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ALIEN SPECIES OF VASCULAR PLANTS IN PLANT COMMUNITIES OF THE MIDDLE TAIGA OF THE ARKHANGELSK REGION

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In this article we discuss the distribution of alien species in the vegetation cover of the middle taiga of the Arkhangelsk Region. This is a relevant problem that has not been studied so far. We used the data of long-term biogeographic studies obtained from the Ustyanskaya Educational and Research Station located in the Arkhangelsk Region, M.V. Lomonosov Moscow State University, Faculty of Geography; as well as our own field materials for 2019-2022. We determined the composition of alien plant species in the study area and analyzed their taxonomic belonging, as well as their ecological and geographical characteristics. We used traditional methods of botanical-geographical field survey and desk processing of collected data, coupled with a list of scientific publications written on the role of alien species in plant communities. Moreover, we analyzed the ecological ranges of species based on D.N. Tsyganov's ecological scales and mapped the mass occurrence of the most widespread alien species in the key sites of the study area. The results of this study revealed that alien species in the vegetation cover of the middle taiga of the Arkhangelsk Region currently account for about 9% of the floristic list, most of them being introduced into the region intentionally during agricultural activities. The taxonomic spectrum of such species is mostly represented by Asteraceae, Fabaceae and Brassicaceae families that are common in North America and Asia. In terms of coenotic aspects, these species are distributed mainly in floodplain and upland meadows communities, in fallow lands, secondary forests, anthropogenic coenoses of residential areas, along the roads. Most of these species grow in the middle taiga due to the presence of large river valleys, a well-developed agriculture and a railroad network.

Keywords: alien plant species, taxonomic composition, ecologic and coenotic composition, geographical elements, ecological scales, plant communities.
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The invasion of alien plant and animal species is a global environmental problem that greatly damages ecosystems, agriculture and human health. Moreover, it is aggravated by another global issue as the biodiversity loss and, therefore, the loss of ecosystem functions of biodiversity. Many foreign scientific works (Elton, 1960; Brown, Peet, 2003; Richardson et al., 2000) as well as the Russian ones (Berezutsky, 2009; Tishkov, 2005; Morozova, Tsarevskaya, 2010; Reshetnikova et al., 2019) study alien plant species, while the measures to combat their invasion are part of the most important international documents, such as "The Convention on Biological Diversity" (1993) or "Pan-European Biological and Landscape Diversity Strategy" (1995). In 2009, Russia started to compile Black Data Books with generalized biological features and dynamics of the alien species invading from the study region and developing secondary ranges (Vinogradova et al., 2010). Sever years later, Black Data Books of the Tver Region (Vinogradova et al., 2011), Siberia (Black Data Book ..., 2016), and Kaluga Region (Reshetnikova et al., 2019) were also published.

A number of concepts and terms was introduced and established by the papers that study alien plant species (Baranova et al., 2018; Akatov et al., 2009; Alien ..., 2010). An important part in the

study of the alien species behavior in new territories is their behavior and introduction into natural ecosystems, i.e. naturalization or, in other words, the process of alien species overcoming various obstacles, and their ability to adapt and reproduce in new geographical and ecological conditions (Khorun, Kazakova, 2013). It is known that the efficiency of such species entering new ecosystems depends on the properties of said ecosystems, which, in turn, is part of the "ecosystem invasive susceptibility" concept, i.e. a set of characteristics of an ecosystem (community, habitat) that determines the introduction and development possibilities of alien species within it (Baranova et al., 2018).

Thus, identification and cataloguing of alien species in a certain territory, study of their ecological and cenotic features and assessment of the possibilities of their introduction into natural communities are required to prevent their negative impact on the environment. It is important to keep in mind that the problem of their introduction into taiga regions of Russia, including the Arkhangelsk Region, is still severely uncharted. Agricultural and forestry development of the central sector of the middle taiga in European Russia takes a long time, especially along the valleys of such large rivers as the Northern Dvina, Vaga and Ustya. However, this development accelerated in the 20th century as the volume and rate of forest clearing increased, followed by the agricultural load, such as dairy and crop farming.

The aim of this study is to identify the composition, ecological and geographical characteristics of alien species in the vegetation cover of the middle taiga of the Arkhangelsk Region, and to determine the possibilities of introducing such species into natural ecosystems.

Materials and Methods

Ustyanskaya Educational and Research Station of M.V. Lomonosov Moscow State University is located in the Zayacheritsky Pogost Village, Ustyansky District, Arkhangelsk Region (N 60° 53' 45", E 43° 12' 54"). Our study took place on several key sites around the station and within the district itself (Fig. 1). This territory lies in the interfluve of the Vaga River tributaries, the Ustya and Kokshenga Rivers, on the Ustyansky Plateau that was formed by marls, sands, dolomites and Permian limestones, covered with relatively shallow quaternary deposits, such as glacial boulder loams, glaciolacustrine loams and loamy sands, as well as fluvioglacial sands and Moscovian loamy sands. The soddy carbonate soils are distributed due to the patches of surface carbonate rocks; the podzolic soils are climatic (Khoroshev, 2005). The local climate is temperate continental, with long cold winters and moderately warm summers. Hydrologically, the territory is a well-drained plain, with a good ground runoff and a dense, developed network of large and small rivers, a specific feature of which is the fact that their valleys are embedded in the former channels of glacial meltwater streams and glaciolacustrine depressions, formed by fluvioglacial deposits. Thus, the size and embedment of river valleys even for small rivers (e.g., the Zayachya River) are quite significant. However, the increased humidity factor and peculiar geological structure cause large oligotrophic swamps to form in the vast watershed areas (Gorbunova et al., 2014).

