Distribution and habitat features of rare orchid species (*Orchidaceae Juss.*) in the National Park "Nizhnyaya Kama"

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Abstract. The orchid species protected in the Republic of Tatarstan are sensitive to certain environmental conditions, therefore, when they are disturbed, they can disappear. As a result of studies carried out in 1998-2022 on the territory of the National Park "Nizhnyaya Kama" (Tatarstan, Russia), maps of the distribution of orchid species were built. It was revealed that only 7 species of orchids are found on the territory of the national park, which is 23% of the total number of orchids in Tatarstan, there are practically no meadow and wet-meadow orchids in the vast areas of meadowlands of the Nizhnekamsk reservoir. The background species is the unprotected *Epipactis helleborine*, which is noted in 61% of the descriptions with orchid species. The 4 species are noted in the conservation zone, 6 - in the specially protected zone, and 3 - in the recreational area. In dynamics, an increase in the distribution of *P. bifolia* and *P. cucullata* was noted. In 2019-2021, 2 habitats of *Goodyera repens* were found in the conservation zone. However, since 2010, the area of spruce-birch and pine-birch sphagnum communities has sharply decreased, where large populations of *P. bifolia* were noted. In recent years, *D. incarnata* has not been recorded since swampy meadows have practically disappeared. Forest species of orchids mainly grow in spruce-pine, coniferous-broad-leaved and coniferous-birch forests with a good moss cover.

1 Introduction

Currently, all studies related to the study of rare and endangered species, which include the Orchidaceae family, do not lose their significance and relevance, since biodiversity conservation remains a priority for ecology and nature protection [1, 2]. Family Orchidaceae Juss. belongs to one of the largest families among flowering plants, however, a large number of orchid species are represented by rare plants. According to T.I. Varlygina (2022) [3], the total number of orchids listed in the regional Red Books of the European part of Russia is 39, 18 of which are included in the Red Data Book of the Russian Federation (2008) [4]. In modern conditions of natural complex fragmentation, land use change, habitat disturbance,

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and anthropogenic impacts intensification, orchids are among the first to disappear [5, 6]. Due to climate change, there has been some decline in orchid populations or their migration to higher latitudes or mountains [7, 8, 9, 10]. For the effective protection of rare and endangered species of orchids, it is necessary to preserve and protect the entire ecosystem; therefore the organization of specially protected natural areas contributes to integrated protection [11]. The reasons for the rarity of Orchidaceae species are the specific features of their biology and ecology, such as poor seed germination, lack of endosperm in seeds, mycotrophy, dependence on fungi, and narrow ecological tolerance to abiotic and phytocoenotic factors [5]. About 30 species of orchids grow in the Republic of Tatarstan (RT), some of them – *Calypso bulbosa (L.) Oakes.*, *Cypripedium guttatum Sw.*, *C. macranthos Sw.*, *Epipogium aphyllum Sw.*, located on the border of their natural habitat, are considered to be practically extinct. Only *Epipactis helleborine (L.) Crantz* is often found in forests, parks, and recreational areas of large cities and is not included in the RT Red Data Book (2016) [12]. In the conditions of the intensively developed Tatarstan territory, it is important to assess the orchid distribution, search for new locations, and monitor orchid populations. In specially protected natural areas (SPNR) – the Volzhsko-Kamsky Nature Biosphere Reserve and the National Park "Nizhnyaya Kama", such studies are of particular importance. On the territory of the National Park "Nizhnyaya Kama", population studies of orchids have been carried out for more than twenty years, which made it possible to identify the orchid's species composition, the features of their distribution, and the condition of their habitats.

