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Current State of Flora of the Lower Kama National Park Evidence from the Borovetsky Forest (Russia).

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ABSTRACT

The Borovetsky forest (9344 ha) is one of the largest woodlands of the Lower Kama National Park located on the North-East of the Republic of Tatarstan within the East part of the Russian Plain. The article presents data on the inventory and taxonomic diversity, as well as the results of areographic, biomorphologic, eco-coenotic analysis and evaluation of the adventive fraction of flora of vascular plants of Borovetsky forest. Flora of the Borovetsky forest is represented by 489 species, which are dominated by those with broad geographic ranges. The endemics of the Volga-Ural region are of particular interest. This concerns *Pilosella trichocymosa* (Zahn.) Schljak. and *Cicerbita uralensis* (Rouy) Beauv - having relatively small geographic ranges. With regard to phytocoenotic confinedness, the plants of the investigated territory belong to 23 eco-coenotic groups. Biocenosis of the Borovetsky forest include 25 species of vascular plants listed in the Red Data Book of the Republic of Tatarstan, and 2 species – listed in the Red Data Book of the Russian Federation. The obtained results can be used in the monitoring of the Borovetsky forest phytocenosis.

Keywords: flora of vascular plants, species diversity, typological diversity, adventive flora, Borovetsky forest, Lower Kama National Park, specially protected natural areas.

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INTRODUCTION

The loss of biodiversity on the planet is one of the pressing environmental problems of our age. In the Convention on Biological Diversity [1], biodiversity is regarded as a global stabilizing factor that determines sustainable functioning of territorial ecosystems and the biosphere as a whole. In this regard, monitoring studies of biological systems become especially relevant [2, 3].

To preserve the diversity of natural biological systems at the level ensuring their sustainable existence and use, the National Strategy of Biodiversity Conservation of Russia [4] was developed in 2002. It is implemented by ministries and committees on ecology, research institutes and, in the first place, specially protected natural reservations (reserves, national parks, and wildlife sanctuaries) [5].

Surveillance study of biosystems organization conducted at different levels are actively carried out both in undisturbed or relatively undisturbed areas of the biosphere [6, 7] and the territories exposed to man-made impact [8, 9]. In recent time, the issues of the anthropogenic transformation of the natural environment, particularly vegetation, acquire a special urgency since this reduces ecosystem resilience to various kinds of external influences [5].

Study of the current status of specially protected natural reservations allows organizing and adjusting work for the conservation of the biological diversity of plant resources of Russia.

METHODS

The source material for the current work were the results of field studies conducted in the territory of the Borovetsky forest during growing seasons of 1997-2015 with the use of route-reconnaissance method in combination with the sample plot method [10]. A compendium of the flora of vascular plants served a material for current analysis [11]. In our work we used traditional methods of taxonomic, biomorphological, areographic, and eco-coenotic analysis of the flora.

DISCUSSION AND RESULTS.

In accordance with physical-geographical zoning, Lower Kama National Park (hereinafter «Lower Kama» NP) is located at the junction of the Vyatka-Kama province of Forest region and the province of the High trans-Volga region of the Forest-steppe region within the East part of the Russian Plain [12]. According to botanical-geographical zoning, the «Lower Kama» NP is located in the Elabuga-Fore-Kama erosion dissected region of sub-taiga Transural broadleaf deciduous-fir-spruce nemoral herbal, pine-broadleaf deciduous, pine herbal forests with fragments of marshy floodplain forests and marshes of the Vyatka-Kama region, dark coniferous-broadleaf deciduous, lowland hygrophytic nemoral forests and marshes [13].

Typologically, naturally conditioned forests of the «Lower Kama» NP are coniferous-broadleaf deciduous forests (pine- broadleaf deciduous and spruce-broadleaf deciduous), coniferous forests (pine, pine-spruce with fir), and, to a lesser extent, broadleaf deciduous forests. The second growth timber is represented by birch forests, aspen forests, and black poplar grove.

