Floristic core of the Russian Plain pine forests along *Pinus sylvestris* southern borders

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**Abstract.** Pine forests - forest tracts on the sandy left banks, where the main area is occupied by plant communities with a predominance of *Pinus sylvestris*. Due to the significant distance from each other, the floras of the pine forests differ. However, the flora of these pine forests also shares common characteristics. In order to establish the floristic unity of the forests at the southern limit of the distribution of *Pinus sylvestris*, work was carried out to identify their floristic core. For 20 years, floristic surveys have been carried out in the forests of the steppe and forest-steppe zones. A general floristic list was compiled, with the identification of aboriginal and alien fractions, and the floristic core was established. Revealed: the core of the flora is determined by the pine forest flora with the lowest number of species among the comparable pine forests. The core of the flora of the studied pine forests included 30.8% of the species of the general flora. An increase in the number of analyzed floras will bring accuracy to the determination of the floristic core. This will make it possible to form an understanding of the pine forest flora as a single floristic complex.

**1. Introduction**

The objects of research were the flora of the insular pine forests of the Russian Plain on the southern limit of the distribution of *Pinus sylvestris* L. Under the pine forest, following E A Starodubtseva [1], we understand insular forests (isolated areas) on the sandy left banks, where the main forest area is occupied by plant communities with a predominance of *Pinus sylvestris*. Pine forests are widespread in the forest-steppe and steppe zones, the climate of which is not very favorable for the development of forest vegetation [2]. The edge of the areal location of pine forests makes them the most sensitive and dynamic to environmental changes, which is primarily reflected in the composition and development of the flora [3]. The flora of the pine forests differs from the flora of the surrounding landscapes [4] and makes a certain contribution to the phytodiversity of the regions in which the studied forests are located.

Due to the significant distance from each other, the history of development and the peculiarities of the conservation status, the flora of the pine forests differ from each other; possess originality and uniqueness due to endemics and relics that have found habitats in their territories. However, the floras of these pine forests also have common features that determine the characteristics and character of these insular forests. The basis for establishing the similarity and difference of the flora studied is the discovery of the floristic nucleus as the basis of the flora formed according to the conditions of the given territory [5].
The relevance in determining the floristic core is not only to identify the genesis, but also to
determine the vector of development of modern flora and the ecosystems under study.
A V Gornov [6] in his work on the classification of forests in European Russia compares the
studied phytocenoses using both floral and dominant geobotanical approaches. This helps him not only
to classify, but also to draw conclusions about the ecological regime of the studied phytocenoses, as
well as to establish their origin.
The work on identifying the aboriginal core of the flora of the Kilmez-Zakamsky floristic district of
the Udmurt Republic conducted by O G Baranova [7] made it possible to identify the most floristically
rich area. The flora of this area includes the species composition of other compared areas and is the
habitat of a large number of plants listed in the Red Book of the region, which makes it possible to
determine it as a reference for the studied territory in floristic terms.
The works of N V Genikova et al. [8] are devoted to the identification of the preservation of the
forest cenoflora after catastrophic logging. The authors, in the course of determining the floristic unity
between the compared phytocenoses, managed to establish the percentage of the preserved cenoflora
of indigenous forest communities. In the article A M Kryshen et al. [9] notes that the approach with
the determination of biological, including floral, nuclei when establishing the safety of forest
phytocenoses after logging is used by specialists from many countries, including: Finland, Sweden, the
USA, Canada, Argentina, Australia, Russia.
In order to establish the nature of the modern flora of the pine forests of the Russian Plain at the
southern limit of the distribution of Pinus sylvestris L., we have carried out work to identify the
floristic core for the first time.

