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## Synanthropization of small towns' flora (Krasnoyarsk region)

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**Abstract.** The aim of this work is to identify the features of the synanthropic component of the flora of Sosnovoborsk, a satellite town of the regional center of Krasnoyarsk (Krasnoyarsk region). Based on the study of 7 model sections within the administrative boundaries of Sosnovoborsk, which differ in the phytocenotic diversity of the landscape and the characteristics of the anthropogenic load, the composition and structure of the synanthropic fraction of the flora: the share of apophytes and advents, hemerophiles and hemerophobes, synanthropic groups of species according to the degree of naturalization and certain activity criteria, were chosen. It was established that there was a prevalence of apophytes in the city flora (92%), where 54.2% of the total number of apophytes there were hemerophiles, which is generally typical of urban floras. Among minor advents (8.0%), colonophytes dominate (54.8% of the advent fraction). The basis of the synanthropic fraction of the flora of Sosnovoborsk (57.9% of the total flora) is rural species (according to I. Hensky) - 45.5%, consisting only of apophytes and found in all model sections of the city. At the present stage, a change in the floristic composition of Sosnovoborsk is due to urban-philic species (54.2%). The low adventization index (0.08) arises from the predominance of colonophytes (54.8% of the adventitious fraction), as well as the content of adventitious species in the composition of small satellites (58.1% of the adventitious fraction) and citizens (41,9 %).

### 1. Introduction

Urbanization as the main feature of modern civilization directly affects vast areas of the globe, causing sharp and rapid changes in the landscape, while the actual impact of the city on nature goes far beyond its administrative borders. All species that grow in anthropogenic and anthropogenic-disturbed habitats - industrial zones, environs of the private sector and vegetable gardens, landfills, and vacant lots, roadsides of country and central roads, lawns, courtyards of multi-story residential buildings are broadly defined as synanthropic flora [1].

With synanthropization, narrowly distributed species are replaced by cosmopolitans; the replacement of species associated with a certain combination of environmental conditions (stenotopic), species which are more durable to a variety of conditions (eurytopic); substitution of moisture-loving plants for more xerophilous ones. The performed work on the research of the flora of large cities [2–5] testifies to the originality and richness of urban flora, due to human activity and reflecting, to a certain extent, the degree of their anthropogenic transformation. The synanthropic flora of the city is a



complex dynamic semi-natural system, which is constantly changing qualitatively and quantitatively. The appearance and naturalization of new introduced species of plants, activating the processes of coenoflora change play an important role. Some species are stably kept in new habitats, but are not prone to abundant resettlement, others are successfully distributed according to new phytocenoses, but do not occupy dominant positions in terms of abundance and diversity, but in some cases they may be aggressive and displace native representatives of the flora [6, 7]. In the flora of Sosnovoborsk, such an example is *Equisetum hyemale*: capturing a leading position in some anthropogenically disturbed phytocenoses and, becoming a dominant, it displaces indigenous species, mastering new areas. Many authors note a high correlation of these processes: the more active is the process of adventitization of species, the more intense is the process of reducing biodiversity. Therefore, the research of various characteristics of synanthropic flora of cities is of great importance in general to assess their condition and the ability to control the process of synanthropization.

Despite the increased interest in researching the flora and vegetation of urban ecosystems, mainly the features of large metropolises have been studied [1]. Small young cities, by the example of which the development trends of various components of the flora can be identified and traced, are of particular interest.

The aim of this work is to identify the synanthropic component of the flora of the young satellite town of Sosnovoborsk (Krasnoyarsk region) on the basis of many years of research. Sosnovoborsk is one of the young satellite cities of the regional center in Krasnoyarsk region with a developing social and economic infrastructure associated with a large regional megalopolis. It was founded in 1971 as a workers' settlement in connection with the construction of the largest factory of trailers for KamAZ vehicles to the north-east of the regional center - the city of Krasnoyarsk. Since 1973 it is called Sosnovoborsk, thanks to the pine forests surrounding a small town.

## 2. Research materials and methods

The synanthropic flora was revealed simultaneously with the study of the entire urban flora [8]. Initially, stock collections stored in the Herbaria of Siberia (Herbarium named after L.M. Cherepnina Krasnoyarsk State Pedagogical University (KRAS), Herbarium named after P.N. Krylova, Tomsk State University (TK), Herbarium of the Central Siberian Botanical Garden SB RAS (NS), collections of Krasnoyarsk Regional Museum of Local Lore, etc.) have been studied.