Natural planted forest and forestation collectively account for 63.6% of the National Park area and are represented by four cluster areas, including the Borovetsky forest. Forestlands of the National Park differ in terms of areal characteristics, remoteness from settlements, the degree of economic exploitation, accessibility to visitors, as well as various functional purposes. Natural forests continue to face intense economic and recreational impacts, being located in close proximity to large industrial-territorial complex of the Lower Kama region. In this connection, they differ in the degree of transformation due to past and present anthropogenic influence.

The Borovetsky forest with a total area of 9344 hectares, is located in 2 km North-East of the city of Naberezhnye Chelny. The forestland is located on the left low-lying shore of the Nizhnekamsk reservoir occupying the watershed, the upper, middle, lower slopes and terraces of the Kama River. Functionally, the forestland is divided into reserved, specially protected, and recreation zones, as well as the economic zone. The Borovetsky forest is characterized by a mosaic structure of biotopes and diversity of forest site type. The most

part of the forest is represented by shrub-moss pine woods, sorrel pine woods, aspen forests (broad herbal and nemoral herbal), and birch (mixed herbs). A characteristic feature of the Borovetsky forest is the availability of the pine forests of spruce and fir, oak and linden in the forest stand and undergrowth; the undergrowth is characterized by large amount of Norway maple, viburnum and rowan. Closer to the Kama River, pine forests are replaced by dark coniferous forest areas with spruce and fir. The district of "Kyzyl-Tau" fir woods (3.0 hectares) is unique in terms of scientific interest and forestry, because it is the only place in the Middle Volga region, where spruce and fir "move" across the Kama River and form plantations in the immediate neighborhood with the forest-steppe.

In addition to forest plantations, the Borovetsky forest is characterized by the presence of marshes (8.0 ha), springs and lakes (6.0 ha). Meadowlands cover an area of 51 hectares. At that, over 200 hectares are occupied by the roads, cleared strips, and linear facilities of market participants (underground conduits, gas and oil pipelines, and electric power transmission lines).

Flora of the Borovetsky forest is represented by 489 species of vascular plants belonging to 290 genera, 83 families, accounting for 63% of total flora of the «Lower Kama» NP [11] and 30% of the flora of the Republic of Tatarstan [13]. Rich species composition is due to the diversity of ecotypes and habitats (forest, forest-edge, meadow, coastal, lake, floodplain, wetland) represented in the forest. Among the families, leading in number of species, we can distinguish *Asteraceae* Dumort., *Poaceae* Barnhart, *Rosaceae* Juss., *Fabaceae* Lindl. etc. (Table 1). Spectrum of the leading families is almost completely similar to a spectrum of the flora of the «Lower Kama» NP and the Republic of Tatarstan in general.

Table 1: Spectrum of the leading families of the flora of the Borovetsky forest

#	Rank	Family	Number of species	Number of genera	Proportion, %
1	1	*Asteraceae* Dumort.	68	39	13.9
2	2	*Poaceae* Barnhart	39	24	8.0
3	3	*Rosaceae* Juss.	36	16	7.4
4	3	*Fabaceae* Lindl.	36	12	7.4
5	4	*Lamiaceae* Lindl.	20	14	4.1
6	5	*Caryophyllaceae* Juss.	19	15	3.9
7	6	*Scrophulariaceae* Juss.	16	7	3.3
8	7	*Apiaceae* Lindl.	15	14	3.1
9	7	*Brassicaceae* Burnett	15	13	3.1
10	8	*Ranunculaceae* Juss.	14	8	2.9
11	8	*Violaceae* Batsch	14	1	2.9