2. Models and methods
For 20 years, we have carried out floristic surveys in the forests of the Russian Plain: Usmansky,
Khrenovsky, Buzuluksky and Krasnosamarsky (figure 1).
Usmansky and Khrenovsky pine forests are located in the subzone of the forest-steppe of the Oka
and Don Rivers lowland. Geographically, Usmansky pine forest is located at the junction of 2 regions:
Lipetsk and Voronezh. Its total area is 707.0 km², of which 310.53 km² are included in the state nature
reserve. Khrenovsky pine forest, with an area of 402.1 km², is located 75 km southeast of Usmansky
pine forest on the territory of the Voronezh Region and has the status of a regional reserve.
Buzuluksky and Krasnosamarsky pine forests are located in the steppe zone of the Trans-Volga
region. Krasnosamarsky pine forest (135.5 km²) is part of the ‘Samarsky’ municipal park of the
Samara region. In the southeast of this region, Krasnosamarsky pine forest is connected by a narrow
strip of forest (about 36 km long) along the right bank of the river Samara with Buzuluksky pine
forest, developing on the border of two administrative regions of Samara and Orenburg. Buzuluksky
pine forest occupies an area of 1067.9 km², of which 143.99 km² is a protected zone of a national park
of federal significance.
Scientific research was carried out by the route method, taking into account the whole variety of
biocenoses in the Usmansky (2009–2011), Khrenovsky (2009–2020), Buzuluk (1999–2020) and
Krasnosamarsky (2009–2013) pine forests. The collected plants became the property of the herbarium
collection of the Steppe Institute of the Ural Branch of the Russian Academy of Sciences (ORIS) and
the Institute of Ecology of the Volga Basin of the Russian Academy of Sciences (PVB). Some of the
herbarium specimens were donated to the herbarium of the Voronezh State University (VOR) and the
V L Komarov RAS (LE).
The analysis of literary sources is carried out. On the flora of the pine forests of the Oka and Don Rivers lowland, information has been worked out from the sources: some data on the flora of the part of the Usmansky pine forest located in the Lipetsk region are given [11]; the work [1] is devoted to the flora of the reserved part of the Usmansky pine forest in the Voronezh region. A detailed description of the floristic finds from the Khrenovskoy pine forest is given in the work [12]. Data on alien species inhabiting the territory of the Usmansky and Khrenovskoy pine forests are contained in the works [13-14]. The most detailed information on the flora of the Buzuluksky pine forest is presented in the monograph [15]. The work [16] is fundamental for the flora of the Krasnosamarsky pine forest. This book also contains information about alien elements for the flora of the Trans-Volga region forests.

On the basis of the data obtained, a general floristic list was compiled with the identification of aboriginal and alien fractions, and a floristic core was established. The floristic core consists of species that were reliably recorded in the floras of all the studied pine forests. Parts of the species, for the floras of some pine forests, are aboriginal, while for others they are included in the alien fraction. Therefore, when analyzing the taxonomic structure of the aboriginal and alien fractions of the floristic core, only species were taken into account, which in the studied pine forests have the same belonging to the fraction.

Using the principle of the distribution of species between systematic categories of the highest rank, the taxonomic structure of the general flora and its core, as well as their alien and aboriginal fractions, has been established.

When identifying the features of the character of the taxonomic spectrum of the studied floras, the approaches of A P Khokhryakov [17].

Latin names of vascular plant taxa are given according to S K Cherepanov [18].

3. Results and discussion
The taxonomic structure established for the flora of each pine forest (table 1) made it possible to determine the total floristic richness of the pine forests, composed of 1344 species of 547 genera from 125 families. More than 60.0% of species are concentrated in 14 families (table 2), which include 349...
genera, which is 63.8% of all recorded genera in the flora of the studied pine forests. A significant proportion is accounted for by the aboriginal fraction floras pine forests, where 1055 species from 447 genera of 107 families are counted. The species of only the aboriginal fraction are united in 355 genera of 64 families. The alien fraction of the studied floras is composed of 236 species of 184 genera of 59 families. Here, 92 genera and 15 families contain only alien species. In the flora of the studied pine forests, 34 species are common for the flora of 2 and more pine forests, but belong to different fractions. Also, 19 introduced species from 9 genera of 5 families were registered in the floras of the studied forests massifs areas. The main indicators of the flora of all pine forests and its core are summarized in table 1.

