

# Forecasting the impact on endangered wildlife species affected by the planned restoration of wetlands after peat mining (Nizhny Novgorod region, Russia)

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**Abstract.** This paper is aimed to generalize and analyze information about endangered wildlife species in the disturbed fen site (comparing the state of surrounding wetlands) to predict their condition during rehabilitation and restoration of the site and subsequent monitoring during successional processes in the wetland ecosystems. The research was carried out on the territory of the Biosphere Reserve of UNESCO "Nizhegorodskoe Zavolzhye" on the example of the Kamskoe–Osinovye Kotly mire, which is a part of the Ramsar wetlands "Kama-Bakaldino Mires" (Nizhny Novgorod region). The area of the mire is about 15,000 hectares. A part of the mire with a total area of 2,770 hectares was drained and disturbed as a result of peat extraction since the 1970s to 1990s. We carried out surveys of flora and vegetation counts of small mammals, birds, amphibians and reptiles, butterflies and moths in 2021. Also for the analysis we used research data obtained in 1981-2019. A total of 58 endangered wildlife species listed in the Red Data Book of the Nizhny Novgorod region were registered in the studied territory, 14 species of which were discovered here for the first time. The location of the site which are planned to be restored, in the central part of the mire, surrounded by undisturbed communities is a condition for its successful restoration with the full biota after watering. Secondary watering of the site of former peat mining will not cause damage to endangered wildlife species. To maintain biodiversity and conserve the complex of meadow and semi-forest species we recommend carrying out the haymaking in the open spaces adjacent to the mire on the territory of the projected national park. Also we believe the succession processes in the mire and the endangered wildlife species conditions to have to be controlled.

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## 1 Introduction

The international ecological community recognizes the restoration of natural ecosystems disturbed by man as a problem of urgent concern, and measures aimed at its implementation ensure sustainable development [1-4]. Wetlands play a significant role in carbon deposition. Peatlands disturbed after peat extraction and drainage, on the contrary, have become a source of greenhouse gases and increase wildfire danger. Therefore, the restoration and rehabilitation of numerous disturbed peatlands in European Russia is very relevant. Many environmental activities have been addressed to this problem last years [5-8]. However, secondary communities having developed in the damaged wetland areas after the transformative human activity can be inhabited by protected wildlife species [9]. Developing projects for the wetland restoration it should be considered.

The territory of our surveys was the Kamskoe–Osinovye Kotly mire with the total area of about 15,000 hectares., which is a part of the Ramsar wetlands "Kama-Bakaldino Mires" (Nizhny Novgorod region) [10, 11]. A part of the mire with a total area of 2,770 hectares was drained and damaged as a result of peat extraction since the 1970s to 1990s. The rest part of the mire is declared a protected area of regional significance. It is located on the territory of the Biosphere Reserve of UNESCO " Nizhegorodskoe Zavolzhye", 4 km from the border of the Kerzhensky State Nature Reserve. Now the main part of the Kamskoe–Osinovye Kotly mire is included in the projected national park. Peat wildfires that regularly occur on the site of former peat mining threaten the existence of protected natural habitats. Restoration and rehabilitation of peatlands is the most effective measure to reduce wildfire danger, recover their biological diversity and environmental significance. The watering of this site will allow to consider the peatland restoration project as a contribution to the fulfillment of obligations under the Ramsar Convention, as well as to create a precedent for approving the methods of sustainable nature management within the UNESCO Biosphere Reserves concept.

## 2 Materials and methods

The authors in different years (since the 1980s) carried out surveys to found the endangered wildlife species in the Kamskoe–Osinovye Kotly mire and monitor their condition and the numbers, as well as took part in the projection of protected areas here. The huge data on the specific features of the territory has been obtained. These data were mainly used in preparing the Red Data Book of the Nizhny Novgorod region [12, 13]. The territory of peat mining in the course of such studies was usually ignored.

During the our research in May–November 2021, two study plots were set up in the Kamskoe–Osinovye Kotly mire: 1) the territory drained and damaged after peat mining, which was in the 1970s–90s (the site of the planned watering and restoration of peatlands); 2) the site of the undisturbed by human activity peat bog, not affected by the wildfire in 2010. The distance between the study plots is about 12 km.

