

Mordovia State Nature Reserve as a hotspot of invertebrate biodiversity (European Russia)

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Abstract. To study and conserve biological diversity is one of the most important tasks of protecting natural ecosystems. According to long-term data, the biodiversity of invertebrates of Mordovia State Nature Reserve accounts for 6823 species out of 10 types of invertebrates: Rhizopoda (58 species), Porifera (1), Platyhelminthes (156), Nematoda (67), Annelida (4), Acanthocephala (1), Mollusca (62), Bryozoa (1), Rotifera (80), and Arthropoda (6393). Thus, the Mordovia State Nature Reserve belongs to one of the hotspots of biodiversity in the forests of the temperate zone in European Russia. It is home to a large number of rare species and three endemic species. The protected area is connected by ecological corridors with other territories and can be a source of genetic and species diversity for nearby ecosystems.

1 Introduction

To study and conserve biological diversity is one of the most important tasks of protecting natural ecosystems. However, anthropogenic transformation of ecosystems as a result of climate change has recently had a significant impact on biodiversity [1-3]. Urbanization, the use of pesticides in agriculture, fires and other natural disasters, deforestation, fragmentation of landscapes has a direct and indirect impact on the decline of biodiversity [4-6]. Protected areas play a special role in the study and conservation of biodiversity as places of the greatest concentration of fauna and flora. For this reason, the value of protected areas is steadily increasing [7, 8].

To preserve biodiversity on a global scale, it is necessary to identify the main factors determining the distribution of species in habitats, their migrations, seasonal dynamics and other phenomena. Such studies can be carried out in areas that are little affected by humans, which are the protected area [9-11]. Studying the entire fauna and general monitoring is the best way to study biological diversity in protected area ecosystems. At the same time, such studies are fraught with difficulties due to a lack of human resources and researchers, and therefore certain insect families or ecological groups of animals and plants that are bioindicators are more often used [8, 12-14]. On the other hand, for a certain time, the analysis of biodiversity may well be performed, which is used to compile a checklist. This can be done only if the most diverse methods of study are applied, which could cover all

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ecological groups of invertebrates [15-18]. The result of such large-scale studies is the identification of biodiversity hotspots in certain climatic zones. Biodiversity hotspots are rich in rare and endemic species, but to one degree or another they may be threatened by anthropogenic impact. Therefore, in this case, they are considered a priority for preservation. Biodiversity conservation planning requires a whole range of efforts on the part of the conservation community [19-21].

2 Materials and methods

The Mordovia State Nature Reserve (MSNR) was established in 1936. It is located in the Temnikovsky district of the Republic of Mordovia on the border with the Nizhny Novgorod region (the center of European Russia; (54.42–54.56 N, 43.04–43.36 E; up to 190 m a.s.l.)). The area of the territory is 321.62 km². The northern border runs along the Satis River, the right tributary of the Moksha, further east – along the Arga River, which flows into the Satis River. The western border runs along the Chernaya, Satis and Moksha rivers.

The MSNR is a forest reserve. However, about a third of its territory was damaged by major fires in 2010 and 2021 [22]. According to the natural zoning, the MSNR forest area belongs to the zone of coniferous-deciduous forests. On the south side of the MSNR there is a forest-steppe. In general, the vegetation cover of MSNR has a taiga character with a certain attraction to the complex of broad-leaved forests. *Pinus sylvestris* is the main tree species in the MSNR. It forms pure or mixed plant communities in the southern, central and western parts. Forests of *Betula pendula* occupy the second place in the MSNR forest area and mainly grow on the sites of harems. The forest ecosystems of *Tilia cordata* are located in the northern and southwestern parts. These are secondary plant communities that have arisen on the site of pine forests and lime-spruce forests. *Quercus robur* L. grows in floodplains of rivers. Forests of *Picea abies* and *Alnus glutinosa* are located mainly in floodplains of small rivers and streams and occupy small areas. Meadow ecosystems are located along the Moksha River in the southwest. In the center of the forests, there are sometimes glades of different sizes.