Table 1. The main indicators of the general flora of pine forests and its core.

| Floras pine forests and its fractions | Absolute number of taxa/% of the total flora of all pine forests | The proportion of taxa included in the core (%) |
|---------------------------------------|---------------------------------------------------------------|-----------------------------------------------|
|                                       | species            | genus          | family        | species | genus | family |
| Usmansky total                        | 1076/80.0          | 512/93.6       | 123/98.4      | 38.5    | 54.1  | 69.6   |
| aboriginal                            | 848/80.4           | 401/89.7       | 105/98.1      | 41.5    | 58.1  | 78.1   |
| alien                                 | 216/91.5           | 161/87.5       | 58/98.3       | 19.4    | 24.8  | 43.1   |
| Khrenovskoy total                     | 850/63.2           | 430/78.6       | 108/86.4      | 48.7    | 64.4  | 80.6   |
| aboriginal                            | 718/68.1           | 360/80.5       | 98/91.6       | 49.0    | 64.7  | 83.7   |
| alien                                 | 130/55.1           | 111/60.3       | 43/72.9       | 32.3    | 30.8  | 58.1   |
| Byzylyksky total                      | 794/59.1           | 383/70.0       | 101/80.8      | 52.1    | 72.3  | 86.1   |
| aboriginal                            | 675/64.0           | 327/73.2       | 92/96.0       | 52.1    | 71.3  | 89.1   |
| alien                                 | 112/47.5           | 92/50.0        | 40/67.8       | 37.5    | 43.5  | 62.5   |
| Krasnosamarsky total                  | 674/50.1           | 352/64.4       | 93/74.4       | 61.4    | 78.7  | 93.5   |
| aboriginal                            | 591/56.0           | 306/68.5       | 88/82.2       | 59.6    | 39.4  | 93.2   |
| alien                                 | 80/33.9            | 70/38.0        | 31/52.5       | 52.5    | 50.0  | 80.6   |
| Flora and its fractions               | Flora of all pinus forests (absolute quantity) | The core of the pine forests flora (absolute quantity/% from all flora) |
|                                       | species | genus | family | species | genus | family |
| total                                 | 1344    | 547   | 125    | 414/30.8 | 277/50.6 | 87/69.6 |
| aboriginal                            | 1055    | 447   | 107    | 352/33.4 | 233/52.1 | 82/76.6 |
| alien                                 | 236     | 184   | 59     | 42/17.8  | 40/21.7  | 25/42.4 |

According to the established taxonomic structure (table 2), in the first triad of leading families, in addition to *Asteraceae* and *Poaceae*, there is *Rosaceae*, which indicates the Central European character (As-Po-Ro) of the flora. The Eastern European subtype of flora (Fa-Br-Cy) defines the first family of the second triad - *Fabaceae*. The high position of *Brassicaceae* in the general floristic spectrum was provided by the species of the alien fraction. In the aboriginal fraction of the flora of all pine forests, the *Cyperaceae* family has a more significant position in terms of the number of species. The families *Caryophyllaceae*, *Scrophulariaceae*, *Lamiaceae*, *Apiaceae*, *Ranunculaceae* generally occupy the usual position for pine forests flora in the spectrum and are among the top ten.
Table 2. Leading families by the number of species and genera in the total flora of the studied pine forests.