According to the results of preliminary analysis of satellite images and other data obtained earlier we revealed areas with rather homogeneous vegetation, and during the surveys on the territory we made geobotanical relevés on those areas on circular plots with a radius of 10 m. In total, 31 geobotanical relevés were made on the studied territory, including 25 relevés on the damaged plot and 6 relevés on the undisturbed plot. Geobotanical relevés were carried out following the methods proposed by Sukachev [14]. A list of vascular plant species of the studied area has been compiled. In the list of plant species, the nomenclature, including Russian and Latin names of species, as well as the position of plant taxa follows Mayevsky [15].

To characterize the species composition and abundance of small mammals, we used standard methods of census and data processing. We used Gero's traps to catch small mammals: along the transect every trap was placed 5 m apart from another. At each of the study plots we conducted 80 trap-days.

Bird counts at study plots were carried out on transects with an unlimited field of view [16]. One transect was set up across the damaged plot (1.96 km) and another – through the undisturbed one (1.22 km). We counted birds on both transects two times: at the beginning of May and at the beginning of June.

Also we carried out a census of amphibian and reptile numbers. The total length of the survey transects was 16.89 km, including 9.23 km on the damaged plot, 7.66 km on the undisturbed plot, and the transect width was 2 m.

The Lepidoptera was recognized as a model group of arthropods. The species composition and numbers of moths were being identified by attracting with mercury and ultraviolet lamps to a white screen. The screens worked for 10 nights (5 on each study plot). Diurnal butterflies were being identified on routes during a day. The counts were carried out every month from May to September. The length of the routes was 11.40 km, including 6.73 km on the damaged plot, 4.67 km on the undisturbed plot.

### 3 Results

The vegetation of the territory of former peat mining is secondary birch aspen-birch and willow forests, with extremely poor herb layer, where *Carex lasiocarpa* Ehrh., *Calamagrostis canescens* (Weber) Roth, *Molinia caerulea* (L.) Moench. In the forest floor *Polytrichum commune* Hedw. predominate, in some communities herbs are absent. The age of trees here is 10-12 years, and the height varies from 1-2 to 4-5 m. Small open spaces of peat mining fields are covered by *Calamagrostis canescens* and sedges. Along the drainage channels, vegetation is characterized by a great diversity due to the presence of swamp and aquatic species into communities, however, the share of herb layer in the composition of communities is also small – these are birch forests predominated by *Calamagrostis canescens* with sedges or with *Polytrichum*, *Calamagrostis epigeios* (L.) Roth with ferns. In the places of the former buildings and along the roads, we noted grassland and wood communities with predominance of *Urtica dioica* L., *Calamagrostis epigeios* and other herb species.

Lake Kamskoye is located in the central part of the damaged part of the mire. Along the shores of the lake, communities with *Calamagrostis canescens* develop a belt about 2-3 m wide, then at the depth of 0.5–1 m communities with *Phragmites australis* (Cav.) Trin. ex Steud. and *Equisetum fluviatile* L. predominate, as the depth increases to 1.5 m, the community with *Nuphar lutea* (L.) Sm. is noted, at a depth of up to 2 m – with *Myriophyllum sibiricum* Kom. and *Potamogeton crispus* L.

The undisturbed part of the mire is a complex of swamp, fen and bog communities. Along the periphery of the mire we recorded alder (*Alnus glutinosa* (L.) Gaertn.) and alder-birch swamps dominated by sedges, large ferns and reed. Toward the center of the mire, swamps are replaced by moistened mesotrophic birch-pine fens with *Salix cinerea*, reed, *Menyanthes trifoliata* L. and *Sphagnum*, that are changed by meso-oligotrophic birch fens with *Carex lasiocarpa* and *Sphagnum*. In the center of the undisturbed part of the mire, we found oligotrophic pine bogs with evergreen shrubs, *Eriophorum vaginatum* L. and *Sphagnum*. On the drained lands of the mire we recorded mainly pine forests at the age of 60-80 years predominated by *Vaccinium myrtillus* L. In the undisturbed part of the mire outside the study plot, there are lakes Maloe Plotovo, Chernoe and Pustoe.