The vegetation cover of the study area is dominated by different types of taiga forests formed by a spruce hybrid (*Picea* x *fennica* (Regel) Kom) and the Scots pine (*Pinus sylvestris* L.). Secondary forests are formed mainly by silver (*Betula pendula* Roth) and downy birches (*B. pubescens* Ehrh.), and sometimes by aspen (*Populus tremula* L.) and grey alder (*Alnus incana* (L.) Moench). Moreover, there can be found occasional and mostly afforested swamps, as well as meadow communities located in river floodplains. Due to the wide distribution of fertile soddy carbonate soils, the south of the Arkhangelsk Region has been well-developed for a long time now. Upland meadows are formed on the watersheds of former agricultural lands, transforming later into forest communities. The deciduous species are the main reason of overgrowing, changing the natural structure of forest communities. In the center and north of the Ustyansky District,

deforestation causes a great impact on the natural complexes. The area near the Arkhangelsk–Konosha–Kotlas Railroad is transformed the most.

Thus, the vegetation cover of the study territory is diverse and highly modified by anthropogenic impact (Gusev, 1974; Flora and Fauna of the Middle Taiga ..., 2003; Gorbunova et al., 2014). Long-term agricultural and forestry development, as well as a thick road and railroad network increase the possibility of alien plant species to penetrate and take root in this territory. In nature, this process is facilitated by the developed river network with large river valleys that stretch in meridional direction, and diverse soil cover with occasional fertile soils that are not typical for taiga.

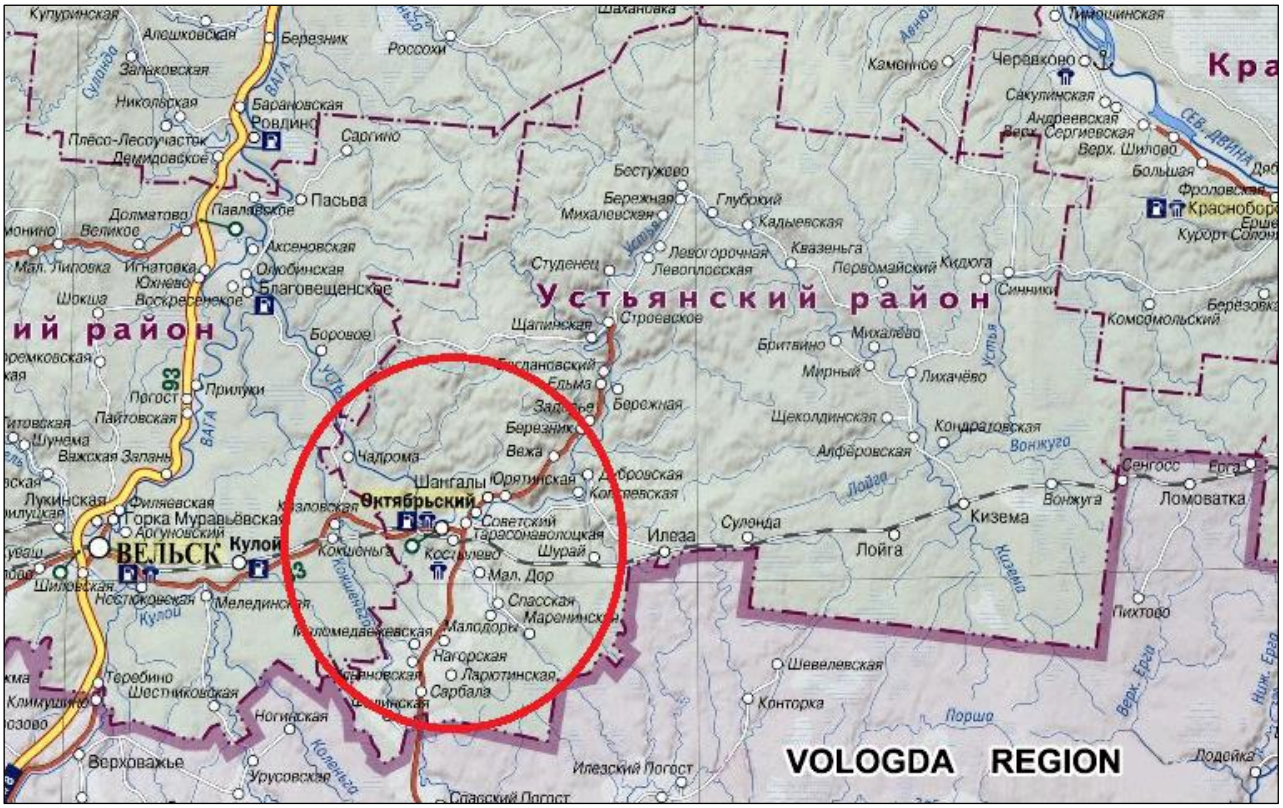

Fig. 1. The study area (circled) on the contemporary map of the Arkhangelsk Region.

