *Cirsium arvense*, *Agrimonia eupatoria*, *Cichorium intybus*, *Pimpinella saxifraga*, *Astragalus danicus*, *Fragaria viridis*, and *Carex spicata*.

II – Dry meadows near forest shelter belts. These are similar to dry meadows but are distinguished by the presence of Betula-dominated or mixed shelter belts situated 30-50 meters away from the meadows. Plant species identified here include *Cirsium arvense*, *Consolida regalis*, *Achillea millefolium*, *Matricaria matricarioides*, *Calamagrostis epigejos*, *Bromus inermis*, *Thlaspi arvense*, *Brassica rapa*, *Polygonum aviculare*, *Cyanus segetum*, *Leucanthemum vulgare*, *Viola arvensis*, and *Phleum pratense*.

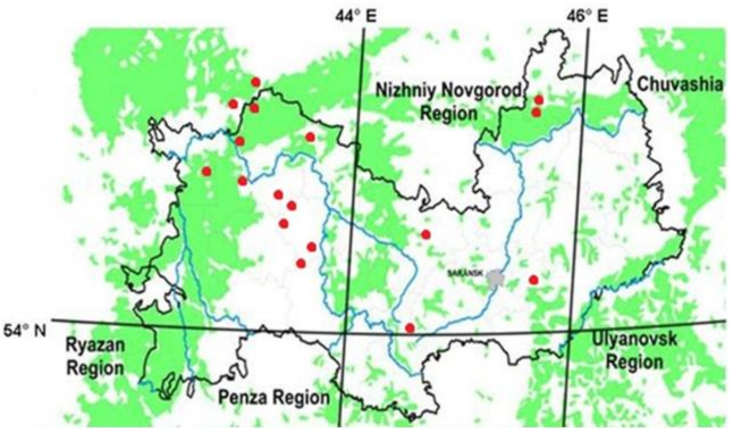
III – Wet floodplain meadows. Found in floodplains of small streams and rivers, these meadows are situated on relatively moist sandy and sandy-loam soils. The species present in these habitats include *Rumex confertus*, *Taraxacum officinale*, *Carex spicata*, *Carex vulpina*, *Agrimonia eupatoria*, *Bromus inermis*, *Tussilago farfara*, *Dactylis glomerata*, *Cichorium intybus*, *Stellaria media*, *Echium vulgare*, *Scorzoneroides autumnalis*, *Trifolium hybridum*, *Alchemilla* species, *Scirpus sylvaticus*, and *Carex acuta*.

IV – Floodplain meadows influenced by livestock grazing. These habitats are similar to wet floodplain meadows but differ due to greater soil compaction caused by grazing, which affects both the soil and vegetation cover.

Scientific names were referenced from The PlantList database (http://www.theplantlist.org/).

Collection methods

We gathered data using pitfall traps from April to September in the years 2009, 2010, 2014, and 2019. The traps used were 0.5-liter cups filled with a 4% formalin solution. Each site contained ten traps arranged in a single row, spaced 2 to 3 meters apart. A total of 17 sites in the Nizhniy Novgorod region and the Republic of Mordovia were surveyed **(Figure 1)**. At each site, only one line of ten traps was set up for the study.



a)

b)

Figure 1. Study territory; places, where material is collected, are indicated by red dots.

Data analysis

The diversity of ground beetles in the ecosystems was assessed using two diversity indices: the Shannon-Wiener index (H'), which gives equal weight to both rare and common species, and Simpson's index (1-D), which is more sensitive to variations in the most abundant species [33]. The evenness of the beetle populations across the five sampling locations was determined using the Berger and Parker index. Data analysis was conducted using Microsoft Excel, with average values presented in the tables.

A total of over 3,400 specimens were collected over 4,750 trap days. To quantify species abundance, we categorized the species as follows: dominant species (abundance > 5%), subdominant species (abundance between 2% and 5%), moderately abundant species (abundance between 1% and 2%), and rare species (abundance < 1%). Beetle density was measured as the number of beetles captured per one hundred traps per day (exemplars/100 trap-days).

The identification of ground beetle species was performed using the identification keys from the studies by Kryzhanovskij [34], and Kryzhanovskij [35]. The Carabidae classification followed the system provided by the Zoological Institute of the Russian Academy of Sciences [36], supplemented by the catalog of Kryzhanovskij *et al*. [37]. Nomenclature was based on the catalog of Palearctic beetles [38]. Species marked with an asterisk (*) indicate those that were recorded for the first time in the Republic of Mordovia. The collected material is preserved in the Mordovia State Nature Reserve's collection in Pushta, Russia.

