Territorial Protection of Rare Orchid Species (Orchidaceae) in the Nizhny Novgorod Region

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Abstract. This study aims at the analysis of the current status of the territorial protection of rare orchid species in the Nizhny Novgorod region to solve the problems of further maintaining biodiversity in the region and developing the system of protected areas. The total area of 411 existing and 147 projected protected areas in the region together with buffer zones is 8350 km² (11% of the region area). For the analysis, we used data from the Herbarium of the Lobachevsky State University of Nizhny Novgorod (NNSU), scientific publications and data obtained by the authors during surveys in 1986–2019. To determine the level of territorial protection we used the frequency of occurrence of rare orchid species in the protected areas estimated in points. It was calculated at the basis on the share of the number of discovered locations of the species per the total number of findings of that species in the region. Also we took into consideration numbers and areas of protected areas where the orchid species are protected, their status and category (federal or regional, established or projected), as well as actual records of orchids on these areas over the past 20 years. A total of 19 rare orchid species are protected at 65 established and 11 projected protected areas of the Nizhny Novgorod region. Ten orchid species are recognized as well provided with territorial protection (52.6%). The level of territorial protection of 4 species is recognized as satisfactory. At the same time 4 species of orchids are poorly protected. The threat of extinction of these orchid species in the region is significant. Three species of orchids, which are probably extinct in the Nizhny Novgorod region, are absent in the protected areas. The number of rare species growing on existing protected areas ranges from 1 to 11 and depends on different criteria (level of the flora research, diversity of habitats) and has a weak positive correlation with the area (correlation coefficient – 0.46). We predict a significant increase in the number of finds of rare orchids in protected areas with a detailed flora inventory conducting. The system of protected areas established in the region as a whole provides a satisfactory level of protection for rare orchids. Nevertheless, the territorial protection of these plants needs to be improved.

1. Introduction

Orchidaceae Lindl. is one of the most vulnerable component of natural ecosystems: about 60% of the orchid species growing in Russia are included in the Red Book of the Russian Federation [1]. This circumstance actualizes conducting the regional census of orchids [2-7] and studies of the current state of territorial protection of orchids at the regional level [8-11].

Considering the families of Angiosperms that comprise the flora of the Nizhny Novgorod region Orchidaceae Lindl. includes the largest portion of rare, vulnerable and endangered species, 71% of
which are listed in the regional Red Data Book, including 11 species from the Red Data Book of Russian Federation [12-14]. Habitat destruction in the process of nature management is recognized as the most hazardous to them. Thus the main way of conservation is the establishment of protected areas. The total area of 411 existing and 147 projected protected areas in the region together with buffer zones is 8350 km² (11% of the region area).

The Nizhny Novgorod Region (area – 76,600 km²) is located in the center of the Russian Plain. A total 411 protected areas (PAs) have been established in the Nizhny Novgorod region. In addition, 147 areas have been reserved for the protected areas approving. The total area of the existing and projected PAs together with the buffer zones is 8350 km² (11% of the region area). More than half of the regional PAs were established in 1986–1998. Reservation of areas for the PAs establishment was carried out in 1994. The main task of the development of the regional network of PAs was to provide territorial protection of the largest remained areas of the least disturbed ecosystems (old growth forests, remained areas of meadow steppes and wetlands). The habitats of rare wildlife species was one of the criteria for the protected area establishing. Under the socio-economic conditions of 1986-1998 it was the priority to establish PAs in the shortest possible time, but not to conduct a complete census of rare wildlife species.

Rare orchid species grow in many PAs of the region. The purpose of this study is to analyze the current state and ensure the territorial protection of rare orchid species in the Nizhny Novgorod region in order to solve the problems of further biodiversity conservation in the region and developing a network of protected areas.