| Family                  | Number of species | Share of all species | Place | Number of genus | Share of all genus | Place |
|-------------------------|-------------------|----------------------|-------|-----------------|-------------------|-------|
| Asteraceae (As)         | 174               | 12.9                 | 1     | 61              | 11.2              | 1     |
| Poaceae (Po)            | 121               | 9.0                  | 2     | 51              | 9.3               | 2     |
| Rosaceae (Ro)           | 73                | 5.4                  | 3     | 25              | 4.6               | 6     |
| Fabaceae (Fa)           | 67                | 5.0                  | 4     | 23              | 4.2               | 8     |
| Brassicaceae (Br)       | 63                | 4.7                  | 5     | 34              | 6.2               | 3     |
| Cyperaceae (Cy)         | 62                | 4.6                  | 6     | 9               | 1.6               | 12-13 |
| Caryophyllaceae (Ca)    | 59                | 4.4                  | 7     | 26              | 4.8               | 5     |
| Scrophullariaceae (Sc)  | 57                | 4.2                  | 8     | 15              | 2.7               | 10-11 |
| Lamiaceae (La)          | 54                | 4.0                  | 9     | 24              | 4.4               | 7     |
| Apiaceae (Ap)           | 40                | 3.0                  | 10    | 32              | 5.9               | 4     |
| Ranunculaceae (Ra)      | 37                | 2.8                  | 11    | 18              | 3.3               | 9     |
| Chenopodiaceae (Ch)     | 32                | 2.4                  | 12    | 9               | 1.6               | 12-13 |
| Polygonaceae (Po)       | 28                | 2.1                  | 13    | 7               | 1.3               | 14    |
| Boraginaceae (Bor)      | 26                | 1.9                  | 14    | 15              | 2.7               | 10-11 |
| total                   | 893               | 66.4                 | –     | 349             | 63.8              | –     |

It is interesting that Chenopodiaceae appears among the leading families in terms of the number of species in the common pine forests flora. The presence of this family among the leading ones is noted only in the taxonomic spectrum of the alien fraction of the floras. This is probably due to the specifics of economic activity in the forests, which affects the species composition of this family. In the Khrenovskoy pine forest, where logging is underway, about 40% of the species of the Chenopodiaceae family are found in the flora of this forest only, among the studied ones. In the Buzulucksy pine forest, part of the territory is given over to oil production, where secondary overgrowth is mainly due to species of the family of the Chenopodiaceae. Here, 33.3% of all species from the Chenopodiaceae family recorded in the pine forest flora are found only in this forest. In Krasnosamarsky pine forest, 26.3% of the species of Chenopodiaceae were recorded only for the flora of this forest massiv, among the compared ones. Unlike other pine forests, where the share of alien species of this family is high, a significant part of the Chenopodiaceae is aboriginal here, which is associated with the presence of saline landscape elements in the forest.

Of all the species recorded in the floras of the studied pine forests, 414 species from 277 genera of 87 families participate in the composition of the floristic core. The core of the aboriginal flora fraction comprises 352 species from 233 genera of 82 families.

In addition to Asteracea and Poaceae, the first triad of the leading families of the floristic core and its aboriginal fraction includes Rosaceae and Fabaceae (As-Po-Ro + Fa), thus determining the mixed (Central and Eastern European) nature of the flora core. The second triad, defining a subtype of flora, includes the families Caryophyllaceae, Lamiaceae, Scrophullariaceae, and Brassicaceae (Ca-La-Se + Br). In the aboriginal fraction of the flora core of the pine forest, the Brassicaceae family is not included in the second three leaders (Ca-Sc-La). The families of the second triad, among the leading in terms of the number of species, are characteristic of the Eastern European flora, which determines the subtype of the floristic core and its aboriginal fraction (table 3).

In general, the family-species spectrum, both in general for the flora nucleus and its aboriginal fraction, is similar, with the exception of the position of the Brassicaceae family. The latter in the flora of the nucleus is of greater importance, sharing the 7th line of the rating with the Scrophullariaceae family. In the aboriginal fraction of the flora nucleus, this family is not included in the top ten.
Table 3. Leading families by the number of species and genera of the floristic core the studied pine forests in the total flora and its aboriginal fraction.

