Floristic diversity of the state natural sanctuary "Bushkovskiy forest" (the Kirov region, Russia)

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Abstract. The paper presents the results of the complex analysis of the flora structure of the state natural sanctuary "Bushkovskiy forest". The research had been made on the area of 9274.8 ha within the period of 2004–2023. Route recognition method was used together with geobotanical description of certain phytocoenoses on temporary sample plots made according to traditional methods. There vascular plant flora contains 270 taxon from 196 genera, 73 families, four classes and three divisio. On the territory of the sanctuary a rare species grows which is registered in the Red Data Book of the Russian Federation – *Epipogium aphyllum* Sw. The plants are distributed into 13 ecological-coenotic groups. As for the number of species, the floodplain meadow (21.9%), nemoral (17.0%), and boreal (12.6%) groups prevail. Among biological types hemicryptophythes prevail (49.6%); as for the biomorphological structure, dry ground grass polycarpics prevail (65.2%), and, among the latter, short rhizomatous (18.1%) and long rhizomatous (17.4%) grasses prevail. Plants of six hemerobia stages are represented in the flora, for a total, anthropophobic species (species of the a-o-m interval) account for 69.0%. Correlation of hemerobia stages, as well as a small share of adventitious species (3.0%), shows that the natural ecosystem of the sanctuary suffers from a certain anthropogenic load.

1 Introduction

Accoding to the Convention adopted at the UNO conference in 1992, presering biological diversity is the world general assignment [1]. The main condition of it consists in peserving *in-situ* – preserving ecosystems and natarl habitats of the species, support and rehabilitation of viable populations of species in their natral habitats. The appropriate way of presering biodiversity *in-situ* is setting up specially protected natural areas (SPNA). In researching such areas special attention is paid to phytodiversity [2-3], which determines diversity of biotopes and phytocoenoses, the composition of fauna complex.

In Russia there are different categories of SPNA, such as state nature reserves, national parks, natural parks, state natural sanctuaries, natural monuments, dendrological paks, and botanic gardens [4]. In the Kirov region there is a net of preserved territories

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consisting of 152 units, in total they accont for 3.12% of the area of the region [5]. One of the unique SPNA with the original floral coplex is the state natural sanctuary (SNS) of regional significance "Bushkovskiy forest" (the Urzhum district). In this area broadleaved fir-spruce forests are spread, with predominant or numerous share of broadleaved tree species, with rich underbush and broadleaved grasses prevailing in the subshrub layer [6]. Researching poly-dominant multispecies forests with cohabitating species of dark coniferous (*Picea* A. Dietr. and *Abies sibirica* Ledeb.) and broadleaved (*Acer platanoides* L., *Tilia cordata* Mill., *Quercus robur* L., *Ulmus glabra* Huds. et al.) trees is important for maintaining ecosystematic functions of phytocoenoses and peserving α- and β-diversity. Studies of local flora allows getting data; and as compared with the data on the adjoining territories, they contribute to stating the laws of histoical development of the plant cover of the region.

The paper aims at the complex analysis of vessel plant flora of the state natural sanctuary "Bushkovskiy forest" for the sake of organizing long-term rerseach in its dinamics.

2 Material and Methods

The state natural sanctuary "Bushkovskiy forest" amounts to the area of 9274.8 ha. It is situated in the west of the Urzhum district, on the Urzhum inland plateou of the Vyatka sloping hill, in the sub-zone of mixed (or broadleaved-coniferous, sub-taiga) wood stand, within the agro-climatic zone which is warm enough, as compared with other zones of the Kirov region [7-8]. Within the sanctuary there are many small rivers: the Mazarka, the Syubinka, the Vodovoyka, etc., there are marshy areas, as well as the hydrological natural monument Lake Shaitan.

We were reseaching flora and vegetation of the SNS "Bushkovskiy forest" from 2004 to 2023. Flora was researched with the Route recognition method combined with analysing the plant composition in different biotopes of the naturral complex in more detail. Routes were chosen and base sections were made taking into accont full diversity of plant associations. Geobotanic desciptions on temporary sample plots were made with the use of common methods [9].

Accoding to field research results a summary of vascular plant flora of the SNS "Bushkovskiy forest" was made. The analysis of the flora taxonymic structure was made in accordance with the phylogenetic conception PPG I [10] for higher seedless plants. The structure of taxons of seed plants was described according to A. L. Takhtadganyan [11] and APG IV [12]. Nomenclature was made accoding to the database "Plants of the World online" [13]. Alongside with the taxonomic analysis biomorphological [14-15] and ecological-coenotic [16] analyses were made.