A significant part of modern records of rare orchids was made by us mainly during surveys of the territory aimed at the protected areas projecting in 1986–1998. All this information was included in the regulations of particular PAs. Also additional data were obtained in the course of monitoring the state of PAs during 1999–2019. We have analyzed samples of the Herbarium of the Lobachevsky State University of Nizhny Novgorod (NNSU) and publications on orchids. Information on rare orchid distribution in the region, in particular in PAs, is largely summarized in two editions of the Red Data Book of the Nizhny Novgorod Region [12, 14].

For each rare orchid species we have determined the number and square of PAs (established and projected), where it was registered. Unfortunately the current level of investigations does not allow quantitative estimates of the abundance of rare orchids both in the region as a whole and in PAs. Therefore, evaluating the degree of territorial protection, we used point estimates for the rare orchid occurrence in PAs, which are based on the share of the species locations within PAs of the total number of the species locations in the region at whole (Table 1).

| Share of the species finds, % | Points |
|------------------------------|--------|
| 0                            | 0      |
| 1–25                         | 1      |
| 26–50                        | 2      |
| 51–75                        | 3      |
| 76–99                        | 4      |
| 100                          | 5      |

The assessment of rare orchid occurrence is insufficient to determine the degree of their territorial protection. Thus we also take into account the number and square of PAs, where these species are protected, as well as the records having been confirmed or no over the past 20 years, the status and position of PAs (federal or regional, established or projected).

For each PA we have determined the number of registered rare orchid species. We have analyzed the occurrence of orchids in PAs of different categories. We estimated the significance of various parameters (ecosystem diversity, degree of flora research, area) that determined the number of rare orchid species in a protected area. The correlation coefficient has been calculated between the number
of rare orchid species recorded in 76 PAs and the square of these PAs. Regular monitoring of the state of the discovered populations of orchids was carried out in the State Nature Biosphere Reserve "Kerzhensky" [15]. Based on the results of this monitoring, the population numbers of rare orchid species in the protected area were calculated.

2. Results and Discussion
Of the 22 orchid species listed in the Red Data Book of the Nizhny Novgorod Region, 19 are encountered in PAs (Table 2). Following the ranges presented in Table 1 the occurrence in PAs is estimated in points.

| № | Species | Protected Areas | Occurrence in PAs, points |
|---|---------|-----------------|--------------------------|
|   |         | established     | projected                |
|   |         | number, ind.    | area, km² | number, ind. | area, km² |
| 1 | Cypripedium guttatum Sw.* | 6 | 1462.84 | 0 | 0.00 | 3 |
| 2 | Cypripedium calceolus L.** | 32 | 1899.44 | 2 | 8.47 | 4 |
| 3 | Cypripedium macranthon Sw.** | 0 | 0.00 | 0 | 0.00 | 0 |
| 4 | Cephalanthera rubra (L.) Righ.** | 4 | 795.41 | 0 | 0.00 | 3 |
| 5 | Epipactis palustris (Mill.)* | 8 | 255.67 | 1 | 10.71 | 2 |
| 6 | Epipactis atrorubens (Hoffm.) Bess.* | 0 | 0.00 | 0 | 0.00 | 0 |
| 7 | Listera cordata (L.) R. Br.* | 1 | 575.17 | 1 | 4.13 | 1 |
| 8 | Hammarbya paludosa (L.) O. Kuntze* | 4 | 695.95 | 0 | 0.00 | 3 |
| 9 | Malaxis monophylla (L.) Sw.* | 4 | 206.62 | 1 | 5.00 | 2 |
| 10 | Liparis loeselii (L.) R.Br.* | 2 | 197.89 | 0 | 0.00 | 2 |
| 11 | Calypso bulbosa (L.) Oakes** | 1 | 296.80 | 0 | 0.00 | 2 |
| 12 | Corallorhiza trifida Chatel.* | 8 | 1161.92 | 3 | 170.06 | 2 |
| 13 | Epipogium aphyllum (F.W. Sghmidt) Sw.** | 2 | 200.49 | 0 | 0.00 | 3 |
| 14 | Herminium monorchis (L.) R. Br.* | 5 | 127.21 | 0 | 0.00 | 2 |
| 15 | Coeloglossum viride (L.) Hartm.* | 1 | 2.16 | 0 | 0.00 | 1 |
| 16 | Platanthera chlorantha (Cust.) Reichb.* | 10 | 84.65 | 1 | 37.82 | 4 |
| 17 | Neottianthe cucullata (L.) Righ.** | 7 | 932.75 | 1 | 4.13 | 3 |
| 18 | Dactylorhiza cruenta (O.F. Muell.) Soó** | 4 | 444.87 | 0 | 0.00 | 3 |
| 19 | Dactylorhiza baltica (Klinge) Orlova** | 1 | 197.30 | 0 | 0.00 | 3 |
| 20 | Dactylorhiza traunsteineri (Saut.) Soó** | 4 | 528.76 | 4 | 221.39 | 3 |
| 21 | Orchis militaris L.** | 8 | 13.36 | 0 | 0.00 | 3 |
| 22 | Orchis ustulata L.** | 0 | 0.00 | 0 | 0.00 | 0 |

