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Red Data Book vascular plants in the Mordovia State Nature Reserve, a protected area in European Russia

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Summary: Protected areas are widely considered as tool for biodiversity conservation on a global scale. Current lack of data on biodiversity and threats in federal Russian protected areas is recognised. It especially concerns patterns of spatial plant distribution in natural ecosystems in both Russia and the whole world. Hence, research of plant diversity in protected areas is very important to obtain comprehensive knowledge on the functioning and management of plant diversity refugia. We aimed to study the most threatened component of plant diversity (i.e. Red Data Book species) in the Mordovia State Nature Reserve located in European Russia. We used personal (2010–2018) and literary (1936–2009) data to obtain information on habitat preferences, IUCN status, year of the first record, spatial plant distribution in protected area and taxon's representativeness index (RI) for 47 protected vascular plant species currently known in the Mordovia State Nature Reserve. We demonstrate the higher species richness in the vicinity of some research stations and its decrease when moving away from them. These results highlight the significance of biodiversity research. It also outlines the need to inverstigate less-studied areas (white gaps) in the Mordovia State Nature Reserve. During the preparation of the flora list for the Mordovia State Nature Reserve, we recognised an increase of the number of Red Data Book species. We thus indicate two major peaks (ending in 1960 and the other in 1987) and one insignificant peak (2013–2016) of species number increasing within the protected area. 63.9% of the total number of protected plant taxa are confirmed by only 1–4 records: 14 Critically Endangered, nine Endangered, four Vulnerable and two Data Deficient species. This underlines the need for additional investigations. Seven plant species growing in the Republic of Mordovia occurr only in the protected area, which highlights the uniqueness of the Mordovia State Nature Reserve for conservation of plant diversity. We suggest further studies of plant diversity in the Mordovia State Nature Reserve and a comprehensive analysis of patterns of spatial plant distribution in the protected area.

Keywords: biodiversity, habitat preference, Mordovia State Nature Reserve, nature conservation, protected species, representativeness index

Global biological diversity is seriously decreasing due to human influences. They are represented by habitat destruction, fragmentation and pollution, direct persecution, extinction of species and climate change (Gaston et al. 2008; Butchart et al. 2010; Mizin et al. 2018). The consequent declining of diversity impacts local ecosystems (Díaz et al. 2006; Berezenko & Milchakova 2018; Gebremedihin et al. 2018) and also biodiversity on regional and global scales (Faith et al. 2010). Furthermore, Goettsch et al. (2015) demonstrated that the conservation of plant diversity attracts considerably less attention than the animal conservation, because plants are less popular than animals. As a result, plant conservation is considerably under-resourced compared to the conservation of animals (Havens et al. 2014).

The national protected area networks are the main global tool to conserve local to regional biodiversity. Protected areas (PA) are considered the most effective effort to protect characteristic or threatened species, habitats and ecosystems and to counteract the biodiversity loss (Geldmann et al. 2013; Coetzee et al. 2014; Gray et al. 2016; Watson et al. 2016). At present, protected

area network covers globally about 14.9% of the world's terrestrial land surface (Belle et al. 2018). Numerous studies are concentrated on different types of protected areas, e.g. nature reserves, national parks, etc. Sometimes, PAs are considered the only remaining stock sites for species' populations (Jackson & Gaston 2008), the existence of which depends on PA effectiveness. Margules & Pressey (2000) stated two primary objectives of protected areas. First, protected areas must include a sample of biodiversity and, preferably, a large percentage, with a particular emphasis on rare, threatened or other taxa having significant conservation concern. Second, protected areas must protect or buffer the biodiversity sample from threatening processes. However, the first objective gets much more attention and number of studies (e.g. Martinez et al. 2006; Pawar et al. 2007; Ruchin & Egorov 2017; Kolyuchkina et al. 2018), although estimation of qualitative biodiversity patterns is not less important in the line of nature conservation. In most cases, the studies resulted in conclusions about inefficiency of protected area networks in different regions worldwide (e.g. Khapugin et al. 2017b; Xu et al. 2018; Kukkonen & Tammi 2019) and, consequently, included recommendations on their improvement. Plants are the backbone of life on earth and are essential for human wellbeing (Kier et al. 2005; Corlett 2016), where only seed plants comprise about 400 000 taxa (Govaerts 2001). In this context, studies of plant diversity, especially of rare and threatened species, in protected areas are extremely important.

Red Lists and Red Data Books are essential tools in biodiversity protection and in generating public and policy support for species conservation (Collar 1996; Rodrigues et al. 2004; Petrova & Vladimirov 2009). Listing species according to the conservation significance and extinction risk is an essential tool for estimating the efficiency of species conservation policy (Mace et al. 2008). Vascular plants, as organisms determining the natural conditions in ecosystems, need special attention in planning and forming regional, national and global Red Lists.

In this study, we aimed to investigate the current state of Red Data Book plant diversity in a protected area in European Russia (Republic of Mordovia), the Mordovia State Nature Reserve. It was established in 1936 and botanical studies started directly, resulting in the 1st list of the flora of the Mordovia State Nature Reserve (Kuznetsov 1960), later supplemented by Tsinger (1966). The republication of the Mordovia State Nature Reserve's flora was the next step of the floristic investigation. After 20 years lack of data, it was finished including additions by Tereshkin & Tereshkina (2006). During 2009–2018, in the framework of an intensive investigation of the protected area's botanical diversity, new species have been discovered for the first time in the Mordovia State Nature Reserve, including rare and threatened plant species (Khapugin et al. 2012, 2013a, 2013b, 2015b). Population-based investigations have been carried out for some plant species (Khapugin 2017; Khapugin et al. 2015a, 2016a, 2017a). As a result of long-term studies of plant diversity in the Mordovia State Nature Reserve and the whole Republic of Mordovia, all species of the Red Data Book of the Republic of Mordovia (Silaeva 2017) have been estimated using IUCN categories and criteria (Khapugin et al. 2017d). The first stage of systematic conservation planning includes general information on the locations of threatened and regionally rare and protected species in a region or in parts of it (Margules & Pressey 2000). The accumulated data on diversity of Red Data Book plants of the Mordovia State Nature Reserve allowed us to analyse their current state on the eve of the recently published Red Data Book of the Republic of Mordovia (Silaeva 2017) and the flora synopsis of the Mordovia State Nature Reserve (Vargot et al. 2016a).

Materials and Methods

Study area

The Mordovia State Nature Reserve is located in the northwest of the Republic of Mordovia in Russia: 54.42–54.56 N, 43.04–43.36 E, up to 190 m a.s.l., 321.62 km^2 (Fig. 1). Its flora includes 809 species from 99 families (Vargot et al. 2016a).

Forest communities cover 89.3% of the total area. *Pinus sylvestris* L. is the main forest-forming wood species in the reserve. It forms pure or mixed forest communities. *Betula pendula* Roth ranks in the second place forming predominantly secondary communities at logging sites and at burnt forest sites. *Tilia cordata* Mill. forests are encountered in the northern part of the Mordovia Reserve. *Quercus robur* L. forests are distributed in floodplains of the Moksha river in the western part. *Picea abies* L. forests are located predominantly in floodplains of rivers and streams (Pushta, Vyaz-Pushta, Vorsklyay, Arga, etc.) and cover only small areas. There are numerous oligotrophic mires dominated by *Sphagnum* or *Sphagnum-Carex* communities. Floodplain meadows are situated mainly in floodplains of Satis river and Moksha river in western and northwestern sites of the protected area (Tereshkin & Tereshkina 2006; Vargot et al. 2016a).

Data collection and analysis

For investigations, we used vascular plant species of the Mordovia State Nature Reserve, which are included in the Red Data Book of the Republic of Mordovia (Silaeva 2017). We analysed herbarium data from collections HMNR, GMU and MW. Other information was extracted from currently available publications on the flora of the Mordovia State Nature Reserve (Kuznetsov 1960; Borodina et al. 1987; Vargot et al. 2016a).