A total of 58 endangered wildlife species listed in the Red Data Book of the Nizhny Novgorod region were registered in the Kamskoe–Osinovye Kotly mire (Table 1). A large

number and diversity of endangered species in this territory indicates the species richness and high preservation of the biota in general. Until 2021, 44 endangered species were known to inhabit this mire. As a result of research in 2021, 24 endangered wildlife species were found in the study plots of the Kamskoe–Osinovye Kotly mire, including 14 species were recorded here for the first time. Previously known data have been confirmed for 8 species. Two species (*Pandion haliaetus* and *Celaena hawortii*) were found on the territory of peat mining in 2021. Earlier, they were known inhabiting only the undisturbed part of the mire (Table 1 and 2).

The absolute majority (79.3%) of endangered species were recorded only in the undisturbed part of the mire. Six (10.35%) endangered species have been registered only on the damaged plot. Another 6 (10.35%) species inhabit both plots (Table 1 and 3). The Jaccard similarity for the composition of endangered species of the two study plots is 10.35%.

**Table 1.** Endangered wildlife species listed in the Red Data Book discovered in the Kamskoe–Osinovye Kotly mire.

№	Species	Damaged plot	Undisturbed plot
1	<i>Myotis daubentoni</i> Kuhl		+
2	<i>Gavia arctica</i> L.**	+	+
3	<i>Ardea cinerea</i> L.*	+	
4	<i>Pandion haliaetus</i> L.	+***	+
5	<i>Circaetus gallicus</i> Gmel.		+
6	<i>Hieraaetus pennatus</i> Gmel.		+
7	<i>Aquila clanga</i> Pall.		+
8	<i>Aquila chrysaetos</i> L.		+
9	<i>Haliaeetus albicilla</i> L.		+
10	<i>Grus grus</i> L.**	+	+
11	<i>Rallus aquaticus</i> L.**	+	
12	<i>Pluvialis apricaria apricaria</i> L.		+
13	<i>Tringa glareola</i> L.	+	+
14	<i>Numenius arquata</i> L.		+
15	<i>Numenius phaeopus</i> L.		+
16	<i>Chlidonias niger</i> L.		+
17	<i>Sterna hirundo</i> L.		+
18	<i>Cuculus saturatus</i> Blyth		+
19	<i>Strix nebulosa</i> J. R. Forst		+
20	<i>Picoides tridactylus</i> L.		+
21	<i>Anthus pratensis</i> L.		+
22	<i>Locustella luscinioides</i> Savi*	+	
23	<i>Lanius excubitor</i> L.		+
24	<i>Emberiza rustica</i> Pall.*		+
25	<i>Coronella austriaca</i> Laurenti		+
26	<i>Pelias (Vipera) berus</i> L.		+
27	<i>Psophus stridulus</i> L.		+
28	<i>Bombus muscorum</i> L.		+
29	<i>Bombus schrencki</i> Mor.		+
30	<i>Iphiclidus podalirius</i> L.		+
31	<i>Clossiana eunomia</i> Esp.**		+
32	<i>Boloria aquilonarus</i> Stich.		+
33	<i>Oeneis jutta</i> Hbn.		+
34	<i>Selenia lunularia</i> Hbn.*		+
35	<i>Parectropis similaria</i> Hufn.*		+
36	<i>Idaea sylvestriaria</i> Hbn.		+
37	<i>Cyclophora annularia</i> Fabricius*		+

