IECD 2022

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Proceedings

To What Extent Are Protected Areas Freer of Alien Plants Than Managed Areas within Biodiversity Coldspots? A Case Study of the Mordovia State Nature Reserve, European Russia †

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† Presented at the 2nd International Electronic Conference on Diversity (IECD 2022)—New Insights into the Biodiversity of Plants, Animals and Microbes, 1–15 March 2022; Available online: https://iecd2022.sciforum.net/.

Abstract: As it is known, Protected Areas networks should (once again) protect the native ecosystems from the negative influence of alien species introduction. In this study, we select a Protected Area (Mordovia State Nature Reserve, IUCN category: I) in European Russia (Republic of Mordovia). Moreover, alien floras have never been compared between the Mordovian regional districts (managed areas) and Protected Areas. We aimed to compare the alien species proportion between the flora of the Mordovia State Nature Reserve and 23 floras of the regional districts. For this purpose, we used actual floristic checklists of both Mordovia State Nature Reserve (at present, more than 800 species) and the whole Mordovia (at present, more than 1470 species), as well as the set of the published additions to the flora of the region and Protected Area. The temporal comparison was performed between data of 2010 and 2022 years. We hypothesized that, contrary to the widely known fact on the intactness of Protected Areas, the Mordovia State Nature Reserve is characterized by a high proportion of alien plant species. The obtained results demonstrated that in the Mordovia State Nature Reserve, the alien species proportion before starting intense botanical studies was lower (10.7%) than in floras of certain managed areas (17.7% in the Kochkurovo district, 18.8% in the Insar district, or 22.0% in the Ardatov district). At the same time, additional studies have resulted in a considerable increase in the alien species proportion in the flora of the Protected Area (19.0%) in comparison with data of the 2010 year. This indicates both the initial underestimation of the Protected Area's flora and the importance of additional purposeful investigations in obtaining the complete data on the flora composition. The obtained results in comparison with updated data for the Mordovian districts' floras are discussed in light of the current knowledge on the flora of the Mordovia State Nature Reserve and the Republic of Mordovia as a whole.

Keywords: alien plants; biological invasions; protected areas; biodiversity; flora; Russia; Europe

Academic Editor: Ben Erik Van Wyk

Published: 15 March 2022

1. Introduction

At present, biological invasions are recognized as a serious threat to biodiversity and human well-being in many regions of the world. However, no one alien species is originally invasive. From the introduction moment of an alien species into the area of the secondary range until its recognition as an invasive species, it goes through several invasion stages. This topic is also being studied in detail [1–3], considering the stages, barriers, management, and terminology of biological invasions. All authors agree that bioinvasions begin with the introduction of an alien species into the invaded range. Therefore,

monitoring and identification of alien species at the early stages of introduction (as cultivated or newly noted species for the first time) is an important task for the timely adoption of preventive measures against the invasion and its eradication.

Recently it was shown [4] that biological invasions are among the three leading drivers of plant extinction in biodiversity hotspots, while in biodiversity coldspots its role is less significant. This was confirmed for Russia, where invasive species play a negligible role as a possible driver of plant extinction [5]. Existing databases on the biodiversity of naturalized species allow us to gradually accumulate the data [6]. On their basis, it has already been demonstrated that certain regions of North America and Australia are the largest recipients of invasive species [7]. However, this analysis did not include considerable areas of Eastern Europe, Western Asia, and Siberia [7]. The next study [8] showed a more complete picture, where the largest number of invasive species was noted for South Africa, India, California (USA), Cuba, Florida (USA), Queensland (Australia), and Japan, while the territory of Russia was characterized by a relatively low richness of invasive species. This is consistent with the Russian-scale study [9], where just 354 invasive plant species were recorded for the area of Russia (ca. 17.13 million km2) (vs. 1753 plants in California [8], 423 970 km2). However, up-to-date data on the composition and distribution of alien species in Russia are still insufficient.

Protected Areas (PAs) represent ecosystems valuable for the conservation of populations of native species and their habitats. This determines their value for nature conservation [10]. This does not mean that the boundaries of Protected Areas completely prevent the introduction of alien species [11,12]. Nevertheless, a number of studies show that within Protected Areas, the alien species richness is lower [13] or significantly lower [12] than outside the boundaries of these territories. There are no such comparative studies for Russian Protected Areas.