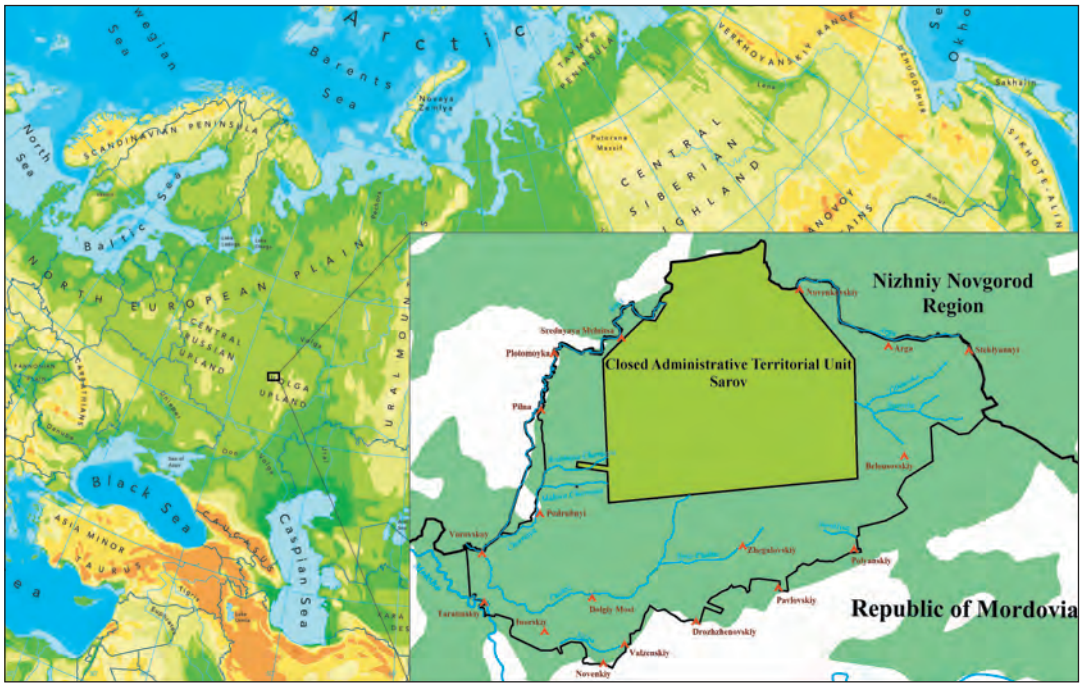

Figure 1. Location of the Mordovia State Nature Reserve. Red symbols within the Mordovia State Nature Reserve are research stations.

We estimated an increase of the number of Red Data Book plant species in the Mordovia State Nature Reserve during 1936–2018. For this purpose, we ascertained data of the first record of each protected species in the studied area. Thus, we counted the total number of Red Data Book plants. We also considered separately the first records which have been rediscovered later and those which have not been rediscovered. Plant populations more than 500 m apart from each other were considered as separate locations. We assigned all records of plants to quarters of the Mordovia State Nature Reserve. 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 along quarters is similar to the grid mapping method using 1 km^2 cell size.

To reveal patterns of spatial distribution of protected vascular plants in the Mordovia State Nature Reserve, we counted the number of Red Data Book species per quarter of the protected area. We used these data to create the range map showing biodiversity hotspots and coldspots of Red Data Book plants.

We analysed the species confinement to different habitats. We distinguished following habitat types: forests (incl. burned coniferous forest, coniferous forest, deciduous forest, mixed forest), floodplain meadows, water bodies (incl. shores), man-made habitats (i.e. roadsides, arable lands, etc.) and *Sphagnum* mires.

To calculate the Representativeness Index of each protected vascular plant in the Mordovia State Nature Reserve, we proposed and used the following formula:

$$RI = \frac{N_{PA}}{N_{TOTAL}} \times 100\%$$

RI – Representativeness Index (RI) of a taxon, N_{PA} – the number of taxon's locations known within a protected area, N_{TOTAL} – 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 protected plants of the Mordovia State Nature Reserve into the following four quartiles: Q1 with RI values 76–100%, Q2 with 51–75%, Q3 with 26–50% and Q4 with RI values from 0.1–25%. To demonstrate the conservation status of vascular plant species involved in the present study, we used the IUCN categories assigned to each taxon according to Khapugin et al. (2017d).

All calculations have been conducted using Microsoft Excel software. Contour map has been created using Surfer 11 and MapInfo 11.5 software.

Results

As a result of long-term botanical studies in the Mordovia State Nature Reserve and generalisation of available publications, we have obtained data on 47 protected vascular plants in the protected area (Table 1). *Cypripedium calceolus* (L.) Rich., *Cephalanthera rubra* L. and *Neottianthe cucullata* (L.) Schltr. are included in the Red Data Book of the Russian Federation (Bardunov & Novikov 2008), which come to 20% of the total number of plant species of the Red Data Book of Russian Federation known in Mordovia. We excluded three species (*Caulinia tenuissima* (A. Br. ex Magnus) Tzvelev, *Rhynchospora alba* (L.) Vahl, *Elatine hydropiper* L.) from our analysis, because these plants are currently located outside the protected area. They are situated within Closed Administrative Territorial Formation Sarov. This area was a part of the Mordovia State Nature Reserve earlier (Khapugin et al. 2015a; Vargot et al. 2016b).

Table 1. The list of Red Data Book plant species known in the Mordovia State Nature Reserve (European Russia).

Species	Habitats	RI, %	Regional Red List (Khapugin et al. 2017d)	Global Red List (IUCN 2018)
Alnus incana (L.) Moench	DF, MMH	100.0	CR	LC
Andromeda polifolia L.	SM	53.3	NT	LC
Botrychium virginianum (L.) Sw.	DF	50.0	CR	–
Carex chordorrhiza Ehrh.	SM	50.0	CR	LC
Carex disperma Dew.	CF, DF, SM	57.1	EN	–
Carex limosa L.	SM	15.4	VU	LC
Carex paupercula Michx.	CF, MF	80.0	CR	–
Carex rhynchophysa C.A. Mey.	CF, MF	50.0	EN	–
Cephalanthera rubra (L.) Rich.	CF	27.3	CR	–
Corallorhiza trifida Chatel.	CF, DF	55.6	CR	–
Cypripedium calceolus L.	CF, DF	16.7	EN	LC
Dactylorhiza maculata (L.) Soó	DF	50.0	EN	–
Diplazium sibiricum (Turcz. ex G. Kunze) Kurata	UNC	100.0	DD	–
Drosera rotundifolia L.	SM	19.2	NT	LC
Eriophorum latifolium Hoppe	CF	25.0	EN	LC
Galium triflorum Michx.	CF, DF	75.0	CR	LC
Glyceria lithuanica (Gorski) Gorski	CF, DF	66.7	CR	–
Goodyera repens (L.) R. Br.	CF, MF	82.6	EN	–
Gratiola officinalis L.	FM, MMH	35.7	VU	LC
Gymnadenia conopsea (L.) R. Br.	CF, MF	50.0	VU	–
Hieracium arcuatidens (Zahn ex Petunn.) Üksip	MF	100.0	DD	–
Holcus mollis L.	CF	100.0	CR	–
Huperzia selago (L.) Bernh. & Schrank et Mart.	CF, MF	75.0	CR	–
Iris sibirica L.	FM	14.3	NT	–
Juniperus communis L.	CF	35.9	NT	LC
Lerchenfeldia flexuosa (L.) Schur	CF	100.0	CR	DD
Linnaea borealis L.	CF	55.4	NT	–
Listera cordata (L.) R. Br.	CF, MF	100.0	CR	–
Lunaria rediviva L.	DF	66.7	EN	LC
Lycopodiella inundata (L.) Holub	SM	33.3	VU	LC
Malaxis monophyllos (L.) Sw.	CF	50.0	EN	–
Moneses uniflora (L.) A. Gray	CF, DF, MF	41.2	EN	–
Neottianthe cucullata (L.) Schlecht.	CF, MF	35.0	EN	–
Oxycoccus palustris Pers.	SM	27.9	NT	LC
Pedicularis dasystachys Schrenk	FM	100.0	CR	–
Polygala wolfgangiana Bess. ex Szafer, Kulcz. & Pawł.	CF	50.0	CR	–
Potamogeton alpinus Balb.	WBS	60.0	EN	LC
Potamogeton obtusifolius Mert. & Koch	WBS	30.8	VU	LC
Potamogeton praelongus Wulfen	WBS	16.7	VU	LC
Pulsatilla patens (L.) Mill.	CF	20.4	NT	–
Pyrola media Sw.	CF, DF	55.6	EN	–
Ranunculus trichophyllus Chaix	WBS	12.5	EN	LC
Salix lapponum L.	SM	9.1	EN	–
Scheuchzeria palustris L.	SM	44.4	EN	LC
Senecio tataricus Less.	DF	20.0	EN	–
Trapa natans L.	WBS	5.3	NT	LC
Viola uliginosa Bess.	DF	50.0	CR	–

Note: RI – representativeness index; CF – coniferous forest; DF – deciduous forest; MF – mixed forest; FM – floodplain meadow; WBS – water body and shore; MMH – man-made habitats; SM – *Sphagnum* mire.

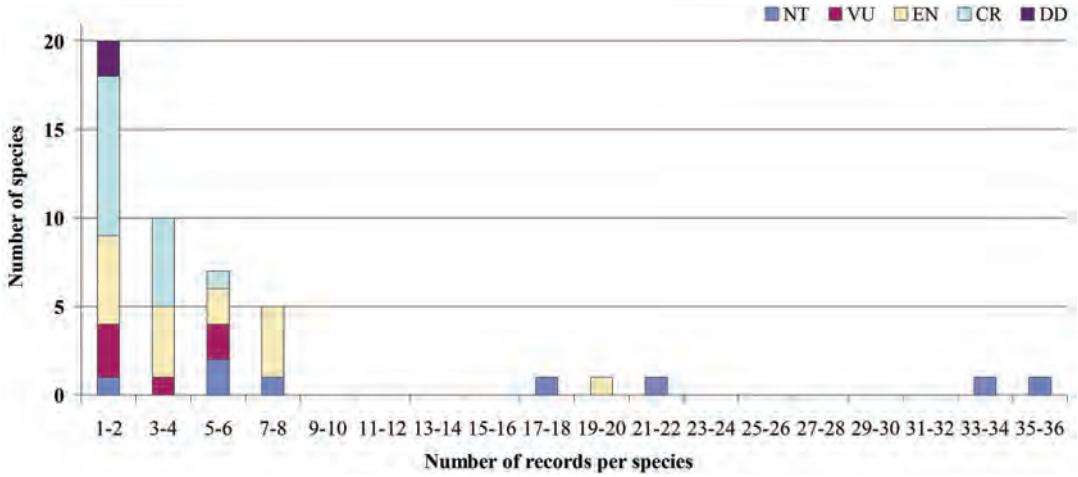

Figure 2. Number of protected vascular plant species depending on record number confirming their presence in the Mordovia State Nature Reserve.