Results and Discussion

In total, 110 species of ground beetles from 35 genera were recorded across all meadows **(Table 1)**. 4 species were newly identified in the Republic of Mordovia. The genera Amara (19 species), Harpalus (15 species), and Pterostichus (12 species) contained the highest number of species. Many of these species are typical of broad Holarctic and Palearctic distributions. The majority of the collected beetles were common and abundant species found in the forest-steppe zone of European Russia.

Table 1. The fauna and dynamic density (ex./100 trap-days) of species collected in four types of meadow biotopes

Species	Dry meadows	Dry meadows adjacent to forest shelter-belts	Wet floodplain meadows	Floodplain meadows affected by livestock grazing
Cicindelinae				
Cylindera germanica (Linnaeus, 1758)		7.58		
Cicindela campestris Linnaeus, 1758	0.07			0.61
Carabinae				
Leistus ferrugineus (Linnaeus, 1758)		0.08		
Notiophilus germinyi Fauvel, 1863		0.33		

Loricera pilicornis (Fabricius, 1775)		0.08	1.05	
Clivina fossor (Linnaeus, 1758)			0.07	
Calosoma maderae (Fabricius, 1775)		0.25		
Carabus cancellatus Illiger, 1798	0.07	0.33	0.46	
Carabus clathratus Linnaeus, 1761	0.07		0.13	
Carabus glabratus Paykull, 1790			0.13	
Carabus granulatus Linnaeus, 1758			1.96	
Trechus secalis (Paykull, 1790)	0.07	0.67	1.18	
Trechus quadristriatus (Schrank, 1781)		0.17		
Bembidion biguttatum (Fabricius, 1779)			1.70	
Bembidion dentellum (Thunberg, 1787)			1.24	
Bembidion gilvipes Sturm, 1825			0.07	
Bembidion lampros (Herbst, 1784)		0.25	0.13	
Bembidion properans (Stephens, 1828)		2.08	0.78	
**Bembidion schuppelii* Dejean, 1831			0.72	
Bembidion quadrimaculatum (Linnaeus, 1760)		1.17		
Patrobus atrorufus (Ström, 1768)		0.08	0.07	
Stomis pumicatus (Panzer, 1796)		0.08	0.26	
Poecilus cupreus (Linnaeus, 1758)	0.15	5.25	2.03	0.45
Poecilus lepidus (Leske, 1785)	0.22	0.83		
Poecilus sericeus Fischer von Waldheim, 1824	0.07			
Poecilus versicolor (Sturm, 1824)	6.76	1.58	4.44	1.06
Pterostichus anthracinus (Illiger, 1798)			13.46	
**Pterostichus cursor* (Dejean, 1828)			0.13	
Pterostichus gracilis (Dejean, 1828)			4.90	0.15
Pterostichus macer (Marsham, 1802)		0.17		
Pterostichus mannerheimii (Dejean, 1831)			0.13	
Pterostichus melanarius (Illiger, 1798)	0.07	13.08	5.75	
Pterostichus minor (Gyllenhal, 1827)	0.07		0.39	
Pterostichus niger (Schaller, 1783)	0.07	0.17	1.44	
Pterostichus nigrita (Paykull, 1790)			3.20	
Pterostichus oblongopunctatus (Fabricius, 1787)	0.15	0.42		
Pterostichus strenuus (Panzer, 1796)		0.08	0.46	
Pterostichus vernalis (Panzer, 1796)			1.96	
Calathus erratus (C. Sahlberg, 1827)	1.25	13.25		3.79
Calathus fuscipes (Goeze, 1777)	2.94	3.83	3.01	0.61
Calathus melanocephalus (Linnaeus, 1758)	1.32	3.33	1.31	2.27
Dolichus halensis (Schaller, 1783)		0.08		
Limodromus krynickii (Sperk, 1835)		0.17		
Agonum duftschmidi J. Schmidt, 1994			3.07	
Agonum fuliginosum (Panzer, 1809)		1.92	0.13	
Agonum viduum (Panzer, 1796)			0.33	
Oxypselaphus obscurus (Herbst, 1784)		0.58	0.39	
Synuchus vivalis (Illiger, 1798)		0.25	0.20	
Amara aenea (De Geer, 1774)	0.81	2.92	0.33	1.36
Amara apricaria (Paykull, 1790)		0.25		
Amara aulica (Panzer, 1796)	0.22	0.08	0.72	