Mordovia State Nature Reserve (IUCN category: Ia) is one of the PAs in the Republic of Mordovia (European Russia). In this PA, research of vascular plants has intensified from 2010 to the present, 2022 [14]. At the same time, a checklist of the flora of the Republic of Mordovia was published [15]. It makes it possible to compare the alien floras of the Mordovia State Nature Reserve and separate municipal districts (23 in total) of the Republic of Mordovia. This study was aimed to compare the alien species proportion (ASP) in floras of a Protected Area of the Mordovia State Nature Reserve and of managed areas of the municipal districts (hereinafter–districts) of the Republic of Mordovia over 2010–2022. We stated the following research tasks: (i) to compare the ASP in the flora of the Mordovia State Nature Reserve and floras of the districts of the Republic of Mordovia from 2010 to early 2022; (ii) to assess the contribution of native and alien plant species to floras of the Mordovia State Nature Reserve and districts of the Republic of Mordovia over 2010–2022. We hypothesized that prior to the start of intensive floristic research in the Republic of Mordovia and the Mordovia State Nature Reserve (pre-2010), in the flora of the Protected Area, the ASP was considerably less than in the flora of any district of the Republic of Mordovia, while active botanical studies in 2010–2022 led to a certain increase in the ASP in the flora of the Mordovia State Nature Reserve.

2. Material and Methods

2.1. Study Area

The Republic of Mordovia is located on the borders of the forest and forest-steppe natural zones in the middle belt of European Russia. It has an area of about 26 200 km2. The region is characterized by a high level of habitat diversity. Coniferous and mixed (coniferous-deciduous) forests are confined predominantly to the western and northwestern parts of the Republic of Mordovia. Broadleaved forests are situated in the central and eastern parts of Mordovia. The forest-steppe habitats are located in the eastern and southeastern parts of the region [16]. In water bodies, 163 species and nine hybrids are known [15]. Mires cover about 5% of the Mordovia's area, which is reflected in the high *Sphagnum*

species diversity [17]. The Republic of Mordovia is divided into 23 municipal districts (hereinafter–districts) (Figure 1).

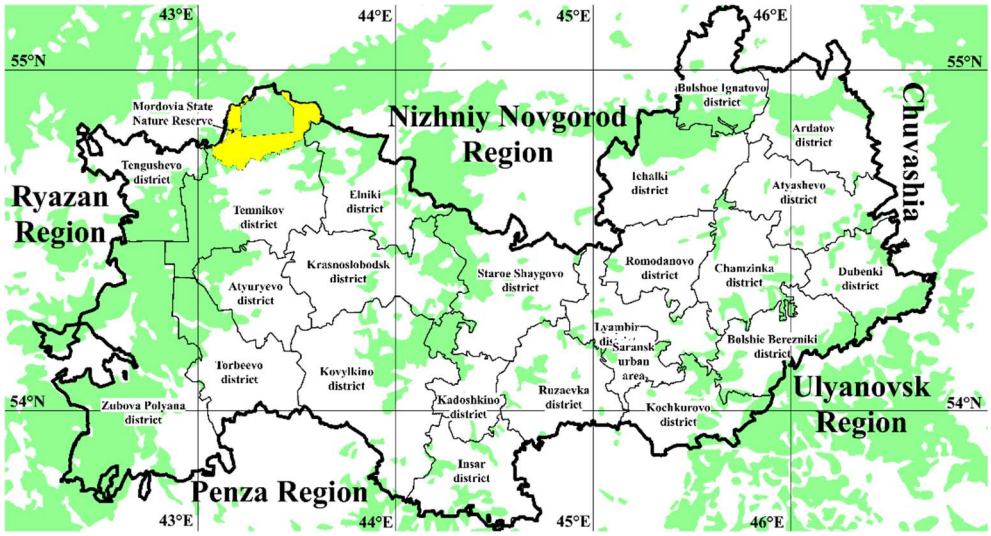

Figure 1. The location of the Mordovia State Nature Reserve and municipal districts in the Republic of Mordovia (European Russia).