All Red Data Book plants have been found in 265 locations in the Mordovia State Nature Reserve. Most of them (42.6% of total species number) are represented by 1–2 records in the protected area (Fig. 2). At the same time, 21.3% (10 species) and 14.9% (seven species) are known in the Mordovia State Nature Reserve based on 3–4 and 5–6 records respectively. Only three Red Data Book species (*Pulsatilla patens* (L.) Mill., *Juniperus communis* L., *Linnaea borealis* L.) are represented by more than 20 records.

Generalised data on the increase of the number of Red Data Book species in the Mordovia State Nature Reserve in 1936–2018 demonstrate a non-linear trend curve (Fig. 3). In the 1960 peak, all previous records mentioned by Kuznetsov (1960) were included, even if these plant species had been found before 1960. Herbarium specimens were not indicated in this publication. Noteworthy, the first finding of the protected *Moneses uniflora* (L.) A. Gray in the protected area was made in 1928 (Kuznetsov 1960), eight years before the establishment of the Mordovia State Nature Reserve. We could distinguish several periods, when richness of Red Data Book species increased considerably in the Mordovia State Nature Reserve, i.e. before 1960 and before 1987. There was a long period (1985–2013), when only one species (*Polygala wolfgangiana* Bess. ex Szafer, Kulcz. & Pawł. [= *Polygala podolica* DC. according to The PlantList (2019)]) was found for the first time in the Mordovia Reserve. At the same time, there was a slightly active period (2013–2016) reflecting an increase of species richness from 44 to 47 species. It is important that a significant part of the first records of protected species was not rediscovered later (Fig. 3).

Processing of data on spatial distribution of protected plants in the Mordovia State Nature Reserve allowed us to indicate biodiversity hotspots and coldspots in this protected area (Fig. 4). The created range map demonstrates several biodiversity hotspots in south-west and in central Mordovia State Nature Reserve. These points of highest species richness are confined to the research stations (Fig. 1). The neighbourhoods of the settlement Pushta and the research stations Dolgiy Most, Pavlovskiy, Polyanskiy, Inorskiy, Taratinskiy are richest in protected plant species. At the same time, we noted a few small areas with the lowest number of protected plant species, predominantly in the northwestern and eastern parts of the Mordovia State Nature Reserve (Fig. 4).

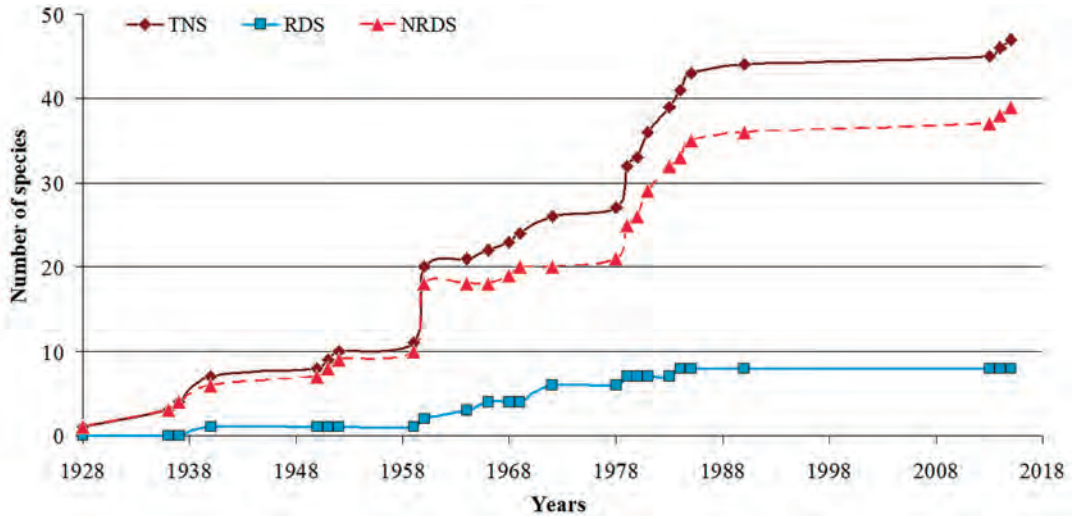

Figure 3. The increase of the number of the Red Data Book vascular plant species in the flora of the Mordovia State Nature Reserve in 1936–2018. TNS – total number of protected species discovered the Mordovia State Nature Reserve; RDS – number of species which have been rediscovered in the Mordovia State Nature Reserve; NRDS – number of species which have not been rediscovered in the Mordovia State Nature Reserve.

Analysis of habitat confinement of protected plants show an undoubted predominance of coniferous forests as refugia of threatened species in the Mordovia State Nature Reserve (Fig. 5). This is evidenced by more than 60% of all records of protected plant species in pine and spruce forests. A significant number of records (10.7% of total) has been discovered in deciduous forests, whereas only eight locations of Red Data Book plants have been found in ecotonal (mixed) forests.

It's noteworthy that a considerable proportion of records (15.7% of the total number) has been revealed in *Sphagnum* mires, despite its small area in the studied protected area (5.58 km^2 or

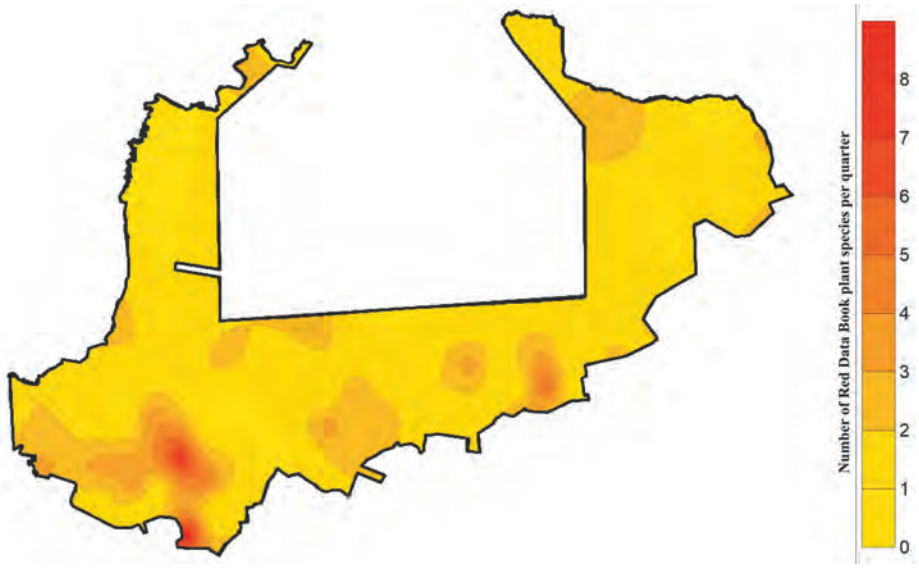

Figure 4. Contour map showing the number of Red Data Book vascular plant species per quarter of the Mordovia State Nature Reserve.

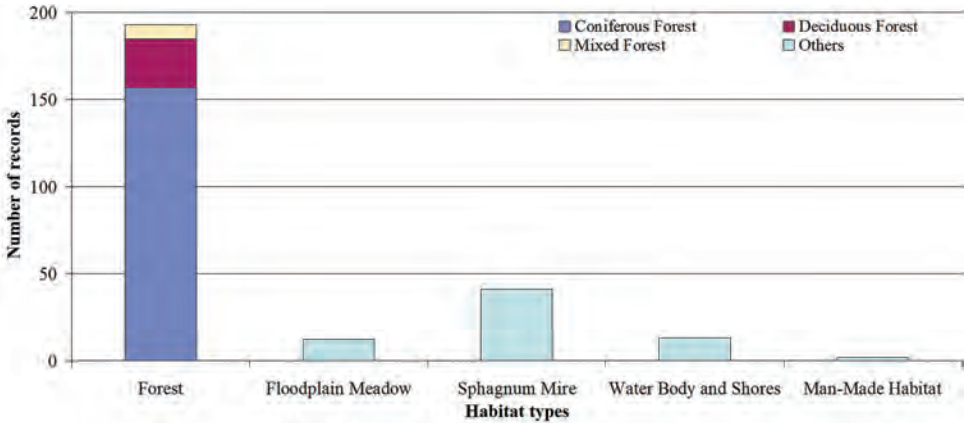

Figure 5. Habitat preferences of Red Data Book vascular plant species in the Mordovia State Nature Reserve.

1.7% of total area of the Mordovia State Nature Reserve, according to Grishutkin (2011); pers. comm. O.G. Grishutkin). At the same time, the least number of locations of protected plant species (0.8%) has been found in man-made habitats (Fig. 5).

