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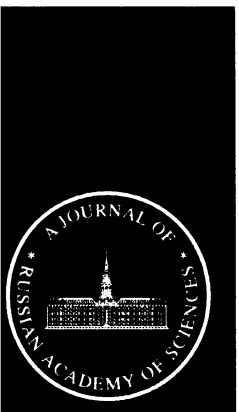

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Comparative Assessment of the Level of Plant Cover Synanthropization in Specially Protected Areas

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Abstract—Tendencies in plant cover synanthropization depending on the pattern and intensity of anthropogenic impacts on natural complexes have been revealed in specially protected areas of different classes (a nature reserve and a nature park).

Key words: biodiversity, nature reserves, vegetation, anthropogenic transformation, synanthropization.

Synanthropization of plant cover is actually an adaptation of the flora to environmental conditions that have been altered or created as a result of human activities (Gorchakovskii, 1984, 1999). Its manifestations are diverse and include, in particular, the invasion of adventitious plants (anthropophytes) and the advancement and activation of some indigenous plants (apothytes). This is accompanied by a general impoverishment of regional and local floras, substitution of their autochthonous components by allochthonous components, and the structural simplification and unification of plant communities. In measures aimed at biodiversity conservation, an important task is to reduce the adverse consequences of plant cover synanthropization. Therefore, it is necessary to analyze tendencies in the process of synanthropization in different regions and at various combinations of natural and anthropogenic factors.

The plant cover of specially protected areas (nature reserves, nature parks, etc.) is also subject to synanthropization and vulnerable to anthropophyte invasion. This problem has attracted the attention of many researchers. Thus, recent publications provide data on the proportion of synanthropic species in the floras of 35 nature reserves of the former Soviet Union (Nukhimovskaya, 1984), as well as of the Kronotskii (Ovcharenko and Rassokhina, 1989), Il'menskii (Gorchakovskii and Kozlova, 1998), Laplandskii (Berlina, 1999), Altaiskii (Zolotukhin *et al.*, 2003), and Kerzhenskii reserves (Urbanavichute, 2003); the Ojcow National Park in Poland (Michalir, 1992); the National Park of Lithuania (Sinkyavichene, 1981); etc. Of special interest are the data concerning a very high synanthropization level in the flora of the Voronezh Nature Reserve (40%), which includes 146 anthropophytes (Starodubtseva, 1987).

In this paper, we present the results of studies on tendencies in plant cover synanthropization in specially protected areas of different classes (a nature reserve and a nature park) differing in the level of anthropogenic impacts on the plant cover. Nature reserves are restricted areas in which scientific research is mainly performed, whereas the number of visitors and commercial activity are strictly limited. Nature parks are open for visitors, but the sites and routes for tourism and recreation are controlled by the administration, and excursions are escorted by guides. Thus, the anthropogenic impact on nature parks is stronger.

STUDY REGION AND OBJECTS

Studies were performed in the Visim Biosphere Reserve and the Olen'i Ruch'i Nature Park. According to physiographic zoning, they are in the southern taiga subzone of the low-mountain part of the Middle Urals.

The Visim Biosphere Reserve is in the upper reaches of the Sulem River, a tributary of the Chusovaya River. Its initial area was 135 km^2 (in 1973), but it increased to 335 km^2 after receiving the status of a biosphere reserve (May 2001). Data on the flora concern its former area, which has been better studied in the floristic aspect.

The eastern part of the reserve is in the region of mountain massifs with elevations of up to 699 m a.s.l. (the town of Bol'shoi Sutuk), and the western part is in residual mountains on the western slope, in the area with undulating or flat topography, with depressions and elevations reaching 362 m a.s.l.

The plant cover of the reserve consists mainly of spruce (*Picea obovata*), fir (*Abies sibirica*), and fir–spruce forests along with derivative birch forests (*Betula pendula* and *B. pubescens*) and, less frequently, aspen forests (*Populus tremula*), often with an admixture of spruce and fir. In addition, there are mesophilic meadows (in place of cut-out forests) and bogs.

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The Olen'i Ruch'i Nature Park is in the Serga River basin. Part of its territory is on the undulating western slope of the Middle Urals (the northern sector of the Bardymskii Ridge with elevations of 435–489 m a.s.l.), and another part is in the piedmont depression (324–339 m a.s.l.). The total area of the park is 120 km^2, and the protected area is 100 km^2.