The model Protected Area, Mordovia State Nature Reserve, is situated in the north-western part of the Republic of Mordovia (Figure 1). It covers 321.62 km^2. In terms of the vegetation cover, forests cover 89.3% of the total area. Pine (*Pinus sylvestris* L.) is the main forest-forming species. Birch (*Betula pendula* Roth) is the second-ranking forest-forming tree species. Linden (*Tilia cordata* Mill.) forests are situated in the north of the Mordovia State Nature Reserve. Oak (*Quercus robur* L.) forests cover small patches in the west of the Protected Area. Spruce (*Picea abies* (L.) H.Karst.) forests are concentrated mainly in flood-plains of rivers and streams with a relatively small area [14]. Young deciduous trees (*Betula pendula*, and rarer *Populus tremula* L. and *Alnus glutinosa* (L.) Gaertn.) predominate in areas damaged by wildfires in 2010 and 2021 [18].

2.2. Study Design

We used the checklist of the flora of the Republic of Mordovia [15] as a background source to reveal the number of native and alien species for each district of Mordovia. Then, we analyzed the entire set of publications about the flora and vegetation with a focus on floristic news of the districts of the Republic of Mordovia to identify additions to the flora of both native and alien species to floras of the districts over 2010–2022. The list of the found publications on the flora of districts of the Republic of Mordovia is given in Table A1. Some floristic studies of the Republic of Mordovia were published in 2010, like the background reference [15], but later than this publication. Consequently, these floristic findings have not been reflected in [15]. To consider them without confusing with background data [15], we counted these few additions together with data of 2011. The target PA, Mordovia State Nature Reserve, is completely located within the Temnikov district. Therefore, for this district, we calculated the ASP values in two versions. In the first variant (designated as Tm+), the ASP was calculated taking into account the floristic news of 2010–2022 obtained in the Temnikov district only in the area of the Mordovia State Nature Reserve. In the second version (designated as Tm-), the ASP was calculated without taking into account the floristic news of 2010–2022 obtained in the Temnikov district only in the Protected Area. This was performed to estimate the role of floristic research in the Mordovia State Nature Reserve in supplementing the flora of the Temnikov district.

To reveal the accurate number of alien and native species in the flora of the Mordovia State Nature Reserve by 2010 (a reference year), we used published checklists of its flora

[19,20] and all papers published consequently before 2010 [21,22]. To determine the changes in the number of both native and alien species in the flora of the Protected Area from 2010 to 2022, we analyzed all known publications on the flora of the Mordovia State Nature Reserve over this period. These publications are listed in Table A2.

The ASP was defined as the ratio of the number of alien plant species in the managed or protected area to the total number of species in the flora. To present these values with higher facilitation as percentages, we multiplied them by 100%. Among the analyzed managed areas of districts, Saransk urban district and Ruzaevka district were excluded from the analysis. Based on the results of the generalized extreme studentized deviate test, they were recognized as significant ($p < 0.05$) outliers. All calculations were performed in Microsoft Excel (Microsoft Office 2010, v. 14.0.6023.1000) and PAST v. 4.08 [23].

3. Results

By 2010, the ASP of Mordovian districts varied from 16.27% in Dubenki district to 22.84% in Krasnoslobodsk district. In Figure 2, the studied areas are divided into two conditional groups, depending on the ASP values found by 2010; i.e., areas with ASP values less than 19.0% are presented in Figure 2A, and areas with ASP values of more than 19.0% in Figure 2B.