We studied alien species in the south of the region by analyzing numerous publications on the local flora, such as “Flora of the North-East of the European part of the USSR” (1974), “Flora of the Arkhangelsk Region” (Schmidt, 2005), “Flora and Fauna of the Middle Taiga of the Arkhangelsk Region …” (2003). To determine the ranges of the studied species, we used O.V. Morozova’s database “Alien Species on the Territory of Russia” (2010), as well as some works on alien species and their cultivation in the said region (Mishurov et al.; 1999; Konovalova et al., 2013).

For this paper we used 102 modern geobotanical releves (from 2019 to 2022) of plant communities where the alien species were present at the key sites of Ustyansky District, Arkhangelsk Region, made according to the standard methodic (Methods …, 2002) for the main types of communities common for the territory. We also included 280 geobotanical releves made by the Department of Biogeography during the field works in the Ustyansky District in the 1990-2000s, and used them to study the distribution dynamics of alien species in the area. Additionally, we used our own notes on findings of alien species along roadsides.

We used D.N. Tsyganov's ecological scales (1983) to describe the ecological characteristics of alien species and their belonging to various ecological groups. Taxonomic affiliation of vascular plant species is given according to Plantarium, an open online galleries and plant identification guide (2023), while ecological and coenotic characteristics are provided according to "Flora of Vascular Plants of Central Russia" (2004). The constancy index of species participation in a certain community type was calculated according to the known methods (Methods ..., 2002) as a share of geobotanical releves with certain species in the total number of releves of one community type. Topographic maps (scaled 1:10,000 and 1:25,000) of the fieldwork area were used to show the distribution of communities containing alien species; a schematic map of the alien species abundance within the 2 key sites was compiled in QuantumGIS.

Results and Discussions

The modern floristic composition of the study territory lists 547 species from 79 families (Eremeeva, Leonova, 2022). After analyzing a number of literary sources (Flora of the North-East …, 1974; Flora and Fauna of the Middle Taiga …, 2003; Schmidt, 2005; Alien Species …, 2010), we found out that the alien species were represented by 48 vascular plant species from 19 families. The most well represented is the Fabaceae family with 9 species, e.g. large-leaved lupine (*Lupinus polyphyllus* Lindl.) and fodder galega (*Galega orientalis* L.). It is followed by Asteraceae with 7 species, e.g. common chicory (*Cichorium intybus* L.) and Canada goldenrod (*Solidago canadensis* L.). The third family is Rosaceae with 6 species, e.g. Japanese rose (*Rosa rugosa* Thunb.) and apple tree (*Malus domestica* Borkh.). Generally, in the study territory these species are represented by one in each genus, with the exception of *Epilobium* and *Artemisia*, represented by 2 species: estragon (*Artemisia dracunculus* L.) and sagebrush (*A. sieversiana* Willd.); American (*Epilobium adenocaulon* Hausskn.) and northern willow-herb (*E. pseudorubescens* A.K. Skvortsov).

After analyzing the complete list of local flora, we established that alien species account for 9% of the total flora of the study territory. In general, Poaceae, Cyperaceae and Asteraceae are the dominant ones, which is common for the Boreal floristic region (Tolmachev, 1974), while Fabaceae, Asteraceae, Rosaceae and Brassicaceae are the dominant ones among alien species (Fig. 2).

The species that have invaded this region origin mainly from North America (11 species), Asia (10 species) and Europe (8 species), while almost half of them are widely distributed on several continents (Fig. 3). A complete list of registered species and their natural ranges is given in Table 1.

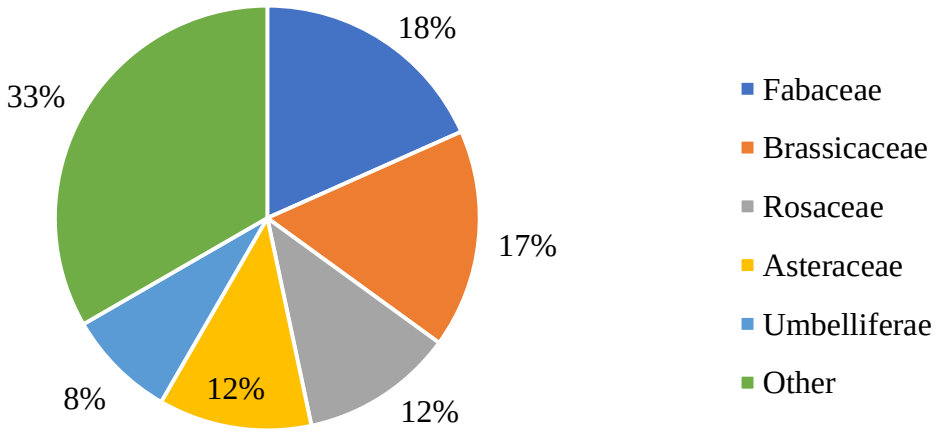

Fig. 2. Taxonomic composition of alien plant species in the study area.