2 Materials and methods

The National Park "Nizhnyaya Kama" was organized in 1991. It is geographically located in the north-eastern part of the Republic of Tatarstan, on the right and left banks of the Kama River (Fig. 1). The national park included the forests of the Yelabuga and Beloussky forestries, as well as floodplain haylands classified as agricultural lands. The modern area of the national park is 26455 hectares.
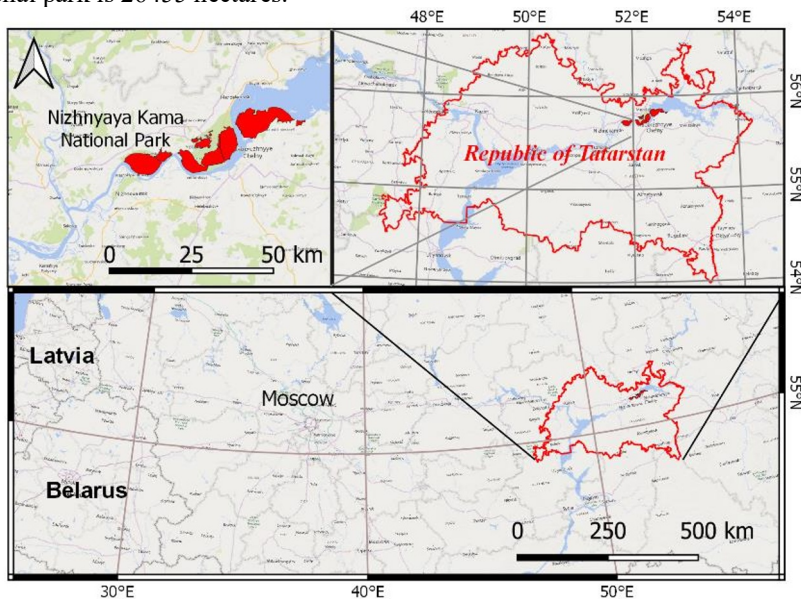
Fig 1. National Park "Nizhnyaya Kama" location.

The territory of the national park belongs to the Vyatka-Kama plain region of dark coniferous-broad-leaved forests and valley hygrophytic nemoral forests, to the landscape of the Yelabuga-Predkama erosion-dissected region of the subtaiga Cis-Ural broad-leaved-fir-spruce and pine-broad-leaved and pine grass forests [13, 14].

To assess the distribution of rare orchid species, personal route studies were used from 1998 to 2022, data from the herbarium of the Kazan Federal University and the Flora database [15]. Descriptions of plant communities of orchid habitats were carried out according to generally accepted geobotanical methods and ecological-coenotic analysis. Locations coordinates were also determined and the mapping of populations in phytocoenoses was carried out. Abundance, density, age structure, and base spectrum were determined in populations. The base spectrum was determined as the average value of the individuals relative number (M) of each age group (in %), based on the study of the age structure of several populations growing in different environmental conditions. For the basic spectrum, there is a certain zone within which population fluctuations are possible – it lies within the $M \pm 3\sigma$ limits (where σ is the standard deviation) [16]. According to morphological features, ontogenetic groups were determined: juvenile (j); immature (im); virginal (v); young generative (g1); average generative (g2). For this, published ontogenies of some orchid species were used [17, 18, 19]. The unit of population studies of tuberoid species is an individual, in rhizomatous species - a partial above-ground shoot.

3 Results

Geobotanical descriptions of the "Flora" database were collected by employees of the Kazan federal university and the National Park "Nizhnyaya Kama": Prokhorov V.E., Lukyanova Yu.A., Rogova T.V., Fardeeva M.B., Shaikhutdinova G.A., Shafigullina N.R., Eskina A.E., descriptions of orchids since 1939 were also used, which makes it possible to display the fairly complete orchids distribution pattern by the "Nizhnyaya Kama" territory. In total, there are more than 2000 geobotanical descriptions for the national park in the Flora database [15], 265 descriptions associated with orchid finds were identified, and 1-3 species of orchids could be noted in the same description. According to the results of research, only 7 species of orchids were identified at the national park territory, which is 23% of the total number of Tatarstan orchids, and only 13.2% of geobotanical descriptions with orchid species in phytocoenoses.

The largest number of descriptions – 163 – is given for *Epipactis helleborine*, which is indicated in 49 quarters of the national park, the species is common for Tatarstan. Among the rare species in terms of the number of descriptions, the leaders are *Platanthera bifolia* – 41; *Ponerorchis cuculata* (L.) X.H. Jin, Schult. & W.T. Jin (or *Neottianthe cucullata*) – 48 descriptions.

Based on the distribution analysis, it was revealed that out of 265 geobotanical descriptions, 61.5% are *Epipactis helleborine* finds, 18.1% – *Ponerorchis cuculata*, 15.5% – *Platanthera bifolia*, and 13.5% – *Neottia nidus-avis*. Quite rare – *Dactylorhiza incarnata*, *Cephalanthera rubra* – 1.5% (3-4 findings in the national park), and *Goodyera repens* – only 2 habitats (0.75%) (Table 1).

A differentiated regime of special protection has been established in the national park, taking into account natural and historical-cultural features, the scientific and educational significance of individual sites, differences in the degree of anthropogenic factors influence, and accessibility for visitors. By this, the following functional zones have been identified – conservation, specially protected, recreational, and economical. Since orchids are found in forest quarters confined to different functional zones, an analysis was made of the species' occurrence by functional zones.

