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The role of Russian federal protected areas in conservation of plant species included in the Red Data Book of Russian Federation (Volga Federal District)

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Summary: The main task of protected areas is biodiversity conservation primarily concerning threatened species of plants and animals. Their value is the greater, the higher number of threatened species populations is located in this area. In Russia, conservation of species included in the Red Data Book of Russian Federation (hereafter – Russian Red Data Book plant species), has the highest priority. In this paper, we studied Russian Red Data Book plant species, known in ten protected areas of Volga Federal District (European Russia). We estimated the number of Russian Red Data Book plant species per protected area; Representativeness Index of each species per protected area; proportion of Russian Red Data Book species populations of which are being studied in protected areas; rarity categories of each plant species according to regional Red Data Books. We found out that in studied protected areas 29 Russian Red Data Book plant species are known. In different regions, populations of 6.7% to 60.0% of all Russian Red Data Book plant species are present in the studied protected areas. At the same time, Representativeness Index of these plants varied from 0.67% (*Cypripedium calceolus*, Bolshaya Kokshaga State Nature Reserve) to 78.6% (*Thymus cimicinus*, Khvalynsky National Park). Population-based studies of Russian Red Data Book plant species have not been carryed out for all of them in studied protected areas. The situation is the most favorable in Bolshaya Kokshaga State Nature Reserve and National Park 'Smolny', because population-based studies cover all Russian Red Data Book plant species known in these territories. In Khvalynsky National Park and Mordovia State Nature Reserve, population-based studies cover more than 50% of all Russian Red Data Book plant species known in these protected areas. There are no data on population characteristics of Russian Red Data Book plant species in National Park 'Chavash Varmane' (*Cephalanthera rubra*) and Vishersky State Nature Reserve (*Calypso bulbosa*, *Sedum roseum*). The obtained data allow us to make some recommendations concerning investigations of threatened plant species in protected areas. Firstly, we recommend to organize systematic (optimally – annual) investigations of Russian Red Data Book plant species in each protected area. Secondly, population-based studies should cover at least one population of each Russian Red Data Book plant species in protected areas. Thirdly, the obtained and analyzed data on threatened plant species should be published in journals available to wide scientific audience to avoid the loss of data.

Keywords: vascular plants, plant conservation, plant population, Representativeness Index, conservation area

Currently, biodiversity conservation is one of the main tasks in nature investigations (Rands et al. 2010). For this purpose, there is a wide range of approaches comprising conservation of certain, usually threatened, species and conservation of certain habitats and ecosystems (Françoso et al. 2015; Revkov et al. 2018). Biodiversity loss is noted in different regions of the world (e.g. Biggs et al. 2008; Johnson et al. 2017), despite of numerous recommendations and actions aimed to protect both species and their habitats (e.g. Tittensor et al. 2014; Chifundera 2019). Consequently, this causes an increase in rates of species extinction in recent centuries (Le Roux et al. 2019). The establishment of protected areas is the main tool generally accepted for

Table 1. Characteristics of ten federal protected areas studied in the Volga Federal District (European Russia).

Protected area	Abbreviation	Area (km^2)	Latitudes	Longitudes
Basegi State Nature Reserve	BSNR	380.68	58.70° – 59.00° N	58.17° – 58.67° E
Bolshaya Kokshaga State Nature Reserve	BKSNR	214.28	56.61° – 56.74° N	47.19° – 47.39° E
Mordovia State Nature Reserve	MSNR	321.62	54.42° – 54.56° N	43.04° – 43.36° E
Prisurskiy State Nature Reserve	PSNR	91.50	54.95° –55.03° N	46.63° – 46.87° E
Vishersky State Nature Reserve	VSNR	2412.00	58.67° – 59.45° N	60.90° – 61.67° E
Zhiguli State Nature Biosphere Reserve	ZSNBR	231.60	53.44° – 53.33° N	49.57° – 50.00° E
Khvalynsky National Park	KNP	260.37	52.81° – 52.28° N	47.50° – 48.34° E
National Park 'Chavash Varmane'	CVNP	252.47	54.72° – 54.93° N	47.17° – 47.37° E
National Park 'Smolny'	NPS	363.86	54.72° – 54.88° N	45.07° – 45.62° E
Saratovskiy State Nature Sanctuary	SS	443.02	51.32° – 51.11° N	47.52° – 48.05° E

containment of biodiversity loss (e.g. Françoso et al. 2015; Pinheiro et al. 2018). Numerous investigations around the world confirm the positive role of protected areas in conservation and restoration of biodiversity and environment conditions (Geldmann et al. 2013; Gebremedihin et al. 2018; King & Gurnell 2019). Detailed studies in protected areas allow to describe new taxa (e.g. Ponert et al. 2016; Nourti et al. 2019) and to clarify actual distribution of animals and plants in separate regions of the world (e.g. Tagane et al. 2018; Tomaszewska et al. 2018).