Geographical structure of the flora of the investigated area is represented by 45 habitat types. Species with wide habitats such as *Holarctic* and *Eurasian* ones are predominant; they include more than half of the whole flora (63.6%). At that, among the latter there are 136 species with Euro-Western Asian type of habitat (27.8%). This ratio of geographical features of the flora is typical for the whole territory of the Republic of Tatarstan [13]. Simultaneously, the types with small habitats were identified as well: In North America (*Xanthium albinum* (Widd.) H. Scholz (*X. strumarium* auct.), *Lepidotheca suaveolens* (Pursch) Nutt. (*Chamomilla suaveolens* (Pursh) Buchenau), *Conyza canadensis* (L.) Cronq., *Lupinus polyphyllus* Lindl., *Elodea canadensis* Michx., *Phacelia tanacetifolia* Benth., *Acer negundo* L., *Oenothera biennis* L., *Amelanchier spicata* (Lam.) C. Koch, *Amaranthus albus* L., *Amaranthus blitoides* S. Watson, *Amaranthus retroflexus* L.), in Mediterranean (*Vicia villosa* Roth., *Onopordum acanthium* L., *Eragrostis pilosa* (L.) Beauv., *Lolium perenne* L.), in south-west Asia (Senecio vernalis Waldst. & Kit., *Medicago sativa* L.), in Central Asia (*Impatiens parviflora* DC., *Salsola collina* Pall.). The endemics of the Volga-Ural region *Pilosella trichocymosa* (Zahn.) Schljak. and

Cicerbita uralensis (Rouy) Beauv., having relatively small habitats, are of particular interest. Both species in the National Park area are rare and minimally active.

Analysis of plant life forms by K. Raunkier [14] showed that the spectrum of life forms of the Borovetsky forest plants is in general typical of the temperate zone – more than 50% of all species are the hemicryptophyte (254 species). Second place is occupied by the therophytes – 16.8%, and third place belongs to cryptophytes (geophytes – 10.6%, helophytes – 2.9%, hydrophytes – 1.8%). Phanerophytes are represented by 44 species

(nanophanerophytes – 4.3%, mesophanerophytes – 3.3%, microphanerophytes – 1.4%), and chamaephytes are represented by 34 species (of 7.0%). In general, the range of life forms is characteristic of the moderately cold forest zone. A large percentage of hemicryptophytes in the flora of the Borovetsky forest is indicative of the process of the so-called anthropogenic "steppification" of cenosis [13].

Predominating perennials – 76.3% (373 species) – in the flora of the Borovetsky forest indicate the formation of self-regulating sustainable plant communities.

In terms of phytocoenotic confinedness, the plants of the investigated territory are divided into 23 ecological-coenotic groups (Table 2).

Table 2: Ecological-coenotic spectrum of the Borovetsky forest flora

Phytocenotic confinedness	Number of species	Proportion, %	Ecological-coenotic groups	Proportion, %
Forest group	114	23.3	boreal	5.5
			coniferous	3.7
			nemoral	9.2
			boreal-nemoral	4.9
Marsh group	63	12.9	upland-marsh	0.8
			lowland- marsh	2.7
			wetland	1.6
			hygrophytic	2.7
			water	2.9
			riverside	2.2
Meadow group	165	33.7	meadow	14.3
			forest-meadow	9.6
			wet-meadow	5.9
			steppificated meadow	2.9
			dry-meadow	0.6
			saliferous-meadow	0.4
Steppe group	17	3.5	medow-steppe	2.3
			steppe	0.4
			forest-steppe	0.6
			stony-steppe	0.2
Weed group	130	26.6	ruderal	23.7
			cultivated	2.7
			segetial	0.2

The proportion of forest species is 23.3% (114 species), including nemoral species associated with broadleaf deciduous forests – 45 species (9.2%), boreal forests - 27 species (5.5 %), and coniferous forests – 18 types (of 3.7%). Besides, 63 species (12.9 %) are associated with communities of wetland habitats; among them 14 (2.9%) are pure aquatic; 13 species (2.7%) are associated with lowland marshes, and 11 species (2.2%) represent riverside habitats. The group of meadow species accounts for 33.7% of the flora. Plants growing in the meadows of various types account for 70 species (14.3%), growing in forest-grassland (forest edge) account for 47 species (9.6%), and growing in wet meadows – 29 species (5.9%). A separate group consists of weed plant species associated with disturbed habitats. Their proportion accounts in general for 130 species (26.6%), among which the leading position belongs to the ruderal (garbage) types – 116 (23.7%), while cultivated types account for 13 spices (2.7%).