Amara bifrons (Gyllenhal, 1810)		2.42	0.07	
Amara communis (Panzer, 1797)	1.25		4.12	0.76
Amara consularis (Duftschmid, 1812)		0.67	0.07	
Amara equestris (Duftschmid, 1812)	8.24	2.08	0.65	3.03
Amara eurynota (Panzer, 1796)		0.08		
Amara fulva (Müller, 1776)				0.15
Amara ingenua (Duftschmid, 1812)	0.22			0.30
Amara littorea C.G. Thomson, 1857		0.08		
Amara montivaga Sturm, 1825		1.08		
Amara nitida Sturm, 1825	0.07	0.08		
Amara ovata (Fabricius, 1792)		20.58		0.15
Amara plebeja (Gyllenhal, 1810)	0.07		0.13	
Amara praetermissa (C. Sahlberg, 1827)			0.07	
Amara similata (Gyllenhal, 1810)		0.67		
Amara spreta Dejean, 1831			0.13	
Amara tibialis (Paykull, 1798)		0.08		
Acupalpus meridianus (Linnaeus, 1761)			0.07	
Anisodactylus binotatus (Fabricius, 1787)	0.07			
Anisodactylus nemorivagus (Duftschmid, 1812)		5.25		
Anisodactylus signatus (Panzer, 1796)		0.08		0.61
Harpalus affinis (Schrank, 1781)	0.59	0.92		1.06
Harpalus calathoides Motschulsky, 1844				1.36
Harpalus calceatus (Duftschmid, 1812)		0.17		
Harpalus distinguendus (Duftschmid, 1812)	0.66	0.67		
Harpalus griseus (Panzer, 1796)			0.07	
Harpalus latus (Linnaeus, 1758)	2.94	0.08	1.31	
Harpalus luteicornis (Duftschmid, 1812)		0.17		
Harpalus progrediens Schauberger, 1922	0.37			0.91
Harpalus pumilus Sturm, 1818		0.08		
Harpalus rubripes (Duftschmid, 1812)	0.59	3.25	0.59	1.21
Harpalus rufipes (DeGeer, 1774)	0.74	1.75	2.42	1.52
Harpalus smaragdinus (Duftschmid, 1812)				0.45
Harpalus tardus (Panzer, 1796)				0.45
Harpalus xanthopus winkleri Schauberger, 1923	0.07	3.67	2.16	
Harpalus zabroides Dejean, 1829		0.17		
Ophonus azureus (Fabricius, 1775)		2.08		
Ophonus cordatus (Duftschmid, 1812)	0.07	4.08		
**Ophonus diffinis* (Dejean, 1829)		0.33		
Ophonus puncticeps Stephens, 1828	0.07			
Ophonus rufibarbis (Fabricius, 1792)			0.20	0.15
Ophonus stictus Stephens, 1828	0.07			
**Ophonus subquadratus* (Dejean, 1829)		11.83		
Panagaeus bipustulatus (Fabricius, 1775)	0.07	3.50	0.07	0.15
Panagaeus cruxmajor (Linnaeus, 1758)			0.13	
Callistus lunatus (Fabricius, 1775)	0.15			
Chlaenius nigricornis (Fabricius, 1787)			5.82	
Oodes helopioides (Fabricius, 1792)			0.13	

Licinus depressus (Paykull, 1790)	0.07	0.17	0.59	
Badister bullatus (Schrank, 1798)		0.58		
Badister lacertosus Sturm, 1815			0.72	
Badister meridionalis Puel, 1925		0.50		
Badister peltatus (Panzer, 1796).			0.26	
Badister unipustulatus Bonelli, 1813		0.17	3.86	
Lebia chlorocephala (Hoffmann, 1803)	0.07	0.08	0.07	
Lebia cruxminor (Linnaeus, 1758)	0.66	0.08	0.07	
Philorhizus sigma (Rossi, 1790)			0.07	
Microlestes maurus (Sturm, 1827)			0.13	
Microlestes minutulus (Goeze, 1777)	0.22			
Cymindis angularis Gyllenhal, 1810	0.07			0.15
Total number of exemplars	433	1547	1249	150
Shannon index	2.52	3.14	3.29	2.78
Simpson index (1–D)	0.14	0.07	0.06	0.08
Berger and Parker index	0.26	0.16	0.16	0.17
Number of species	40	65	62	24

In the studied meadow biocenoses, only 9 ground beetle species were recorded, making up 8.2% of the total fauna. These included *Poecilus cupreus*, *Poecilus versicolor* (a meadow mesophile), *Amara equestris*, *Amara aenea*, *Harpalus rufipes*, *Harpalus rubripes*, *Calathus melanocephalus*, *Calathus fuscipes*, and *Panagaeus bipustulatus*, all of which are eurybionts. Additionally, 54 species (49.1%) were exclusive to a single meadow type.