Table 1. Characteristics of rare orchid species of the National Park "Nizhnyaya Kama".

Species	Rarity (RT Red Data Book)	Number, qty ∕ area; Base population spectrum, %: j: im: v: g	Habitat (forest quarter)
Rhizomatous species			
Cephalanthera rubra (L.) Rich)	"2" – species that reduce number	5-20 ∕ 100 m²; 0: 3: 68: 29	Linden forest with spruce, fir, and pine (48); spruce forest with pine (98); dry pine forests (43; 140).
Goodyera repens (L.) R.Br.	"2" – species that reduce number	10-25 ∕ 25 m²; 0: 22: 48: 30	Pine forest with spruce and fir (15); pine forest with spruce and linden (43).
Neottia nidus-avis (L.) Rich.	"3" – rare species	5-50 ∕ 100 m²; 0: 0: 2: 98	Linden forests (45), compound linden forests with spruce and fir (25); birch forests with aspen (72), birch forests with linden (46); pine forests with birch (113).
Epipactis helleborine (L.) Crantz	common species	20-60 ∕ 100 m² 2: 23: 47: 28	In all types of deciduous, mixed, coniferous forests, along edges and forest clearings.
Tuberoid species			
Platanthera bifolia (L.) Rich.	"3" – rare species	20-50 ∕ 100 m² 28: 25: 23: 26	Reed, bracken pine forests, mossy birch forests with spruce, sphagnum-mossy poplar forests with birch and pine; sphagnum birch forests with pine, complex linden forests with spruce and pine, forest clearings and edges.
Ponerorchis cuculata (L.) X.H. Jin, Schult. & W.T. Jin.	"2" – species that reduce number	3-65 ∕ 100 m²; 15: 22: 35: 28	Bracken pine forests, lingonberry-mossy pine forests with spruce; blueberry-cowberry-mossy spruce forests with pine; lichen-mossy pine forests, bramble-mossy complex pine forests with spruce and linden
Dactylorhiza incarnate (L.) Soó	"3" – rare species	5-40 ∕ 100 m²; 5: 15: 40: 40	Waterlogged willows, waterlogged meadows (102; 106).

On the territory of the National Park "Nizhnyaya Kama", 93 orchid habitats are noted in the conservation area (35.1%). *E. helleborine* occurs in 56% of phytocoenosis confined to the conservation area. Rare species of orchids are less common: *Ponerorchis cuculata* – in 22% of phytocoenoses, *Platanthera bifolia* – 12%, *Neottia nidus-avis* – 6.8%, *Cephalanthera rubr*a – 1.1%, *Goodyera repens* – 2.1%. In the specially protected zone, there are 42 geobotanical descriptions (16%), 63.9% contain *E. helleborine*, 13.9% – *P. cuculata*, 11.2% – *P. bifoli*a, 8.3% – *Neottia nidus-avis*. Only 2.7% of the specially protected zone habitats contain *C. rubra. D. incarnata*. It was also revealed that there are 132 descriptions with orchids (49%) in the recreational zone: D. incarnata was noted in 1.5% of habitats, C. rubra – 0.75%, *P. bifolia* – *16.4%*, *P. cuculata* – 14.5%, *Neottia nidus-avis* – 2.2%, *E. helleborine* – 64.18%. *Goodyera repens* are not observed in this area. Only one description of a phytocoenosis with *Neottia nidus-avis* was found for the economic zone, the rest are noted in areas adjacent to the national park.