We analysed data on Representativeness Index for protected plant species in the Mordovia State Nature Reserve by applying five IUCN categories. Figure 6 shows that proportion of 4th quartile species decreased with an increase of threat category (from NT to EN), while the number of the most representative plant species increased from EN to CR. At the same time, all Data Deficient (DD) taxa (*Diplazium sibiricum* (Turcz. ex G. Kunze) Kurata, *Hieracium arcuatidens* (Zahn ex Petunn.) Üksip) had 100% value of Representativeness Index.

Conservation value of a protected area is indicated by species, which are known exactly in this territory within a region. With a certain degree of conditionality, such species can be considered as 'regional endemics'. As a result of RI value calculation, we distinguished a group of the Red Data Book plant species, which is known in the region (Republic of Mordovia) only within the Mordovia State Nature Reserve (i.e. RI = 100%). These are two Data Deficient species (*Diplazium sibiricum*, *Hieracium arcuatidens*) and five Critically Endangered species (*Alnus incana* (L.) Moench, *Holcus mollis* L., *Lerchenfeldia flexuosa* (L.) Schur (= *Deschampsia flexuosa* (L.) Trin.), *Listera cordata* (L.) R. Br., *Pedicularis dasystachys* Schrenk).

As all plants included in the Red Data Book of the Republic of Mordovia have been estimated according to the IUCN criteria and categories (Khapugin et al. 2017c, 2017d), we show the proportion of five IUCN categories (DD, CR, VU, EN, NT) in terms of the number of protected plant species known in the Mordovia State Nature Reserve in this study (Fig. 7). In addition, we compare it with the same categories of Red Data Books of the Republic of Mordovia (Khapugin et al. 2017d), Bulgaria (Peev et al. 2015), Poland (Kaźmierczakowa et al. 2014) and with Red Lists of complete floras of the following European countries: Slovakia (Eliáš jr. et al. 2015), Bulgaria (Petrova & Vladimirov 2009) and Hungary (Barina et al. 2007).

We noticed that Red Data Books of European countries (e.g. Poland and Bulgaria) are characterised by a low proportion or absence of Near Threatened taxa. At the same time, the Red Data Book of the Republic of Mordovia includes a significant proportion of NT species (17.5% of total). Approximately the same proportion of species with this threat category is found in Red Lists of complete floras in countries of Central Europe (Fig. 7). We also noticed the obviously higher

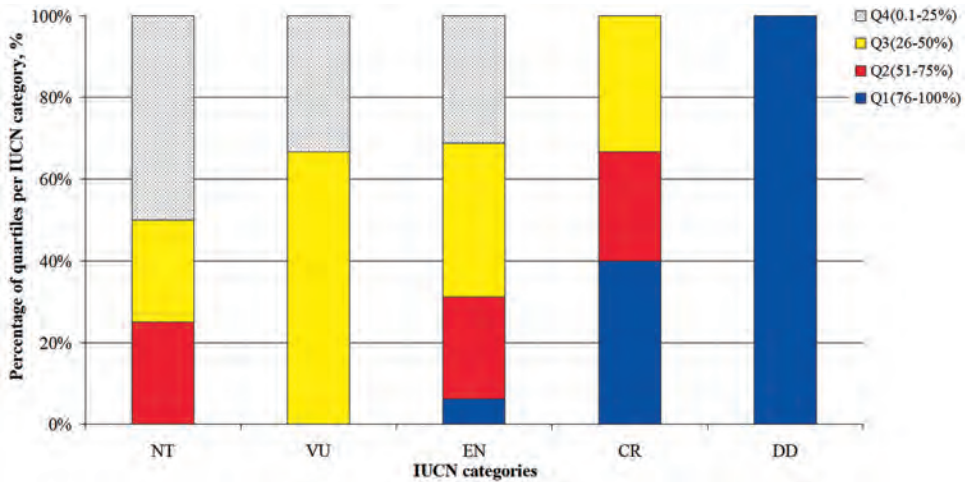

Figure 6. Proportions of quartiles of Representativeness Index values for Red Data Book vascular plants in the Mordovia State Nature Reserve.

proportion of Critically Endangered and Endangered taxa in Red Data Books compared to red lists of vascular plants (Slovakia, Bulgaria, Hungary), in which Near Threatened taxa had higher proportion.

Discussion

Assessment of existing protected areas efficiency could be carried out by different methods on a global scale (Wierzbowska et al. 2012; D'Amen et al. 2013; Rodríguez-Rodríguez & Martinez-Vega 2018), e.g. estimation of composition, conservation status and representativeness of taxa within protected area networks (Du et al. 2018; Hoffmann et al. 2018; Ribeiro et al. 2018). These indicators could be different even for closely located areas (Kalikhman 2007; Baldi et al. 2018). Russian protected areas cover 12.3% (including 3.7% of federal PAs) of the total

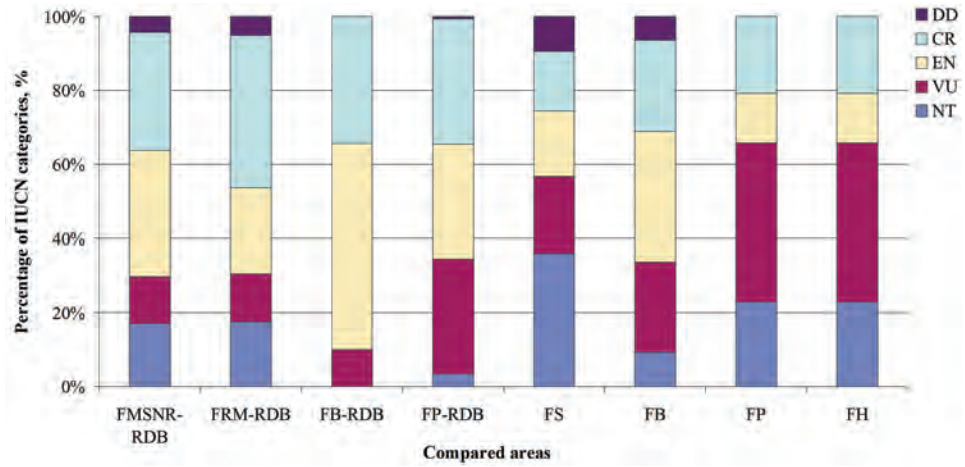

Figure 7. Proportions of IUCN categories applied to the Red Data Book vascular plants in the Mordovia State Nature Reserve. [FMSNR-RDB] this study, [FRM-RDB] the whole territories of the Republic of Mordovia (Khapugin et al. 2017d), [FB-RDB] Bulgaria (Peev et al. 2015), [FP-RDB] Poland (Kaźmierczakowa et al. 2014), and [FS] the whole flora list of Slovakia (Eliáš jun. et al. 2015), [FB] Bulgaria (Petrova & Vladimirov 2009), [FH] Hungary (Barina et al. 2007).

area of Russian Federation. However, numerous global reviews and assessments of biodiversity demonstrate a lack of data from Russia and CIS countries (e.g. Yesson et al. 2007; Meyer et al. 2016; Kehoe et al. 2017; Tedersoo et al. 2018). Therefore, the present study on status assessment of protected plant species in a protected area of European Russia is an important contribution to the knowledge of threatened biodiversity of Europe and Eurasia as a whole.

Our study demonstrated that the Mordovia State Nature Reserve includes populations of 26.6% of total number of Red Data Book plant species known in the Republic of Mordovia. At the same time, 40.2% Red Data Book plants of Mordovia confined to steppes are not able to grow in this area due to the absence of suitable biotopes (Khapugin & Silaeva 2013; Khapugin et al. 2017b), because most area of the Mordovia State Nature Reserve is covered by forest communities. We propose that the number of Red Data Book (= threatened) plant species per protected area could be dependent on diversity of plant communities within this territory. For instance, a high number of Red Data Book plants has been noted in the Karadag State Nature Reserve (39% of the total number of plant species included in the Red Data Book of the Crimean Republic, see Kostenko 2016) and in National Park 'Belovezhskaya Pushcha' (34.1% of the total number of plant species included in the Red Data Book of Belarus, see Vasilyevich 2019). Both protected areas are characterised by a high diversity of plant communities. A less proportion of Red Data Book plant species per PA has been noted in Pirin National Park (20.0% of the total number of plant species included in the Red Data Book of Bulgaria, see Peev et al. 2015) and in Uzhansk National Park (18.3% of the total number of plant species included in the Red Data Book of Ukraine, see Kricsfalusy et al. 2010). These protected areas are characterised by a intermediate degree of phytocoenotic diversity. Finally, only 12% of the total number of plant species included in the Red Data Book of Nizhniy Novgorod region (Urbanavichute 2014) has been found in the Kerzhenskiy State Nature Reserve. Its area is almost completely covered by forest communities, and thus characterised by a low diversity of plant communities.