The abundance and dominance of species varied across biocenoses. In dry meadows, *Amara equestris* and *Poecilus versicolor* were the most prevalent, comprising 25.9% and 21.2% of the population, respectively. Together, these two species accounted for nearly half of the beetle specimens in dry meadows by numerical abundance. This pattern was also evident in the dominance index results.

In dry meadows near forest shelter belts, 4 dominant species were recorded: Amara ovata (16.0%), Pterostichus melanarius (10.1%), Ophonus subquadratus (9.2%), and Calathus erratus (10.3%). All of these species are meadow mesoxerophiles and eurybionts. In wet floodplain meadows, five species dominated: *Pterostichus anthracinus* (16.5%), *Pterostichus melanarius* (7.0%), *Pterostichus gracilis* (6.0%), *Chlaenius nigricornis* (7.1%), and *Poecilus versicolor* (5.4%), with forest species also present. In floodplain meadows influenced by livestock grazing, seven species were most abundant: *Amara equestris* (13.3%), *Harpalus rufipes* (6.7%), *Harpalus rubripes* (5.3%), *Amara aenea* (6.0%), *Harpalus calathoides* (6.0%), *Calathus erratus* (16.7%), and *Calathus melanocephalus* (10.0%). The diverse range of dominant and subdominant species (which are not listed here) highlights the richness of species in these communities, reflecting a varied ground beetle population structure.

The number of ground beetle species in individual meadow biocenoses ranged from 24 to 65 **(Table 1)**. The wet floodplain meadows showed the highest Shannon index, indicating maximum species diversity with the lowest Simpson index, signifying minimal species dominance at this site **(Table 1)**. A similarly high Shannon index was observed in dry meadows near forest shelter belts, while the dry meadows had the lowest value for this index.

An increase in the Simpson index and Berger-Parker index reflects a decline in biocenose diversity and a rise in the dominance of specific species [39]. In dry meadows, a notable rise in these indices was observed, indicating a significant reduction in biodiversity and a higher dominance of 1–2 species, compared to dry meadows near forest shelter-belts. As mentioned previously, *Amara equestris* and *Poecilus versicolor* were the dominant species in this case.

Cluster analysis, utilizing the Jaccard similarity index, revealed that dry meadows and dry meadows near forest shelter belts had the most similar ground beetle species composition **(Figure 2)**. The species count in dry meadows was 40, whereas it was significantly higher in the meadows near the shelter belts, with 65 species **(Table 1)**. Despite the differences in the fauna of these biotopes, this similarity can be attributed to the presence of certain species that prefer to remain under tree canopies and do not migrate toward open meadows. Floodplain meadows impacted by livestock grazing showed the most distinct difference from all other meadow types. The intense grazing pressure significantly alters the ground beetle fauna in these areas.

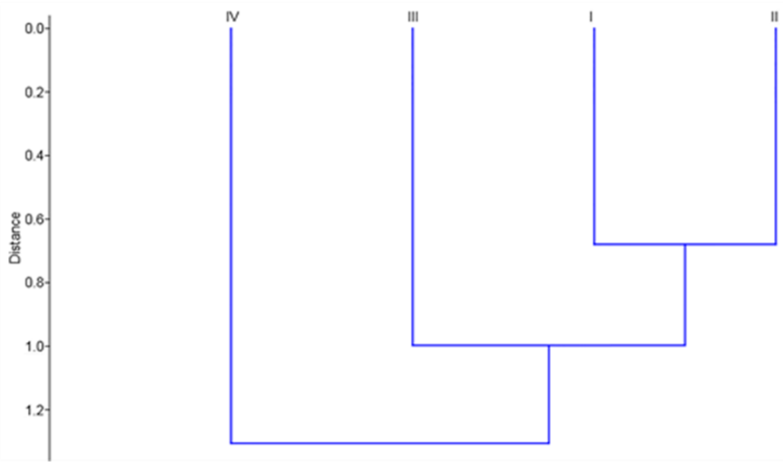


Figure 2. The similarity of four meadow biotope types based on the jacquard index; I: dry meadows; II: dry meadows adjacent to forest shelter-belts; III: wet floodplain meadows; IV: floodplain meadows affected by livestock grazing

The genera *Amara*, *Harpalus*, and *Pterostichus* exhibited notable species diversity, with a total of 46 species represented. A similar trend was observed in meadow biotopes across northern and southwestern European Russia [40]. Data analysis revealed that, in the formation of ground beetle populations, the primary influence comes from species groups associated with open habitats, such as meadows, meadow fields, and fields.

