RED DATA BOOK INVERTEBRATES
IN A PROTECTED AREA OF EUROPEAN RUSSIA

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Protected Areas are considered as primary efforts for biodiversity conservation worldwide. However, there is a lack of data on the biodiversity and threats for most of the federal-level Russian Protected Areas, especially for invertebrates. Intensive research on invertebrate diversity in Protected Areas is highly important to obtain comprehensive knowledge for the management of natural refugia of biodiversity. In the present paper, we studied the most vulnerable component of invertebrate diversity, i.e. the Red Data Book species, in the Mordovia State Nature Reserve (European Russia). We used both new (2007–2018) and literature (1936–2006) data to obtain information on habitat preferences, year of the first record, and spatial distribution in the Protected Area for 121 invertebrate Red Data Book species known from the Mordovia State Nature Reserve. Our study demonstrated a remarkable increase in the Red Data Book invertebrate diversity as a consequence of the research intensification in the Protected Area in the last ten years. This is also related to the fact that only 1–2 records are known for a large number of species (57.9%) within the Protected Area. The highest species richness was found close to the research stations (cordons). On one hand, this highlights their significance for biodiversity research. On the other hand, it outlines the need for performing more research in less-studied areas of the Mordovia State Nature Reserve. Finally, the species currently known for Mordovia and Russia only from this Protected Area (27 and four species, respectively) highlight the importance of the Mordovia State Nature Reserve at regional and national levels.

Key words: biodiversity, habitat preference, Mordovia State Nature Reserve, nature conservation, representativeness index

INTRODUCTION

Human impacts on nature have led to an accelerated biodiversity loss, with harmful consequences to many ecosystem processes and functions (Thuiller 2007, Butchart et al. 2010, Dirzo et al. 2014). This has lead to an increase in the number of studies on biodiversity as well as in the efforts for its conservation. A consequence of these efforts is the declaration of Protected Areas in many regions of the world (Halffter 2005, Zografou et al. 2014). These areas spearhead the global conservation effort (Watson et al. 2014). Currently, the global Protected Area Network covers about 15% of the world’s terrestrial land surface (Belle et al. 2018). However, the designation of these protected
areas rarely considers invertebrates. For the vast majority of protected areas, only studies focusing on conspicuous groups of vertebrates and plants are available (Carignan & Villard 2002, Rodrigues et al. 2004, Young et al. 2014). The invertebrate biodiversity in Protected Areas remains largely unexplored, although these animals are key elements in the functioning of all terrestrial ecosystems. Samways (2005) and Cardoso et al. (2011) indicated that insects are almost four-fifths of the total of terrestrial species. However, estimations of the invertebrate diversity (e.g., Ramos et al. 2001) are rare due to the limited taxonomic and distribution knowledge about different taxonomic groups (Martín-López et al. 2007). This causes a need to investigate the effectiveness of Protected Area Networks to protect the invertebrate diversity in different regions of the world. It especially concerns biodiversity coldspots (i.e., areas with low diversity, such as the Russian Federation) of the world because the main attention of researchers is often riveted on hotspots (Kareiva & Marvier 2003).

Red Lists play an important role in generating public and policy support for species conservation (Rodrigues et al. 2006). Listing species according to their relative risk of extinction and comparing regularly updated Red Lists is a powerful tool in assessing the efficacy of species conservation policies (Stork et al. 1996, Mace et al. 2008). In the case of insects, and invertebrates in general, however, it has been noted that Red Lists principally reflect the state of knowledge rather than the actual status of a species’ extinction risk (Cardoso et al. 2012).

In this study, we aimed to assess the current state of the Red Data Book insect diversity in a Protected Area in European Russia (Republic of Mordovia), the Mordovia State Nature Reserve. The Mordovia State Nature Reserve was established as a Protected Area in 1936. In this Protected Area, there was a lack of systematic investigations of the invertebrate diversity before 2007. During 2007–2018, more than 5,000 invertebrate species have first been discovered for the Nature Reserve in the framework of an intensive investigation of the Protected Area’s entomological diversity (Ruchin et al. 2013, Makarkin & Ruchin 2014, Ruchin & Artaev 2016, Mandelshtam & Egorov 2017, Ruchin & Makarkin 2017, Ruchin & Mikhailenko 2018). Of these, 2,600 invertebrate species were firstly found for the whole Republic of Mordovia (Makarkin & Ruchin 2010, Bezina 2014, Bolshakov et al. 2014, Budaeva & Ruchin 2014, Semenov 2016, Ruchin & Egorov 2017b, Bolshakov et al. 2018, Chursina & Ruchin 2018a), including five species newly found for the Russian Federation (Mokrousov et al. 2013, Tomaszewska et al. 2018, Zemoglyadchuk et al. 2019). Results of the intensive entomological studies allowed a significant extension of the geographical ranges of some invertebrate species (Legalov et al. 2014, Ruchin & Artaev 2016, Anufriev 2017, Bolshakov et al.
2017, Egorov & Shapovalov 2017, Ruchin & Egorov 2018b,d,e). Concerning the Red Data Book invertebrate species, after the publication of the Red Data Book of the Republic of Mordovia (Astradamov 2005), 164 invertebrate species were recommended to be included in its second edition (Makarkin & Ruchin 2015, Mikhailenko & Ruchin 2015, Ruchin & Egorov 2015, 2017b, Ruchin & Nikolaeva 2015, Stoyko & Komarova 2015, Bolshakov & Ruchin 2018), while 35 invertebrate species were suggested to be excluded from the main list of the Red Data Book of the Republic of Mordovia (Egorov & Ruchin 2009, Ruchin & Nikolaeva 2015, Bolshakov & Ruchin 2015, Ruchin & Egorov 2017b). The first stages of systematic conservation planning should always include data collection on the location of threatened and regionally rare species in a region or its part (Margules & Pressey 2000).