Remarks: * – the species is listed in the Red Data Book of the Nizhny Novgorod Region, ** – the species is listed in the Red Data Books of the Russian Federation and the Nizhny Novgorod Region

We believe Cypripedium calceolus to be provided with territorial protection better than other orchid species. Its habitats are protected in 32 established and 2 projected PAs that comprise 75% of the known species habitats in the region. The establishment of new protected areas specially for the Cypripedium calceolus conservation is not required. In the future, with the development of the regional system of protected areas, the number and share of protected populations of Cypripedium calceolus may increase significantly.

We consider the level of territorial protection of nine orchid species to be well, among which we identified three groups. The first comprises Neottianthe cucullata and Cephalanthera rubra. Both species are listed in the Red Book of the Russian Federation. More than half of the known these species locations...
in the Nizhny Novgorod region is within PAs, which number and square is large. The largest populations of Neottianthe eucullata and Cephalanthera rubra in the region are located on the territory of the Kerzhensky State Nature Biosphere Reserve, which guarantees their conservation.

The second group also includes two species – Cyripedium guttatum and Hammarbya paludosa. For these species territorial protection is provided for more than half of the known locations in the region, they are protected in several large protected areas, among which is the Kerzhensky State Nature Biosphere Reserve. However the largest species populations are not protected.

The third group consists of five species: Platanthera chlorantha, Dactylorhiza trunsteineri, Orchis militaris, Corallorhiza trifida, Epipactis palustris. Each of them has the only known protected populations of at least several hundred thousand. The threat of loss of these orchids in the region is significant. There is a need for a special protection of the region.

We consider the level of territorial protection of four orchid species to be satisfactory, but requiring significant improvement. For three of them (Malaxis monophyllos, Herminium monorchis, Dactylorhiza cruenta) no more than half of the known habitats in the region is protected in 4-5 regional PAs. Listera cordata has been registered in only two PAs. The largest species population consisting of thousands of individuals is protected in the Kerzhensky State Nature Reserve. The second protected population is located in a projected PA. We suppose the species with a satisfactory level of territorial protection need to increase the number of PAs by 25–50%.

Four orchid species are poorly provided with territorial protection: Epipogium aphyllum, Calypso bulbosa, Dactylorhiza baltica, Liparis loeselii. Each of them has the only known population under protection. The threat of loss of these orchids in the region is significant. There is a need for a special search for new habitats and taking them under protection.

Coeloglossum viride can be considered as being provided with nominal territorial protection only. This species was encountered by Averkiev in 1909 (NNSU) on the territory of the modern natural monument "Malinovaya Gryada" in the territory of Nizhny Novgorod. It is unknown whether this species population has remained now. There are no other records of Coeloglossum viride within PAs. Three orchid species: Cyripedium macranthon, Epipactis atrorubens, Orchis ustulata are absent in PAs. These species are included in the flora of the Nizhny Novgorod region on the basis of known locations that have survived to this day in the region are unknown [11, 16-18].