Dry meadows stand out from other biotopes studied due to their distinct moisture conditions. These meadows are relatively drier, which allows herbaceous Poaceae species, as well as weed species, to thrive more abundantly. Typically, these meadows are not mowed and are not used for grazing. Under these conditions, the ground beetle species composition is dominated by species from the meadow complex and eurybionts [40]. Our findings aligned with these observations.

Forest edges and shelter belts influence insect diversity by providing additional habitats, including summer hibernation sites, wintering grounds, mating areas, and feeding locations. These ecotones can limit migration and alter the daily and seasonal movements of insects. Consequently, the species diversity of insects near forest biotopes is typically higher [41-43]. Our study confirmed this trend, as the presence of forest shelter belts near dry meadows significantly enhanced the species diversity of ground beetles, which utilize these shelter belts for various life processes.

In our study, wet floodplain meadows had a well-developed herbaceous layer and moderate moisture levels. The species diversity of ground beetles was notably high, with 62 species identified. Similar species numbers were observed in floodplain meadows in Belarus [44], the Kirov region of Russia [45], and Poland's Masovian Lowland [46]. However, floodplain meadows in the Ryazan region (central European Russia) exhibited even greater ground beetle diversity. Researchers linked this to the varied topography and the patchy nature of vegetation in that area [47]. The presence of habitats with different soil and plant characteristics allows for the migration and exchange of species, contributing to a higher diversity of ground beetles across various habitats [47]. In our study, the wet floodplain meadows were fairly uniform, with little variation in their plant diversity.

In central European Russia, floodplain meadows impacted by livestock grazing serve as summer pastures for herbivores, typically utilized throughout the growing season. Daily grazing leads to the gradual degradation of the meadow ecosystem. It is well-established that excessive soil pressure from grazing can cause significant damage to floodplain meadows, including physical compaction of the soil and partial destruction of vegetation cover [48, 49]. Additionally, the large volume of manure deposited in these areas can have varying impacts on different insect groups, though its effects are less pronounced than the damage caused by trampling [50]. We believe that the decline in species diversity of ground beetles in these biotopes is primarily due to the intense grazing pressure.

Conclusion

A total of 110 ground beetle species across 35 genera were recorded in the meadow biocenoses of the Nizhniy Novgorod region and the Republic of Mordovia. The genera Amara, Harpalus, and Pterostichus showed the greatest species diversity. Eurybionts and meadow species formed the core of the meadow carabid fauna. The greatest diversity was observed in dry meadows near forest shelter belts and wet floodplain meadows. Forest shelter belts introduced a level of habitat variability in otherwise uniform meadows, boosting both species richness and beetle population density. Wet floodplain meadows, with their dense herbaceous layers and higher moisture levels, also supported greater species diversity of ground beetles. In contrast, floodplain meadows impacted by livestock grazing exhibited the fewest species, likely due to the damaging effects of trampling and soil degradation.