The presence of the most protected plant species in the Mordovia State Nature Reserve has been confirmed by a small number of records. A large number of them was not rediscovered later. Thus, we can see an example of 'find and forget' in study of plant diversity of the Mordovia State Nature Reserve, when a population is being visited once during the whole study period. Similar examples are known from studies of animals (Pearson et al. 2007) as well as plants (Chmara et al. 2013). At the same time, we demonstrated the large number of locations and relatively low values of Representativeness Index (20.4%, 35.9%, 55.4% respectively) for *Pulsatilla patens*, *Juniperus communis* and *Linnaea borealis*. This clearly indicates that these species are not threatened with extinction in this region. This could be a presupposition for recommending the further exclusion of these plant species from the Red Data Book of the Republic of Mordovia (Silaeva 2017).

The biodiversity hotspot model has been originally used in the tropics rich in endemic species (Myers et al. 2000). In global coldspots, however, other factors determine the degree of species richness. Different regional studies aimed at determination of regional hotspots of biodiversity in these regions (e.g. Reid 1998; Baltensperger & Huettmann 2015; Cooper-Bohannon et al. 2016). In the present study, we demonstrate hotspots of Red Data Book plant species in the Mordovia State Nature Reserve. Their locations largely coincide with the position of some research stations of the Mordovia State Nature Reserve (see Fig. 1 and Fig. 4) as well as the site 'Igishev Bugor' in the center of the protected area. This emphasises the important role of research stations in investigating biodiversity of certain areas. Efficiency of biodiversity studies

can also be increased by a higher density of research stations (e.g. Mishra 2013). At the same time, our data are a presupposition for additional botanical research at a greater distance from the research stations. A low diversity of Red Data Book plant species (biodiversity coldspots) is in the northwestern and eastern parts of the Mordovia State Nature Reserve. Previously, these areas had been covered by impassable forests, but they were burnt completely during a wildfire in 2010. Since then, only few data on the presence of Red Data Book plants in these areas have been evaluated. So we can only suppose that populations of some of protected plant species could be damaged, while populations of some fire-tolerant plants could have survived to date. In addition, the curve of long-term dynamics of protected species number show that the growth of species number in the Mordovia Reserve could be observed exactly in periods of preparation of floristic lists for these protected areas, e.g. Kuznetsov (1960), Borodina et al. (1987) and Vargot et al. (2016a). At the same time, most of the first records of protected plant species have not been rediscovered. The reasons for these phenomena concern the social component of the botanical research in the Mordovia Reserve. And they cannot be explained using data obtained in present study. However, this underlines the urgent need for special studies to rediscover these records of Red Data Book species in the nearest future.

Coniferous forests were typical habitats for most of the Red Data Book plants known in the Mordovia State Nature Reserve. On the one hand, predominance of pine forests (47.7% of total forest area) can explain the revealed results. On the other hand, the Mordovia State Nature Reserve is situated near the southern boundary of the continuous distribution of coniferous forests. Therefore, populations of many boreal plant species are at the limit of their natural ranges and threat with extinction in the region (Khapugin et al. 2017b, 2017d). Obtained results on Red Data Book plants are in accordance with data showing that forest ecosystems are refugia of threatened plants and animals in the temperate zone (Boch et al. 2013; Khapugin & Chugunov 2015; Ruchin & Egorov 2018a, 2018b; Tomaszewska et al. 2018; Ruchin et al. 2019a). In particular, it concerns special studies in pine (e.g. Ecroyd & Brockerhoff 2005) and spruce (e.g. Nascimbene et al. 2009) forests.

Despite the small area in the Mordovia State Nature Reserve, *Sphagnum* mires contain 1.5 times more records of protected plant species than deciduous forests (Fig. 5). These patches could be considered 'islands' of boreal biodiversity in temperate Eurasia (Calmé et al. 2002). In addition, mires are plant communities that are fairly stable and only change little in time. This is evidenced by palaeoecological studies of several mires of the Mordovia State Nature Reserve (Novenko et al. 2017), which are about 7000 years old. These *Sphagnum* mires are habitats of many boreal and arctic-boreal plant species (e.g. *Oxycoccus palustris* Pers. (= *Vaccinium oxycoccos* L.), *Andromeda polifolia* L., *Scheuchzeria palustris* L.). We suppose a further increase in number of locations of these species, because *Sphagnum* mires are still insufficiently investigated. Moreover, some Red Data Book plants of oligotrophic mires (e.g. *Drosera rotundifolia* L., *Hammarbya paludosa* (L.) Kuntze, *Scheuchzeria palustris*) are not visible every year. Other habitat types are represented by a less number of records of protected plant species in the Mordovia State Nature Reserve. This especially concerns man-made habitats and a greater sensitivity of threatened plant populations to habitat disturbances. This is especially noticeable in comparison to invertebrates, some of which inhabit roadsides and other man-made habitats (Larsen et al. 2003; Ruchin et al. 2019).

High values of Representativeness Index obtained for more threatened taxa (Critically Endangered, Endangered) indicate high conservation significance. For instance, five Mordovian Critically

Endangered taxa (*Alnus incana*, *Holcus mollis*, *Lerchenfeldia flexuosa*, *Listera cordata*, *Pedicularis dasystachys*) only grow in the Mordovia State Nature Reserve (i.e. RI = 100%). It is noteworthy that besides of *Alnus incana* also other mentioned plant species were rediscovered there: 59 years (*Lerchenfeldia flexuosa* in 1960) and respectively 34 years (*Pedicularis dasystachys* in 1985) ago. The same situation occurs with two Data Deficient species known from the protected area: *Diplazium sibiricum* was discovered 82 years ago (in 1937) and *Hieracium arcuatidens* was found 36 years ago (in 1983). Therefore, there is a clear and urgent need to intensify research on rediscovery and the search for new locations of these species in the Mordovia State Nature Reserve.

At the same time, Representativeness Index values are lower for most of the protected plants with low threat status (i.e. Vulnerable and Near Threatened). This suggests that these species (e.g. *Trapa natans* L., *Pulsatilla patens*, *Juniperus communis*) occur relatively frequently in the Republic of Mordovia. Moreover, some plant species are able to survive after a fire impact (*Pulsatilla patens*, see Khapugin et al. 2016b). In general, fire factor can sometimes positively influence the growth and development of some aquatic Red Data Book plant species (i.e. *Trapa natans*, see Hummel & Kiviat 2004).

In general, the ratio of the Red Data Book species classified by IUCN categories in the Mordovia State Nature Reserve is similar to that in the whole region of the Republic of Mordovia (Fig. 7). The considerable contribution of Critically Endangered and Endangered species in the ratio indicates the significance of the Mordovia State Nature Reserve in the conservation of protected plant populations. Undoubtedly, a considerable proportion of Near Threatened species is noteworthy. This distinguishes the ratio of the species of Red Data Book of the Republic of Mordovia by IUCN categories from those in the Red Data Books of Bulgaria and Poland. However, Red Lists of the floras of Bulgaria, Slovakia and Hungary include 9.4%, 36.0% and 22.8% Near Threatened species. In our opinion, this can be explained by the differences in the compilation of the species list of the Red Data Book and the assessment of these taxa according to the IUCN guidelines and criteria. A good example is the Bulgarian flora. In this country, all plant species have been assessed originally according to IUCN guidelines and criteria (Petrova & Vladimirov 2009). After that, only the most threatened taxa (Critically Endangered, Endangered and Vulnerable) have been included in the Red Data Book of Bulgaria (Peev et al. 2015). This algorithm allows to take under protection (i.e. include in the Red Data Book) the most threatened species of a certain territory. Contrary, the assessment of plant species of the Republic of Mordovia according to IUCN guidelines and criteria (Khapugin et al. 2017c, 2017d) was conducted for species, which have already been approved for inclusion in the Red Data Book of the Republic of Mordovia (Silaeva 2017). That's why the Red List of the Republic of Mordovia includes 17.5% Near Threatened and 5.1% Data Deficient plant species. Based on this, we strongly recommend that the next edition of the Red Data Book of the Republic of Mordovia should include only the most threatened plant species.

Conclusions

Although protected areas have in general higher values of biodiversity indicators than adjacent areas (Gray et al. 2016; Araújo et al. 2007), Red Data Book species can be concentrated only in their restricted patches (Paciorek et al. 2016; Wathen et al. 2014). Data on biodiversity hotspots and coldspots in the Mordovia State Nature Reserve contribute to the development of protected area management strategies and the identification of zones of special protection regime.

Our results indicate the key role of research stations in the study of protected species diversity of a certain area. Of 47 Red Data Book plant species of the Mordovia Reserve, the presence of 42.6% and 21.3% species are confirmed in 1–2 and 3–4 locations. This shows the urgent need to confirm the presence of many protected species by finding new locations as a result of additional botanical studies. We could expectedly demonstrate that most of the protected plant species are confined to coniferous forests and *Sphagnum* mires in the Mordovia State Nature Reserve. Especial conservation significance of the studied protected area is caused by high values of Representativeness Index of Critically Endangered plant species. Moreover, we noted a tendency to an increase in the proportion of Critically Endangered and Endangered species with an increase in the Representativeness Index values of species. Red Data Book plant species known in the Republic of Mordovia only from the Mordovia State Nature Reserve (i.e. RI=100%) have the highest conservation significance. This group includes two Data Deficient (*Diplazium sibiricum*, *Hieracium arcuatidens*) and five Critically Endangered species (*Alnus incana*, *Holcus mollis*, *Lerchenfeldia flexuosa*, *Listera cordata*, *Pedicularis dasystachys*).