The degree of antropogenic impact and damage to the plant cover were estimated according to the phytome in the flora and their hemerobia estimations. It was based on the method of distributing taxons into seven stages: a – ahemerobic, o – oligohemerobic, m – mesohemerobic, b – β-euhemerobic, c – α-euhemerobic, p – polyhemerobic, t – metahemerobic species [17]. Hemerobiality index was calculated as a correlation of the species number in the researched phitocoenoses of the sanctuary with b-c-p-t-components in the spectrum of hemerobiality of the species with a-o-m-components [18].

3 Results and Discussion

3.1 Taxonomic analysis

The research showed that 270 vascular plant species grow on the territory of the sanctuary "Bushkovskiy forest", they belong to 196 genera and 73 families (Table 1).

The species of Magnoliopsida – 250 (92.6%) prevail in the researched flora, among them Dicotyledonae predominate. The second place, as for the number of speceis, is taken by Polypodiopsida – 13 (4.8%), the third – by Pinopsida (6 species – 2.2%).

Table 1. Correlation of the main flora taxonomic groups in the state natural sanctuary "Bushkovskiy forest".

Plant groups			Species		Genera		Families	
			number	%	number	%	number	%
Lycopodiophyta	Lycopodiosida		1	0.4	1	0.5	1	1.4
Polypodiophyta	Polypo-diopsida	Equisetidae	3	1.1	1	0.5	1	1.4
		Polypodiidae	10	3.7	5	2.6	4	5.5
Spermatophyta	Pinopsida		6	2.2	4	2.0	2	2.7
	Magno-liopsida	Dicotyledonae	202	74.8	145	74.0	51	69.8
		Monocotyledonae	48	17.8	40	20.4	14	19.2
In total			270	100	196	100	73	100

The avearge diversity level within one family is 3.4 species. The flora of the "Bushkovskiy forest" includes 17 families with the number of species either equal to, or prevailing the average level. On the whole, they contain 182 species, which accounts for 67.4% of the total nuber of species. 22 families are repesented by 2–3 species, and 35 families are represented by one taxon. The latter account for 13.0% of the species number. The leading 10 families include 138 species, which accounts for 51.1% of all the flora taxons found out there.

The spectrum of the leading families is very close to the typical one for the flora of the Kirov region: Asteraceae – 31 species (11.5%), Poaceae – 20 (7.4%), Rosaceae – 18 species (6.7%), Fabaceae – 16 species (5.9%), Lamiaceae – 12 species (4.4%), Ranunculaceae – 11 species (4.1%), Cyperaceae – 8 species (3.0%), Apiaceae – 8 species (3.0%), Caryophyllaceae – 7 species (2.6%), Scrophulariaceae – 7 species (2.6%).

On the whole, the spectrum of the leading families coresponds to the rules typical for spectrums of taiga flora: the first place is taken by Asteraceae, the following family trailing by 4.1%; a large number of species belonging to the first three families (Asteraceae, Poaceae, and Rosaceae), acconting for 25.6% of the flora in total. A considerable role of the family Apiaceae is connected with the fact that the research area is located in the sub-zone of coniferous-broadleaved forests, so that it is closer to southern regions which are the centres of the family diversity. Unlike the taiga flora spectum of the Kirov region [19], the spectrum in question lacks the family Brassicaceae, which is represented there just by three species, while on the territory of the Kirov region the family in question is among the leading ones. The reason of it is that in the region this family is represented by annual and biennial monocarpic grasses wich are moslty met in damaged ecotopes; in conditions of the Bushkovskiy forest they are not able to compete with polycarpics. On the whole, the fact of pevailing of the families in qestion is characteistic of Holarctic flora and it indicates the impact of boreal regions.

The spectrum of the leading families, as for the number of genera, is as follows: Asteraceae – 27, Poaceae – 18, Rosaceae – 13, Lamiaceae – 10, Ranunculaceae and Fabaceae – 8 each, it also typical for the continental boreal flora. As for polyspecies

genera, *Carex* L. (6 species), *Viola* L., *Campanula* L. and *Dryopteris* Adans. (5 species each), *Trifolium* L., *Veronica* L., *Epilobium* L., *Stellaria* L. (4 species each) are distinguished. The genus coefficient of 1.4 is significant. It indicates uniqueness of the physical-geographical environment for flora development. The coefficient is always lower for floras formed in conditions of homogeneous climate and flat relief.

On the territory of the sanctuary one can meet *Epipogium aphyllum* Sw. – a rare species registered in the Red Data Book of the Russian Federation [20]. It has two habitat areas: in 2018 it was found in a spruce-birch-linden forest with mixed herbs, in 2021 – in a buckler fern and aise-weed linden forest. Coenopopulations are small: the both of them consist of five generative plant units.

