Actual problems of biodiversity conservation in the central Russian Plain forest-steppe

S V Bakka¹², N Y Kiseleva², A A Shestakova², O V Birykova³

¹²State Nature Reserve "Nurgush", Kirov, Russia
²Minin Nizhny Novgorod State Pedagogical University, Nizhny Novgorod, Russia
³Lobachevsky State University of Nizhny Novgorod, Nizhny Novgorod, Russia

E-mail: sopr_nn@mail.ru

Abstract. The relevance of the study is determined by the critical state and negative trends in the development of remained fragments of meadow steppe and upland oak forest ecosystems in the Nizhny Novgorod region, located in the center of the Russian Plain. The paper's aim is to substantiate the activities required to conserve biological diversity on the northern border of the meadow steppes. It targets to assess the current state of endangered ecosystems of the forest-steppe zone of the region, to analyze their role in maintaining species diversity in the Nizhny Novgorod region, to substantiate approaches to the organization of nature management and territorial protection of the forest-steppe nature, ensuring the conservation of biodiversity. We provide the results of perennial surveys of meadow steppes and upland oak forests in 1982–2019, and analysis of these ecosystems as habitats for wildlife species listed in the Red Data Book of the Nizhny Novgorod region. Meadow steppes on the northern border of distribution are shown to encompass currently only 0.36% of the former area. Furthermore the modern area of old-growth upland oak forests of the region comprises 0.3% of the former one of broad-leaved forests. We have discovered 33.3% of wildlife species listed in the Red Data Book to associate with the zonal ecosystems remaining in the Nizhny Novgorod forest-steppe; and argued the necessity of a comprehensive solution to the problem of biodiversity conservation in the forest-steppe zone as well. Territorial protection of rare wildlife species and remained fragments of zonal ecosystems should be combined with elements of restorative economic impact. A complete prohibition of economic activities in protected areas is not advisable. The need for special programs for the restoration of certain lost elements of the biological diversity of the forest-steppe is discussed.

1. Introduction

The forest-steppe zone in the central part of the Russian Plain is one of the territories, which have been most transformed by human economic activity. Forest-steppe is an alternation of areas of deciduous forests and meadow steppes. Initially, the dynamic balance between forest and steppe fragments was maintained with the participations of large herbivorous mammals (bison, aurochs, tarpan), and after their extinction it was maintained exclusively by human economic activities (felling of forests, plowing of land, grazing).

We consider the problems of biodiversity conservation in the forest-steppe regions using the example of the Nizhny Novgorod region, located in the center of the Russian Plain. Forest-steppe landscapes occupy about 22.7 thousand km² in the southeast of the region. The history of land use, numbering several millennia, has determined the modern nature of landscapes and the current state of
natural ecosystems. The forests that had existed in the study area were being repeatedly cut down and burnt during the period of slash-and-burn agriculture. In different historical periods, agriculture and nomadic pastoralism replaced each other. Since the 17th century, deforestation has been increased rapidly; it was caused by the developing of potash production, and the plowing area. The transformation of the remaining forests was completed by clear felling of the Soviet era. In the same period, the last areas of meadow steppes on the uplands disappeared. At the end of the 20th century, the plowed area in some regions was 60-80%, the forest cover did not exceed 10% (in some regions – 2%) [1-3]. At the same time, fragments of oak forests have survived in the Nizhny Novgorod region, where the age of trees of the canopy exceeds 200 years. Meadow steppes in the region are located on the northern border of their distribution. The remaining steppe areas are characterized by high floristic richness and diversity [4].

In the Nizhny Novgorod forest-steppe, the legacy effect is clearly manifested – a modern ecological response to past impacts [5, 6]. This effect makes the problems of biodiversity conservation in the forest-steppe especially difficult and sophisticated. In nature conservation biology, it is generally accepted the natural objects be conserving fundamentally easier and cheaper than restoring its lost components of biodiversity. Unfortunately in the forest-steppe zone, only territorial protection of main habitats of rare wildlife species is not enough. Special measures should be implemented for natural ecosystems recovering. This study is aimed to prove the need to develop a comprehensive program for the conservation and restoration of biodiversity in the Nizhny Novgorod forest-steppe.

