Adventive component flora of the southern part of Sakhalin Island

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Abstract. The article is devoted to the adventive flora of the southern part of Sakhalin Island. Nowadays, 274 species of adventive plants, belonging to 192 genera and 57 families, have been identified here. Five families (Amaranthaceae, Cannabaceae, Commelinaceae, Linaceae, and Malvaceae) are represented by invasive species only. The structure of the leading families and genera is analyzed, the participation of adventive species information of plant communities is indicated. Adventive species are classified into life forms, method of entering and degree of naturalization.

1. Introduction
The adventive component of flora is a dynamic system constantly being in the stage of active formation, both due to the deliberate, targeted bringing of new plant species during the introduction or formation of modern agricultural crops, and their accidental entering. In the past half century, a sharp increase in the rate and extent of invasion of alien species into natural landscapes has been observed all over the world. The expansion of adventive elements occurs beyond any boundaries and, as a result, leads to the transformation of local plant communities, contamination of the genetic fund of populations of native plant species and poses a threat to the conservation of biological diversity in general [1, 2].

Invasive plants, being part of the adventive component, are distinguished by their ability to quick settling and development a wide range of ecotopes. Therefore, the identification of adventive plant species, as well as monitoring of their distribution and abundance, is extremely important and relevant, since they can not only disrupt the development and balance of natural plant communities and lead to pollution of the genetic fund of local populations, but also become malicious weeds over time. The study of alien species, including invasive or potentially invasive ones, in recent decades has become one of the important directions of fundamental and applied works [3].

The number of regions of our country has the lists of stranger plants with the greatest danger to the health of people and domestic animals. For the European part of Russia, “The Black Book” was published including the characteristics of widespread and aggressive alien plant species [3]. Along with this, in some cities and regions of the Far East, adventive taxa have already been made known [4–8]. However, very little attention is still paid to the study of the adventive component of the flora on Sakhalin Island, and it is of a fragmentary nature, despite the fact that certain efforts are being made in this direction [9–13]. Regarding this fact, the purpose of this work is to analyze adventive plant species in the southern part of Sakhalin Island, the natural landscapes of which have been most transformed over the past century.
2. Materials and methods
Studies of the adventive flora of the southern part of Sakhalin were carried out in 5 geobotanical regions of the island [14], from its southern tip to the Poyasok isthmus. Administratively, this part of Sakhalin covers Tomarinsky, Dolinsky, Kholmsky, Anivsky, Yuzhno-Sakhalinsky, Korsakovsky and Nevelsky regions, which are the most economically developed.

Field studies of the adventive flora of the southern part of Sakhalin Island were carried out during the spring, summer and autumn seasons of 2018–2021, using the method of route-floristic description of the territory. They were accompanied by the collection of herbarium specimens for further identification. Studies of the most economically developed settlements were carried out repeatedly at different times of the growing season: Korsakov, Prigorodnyoe, Okhotskoye, Aniva, Nevelsk, Kholmsk, Yuzhno-Sakhalinsk, Novo-Aleksandrovsk, Lugovoye, Dolinsk, Sokol, Vzmyorye, Tomari, Ilyinskoje, etc. Particular attention was paid to the areas of the most intensive entering and concentration of adventive plants – railway stations, seaports, man-made territories, wastelands, landfills for solid waste, roadsides and railways, parks and squares, summer cottages, vegetable gardens and agricultural fields.

To analyze the adventive fraction of the flora, published works on the diversity and distribution of vascular plants on Sakhalin Island [15, 16], materials from the herbarium of the IMGG FEB RAS were critically worked out, and our own field studies were carried out.

The selection of adventive species by the method of entering and the degree of naturalization was carried out according to the system of F.G. Schroeder [17]. Xenophytes, ergaziophytes, and xenorgaziophytes were distinguished according to the method of entering of adventive plants, and ephemerophytes, colonophytes, epecophytes and agriophytes were distinguished according to the degree of naturalization. The analysis of life forms of plants is given according to the classifications of C. Raunkiaer [18].