The aim of this study was to analyse the current state of the diversity of the Red Data Book invertebrates of the Mordovia State Nature Reserve on the eve of the forthcoming second edition of the Red Data Book of the Republic of Mordovia.

MATERIAL AND METHODS

Study area

The Mordovia State Nature Reserve is situated in the northwest part of the Republic of Mordovia, Russian Federation (54.42–54.56 N, 43.04–43.36 E; up to 190 m a.s.l., Fig. 1). The Mordovia Reserve area is 321.62 km². Its flora includes 809 species from 99 families (Vargot et al. 2016).

Forest communities cover 89.3% of the total Mordovia Reserve area. Pine (Pinus sylvestris L.) is the main forest-forming wood species in the reserve. It forms pure or mixed forest communities. Birch (Betula pendula Roth) ranks second in areas covered by forests. It forms predominantly secondary communities at logging sites and at burned forest sites. Small-leaved linden (Tilia cordata Mill.) forests are present in the northern part of the Mordovia Reserve. Oak (Quercus robur L.) forests are distributed in the floodplain of the river Moksha in the western part of the Mordovia Reserve. Spruce (Picea abies L.) forests are located predominantly in floodplains of rivers and streams (Pushhta, Vyaz-Pushta, Vorsklyay, Arga, etc.) and cover small areas. There are numerous oligotrophic mires dominated by Sphagnum or Sphagnum – Carex communities. Floodplain meadows are situated mainly in floodplains of the river Satis and the river Moksha in the western and northwestern parts of the Protected Area (Tereshkin & Tereshkina 2006, Vargot et al. 2016).

Data collection and analysis

As a target group, we selected invertebrate species included in the Red Data Book of the Republic of Mordovia, which are known from the Mordovia State Nature Reserve. Apart of them, our study considered also invertebrates suggested for inclusion for its second edition (see – Makarkin & Ruchin 2015, Mikhailenko & Ruchin 2015, Ruchin & Egorov 2017b).
rov 2015, Ruchin & Nikolaeva 2015, Bolshakov & Ruchin 2016). At the same time, four species (Argyroneta aquatica (Clerck, 1757), Dolomedes fimbriatus (Clerck, 1757), Bombus lapidarius (Linnaeus, 1758), Centrotus cornutus (Linnaeus, 1758)), included in the Red Data Book of the Republic of Mordovia (Astradamov 2005), were excluded from our analysis because actually these invertebrates are common species in the region (personal data). 2007–2018 data on species diversity were collected predominantly by the first author. Previous data have been extracted from publications concerning the fauna of the Mordovia State Nature Reserve (Plavilshchikov 1964, Feoktistov 2011, Ruchin 2018, Ruchin & Grishutkin 2018). Voucher specimens collected during the study period are stored in the Collection of the Mordovia State Nature Reserve and in personal collections of the authors. Some individuals were released into nature after capture.

We estimated the increase in the number of the Red Data Book invertebrate species in the Mordovia State Nature Reserve using the first record of each species in the Protected Area, and the total number of records per each species known in the Mordovia Reserve. We assigned all known records to quarters of the Protected Area. A quarter is a square forestry unit (ca. 1×1 km) surrounded by clearings from south to north and from west to east. Hence, species distribution among quarters follows a grid system using 1 km² cell size.

To reveal patterns of spatial distribution of the Red Data Book invertebrates in the Mordovia State Nature Reserve, we counted the number of the Red Data Book species per quarter. These data have been used to show the biodiversity hotspots and coldspots of Red Data Book invertebrates in the Mordovia State Nature Reserve.

We analysed species confinement to different habitats by using the following habitat classification: forests (incl. burned coniferous forest, coniferous forest, deciduous forest, mixed forest), edges of forest (incl. edge of coniferous forest, edge of deciduous forest, edge of mixed forest), forest glades (incl. glade of coniferous forest, glade of deciduous forest, glade of mixed forest), floodplain meadows, water bodies (incl. shores), man-made habitats (i.e. roadsides, arable lands, etc.), Sphagnum mires.

Fig. 1. Geographic location of the Mordovia State Nature Reserve in Europe. Symbols within the Mordovia State Nature Reserve indicate research stations (cordons)
To calculate a Representativeness Index (RI) of each Red Data Book invertebrate in the Mordovia State Nature Reserve, we proposed and used the following formula:

\[ R = \frac{N_\text{PA}}{N_{\text{TOTAL}}} \times 100\% \]

where \( N_{\text{PA}} \) is the number of taxon’s locations known within a Protected Area, and \( N_{\text{TOTAL}} \) is the total number of taxon’s locations within a region (in this study, it is the Republic of Mordovia).

Depending on the RI values, we distinguished all Red Data Book invertebrates of the Mordovia State Nature Reserve into the following four groups using quartiles: Q1 having RI values 76–100%, Q2 – 51–75%, Q3 – 26–50%, and Q4 with the RI values from 0.1% to 25%.

To express the conservation status of the invertebrate species involved in the study, we used the rarity category reported in the Red Data Book of the Republic of Mordovia (Astradamov 2005), as follows:

0 – Probably extinct species. Populations of these species have probably disappeared from the territory of the Republic of Mordovia. These species have not been recorded in the wild during the past 50 years, either in points where the species were known to be formerly present or at any other potential locations. Nevertheless, the possibility that some individuals or populations have been overlooked cannot be completely excluded.