The nature of MSNR has been studied since its inception. In the early years, large expeditions were conducted that covered the entire territory of MSNR. During this period, information has accumulated, which has been published in various publications. We have worked out all publications on invertebrate biodiversity of MSNR. My colleagues and I conducted our own research from 2007 to 2022. For these studies, many different ways of studying biodiversity were used, both stationary and seasonal, also we made small trips to the most distant habitats. All methods, both traditional and original, were also used to collect the material. All collected samples, as well as early publications by other authors, were viewed by specialists in their scientific fields using the most modern reference books.

3 Results

According to 85 years of research, the biodiversity of MSNR accounts for 6823 species from 10 types of invertebrates (18 classes and 53 orders): Rhizopoda (58 species), Porifera (1), Platyhelminthes (156), Nematoda (67), Annelida (4), Acanthocephala (1), Mollusca (62), Bryozoa (1), Rotifera (80), and Arthropoda (6393). At the same time, insects make up the bulk of terrestrial diversity, being considered the most important animals in terrestrial and aquatic ecosystems: the species abundance of this group includes 6094 species (Table 1).

Worms of these types Platyhelminthes, Nematoda, Annelida, Acanthocephala account for a small number of species out of all invertebrates. All currently registered species are representatives of the parasitic complex.

As Table 1 shows, many types of invertebrates are still poorly studied. This is especially relevant for soil Nematoda and aquatic invertebrates (for example, Rotifera and Crustacea).

Table 1. Invertebrate biodiversity of the Mordovia State Nature Reserve.

Phylum	Class	Order	Number of species
RHIZOPODA	Lobosea	Arcellinida	37
	Filosea	Gromiida	21
PORIFERA	Haplosclerida		1
PLATYHELMINTHES	Trematoda	Plagiorchiida	87
		Strigeidida	8
		Echinostomida	7
	Cestoda	Cyclophyllidea	54
NEMATODA		Rhabditida	8
		Strongylida	34
		Enoplida	16
		Spirurida	3
		Ascaridida	5
		Oxyurida	1
ANNELIDA	Hirudinea	Arhynchobdellida	1
		Rhynchobdellida	3
ACANTHOCEPHALA	Archiacanthocephala	Oligacanthorhynchida	1
MOLLUSCA	Gastropoda	Neotaenioglossa	3
		Pulmonata	54
	Bivalvia	Veneroidea	5
BRYOZOA	Phylactolaemata		1
ROTIFERA	Eurotatoria	Flosculariacea	7
		Ploima	73
ARTHROPODA	Malacostraca	Isopoda	1
	Branchiopoda	Diplostraca	38
	Maxillopoda	Cyclopoida	12
	Entognatha	Collembola	31
	Ectognatha	Zygentoma	1
		Ephemeroptera	6
		Odonata	32
		Blattoptera	2
		Mantoptera	1
		Orthoptera	46
		Dermaptera	2
		Psocoptera	1
		Thysanoptera	1
		Phthiraptera	5
		Heteroptera	484
		Coleoptera	2204
		Neuroptera	34
		Raphidioptera	3
		Megaloptera	1
		Trichoptera	67
		Mecoptera	5
		Lepidoptera	1414
		Hymenoptera	575
		Siphonaptera	3
		Diptera	1207

	Arachnida	Pseudoscorpiones	1
		Opiliones	1
		Aranei	207
		Mesostigmata	1
		Ixodida	1
		Prostigmata	2
	Diplopoda	Polydesmida	1
		Julida	3
Total	18	53	6823

The greatest biodiversity is a characteristic for three orders: Coleoptera (32.3% of the total number of species), Lepidoptera (20.7%) and Diptera (17.7%). It is clear that these groups, together with Hymenoptera, are the core of the biodiversity of terrestrial ecosystems on almost all continents. We think that these orders have also not yet been fully studied and their species diversity has not been fully revealed. For example, three new species of Diptera (*Earomyia mordovia*; *Lonchaea cryptica*; *Lydella villosiventralis*) have been described from the territory of MSNR, and more than 30 species have been registered for the first time in Russia and Europe [23-26].