Flora was studied by the route method in combination with the model method of the urban landscape since 2008 in the spring, summer and autumn vegetation periods [9, 10]. Within the administrative boundaries of Sosnovoborsk, 7 model sites were studied (Fig. 1), which were notable for the phytocenotic diversity of the landscape and the characteristics of the anthropogenic load: 3 sites - a forest park (Fp), the bank of the river Esaulovka (Be), meadow sanitary protection zone (Sz) formed by the remains of native flora; the rest are formed as a result of human activities.

The synanthropic component of the flora of Sosnovoborsk was analyzed using the method of activity of synanthropic plant species according to I. Hensky [11, 12], which merit is the ability to group and identify the activity of synanthropic groups based on a quantitative assessment of the distribution of each species by model sections in accordance with its abundance.

When identifying the adventitious component of the studied flora, the present and past distribution of species, their ecological confinements, as well as their relationship with certain communities were taken into account. In addition, literary information about the alien nature of the species in published flora and compendiums was taken into account.

When analyzing the adventitious fraction according to the degree of introduction and naturalization, the classification F.-G. Schröder was used [13].

## 3. Results and discussion

When assessing the level of synanthropization, the degree of "tolerance" of plants to anthropogenic effects, the origin and method of naturalization of adventive species are taken into account [14]. In the flora of any territory, two main components can be distinguished: indigenous species - species of local

flora; apophytes and adventive species - species that appeared on this territory as a result of human activities [3, 7, 15].

Indigenous species normally populate in natural vegetation, under the influence of anthropogenic impacts they pass into secondary synanthropic habitats. In this regard, to assess the resistance of species to the action of anthropogenic factors, the scale of hemorrhage (anthropotolerance) developed by foreign scientists was used [16]. Heterogeneity, that is, the resistance of plant species to anthropogenic effects is largely determined by their distribution in an urbanized area.

In the flora of Sosnovoborsk, apophytes make up 92%, which is slightly higher than in the closely located (39 km) regional center (85.8%) [3], which is apparently related to the age of cities.

According to the degree of hemorrhage, among the species of this group, hemophobes (urbanophobes) are distinguished – species are unstable and weakly resistant to anthropogenic impact and, as a result, avoiding the urban environment and able to exist mainly in areas of natural vegetation and urban fringe (*Filipendula ulmaria*, *Butomus umbellatus*, etc.), and also hemerophiles (urbanophiles) – species that can tolerate urban conditions, including industrial pollution (*Equisetum arvense*, *Anagallidium dichotomum*, *Arabis pendula*, *Cynoglossum officinale*, etc.).