1 – Endangered species. Species whose populations have reached critically small sizes and/or their habitats have changed in such a way that their survival is unlikely if the impact of threat factors persists.

2 – Vulnerable species. Species characterised by steadily declining populations in the region, which can quickly fall into the category of endangered species if impacts of unfavorable factors persist.

3 – Rare species. Species of high vulnerability because of their small population size in the region. They are distributed over a limited area or a large scale, but with a very low density.

4 – Indeterminate species. Species whose populations could be classified into one of the previous categories, but information about their present state is insufficient to accurately determine their status.

5 – Recovered or recovering species. Species whose abundance and distribution area (under the impact of natural factors or human actions aimed to recover species populations) lead to be recovered to a status for which they will not need special measures for protection and restoration.

Contour map has been created using the MapInfo 11.5 software.

RESULTS AND DISCUSSION

As a result of annual entomological investigations in the Mordovia State Nature Reserve and examination of available publications, we obtained data on 121 Red Data Book invertebrates known within the Protected Area (Table 1S). Among them, 12 species (10% of the total number) are recommended to be included in the second edition of the Red Data Book of the Russian Federation (Ilyashenko et al. 2018). Notably, there are 14 such species known in the whole Republic of Mordovia. Hence, 12 of 14 (86%) species of the Red Data Book of the Russian Federation (Danilov-Danilyan 2001) are known to be present in the Mordovia State Nature Reserve (the two absent species are Aphodius bimaculatus (Laxmann, 1770) and Omias verruca Boheman, 1834).
Overall, Red Data Book invertebrate species were represented by 402 locations in the Mordovia State Nature Reserve. Most of them (57.9%) have been represented by only 1–2 records in the Mordovia State Nature Reserve (Fig. 2). The number of species per class of records followed a power function with a negative exponent. Thus most of species are known by 1 or two records, and the number of species known for more records decreases rapidly, with remarkably few invertebrate species represented by at least nine records (e.g., *Protaetia fieberi* Kraatz, 1880 with 18 records, *Xylocopa valga* Gerstaecker, 1872 with 15 records, *Agriades optilete* (Knoch, 1781) with 13 records). This pattern is consistent with those observed for invertebrates (e.g., *Pentinsaari et al.* 2014, *Sushko* 2017) and vertebrates (*Silveira et al.* 2003, *Pacheco & Olmos* 2005) from other contexts.

Because of the immense lack of knowledge on the conservation status of invertebrates, any intensification in the study of these animals could lead to a remarkable increase in the number of known species and their presence in Protected Areas with possible description of new taxa (Anufriev 2016, Bouchard et al. 2017, Mayhew 2018). Generalised data on the increase in the number of species known from the Mordovia State Nature Reserve between 1936 and 2018 shows that a plateau is far from being reached (Fig. 3). Thus the number of the Red Data Book invertebrates will be likely increase with further research.

The first record of a Red Data Book species (*Podisma pedestris* (Linnaeus, 1758)) has been reported in 1936. Plavilshchikov (1964) published the first relatively comprehensive list of insect species for the Mordovia State Nature Reserve. In the late 1960s – early 1970s, Lepidoptera and Heteroptera were mainly investigated. Between 1936 and 1986, the list of the Red Data Book invertebrates increased up to 40 species. During the next 20 years (1986–2006), there were no additions to the list of the Red Data Book invertebrates in the Mordovia State Nature Reserve due to the complete lack of entomological

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**Fig. 2.** Number of Red Data Book invertebrate species for different classes of records in the Mordovia State Nature Reserve

\[ y = 92.392x^{-0.94} \]

\[ R^2 = 0.949 \]
studies. A period of intensive entomological studies in the Mordovia State Nature Reserve started in 2007. Thus, between 2007 and 2018, the fauna of the Red Data Book invertebrate species has remarkably increased (by 80 species). To obtain field data we used different approaches and catch methods: pitfall traps, light traps, ferental crown traps, Malaise traps and others (e.g., see Ruchin & Egorov 2018a). The preparation of the first edition of the Red Data Book of the Republic of Mordovia (Astradamov 2005) was a main driving force for the study of the Red Data Book species in the region. A permanent monitoring of the Red Data Book taxa, a search for their detailed distribution, the study of their biology and ecology, and the biodiversity investigation of different invertebrate groups allowed the addition of more than 5,000 invertebrate species to the fauna of the Mordovia State Nature Reserve (Ruchin 2011, 2015a,b, 2017).

Data on the spatial distribution of the Red Data Book invertebrates in the Mordovia State Nature Reserve allowed the identification of biodiversity hotspots within the Protected Area. Figure 4 shows that the highest number of the Red Data Book invertebrate species per quarter was found in the south-west of the Mordovia State Nature Reserve. This is explained by a large diversity of landscapes and ecotones in this area. This part of the Mordovia Reserve includes floodplain meadows and deciduous forests, old-growth broad-leaved (Quercus robur, Ulmus spp., Tilia cordata) forests, oxbow lakes with shores, mixed forests with different-species in the second and third layers, large glades and edges of forests, and mires of different types. In general, the highest species diversity was observed around research stations of the Mordovia State Nature Reserve represented by the settlement of Pushta and cordon(s) (a cordon is one or few inhabited or uninhabited building(s), which serve(s) as a home for forest rangers and/or as research stations), such as cordon Steklyannyi, cordon

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**Fig. 3.** Increase in the Red Data Book invertebrate species for the fauna of the Mordovia State Nature Reserve for the period 1936–2018
Srednyaya Melnitsa, cordon Pavlovskiy, cordon Vorovskoy, cordon Inorskiy, cordon Dolgiy Most, cordon Zhegalovskiy, cordon Drozhdovenkovskiy – see Fig. 1). Thus, it can be seen from Fig. 4 that the presence and density of research stations (settlements and cordons) positively influences the diversity and richness of known species in the various sectors of the Protected Area. The efficiency of studies can also be increased with increasing density of research stations in other environmental studies (e.g., Mishra 2013).