Pine forests (*Pinus sylvestris*), sometimes with an admixture of Siberian larch (*Larix sibirica*), prevail in the park. Another important component of the plant cover is represented by spruce and fir–spruce forests with linden (*Tilia cordata*) and, less frequently, Norway maple (*Acer platanoides*). However, as a result of economic activity (tree cutting, cattle grazing, and hay harvesting), most pine and dark conifer forests were replaced by birch, aspen, and mixed conifer–small-leaf forests. A smaller area is occupied by secondary mesophilic meadows and groups of petrophilous and xerophilous plants on stony slopes formed of calcareous rocks.

METHODS

A route survey of habitats anthropogenically transformed to any extent (the vicinities of guardhouses, abandoned hayfields and forest margins, roads and paths, etc.) was conducted in both the reserve and the nature park. In addition, the railroad embankment was examined in the nature park. Test plots (5 × 5 m) were established near guardhouses and in hayfields and forest margins. In roads and paths, we conventionally distinguished the area between ruts, the ruts, and the roadside in the former case and the rut and roadside in the latter case. In each area, 0.5 × 10-m transects were laid in 7–10 replications. The species composition of plants, species abundance, and total coverage were assessed along the transects and in test plots. To determine the contribution of synanthropic species to the total coverage, plots 0.5 × 0.5 m in size were laid, in which the coverage of individual species was estimated. Similar plots were used to determine the contribution of synanthropic species to the aboveground phytomass. To this end, all plants in the plot were cut at the soil surface, divided into synanthropic and nonsynanthropic components, dried to an air-dry state, and weighed.

The extent of anthropogenic transformation of the flora and individual plant communities was estimated from the following parameters: (1) the synanthropization index, i.e., the proportion of synanthropic species (both apothytes and anthropophytes) relative to the total number of species; (2) the apophytization index, i.e., the proportion of apophytes relative to the total number of synanthropic species; (3) the adventization index, i.e., the proportion of adventitious species (anthropophytes) relative to the total number of species; (4) the contribution of synanthropic species to the total coverage and aboveground phytomass of plant communities.

With regard to these indices, we distinguished synanthropized and synanthropic plant communities, and the former were further subdivided into slightly, moderately, and strongly synanthropized communities.

THE FLORA OF PROTECTED AREAS AND ITS SYNANTHROPIC COMPONENT

According to Marina (1987, 1996, 2001) and more recent data (Telegova and Yudin, 2002), the flora of the Visim Nature Reserve includes 436 species of vascular plants.

As follows from the results of our studies, the synanthropic component of the flora includes 86 species; the synanthropization index is 19.7, the adventization index is 2.5, and the apophytization index is 93.2; and the species density of the synanthropic component (the number of species per 10 km^2) is 6.4.

The species of the synanthropic component belong to 66 genera; the average numbers of species per genus and per family are 1.3 and 3.7, respectively; the genera represented by the greatest numbers of species are *Alchemilla* (5), *Myosotis* (3), and *Agrostis* (3).

The flora of the Olen'i Ruch'i Nature Park comprises 926 species of vascular plants (Gorchakovskii *et al.*, 2004). According to our data, the synanthropic component consists of 187 species, and its species density is 15.5. The synanthropization index of the flora is 20.2, the adventization index is 9.2, and the apophytization index is 67.4. The species of the synanthropic component belong to 128 genera; the average number of species per genus and per family are 1.4 and 1.3, respectively. The largest genera (four species in each) are as follows: *Rumex*, *Ranunculus*, *Potentilla*, *Galeopsis*, *Achemilla*, and *Veronica*.

Specific features of synanthropic components in the floras of the nature reserve and nature park can be inferred from the numerical composition and order of 11 dominant families (Table 1). These families account for 87.5% of the total floristic composition in the reserve and for 81% in the nature park.