Thus, systematically the flora of the Bushkovskiy forest has its peculiar features: low species saturation (0.34 species/km^2); a high percentage of the leading families represented by one species; a comparatiely low genus coefficient.

3.2 Ecological-coenotic analysis

The flora of the SNS "Bushkovskiy forest" includes taxons of 13 ecological-coenotic groups (Table 2). Ecological-coenotic analysis showed prevailance of species connected with meadow phytocoenoses, broadleaved and taiga forests. Species of the floodplain-meadow ecological-coenotic group account for 21.9%, of the nemoral one – for 17.0%, and of the boreal one – for 12.6%. The highest share of species of the floodplain meadow ecological-coenotic group is found on forest glades, on meadows near Lake Shaitan, on felling sites, which is caused by a favourable light status there. The species of nemoral and boreal elements had played the leading role in forest flora formation. Principally it was influenced by species of the nemoral element, they are usual satellites of *Tilia cordata* in broadleaved forests, some of them are dominants and edificators (*Aegopodium podagraria* L., *Mercurialis perennis* L., *Milium effusum* L. et al.). Boreal species are typical for the geographical zone of the area under research.

Table 2. Ecological-coenotic structure of flora of the sanctuary "Bushkovskiy forest".

Group	Number	%	Group	Number	%
Boreal (Br)	34	12.6	Intrawater (InW)	7	2.6
Nemoral (Nm)	46	17.0	Oligotrophic (Olg)	2	0.7
Pine (Pn)	13	4.8	Wetland (Wt)	29	10.7
Nitrophil (Nt)	31	11.5	Boreal-edge (BrH)	6	2.2
Upland meadows (MDr)	27	10.0	Alluvial (Al)	1	0.4
Floodplain meadows (MFr)	59	21.9	Adventive (Ad)	8	3.0
Edge (ExEd)	7	2.6			

Plant communities of the "Bushkovskiy forest" are met on soils rich enough, as for plants of the lower layer, they are characterized by a high degree of shadowing and high degree of humidification. Thus nitrophilous species are represented in the flora fairly completely (11.5%), as well as plants of the wetland (10.7%) ecological-coenotic group.

The lowest variables are characteristic of the oligotrophic (0.7%) and alluvial (0.4%) goups. Presence of adventive species (3.0%) indicates damage in forest communities. The most part of alien species appeared on the territory of the sanctuary as a result of some spontaneos introdction, but there are species wich were intoduced purpousfully. For example, even in the times of the forest's last owner, the peasant-millionaire and big lumberman Nikifor Bushkov (the Bushkov's dacha) *Caragana arborescens* Lam. was planted in the northern quarters.

Probably, ecological-coenotic structure of flora of the SNS "Bushkovskiy forest" has developed from different elements and nowadays its contemporary anthopogenic transformation is going on due to moderate anthropogenic activity and recreation.

Species of forest communities pevail in flora, they accont for 45.9% (124 species) of the total species diversity. The second place is taken by grass communnities species – 118 (43.7% of the flora in total). Forest edge species accont for 4.8% (13 species). In regard to the humidity factor mesophytes dominate in the flora of the Bushkovskiy forest – 179 species (66.3%), hygrophytes are represented by 63 species (23.3%), and mesoxerophytes and xerophytes together account for 13 species (5.1%). Diversity of ecological groups in regard to humidity is connected with relief heterogeneity and, consequently, heterogeneity of the plant cover on the territory of the sanctuary, with different water bodies and swampy areas. On the whole, mesophyte species of grass and forest prevail on the researched territory – 86 (31.9%) and 80 (29.6%) species accordingly.

3.3 Biomorphological analysis

According to the system of C. Raunkiaer [15], five main biological types are repesented in the spectrum (Figure 1), what is also conditioned by biotopes diversity in the Bushkovskiy forest. Hemicryptophytes prevail, accounting for almost a half the species of the researched flora; it is characteistic of snow-forest boreal climate. Among cryptophytes geophytes prevail (33 species, or 12.2% of the total number of species), helophytes are less numerous (15 species, 5.6%), as well as hydrophytes (3 species, 1.1%). As for phanerophytes, mezo-, mico-, and nanophytes are presented: 17 species (6.3% of the total species number), 8 species (3.0%), and 10 species (3.7%) accordingly. Therophytes take the fourth place, they are presented because there are roads, paths, cleared strips, openings, and other sites with on- and along-growing species of this biological type.