Low diversity of Red Data Book invertebrate species in the central and eastern parts of the Mordovia State Nature Reserve could be explained by different reasons. First, these areas are represented predominantly by pine forests with the insignificant presence of *Tilia cordata, Picea abies* or *Betula pendula* into the second layer and with shrub layer represented mainly by *Sorbus aucuparia* and *Frangula alnus*. Thus, the lack of broad-leaved trees possibly influences negatively the diversity of saproxylic beetles. Absence of meadows affects negatively Orthoptera and Lepidoptera. In addition, the lack of water bodies negatively influences Odonata, Lepidoptera, and Mollusca. Second, the central and eastern parts of the Mordovia State Nature Reserve have been damaged by humans, as also indicated by palaeobotanical data (see Novenko et al. 2017). In these parts of the Protected Areas, broad-leaved forests have been changed into pine forests, wildfires became more frequent and *Picea abies* started penetrating into the forest communities.

Analysis of habitat confinement of the Red Data Book invertebrates showed the importance of forest ecosystems as refugia for threatened species.
in the Mordovia State Nature Reserve (Fig. 5) (Bengtsson et al. 2000, Kovac et al. 2018). This is clearly explained by the predominance of forest habitats (89.3% of total Protected Area) in the Mordovia State Nature Reserve. There were remarkably fewer Red Data Book invertebrate species in *Sphagnum* mires (18 records), floodplain meadows (9 records), water bodies and their shores (8 records), man-made habitats (7 records). In addition, Fig. 5 demonstrates a considerably high number of Red Data Book invertebrates within mixed forests, as well as on edges and glades of mixed forests. This is in accordance with data of other investigations (e.g., Sümege et al. 2012, Novenko et al. 2018) that reported high species diversity in ecotone plant communities.

In the Mordovia State Nature Reserve, floodplain broad-leaved forests (linden forests and oak forests) are of special interest. This is a unique refuge for the forest fauna and flora that remained little affected by human activity for many centuries. The largest portion of such forests is located in the western, southwestern and northern parts of the Protected Area. In these areas, centuries-old *Quercus robur*, large *Tilia cordata* and *Fraxinus excelsior* L. trees still survive. There are numerous fallen and gradually decaying trunks of these trees, extremely important for the persistence of saproxylic insects. Additionally, floodplains form unique conditions for numerous saproxylic beetles and numerous species associated with broad-leaved forests and which are known only in these areas. Of special interest are some species included the current edition of the Red Data Book of the Russian Federation (Danilov-Danilyan 2001) and species recommended for inclusion in its second edition (Ilyashenko et al. 2018). They are: *Ceruchus chrysomelinus* (Hochenwarth, 1785), *Lucanus cervus* (Linnaeus, 1758), *Trypocopris vernalis* (Linnaeus, 1758), *Osmoderma barnabita* Motschulsky, 1845, *Protaetia speciosissima* (Scopoli, 1786), *Protaetia fieberi* (Kraatz, 1880), *Elater ferrugineus* Linnaeus, 1758 (Ruchin & Egorov 2017b, 2018a). Also, four species (*Allonyx quadrimaculatus* (Schaller, 1783), *Leptura aurulenta* Fabricius, 1793, *Nothochrysa fulviceps* (Stephens, 1836), *Catocala promissa* ([Denis et Schiffermüller], 1775)). These species are confined to these areas and are known only in the Mordovia State Nature Reserve in Russia (Bolshakov & Ruchin 2016, Ruchin & Egorov 2018b,d, Tomaszewska et al. 2018).

Meadows cover about 1% of the total Protected Area. They are located predominantly in the western and southwestern parts of the Mordovia State Nature Reserve and around cordons. For this, cordons play a very important role in biodiversity maintenance. The cordons previously served as the residence of the Mordovia Reserve officers who constantly grazed cattle or mowed grass on the nearby meadows. Typically, the number of animals grazed was quite low. Grazing and mowing brought certain benefits, counteracting the overgrowth of meadows by woody and weed-meadow plants. Exactly these conditions allowed the persistence of a *Parnassius apollo* population for a long time. However, it has gradually compromised by the decline of *Sedum maxi-
mum (L.) Hoffm. populations, a feeding plant for *P. apollo* larvae (Ruchin & Grushutkin 2018). Within the Mordovia State Nature Reserve, populations of the following xerophilic species survive in meadow habitats: *Myrmeleotettix maculatus* (Thunberg, 1815), *Sphingonotus caeruleus caeruleus* (Linnaeus, 1767), *Psophus stridulus* (Linnaeus, 1758) (Orthoptera), *Parnopes grandior* (Pallas, 1771) (Hymenoptera), *Dysauxes ancilla* (Linnaeus, 1767), *Panthea coenobita* (Esper, 1785) (Lepidoptera). Due to the particular microclimatic conditions and mesophilisation processes, some meadow sites of the Mordovia State Reserve (especially in the Moksha river floodplain) are the only habitats for the lepidopterans *Phragmataecia castaneae* (Hübner, 1790), *Zygaena centaureae* Fischer von Waldheim, 1832, *Carcharodus alceae* (Esper, 1780), *Melitaea phoebe* (Goeze, 1779), *Chortobius hero* (Linnaeus, 1760), *Lycaena hippothoe* (Linnaeus, 1760).