4 Discussion

Natural ecosystems are the key to maintaining human prosperity in a warming world. Untouched forest ecosystems absorb a significant amount of carbon, they preserve the natural ecological balance, they are the center of conservation of species and genetic diversity, a refuge for many species. Thus, untouched forest ecosystems are biodiversity hotspots. This makes forest conservation the most important approach to combating global warming [1, 27, 28].

The term “biodiversity hotspot” is used to refer to regions or zones with high species richness [29]. In industrially developed regions of the planet, such biodiversity hotspot is protected areas. As a result of systematic entomological studies in the MSNR and generalization of all available publications, we obtained data on 6823 invertebrate species. We are not aware of similar generalizations for other protected areas located in the forest climate zone. However, there is some information about individual groups of insects that occur in other protected areas. For example, the species diversity of Coleoptera in Białowieża National Park (Poland) is 2973 species [30], in Great Smoky Mountains National Park (USA) 2522 species [31]. In the MSNR, the number of Coleoptera species is lower, but at the same time, the area of the MSNR territory is 2.0 and 6.6 times smaller than the specified protected areas, respectively.

In addition to the total number of species, the number of rare and endemic species is an indicator of the stability and importance of the protected area in the surrounding landscape. One hundred and twenty protected invertebrate species are known in the MSNR [32]. The largest indicator of the number of protected species is observed in the southwestern part, where the diversity of landscapes and ecotones is very high. There are floodplain forests and meadows, broad-leaved forests with old-growth trees (oak, elm, linden), lakes with coastal fauna, mixed forests with diverse second and third tiers, large clearings and forest edges, swampy areas. As a result of calculating the representativeness index, a number of species was shown that is known only on the territory of the MSNR within the region (Republic of Mordovia). The conservation of populations of 27 species in the region is carried out only due to the high diversity of communities and the protection of MSNR forests [32]. Of the endemic species, we noted 3 species of Diptera, which were first described for science from this territory (*Earomyia mordovia*; *Lonchaea cryptica*; *Lydella villosiventralis*) and are still unknown anywhere else.

The key biodiversity zones approach [28] assumes a global standard for identifying marine, terrestrial and freshwater sites that make a significant contribution to global biodiversity conservation. Wilderness areas are ecologically untouched areas of land and seascapes that are mostly free from anthropogenic disturbances. Such areas on a planetary scale are important for life support and are crucial for the long-term conservation of endangered species. Well-interconnected ecosystems are crucial for maintaining important ecological and evolutionary processes (including species migration and gene flow), especially when species face rapid climatic and ecological changes [19, 28]. Relatively speaking, one protected area cannot cope with the conservation of biodiversity, and only the relationship with other nearby protected areas or untouched areas provides a sustainable system for the conservation of biodiversity. The MSNR forest ecosystems are arranged in such a way that there are corridors for species migration to other ecosystems.

Another positive aspect that influences the increased biodiversity is the location of the MSNR away from large settlements. It is often believed that high population density is often used as a proxy for threats to biodiversity [19]. In this case, urbanization has not affected the surrounding ecosystems in any way.

5 Conclusion

Mordovia State Nature Reserve forests represent an integral ecosystem, which is distinguished by a significant species diversity of invertebrates. Such biodiversity, combined with the findings and description of new species, suggests that the Mordovia State Nature Reserve belongs to one of the hotspots of biodiversity in the forests of the temperate zone of European Russia. It is home to a large number of rare species and three endemic species. At the same time, the protected area is not closed or isolated. It is connected by corridors (forest ecosystems) with other territories and can be a source of genetic and species diversity for nearby ecosystems.

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