Rare orchid species are protected in 65 established and 11 projected PAs. The number of rare species in established PAs ranges from one to eleven. No more than two orchid species are protected in 54 established PAs (83%), three or more – in eleven (17%). Projected PAs contain 1–2 species each (Table 3).

**Table 3. Number of rare orchid species per a protected area in the Nizhny Novgorod region**

| Rare orchid species per PA | Established PAs | Projected PAs |
|--------------------------|-----------------|---------------|
|                          | number, ind. | area, km² | number, ind. | area, km² |
| 11                       | 1              | 197.30     | 0            | 0.00      |
| 7                        | 1              | 575.17     | 0            | 0.00      |
| 4                        | 3              | 311.97     | 0            | 0.00      |
| 3                        | 6              | 263.61     | 0            | 0.00      |
| 2                        | 12             | 546.41     | 3            | 19.84     |
| 1                        | 42             | 952.73     | 8            | 422.02    |
| Total                    | 65             | 2847.19    | 11           | 441.86    |

We have analyzed the number of rare orchid species protected in PAs according to their category (Table 4). The largest number of orchids (11) was registered on the territory of the regional nature reserve “Pustynskiy” (Table 5). There are seven species in the State Nature Biosphere Reserve...
"Kerzhensky" (Table 6). No more than four were found in other PAs. The average number of protected species in nature monuments is lower than in reserves. Only one rare orchid species was registered in the protected landscapes (established and projected) per each.

Table 4. The number of rare orchid species in the protected areas of different categories in the Nizhny Novgorod region

| Category and status of PAs                        | Protected areas with rare orchids | Number of rare orchid species per protected area |
|--------------------------------------------------|-----------------------------------|-------------------------------------------------|
|                                                  | number, ind. | area, km² | total limits | average area | Std. dev. |
| State nature biosphere reserve, established      | 1            | 575.17    | 7            | 7            | 7         | –        |
| Nature reserve (zakaznik), established           | 6            | 958.56    | 12           | 1–11         | 3.83      | 3.76     |
| Nature monument, established                      | 56           | 920.71    | 16           | 1–4          | 1.45      | 0.74     |
| Protected landscapes, established                 | 2            | 392.74    | 2            | 1            | 1         | –        |
| Established protected areas, total               | 65           | 2847.18   | 19           | 1–11         | 1.75      | 1.59     |
| Nature reserve (zakaznik), projected             | 2            | 190.82    | 2            | 1            | 1         | –        |
| Nature monument, projected                        | 8            | 51.69     | 7            | 1–2          | 1.38      | 0.52     |
| Protected landscapes, projected                   | 1            | 199.35    | 1            | 1            | 1         | –        |
| Projected protected areas, total                  | 11           | 441.86    | 8            | 1–2          | 1.27      | 0.47     |
| TOTAL                                            | 76           | 3289.04   | 19           | 1–11         | 1.68      | 1.49     |

Table 5. Records of rare orchid species in the territory of the regional natural reserve «Pustynsky»

| №  | Species                                      | Year       | First record | Last record |
|----|----------------------------------------------|------------|--------------|-------------|
| 1  | Cypripedium guttatum Sw.*                   | 1947       | 1980         |
| 2  | Cypripedium calceolus L.**                  | 1939       | 2019         |
| 3  | Cephalanthera rubra (L.) Righ.**             | 1950–e     | 2002         |
| 4  | Epipactis palustris (Mill.)*                 | 1988       | 2019         |
| 5  | Malaxis monophyllus (L.) Sw.*               | 1950–e     | 2019         |
| 6  | Liparis loeselii (L.) Righ.**               | ??         | ??           |
| 7  | Corallorhiza trifida Chatel.*               | 1947       | 2019         |
| 8  | Epipogium aphyllum (F.W. Schmidt) Sw.**      | ??         | ??           |
| 9  | Neottianthe cucullata (L.) Righ.**          | 1935       | 2019         |
| 10 | Dactylorhiza cruenta (O.F. Muell.) Soó*     | 2014       | 2014         |
| 11 | Dactylorhiza baltica (Klinge) Orlova**      | 2015       | 2015         |