As a rule, protected areas are aimed at the conservation of most threatened species of both animals and plants (Williams et al. 1996). In turn, this requires an establishment of conservation status of each species on the basis of data on its ecology, biology and geographic distribution. In Russia and some other European countries (e.g. Bulgaria, Poland, Finland), threatened taxa are similar to taxa included in both regional and federal Red Data Books (Govorushko & Nowicki 2019; Khapugin & Ruchin 2019; Ruchin & Khapugin 2019). Compared to regional Red Data Books, conservation of species included in federal Red Data Books has a higher, national level. Therefore, their investigations are the most significant in terms of conservation of the species most threatened in Russia.

The Volga Federal District is located in European Russia. Within its range, the following natural zones occur: taiga, broadleaved forests, forest-steppe and steppe. This causes considerable biotopic and, consequently, taxonomic diversity in protected areas of the Volga Federal District. In this regard, numerous studies of plant species included in the Red Data Book of Russian Federation (Bardunov & Novikov 2008) (hereafter – Russian Red Data Book plant species) are known in regions of Volga Federal District. Obtained data have primary value for supplementation of information contained in the Red Data Book of Russian Federation (Bardunov & Novikov 2008). Due to a high degree of urbanization and anthropogenic disturbance of natural ecosystems, protected areas are almost only sites, where populations of threatened plant species are able to survive. This study is aimed at the estimation of the role of ten protected areas of the Volga Federal District in conservation of Russian Red Data Book plant species.

Materials and methods

The Volga Federal District is represented by 26 federal protected areas including 14 state nature reserves, eight national parks, three federal sanctuaries. In the present study, we used data of the Russian Red Data Book plant species known from the following ten protected areas: Basegi

Figure 1. The locations of studied protected areas in European Russia. 1 – Basegi State Nature Reserve, 2 – Bolshaya Kokshaga State Nature Reserve, 3 – Mordovia State Nature Reserve, 4 – Prisurskiy State Nature Reserve, 5 – Vishersky State Nature Reserve, 6 – Zhiguli State Nature Biosphere Reserve, 7 – Khvalynsky National Park, 8 – National Park 'Chavash Varmane', 9 – National Park 'Smolny', 10 – Saratovskiy State Nature Sanctuary.

State Nature Reserve, Bolshaya Kokshaga State Nature Reserve, Mordovia State Nature Reserve, Prisurskiy State Nature Reserve, Vishersky State Nature Reserve, Zhiguli State Nature Biosphere Reserve, Khvalynsky National Park, National Park 'Chavash Varmane', National Park 'Smolny', Saratovskiy State Nature Sanctuary (Table 1; Fig. 1).

We identified the complete list of Russian Red Data Book plant species in each protected area. For each species, we found a number of its populations represented in the protected area and the Russian region. We indicated whether population-based studies have been conducted in the protected area. We calculated the ratio of Russian Red Data Book plant species per protected area of the total number of Russian Red Data Book plant species in the region. On the basis of obtained data, we calculated Representativeness Index (RI) of each plant species in the protected area according to the following formula (see also Khapugin & Ruchin 2019):

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

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 of Russia. Depending on the RI values of each Red Data Book plant, we calculated the average RI value of each studied protected area (Appendix 1).

According to the Red Data Book of the Russian Federation (Bardunov & Novikov 2008), all species were classified into the following rarity categories:

0 – Probably extinct species. Populations of these plants have probably disappeared from the territory of the study area. These plants were not recorded in the wild during the past 50 years, neither in locations where the species were known to have been formerly present, nor at any other potential location. Nevertheless, the possibility that some individuals or populations have been

Table 2. The value of protected areas regarding conservation of plant species included in the Red Data Book of Russian Federation [RDB RF] (Bardunov & Novikov 2008).