References

Araújo M. B., Lobo J. M. & Moreno J. C. (2007): The effectiveness of Iberian protected areas in conserving terrestrial biodiversity. – Conservation Biol. **21**(6): 1423–1432. DOI: 10.1111/j.1523-1739.2007.00827.x

Baldi G., Schauman S. A., Texeira M., Marinaro S., Martin O. A., Gandini P. & Jobbágy E. G. (2018): Nature representativeness in South American protected areas: Country contrasts and conservation priorities. – BioRxiv 456558. DOI: 10.1101/456558

Baltensperger A. P. & Huettmann F. (2015): Predictive spatial niche and biodiversity hotspot models for small mammal communities in Alaska: applying machine-learning to conservation planning. – Landscape Ecol. **30**(4): 681–697. DOI: 10.1007/s10980-014-0150-8

Bardunov L. V. & Novikov V. S. [ed.] (2008): Red Book of Russian Federation (plants and fungi). – Moscow: KMK Scientific Press Ltd. [In Russian]

Barina Z., Csiky J., Farkas S., Jakab G., Király G., Lájer K., Mesterházy A., Molnár V. A., Nagy J., Németh C. S., Pál R., Pifkó D., Pinke G. Y., Schmotzer A., Somlyay L., Sramkó G., Vidéki R. & Vojtkó A. (2007): Red list of the vascular flora of Hungary. – Sopron: Saját kiadás.

Belle E., Kingston N., Burgess N., Sandwith T., Ali N. & MacKinnon K. [eds] (2018): Protected planet report 2018. – Cambridge, Gland & Washington: UNEP-WCMC, IUCN & NGS.

Berezenko N. S. & Milchakova N. A. (2018): Long-term changes of macrophytobenthos of "Sudzhuk Lagoon" Natural Monument (Black Sea). – Nat. Conservation Res. **3**(4): 59–67. DOI: 10.24189/ncr.2018.060

Boch S., Prati D., Hessenmöller D., Schulze E.-D. & Fischer M. (2013): Richness of lichen species, especially of threatened ones, is promoted by management methods furthering stand continuity. – PLoS ONE **8**(1): e55461. DOI: 10.1371/journal.pone.0055461

Borodina N. V., Dolmatova L. V., Sanaeva L. V. & Tereshkin I. S. (1987): Vascular plants of the Mordovia State Nature Reserve. – Moscow: VINITI. [In Russian]

Butchart S. H. M, Walpole M., Collen B., van Strien A., Scharlemann J. P., Almond R. E., Baillie J. E., Bomhard B., Brown C., Bruno J., Carpenter K. E., Carr G. M., Chanson J., Chenery A. M., Csirke J., Davidson N. C., Dentener F., Foster M., Galli A., Galloway J. N., Genovesi P., Gregory R. D., Hockings M., Kapos V., Lamarque J. F., Leverington F., Loh J., McGeoch M. A., McRae L., Minasyan A., Hernández Morcillo M., Oldfield T. E., Pauly D., Quader S., Revenga C., Sauer J. R., Skolnik B., Spear D., Stanwell-Smith D., Stuart S. N., Symes A., Tierney M., Tyrrell T. D., Vié J. C. & Watson R.

(2010): Global biodiversity: indicators of recent declines. – Science **328**(5982): 1164–1168. DOI: 10.1126/science.1187512

Calmé S., Desrochers A. & Savard J.-P.L. (2002): Regional significance of peatlands for avifaunal diversity in southern Quebec. – Biol. Conservation **107**: 273–281. DOI: 10.1016/S0006-3207(02)00063-0

Chmara R., Szmeja J. & Ulrich W. (2013): Patterns of abundance and co-occurrence in aquatic plant communities. – Ecol. Res. **28**(3): 387–395. DOI: 10.1007/s11284-013-1028-y

Coetzee B.W., Gaston K.J. & Chown S.L. (2014): Local scale comparisons of biodiversity as a test for global protected area ecological performance: a meta-analysis. – PLoS ONE **9**: e105824. DOI: 10.1371/journal.pone.0105824

Collar N. (1996): The reasons for Red Data Books. – Oryx **30**(2): 121–130. DOI: 10.1017/S003060 5300021505

Cooper-Bohannon R., Rebelo H., Jones G., Cotterill F., Monadiem A., Schoeman M.C., Taylor P. & Park K. (2016): Predicting bat distributions and diversity hotspots in southern Africa. – Hystrix **27**(1). DOI: 10.4404/hystrix-27.1-11722

Corlett R.T. (2016): Plant diversity in a changing world: status, trends, and conservation needs. – Pl. Diversity **38**: 10–16.

D'Amen M., Bombi P., Campanaro A., Zapponi L., Bologna M.A. & Mason F. (2013): Protected areas and insect conservation: questioning the effectiveness of Natura 2000 network for saproxylic beetles in Italy. – Animal Conservation **16**(4): 370–378. DOI: 10.1111/acv.12016

Díaz S., Fargione J., Chapin F.S. & Tilman D. (2006): Biodiversity loss threatens human well-being. – PLoS Biology **4**(8): e277. DOI: 10.1371/journal.pbio.0040277

Du B., Zheng Y., Liu J. & Mao D. (2018): Threatened plants in China's Sanjiang Plain: Hotspot distributions and gap analysis. – Sustainability **10**(1): 194. DOI: 10.3390/su10010194

Ecroyd C. & Brockerhoff E. (2005): Floristic changes over 30 years in a Canterbury Plains kānuka forest remnant, and comparison with adjacent vegetation types. – New Zealand J. Ecol. **29**(2): 279–290.

Eliáš jr. P., Dítě D., Kliment J., Hrivnák R. & Feráková V. (2015): Red list of ferns and flowering plants of Slovakia [5th ed.] (October 2014). – Biologia **70**(2): 218–228.

Faith D.P., Magallón S., Hendry A.P., Conti E., Yahara T. & Donoghue M.J. (2010): Ecosystem services: An evolutionary perspective on the links between biodiversity and human well-being. – Curr. Opin. Environm. Sustain. **2**(1–2): 66–74. DOI: 10.1016/j.cosust.2010.04.002

Gaston K.J., Jackson S.F., Cantú-Salazar L. & Cruz-Piñón G. (2008): The ecological performance of protected areas. – Annual Rev. Ecol. Evol. Syst. **39**(1): 93–113. DOI: 10.1146/annurev.ecolsys.39.110707.173529

Gebremedihin K.M., Birhane E., Tadesse T. & Gbrewahid H. (2018): Restoration of degraded drylands through exclosures enhancing woody species diversity and soil nutrients in the highlands of Tigray, Northern Ethiopia. – Nat. Conservation Res. **3**(1): 1–20. DOI: 10.24189/ncr.2018.001

Geldmann J., Barnes M., Coad L., Craigie I.D., Hockings M. & Burgess N.D. (2013): Effectiveness of terrestrial protected areas in reducing habitat loss and population declines. – Biol.Conservation **161**: 230–238. DOI: 10.1016/j.biocon.2013.02.018

Goettsch B., Hilton-Taylor C., Cruz-Piñón G., Duffy J.P., Frances A., Hernández H.M., Inger R., Pollock C., Schipper J., Superina M., Taylor N.P., Tognelli M., Abba A.M., Arias S., Arreola-Nava H.J., Baker M.A., Bárcenas R.T., Barrios D., Braun P., Butterworth C.A., Búrquez A., Caceres F., Chazaro-Basañez M., Corral-Díaz R., Del Valle Perea M., Demaio P.H., Duarte de Barros W.A., Durán R., Yancas L.F., Felger R.S., Fitz-Maurice B., Fitz-Maurice W.A., Gann G., Gómez-Hinostrosa C., Gonzales-Torres L.R., Patrick Griffith M., Guerrero P.C., Hammel B., Heil K.D.,

Hernández-Oria J. G., Hoffmann M., Ishihara M. I., Kiesling R., Larocca J., León-de la Luz J. L., Loaiza S. C. R., Lowry M., Machado M. C., Majure L. C., Ávalos J. G., Martorell C., Maschinski J., Méndez E., Mittermeier R. A., Nassar J. M., Negrón-Ortiz V., Oakley L. J., Ortega-Baes P., Ferreira A. B., Pinkava D. J., Porter J. M., Puente-Martinez R., Gamarra J. R., Pérez P. S., Martínez E. S., Smith M., Manuel Sotomayor M. Del C., Stuart S. N., Muñoz J. L., Terrazas T., Terry M., Trevisson M., Valverde T., Van Devender T. R., Véliz-Pérez M. E., Walter H. E., Wyatt S. A., Zappi D., Alejandro Zavala-Hurtado J. & Gaston K. J. (2015): High proportion of cactus species threatened with extinction. – Nature Plants **1**: 15142. DOI: 10.1038/nplants.2015.142

Govaerts R. (2001): How many species of seed plants are there? – Taxon **50**(4): 1085–1090.