3. Results of researches
Nowadays, as a result of researches, it has been established that the adventive fraction of the flora of South Sakhalin includes 274 species of vascular plants from 192 genera belonging to 57 families. Among them, the largest family is Asteraceae, which includes 36 genera and 51 species, it is 18.6% of the total number of species of adventive flora in the southern part of the island. The most common representatives of this family are Achillea millefolium L., Arctium tomentosum Mill., Artemisia vulgaris L., Conyza canadensis (L.) Cronq., Gnaphalium sylvaticum L., Lepidotheca suaveolens (Pursh) Nutt., Leucanthemum vulgare Lam., Pilosella aurantiaca (L.) F.W. Schultz et Sch. Bip., Senecio vulgaris L., Taraxacum officinale Wigg. and others. After Asteraceae there are such families as Poaceae – 14.6%; Fabaceae – 9.5%; Brassicaceae – 6.9%; Polygonaceae – 5.1%; Caryophyllaceae – 4.4%, Scrophulariaceae – 4.4%, etc. The taxonomic characteristic of 10 leading families of the adventive flora of the studied area is shown in table 1.

| № | Family            | Quantity of species | Share of participation, % | Quantity of genera | Share of participation, % |
|---|-------------------|---------------------|---------------------------|-------------------|---------------------------|
| 1 | Asteraceae        | 51                  | 18.6                      | 36                | 18.8                      |
| 2 | Poaceae           | 40                  | 14.6                      | 26                | 13.5                      |
| 3 | Fabaceae          | 26                  | 9.5                       | 13                | 6.8                       |
| 4 | Brassicaceae      | 19                  | 6.9                       | 16                | 8.3                       |
| 5 | Polygonaceae      | 14                  | 5.1                       | 10                | 5.2                       |
| 6 | Scrophulariaceae  | 12                  | 4.4                       | 10                | 5.2                       |
| 7 | Caryophyllaceae   | 12                  | 4.4                       | 7                 | 3.6                       |
| 8 | Rosaceae          | 8                   | 2.9                       | 7                 | 3.6                       |
| 9 | Lamiaceae         | 6                   | 2.2                       | 5                 | 2.6                       |
| 10| Pinaceae          | 6                   | 2.2                       | 3                 | 1.6                       |
| Total: | 194              | 70.6                | 133                       | 69.3              |

Table 1. Spectrum of 10 leading families of adventive flora of South Sakhalin.
The first triad of families includes 117 species of adventive plants, and the leading 10 families cover 194 species, or 70.6% of the total number of taxa. As a whole the adventive flora of the southern part of Sakhalin is represented by 57 families, and 5 families, such as Amaranthaceae, Cannabaceae, Commelinaceae, Linaceae and Malvaceae, contain exclusively strangers. In this case, the multi-species genera are Trifolium (include 7 species), Poa (6), Veronica (5), Vicia (4). The rest of the genera include 3 or fewer species.

Analysis of the structure of adventive plant species due to life expectancy showed that perennial plants include 148 species, and juveniles (one- and biennials) – 126 species. All the main life forms are represented in the adventive flora of South Sakhalin, their ratio is shown in figure 1.

**Figure 1.** The ratio of life forms of the adventive flora of the southern part of Sakhalin.

In the adventive flora of the southern Sakhalin, hemicryptophytes predominate and cover 117 species (43%); therophytes – 106 (39%); phanerophytes – 37 (13%) and hamefits – 3 types (1%).

Introduced species of trees and shrubs (phanerophytes) are of great environmental and aesthetic importance in the urban environment. In the first half of the last century, Juglans mandshurica Maxim., Pinus koraiensis Siebold et Zucc., Populus nigra L., Salix koriyanagi Kimura ex Goerz, were planted on the streets of Yuzhno-Sakhalinsk, many of which have survived to our time. In the Soviet period, such out-of-district trees and shrubs species as Acer platanoides L., A. negundo L., Caragana arborescens Lam., Fraxinus pennsylvanica Marsh., Padus maackii (Rupr.) Kom., Physocarpus opulifolius (L.) Maxim., Pinus sylvestris L., Populus alba L., Robinia pseudoacacia L. and etc. were widely used in the greening of the regional capital [19]. The modern dendroflora of Sakhalin is represented by 37 strangers, which is 13% of the adventive component of the flora of South Sakhalin.

The overwhelming majority of adventive species have successfully established themselves in communities on anthropogenically disturbed landscapes. According to the degree of naturalization, four groups are distinguished, and according to the method of entering – three groups (table 2). We excluded phanerophytes from the group according to the degree of naturalization because of their use only in local areas, mainly for greening urban areas, therefore, rarely spreading beyond their original habitat, with the exception of some species, for example, *Acer negundo*.