Protected area	Species number per protected area	SNPA/tSN %	SNPA/tRFSN %	PSPS %	Mean Representativeness Index	
					M ± m	Min–Max
BSNR	3	4.3	13.6	33.3	10.17 ± 3.70	3.85–16.67
BKSNR	4	2.7	33.3	100.0	21.00 ± 10.38	0.67–50.00
MSNR	3	1.8	21.4	66.7	26.77 ± 6.47	14.30–36.00
PSNR	4	1.9	26.7	75.0	27.60 ± 5.13	15.38–40.00
VSNR	2	2.9	9.1	0.0	4.17*	–
ZSNBR	12	4.9	60.0	33.3	14.77 ± 3.93	4.55–50.00
KNP	20	7.4	54.1	47.6	38.75 ± 5.39	1.25–78.57
CVNP	1	0.5	6.7	0.0	25.00*	–
SNP	4	2.4	28.6	100.0	20.43 ± 13.31	2.20–60.00
SS	3	1.1	8.1	25.0	8.39 ± 4.30	2.00–18.18

Note. SNPA/tSN – Percentage of RDB RF species in protected area from total number of species included in a regional Red Data Book; SNPA/tRFSN – Percentage of RDB RF species in protected area from total number of RDB RF species in a region; PSPS – Proportion of species whose populations are studied in a protected area; M – mean arithmetic value, m – error, asterisk (*) indicates positions where only one species per protected area is noted. Names of protected areas: ZSNBR – Zhiguli State Nature Biosphere Reserve, BSNR – Basegi State Nature Reserve, BKSNR – Bolshaya Kokshaga State Nature Reserve, KNP – Khvalynsky National Park, SS – Saratovskiy State Nature Sanctuary, VSNR – Vishersky State Nature Reserve, PSNR – Prisurskiy State Nature Reserve, CVNP – National Park 'Chavash Varmane', MSNR – Mordovia State Nature Reserve, SNP – National Park 'Smolny'.

overlooked due to dormancy cannot be completely excluded. Under favorable conditions, plants develop vegetative and /or generative organs and become detectable.

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 characterized 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 in 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 – Recovering and recovered species. Species, their number and occupancy area of which are started to be recovered under natural conditions or human conservation actions, and, consequently, approaching the state they do not need special measures for conservation and restoration.

Scientific names of plant taxa were standardized according to The PlantList database (http://www.theplantlist.org/). All calculations have been processed using Microsoft Excel and PAST 3.20 (Hammer et al. 2001).

Results and Discussion

Our investigation has resulted in data on 29 Russian Red Data Book plant species (Appendix 1), known in ten protected areas of six Russian regions (Chuvash Republic, Permsky Krai, Republic of Mari El, Republic of Mordovia, Samara region, Saratov region). The number of Russian Red Data Book plant species per protected area varied from one (National Park 'Chavash Varmane') to 20 (Khvalynsky National Park) taxa (Table 2) classified into four rarity categories (Fig. 2). The number of species per protected area did not correlate with size of the protected area ($r = -0.25$, $p > 0.05$). Although some authors (Gurd et al. 2001; Friedlander et al. 2007; de Carvalho et al. 2017) demonstrated that larger protected areas are more effective in terms of conservation of plant and animal populations. The obtained data could indicate that in order to conduct the unbiased estimation of protected area conservation value, we should consider all Red Data Book species in a region instead only species included in the Red Data Book of Russian Federation. Different authors (van Swaay et al. 2011; Khapugin et al. 2017b; Kestemont 2019) highlighted the high significance of intra-national (i.e. regional) estimations of conservation value of species in order to obtain conservation status at the national level.

The assessment of protected area value in conservation of regional species biodiversity could be conducted through the ratio of the number of Red Data Book species per protected area to the total number of plant species included in both regional and federal Red Data Books in a region. The highest value in terms of regional plant diversity conservation could be demonstrated for the Zhiguli State Nature Reserve (containing 4.9% of total number of regional Red Data Book