The regional natural reserve "Pustynsky" is characterized with a high diversity of landscapes and ecosystems. Due to the complex geomorphological structure (high dunes, karst sinkholes with limestone outcrops), almost all types of plants communities (including different types of forests, meadows and wetlands) characteristic for central European Russia are represented in the reserve. The territory of the Pustynsky reserve has the richest history of biological research in the region. The Nizhny Novgorod geobotanical expedition worked here in 1926–1927, field educational practices of students of the Faculty of Biology of the Lobachevsky State University have been conducted here since 1934. The Pustynsky reserve is one of the most fully surveyed territories of the Nizhny Novgorod region. Nine orchid species growing were confirmed by herbarium samples here in different years (NNSU). Notes on Liparis loeselii and Epipogium aphyllum growing here seem doubtful [12]. Unfortunately regular studies of the abundance, population structure and ecology of rare orchids in the Pustynsky reserve have not been carried out. Now the reserve is an experimental site for the reintroduction of rare orchids propagated in
the Botanical Garden of the Lobachevsky State University [19, 20].

Inventory of the flora of vascular plants was carried out in the State Nature Biosphere Reserve "Kerzhensky". The reserve is located on an outwash plain with a relatively flat relief. There is a great diversity of forests and wetlands. Old growth forests occupy a small part of the area. Secondary pine-birch communities are represented in burnt-out areas of 1972 and 2010 that predominate on the territory of reserve. Ecosystems of continental and floodplain meadows are fragmented and insignificant in area. The study aimed on orchid inventory is rather comprehensive. The list of orchid species was increased over a quarter of a century: four species were found in the first years of the inventory of the flora of the reserve, three more species were discovered after 20 years of surveys of the territory. Information on the dates of the first records and the terms of monitoring the rare orchid populations is presented in Table 6. Monitoring of six of the seven rare orchid species growing in the reserve is carried out every year.

Table 6. The dates of the first records and terms of monitoring of the rare orchid populations in the territory of the State Nature Reserve "Kerzhensky".

| № | Species | Year of the first record | Year of monitoring on the permanent plots | Year of monitoring without setting the permanent plots |
|---|---------|-------------------------|------------------------------------------|-----------------------------------------------|
| 1 | Cypripedium guttatum Sw.* | 2018 | – | 2018–2019 |
| 2 | Cypripedium calceolus L.** | 2017 | – | 2017–2019 |
| 3 | Cephalanthera rubra (L.) Righ.** | 1994 | 2001–2019 | – |
| 4 | Listera cordata (L.) R. Br.* | 1994 | 2009–2019 | – |
| 5 | Hammarbya paludosa (L.) O. Kuntze* | 2014 | – | 2016–2019 |
| 6 | Corallorhiza trifida Chatel.* | 1996 | – | – |
| 7 | Neottianthe cucullata (L.) Righ.** | 1995 | 2001–2019 | – |

The State Natural Biosphere Reserve "Kerzhensky" is the only territory in the Nizhny Novgorod region where regular population studies of orchids are conducted [15]. The orchid numbers in the protected area calculated according the results of this monitoring are presented in Table 7. The largest populations of Cephalanthera rubra, Listera cordata, Neottianthe cucullata known in the Nizhny Novgorod region are protected in the Reserve.

Table 7. The rare orchid population sizes in the territory of the State Nature Reserve "Kerzhensky".

| № | Species | Areas, m² | Number of shoots |
|---|---------|-----------|------------------|
| | | | generative | vegetative |
| 1 | Cypripedium guttatum Sw.* | 6300 | 25–37 | 393–550 |
| 2 | Cypripedium calceolus L.** | 5850 | 36–45 | 37–122 |
| 3 | Cephalanthera rubra (L.) Righ.** | 5000 | 40–141 | 27–71 |
| 4 | Listera cordata (L.) R. Br.* | 200 000 | 4000–60 000 | 8000–68 000 |
| 5 | Hammarbya paludosa (L.) O. Kuntze* | 50 | 7–18 | 1–46 |
| 6 | Corallorhiza trifida Chatel.* | 150 | dozens | 0 |
| 7 | Neottianthe cucullata (L.) Righ.** | 10 000 000 | 8800–2 085 000 | 26 300–13 150 000 |