Figure 6 presents values of the Representativeness Index (RI) for the Red Data Book invertebrate species of the Mordovia State Nature Reserve. Among all studied taxa, RI values of Neuroptera, Heteroptera, and Mollusca species were less than 50%. However, these taxa included the smallest number of the Red Data Book invertebrate species in the Mordovia State Nature Reserve. These are one Neuroptera species (*Nothochrysa fulviceps* (Stephens, 1836)), two Heteroptera species (*Cercopis vulnerata* Rossi, 1807, *Pygolampis bidentata* (Goeze, 1778)), and two Mollusca species (*Acroloxus lacustris* (Linnaeus, 1758), *Planorbis carinatus* O.F. Müller, 1774). Orthoptera have an intermediate position because they include species with both high (*Podisma pedestris* (Linnaeus, 1758), RI = 100%) and low (*Myrmeleotettix maculatus* (Thunberg, 1815), RI=23.1%; *Stenobothrus nigromaculatus* (Herrich-Schaffer, 1840), RI = 16.7%) RI values.

| Habitat types | Number of records |
|---------------|------------------|
| Forest        | 250              |
| Edge of Forest| 200              |
| Glade         | 150              |
| Floodplain Meadow | 100         |
| Sphagnum Mire | 50               |
| Water Body and Shores | 50           |
| Man-Made Habitat | 50            |

Fig. 5. Habitat preferences of Red Data Book invertebrate species in the Mordovia State Nature Reserve.
values. Finally, each of the four remaining orders (Coleoptera, Lepidoptera, Hymenoptera, Diptera) contains at least 40% Red Data Book species with RI values equal to or higher than 50%. Coleoptera and Lepidoptera are the groups with the highest number (31 and 70 taxa, respectively) of the Red Data Book invertebrate species known in the Mordovia State Nature Reserve.

The conservation value of a Protected Area is obviously increased by the species that are known for only the concerned area within a region (Ruchin & Kurmaeva 2010, Mikhailenko & Ruchin 2015, Ruchin & Egorov 2015, 2017b, 2018a, Bolshakov & Ruchin 2016). On the basis of the RI values, we distinguish a group of Red Data Book invertebrate species of the region (Republic of Mordovia), which are known here only in the Mordovia State Nature Reserve (i.e., RI=100%). They are represented by one Orthoptera species (Podisma pedestris), six Coleoptera species (Lebia marginata (Geoffroy, 1785), Sphaerites glabratus (Fabricius, 1792), Elater ferrugineus Linnaeus, 1758, Allonyx quadrimalculus (Schaller, 1783), Evodinellus borealis (Gyllenhal, 1827), Leptura aurulenta Fabricius, 1793), and 20 Lepidoptera species (Eversmannia exornata (Eversmann, 1837), Arichanna melanaria (Linnaeus, 1758), Phyllodesma ilicifolia (Linnaeus, 1758), Smerinthus caecus (Ménétriés, 1857), Cerura erminea (Esper, 1783), Ptilodon cucullina ([Denis et Schiffermüller], 1775), Odontosia carmelita (Esper, 1799), Clostera anastomosis (Linnaeus, 1758), Dicallomera fascelina (Linnaeus, 1758), Calliteara abietis ([Denis et Schiffermüller], 1775), Eilema depressum (Esper, 1787), Lithosia quadra (Linnaeus, 1758), Rhyparia purpurata (Linnaeus, 1758), Dysauxes ancilla (Linnaeus, 1767), Minucia lunaris ([Denis et Schiffermüller], 1775), Panthea coenobita (Esper, 1785), Anarta myrtilli (Linnaeus, 1760), Boloria aquilonaris (Stichel, 1908), Scolitantides orion (Pallas, 1771), Agriades opitilete (Knoch, 1781)). Thus, the special protection regime and habitat diversity of the Mordovia State Nature Reserve is important to counteract the regional extinction of these 27 species in the Republic of Mordovia.

Fig. 6. Proportions of Representativeness Index values for the Red Data Book invertebrates in the Mordovia State Nature Reserve

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### CONCLUSIONS

The main cause for Protected Areas establishment is a need to protect threatened and rare plants and animals from extinction. However, in most cases, conservation measures are focused on the largest and most remarkable animals (Sui et al. 2008, Zhang et al. 2015, Mizin et al. 2018, Samson & Ramakrishnan 2018) and plants (Bauer et al. 2016, Wicaksono et al. 2016). Although conservation of these species is undoubtedly important, we should not ignore a need to study and preserve all imperiled organisms. Globally or regionally threatened invertebrate species play an important role for ecosystem functioning, yet their remain less considered in conservation programs. Protected Areas, as islands of the least destructed natural ecosystems, are main refugia of invertebrate diversity, including threatened and rare species.