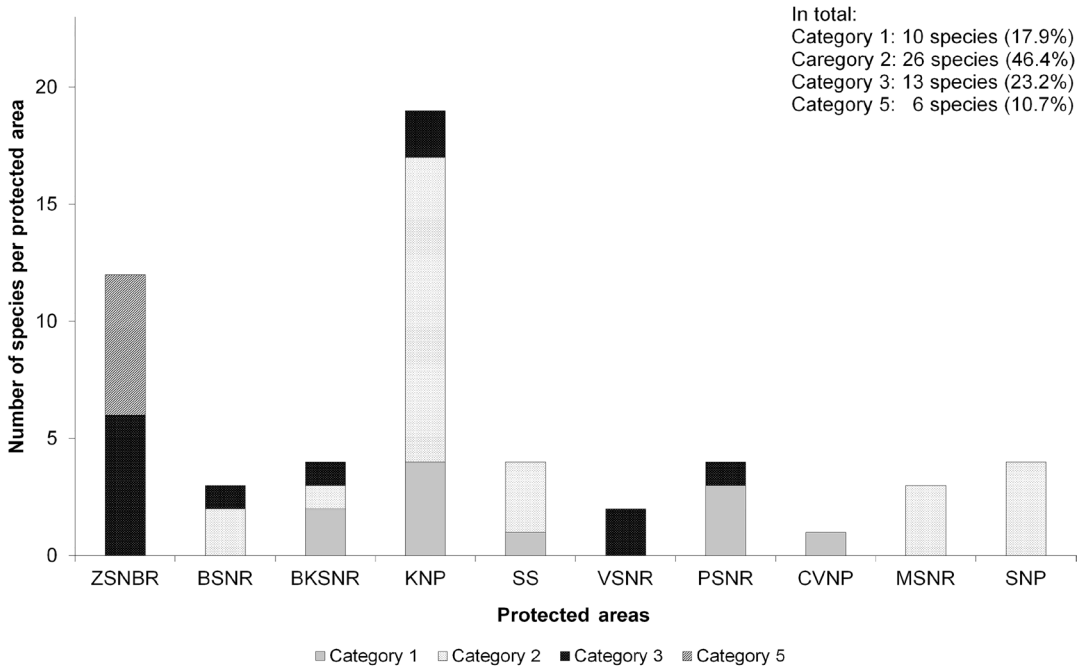

Figure 2. Total number of Red Data Book species of each rarity category, which are known in ten protected areas studied. ZSNBR – Zhiguli State Nature Biosphere Reserve, BSNR – Basegi State Nature Reserve, BKSNR – Bolshaya Kokshaga State Nature Reserve, KNP – Khvalynsky National Park, SS – Saratovskiy State Nature Sanctuary, VSNR – Vishersky State Nature Reserve, PSNR – Prisurskiy State Nature Reserve, CVNP – National Park 'Chavash Varmane', MSNR – Mordovia State Nature Reserve, SNP – National Park 'Smolny'.

and 60.0% of total number of Red Data Book of Russia) and the Khvalynsky National Park (containing 7.4% of total number of regional Red Data Book and 54.1% of total number of Russian Red Data Book plant species per region). The National Park 'Chavash Varmane' and Vishersky State Nature Reserve have the least number of Russian Red Data Book plant species in the regions (Chuvash Republic and Permsky Krai, respectively).

In regards of populations of Red Data Book plant species, it is important to understand that the protected area can serve as refugium either for only one population of the species or for all plant populations in the region. Estimating this, we calculated RI value of species per protected area (Appendix 1). Then, the average RI value per protected area was calculated by generalizing data for all species in protected area (Table 2). The obtained data demonstrated that the highest average RI values were in Khvalynsky National Park (RI = 38.75 ± 5.39%) and Mordovia State Nature Reserve (RI = 26.77 ± 6.47%). At the same time, the Representativeness Index had higher values for certain plant species. For instance, *Thymus cimicinus* Blume ex Ledeb. had RI = 78.6% in the Khvalynsky National Park (i.e. more than three quarters of all species populations are located within this protected area), while four plant species (*Potentilla volgarica* Juz., *Astragalus zingeri*, *Thymus cimicinus* Blume ex Ledeb., *Globularia punctata* Lapeyr.) had RI values from 71.4% to 78.6% in the Khvalynsky National Park. One of the main tasks of protected areas is to cover the highest number of threatened species populations (Rodrigues et al. 2004; Rutovskaya et al. 2017). Our data indicate the high significance of the studied protected areas in conservation of plant populations in the region.