Gray C. L., Hill S. L., Newbold T., Hudson L. N., Börger L., Contu S. & Scharlemann J. P. (2016): Local biodiversity is higher inside than outside terrestrial protected areas worldwide. – Nat. Commun. **7**: 12306. DOI: 10.1038/ncomms12306

Grishutkin O. G. (2011): The area and spatial distribution of mires in the Mordovia State Nature Reserve. – Proceedings of the Mordovia State Nature Reserve **9**: 280–281. [In Russian]

Havens K., Kramer A. T. & Guerrant E. O. (2014): Getting plant conservation right (or not): the case of the United States. – Int. J. Pl. Sci. **175**(1): 3–10. DOI: 10.1086/674103

Hoffmann S., Beierkuhnlein C., Field R., Provenzale A. & Chiarucci A. (2018): Uniqueness of protected areas for conservation strategies in the European Union. – Scientific Reports **8**(1): 6445. DOI: 10.1038/s41598-018-24390-3

Hummel M. & Kiviat E. (2004): Review of world literature on water chestnut with implications for management in North America. – J. Aquatic Pl. Managem. **42**: 17–27.

IUCN (2018): The IUCN Red List of Threatened Species. Version 2018-2. – http://www.iucnredlist.org [Accessed: 01 February 2019].

Jackson S. F. & Gaston K. J. (2008): Land use change and the dependence of national priority species on protected areas. – Global Change Biol. **14**(9): 2132–2138. DOI: 10.1111/j.1365-2486.2008.01628.x

Kalikhman T. P. (2007): Special Protected Natural Areas of Baikal Region. – Izvestiya RAN. Seriya Geograficheskaya **3**: 75–86. [In Russian]

Kaźmierczakowa R., Zarzycki K. & Mirek Z. (2014): Polska Czerwona Księga Roślin. Paprotniki i rośliny kwiatowe. Polish Red Data Book of Plants. Pteridophytes and flowering plants. Wyd. III. uaktualnione i rozszerzone. – Kraków: Instytut Ochrony Przyrody PAN.

Kehoe L., Romero-Muñoz A., Polaina E., Estes L., Kreft H. & Kuemmerle T. (2017): Biodiversity at risk under future cropland expansion and intensification. – Nat. Ecol. Evol. **1**: 1129–1135. DOI: 10.1038/s41559-017-0234-3

Khapugin A. A. (2017): *Hieracium sylvularum* (Asteraceae) in the Mordovia State Nature Reserve: invasive plant or historical heritage of the flora? – Nat. Conservation Res. **2**(4): 40–52. DOI: 10.24189/ncr.2017.013

Khapugin A. A. & Chugunov G. G. (2015): Two populations of *Lunaria rediviva* L. (Cruciferae Juss.) at the eastern edge of its range. – Wulfenia **22**: 83–94.

Khapugin A. A., Chugunov G. G., Grishutkin O. G., Dementeva A. E. & Cherepanova E. A. (2013a): Records of new and rare species of native flora of the Mordovia State Nature Reserve in 2012. – Proceedings of the Mordovia State Nature Reserve **11**: 279–282. [In Russian]

Khapugin A. A., Chugunov G. G., Silaeva T. B. & Kunaeva E. N. (2016a): *Neottianthe cucullata* (L.) Schltr. (Orchidaceae Juss.), an endangered orchid in Central Russia. – Wulfenia **23**: 189–202.

Khapugin A. A., Chugunov G. G. & Vargot E. V. (2017a): *Cypripedium calceolus* (Orchidaceae) in Central Russia: a case study for its populations in two protected areas in the Republic of Mordovia (Russia). – Lankesteriana **17**(3): 403–417. DOI: 10.15517/lank.v17i3.31577

Khapugin A.A., Chugunov G.G., Vargot E.V. & Silaeva T.B. (2017b): Vascular plants at the protected areas network of the Republic of Mordovia: present status and prospects. – In: Mukul S.A. & Rashid A.Z.M.M. [eds]: Protected areas: Policies, management and future directions: 203–231. – Hauppauge, NY: Nova Science Publishers, Inc.

Khapugin A.A. & Silaeva T.B. (2013): The cover of steppe vascular plants by the protected area network of the Republic of Mordovia (Russia). – In: Morales Prieto M.B. & Traba Diaz J. [eds]: Steppe ecosystems: Biological diversity, management and restoration: 211–220. – New York: Nova Science Publishers, Inc.

Khapugin A.A., Silaeva T.B., Vargot E.V. & Chugunov G.G. (2017c): IUCN guidelines using for assessment of plants from the Red Book of Russian Federation at regional level: a case study for the Republic of Mordovia (Russia). – Hacquetia **16**(1): 19–33. DOI: 10.1515/hacq-2016-0012

Khapugin A.A., Silaeva T.B., Vargot E.V., Chugunov G.G., Grishutkina G.A., Grishutkin O.G., Pismarkina E.V. & Orlova Y.S. (2017d): Estimation of taxa included in the first volume of the Red Data Book of the Republic of Mordovia (Russia) using the IUCN Red List categories and criteria. – Nat. Conservation Res. **2**(Suppl. 1): 164–189. DOI: 10.24189/ncr.2017.004 [In Russian]

Khapugin A.A., Vargot E.V. & Chugunov G.G. (2012): Additions to the flora of the Mordovia State Nature Reserve. – Proceedings of the Mordovia State Nature Reserve **10**: 361–364. [In Russian]

Khapugin A.A., Vargot E.V. & Chugunov G.G. (2015a): Materials to the inventory of the flora of the Mordovia State Nature Reserve. – Proceedings of the Mordovia State Nature Reserve **14**: 370–375. [In Russian]

Khapugin A.A., Vargot E.V. & Chugunov G.G. (2016b): Vegetation recovery in fire-damaged forests: a case study at the southern boundary of the taiga zone. – Forest. Stud. **64**: 39–50. DOI: 10.1515/fsmu-2016-0003

Khapugin A.A., Vargot E.V., Chugunov G.G. & Dement'eva A.E. (2013b): Additions and notes to the alien flora of the Mordovian State Nature Reserve. – Russian Journal of Biological Invasions **4**(3): 200–207. DOI: 10.1134/S2075111713030041

Khapugin A.A., Vargot E.V., Mežaka A. & Chugunov G.G. (2015b): Novelties in the flora of the Mordovia State Nature Reserve. – Proceedings of the Mordovia State Nature Reserve **14**: 430–433. [In Russian]

Kier G., Mutke J., Dinerstein E., Ricketts T.H., Küper W., Kreft H. & Barthlott W. (2005): Global patterns of plant diversity and floristic knowledge. – J. Biogeogr. **32**(7): 1107–1116. DOI: 10.1111/j.1365-2699.2005.01272.x

Kolyuchkina G.A., Syomin V.L., Simakova U.V. & Mokievsky V.O. (2018): Presentability of the Utrish Nature Reserve's benthic communities for the North Caucasian Black Sea Coast. – Nat. Conservation Res. **3**(4): 1–16. DOI: 10.24189/ncr.2018.065

Kostenko N.S. (2016): Raritet species of flora and fauna at the Karadag Nature Reserve. – Proceedings of the T.I. Vyazemsky Karadag scientific station – Nature Reserve of the RAS **1**: 56–85. [In Russian]

Kricsfalusy V., Budnikov G. & Lesio I. (2010): Rare and protected plant species of the Uzhansky National Nature Park (Transcarpathia, Ukraine). – Thaiszia **20**: 115–125.

Kukkonen M. & Tammi I. (2019): Systematic reassessment of Laos' protected area network. – Biol. Conservation **229**: 142–151. DOI: 10.1016/j.biocon.2018.11.012

Kuznetsov N.I. (1960): Flora of fungi, lichens, bryophytes and vascular plants in the Mordovia State Nature Reserve. – Proceedings of the Mordovia State Nature Reserve **1**: 71–128. [In Russian]

Larsen K.J., Work T.T. & Purrington F.F. (2003): Habitat use patterns by ground beetles (Coleoptera: Carabidae) of northeastern Iowa. – Pedobiologia **47**: 288–299.

Mace G.M., Collar N.J., Gaston K.J., Hilton-Taylor C., Akçakaya H.R., Leader-Williams N., Milner-Gulland E.J. & Stuart S.N. (2008): Quantification of extinction risk: IUCN's system

for classifying threatened species. – Conservation Biol. **22**: 1424–1442. DOI: 10.1111/j.1523-1739.2008.01044.x

Margules C. R. & Pressey R. L. (2000): Systematic conservation planning. – Nature **405**(6783), 243–253. DOI: 10.1038/35012251

Martinez I., Carreno F., Escudero A. & Rubio A. (2006): Are threatened lichen species well-protected in Spain? Effectiveness of a protected areas network. – Biol. Conservation **133**(4): 500–511. DOI: 10.1016/j.biocon.2006.08.003

Meyer C., Weigelt P. & Kreft H. (2016): Multidimensional biases, gaps and uncertainties in global plant occurrence information. – Ecol. Letters **19**(8): 992–1006. DOI: 10.1111/ele.12624

Mishra A. K. (2013): Effect of rain gauge density over the accuracy of rainfall: a case study over Bangalore, India. – SpringerPlus **2**(1): 311. DOI: 10.1186/2193-1801-2-311

Mizin I. A., Sipko T. P., Davydov A. V. & Gruzdev A. R. (2018): The wild reindeer (*Rangifer tarandus*: Cervidae, Mammalia) on the arctic islands of Russia: a review. – Nat. Conservation Res. **3**(3): 1–14. DOI: 10.24189/ncr.2018.040