In this study, we demonstrated a significant increase in the known diversity of invertebrate species with increasing research investigations in a limited area, the Mordovia State Nature Reserve. Out of the more than 6,000 invertebrate species revealed during 1936–2018, we considered 120 taxa as Red Data Book invertebrates in the Republic of Mordovia. We showed a remarkable decrease in known species diversity when moving away from research stations (e.g., cordons or settlements). This is probably because 58.3% of the Red Data Book species were found in the recent ten years and are confirmed predominantly only by 1–2 records. Hence, further surveys of areas remote from cordons could reveal a more widespread distribution of these invertebrate species. Most of the Red Data Book invertebrate species in the Mordovia State Nature Reserve are confined to forest ecosystems with many records in ecotone communities (mixed forests, glades, and edges of mixed forests). Despite the small area, oligotrophic Sphagnum mires and floodplain meadows were also important refugia for Red Data Book invertebrate species of the Republic of Mordovia. We found four and 27 invertebrate species known only from the Mordovia State Nature Reserve for the whole Russia and the Republic of Mordovia, respectively. However, we can expect that these species will be found outside the Mordovia Reserve during further investigations in the Republic of Mordovia and Russia as a whole. Finally, we propose to promote the knowledge of the whole invertebrate fauna of the Mordovia State Nature Reserve and the whole Republic of Mordovia to identify biodiversity hotspots and coldspots at different spatial scales.

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Table S1. The list of the Red Data Book invertebrate species known in the Mordovia State Nature Reserve (European Russia). RI = Representativeness index; RC2005 = Rarity category (according to Astradamov 2005), RC2001 = Rarity category (according to Danilov-Danilyan 2001).

| Species | Habitats | RI, % | RC2005 | RC2001 |
|---------|----------|-------|---------|--------|
| Anax imperator Leach, 1815 | WBS | 16.7 | 2 | 3 |
| Orthoptera | | | |
| Chorthippus pullus (Philippi, 1830) | MF | 50.0 | 3 | – |
| Myrmelotettix maculatus (Thunberg, 1815) | GMH, MMH | 23.1 | 3 | – |
| Podisima pedestris (Linnaeus, 1758) | MF, CF, MMH, GMF | 100.0 | 1 | – |
| Psophus stridulus (Linnaeus, 1758) | MF | 28.6 | 2 | – |
| Sphingonotus caerulans caerulans (Linnaeus, 1767) | BCF, MMH | 45.5 | 3 | – |
| Stenobothrus nigromaculatus (H.-S., 1840) | ? | 16.7 | 4 | – |
| Heteroptera | | | |
| Cercopis vulnerata Rossi, 1807 | GMF, GDF | 50.0 | 4 | – |
| Cicadetta montana (Scopoli, 1772) | GMF | 15.8 | 2 | – |
| Pygolampis bidentata (Goeze, 1778) | GMF | 12.5 | 2 | – |
| Coleoptera | | | |
| Allonyx quadrimaculatus (Schaller, 1783) | DF | 100.0 | 3 | – |
| Aromia moschata (Linnaeus, 1758) | DF | 26.7 | 3 | – |
| Calosoma auropunctatum (Herbst, 1784) | MMH | 9.1 | 2 | – |
| Calosoma investigator (Illiger, 1798) | CF, MF | 18.8 | 3 | – |
| Calosoma sycophanta (Linnaeus, 1758) | EMF | 10.0 | 3 | 2 |
| Carabus aurolimbatus Dejean & Boisduval, 1829 | FM | 33.3 | 4 | – |
| Carabus clathratus Linnaeus, 1761 | DF, MF, FM | 35.0 | 3 | – |
| Carabus nitens Linnaeus, 1758 | MF | 28.6 | 3 | – |
| Carabus schoenherri Fischer von Waldheim, 1820 | DF | 40.0 | 3 | – |
| Ceruchus chrysomelinus (Hochenwarth, 1785) | MF, DF | 50.0 | 3 | 2 |
| Copris lunaris (Linnaeus, 1758) | MF | 41.7 | 3 | – |
| Dytiscus latissimus Linnaeus, 1758 | WBS | 33.3 | 3 | 2 |
| Elater ferrugineus Linnaeus, 1758 | DF, MF | 100.0 | 1 | 2 |
| Emus hirtus (Linnaeus, 1758) | EMF | 16.7 | 3 | – |
| Evodinellus borealis (Gyllenhal, 1827) | MF, DF | 100.0 | 3 | – |
| Gnorimus variabilis (Linnaeus, 1758) | MF, DF, EDF | 66.7 | 3 | – |
| Hololepta plana (Sulzer, 1776) | DF | 20.0 | 3 | – |
| Lebia marginata (Geoffroy, 1785) | EMF | 100.0 | 3 | – |
| Species                                      | Habitats | RI,% | RC2005 | RC2001 |
|----------------------------------------------|----------|------|--------|--------|
| *Leptura aurulenta* Fabricius, 1793          | DF       | 100.0| 3      | –      |
| *Lucanus cervus* (Linnaeus, 1758)           | EMF      | 25.0 | 3      | 2      |
| *Meloe variegatus* Donovan, 1793             | EMF      | 50.0 | 3      | –      |
| *Necydas major* Linnaeus, 1758               | MF, DF   | 35.7 | 3      | –      |
| *Osmoderma barnabita* Motschulsky, 1845      | DF, MF   | 44.4 | 2      | 2      |
| *Protaetia fieberi* (Kraatz, 1880)           | MF, DF, EDF | 66.7 | 3      | 2      |
| *Protaetia speciosissima* (Scopoli, 1786)    | MF, DF   | 53.8 | 2      | 2      |
| *Purpuricenus kaehleri* (Linnaeus, 1758)     | MF, DF   | 62.5 | 1      | –      |
| *Pyrochroa coccinea* (Linnaeus, 1760)        | CF, MF   | 28.6 | 3      | –      |
| *Sphaerites glabratus* (Fabricius, 1792)     | CF, MF   | 100.0| 3      | –      |
| *Trypocopris vernalis* (Linnaeus, 1758)      | MF       | 75.0 | 3      | 2      |
| *Valgus hemipterus* (Linnaeus, 1758)         | MF, CF   | 56.3 | 4      | –      |
| *Velleius dilatatus* (Fabricius, 1787)       | MF, EDF, DF | 57.1 | 3      | –      |