The spectrum includes plants which can exist as several different biological types. Annual, biennial and winter-annual monocarpics of the families Asteraceae, Apiaceae, et al. are met as theropytes or hemicryptophytes (7 species, or 2.6% of the flora in total). Mostly long-root gramineous plants and river grasses are represented as geophytes or hemicryptophytes; after the dormant period their shoot system develops from buds placed either in soil, or on the soil surface. They amount for 2.2% (6 species).

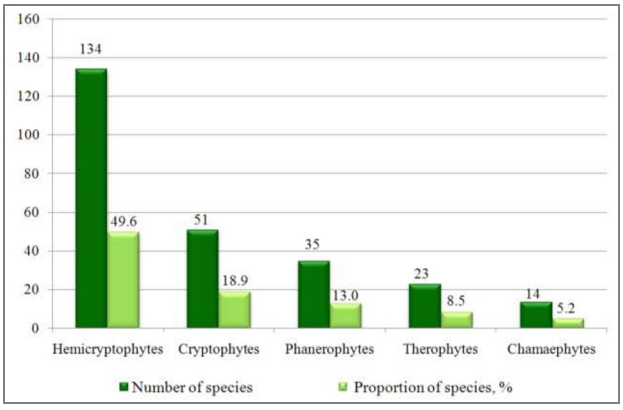

Fig. 1. Correlation of biological types in flora of the sanctuary "Bushkovskiy forest".

Accoding to I. G. Serebryakov's approach [14], plants of all the branches are met on the territory of the sanctuary: woody, semiwoody, ground and water grasses. Ground grass polycapics pevail, short rhizomatous and long rhizomatous grasses are equally

presented (Table 3). This is also characteristic of floras of snow-forest, boreal climate, in such conditions grasses have abilities for reactivation of their development, competition, and vegetative popagation due to storing protective buds on modified shoots.

The number of grass monocarpics is smaller by 4.8 fold, as compared with grass policarpics. They include annual, biennial, and perennial plants, hemiparasites (*Euphrasia glabrescens* (Wettst.)Wiinst., *Odontites vulgaris* Moench, *Rhinanthus minor* L.) and a parasite (*Cuscuta europaea* L.). Plants with such a life-form are often met on lands with faulted cover, there are just some few of such in the SNS "Bushkovskiy forest". The second group, as for the number of species, includes woody plants with trees prevailing (Table 3). As for the life span of leaves, trees are divided into therophyllous (13 species, 4.8% of the total species number) and aiphyllous (5 species, 1.9%) ones. Depending on the branching point, shrubs have geoxylic (3 species, 1.1% of the total species number), aeroxylic (7 species, 2.6%), and aeroxylic-geoxylic (5 species, 1.8%) forms. All the dwarfshrubs are geoxylic, they belong to Ericaceae and Pyrolaceae.

Table 3. Flora biomorphological structure of the sanctuary "Bushkovskiy forest".

Life form	Number	%	Life form	Number	%
1. Woody plants	40	14.8	3.2. Monocarpic herbs	37	13.7
1.1. Tree	18	6.7	– annual	16	5.9
1.2. Shrub	15	5.5	– annual-biennial	4	1.5
1.3. Dwarfshrubs	5	1.9	– biennial and perennial	13	4.8
1.4. Tree or shrub	2	0.7	– hemiparasite	3	1.1
2. Semiwoody plants (Semishrub)	1	0.4	– parasite	1	0.4
3. Ground herbs	213	78.9	4. Water herbs	16	5.9
3.1. Polycarpic herbs	176	65.2	4.1. Amphibious herbs	10	3.7
– tap-root	19	7.0	4.1.1. Polycarpic herbs	8	3.0
– fibrillose racemose root system	6	2.2	– long rhizomatous	6	2.2
– short rhizomatous	49	18.1	– stolon-tuber-forming	1	0.4
– long rhizomatous	48	17.8	– loose-bunch	1	0.4
– dense sod	3	1.1	4.1.2. Monocarpic herbs	2	0.7
– loose sod	14	5.2	4.2. Floating and underwater herbs	6	2.2
– stoloniferous	18	6.7	4.2.1. Polycarpic herbs	6	2.2
– creeping	6	2.2	– turion-forming	3	1.1
–tuber-forming	5	1.9	– frond	3	1.1
– soboliferous	7	2.6			
– protosomic	1	0.4			

Among water grasses policapics prevail in number (14 species, or 5.2% of the total species number), though, as for their life span, these are mosly biennials or annuala with vegetative origin. On the whole, aquatic flora is less researched, as compared with dry land flora. Probably, further monitoring could add some of the former to the list of species.