| Families          | Number of species in the core of the flora (place in the spectrum) | Number of species in the core of the aboriginal flora fraction (place in the spectrum) | Number of genus in the core of the flora (place in the spectrum) | Number of genus in the core of the aboriginal flora fraction (place in the spectrum) |
|-------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------|----------------------------------------------------------------------------------|
| Asteraceae        | 52(1)                                                        | 44(1)                                                                           | 37(1)                                                         | 31(1)                                                                           |
| Poaceae           | 29(2)                                                        | 24(2)                                                                           | 20(2)                                                         | 16(2)                                                                           |
| Rosaceae          | 24(3-4)                                                      | 22(3)                                                                           | 15(6)                                                         | 14(4-5)                                                                         |
| Fabaceae          | 24(3-4)                                                      | 21(4)                                                                           | 13(7-8)                                                       | 11(6-7)                                                                         |
| Caryophyllaceae   | 20(5)                                                        | 19(5)                                                                           | 16(4-5)                                                       | 15(3)                                                                           |
| Lamiaceae         | 19(6)                                                        | 16(7)                                                                           | 16(4-5)                                                       | 14(4-5)                                                                         |
| Scrophullariaceae | 18(7-8)                                                      | 18(6)                                                                           | 7(10)                                                         | 7(9-10)                                                                         |
| Brassicaceae      | 18(7-8)                                                      | 10(12)                                                                          | 17(3)                                                         | 9(8)                                                                            |
| Apiaceae          | 16(9)                                                        | 14(8-9)                                                                          | 13(7-8)                                                       | 11(6-7)                                                                         |
| Ranunculaceae     | 15(10)                                                       | 14(8-9)                                                                          | 8(9)                                                          | 7(9-10)                                                                         |
| Polygonaceae      | 13(11)                                                       | 10(10-12)                                                                        | 5(11)                                                         | 3(12)                                                                           |
| Cyperaceae        | 10(12)                                                       | 10(10-12)                                                                        | 4(12)                                                         | 4(11)                                                                           |
| total             | 258                                                          | 222                                                                              | 171                                                           | 142                                                                             |

While the balance between the floristic core and its aboriginal fraction is maintained in the family-species spectrum, the difference is clearly visible in the family-genus spectrum. Thus, in the core of the flora, due to the high diversity of genera, the *Brassicaceae* family is among the top three leaders, while in the aboriginal fraction the number of genera of this family is less.

The features of the floristic core are also reflected in multi-species genera. Despite the fact that the most diverse genus in the floras of all pine forests is *Carex* (from 36 and 34 in the floras of the Usmansky and Khrenovskoy pine forests, to 22 and 12 in the floras of the Buzuluksky and Krasnosamarsky pine forests, respectively), there are only 7 species of this genus in the floristic core. The largest share of participation in the addition of the floristic core belongs to the genus *Veronica* - 8 (17 and 15 - in the floras of the Usmansky and Khrenovskoy pine forests, 14 and 10 - in the floras of the Buzuluksky and Krasnosamarsky pine forests, respectively). The percentage of species included in the floristic core (6 species from each genus) is high among the genera *Salix, Ranunculus, Rumex, Galium, Artemisia*.

The richness of the genera *Carex, Salix, Veronica, Galium*, and *Ranunculus* is characteristic of boreal floras. The species of these genera, noted in the flora of the studied pine forests, occupy well-humid forest, meadow, water and near-water habitats, which are abundant in the studied forests. They often dominate communities and act as edificators. The genus *Artemisia* is widespread in the extratropical regions of the northern hemisphere with an arid climate. Species of this genus are not typical for forest ecosystems and are more often found in open steppe meadows, in anthropogenically disturbed areas.

The genera *Campanula, Poa* and *Potentilla* have 5 species each. Species of the genus *Campanula* do not form groups, occur sporadically, and are permanent elements of forest and meadow biocenoses of the studied pine forests. Species of the genus *Potentilla* have a wide geographic and ecological range and, even in a pine forest, are not limited to natural censuses, sometimes acting as edificators in disturbed areas in forests. Representatives of the *Poa* genus are mainly confined to areas with cold and temperate climates [19]. In pine forests, species of this genus occupy steppe areas, sometimes acting as dominants of the community. Individual tussocks are found along forest edges, as well as in areas of pine forests that have previously been logged and burned. 4 species in the genera *Equisetum, Chenopodium, Juncus, Lathyrus, Viola, Verbascum, Vicia, Ulmus*. The genera entered the floristic
core with 3 species: Acer, Angelica, Euphorbia, Geum, Inula, Lemna, Persicaria, Populus, Rubus, Sparganium, Thalictrum, Trifolium, Typha.