The composition and order of the first three families represented by the greatest numbers of species are important parameters characterizing the taxonomic composition of floras. In the reserve, the first triad is represented by the families Poaceae–Asteraceae–Rosaceae; in the nature park, by Asteraceae–Brassicaceae–Poaceae. Since two places in the first triad almost always belong to the families Poaceae and Asteraceae (at least in the Holarctic floral kingdom), Khokhryakov (2000) proposed to determine the type of flora by the third member of the triad (which does not necessarily occupy the third place in it). According to such a principle of assessment, the synanthropic component in the flora of the reserve belongs to the Rosaceae (conventionally European) type, and that in the flora of the nature park belongs to the Brassicaceae + Caryophyllaceae (extreme) type.

Table 1. Dominant families in the synanthropic component of the floras of specially protected areas

Family	Reserve		Nature park	
	%	place	%	place
Poaceae	19.8	1	8.0	3
Asteraceae	12.8	2	18.1	1
Rosaceae	9.3	3	6.4	4–7
Fabaceae	7.0	4–5	6.4	4–7
Lamiaceae	7.0	4–5	6.4	4–7
Caryophyllaceae	5.8	6	4.8	8–9
Apiaceae	4.7	7–8	4.8	8–9
Polygonaceae	4.7	7–8	6.4	4–7
Brassicaceae	3.5	9–11	9.0	2
Boraginaceae	3.5	9–11	2.7	11
Juncaceae	3.5	9–11	1.6	–
Scrophulariaceae	1.2	–	3.7	10

The fact that the family Brassicaceae holds the second place in the synanthropic component of the nature park flora is explained by a large proportion of adventive plants growing mainly on the railroad embankment and in the village.

VEGETATION OF ANTHROPOGENICALLY DISTURBED HABITATS

Within the study area, the entire variety of anthropogenically disturbed habitats can be reduced to the following categories: (1) forest margins, (2) abandoned hayfields, (3) areas near houses, (4) roads and paths, and (5) railroad embankment (only in the nature park). Table 2 shows characteristics of plant communities typical of these habitats.

Plant communities of forest margins. This category includes strips of weakly disturbed vegetation at the margin of a dense forest in open areas (glades, clearings, etc.) that have appeared as a result of tree cutting or after fires. In the nature reserve, this vegetation is represented by four communities in which the dominant species are *Agrostis clavata, A. stolonifera, Calamagrostis langsdorffii, C. obtusata, Chamaenerion angustifolium, Equisetum sylvaticum, Epilobium adenocaulon, Poa pratensis, Ranunculus repens, Stellaria bungeana,* and *Trifolium medium.* The total number of species in them is 84.

In the nature park, the set of communities is greater and the species richness is higher (9 communities and 125 species). The dominants and codominants include *Aegopodium podagraria, Agrostis gigantea, Angelica sylvestris, Bupleurum longifolium, Calamagrostis arundinacea, Carex montana, Lathyrus vernus, Poa nemoralis, Polygonum bistorta, Potentilla erecta,*

Table 2. Synanthropized and synanthropic vegetation of anthropogenically disturbed habitats in the reserve (above the line) and the nature park (below the line)

Parameter	Forest margins	Abandoned hayfields	Areas near houses	Roads and paths
Number of communities	4 9	13 10	7 16	9 11
Total number of species	84 125	128 130	107 138	78 112
Number of species per test plot	11–23 20–40	21–35 18–30	21–34 13–30	4–28 1–40
Synanthropization index, %	35–60 25–60	40–80 70–85	50–85 60–90	30–100 50–100
Adventization index, %	0–6 0	0–5 0–5	0–10 0–22	0–5 0–10
Total coverage, %	40–95 20–60	60–90 30–80	70–95 70–100	10–80 10–60
Contribution of synanthropic species to coverage, %	25–50 25–60	40–70 60–80	70–95 70–95	10–100 80–100
Aboveground phytomass stock, g/m^2	132.6 ± 11.5 134 ± 12.1	141.2 ± 16.2 246.4 ± 31.3	206 ± 2.8 228.4 ± 18.1	71.2 ± 8.1 114 ± 20.4
Contribution of synanthropic species to phytomass stock, %	15–55 5–45	45–75 30–80	45–90 25–100	25–100 55–100

Primula macrocalyx, Ranunculus auricomus, R. monophyllus, Rubus saxatilis, Stellaria holostea, Veratrum lobelianum, and *Veronica chamaedrys.*

According to the level of synanthropization and other indices, marginal communities of both protected areas are fairly similar, but species density is slightly higher in the nature park.