**Table 2.** The ratio of adventive species in the flora of South Sakhalin according to the degree of naturalization and the method of entering.

| Group of species on a way | Quantity of species | % of the total number of adventive species |
|--------------------------|---------------------|-------------------------------------------|
| Naturalizations:         |                     |                                           |
| Epecophytes              | 140                 | 59.1                                      |
| Colonophytes             | 66                  | 27.8                                      |
| Ephemero phytes          | 11                  | 4.7                                       |
| Agriophytes              | 20                  | 8.4                                       |
| Total:                   | **237**             |                                           |
| Immigrations:            |                     |                                           |
| Xenophytes               | 162                 | 59.1                                      |
| Ergaziophytes            | 97                  | 35.4                                      |
| Xenoergaziophytes        | 15                  | 5.5                                       |
| Total:                   | **274**             |                                           |
Ergaziophytes were introduced into cultivation in different periods of urbanization as decorative, used for greening cities, or food and forage plants (Acer negundo, Fraxinus pennsylvanica, Heracleum sosnowskyi Manden., Lupinus nootkatensis Donn ex Sims, Solidago canadensis L. and others). Here, the Heracleum sosnowskyi should be especially noted, which was brought to Sakhalin in 1962 to create a highly productive silage culture and improve the fodder base of the livestock complex [20]. Possessing strong grow power, abundant seeding and high competitive ability, it quickly captured many disturbed areas, wastelands and formed single-species cenopopulations, and at the same time, actively displacing native species. Some species of cereals and legumes were brought to Sakhalin by Japanese (from 1905 to 1945) and Russian (starting from the second half of the 20th century) settlers. First of all, these were forage grasses, Anthoxanthum odoratum L., Dactylis glomerata L., Phleum pratense L., Poa pratensis L., Trifolium repens L., T. pratense L., etc. [19].

Among the adventive plants of South Sakhalin, more than 20 species have acquired an invasive status, which have successfully adapted to local natural and climatic conditions, quickly spread around the island and develop new types of habitats, have a high reproductive potential, actively compete not only with synanthropic, but also with meadow, floodplain and forest native species in anthropogenically transformed communities [16].

The adventive species in the studied area occupy different ecotopes. The most active formation of local cenopopulations of adventive plants occurs in ruderal habitats and disturbed meadows (Cerastium holosteoides Fr., Galium spurium L., Leucanthemum vulgare, Lupinus nootkatensis, Pilosella aurantiaca, Rhinanthus minor L., Trifolium pratense, etc.); on ravines and ditches (Berteroa incana (L.) DC., Impatiens glandulifera Royle (figure 2), Heracleum sosnowskyi); in vegetable gardens and arable lands (Brassica campestris L., Galinsoga parviflora Cav. (figure 2), Spergula arvensis L., Stellaria media (L.) Vill.), as well as on the sides of roads and railways (Conyza canadensis, Heracleum sosnowskyi, Hordeum jubatum L., Linaria vulgaris Mill., Reynoutria japonica Houtt., etc.). They grow not only in anthropogenically transformed habitats, but often appear in weakly disturbed plant communities, forming monodominant groups.

At the first stages of dispersal, plants are found only singly, then their local groups appear, which, gradually expanding their occupied areas, form already closed thickets. For example, Galega orientalis Lam. was noticed in 1992 on the territory of the Botanical Garden in Yuzhno-Sakhalinsk with two small groups, and then the population increased approximately threefold. In
2006, individual samples were found in the northwestern part of the island on the line of the main oil and gas pipeline. Apparently, the seeds were introduced under the biological recultivation by grass mixtures [21]. Nowadays several more new localities of Galega orientalis have been noted on the road section Bereznyaki-Yuzhno-Sakhalinsk, as well as on the outskirts of agricultural fields. Along with this, further active spread of Pastinaca sylvestris Mill. and Inula helenium L. should be noted outside their primary habitats. Of course, the process of plant immigration is ongoing, and the flora is replenished with new taxa. This is evidenced by the identification of new adventive species in the flora of Sakhalin Island.

4. Conclusion

1) The adventive component, as the most dynamic part of the flora, is constantly being replenished with new species. Nowadays, the adventive flora of the southern part of Sakhalin Island includes 274 species of higher vascular plants belonging to 192 genera and 57 families. Five families are represented only by invasive species – Amaranthaceae, Cannabaceae, Commelinaceae, Linaceae, and Malvaceae.

2) Analysis of the species structure of the adventive flora of the southern Sakhalin showed that the Asteraceae families cover 51 species (18.6 %) and 36 genera, Poaceae – 40 species (14.6 %) and 26 genera, Fabaceae – 26 species (9.5 %) and 23 genera, Brassicaceae – 19 species (6.9 %) and 16 genera and Polygonaceae – 4 species (5.1 %) and 10 genera.

3) According to the ratio of life forms in the adventive flora of the southern part of Sakhalin, hemicryptophytes (117 species) predominate and therophytes (106 species). The dominant group due to the way of immigration occurred xenophytes (162 species), and according to the degree of naturalization, epecophytes predominate (140 species).

4) Adventive species are mainly confined to ruderal habitats, they are often found along roadsides, in settlements, in the place of abandoned settlements, and some of them have penetrated into natural cenoses and become invasive.

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