**Neuroptera**

| Species                                      | Habitats | RI,% | RC2005 | RC2001 |
|----------------------------------------------|----------|------|--------|--------|
| *Nothochrysa fulviceps* (Stephens, 1836)     | MF       | 25.0 | 1      | –      |

**Lepidoptera**

| Species                                      | Habitats | RI,% | RC2005 | RC2001 |
|----------------------------------------------|----------|------|--------|--------|
| *Acossus terebrus* ([Den. et Schiff.], 1775) | DF       | 60.0 | 3      | –      |
| *Agriades optilete* (Knoch, 1781)            | SM       | 100.0| 1      | –      |
| *Anarta myrtilli* (Linnaeus, 1760)           | ECF      | 100.0| 1      | –      |
| *Arctia flavia* (Fuessly, 1779)              | MF       | 50.0 | 4      | –      |
| *Argynnis laodice* (Pallas, 1771)            | MF       | 75.0 | 4      | –      |
| *Arichanna melanaria* (Linnaeus, 1758)       | SM       | 100.0| 1      | –      |
| *Boloria aquilonaris* (Stichel, 1908)        | SM       | 100.0| 1      | –      |
| *Brenthis daphne* ([Den. et Schiff.], 1775)  | GMF, DF, MF, MMH, FM | 55.6 | 3      | –      |
| *Callimorpha dominula* (Linnaeus, 1758)      | MF       | 66.7 | 2      | –      |
| *Calliteara abietis* ([Den. et Schiff.], 1775) | CF     | 100.0| 1      | –      |
| *Callopistria juventina* (Stoll, 1782)       | CF       | 75.0 | 2      | –      |
| *Carcharodus alceae* (Esper, 1780)           | FM       | 25.0 | 3      | –      |
| *Catocala promissa* ([Den. et Schiff.], 1775) | MF     | 16.7 | 3      | –      |
| *Celaena haworthii* (Curtis, 1829)           | SM       | 66.7 | 3      | –      |
| *Cerura erminea* (Esper, 1783)               | MF       | 100.0| 3      | –      |
| *Cerura vinula* (Linnaeus, 1758)             | DF       | 71.4 | 3      | –      |
| *Chortobius hero* (Linnaeus, 1760)           | GMF, MF, EMF, FM | 80.0 | 2      | –      |
| *Clostera anastomosis* (Linnaeus, 1758)      | MF       | 100.0| 4      | –      |
| *Comibaena bajularia* ([Den. et Schiff.], 1775) | DF     | 33.3 | 2      | –      |
| Species                                      | Habitats | RI, % | RC2005 | RC2001 |
|----------------------------------------------|----------|-------|--------|--------|
| Coscinia cribraria (Linnaeus, 1758)          | MF       | 66.7  | 3      | –      |
| Dicallomera fascelina (Linnaeus, 1758)       | MF       | 100.0 | 4      | –      |
| Dicycla oo (Linnaeus, 1758)                  | DF       | 50.0  | 3      | –      |
| Driopa mnemosyne (Linnaeus, 1758)            | GMF, GDF, EMF | 23.3 | 3      | –      |
| Dysauxes ancilla (Linnaeus, 1767)            | DF       | 100.0 | 4      | –      |
| Eilema depressum (Esper, 1787)               | MF       | 100.0 | 2      | –      |
| Epicallia villica (Linnaeus, 1758)           | MF       | 50.0  | 2      | –      |
| Erebia aethiops (Esper, [1777])              | EMF      | 66.7  | 3      | –      |
| Eucharia festiva (Hufnagel, 1766)            | MF       | 66.7  | 1      | –      |
| Eudia pavonia (Linnaeus, 1758)               | MF       | 50.0  | 2      | –      |
| Eversmannia exornata (Eversmann, 1837)       | EMF      | 100.0 | 2      | –      |
| Fixsenia ilicis (Esper, [1779])              | MF       | 40.0  | 3      | –      |
| Glaucopsyche alexis (Poda, 1761)             | CF       | 22.2  | 2      | –      |
| Iphicilides podalirius (Linnaeus, 1758)      | GMF, EMF, GCF, FM | 53.8 | 5      | –      |
| Laothoe amurensis (Staudinger, 1892)          | MF       | 25.0  | 2      | –      |
| Lasiocampa quercus (Linnaeus, 1758)          | MF, DF   | 85.7  | 3      | –      |
| Lemonia dumis (Linnaeus, 1760)               | MF       | 50.0  | 3      | –      |
| Lithosia quadra (Linnaeus, 1758)             | ECF      | 100.0 | 1      | –      |
| Lycaena hippothoe (Linnaeus, 1760)           | FM       | 33.3  | 4      | –      |
| Melitaea cinxia (Linnaeus, 1758)             | EMF      | 68.8  | 3      | –      |
| Melitaea diamina (Lang, 1789)                | EMF      | 62.5  | 4      | –      |
| Melitaea phoebe (Goeze, 1779)                | MF       | 45.5  | 3      | –      |
| Minucia lunaris ([Den. et Schiff.], 1775)    | MF       | 100.0 | 3      | –      |
| Neptis sappho (Pallas, 1771)                 | MF       | 28.6  | 3      | –      |
| Odontosia carmelita (Esper, 1799)            | MF       | 100.0 | 2      | –      |
| Pachigastria trifolii ([Den. et Schiff.], 1775) | CF, MF, DF | 100.0 | 4      | –      |
| Panthea coenobita (Esper, 1785)              | MF       | 100.0 | 1      | –      |
| Parnassius apollo (Linnaeus, 1758)           | GMF      | 14.3  | 2      | 3      |
| Pelosia obtusa (Herrich-Schäffer, 1847)     | WBS      | 33.3  | 4      | –      |
| Perictilia matronula (Linnaeus, 1758)        | MF       | 33.3  | 4      | –      |
| Peridea anceps (Goeze, 1781)                 | MF       | 50.0  | 3      | –      |
| Phragmataeca castanea (Hübner, 1790)         | FM       | 50.0  | 4      | –      |
| Phyllodesma ilicifolia (Linnaeus, 1758)      | MF       | 100.0 | 4      | –      |
| Phyllodesma tremulifolia (Hübner, 1809)      | DF       | 50.0  | 2      | –      |
| Proserpinus proserpina (Pallas, 1772)        | MF       | 50.0  | 2      | –      |
| Pseudoterpna pruinata (Hufnagel, 1767)       | CF       | 83.3  | 2      | –      |
| Species                                      | Habits            | RI,% | RC2005 | RC2001 |
|----------------------------------------------|-------------------|------|--------|--------|
| *Ptilodon cucullina* ([Den. et Schiff.], 1775) | MF                | 100.0| 4      | –      |
| *Pyrgus alveus* (Hübnner, [1803])           | EMF               | 50.0 | 3      | –      |
| *Rhodostrophia vibicaria* (Clerck, 1759)     | CF                | 25.0 | 2      | –      |
| *Rhyparia purpurata* (Linnaeus, 1758)        | MF, DF            | 100.0| 3      | –      |
| *Sabra harpagula* (Esper, 1786)              | DF                | 33.3 | 4      | –      |
| *Scolitantides orion* (Pallas, 1771)         | CF                | 100.0| 4      | –      |
| *Scolopteryx moeniata* (Scopoli, 1763)       | CF                | 50.0 | 2      | –      |
| *Scolopteryx mucronata* (Scopoli, 1763)      | CF                | 87.5 | 2      | –      |
| *Setina irrorella* (Linnaeus, 1758)         | MF                | 50.0 | 4      | –      |
| *Smerinthus caecus* (Ménétriès, 1857)        | MF                | 100.0| 1      | –      |
| *Spiris striata* (Linnaeus, 1758)           | MF, CF            | 83.3 | 4      | –      |
| *Staurophora celsia* (Linnaeus, 1758)        | MF                | 16.7 | 3      | –      |
| *Trichiura crataegi* (Linnaeus, 1758)        | MF                | 50.0 | 3      | –      |
| *Watsonalla binaria* (Hufnagel, 1767)        | DF                | 50.0 | 3      | –      |
| *Zerynthia polyxena* ([Den. et Schiff.], 1775) | DF, GMF          | 27.3 | 2      | –      |
| *Zygaena centaureae* Fischer von Waldheim, 1832 | FM                | 33.3 | 4      | –      |