2. Materials and Methods
We started up to search and survey the remaining fragments of meadow steppes and old-growth upland broad-leaved forests in the Nizhny Novgorod region in 1982. Our activities were aimed to develop a regional network of protected areas. Before our surveys starting 10 steppe areas and 3 areas of old-growth upland broad-leaved forests were protected in the region and recommended for protection. Also we researched and recommended for protection 8 areas of the meadow steppe and 16 old-growth deciduous forests in 1982-96. The inventory of meadow steppes in the region was carried out in 2013-2014 [7]. Totally there was 9,235 km of vehicle routes and 418 km of pedestrian routes; 158 fragments of meadow steppes and steppe meadows with a total area of 10752 hectares were examined in detail. Using GIS-software we identified 13087 polygons of slopes of ravines and creeks in the Nizhny Novgorod forest-steppe, 7,485 of which were examined. We found the steppe ecosystems in 313 sites located in 107 systems of erosion landforms. A total of 276 rather large remaining steppe fragments were found in 93 systems of erosion landforms; they were characterized by relatively high floristic diversity and a large number of wildlife species, listed in the Red Data Books of Russia and the Nizhny Novgorod region [8, 9].

In 2019, 29 of the most significant steppe sites were re-examined, as well as 8 natural monuments that preserve upland broad-leaved forests. When examining the most valuable established and projected protected areas, we noted the state of ecosystems as a whole and compared it with the data obtained during previous surveys. Stability, positive or negative trends were also recorded. We identified the negative and threat factors impacting on the ecosystems. The presence (absence) of violations of protection regime was noted as well. Based on the results of surveys, we concluded about the state of protected ecosystems.

We analyzed the list of rare wildlife species listed in the Red Data Book of the Nizhny Novgorod region [8, 9], as well as all published proposals to supplement this list [10-13]. We identified rare species of animals, plants and fungi associated with old-growth broad-leaved forests and meadow steppes. The possibilities of their conservation in nature and the feasibility of special measures for their restoration are considered.

3. Results
In the Nizhny Novgorod region, meadow steppes and upland broad-leaved forests are the least preserved zonal types of vegetation. Steppe areas are located only on the slopes of ravines and creeks.
They are small fragments separated by agricultural landscapes. The area of the remaining steppe meadow fragments with the feather grass (*Stipa*) and other steppe species predominance ranges from 1.4 to 454.1 hectares, on average 71.6 ± 64.8 hectares (n = 136). The total area of the remained steppe communities itself is 2,540 hectares, or 0.36% of the area of their former range [7].

Our observations showed that despite the declaration of steppe areas as natural monuments, they degraded mainly due to excessive pasture load in the 1980s. Plant communities with rich and diverse herbage were replaced by digressive communities with *Festuca valesiaca* Gaunpredominance, and in many places, especially in the Pyana river region, they turned into waste-grounds with bare soil. It was necessary to regulate grazing: to achieve a pasture load not exceeding conditionally cattle per 2-3 hectares of pasture. After 2000, the grazing pressure decreased so much that the opposite threat to the existence of the steppes arose: rapid degradation, as evidenced by the mesophytization of vegetation, replacement of plant communities with a predominance of feather grass (*Stipa*) and other steppe grasses by cenoses characterized by the predominance of *Calamagrostis epigeios* (L.) Roth and *Bromopsis inermis* (Leyss.) Holub, the appearance and increase in the area of populations of *Rosa majalis* Herrm. and *Chamaecytisus rhenicus* (Fisch. ex Wołoszcz.) Klásk. The loss of the diversity of the native steppe flora associated with this process has been recorded [7, 14]. The restoration of pasture cattle breeding in the south-east of the Nizhny Novgorod region has become urgent.

The area of forests dominated by oak has been steadily declining over the centuries until the beginning of the 21st century. The total area of oak forests decreased by 39.1 thousand hectares from 96.8 to 57.7 thousand ha in the Nizhny Novgorod region since 1973 to 2003 [15]. According to our estimates 240 separate sites of old-growth upland oak forests with a total area of 2,812 hectares have been remained in the forest-steppe zone of the region by the end of the 1990s. The average area of the site was 11.7 hectares. The preservation of old-growth upland oak forests of the region is 0.3% of the area of the former range of broad-leaved forests [16].