38	<i>Catarhoe rubidata</i> Den. et Schiff.*	+	
39	<i>Ecliptopera capitata</i> H.-S.*		+
40	<i>Smerinthus caecus</i> Men.*	+	
41	<i>Catocala adultera</i> Men.*		+
42	<i>Catocala pacta</i> L.*	+	
43	<i>Moma alpium</i> Osbeck*		+
44	<i>Celaena hawortii</i> Curt.	+***	+
45	<i>Dolomedes plantarius</i> Clerck	+	+
46	<i>Lycosa singoriensis</i> Laxm.		+
47	<i>Heterocope saliens</i> Lill.		+
48	<i>Holopedium gibberum</i> Zadd.		+
49	<i>Carex chordorrhiza</i> Ehrh.*		+
50	<i>Carex dioica</i> L.		+
51	<i>Carex pauciflora</i> Lightf.*		+
52	<i>Dactylorhiza traunsteineri</i> (Saut.) Soo.**		+
53	<i>Betula humilis</i> Schrank.		+
54	<i>Salix lapponum</i> L. **		+
55	<i>Salix myrtilloides</i> L. **		+
56	<i>Oxycoccus microcarpus</i> Turcz. ex Rupr. **		+
57	<i>Drosera anglica</i> Huds.		+
58	<i>Pedicularis sceptrum-carolinum</i> L.		+

\* – the species was first discovered in the Kamskoe–Osinovye Kotly mire in 2021; \*\* – the previously known species was confirmed in 2021; \*\*\* – the species was previously known in the undisturbed part of the mire, in 2021 the species was also found on the damaged territory.

**Table 2.** The number of endangered wildlife species listed in the Red Data Book of the Nizhny Novgorod region identified in the Kamskoe–Osinovye Kotly mire in different periods of research.

Data of discovery	Species number			
	vertebrates	invertebrates	plants	total
2021	3	9	2	14
the species was previously known in the undisturbed part of the mire, in 2021 the species was also found on the damaged territory	1	1	0	2
the previously known species was confirmed in 2021	3	1	4	8
1981–2019	19	11	4	34
Total	26	22	10	58

**Table 3.** The number of endangered wildlife species listed in the Red Data Book of the Nizhny Novgorod region, inhabiting the study plots.

Study plot, where the species recorded	Species number			
	vertebrates	invertebrates	plants	total
Undisturbed plot	19	17	10	46
Both plots	4	2	0	6
Damaged plot	3	3	0	6
Total	26	22	10	58

## 4 Discussion

The inevitable initial stage of the peatland restoration on the site of former peat mining is the destruction of the system drainage channels developed here and artificial flooding of the

territory. A positive effect is projected at the initial stage of the process: reducing the number and intensity of wildfires or even (with significant flooding) stop them completely. At the same time, a rapid change in the hydrological regime of the territory leads to a radical restructuring of the existing secondary ecosystems.

In the first three to five years after the flooding, a loss of trees (birch, aspen, and willow) will be probably recorded in the most moistened areas. The communities of treeless swamps with predominance of reed and sedge are expected beginning to develop. In many areas with an insignificant depth of flooding and a relatively rich mineral nutrition, we can project willow (mainly *Salix cinerea*) shrub-like forests growing. Birch woods will seem to remain on natural and artificial mesorelief elevations (on peat and sand ramparts along former drainage channels, as well as on the internal drained elevation on the territory of former peat mining).

The first years after flooding, when the collapse of the secondary ecosystems having already developed inevitably occur, and the restored communities of swamps and fens start to develop, are the least favorable for the conservation of biological diversity.

Later 5-10 years after flooding, depending on the depth of the water and the conditions of mineral nutrition, differentiation of the emerging swamp ecosystems will begin. The areas with an average water depth of about 0.5 m will be occupied by swamps predominated by reeds. The less watered areas with rich mineral nutrition will be gradually covered by alder and birch trees. The succession is predicted to undergo to direction of the birch-alder swamp development. Birch and pine fens will appear in areas with poor mineral nutrition, succession will follow the path of formation of pine-birch communities predominating by sedge, reed and sphagnum characteristic of the poor and mesotrophic fens. The predicted differentiation will be evident within 50 years. In the course of succession processes, beavers cause significant damage, whose settlements have existed in one place for one to five years, and then move in another site.

The succession of vegetation will inevitably induce changes in the species composition and numbers of animals. The loss of tree canopy and undergrowth will lead to a decrease in the number of forest (tree-dependent) animal species. However, due to the complex mesorelief and the remained forested areas at drained elevations, the complete loss of any animal species is unlikely. The proportion of waterfowl, near-water, semi-aquatic and aquatic animal species in the fauna will increase during the first decade after flooding. Then, as tree canopy are restored, forest species will return in the communities. The role of obligate swamp species will gradually increase.