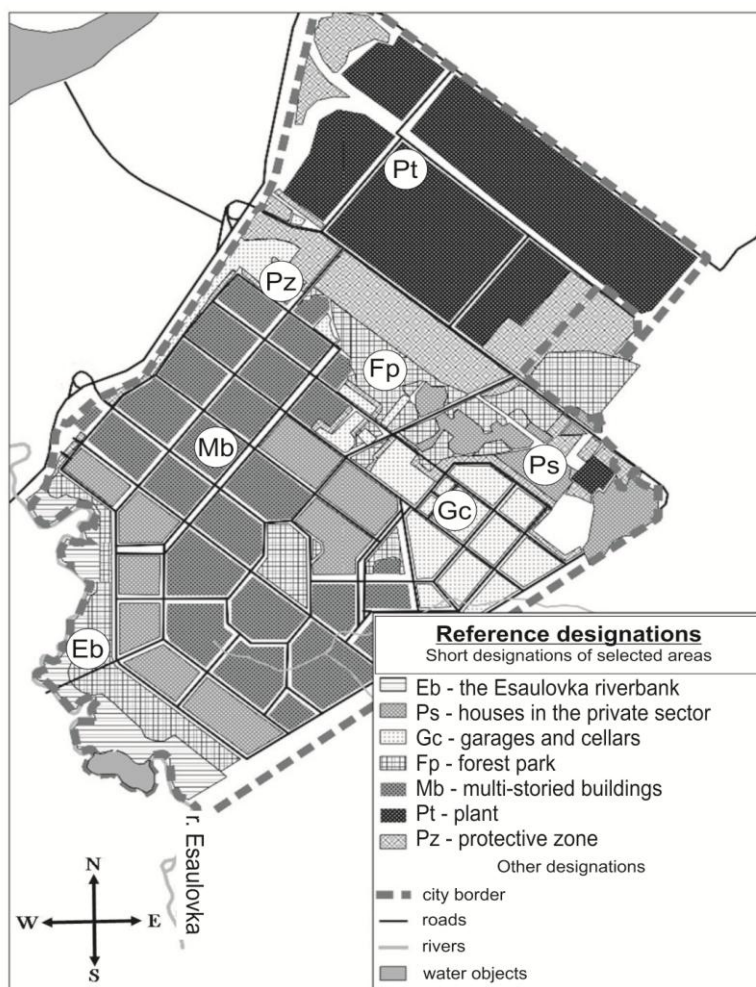
Such species have developed numerous secondary ruderalized habitats in all areas of the city. Some urbanophilic species can dominate the vegetation cover of anthropogenic areas, forming entire thickets (*Chelidonium majus*, *Chenopodium album*, *Melilotus albus*, etc.). In the researched urban flora, there are more hemorrhages (193 species; 54.2% of the total number of apophytes) than hemorophobes (163 species (45.8% of the total number of apophytes), which is generally typical of urban floras [10, 17]. At the same time, in Krasnoyarsk, the species avoiding the urban environment dominate among the apophytes [14]: 598 species of hemerophobic (59.5% of the total number of apophytes), and 264 species of hemerophilic (26.3%). Such a ratio of plant groups of different residence in the megalopolis flora, in general, is not typical of urban floras. Nevertheless, a large number of local, native species and a high percentage of urbanophobes in their composition indicate a fairly well-preserved natural core of the city's flora. In addition, the predominance of hemerophobic species in the native fraction of the flora is a kind of confirmation of the vulnerability of urban flora [18], since the destruction of areas of natural vegetation would mean a sharp depletion of urban flora precisely due to such species.

Adventive species play an insignificant role (8% of the total flora) in the formation of urban flora of Sosnovoborsk, penetrating into its composition with both conscious and unconscious human participation. The development of the city is accompanied by intensive construction, which led to the transformation of natural vegetation, the appearance of anthropogenic habitats, where alien species appear. In some cases, regeneration is carried out using a variety of natural factors (air and water currents, etc.), but the main regeneration routes are, first of all, a well-developed motor transport network, large enterprises of heavy and food industries, receiving raw materials from different regions of Russia and Near Abroad.

The appearance of adventitious species is not associated with the general course of natural florogenesis in this territory. The natural habitat of alien species is usually located at a considerable distance from the sporadically scattered locations of alien origin. In some instances, providing multifold aliens and successful naturalization, the formation of a secondary, synanthropic by origin range can occur in a new type of floristic region. As a rule, adventitious species settle in secondary habitats near the places of intensive human economic activity. Some alien species can subsequently naturalize in the places of synanthropic and spontaneous phytocenoses [19]. Studying the process of replenishing the flora with adventitious species allows us to judge the degree of synanthropization of the researched flora and it is one of the most informative options for biomonitoring the state of the environment.

The share of synanthropic plants in the flora of Sosnovoborsk, including indigenous and adventive species, makes out 57,9 % (224 species) of the total composition of the entire flora, the synthropization index is 0,58. The share of advents is 8,0 % (31 species, ) the advent index is 0,08. Such indicators show a relatively low degree of anthropogenic changes in the urban flora [20, 21] and a high prevalence and preservation of indigenous species in the anthropogenic habitats of the city.

Regarding the adventives group of plants, despite the annual active measures for the introduction of new species and a well-developed agricultural complex, the degree of their naturalization is small. This is primarily due to the ‘youth’ of the urban environment, where the processes of ‘wildness of adventive species and their subsequent introduction into natural communities can be observed in dynamics in the process of long-term monitoring.