As can be seen from the orchids distribution maps compiled based on a geobotanical descriptions analysis, the largest number of orchid finds belongs to conservation and specially protected areas within the Bolshoy Bor and Maly Bor (Yelabuzhskoye forestry) (Fig. 2). Some rare species – *P. bifolia*, *P. cuculata*, *N. nidus-avis*, and *Cephalanthera rubra* (few) are singly observed in the conservation and specially protected areas of the Borovetsky forest and the Kzyl-Tau stow (Chelninskoye forestry) (Fig. 3).
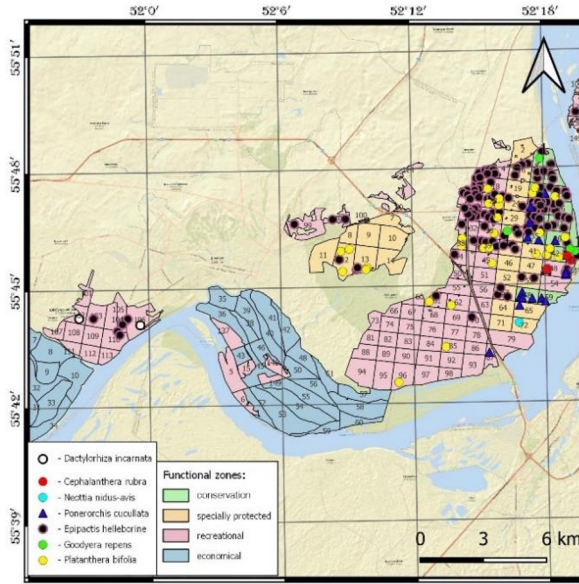
Fig. 1. Distribution of orchids on the territory of the National Park "Nizhnyaya Kama" (Yelabuzhsky district RT)
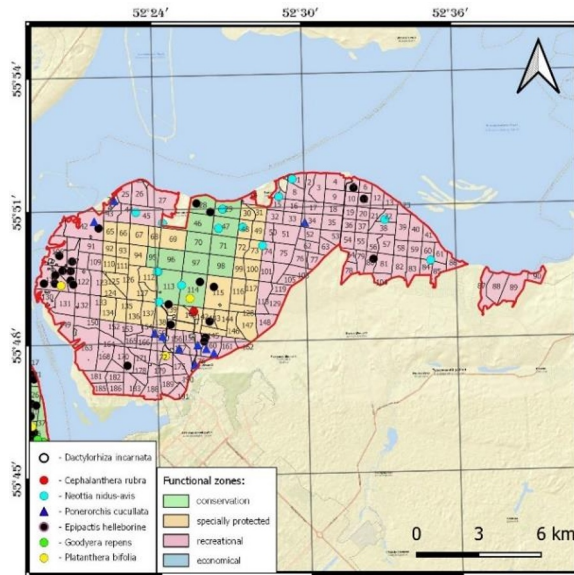
Fig 3. Distribution of orchids on the territory of the National Park "Nizhnyaya Kama" (Tukaevsky district RT)

4 Discussion

By the nature of their behavior in plant communities, most orchids are phytocoenotic and ecotopic patients, stenovalent and stenobiont species that require specific ecological and phytocoenotic conditions [20, 21]. The distribution of nutrients between the processes of reproduction and vegetative growth with biomass accumulation prevails in rhizomatous species, which can be attributed to k-strategists. For r-strategists, tuberoid orchids, most of the nutrients are spent on reproduction processes [5, 22, 23, 24]. As most orchidologists note, the reproduction strategies are different for orchids of non-identical life forms: for tuberoid species (*P. bifolia*, *P. cucullata*, *D. incarnata*), seed propagation predominates, in rhizomatous species (*C. rubra*, *E. helleborine*, *G. repens*, *N. nidus-avis*), as a rule, the vegetative type predominates [5, 25]. Tuberoid orchids are characterised by the development of a large number of seeds with a well-formed embryo; on the contrary, large seeds with small embryos are formed in rhizomatous orchids [5].

Orchid habitats in the national park studied based on geobotanical descriptions and species lists of phytocenoses, were analyzed according to ecological-coenotic characteristics. This made it possible to understand which communities orchids are mainly associated with and to identify the most suitable habitats for them. The Jaccard community coefficient, calculated according to the species lists in which orchids are noted, varies from 0.17 to 0.61, the highest values are typical for coniferous forests – from 0.4 to 0.61.

Among rhizomatous orchids, *Neottia nidus-avis* is quite widespread, most often in linden and complex pine forests, forming small clusters of 5-20 individuals. On the contrary, *C. rubra* is extremely rare in the national park, which is due to its reproductive strategy – it does not form nectar, and insects poorly visit the flowers. In general, throughout the territory of Tatarstan, there is a decrease in the number of locations and populations of *C. rubra*, located on the eastern border of the distribution area (Red Book of the Republic of Tatarstan, 2016). A similar trend is also characteristic of the Bashkir Reserve [22]. On the territory of the National Park "Nizhnyaya Kama", *C. rubra* is found in the shaded coniferous-broad-leaved forests of the Bolshoy Bor – linden forests with spruce or pine forests with spruce and linden. On the territory of the Borovets forest, *C. rubra* grows in disturbed horsetail-reed grass light pine forests, it was sporadically noted in the reserved quarters of the Kzyl-Tau stow.