Special attention should be paid to endangered wildlife species listed in the federal and regional Red Data Books. There are 10 endangered plant species known in the Kamskoe–Osinovye Kotly mire. All of them are found only in the undisturbed territory of the mire and are absent in the site of former peat mining. As peatlands are restored in the damaged part of the mire, endangered plant species are expected to grow here.

The most part of endangered animal species are also associated with undisturbed wetlands. Three species (*Gavia arctica*, osprey and *Dolomedes plantarius*) are found on lakes that are located both in undisturbed and damaged sites of the mire. Two more swamp bird species (Common crane and *Tringa glareola*) and one swamp butterfly species reach to inhabit the flooded open spaces of former peat fields with recovering swamp communities. For all these animals, the planned processes of artificial flooding will play only a positive role.

Six species of animals listed in the Red Data Book of the Nizhny Novgorod region in the study area were discovered only on the part of former peat mining: *Ardea cinerea*, *Rallus aquaticus*, *Locustella luscinioides*, *Smerinthus caecus*, *Catocala pacta*, *Idaea muricata*.

Regardless of the degree of human impact the Kamskoe–Osinovye Kotly mire does not play any significant role as a habitat of the gray heron. In 2021, during the period of post-breeding movements only an adult was encountered on a heavily watered site of former peat mining.

The water rail and the Savi's warbler are associated with reed beds. The planned flooding will create conditions for their significant settlement and population growth. With the gradual reduction of shallow waters with reed beds and the forest development in their place, these birds will be preserved, at least in the reed belt of Lake Kamskoye.

*Smerinthus caecus* and *Catocala pacta* are the oligophages on the willows. They inhabit the Kerzhensky State Nature Reserve outside of peat mining territories. The high mosaic of communities that restore in the flooded area will provide conditions for the conservation of these species.

*Idaea muricata* is a meadow–forest mesophylic species, being a monophage its larva feeds on bedstraws. There is almost no information about the modern habitats of this species in the Nizhny Novgorod region. For its habitat, the meadow and forest edge complexes are necessary, which are highly likely to be preserved due to the mosaic mesorelief of the watered area.

We recommend to the future national park to conduct regular haymaking in the open spaces adjacent to the wetlands. These actions will contribute to the maintenance of biological diversity through the conservation of a complex of species inhabiting meadows and forest edges, as well as increase the recreational attractiveness of the territory.

The comprehensive survey of wetlands conducted in 2021 (before the start of activities on watering the damaged area) allowed us to obtain results that can be recognized as a base for further monitoring of successional processes of wetland restoration. We believe such monitoring being advisable for the projected national park to organize it together with the Kerzhensky State Nature Reserve.

## 5 Conclusion

Restoration and rehabilitation of damaged wetlands is extremely relevant, as they restore the lost biospheric functions of wetlands for carbon deposit, reducing greenhouse gas emissions, maintaining the hydrological regime of the territory, as well as reduce the probability of wildfires, increase the bioresource potential of the territory. The status of the Ramsar site attaches special importance to the restoration of the Kamskoe–Osinovye Kotly mire.

The site being restored is located in the central part of the mire; close to it are undisturbed peatlands. This fact creates conditions for the successful restoration of wetlands with full biota in the disturbed area after its watering.

The the Kamskoe–Osinovye Kotly mire is a habitat for 58 wildlife species listed in the Red Data Book of the Nizhny Novgorod region. All endangered plant species and the majority (87.5%) of animal species are associated with wetlands preserved in their natural state.

Secondary watering of the site of former peat mining will not cause damage to endangered wildlife species. To maintain biodiversity and conserve the complex of meadow and semi-forest species we recommend carrying out the haymaking in the open spaces adjacent to the mire on the territory of the projected national park.

The site being restored is located on the territory of the the Biosphere Reserve of UNESCO "Nizhegorodskoe Zavolzhye". The planned activities contribute to the sustainable development of the territory, that is, they fully correspond to the main tasks of the biosphere reserve.

The State Nature Reserve, as a future tenant of the site, has the opportunity not only to restore the damaged fragment of the Ramsar site, but also to obtain scientific data characterizing the course of this process.

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