In wet floodplain meadows, the Shannon index was the highest, and the Simpson index was the lowest, indicating the greatest species diversity and minimal dominance. Dry meadows, however, exhibited higher Simpson and Berger-Parker indices, with only two species showing dominance. Other meadow types saw dominance from 4 to 7 species. This variety in dominant species suggests a high species abundance and diversity within these biotopes. The Jaccard similarity index revealed that dry meadows and those near forest shelter belts shared the most similar ground beetle species composition, while floodplain meadows subjected to grazing stood apart from all other biotopes.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Mseja GA, Furael BB, Lyakurwa GJ, Martin EH. Herbaceous vegetation communities around lake Manyara, Tanzania: response to environmental gradients. Nat Conserv Res. 2020;5(4):55-64. doi:10.24189/ncr.2020.056
2. Suleymanova GF, Boldyrev VA, Savinov VA. Post-fire restoration of plant communities with Paeonia tenuifolia in the Khvalynsky National Park (Russia). Nat Conserv Res. 2019;4(Suppl.1):57-77. doi:10.24189/ncr.2019.048
3. Dubovik DV, Skuratovich AN, Miller D, Spiridovich EV, Gorbunov YuN, Vinogradova YuK. The invasiveness of Solidago canadensis in the Sanctuary «Prilepsky» (Belarus). Nat Conserv Res. 2019;4(2):48-56. doi:10.24189/ncr.2019.013
4. Assandri G, Bogliani G, Pedrini P, Brambilla M. Species-specific responses to habitat and livestock management call for carefully targeted conservation strategies for declining meadow birds. J Nat Conserv. 2019;52:125757. doi:10.1016/j.jnc.2019.125757
5. Horncastle VJ, Chambers CL, Dickson BG. Grazing and wildfire effects on small mammals inhabiting montane meadows. J Wildl Manage. 2019;83(3):534-43. doi:10.1002/jwmg.21635
6. Kerekes V, Ozogány K, Sándor I, Vegvari Z, Czető C, Nyírő B, et al. Analysis of habitat use, activity, and body condition scores of Przewalski's horses in Hortobagy National Park, Hungary. Nat Conserv Res. 2019;4(Suppl.2):31-40. doi:10.24189/ncr.2019.029
7. Bakiev AG, Gorelov RA, Klenina AA. Post-fire abundance and age composition dynamics of Lacerta agilis (Reptilia, Lacertidae) in the Orenburg State Nature Reserve (Russia). Nat Conserv Res. 2019;4(Suppl.1):105-9. doi:10.24189/ncr.2019.047
8. Hoyle H, Norton B, Dunnet N, Richards JP, Russell JM, Warren P. Plant species or flower colour diversity? Identifying the drivers of public and invertebrate response to designed and annual meadows. Landsc Urban Plan. 2018;180:103-13. doi:10.1016/j.landurbplan.2018.08.017
9. Uligova TS, Gedgafova FV, Gorobtsova ON, Tsepkova NL, Rapoport IB, Tembotov RKh, et al. Meadow biogeocenoses in the subalpine belt of the Kabardino-Balkaria State High-Mountain Reserve (Central Caucasus). Nat Conserv Res. 2019;4(2):29-47. doi:10.24189/ncr.2019.012 [in Russian]