**Figure 1.** Model sites on the territory of Sosnovoborsk.

According to the degree of adaptation in the new geographical conditions (naturalization), in consonance with well-known classifications [13, 14], colonophytes dominate in the flora of Sosnovoborsk, as well as Krasnoyarsk (17 species, 54.8% of the adventitious fraction) *Saponaria officinalis*, *Populus laurifolia*, *Cotoneaster melanocarpus*, *Crataegus pinnatifida*, *Physocarpus opulifolius*, *Calendula officinalis*, etc.). This group consists of feral plants, in the process of their targeted cultivation. They have a rather limited distribution and are practically not currently being introduced into the natural phytocenoses of the city. Further “behavior” of colonophytes can be assessed only during monitoring. The second place belongs to agriophytes (6 species, 19.4% of the adventitious fraction), which makes the question of the presence of an invasive process for the studied flora relevant, since representatives of this group, having an intrusive cultural origin, are also introduced into the natural communities of the city (*Acer ginnala*, *A. negundo*, *Rosa rugosa*, *Hippophaë rhamnoides*, etc.). Random, not stably naturalizing ephemerophytes occupy the third place:

5 species (16.1% of the adventitious fraction). The distribution of the species of these groups is limited mainly by alien places, which are most often referred to as roadsides, embankments, etc. with their special environmental conditions. This shows the favorable role of urban conditions for the primary introduction and resettlement of adventive plants. Epiphytes are of lesser importance, only 3 species (9.67% of the number of advents), which are not found stably in both registered habitats and throughout the city.

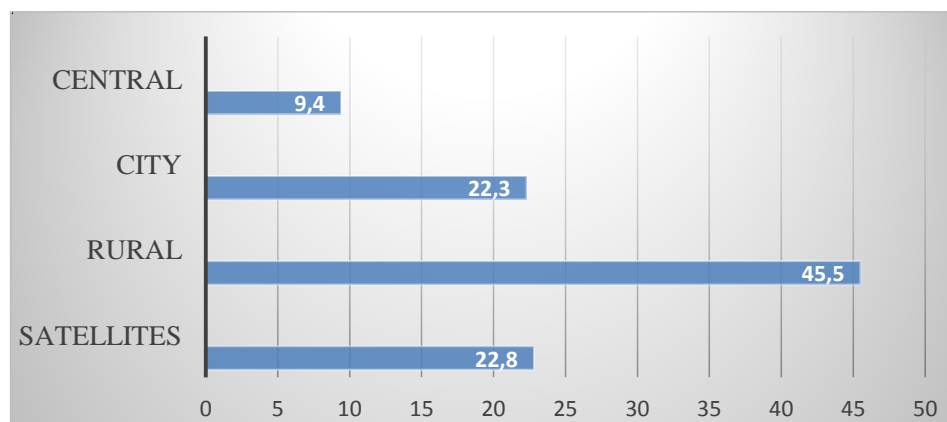
Thus, the share of the adventive component in the composition of the flora is determined by both natural (Siberian flora is in harsher climate) and social factors (duration of development, degree of improvement, sanitary standards, nature of industrial development, etc.) [22].

Adventive species, replacing native species in the arithmetic sum of species, of course, do not replace them in the composition of the flora as a natural system and do not replace the lost native species in the vegetation, but settle on secondary synanthropic ecotopes. Therefore, there is a depletion of natural phytocenoses with a simultaneous substantial enrichment of synanthropic flora. Thus, a 45-year-long life of Sosnovoborsk, in the border with Krasnoyarsk forest-steppe region and the spurs of East Sayan with intensive development of the territory, is sufficient for the appearance of a specific urban flora, combining elements of the natural flora and a typical urban component.

The analysis of the synanthropic flora of Sosnovoborsk was carried out in accordance with the approach of I. Hensky [11, 12], which is based on the allocation of adventitious groups according to the certain criteria of “activity” of species within the model division — prevalence over the researched area and their abundance. As a result, the following synanthropic groups of plants were identified: central species - species with a high abundance and widespread in model areas (22 species); urban residents - species which are abundant in the certain areas (49 species); rural - non-abundant species found in a wide range of the environment (102 species); satellites are species with a low abundance and a limited range of distribution (51 species).