The condition of protected sites of oak forests in the Nizhny Novgorod region is unfavorable. At present, in broad-leaved forests oak seedlings are successfully growing out, a renewal comprising of young individuals up to 0.5 m in height is developing. But later, as a result of shading by undergrowth of linden, maple and hazel underbrush, vitality of these individuals become subletal and they die at an age 10-30 years at a height of 1-2 m. The structure of the oak cenopopulation turns out to be strongly disturbed: older generations of oak are preserved, renewal is present too, but in most cases it has no chance to grow up to the tree canopy.

About 188 rare wildlife species inhabit forest-steppe ecosystems, one third of the total number of species listed in the Red Data Book of the Nizhny Novgorod region (table 1).

**Table 1.** The share of wildlife species listed in the Red Data Book of the Nizhny Novgorod region associated with the original ecosystems of the forest-steppe zone.

| Taxonomic group | Total number in the Red Book | Share (%) of species listed in the Red Book associated with: | | | |
|-----------------|-------------------------------|----------------------------------------------------------|------------------|------------------|------------------|
| Vertebrates     | 127                           | 11.0                                                     | 9.5              | 20.5             |
| Invertebrates   | 160                           | 20.6                                                     | 20.0             | 40.6             |
| Plants          | 180                           | 34.5                                                     | 7.2              | 41.7             |
| Mosses          | 28                            | 0.0                                                      | 14.3             | 14.3             |
| Algae           | 3                             | 0.0                                                      | 0.0              | 0.0              |
| Lichens         | 16                            | 0.0                                                      | 0.0              | 0.0              |
| Fungi           | 50                            | 0.0                                                      | 36.0             | 36.0             |
| Total           | 564                           | 19.3                                                     | 14.0             | 33.3             |
The share of plants growing in meadow steppes and fungi associated with old-growth oak forests is especially high. The rare forest-steppe species include the bustard *Otis tarda* L. and little bustard *Tetrao tetrix* L., which were extinct at the beginning of the 20th century, and *Fritillaria ruthenica* Wikstr., *Ranunculus pedatus* Waldst. & Kit., *Salvia nutans* L., which have probably disappeared, the speckled ground squirrel *Spermophilus suslicus* Gueld. that has been extinct for recent decades.

Studies at the beginning of the 21st century have shown that far from all rare wildlife species associated with the forest-steppe are included in the Red Data Book of the Nizhny Novgorod region. We suggest to include into the Red Data Book of the region two new for the region steppe species of butterflies *Polyommatus damon* (Denis & Schiffermuller, 1775), *Zygaena carniolica* (Scopoli, 1763); as well as the *Onobrychis arenaria* (Kit.) DC that grows exclusively in the surviving steppe communities. Botanists, who studied the southeast of the Nizhny Novgorod region, suggest to include 8 more plant species of the meadow steppe in the Red Data Book: *Carex aspratilis* V.I. Krecz., *Allium flavescens* Besser, *Polygala sibirica* L., *Orobanche elatior* Sutton, *Galatella angustissima* (Tausch) Novopokr., *Artemisia pontica* L., *Taraxacum bessarabicum* (Hornem.) Hand.-Mazz. [10-12]. Entomologists recommend the inclusion in the Red Data Book of the rare nemoral forest species *Watsonalia binaria* Hufn., as well as two steppe butterflies *Chortobius leander* Esp. and *Neolycaena rhynmus* Evers,[13]. As a result of the adoption of these proposals, the share of forest-steppe species in the regional Red Data Book will noticeably increase.

4. Discussion
As a result of human impact on the forest-steppe, meadow steppes and old-growth broad-leaved forests have become disappearing ecosystems in the Nizhny Novgorod region. The total number of surviving fragments of these communities does not exceed 450, and the total area is no more than 6,000 hectares. Considering such a low level of preserving, complete inventory of these communities, state registration and providing the governmental protection and regular monitoring of the state of all surviving areas of old-growth broad-leaved forests and meadow steppes guess to be tasks of high-priority. The conservation significance of these ecosystems is extremely high. They provide the existence of a third of wildlife species requiring protection in the region.