Although the number of plant populations is an important indicator of each protected area, no less importance has the fact, whether the population-based studies of threatened species are conducted in the protected areas. Table 2 demonstrates that population-based studies do not always cover all Russian Red Data Book plant species in protected areas. Noteworthy, in National Park 'Smolny' and Bolshaya Kokshaga State Nature Reserve, population-based studies include all Russian Red Data Book plant species known in these protected areas. The studies cover more than half of all Russian Red Data Book plant species known in the Prisurskiy State Nature Reserve (80.0%) and Mordovia State Nature Reserve (66.7%). At the same time, no population of Russian Red Data Book plant species has been studied in Vishersky State Nature Reserve and National Park 'Chavash Varmane'. This can partially explained by the ability of some plants to be in a 'state of rest' for a long time under unfavorable conditions. For example, annual studies of locations of *Cephalanthera rubra* (L.) Rich. populations in both National Park 'Chavash Varmane' and Mordovia State Nature Reserve have still not been successful despite their search in 1978 and 2011, respectively. Although data of population-based studies of the Russian Red Data Book plant species in the ten protected areas were partially published previously (Ilyina 2005; Rakhmatullin & Dimitriev 2005; Chugunov & Shigaeva 2007; Lavrentyev & Stepanov 2009; Chap & Kiseleva 2014; Nalimova 2014; Ermolaeva et al. 2016; Gafurova 2016; Kiseleva 2017; Senchugova et al. 2017; Khapugin et al. 2017a, 2018; Suleymanova et al. 2019), results of long-term studies of plant populations regarding the most Russian Red Data Book species in protected areas have not been published and are not available online. Therefore, a need to generalize and publish these data in future is appreciated.

In regards of regional rarity categories of Russian Red Data Book plant species known in the studied protected areas, most of the species have the rarity category 2 in different Russian regions (Fig. 2). Among all studied protected areas, only Zhiguli State Nature Reserve includes plants

having the rarity category 5 (i.e. recovering and recovered species). Noteworthy, these species (*Hedysarum grandiflorum* Pall., *Globularia punctata*, *Iris pumila* L., *Fritillaria ruthenica* Wikst., *Koeleria macrantha* (Ledeb.) Schult., *Stipa pennata* L.) have relatively low RI values (5.0%, 10.0%, 4.5%, 6.5%, 13.3% and 5.4%, respectively). This indicates that Zhiguli State Nature Reserve plays still a non-significant role in population restoration of these Red Data Book species in Samara region compared to other sites in the region. In addition, no Red Data Book species with the rarity category 4 (indeterminate species) has been found in the studied protected areas. This indicates that in the studied Russian regions, there are minimal data on the conservation value of Russian Red Data Book plant species including the studied protected areas.

Conclusions

The generalized data on 29 Russian Red Data Book plant species in ten protected areas of six Russian regions demonstrate that existing protected area Network of the Volga Federal District contributes to the conservation of 6.7% to 60.0% of Russian Red Data Book plant species populations known in the region of Russia. At the same time, RI value of species in protected areas varied from 0.67% (*Cypripedium calceolus* L. in the Bolshaya Kokshaga State Nature Reserve) to 78.6% (*Thymus cimicinus* in the Kvalynsky National Park). This indicates that the studied protected areas contribute differently in conservation of regional populations of Russian Red Data Book plant species.

Despite of the high protection level of populations of Russian Red Data Book plant species in federal protected areas, not all of these species are covered by population-based studies. The most favorable conditions are in Bolshaya Kokshaga State Nature Reserve and National Park 'Smolny', where at least one population of all Russian Red Data Book plant species is treated in special studies. More than the half of populations of species known in the studied protected areas serve as objects of study in Prisurskiy State Nature Reserve and Mordovia State Nature Reserve. However, population status of Russian Red Data Book plant species has not been studied yet in National Park 'Chavash Varmane' (*Cephalanthera rubra*) and Vishersky State Nature Reserve (*Calypso bulbosa*, *Sedum roseum*). On the one hand, a lack of data on population status of Russian Red Data Book plant species could be explained by the inaccessibility of their locations and ability of some plants to be in a 'state of rest' for a long time. On the other hand, a lack of data does not allow to establish the population status of nationally threatened species in undisturbed habitats represented in protected areas.

We suggest the following implications as recommendations to improve conservation of Russian Red Data Book plant species in protected areas:

– Population-based studies of Red Data Book plant species should be carried out periodically (annually as optimum) in protected areas.

– Population-based studies of Russian Red Data Book plant species should cover at least one viable population of species in each protected area.