Abandoned hayfields. These are sites of mesophilic meadows in the former felling areas in which previously regular hay harvesting ceased five to six years ago.

Thirteen communities of this type (128 species) were revealed in the reserve. Dominant species include *Alchemilla leiophylla, A. rigescens, Alopecurus pratensis, Calamagrostis obtusata, Carex aquatilis, C. atheroides, C. cinerea, Cicerbita uralensis, Cirsium heterophyllum, Deschampsia cespitosa, Equisetum sylvaticum, Filipendula ulmaria, Galeopsis bifida, Geranium sylvaticum, Hypericum maculatum, Juncus filiformis, Plantago major, Polygonum bistorta, Potentilla erecta,* and *Ranunculus repens.*

In the nature park, vegetation of the second type is represented by ten communities with a total of 130 species. Dominant species include *Aegopodium podagraria, Alchemilla leiophylla, A. rigescens, Anthoxanthum odoratum, Brachypodium pinnatum, Dactylis glomerata, Deschampsia cespitosa, Festuca pratensis, Poa compressa, P. pratensis, Prunella vulgaris, Ranunculus repens, Taraxacum officinale,* and *Veronica chamaedrys.*

In the abandoned hayfields, compared to forest margins, the diversity of communities and the total species richness are increased only in the reserve; in the nature park, these indices remain at approximately the same level. The synanthropization index and the contribution of synanthropic species to the aboveground phytomass are higher than at forest margins, especially in the nature park.

Vegetation in areas near houses. This category includes plant communities that have formed near guardhouses in the reserve and near houses and gardens in the village located in the nature park. In the reserve, such vegetation is represented by 7 communities that include 107 species. The dominant species are *Aegopodium podagraria, Alchemilla rigescens, Anthriscus sylvestris, Chamaenerion angustifolium, Dactylis glomerata, Deschampsia cespitosa, Filipendula ulmaria, Galeopsis speciosa, Heracleum sibiricum, Poa nemoralis, P. trivialis, Ranunculus repens, Stellaria bungeana,* and *Urtica dioica.*

The set of communities in the nature park is more diverse, and species richness is slightly higher (16 communities and 138 species). Dominant species include *Aegopodium podagraria, Alchemilla rigescens, Alopecurus pratensis, Anthriscus sylvestris, Arctium tomentosum, Artemisia vulgaris, Bromopsis inermis, Carum carvi, Chamaenerion angustifolium, Dactylis glomerata, Deschampsia cespitosa, Elytrigia repens, Festuca rubra, Filipendula ulmaria, Galeopsis bifida, G. speciosa, Geranium pratense, Heracleum sibiricum, Poa pratensis, Potentilla erecta, Ranunculus repens, Taraxacum officinale, Trifolium medium, Urtica dioica,* and *Veronica chamaedrys.*

In comparison with the groups considered above, this group is characterized by higher values of the synanthropization index (up to 90%) and the adventization index (up to 22%), as well as by a greater contribution of synanthropic species to the total coverage and aboveground phytomass. These values are especially high in the nature park.

Vegetation of paths and roads. The soil on forest roads and paths is highly compressed, and vegetation is constantly exposed to trampling. The intensity of trampling is especially high in the ruts, being slightly lower in the area between them and on the roadside, as well as on paths.

In the reserve, 9 communities of this type comprise 78 species. Dominants and codominants include *Achillea millefolium, Alchemilla rigescens, Dactylis glomerata, Deschampsia cespitosa, Plantago major, P. urvillei, Poa angustifolia, P. annua, P. pratensis, Polygonum bistorta, Prunella vulgaris, Taraxacum officinale,* and *Trifolium repens.*

In the nature park, the set of communities and the number of species in them are greater (11 communities and 112 species). The dominant species are *Achillea millefolium, Alchemilla rigescens, Dactylis glomerata, Deschampsia cespitosa, Plantago major, P. urvillei, Poa angustifolia, P. annua, P. pratensis, Polygonum bistorta, Prunella vulgaris, Taraxacum officinale,* and *Trifolium repens.*

The synanthropization index in communities of the road–path network is fairly high in both the reserve and the nature park; it attains its highest value (up to 100%) in the communities of ruts and strongly trampled paths. In the reserve, adventive species in most communities of this type are lacking; in the nature park, the adventization index reaches 10% in some places (only on the roadside and paths). The communities of paths and roads are characterized by the lowest productivity; their total coverage is generally low; the contribution of synanthropic species to the total coverage and the aboveground phytomass stock strongly varies, but in some cases (in ruts and on strongly trampled paths) it reaches 100%.