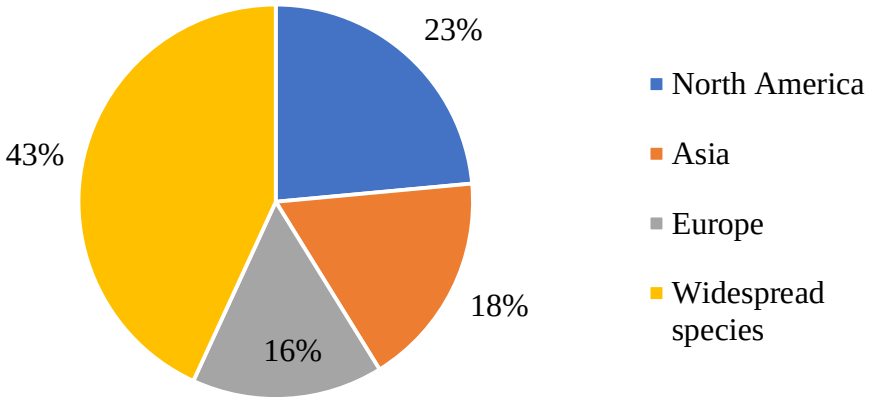

Fig. 3. Regions of origin of alien plant species.

Table 1. Alien plant species of the middle taiga of the Arkhangelsk region (Flora of the North-East ..., 1974; Flora and Fauna of the Middle Taiga ..., 2003).

Latin name	Common name	Family	Range
Acer negundo L.	Manitoba maple	Sapindaceae	North America
Aconitum napellus L.	Garden monkshood	Ranunculaceae	Europe (almost entire Europe outside of Russia)
Amelanchier spicata K. Koch.	Low juneberry	Rosaceae	Atlantic-North American floristic region
Anethum graveolens L.	Dill	Apiaceae	Asia (Anatolia, Iran, Himalayas), North Africa
Anthyllus macrocephala Wender.	Common kidneyvetch	Fabaceae	Europe (forest steppe and European steppes)
Arctium tomentosum Mill.	Woolly burdock[	Asteraceae	Europe (south of the former European USSR, Mediterranean Basin, Western Europe), Asia (Caucasus, Soviet Central Asia, Siberia, Far East)
Armoracia rusticana P.G. Gaerth.	Horseradish	Brassicaceae	Europe (southern regions), Asia (Caucasus, Southern Siberia)
Artemisia dracunculus L.	Wild tarragon	Asteraceae	Europe, Asia (steppes)
Artemisia sieversiana Willd.	Sieversian wormwood	Asteraceae	Asia (Siberia, Southern Far East, Soviet Central Asia, Mongolia, China)
Atriplex patula L.	Spear saltbush	Amaranthaceae	Europe, Caucasus, Anatolia, Siberia, North Africa, North America

Continuation of Table 1.

Latin name	Common name	Family	Range
Berteroa incana L.	False hoary madwort	Brassicaceae	Europe, Asia (forest steppe)
Bunias orientalis L.	Turkish wartycabbage	Brassicaceae	Western and Central Europe, Caucasus, Crimea, Anatolia, Soviet Central Asia, Western Siberia, all of the former European USSR except for its north
Calystegia inflata Sweet	Hedge bindweed	Convolvulaceae	Asia (Far East), USA, Australia
Calystegia sepium	Hedge false bindweed	Convolvulaceae	Asia (Far East), USA, Australia
Caragana arborescens Lam.	Siberian peashrub	Fabaceae	Asia (steppes)
Cichorium intybus L.	Common chicory	Asteraceae	Europe (Mediterranean Basin)
Conium maculatum L.	Poison hemlock	Apiaceae	Europe (Central and Southern), Asia (Caucasus, Anatolia and West Asia, Kazakhstan, China, Southern Siberia)
Echium vulgare L.	Blueweed	Boraginaceae	Europe (forest steppe and steppes), Asia (Caucasus, Anatolia, Soviet Central Asia, south of the Western Siberia)
Elodea canadensis Michx.	American waterweed	Hydrocharitaceae	North America
Epilobium adenocaulon Hausskn.	American willowherb	Onagraceae	North America (Rocky Mountains)
Epilobium pseudorubescens A.K. Skvortsov	False rosebay willowherb	Onagraceae	North America
Erigeron canadensis L.	Canadian horseweed	Asteraceae	North America
Erysimum cheiranthoides L.	Wormseed mustard	Brassicaceae	Europe (Central Europe and Atlantic Region), Asia (Caucasus, Soviet Central Asia, Siberia, Far East), North Africa, North America
Euphorbia cyparissias L.	Cypress spurge	Euphorbiaceae	Europe (Southern and Central)
Galega orientalis Lam.	Eastern galega	Fabaceae	Asia (Caucasus and South Caucasus)
Geranium sibiricum L.	Siberian cranesbill	Geraniaceae	Asia (Siberia, Far East)

Continuation of Table 1.