The Borovetsky forest is a habitat of 25 species of plants listed in the Red Data Book of the Republic of Tatarstan [15]. Decreasing species, which are at risk of further degradation and may vanish within a short period, include *Crepis paludosa* (L.) Moench, *Omphalodes scorpioides* (Haenke) Schrank, *Succisa pratensis* Moench, *Moneses uniflora* (L.) A. Gray (*Pyrola uniflora* L.), *Nymphaea candida* J. Presl, *Actaea erythrocarpa* Fisch., *Galium triflorum* Michx., *Potentilla erecta* (L.) Raeusch., *Dryopteris expansa* (C. Presl) Fraser-Jenk. & Jermy s. l., *Goodyera repens* (L.) R. Br., *Neottianthe cucullata* (L.) Schlech., and *Cephalanthera rubra* (L.) Rich.

The following plants were identified among those belonging to the category of rare species, vulnerable due to low plant population and low prevalence, often located on the border of the habitat: *Arctium*

nemorosum Lej., *Vicia cassubica* L., *Pyrola chlorantha* Sw., *Pyrola minor* L., *Linnaea borealis* L., *Anemonoides altaica* (Fisch. Ex C. A. Mey.) Holub, *Circaea alpine* L., *Lycopodium annotinum* L., *Lycopodium clavatum* L., *Diphasiastrum complanatum* (L.) Holub, *Selinum carvifolia* (L.) L., *Daphne mezereum* L. (*Mezereum officinarum* C. A. Mey.), and *Viola selkirkii* Pursh ex Goldie.

Among the identified plants, 2 species of vascular plants are listed in the Red Data Book of the Russian Federation [16]. These are *Neottianthe cucullata* (L.) Schlech. and *Cephalanthera rubra* (L.) Rich.

The Borovetsky forest, which until the creation of specially protected natural reservations was under the jurisdiction of the Chelninsky forestry, is characterized by a composition diversity of growing stock that is caused by past human activities. In today's conditions, the anthropogenic transformation of forest plantations of the Chelninsky district forestry is due to the operation and maintenance of linear facilities such as power transmission lines, water pipelines, oil and gas pipelines, and highway transportation facilities. Permanent and temporary land transfer for the technical maintenance of linear facilities in "edge-wood" areas results in the fragmentation of plant communities and deterioration of the vegetation cover that is caused by changes in the hydrothermal regime. The lack of leaf canopy, as well as periodic soil disturbance leads to the vegetation xerophytization within these facilities and on adjacent forest areas.

Increasing anthropogenic impact on forest communities accelerates transformation and synantropization of plant communities of the Borovetsky forest that is manifested in the increase of the proportion of synanthropes, both indigenous and adventive.

The structure of the adventive flora of the Borovetsky forest is represented by 51 species belonging to 19 families of the Magnoliophyta plant division. This amount is 10.4% of the total number of species growing in the Borovetsky forest (flora adventization index is equal to 0.1). A significant proportion of the adventive fraction in the flora indicates a high anthropogenic disturbance of the vegetation cover due to the economic activities within limited areas and high recreational load on forestland in general.

The relative location of the adventive component families, leading in number of species, is somewhat different from the flora family spectrum of the forestland as a whole. Considering the change in the families positions, it should be noted that the families of *Asteraceae* Dumort. (15.7% of the total number of adventive flora species) and *Poaceae* Bamhart. (13.7%) hold their positions. The *Brassicaceae* Burnett family (11.8%) is characterized by a higher proportion in terms of involvement of its plants, having exchanged its position with the families *of Rosaceae* Juss. (7.8%), and *Fabaceae* Lindl. (7.8%).

Among life forms (according to K. Raunkier), the most representative are therophytes (60.8% of the total number of adventive flora species), hemicryptophytes (21.6%), and phanerophytes (11.8% per). This distribution corresponds to the climatic conditions of the region.