– The obtained and generalized data on spatial distribution of locations, habitat conditions and population status of Russian Red Data Book plant species should be published in journals available to the wide research audience. This will make it possible to objectively assess and compare the population status of plant species in all Russian regions, when preparing the next edition of the Red Data Book of the Russian Federation.

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Appendix 1. The average Representativeness Index (%) of Red Data Book species in each protected area.

Species	Rarity category according to Bardunov & Novikov (2008)	ZSNBR	BSNR	BKSNR	KNP	SS	VSNR	PSNR	CVNP	MSNR	SNP	Average
Anemone pratensis L.[1]	3				5.6							**5.6**
Anthemis trotzkiana Claus	3				20							**20.0**
Artemisia salsoloides Willd.	3	6.3			35.7							**21.0**
Astragalus zingeri Korsh.	2	14.3			71.4							**42.9**
Calypso bulbosa (L.) Oakes	3		3.8				4.2					**4.0**
Cephalanthera rubra (L.) Rich.	3	33.3			45.5			25	25	30	10	**28.1**
Cypripedium calceolus L.	3	14.3		0.7	50					14.3	9.5	**17.8**
Dactylorhiza majalis subsp. *baltica* (Klinge) H.Sund.[2]	3			50								**50.0**
Dactylorhiza traunsteineri (Saut. ex Rchb.) Soó	3			16.7								**16.7**
Epipogium aphyllum Sw.	2		10	16.7								**13.4**
Euphorbia ×zhiguliensis (Prokh.) Prokh.	3	50										**50.0**
Fritillaria ruthenica Wikst.	3	6.5			7.4							**7.0**
Globularia punctata Lapeyr.	3	10			75							**42.5**
Hedysarum grandiflorum Pall.	3	5			20							**12.5**
Hedysarum razoumovianum DC.	3				50							**50.0**
Hyssopus officinalis subsp. *montanus* (Jord. & Fourr.) Briq.[3]	3				33.3							**33.3**
Iris aphylla L.	2							30			2.2	**16.1**
Iris pumila L.	3	4.5			1.2	5						**3.6**
Koeleria macrantha (Ledeb.) Schult.[4]	3	13.3			38.8							**26.1**
Matthiola fragrans (Fisch.) Bunge	3				41.7							**41.7**
Neottianthe cucullata (L.) Schltr.	3							40		36	60	**45.3**
Neotinea ustulata (L.) R.M. Bateman, Pridgeon & M.W. Chase[5]	2				50							**50.0**
Paeonia tenuifolia L.	2				42.1							**42.1**
Potentilla volgarica Juz.	1				75							**75.0**
Sedum roseum (L.) Scop.[6]	3		16.7				-					**16.7**
Stipa pennata L.	3	5.4			24.8	2		15.4				**11.9**
Stipa pulcherrima K. Koch	3	14.3			9.1							**11.7**
Stipa zalesskii Wilensky	3					18.2						**18.2**
Thymus cimicinus Blume ex Ledeb.	3				78.6							**78.6**
Average		**14.8**	**10.2**	**21.0**	**38.8**	**8.4**	**4.2**	**27.6**	**25.0**	**26.8**	**20.4**	

Note. Names of protected areas: ZSNBR – Zhiguli State Nature Biosphere Reserve, BSNR – Basegi State Nature Reserve, BKSNR – Bolshaya Kokshaga State Nature Reserve, KNP – Khvalynsky National Park, SS – Saratovskiy State Nature Sanctuary, VSNR – Vishersky State Nature Reserve, PSNR – Prisurskiy State Nature Reserve, CVNP – National Park 'Chavash Varmane', MSNR – Mordovia State Nature Reserve, SNP – National Park 'Smolny'.

[1]*Pulsatilla pratensis* (L.) Mill. s.l. according to Bardunov & Novikov (2008).
[2]*Dactylorhiza baltica* (Klinge) N.I. Orlova according to Bardunov & Novikov (2008).
[3]*Hyssopus cretaceus* Dubjan. according to Bardunov & Novikov (2008).
[4]*Koeleria sclerophylla* P.A. Smirn. according to Bardunov & Novikov (2008).
[5]*Orchis ustulata* L. according to Bardunov & Novikov (2008).
[6]*Rhodiola rosea* L. according to Bardunov & Novikov (2008).