Latin name	Common name	Family	Range
Heracleum sosnowskyi Manden.	Sosnowsky's hogweed	Apiaceae	Caucasus
Impatiens glandulifera Royle	Himalayan balsam	Balsaminaceae	Asia (Western Himalayas)
Lathyrus tuberosus L.	Tuberous pea	Fabaceae	Europe (Central Europe, Mediterranean Basin), Asia (Anatolia, Caucasus, Soviet Central Asia, Western Siberia)
Lepidium densiflorum Schrad.	Prairie peppergrass	Brassicaceae	North America
Lotus komarovii Miniaev	Bird's foot trefoil	Fabaceae	Southern Far East
Lupinus polyphyllus Lindl.	Large-leaved lupine	Fabaceae	North America (Rocky Mountains)
Malus domestica Borkh.	Apple tree	Rosaceae	Asia (Soviet Central and East Asia, Caucasus, Far East)
Matricaria discoidea DC.	Wild chamomile	Asteraceae	North America
Medicago varia Martyn	Hybrid alfalfa	Fabaceae	Europe, Asia, Africa (Mediterranean Basin)
Melilotus officinalis L.	Sweet yellow clover	Fabaceae	Europe (Western Europe, south of the former European USSR), Asia (Anatolia, Central and Soviet Central Asia, Iran, Western Siberia)
Papaver somniferum L.	Opium poppy	Papaveraceae	Europe (Mediterranean Basin)
Pastinaca sativa L.	Wild parsnip	Apiaceae	Europe (Central Europe, Mediterranean Basin), Asia (Siberia, Caucasus)
Physocarpus opulifolia (L.) Maxim.	Common ninebark	Rosaceae	North America
Populus alba L.	Silver poplar	Salicaceae	Europe (southern regions), Asia (south of the Western Siberia, Iran, Central Asia)
Potentilla multifida L.	Feather-leaved cinquefoil	Rosaceae	Europe (south-east), Asia (Soviet Central, Central and East Asia, Siberia)
Rosa rugosa Thunb.	Japanese rose	Rosaceae	Asia (Far East)
Sambucus racemosa L.	Red elderberry	Adoxaceae	Europe (mountainous regions)
Saponaria officinalis L.	Common soapwort	Caryophyllaceae	Asia (China)

Continuation of Table 1.

Latin name	Common name	Family	Range
Sisymbrium wolgense M. Bieb	Russian mustard	Brassicaceae	Europe (Lower Volga and Lower Don)
Solidago canadensis L.	Canada goldenrod	Asteraceae	North America (Sonoran floristic region and Rocky Mountains)
Spiraea media Schmidt	Spirea	Rosaceae	Europe (south-east of the Western Europe, south-west of the former European USSR), Asia (Soviet Central Asia, Siberia, Far East)
Vicia sativa L.	Common vetch	Fabaceae	Europe (Mediterranean Basin)

Ecological characteristic is an important part of the study of alien plant species and their potential introduction into natural communities. According to the ecological scales of D.N. Tsyganov (1983), widely used in works on geobotanic and bioindication, such species in our study area were divided in 3 ecological groups by their increasing demand for nitrogen level in soil: *seminitrophilic*, *subnitrophilic* and *nitrophilic*.

The *seminitrophilic* group includes species that grow on relatively nitrogen-poor soils: *Amelanchier spicata*, *Berteroa incana*, *Euphorbia cyparissias*, *Melilotus officinalis* and *Vicia sativa*. The *subnitrophilic* group includes species that grow on adequately nitrogen-rich soils: *Artemisia dracunculus*, *Caragana arborescens*, *Cichorium intybus*, *Impatiens glandulifera*, *Lupinus polyphyllus* and *Populus alba* (Table 1). The *nitrophilic* group includes species that grow on nitrogen-rich soils: *Sambucus racemosa*, *Arctium tomentosum*, *Armoracia rusticana* and *Solidago canadensis*. Among alien species, the *subnitrophilic* and *nitrophilic* ones are prevalent.

The groups of alien species with different requirements to the humidity factor can be classified as follows:

1) humid-steppe with species gravitating to an insignificant deficit of moisture, such as *Artemisia dracunculus*, *Cichorium intybus*, *Euphorbia cyparissias*, *Melilotus officinalis*;

2) subforest-meadow, which is a transitional group between humid-steppe and dry forest-meadow, including the only species – *Berteroa incana*;

3) dry forest-meadow with mesophytic species gravitating to sufficient moisture, such as *Amelanchier spicata*, *Lupinus polyphyllus*, *Vicia sativa*;

4) fresh forest-meadow, which is a transitional group between dry forest-meadow and humid forest-meadow, with such species as *Arctium tomentosum*, *Caragana arborescens*, *Geranium sibiricum*, *Populus alba*, *Solidago canadensis*;

5) humid forest-meadow with permezophytic species gravitating to a slight excess of moisture: *Aconitum napellus*, *Sambucus racemose*;

6) humid forest-meadow, which is a transitional group between humid forest-meadow and wet forest-meadow, including the only species – *Armoracia rusticana*;

7) wet forest-meadow with hygrophytic species inhabiting subaquatic landscapes, such as *Impatiens glandulifera*;

8) shallow-water with hydrophytic species that are partially or completely submerged, such as *Elodea canadensis*.

Thus, alien species have very different requirements, but the fresh forest-meadow group includes the most species, e.g. *G. sibiricum* and *P. alba*. For clarity, their requirements in the

ecological space can be represented in graphs that show the ecological ranges of some alien species depending on soil moisture and nitrogen richness of the soil (Fig. 4).