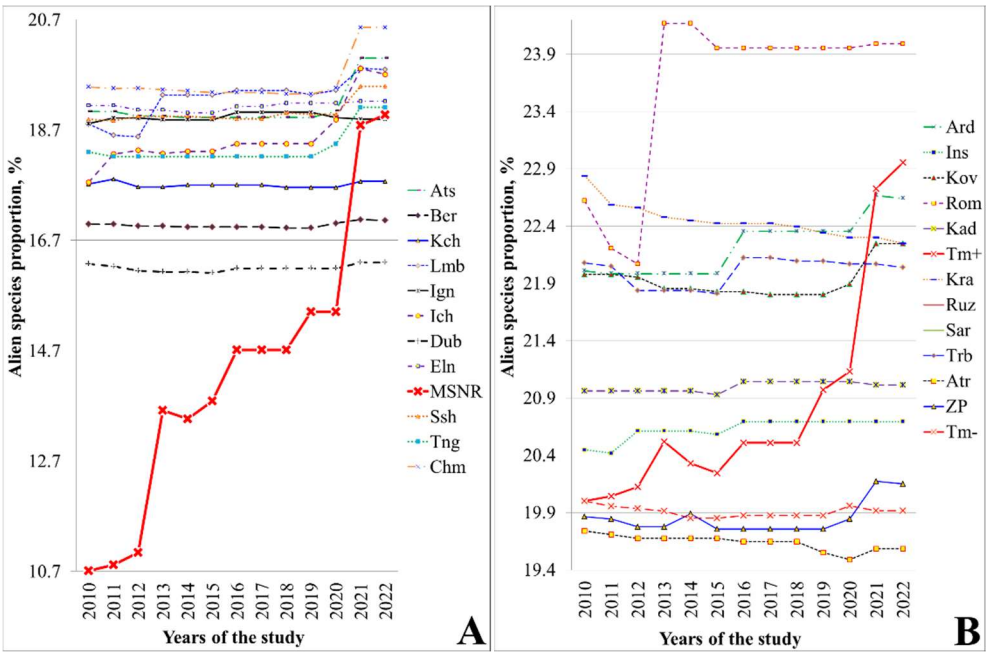

Figure 2. Long-term dynamics of the alien species proportion (ASP) in floras of districts of the Republic of Mordovia and the Mordovia State Nature Reserve (European Russia) over 2010–2022. Designations: Ard—Ardatov district, Atr—Atyuryevo district, Ats—Atyashevo district, Ber—Bolshie Berezniki district, Chm—Chamzinka district, Dub—Dubenki district, Eln—Elniki district, Ich—Ichalki district, Ign—Bolshoe Ignatovo district, Ins –Insar district, Kad—Kadoshkino district, Kch—Kochkurovo district, Kov—Kovylkino district, Kra—Krasnoslobodsk district, Lmb—Lyambir district, MSNR—Mordovia State Nature Reserve, Rom—Romodanovo district, Ssh—Staroe Shaygovo district, Tm+—Temnikov district taking into account floristic novelties found only in the Mordovia State Nature Reserve, Tm+—Temnikov district Temnikov district without taking into account floristic novelties found only in the Mordovia State Nature Reserve, Tng—Tengushevo district, Trb—Torbeevo district, ZP—Zubova Polyana district.

In Figure 2A, it can be seen that in some of the managed areas (districts of the Republic of Mordovia), the ASP increased markedly only in 2020–2022 (e.g., Atyashevo district, Ichalki district, Staroe Shaygovo district, Tengushevo district, Chamzinka district). In these areas, a more marked increase in the number of alien species was found in comparison with native ones (Figure 3), although before 2020, there were no considerable changes

in the ASP. Only Lyambir district was characterized by twice relatively sharp increases in the ASP: by 0.8% in 2013 and by 0.5% in 2020. In other managed areas (Dubenki district, Bolshie Berezniki district, Kochkurovo district, Bolshoe Ignatovo district, Elniki district), only slight increases and decreases in the ASP were observed over 2010–2022, but the ASP rates were generally stable throughout the study period. Figure 3 shows that in these districts of Mordovia, the increase in the total number of species was facilitated by an increase in the number of native species.