Myers N., Mittermeier R. A., Mittermeier C. G., da Fonseca G. A. B. & Kent J. (2000): Biodiversity hotspots for conservation priorities. – Nature **403**(6772): 853–858. DOI: 10.1038/35002501

Nascimbene J., Marini L., Motta R. & Nimis P. L. (2009): Influence of tree age, tree size and crown structure on lichen communities in mature Alpine spruce forests. – Biodiv. & Conservation **18**(6): 1509–1522. DOI: 10.1007/s10531-008-9537-7

Novenko E. Y., Tsyganov A. N., Payne R. J., Mazei N. G., Volkova E. M., Chernyshov V. A., Kupriyanov D. A. & Mazei Y. A. (2017): Vegetation dynamics and fire history at the southern boundary of the forest vegetation zone in European Russia during the middle and late Holocene. – Holocene **28**(2): 308–322. DOI: 10.1177/0959683617721331

Paciorek T., Stebel A., Jankowska-Błaszczuk M. & Wojciechowska A. (2016): Bryophyte species diversity in human-influenced habitats within protected areas – A case study from the Świętokrzyski National Park in Poland. – Herzogia **29**(2): 668–688. DOI: 10.13158/heia.29.2.2016.668

Pawar S., Koo M. S., Kelley C., Ahmed M. F., Chaudhuri S. & Sarkar S. (2007): Conservation assessment and prioritization of areas in Northeast India: priorities for amphibians and reptiles. – Biol. Conservation **136**(3): 346–361. DOI: 10.1016/j.biocon.2006.12.012

Pearson R. G., Raxworthy C. J., Nakamura M. & Townsend Peterson A. (2007): Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. – J. Biogeogr. **34**(1): 102–117. DOI: 10.1111/j.1365-2699.2006.01594.x

Peev D., Petrova A., Anchev M., Temniskova D., Dentchev C. M., Ganeva A., Gusev Ch. & Vladimirov V. [eds] (2015): Red Data Book of the Republic of Bulgaria. Vol. 1. Plants and fungi. – Sofia: Bulgarian Academy of Sciences & Ministry. [In Bulgarian]

Petrova A. & Vladimirov V. [eds] (2009): Red List of Bulgarian vascular plants. – Phytol. Balcan. **15**(1): 63–94.

Reid W. V. (1998): Biodiversity hotspots. – Trends Ecol. Evol. **13**: 275–280. DOI: 10.1016/s0169-5347(98)01363-9

Ribeiro B. R., Martins E., Martinelli G. & Loyola R. (2018): The effectiveness of protected areas and indigenous lands in representing threatened plant species in Brazil. – Rodriguésia **69**(4): 1539–1546. DOI: 10.1590/2175-7860201869404

Rodrigues A. S. L., Andelman S. J., Bakarr M. I., Boitani L., Brooks T. M., Cowling R. M., Fishpool L. D. C., da Fonseca G. A. B., Gaston K. J., Hoffmann M., Long J. S., Marquet P. A., Pilgrim J. D., Pressey R. L., Schipper J., Sechrest W., Stuart S. N., Underhill L. G., Waller R. W., Watts M. E. J. & Yan X. (2004): Effectiveness of the global protected area network in representing species diversity. – Nature **428**(6983): 640–643. DOI: 10.1038/nature02422

Rodríguez-Rodríguez D. & Martínez-Vega J. (2018): Protected area effectiveness against land development in Spain. – J. Environm. Managem. **215**: 345–357. DOI: 10.1016/j.jenvman.2018.03.011

Ruchin A.B. & Egorov L.V. (2017): Overview of insect species included in the Red Data Book of Russian Federation in the Mordovia State Nature Reserve. – Nat. Conservation Res. **2**(Suppl. 1): 2–9. DOI: 10.24189/ncr.2017.016 [In Russian]

Ruchin A.B. & Egorov L.V. (2018a): Discovery of *Allonyx quadrimaculatus* (Schaller, 1783) (Coleoptera Cleridae Clerinae) in Russia. – Redia **101**: 143–146. DOI: 10.19263/REDIA-101.18.19

Ruchin A.B. & Egorov L.V. (2018b): *Leptura aurulenta* (Coleoptera, Cerambycidae), a new record of a very rare species in Russia. – Nat. Conservation Res. **3**(1): 88–91. DOI: 10.24189/ncr.2018.003

Ruchin A.B., Egorov L.V., Sazhnev A.S., Polumordvinov O.A. & Ishin R.N. (2019a): Present distribution of *Protaetia fieberi* (Kraatz, 1880) (Insecta, Coleoptera, Scarabaeidae) in the European part of Russia. – Biharean Biologist **13**: e181206.

Ruchin A.B., Antropov A.V. & Khapugin A.A. (2019): Distribution, abundance, and habitats of rare species *Parnopes grandior* (Pallas 1771) (Hymenoptera, Chrysididae) in Mordovia and adjacent regions, Russia. – Biodiversitas **20**(2): 303–310. DOI: 10.13057/biodiv/d200201

Silaeva T.B. [ed.] (2017): Red Data Book of the Republic of Mordovia, Vol. 1: Rare species of plants and fungi. [2nd ed.] – Saransk: Publisher of the Mordovia State University. [In Russian]

Tedersoo L., Laanisto L., Rahimlou S., Toussaint A., Hallikma T. & Pärtel M. (2018): Global database of plants with root-symbiotic nitrogen fixation: NodDB. – J. Veg. Sci. **29**(3): 560–568. DOI: 10.1111/jvs.12627

Tereshkin I.S. & Tereshkina L.V. (2006): Vegetation of the Mordovia Reserve. Successive series of the successions. – Proceedings of the Mordovia State Nature Reserve **7**: 186–287. [In Russian]

The Plant List (2019): Version 1.1. – http://www.theplantlist.org/ [Accessed: 01 February 2019]

Tomaszewska W., Egorov L.V., Ruchin A.B. & Vlasov D.V. (2018): First record of *Clemmus troglodytes* (Coleoptera: Coccinelloidea, Anamorphidae) for the fauna of Russia. – Nat. Conservation Res. **3**(3): 103–105. DOI: 10.24189/ncr.2018.016

Tsinger O.Ya. (1966): Additions and clarifications to the flora of the Mordovia State Nature Reserve. – Proceedings of the Mordovia State Nature Reserve **3**: 230–233. [In Russian]

Urbanavichute S.P. (2014): Vascular plants of Kerzhenskiy State Nature Reserve included in the Red Data Book of the Nizhniy Novgorod region. – Proceedings of the State Nature Biosphere Reserve 'Kerzhenskiy' **6**: 291–299. [In Russian]

Vargot E.V., Khapugin A.A., Chugunov G.G. & Grishutkin O.G. (2016a): Vascular plants of the Mordovia State Nature Reserve (an annotated species list). – Moscow: Commission of RAS on biodiversity conservation; IPEE RAS. (Flora and fauna of reserves. Issue 128) [In Russian]

Vargot E.V., Shcherbakov A.V., Bolotova Ya.V. & Uotila P. (2016b): Current distribution and conservation of *Najas tenuissima* (Hydrocharitaceae). – Nat. Conservation Res. **1**(3): 2–10. DOI: 10.24189/ncr.2016.022

Vasilyevich B.A. [dir.] (2019): Flora. – In: Web-site of National Park 'Belovezhskaya Pushcha'. – https://npbp.by/eng/about/about-us-in-details/flora/ [Accessed: 11 February 2019]

Wathen S., Thorne J.H., Holguin A. & Schwartz M.W. (2014): Estimating the spatial and temporal distribution of species richness within Sequoia and Kings Canyon National Parks. – PLoS ONE **9**(12): e112465. DOI: 10.1371/journal.pone.0112465

Watson J.E., Darling E.S., Venter O., Maron M., Walston J., Possingham H.P., Dudley N., Hockings M., Barnes M. & Brooks T.M. (2016): Bolder science needed now for protected areas. – Conservation Biol. **30**(2): 243–248. DOI: 10.1111/cobi.12645

Wierzbowska I. A., Olko J., Hędrzak M. & Crooks K. R. (2012): Free-ranging domestic cats reduce the effective protected area of Polish national park. – Mammalian Biology **77**(3): 204–210. DOI: 10.1016/j.mambio.2012.01.004

Xu H., Cao M., Wang Z., Wu Y., Cao Y., Wu J., Le Z., Cui P., Ding H., Xu W., Peng H., Jiang J., Wu Y., Jiang X., Zhang Z., Rao D., Li J., Lei F., Xia N., Han L., Cao W., Wu J., Xia X. & Li Y. (2018): Low ecological representation in the protected area network of China. – Ecol. & Evol. **8**(12): 6290–6298. DOI: 10.1002/ece3.4175

Yesson C., Brewer P. W., Sutton T., Caithness N., Pahwa J. S., Burgess M., Gray W. A., White R. J., Jones A. C., Bisby F. A. & Culham A. (2007): How global is the Global Biodiversity Information Facility? – PLoS ONE **2**(11): e1124. DOI: 10.1371/journal.pone.0001124

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