The core of the alien fraction of the flora is composed of 25 families, 40 genera and 42 species. The most numerous are the families Asteraceae - 7 and Brassicaceae - 6 species. There are 4 species in the Poaceae family. There are 5 families with two species: Chenopodiaceae (Ch), Amaranthaceae (Am), Fabaceae, Lamiaceae and Solanaceae. The rest of the families are represented by one species. The largest number of species in a genus is 2, among them: Atriplex, Amaranthus, Eragrostis, Sonchus. In general, the core of the alien fraction reflects the general character of the alien fraction of the studied pine forests, where the first triad is composed of the families Asteraceae, Poaceae, and Brassicaceae (As-Po-Br). The second triad contains the Chenopodiaceae family [20] (Ch+Am+Fa+La). The presence of Brassicaceae and Chenopodiaceae among the families that determine the nature and subtype of the core of the alien fraction of the flora indicates the influence of the floras of arid regions and the manifestation of proximity to the Turanian flora.

Undoubtedly, the alien faction makes significant adjustments to the formation of modern flora at all levels, including the floristic core.

Special attention should be paid to 18 species from 13 families (Fumariaceae, Pinaceae, Chenopodiaceae, Polygonaceae, Salicaceae, Brassicaceae, Rosaceae, Fabaceae, Apiaceae, Boraginaceae, Lamiaceae, Asteraceae, Poaceae) also registered in all forests, but for some, they are aboriginal, and for others, they are alien. Thus, the aboriginal species of Usmansky and Khrenovskoy pine forests: Fumaria officinalis L., Chenopodium hybridum L., Fallopia convolvulus (L.) A. Love, Capsella bursa-pastoris (L.) Medik., Potentilla supina L., Vicia tetrasperma (L.) Schreb., Lappula squarossa (Rez.) Dum., Dracocephalum thymiflorum L. are alien for Buzuluksky and Krasnosamarsky. On the contrary, alien species in the floras of the Usmansky and Khrenovskoy pine forests: Polygonum aviculare L., Populus alba L., Arabidopsis thaliana (L.) Heynh., Crataegus sanguinea Pall., Pastinaca sativa L., Chondrilla juncea L., Lactuca tatarica (L.) CA Mey., Bromus squarosus L. are aboriginal for the Buzuluksky and Krasnosamarsky pine forests. Pickea abies (L.) Karst. - an alien species for the flora of forest-steppe pine forests and an introduced species in the steppe pine forests.

4. Conclusion
The flora of the pine forest as a whole has a Central European character with an Eastern European subtype. The selected floristic core of the studied pine forests is of a mixed type, combining the Central and Eastern European elements of the flora in an equal volume. A certain correction in the modern development of both the flora of the pine forest as a whole and its core is made by the alien fraction, which shows proximity to the flora of arid territories.

The richness of the overall flora of the pine forests is determined by the flora Usmansky pine forest with the largest number of species, genera and families. The core of the flora is determined by the smallest of the comparable flora of Krasnosamarsky pine forest. The core of the flora of the studied pine forests included only 30.8% of the species from the total flora. Undoubtedly, an increase in the number of analyzed floras and their gradation according to certain characteristics (areas, the presence of a conservation status, etc.), floristic monitoring will bring greater accuracy to the determination of the floristic core of pine forests. This will make it possible to form an understanding of the pine forest flora of the Russian Plain at the southern limit of the distribution of Pinus sylvestris as a single floristic complex with certain taxonomic and ecological characteristics.

Acknowledgement
The study is prepared as part of Institute for Steppe Research Theme # GR AAAA-A21-121011190016-1.

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