**Hymenoptera**

| Species                                      | Habits            | RI,% | RC2005 | RC2001 |
|----------------------------------------------|-------------------|------|--------|--------|
| *Bombus hypnorum* (Linnaeus, 1758)           | EMF               | 85.7 | 3      | –      |
| *Bombus terrestris* (Linnaeus, 1758)         | GMF               | 25.0 | 2      | –      |
| *Orussus abietinus* (Scopoli, 1763)          | EMF, MF, CF       | 53.8 | 4      | –      |
| *Parnopes grandior* (Pallas, 1771)           | GMF, ECF          | 30.8 | 4      | 3      |
| *Xylocopa valga* Gerstaecker, 1872           | GMF, MF, GCF, CF, GDF | 78.9 | 2      | –      |

**Diptera**

| Species                                      | Habits            | RI,% | RC2005 | RC2001 |
|----------------------------------------------|-------------------|------|--------|--------|
| *Laphria gibbosa* (Linnaeus, 1758)           | CF, GMF, EMF      | 57.1 | 2      | –      |

**Mollusca**

| Species                                      | Habits            | RI,% | RC2005 | RC2001 |
|----------------------------------------------|-------------------|------|--------|--------|
| *Acroloxus lacustris* (Linnaeus, 1758)        | WBS               | 14.3 | 4      | –      |
| *Planorbis carinatus* O.F. Müller, 1774      | WBS               | 50.0 | 4      | –      |

**Total**

| Species                                      | Habits            | RI,% | RC2005 | RC2001 |
|----------------------------------------------|-------------------|------|--------|--------|
| Total                                        |                   | 121  | 12     |        |

Abbreviations: BCF – Burned Coniferous Forest, CF – Coniferous Forest, DF – Deciduous Forest, MF – Mixed Forest, ECF – Edge of Coniferous Forest, EDF – Edge of Deciduous Forest, EMF – Edge of Mixed Forest, GCF – Glade of Coniferous Forest, GDF – Glade of Deciduous Forest, GMF – Glade of Mixed Forest, FM – Floodplain Meadow, WBS – Water Body and Shore, MMH – Man-Made Habitats, SM – Sphagnum Mire.