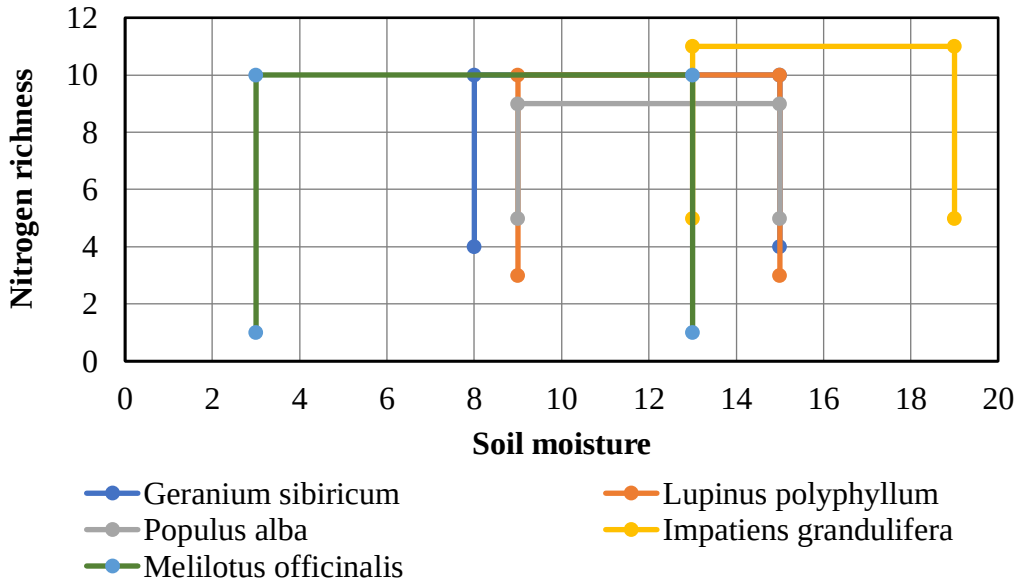

Fig. 4. Ecological ranges of *Geranium sibiricum*, *Impatiens glandulifera*, *Lupinus polyphyllus*, *Melilotus officinalis* and *Populus alba* according to D.N. Tsyganov's scales.

Our analysis showed that many alien species can grow under a wide range of conditions, e.g. *Solidago canadensis*, *Melilotus officinalis* and *Artemisia dracunculus*. Meanwhile, *Sambucus racemosa*, *Populus alba*, *Aconitum napellus* and *Impatiens glandulifera* are the most demanding ones (Fig. 5).

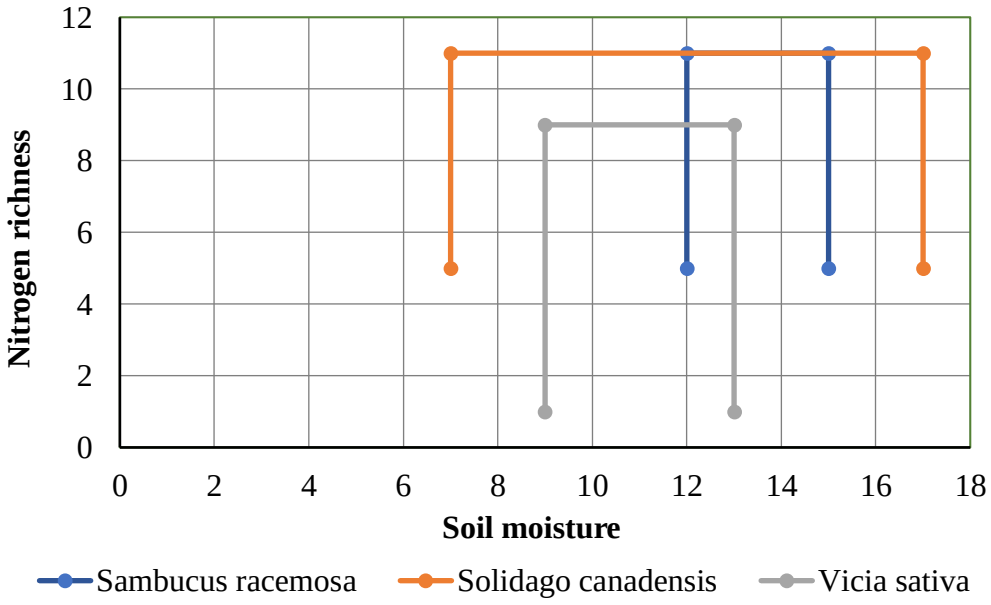

Fig. 5. Ecological ranges of *Sambucus racemosa*, *Erigeron canadensis* and *Vicia sativa* according to D.N. Tsyganov's scales.

Coenotic role of alien species. The distribution of such species in the study area occurs within the following types of plant communities: secondary forests (pine forests, coniferous-small-leaved and small-leaved forests), floodplain meadows, upland meadows and fallows, recovering clearings, roadsides and abandoned villages.

Pine forests with their ground cover dominated by cranberries, boreal dwarf shrubs and wavy hair-grass are distributed on sandy terraces above floodplain of the Ustya and Kokshenga rivers (Photo 1). They all are at different stages of pyrogenic and excisional successions. Presently, only *Lupinus polyphyllus* (Photo 2) can usually be found in those communities, with a constancy of 25%; it is worth noting that it was not recorded at all in pine forests in the 1990-2000s.