10. Dedyukhin SV. Phytophagous beetles (Coleoptera: Chrysomelidae and Curculionoidea), protected and recommended for protection in the regions of the Middle Volga and the Urals. Nat Conserv Res. 2020;5(2):1-27. doi:10.24189/ncr.2020.013 [in Russian]
11. Gebremedihin KM, Birhane E, Tadesse T, Gbrewahid H. Restoration of degraded drylands through exclosures enhancing woody species diversity and soil nutrients in the highlands of Tigray, Northern Ethiopia. Nat Conserv Res. 2018;3(1):1-20. doi:10.24189/ncr.2018.001
12. Dusaeva GKh, Kalmykova OG, Dusaeva NV. Fire influence on dynamics of above-ground phytomass in steppe plant communities in the Burtinskaya Steppe (Orenburg State Nature Reserve, Russia). Nat Conserv Res. 2019;4(Suppl. 1):78-92. doi:10.24189/ncr.2019.050
13. Hurka H, Friesen N, Bernhardt KG, Neuffer B, Smirnov S, Shmakov A, et al. The Eurasian steppe belt: Status quo, origin and evolutionary history. Turczaninowia. 2019;22(3):5-71. doi:10.14258/turczaninowia.22.3.1
14. Tchabovsky A, Savinetskaya L, Surkova E. Breeding versus survival: proximate causes of abrupt population decline under environmental change in a desert rodent, the midday gerbil (Meriones meridianus). Integr Zool. 2019;14(4):366-70.
15. Fedorov NI, Zharkikh TL, Mikhailenko OI, Bakirova RT, Martynenko VB. Forecast changes in the productivity of plant communities in the Pre-Urals Steppe site of Orenburg State Nature Reserve (Russia) in extreme drought conditions using NDVI. Nat Conserv Res. 2019;4(Suppl.2):104-10. doi:10.24189/ncr.2019.044
16. Cicort-Lucaciu AȘ. Road-killed ground beetles prove the presence of Carabus hungaricus (Coleoptera: Carabidae) in North-Western Romania. Nat Conserv Res. 2020;5(3):134-8. doi:10.24189/ncr.2020.035
17. Perazza G, Decarli M. Monitoring of Cypripedium calceolus (Orchidaceae) in the Adamello-Brenta Natural Park (Italy). Nat Conserv Res. 2020;5(Suppl.1):178-84. doi:10.24189/ncr.2020.045
18. Bakka SV, Kiseleva NY, Shestakova AA. Current status, problems and prospects of conservation of meadow steppes in the Nizhny Novgorod region. IOP Conf Ser Earth Environ Sci. 2020;543(1):012014. doi:10.1088/1755-1315/543/1/012014
19. Rainio J, Niemelä J. Ground beetles (Coleoptera: Carabidae) as bioindicators. Biodivers Conserv. 2003;12(3):487-506. doi:10.1023/A:1022412617568
20. Venn SJ, Kotze DJ, Lassila T, Niemelä JK. Urban dry meadows provide valuable habitat for granivorous and xerophylic carabid beetles. J Insect Conserv. 2013;17(4):747-64. doi:10.1007/s10841-013-9558-8
21. Ruchin AB, Alekseev SK, Khapugin AA. Post-fire fauna of carabid beetles (Coleoptera, Carabidae) in forests of the Mordovia State Nature Reserve (Russia). Nat Conserv Res. 2019;4(Suppl.1):11-20. doi:10.24189/ncr.2019.009
22. Bondarenko AS, Zamotajlov AS, Belyi AI, Khomitskiy EE. Fauna and ecological characteristics of ground beetles (Coleoptera, Carabidae) of the Nature Sanctuaries «Prichernomorskiy» and «Tuapsinskiy» (Russia). Nat Conserv Res. 2020;5(3):66-85. doi:10.24189/ncr.2020.032
23. Dymitryszyn I. The effect of the construction and renovation of a highway bypass in Central Poland on the carabid beetle fauna (Coleoptera: Carabidae). Eur J Entomol. 2014;111(5):655-62. doi:10.14411/eje.2014.081
24. Kataev GD. The impact of industrial emissions of copper-nickel smelter complex on the status of populations and communities of small mammals in the Kola Peninsula. Nat Conserv Res. 2017;2(Suppl.2):19-27. doi:10.24189/ncr.2017.033 [in Russian]
25. Rozhnov VV, Lavrinenko IA, Razzhivin VYu, Makarova OL, Lavrinenko OV, Anufriev VV, et al. Biodiversity revision of a large arctic region as a basis for its monitoring and protection under conditions of active economic development (Nenetsky Autonomous Okrug, Russia). Nat Conserv Res. 2019;4(2):1-28. doi:10.24189/ncr.2019.015 [in Russian]
26. Ruchin AB, Alekseev SK, Semishin GB. Seasonal activity dynamics of imago Carabus coriaceus Linnaeus, 1758 (Coleoptera, Carabidae) in mixed forests. Proc Mordovia State Nat Reserve. 2019;23:239-44. [in Russian]
27. Desender K, Dekoninck W, Dufrêne M, Maes D. Changes in the distribution of carabid beetles in Belgium revisited: have we halted the diversity loss? Biol Conserv. 2010;143(6):1549-57. doi:10.1016/j.biocon.2010.03.039