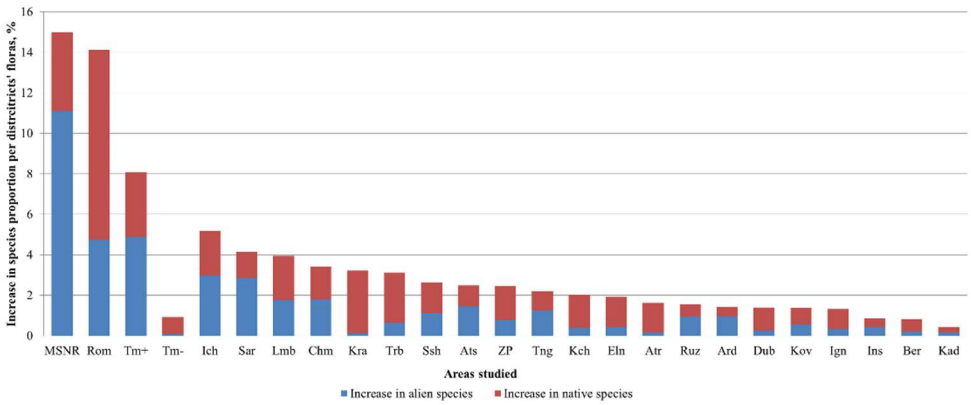

Figure 3. Increase in the number of species in floras of the managed (districts of Mordovia) and protected (Mordovia State Nature Reserve) areas of the Republic of Mordovia over 2010–2022. Designations: Ard—Ardatov district, Atr—Atyuryevo district, Ats—Atyashevo district, Ber—Bolshie Berezniki district, Chm—Chamzinka district, Dub—Dubenki district, Eln—Elniki district, Ich—Ichalki district, Ign—Bolshoe Ignatovo district, Ins –Insar district, Kad—Kadoshkino district, Kch—Kochkurovo district, Kov—Kovylkino district, Kra—Krasnoslobodsk district, Lmb—Lyambir district, MSNR—Mordovia State Nature Reserve, Rom—Romodanovo district, Ruz—Ruzaevka district, Sar—Saransk urban district, Ssh—Staroe Shaygovo district, Tm+—Temnikov district taking into account floristic novelties found only in the Mordovia State Nature Reserve, Tm+—Temnikov district Temnikov district without taking into account floristic novelties found only in the Mordovia State Nature Reserve, Tng—Tengushevo district, Trb—Torbeevo district, ZP—Zubova Polyana district.

The same plot (Figure 2A) shows the trend of the dynamics of the ASP in the flora of the Mordovia State Nature Reserve. This increase in the ASP was especially noticeable in 2020–2022. A constant increase in the number of alien species in the flora of the Mordovia State Nature Reserve was observed against the background of a simultaneous increase in the number of native species (Figure 3): over 2010–2022, the native flora of this Protected Area was supplemented by 29 species. Figure 2A shows that the most considerable increase in the ASP in the Mordovia State Nature Reserve was observed in 2021 (by 3.4%), 2013 (by 2.6%), and 2019 (by 0.7%). Over the study period, the ASP increased by 8.3%. Finally, by 2022, the ASP value in the flora of the Mordovia State Nature Reserve has become higher than the ASP value in four managed areas (Dubenki district, Bolshie Berezniki district, Kochkurovo district, Bolshoe Ignatovo district).

In Figure 2B, several groups of managed areas can be distinguished based on the dynamics of the ASP values. The first group consists of the Mordovian districts, where, by 2022, the ASP has decreased compared to 2010. These are Atyuryevo district, Krasnoslobodsk district, and Temnikov district without taking into account floristic novelties found only in the Mordovia State Nature Reserve (Tm-). For the Krasnoslobodsk district, we found the highest decrease in the ASP value: from 22.8% by 2010 to 22.2% by 2022. Figure 3 shows that in these districts, the increase in the number of species is explained by the floristic findings of almost exclusively native species.

The second group consists of managed areas characterized by an increase in the ASP from 2010 to 2022 (Zubova Polyana district, Insar district, Kovylkino district, Ardatov district, Romodanovo district, and Temnikov district taking into account floristic novelties

found only in the Mordovia State Nature Reserve (Tm+)). Romodanovo district was characterized by the most unstable trend of the ASP. In this area, we found a noticeable decrease in the ASP in 2010–2012 (from 22.6% to 22.0%) with a subsequent sharp increase in 2013 (up to 24.2%) and a gradual decrease to 24.0% by 2022. In both Kadoshkino district and Torbeevo district, the ASP values differed slightly between 2010 and 2022.