Communities of the railroad embankment. This group of communities is represented only in the nature park: there is a local single-track railroad with insignificant traffic. Species from the surrounding communities settle on the slopes of the railroad embankment, and species adapted to growing on a well-drained rubbly substrate settle on the bed proper. The core of communities of the railroad bed is composed of *Puccinellia distans* and *Festuca rubra.* Dominants and codominants include *Artemisia vulgaris, Bunias orientalis, Centaurea scabiosa, Chamaenerion angustifolium,*

Convolvulus arvensis, Crepis sibirica, Elytrigia repens, Equisetum arvense, E. sylvaticum, Festuca pratensis, Fragaria vesca, Heracleum sibiricum, Lathyrus pratensis, Melampyrum nemorosum, Potentilla anserina, Pteridium aquilinum, Rubus caesius, R. idaeus, Rumex acetosa, Tanacetum vulgare, Trifolium medium, Tussilago farfara, Urtica dioica, and *Vicia cracca.*

The total number of species is 121, 15–30 species per test area. The synanthropization index is 65–90%, and the adventization index is 6–28% (higher than in other community groups). The total coverage varies from 40 to 80%, and the contribution of synanthropic species to it is significant: 75–100%. The aboveground phytomass stock is small (on average, 94 g/m^2), with synanthropic species accounting for 95–100% of this value.

CONCLUSIONS

The results of our study show that the species richness of the synanthropic component of the flora is higher in the nature park (187) than in the reserve (86). The species density calculated as the number of synanthropic species per 10 km^2 is also higher in the park (15.5 vs. 6.4 in the reserve), and the same applies to the synanthropization index (20.2 vs. 19.7).

In general, the proportion of anthropophytes in the flora of the protected areas is relatively low, but it is considerably higher in the nature park than in the reserve (adventization indices are 9.2 and 2.5%, respectively). The apophytization index is especially high in the reserve (93.2, compared to 67.4 in the nature park).

With regard to the complex of diagnostic parameters (see above), plant communities of forest margins, abandoned hayfields, and areas near houses can be classified as weakly, moderately, and strongly synanthropized communities, respectively. The vegetation of the road–path network is very heterogeneous, which is explained by the different loads on its individual parts. Ruts are exposed to the heaviest load, and plant communities developing in them are of very poor composition, sometimes monospecific (e.g., with *Poa annua*), and are classified as synanthropic. Plant communities in the area between the ruts and on the roadside usually belong to the categories of moderately and strongly synanthropized communities.

A comparative analysis of our data shows that the total species richness in the main groups of synanthropic and synanthropized communities is higher in the nature park than in the reserve. In most categories of the plant communities considered in this study, the synanthropization index, adventization index, and the contribution of synanthropic species to the total coverage and aboveground phytomass stock are also greater in the nature park. This is evidence that the natural plant cover of the nature park is disturbed to a greater extent.

Both in the reserve and the nature park, synanthropization of the plant cover is accounted for mainly by aboriginal plant species (apophytes), while the proportion of anthropophytes is relatively low. In the reserve, the anthropophyte invasion is apparently hindered due to a greater amount of forests (up to 95% of the total area) with the dominance of dark conifers (*Picea obovata* and *Abies sibirica*), as well as by a relatively strict security system. In the nature park, the density of forest canopy is lower, which is favorable for anthropophyte expansion: in some plant communities near houses and on the railroad embankment, the adventization index reaches 22 and 28%, respectively.

At the early stages of anthropogenic transformation of the plant cover in protected areas, under a weak anthropogenic load, species richness and diversity of plant communities increase due to the invasion of apophytes and anthropophytes, as most of the initial species are preserved. Subsequently, as the load increases, the communities lose some of their initial species, which are replaced by synanthropic forms. Thus, species richness and diversity of communities gradually decrease and their convergence with respect to composition and structure takes place.

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