The spectrum of adventive species life forms (according to I.G. Serebryakov system) is dominated by annual grasses (60.8% from the total number of adventive flora species). Besides, it is represented by trees and shrubs, taproot plant, short-root, loose-bunch, adventitious root plants and soboliferous herbaceous polycarpics.

Among the ecological-coenotic groups, leading position is occupied by ruderal plants, which amount to 68.6% of the total number of adventive species. Second place is occupied by a group of cultivated plants (23.5%). Riverside ecological-coenotic group includes 3 species of adventive plants (5.9%), and water group consists of 1 species (2.0%).

One of the criteria for the classification of stranger species is an immigration method (Table 3). Anthropochores (xerophytes) make up 76.5% of the total number of identified adventive plant species. Other plant species were introduced by human and then run wild (Ergaziofity).

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Table 3: The structure of the adventive flora of the Borovetsky forest

Group	Number of species	Proportion, %	Proportion of flora, %
By way of immigration			
Xerophytes	39	76.5	8.0
Ergaziofity	12	23.5	2.5
By the time of immigration			
Archeophytes	25	49.0	5.1
Kenophites	26	51.0	5.3
By the degree of naturalization			
Ephemerophites	4	7.8	0.8
Kolonophytes	4	7.8	0.8
Epiphytes	36	70.7	7.4
Anthropochores	7	13.7	1.4

Groups of rcheophytes and kenophytes are proportional to each other in terms of immigration time that indicates the equivalence in the adventive flora of species introduced to the flora of the Borovetsky forest over the last few centuries and during earlier periods.

In terms of the naturalization degree of adventive flora, the Borovetsky forest is dominated by species naturalized and spreading in the secondary disturbed (epiphytes) and natural (anthropochores) biotopes. A minor part of the adventive plants has naturalized at the sites of immigration or running wild, though do not give self-seeding (ephemerophites) or are not spread (kolonophytes). This is due to the inadaptability of the majority of adventive species to environmental conditions of the new territory. Thus, the correlation of adventive species groups in terms of the degree of their naturalization shows that the majority of adventive plants have successfully naturalized in their new territory.

CONCLUSION

Flora of the Borovetsky forest is represented by 489 species of vascular plants belonging to 290 genera, 83 families. The leading families are *Asteraceae* Dumort., *Poaceae* Barnhart, *Rosaceae* Juss., *Fabaceae* Lindl., and *Lamiaceae* Lindl. In the geographical structure of the flora more than 60% are species with broad habitats, Holarctic and Eurasian. Besides, the growth of the two endemics of the Volga-Ural region was noted as well. Spectrum of plant life forms of the Borovetsky forest in general is typical for moderately cold zone. A large proportion of hemicryptophytes in the flora points to the process of the so-called anthropogenic "steppification" of cenosis. The flora is dominated by plants of the weed-meadow group (60.3 %), the proportion of forest group is 23.3%, while the proportion of wetland species is 12.9%.

The Borovetsky forest is a habitat of 25 species of plants listed in the Red Data Book of the Republic of Tatarstan, and 2 species listed in the Red Data Book of the Russian Federation.

Anthropogenic disturbance of the vegetation cover of the forestland resulted in a high proportion of adventive species in the flora (10.4%) with a predominance of annual grasses (over 60%). The leading position in the adventive fraction is occupied by ruderal (68.6%) and cultivated species (23.5%). The ratio of adventive plants groups in terms of the degree of naturalization shows that the majority of adventive plants have successfully adopted in their new territory.

The study of the current flora condition is an important element in the research allowing assessment of the current status of vegetation complexes and selection of the methods to optimize regulation of specially protected natural area. As shown by the research outcomes, the Borovetsky forest is experiencing strong anthropogenic impact, caused by human activities and recreation, which provide the primary impact on the composition of the herb layer flora. At the same time, the Borovetsky forest remains valuable woodland from the standpoint of conservation of forest types, species diversity, habitats of rare species, and the diversity of ecotopes. The obtained results can be used to monitor forest phytocenosis of the Borovetsky forest and the Lower Kama National Park in general.

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