We believe the remained old-growth oak forests and meadow steppes being included in the regional system of protected areas is an important way of regulating the nature management. The preserved meadow steppes must be completely protected from plowing, afforestation of slopes, any construction, including linear objects, such as power lines and different pipelines. Felling of oaks with a trunk diameter of more than 70 cm should be prohibited. All trees being infected by tinder fungi should be preserve, because they ensure the survival of rare vertebrates (bats, dormouse, Tawny Owl), insects (*Osmotherma barnabita* Motschulsky, *Protaetia speciosissima* Scop., *Lucanus cervus* L.) and fungi (*Aurantioporus croceus* (Pers. Fr.) Murrill, *Kavinia himantia* (Schw.) J. Eriksson, *Oxiporus obducens* (Pers.) Donk, *Tyromyces kmetii* (Bres.) Bond. et Sing., *Antrodiella foliaceodentata* (Nikol.) Gilb. et Ryvarden, *Tomentella italic* (Sacc.) MJ Larsen).

At the same time, economic activities should not be prohibited at all in the protected areas within the forest-steppe zone. The degradation of meadow steppes in the absence of pasturing was shown in a number of publications on the example of various regions [17-22]. The management of protected areas should provide for the possibility of regulated pasturing. This requirement is implemented in the steppe natural monuments of the Nizhny Novgorod region. However, under modern socio-economic conditions, pastoralism is in decline. Permits for pasturing are not enough. The government should provide a special support to farmers and agricultural producers who are able to organize grazing in the steppe protected areas. In addition, when farming in the forest-steppe zone, activities leading to a decrease in biodiversity should be avoided. Strict rules for pesticide use, the control for arable land area and crop rotation, prevention of soil degradation, etc. should also be realized.

Many experts [14, 23, 24] note the fact that modern oak forests is not able to natural recovery as a result of disturbance of spatial structure, as well as the loss herbivores, whose activities largely seemed to determine the spatial dynamics of the communities. It is obviously the secondary lime forests will
replace the protected oak forests after several decades in the Nizhny Novgorod region. To avoid it the nature management of protected old-growth oak forests should provide for the possibility of carrying out some reforestation measures. Techniques for such reforestation were proposed in several publications [15, 25]. Thus, management of the protected areas of old-growth oak forests should be revised, and all reforestation activities should be carried out according to special individual projects, agreed by the Commission on the Red Data Book of the region and the Ministry of Ecology of the region.

To restore upland oak forests the special program should be adopted at the regional level. The implementation of such a program does not bring short-term economic benefits to forest users; therefore, it requires state support. At the first stage of the activities, the model sites propose to set up for the restoration of oak forest ecosystems. The area should be 100-500 hectares for the sites established outside protected areas, and a few hectares for sites within the boundaries of the largest protected areas that preserve oak forests.

We suggest also considering the possibility of re-acclimatization of the bison in the largest territory of broad-leaved forests in the Nizhny Novgorod region. The only forest massif locating on the border of the Lukoyanov and Pochinki districts is suitable for this propose. The area of the massif is about 455 km². Programs for the restoration of other elements of biological diversity that have been lost or are on the verge of extinction are also relevant (*Spermophilus suslicus, Fritillaria ruthenica, Ranunculus pedatus, Salvia nutans*).

The problems of protection and ecological restoration of ecosystems of the forest-steppe zone were appointed in the Strategy for the Conservation of Biodiversity of the Nizhny Novgorod Region, approved in 2020.

5. Conclusion

As a result of past impacts, zonal forest-steppe ecosystems (meadow steppes and upland oak forests) have turned from dominant to endangered ones. Therefor they require some special measures of ecological restoration. The biodiversity conservation in the forest-steppe zone is an extremely complex and sophisticated problem, and its solution requires to include in the nature management the protection with elements of restorative economic impact, and the special regulation concerning all natural ecosystems as well.

Also we believe a complete inventory, state registration, providing the territorial protection and monitoring of the conditions of all remained fragments of old-growth oak forests and meadow steppes to be required. The nature management should not completely prohibit economic activities on the protected area, but strictly regulate their use. In this way controlled cattle grazing and haymaking should be permitted on the steppe areas. Activities aimed at recover the spatial structure and age spectrum of oak cenopopulations should be implemented in the protected broad-leaved forests.

When farming in the forest-steppe zone, activities leading to a decrease in biodiversity should be avoided. The special governmental program for the restoration of pasture cattle breeding in areas of meadow steppes is required.

Forest management requires the implementation of a special program for the restoration of upland oak forests. Activities that do not bring economic benefits to forest users should be supported by the government.

Programs for the restoration of certain lost elements of biological diversity (bison, ground squirrel, and extinct plant species) are relevant.

The most important condition for success is constant monitoring of the state of biodiversity in the forest-steppe zone.

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