28. Ruchin AB, Egorov LV. Overview of insect species included in the red data book of Russian Federation in the Mordovia State Nature Reserve. Nat Conserv Res. 2017;2(Suppl.1):2-9. doi:10.24189/ncr.2017.016 [in Russian].
29. Ruchin AB, Khapugin AA. Red data book invertebrates in a protected area of European Russia. Acta Zool Academ Sci Hung. 2019;65(4):349-70. doi:10.17109/AZH.65.4.349.2019
30. Zamotajlov AS, Serdyuk VYu, Khomitskiy EE, Belyi AI. New data on distribution and biology of some rare ground beetles (Coleoptera, Carabidae) in South Russia. Nat Conserv Res. 2019;4(4):81-90. doi:10.24189/ncr.2019.066 [in Russian]
31. Egorov LV, Ruchin AB, Semenov VB, Semionenkov OI, Semishin GB. Checklist of the Coleoptera of Mordovia State Nature Reserve, Russia. ZooKeys. 2020;962:13-122. doi:10.3897 /zookeys.962.54477
32. Nora AHN, Mohamed T, Tahar M, Abderrahmane L. Importance of low perennial plant formations to the sustainability of forest ecosystems in the Saida Mountains (Algeria). World J Environ Biosci. 2020;9(2):71-6.
33. Peet RK. The measurement of species diversity. Annu Rev Ecol Syst. 1974;5:285-307. doi:10.1146/annurev.es.05.110174.001441
34. Kryzhanovskij OL. Family Carabidae – Ground beetles. Determinant of the insects of the European part of the USSR. 1965;2:29-77. [in Russian].
35. Kryzhanovskij OL. Coleoptera. Beetles of the Suborder Adephaga: The Trachypachidae, Carabidae Families. Fauna of the USSR, 1 (2), Leningrad. 1983.
36. Makarov KV, Kryzhanovskij OL, Belousov IA, Zamotajlov AS, Kabak II, Kataev BM, et al. Systematic list of carabid beetles (Carabidae) of Russia. 2018. Available from: http://www.zin.ru/Animalia/Coleoptera/rus/car_rus.htm [Retrieved on 08.12.2019]. [in Russian]
37. Kryzhanovskij OL, Belousov IA, Kabak II, Kataev BM, Makarov KV, Shilenkov VG. A checklist of the ground-beetles of Russia and adjacent lands (Insecta, Coleoptera, Carabidae). Sofia – Moscow: PENSOFT Publishers; 1995. 271 p.
38. Löbl I, Löbl D. (Eds.). Catalogue of Palaearctic Coleoptera. Revised and updated revision. Vol. 1. Archostemata – Myxophaga – Adephaga. Lieden-Boston: Brill; 2017. 1443 p. doi:10.1163/9789004330290
39. Chifundera KZ. Using diversity indices for identifying the priority sites for herpetofauna conservation in the Democratic Republic of the Congo. Nat Conserv Res. 2019;4(3):13-33. doi:10.24189/ncr.2019.035
40. Bulokhova NA. Species composition and domination structure of ground beetles (Coleoptera, Carabidae) in meadow ecosystems of southwestern Russia (Bryansk Region). Entomolog Oboz. 1995;74(4):758-63. [in Russian]
41. Burgio G, Sommaggio D, Marini M, Puppi G, Chiarucci A, Landi S, et al. The influence of vegetation and landscape structural connectivity on butterflies (Lepidoptera: Papilionoidea and Hesperiidae), carabids (Coleoptera: Carabidae), syrphids (Diptera: Syrphidae), and sawflies (Hymenoptera: Symphyta) in Northern Italy Farmland. Environ Entomol. 2015;44(5):1299-307. doi:10.1093/ee/nvv105
42. Jahnová Z, Knapp M, Boháč J, Tulachová M. The role of various meadow margin types in shaping carabid and staphylinid beetle assemblages (Coleoptera: Carabidae, Staphylinidae) in meadow dominated landscapes. J Insect Conserv. 2016;20(1):59-69.
43. Allema B, Hemerik L, Rossing WAH, Groot JCJ, van Lenteren JC, van der Werf W. Dispersal of a carabid beetle in farmland is driven by habitat-specific motility and preference at habitat interfaces. Entomol Exp Appl. 2019;167(8):741-54. doi:10.1111/eea.12804
44. Solodovnikov IA. The ground beetles (Coleoptera, Carabidae) of Belarus Poozeriya with the catalogue of Carabidae of Belarus and adjacent countries. Vitebsk: Vitebsk State University Publisher; 2008. 325 p. [in Russian]
45. Tselishcheva LG. The spatial structure of populations of ground beetles (Coleoptera, Carabidae) in flood-plain communities of the Nurgush Nature Reserve. In: Potemkin NA, editor. Long-term processes in natural complexes of nature reserves of Russia. Velikie Luki (RU): Central Forest State Nature Reserve; 2012. p. 239–44.
46. Chechlowski W. Carabid beetles (Coleoptera, Carabidae) of moist meadow on the Mazovian Lowland. Memor Zool. 1989;43:141-67.

47. Trushitsyna OS, Matalin AV, Makarov KV. Long-term dynamics and spatial distribution of stable and labile components in ground beetle communities (Coleoptera: Carabidae) in a mosaic of flood-plain meadows. Period Biol. 2016;118(3):255-72. doi:10.18054/pb.2016.118.3.3928
48. Twardowski JP, Pastuszko K, Hurej M, Gruss I. Effect of different management practices on ground beetle (Coleoptera: Carabidae) assemblages of uphill grasslands. Pol J Ecol. 2017;65(3):400-9.
49. Fan F, Liang C, Tang Y, Harker-Schuch I, Porter JR. Effects and relationships of grazing intensity on multiple ecosystem services in the Inner Mongolian steppe. Sci Total Environ. 2019;675:642-50.
50. Lenoir L, Lennartsson T. Effects of timing of grazing on arthropod communities in semi-natural grasslands. J Insect Sci. 2010;10(1):60. doi:10.1673/031.010.6001