Almost complete inventory of the flora of vascular plants (including orchids) was carried out only in two PAs of the Nizhny Novgorod region: in the Pustynsky reserve and the Kerzhensky State Nature Reserve. In these territories, the largest number of rare orchid species has been noted; 3–4 rare orchid species have been identified in nine PAs. Five of them (the nature reserve "Ichalkovsky", the natural
monuments "Malinovaya Gryada", "Natural boundary Sluda", "Slopes of the valley of the upper reaches of the Ozerka river", "Steppe areas along the Suboy river") are distinguished by profound studies of the flora of vascular plants conducted here. Thus, an obvious important factor determining the number of rare orchid species a PA of the Nizhny Novgorod region is the completeness of the floristic research of the territory. The detailed flora inventory in the PAs seems to increase significantly the list of rare orchid species.

The number of rare orchid species in some PAs depends on the level of diversity of habitats. The largest number of species is noted in the regional nature reserve "Pustynsky", which is distinguished by the greatest landscape and ecosystem diversity. The average number of rare orchid species in reserves is significantly higher than in natural monuments. Most natural monuments were established to protect a specific natural object (forest area, swamp, lake, steppe fragment) with one or two types of habitats, whilst on the territories of most of the reserves forest, bog, meadow and aquatic ecosystems are combined. The number of rare orchid species has a weak positive correlation with the area of PA, the correlation coefficient is 0.46. We assume that the weakness of the correlation is associated with differences in the levels of floristic research in different PAs.

3. Conclusion
Of the 31 orchid species registered in the Nizhny Novgorod region, 22 species (71%) are listed in the regional Red Data Book, including 11 species listed in the Red Data Book of the Russian Federation. The most important limiting factor for orchids is the destruction of habitats in the process of nature management, the main method of conservation is the establishment of PAs.

A total of 19 rare orchid species are protected on 65 established and 11 projected PAs in the Nizhny Novgorod region. We consider 10 orchid species (52.6%) being well provided with territorial protection. It is advisable to increase the number of protected habitats by 10–20% for them. According to our data four species have the satisfactory level of protection and require an increase in the number of PAs by 25-50%. Another four orchid species are poorly provided with territorial protection. The threat of loss of these orchids in the region is significant. There is a need for a special search for new habitats and taking them under protection. One species found within the modern PA at the beginning of the 20th century is provided with nominal territorial protection only. Three species of orchids, which have probably disappeared in the Nizhny Novgorod region, are absent in the PAs. It is advisable to reintroduce them into natural habitats in the existing PAs.

The number of rare orchids in existing PAs ranges from one to eleven. No more than two orchid species are protected in 54 established PAs (83%), three or more – in eleven (17%). Projected PAs have 1–2 species each. The largest number of species – eleven is recorded for the territory of the regional nature reserve "Pustynsky". Seven species grow in the State Nature Biosphere Reserve "Kerzhensky". The largest known populations of Cephalanthera rubra, Listera cordata, Neottianthe cucullata are protected in the reserve. The average number of protected species in natural monuments is significantly lower than in reserves. Only rare orchid is recorded in the protected landscape.

The number of rare orchids a protected area depends on the level of floristic research, on the habitat diversity and has a weak positive correlation with the square of the PA. We predict a significant increase in lists of rare orchid species with conducting a detailed flora inventory.

The representative system of PAs developed in the region as a whole provides a satisfactory level of protection for rare orchid species. Nevertheless, the territorial protection of these plants needs to be improved: it is necessary to approve the projected PAs, as well as establish more PAs to conserve the habitats of species with an insufficient level of territorial protection. It is advisable to continue activities to search the habitats of rare orchid species both within the PAs and beyond.

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