Photo 1. Pine forest in the valley of the Kokshenga River (photo by A.A. Chmykhov).

Photo 2. *Lupinus pollyphyllus* (photo by A.A. Chmykhov).

Coniferous-small-leaved and small-leaved forests with the Finnish spruce hybrid, Scots pine, downy and silver birches, grey alder and aspen are widespread in the study territory. These are secondary forests forming in place of overgrowing fallows and clearings, with a diverse composition of undergrowth and ground cover. Among alien species, *L. polyphyllus* was recorded there, highly abundant in some places, with frequent findings of *Arctium tomentosum*, and single findings of *Sambucus racemosa*. In comparison with the geobotanical releves of the 1990-2000s, *S. racemosa* was recorded there for the first time, and the persistence of *L. polyphyllus* increased from 5% to 30%.

Floodplain meadows in the valleys of the Ustya, Kokshenga and Zayachya rivers have 6 alien species that were found with noticeable constancy in the tall grass-meadowsweet and mixed herbs phytocenoses: *L. polyphyllus, Calystegia sepium, Arctium tomentosum, Pastinaca sativa, Melilotus officinalis* and *Heracleum sosnowskyi* (Photo 3).

Photo 3. *Heracleum sosnowskyi* (photo by A.A. Chmykhov).

Photo 4. Overgrowing fallow land (photo by A.A. Chmykhov).

Upland meadows and fallows are widespread in the study territory, covering former arable lands and pastures, flat interfluves and their slopes (Photo 4). They are heavily infested with alien species: for example, in some places the abundance of *L. polyphyllus* reaches 75% of projective cover, and the presence of *Galega orientalis* and *Cichorium intybus* has increased from 2-3% to 20-25%. *Erysimum cheiranthoides, Matricaria discoidea, Arctium tomentosum, Pastinaca sativa, Heracleum sosnowskyi and Armoracia rusticana* were also found here.

Communities of recovering clearings replacing recently cut pine and spruce forests have a highly diversed herbaceous-shrub layer, composed of boreal, marginal meadow and weed species. *Lupinus polyphyllus* and *Epilobium adenocaulon* are quite consistent and abundant there (Photo 5).

Abandoned villages left in the 1990s are quite common in the study area (Photo 6), overgrowing with layered plant communities. They are heavily infested with alien species, 5 such species being highly abundant according to our geobotanical records. In some villages, a tree stand of alien *Populus alba* has formed. The shrub layer includes *Caragana arborescens* with a projective cover of 10%, and *Spiraea media* with 5-15%. The herbaceous-shrub layer includes such common species as *L. polyphyllus* that occurs in 38% of communities. Additionally, we found *Heracleum sosnowskyi*. Unfortunately, it is impossible to analyze dynamics throughout a long period of time as we do not have any geobotanical records for these villages for the 1990s.

Field roadsides are ruderal groups of shrubs and herbaceous plants, often with the alien species among them, such as *Populus alba, Heracleum sosnowskyi, Galega orientalis, L. polyphyllus, Pastinaca sativa* and *Matricaria discoidea* (Photo 7).

The modern distribution of some alien species in different types of plant communities, as well as their distribution in the 1990-2000s is shown in Figure 6. The number of developed phytocenoses

grew due to pine forests, where *Lupinus polyphyllus* became quite frequent, while the number of species increased in floodplain meadows and decreased in other coenoses.

Photo 5. *Lupinus pollyphyllus* in a clearing (photo by A.A. Chmykhov).

Photo 6. Abandoned village (photo by M.B. Stevanovich).

Photo 7. *Matricaria discoidea* DC on a field road (photo by A.A. Chmykhov).

The distribution of alien species populations differs in different landscape conditions. On the *Zayacheritsky key site* (Fig. 7) located in the landscape of moraine-erosion plain that has been actively developed for a long period, there is a wide distribution of almost all mentioned species. *Lupinus polyphyllus* is almost ubiquitous in every community type. *Heracleum sosnowskyi* is usually found in the Zayachya River valley, which can be explained by the presence of a cattle farm and roads, stretching though the fields along the valley edge. *Galega orientalis* is widespread in upland meadows, secondary forests and near field roads along them. *Cichorium intybus* is found along roadsides, as well as in upland meadows and fallows of the watersheds of small tributaries of the Zayachya River. *Matricaria discoidea* also grows along roadsides throughout the site, while *Melilotus officinalis* and *Epilobium adenocaulon* are less frequent. The highest number of alien species was observed in the center of the plot, especially at Research Station located on the site of a former settlement and school, where alien tree and shrub species were planted more than 70 years ago, so now *Populus alba, Spiraea media, Caragana arborescens* and *Sambucus racemosa* are abundant there. *H. sosnowskyi* and *L. polyphyllus* are also common in the area.

The *Chadromsky key site* of the Educational and Research Station (Fig. 8) is located 50 km north of the Zayachieritsky site, in the valley of the Ustya River. It is part of the landscape of large river valleys with ancient alluvial deposits, which are characterized by thick forest coverage and poor agricultural development, which slows down the penetration and naturalization of alien species. In this area, the Ustya River floodplain is the most overgrown with alien species. *Calystegia sepium* and *Arctium tomentosum* were recorded in its floodplain meadows; *L. polyphyllus* was found in clearings and margins of pine forests; *Matricaria discoidea* was found along a field road; while *Populus alba* is confined to an abandoned summer camp.