In Figure 2B, we deliberately presented separately the ASP trends in the flora of the Temnikov district taking into account (Tm +) and excluding (Tm-) floristic findings made in the district only in the Mordovia State Nature Reserve. We found a considerable contribution of the alien species findings made in this Protected Area in the increase in the ASP for the Temnikov district (Figure 3). This makes the ASP trends of Tm + and Tm- completely different (see Figure 2B), where, in 2010–2022, the ASP decreases slightly for Tm- with a sharp increase for Tm+.

4. Discussion

Our data, obtained before the publication of a reference source [15], showed that by 2010 the ASP was considerably lower in the flora of the Mordovia State Nature Reserve than in floras of any managed areas (districts) of the Republic of Mordovia. In this Protected Area, the ASP was less or only slightly more than in other Protected Areas of Russia [24,25], Ukraine [26], USA [11], and other countries.

This study demonstrates the importance of research efforts [27] in obtaining data on plant diversity in the local floras of the temperate zone So, a decrease in the ASP in certain managed areas (e.g., Krasnoslobodsk district, Atyuryevo district) seems to be associated with intensive research on threatened plant species [28,29]; Table A1. A considerable increase in the ASP in some managed and protected areas was associated with research efforts to study the entire flora [30,31] or directly alien plants [32–34].

Noteworthy both in the Republic of Mordovia [15] and the Mordovia State Nature Reserve [31], alien plants were not classified, based on the internationally accepted nomenclature of alien species [35,36]. At the same time, in most studies around the world, exactly naturalized and/or invasive species are considered as the research object (e.g., [37–39]), without considering casual plants. Nevertheless, we believe that in Protected Areas casual plants should also be considered because in the future some of them can naturalize and even become invasive species. A good example is *Hieracium sylvularum* Jord. ex Boreau in the Mordovia State Nature Reserve. Before its foundation, in the 19th century, this plant was cultivated as an ornamental plant. After the establishment of the Mordovia State Nature Reserve, *H. sylvularum* has naturalized, and it is currently found in natural intact forest habitats within this Protected Area [40]. Our statement is consistent with the results of studies in other regions of the world (e.g., [41–43]), which note that some ornamental plants grown in and around PAs can invade these areas, becoming harmful invasive species. It was also noted [44] that the control for the propagule pressure associated with ornamental plant cultivation is one of the key measures to prevent the introduction and dispersal of alien species in Protected Areas. This is relevant for the area of the Mordovia State Nature Reserve, where the most recent additions to the alien flora have been made due to the findings of ornamental plants escaping in the wild from the former introduction sites [32,45–47]. As a result, by 2022, in the Mordovia State Nature Reserve, the ASP has increased to 19% that is much higher than in many Protected Areas of the world [11,25,26]. Therefore, we can assume that there are many Protected Areas, where the known values of the ASP are underestimated, and additional research efforts aimed to study alien plants may change the current knowledge in this issue.

5. Conclusions

The obtained findings demonstrate that additional research efforts can significantly change the ASP in both managed and protected areas. The special attention to cultivated alien plants, escaping in the wild or not, in Protected Areas allows us for more complete

and timely identification of potentially invasive species. Nowadays, it is impossible to compare the results obtained by us with similar data for Protected Areas outside Russia, since in the Mordovia State Nature Reserve and the Republic of Mordovia, alien plants have not yet been classified in accordance with the international nomenclature of alien species [35,36]. In this regard, we propose the following implications for the Mordovia State Nature Reserve. It is necessary to classify alien plant species known in the Protected Area, according to the international nomenclature of alien species [35,36]. For this purpose, we suggest using a unified framework for biological invasions [2] or the environmental impact classification for alien taxa [48–51].

Author Contributions: Conceptualization, A.A.K. and I.G.E.; methodology, A.A.K.; software, A.A.K.; validation, A.A.K. and I.G.E.; formal analysis, A.A.K.; investigation, A.A.K. and I.G.E.; data curation, A.A.K and I.G.E.; writing—original draft preparation, A.A.K.; writing—review and editing, A.A.K. and I.G.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: This study was performed within the framework of the state assignment FEWZ-2020-0009 from Ministry of Education and Science of the Russian Federation

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. References contributing to the flora of municipal districts of the Republic of Mordovia (European Russia) in 2010–2022.

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