Platanthera bifolia has the largest range of ecological valence to light and humidity factors in comparison with other species, which determines its wide distribution in the National Park [24, 26, 27]. It is also quite resistant to recreational stress [17], so the species is widely distributed in dry pine forests and forest glades of the recreational zone in insignificant loci of 5-10 individuals. The species is found in light pine forests and pine forests with birch, where pine forest and boreal-nemoral forbs predominate, less often forest-meadow and forest-steppe species. A moss cover develops in the habitats, where *Pleurozium schreberi* (Brid.) Mitt, *Dicranum polysetum* Sw, *Dicranum scoparium* Hedw grow [28]. Often *P. bifolia* is found in moist areas of sphagnum light birch and sphagnum-hypnum pine forests with birch, less often in sphagnum shaded birch forests with spruce together with *Pyrola media* Sw, *P. rotundifolia* L., *P. chlorantha* Sw. Unfortunately, after the drought in 2010, wetlands began to dry out and become overgrown with trees and shrubs, which led to a decrease in the abundance of *P. bifolia* in such biotopes.

Bryophilic orchids – *P. cucullata* and *G. repens*, are confined to mossy areas and are located in Tatarstan on the southern border of distribution, therefore they are rare. *G. repens* often occupies shaded and damp areas under the spruce canopy in green moss pine forests with spruce. On the contrary, *P. cucullata* can also be found in lighter and dryish areas of pine forests [29], where the proportion of meadow and forest-meadow forbs increases to 15% and 18%, and weed species to 5-6%. In the national park, species are often found in lichen and lingonberry-mossy pine forests with birch, bilberry-lingonberry-mossy pine forests with

spruce and birch, and complex bramble-blueberry-mossy pine forests with spruce and linden. The communities species composition is represented by boreal chamephytes – *Vaccinium myrtillus* L., *V. vitis-idae*a L., *Rubus saxatilis* L., *Orthilia secunda* (L.) House, boreal-nemoral perennial grasses – *Calamagrostis arundinacea* (L.) Roth, *Carex digitata* L., *Luzula pilosa* (L.) Willd. and pine forests – *Pulsatilla patens* (L.) Mill., less often *P. media*, *P. rotundifolia*, *P. chlorantha*, *Chimaphila umbellata*, (L.) Holub. Mosses in such communities form a dense cover of *P. schreberi*, *D. polysetum*, *D. scoparium*, and rarely – *Rhodobryum roseum* (Hedw.) Limpr., *Hylocomium splendens* (Hedw.) Bruch et al. – typical species of spruce forests [28]. In general, the characteristics of coniferous phytocenoses, in which bryophyllic orchid species are found, are similar to those in the Volga-Kama and Kerzhensky reserves [23].

5 Conclusion

Rare orchid species, being indicators of the uniqueness of natural habitats, confirm the preservation of these phytocenoses on the National Park "Nizhnyaya Kama" territory. In dynamics over the past two decades, there has been an expansion of biotopes occupied by *P. cucullata*, which in 2005-2006 was confined only to the green moss spruce and pine communities of the conservation zone of the national park. In recent years (2018-2022), *P. cucullata* has been widely distributed in lingonberry-bramble and lingonberry-blueberry pure pine forests, dry lingonberry-strawberry pine forests with a slight moss cover, where the number varies from 20 to 50 individuals. A similar trend is typical for *P. bifolia*, usually dispersed by 5-10 individuals in forb, bracken, and reed pine forests. After the 2010 drought, the biotopes of sphagnum-hypnum moist birch forests with spruce and sphagnum pine forests with birch (*Betula pubescens* Ehrh.) almost disappeared, where population loci of *P. bifolia* had a high number - up to 50–60 individuals. Such areas along the edges of the swamps are intensively overgrown with tall grass from sedge and gramen, and P. bifolia is found here singly. The swampy meadows and willow forests along the Tanaevsky forest edges have practically disappeared, where in 2005-2006 numerous, up to 70-80 individuals, of the *D. incarnata* population were found. In recent years, the species has not been found in the descriptions, and the swampy areas are overgrown with birch forests (*Betula pendula* Roth.). Among the rare rhizomatous orchids, the discovery in 2019-2021 of small population loci habitats of *G. repens* is very important.

It should be noted that the species composition of rare orchids is insignificant for such a vast territory; there are practically no meadow and wet meadow orchids in the floodplain-meadow lands of the Nizhnekamsk reservoir. In general, the territory of the Yelabuga cluster of the National Park "Nizhnyaya Kama" is better studied than the plant communities of the Borovets forest and meadowlands, which requires further research.

6 Acknowledgements

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