The analysis of the quantitative ratio of synanthropic groups in the researched flora shows the dominance of non-mass rural species — almost half of the total composition of the synanthropic fraction of the flora is 45.5% (Fig. 2). These species do not show great activity in terms of abundance and diversity within the model division, but, nevertheless, are widely distributed singly or in small groups throughout the city of Sosnovoborsk (*Ranunculus polyanthemos*, *Gypsophila paniculata*, *Silene nutans*, *Amaranthus retroflexus*, *Androsace septentrionalis*, *Lysimachia vulgaris* *Acer negundo*, etc.). и др.).

Almost equal proportion in the synanthropic flora is mass urbanites горожане (*Cannabis sativa*, *Urtica dioica*, *Chamaenerion angustifolium*, *Lathyrus pratensis*, *Vicia amoena*, etc.) and rare satellites (*Cichorium intybus*, *Helianthus tuberosus*, *Inula britannica*, *Calendula officinalis*, *Poa nemoralis*, etc.) - 22.3% and 22.8%, respectively.



**Figure. 2.** The ratio of synanthropic groups in the flora of Sosnovoborsk [according to I. Hensky, 1982]: vertically – the names of synanthropic groups; horizontally - % of the total number of synanthropic species.



The central species (*Bromopsis inermis*, *Elytrigia repens*, *Poa angustifolia*, *Taraxacum officinale*, *Linaria vulgaris*, etc.), found and abundantly distributed within each model site, have a low indicator (9.4%) of participation in the synanthropic fraction. The qualitative characteristic of each group reveals its composition in relation to the apophytic or adventitious fraction of the synanthropic flora of Sosnovoborsk. The composition of the urban residents and satellites is mixed, including both apophytes and advents. The core of the synanthropic flora is formed by central and rural groups, consisting only of apophytes and found in all model section

Analysis of the distribution of the selected groups by model sections allows us to identify their activity under conditions of different phytocenotic affiliation and anthropogenic load (Table).

The analysis of the activity of synanthropic groups by model sections was carried out in two directions. The dynamics of the abundance of the synanthropic group across all model plots reveals the characteristic features of the distribution in accordance with the environmental conditions of the model site. Central species, as indicated above, in terms of quantitative indicators show weak activity in its diversity, regardless of their phytocenotic confinement, but have a high abundance within each model section. The group of city dwellers is more confined to the housing development zone, which is characterized mainly by lawn, roadside, and house habitats for plants. Rural species are most active in multi-story neighborhoods and industrial sites. Satellites are distributed mainly in the multi-storey building zone, where each synanthropic representative of this group is rare and single.

**Table 1.** The quantitative ratio of the species of synanthropic groups according to the model sections of Sosnovoborsk.

Synanthropic groups	Model sections /number of species / % from synanthropic fraction						
	Fp	Mb	Eb	Ps	Sz	Gc	Pz
<b>Central</b>	21/9,4	21/9,4	21/9,4	21/9,4	21/9,4	21/9,4	21/9,4
<b>Urban</b>	20/8,9	44/19,6	10/4,5	21/9,4	24/10,7	7/3,1	26/11,6
<b>Rural</b>	60/26,3	89/39,7	37/16,5	52/23,2	57/25,4	31/13,8	62/27,7
<b>Satellites</b>	-	39/17,4	1/0,4	3/1,3	6/2,7	-	2/0,9
In total:	101/45,0	191/85,3	69/30,8	97/43,3	109/48,7	59/26,3	111/49,6

The quantitative ratio of four groups within the model section characterizes synanthropic changes in the flora of each model site. As a result of the study, among representatives of other groups in each model division, rural ones prevail sporadically over its territory. This testifies to the lack of dominance and the weak nature of their distribution in the phytocenoses of Sosnovoborsk.

#### 4. Conclusions

Thus, the predominance of tolerant apophytic species over adventitious species in the synanthropic fraction of the flora of Sosnovoborsk emphasizes the safety of the native fraction of the flora in a young urban environment. At the present stage, a change in the floristic composition of Sosnovoborsk is due to urban-philic species (54.2 %).

Rural species (45.5%) are considered as the core of apophytes in the flora of the city. The low adventization index (0.08) is due to the predominance of colonophytes (54.8% of the adventitious fraction), as well as the content of adventitious species in the composition of small satellites (58.1% of the adventitious fraction) and citizens (41.9%).

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