3.4 Analysis of hemerobia groups

In the hemerobia spectrum (Figure 2) mesohemerobic species prevail, these are taxons of semi-natural communities resistable to anthropogenic impact. The second place is taken by oligohemerobic species, these are plants growing in communities close to natural, they are able to resist some minor impact. The third place is taken by β-euhemerobic species wich can only bear some slight deformity of the grownd. The last place is taken by ahemerobic species, they cannot stand any anthropogenic influence, such as, *Abies sibirica*, *Lycopodium annotinum* L., *Picea obovata* Ledeb. et al. Anthropophobic species (a-o-m-species) account for 69.0%, the share of anthropotolerant species (b-c-p-t-species) is 31.0%. The index of flora hemerobiality of SNS "Bushkovskiy forest" is 0.45, which is low. The index is close to the one of the flora of natural vegetation communities of the South-Ural state nature reserve (from 0.2 to 0.5) [21], as well as of the nature monument "Velikoretskoye" (0.5) [22] and other SPNA.

Thus, according to hemerobia stages, the flora of the sanctuary is under some slight anthropogenic load. The indicators of that are adventitious species (*Acer negundo* L., *Lupinus polyphyllus* Lindl., *Medicago sativa* L. et al.). They grow along cleared strips, on the meadows on the banks of the Shaitan Lake which serve as recreation places for the population, also they occupy the felling places.

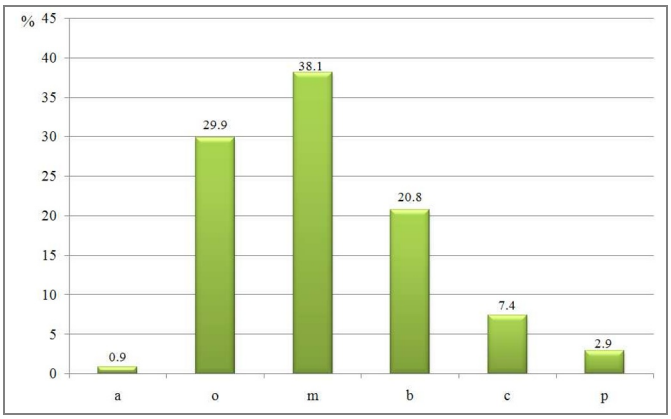

Fig. 2. The hemerobia spectrum of flora of the sanctuary "Bushkovskiy forest": on the X axis – levels of hemerobia: a – ahemerobes; o – oligohemerobes; m – mesohemerobes; b – β-euhemerobes; c – α- euhemerobes; p – polyhemerobes.

4 Conclusion

The SNS "Bushkovskiy forest" is the only one in the Kirov region that serves for preserving broadleave-furtree-spruce forests of the region with their special flora and fauna, with elements of both oak wood and dark coniferous forest. This fact raises the sanctuary's nature-protective value, as well as the importance of regular research and monitoring of biota within its boundaries.

As a result of the research of the SNS "Bushkovskiy forest", a flora summary was made, it includes 270 species of vessel plants, belonging to 196 genera, 73 families, four classes, three divisio (Lycopodiophyta, Polypodiophyta, Spermatophyta). The spectrum of the leading families is typical for the Kirov region, though their order differs, so that Brassicaceae was not included in the top ten.

The flora ecological-coenotic spectrum consists of 13 ecological-coenotic plant groups, among them floodplain meadow (21.9%), nemoral (17.0%), and boreal (12.6%)

groups pevail. The adventive component is only 3.0%, which indicates a low ratio of change of natural communities in course of synantropization and adventizaton. It is also proved by prevaiance of anthropophobic species in the hemerobia spectrum. Still, to preserve the existing diversity it is necessary to prevent spread of adventive taxons, to strictly regulate their numerosity and the size of their coenopopulations on the territory of the sanctuary.

Biomorphological analysis showed that polycarpic grasses (65.2%) and hemicryptophytes (49.6%) prevail in flora, which reflects the physico-geographical position of the SNS "Bushkovskiy forest".

Thus, complex analysis showed that modern taxonomic and typological flora diversity was formeded and is still in the process of being formed due to a complex of factors: the peculiarities of long and complex historical development of the vegetation cover were conditioned by transforamtion of the relief, soil, climate, diversity of biotopes, territory's irregularity due to numerous shallow streams, prevailace of broadleaved-conifeous and conifeous-broadleaved forests with a high crown density, the growing role of *Tilia cordata* and *Acer platanoides* in phytocoenoses, the growing role of human economic activities both in the past and nowadays, and receation.

The data presented serve as a gound for the monitoing of the flora content, and would add to the regulations of thier preserving on the basis of knowledge on ecological-phytocoenotic and historrical-biological peculiarities.

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