To assess the degree of alien species invasion in the study area by comparing it with other areas of the middle taiga of the Arkhangelsk Region, we collected data on floristic areas (Schmidt, 2005; Morozova, Tsarevskaya, 2010) for this subzone and calculated the share of alien species (Table 2).

According to the floristic zones of this region (Schmidt, 2005), there are 6 districts in the middle taiga: Kozhozersky, Severo-Dvinsky, Emetsky, Lachsky, Nyandomsky, and Vychegodsky (Fig. 9). The largest number of 112 alien species (16% of the floristic list) was recorded for the Kozhozersky district, which could be due to the proximity of the Northern Railroad, a rather good development of the territory and the proximity of the valley of the large Onega River (Schmidt, 2005).

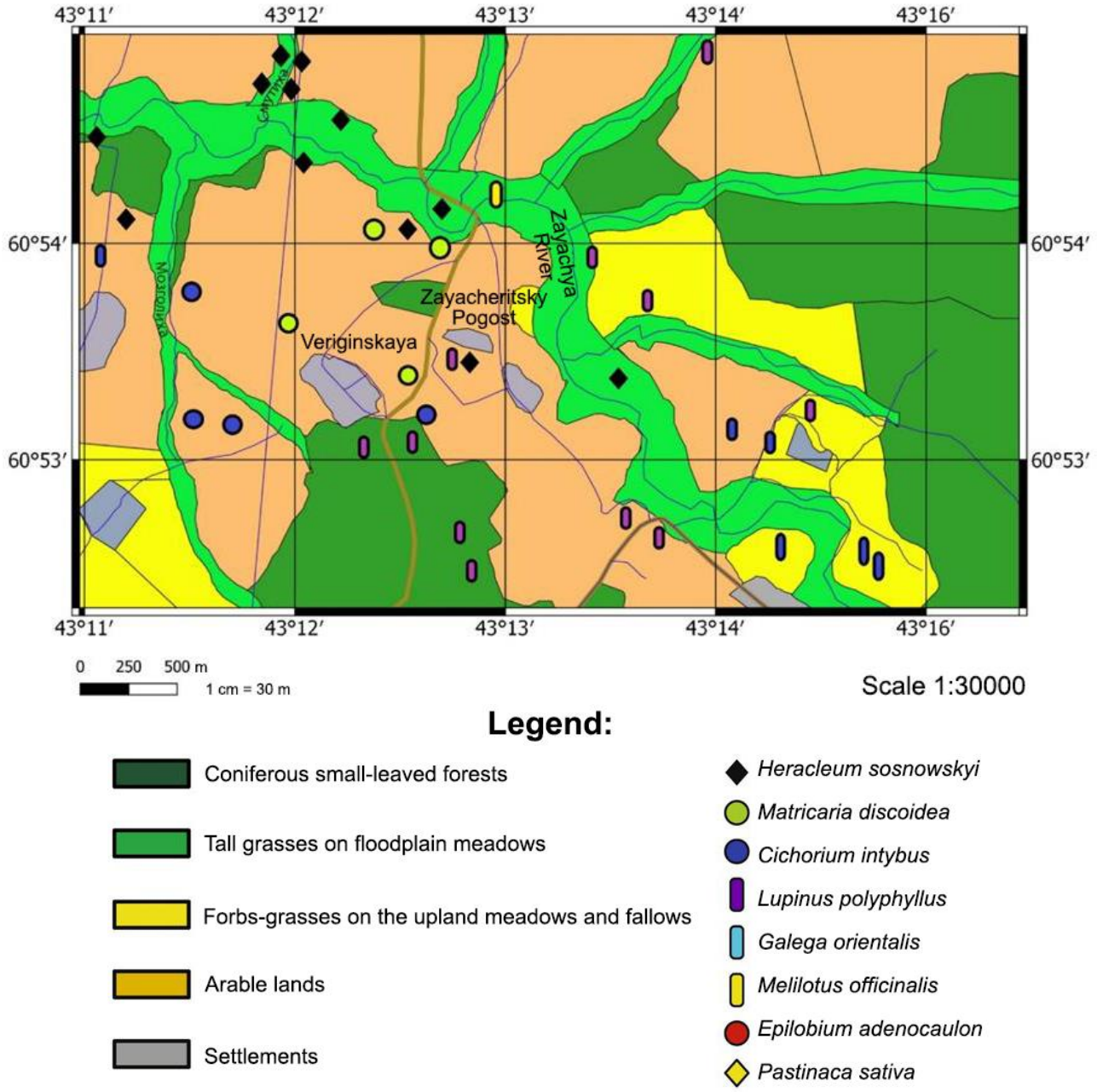

Fig. 6. Map of abundance of alien plant species within the territory of the Zayacheritsky key site of the Ustyansky Station.

The studied territory of the Ustyanskaya Educational and Research Station is located in the Nyandomsky floristic region, with 51 alien species which is 8% of the total flora of the region. The region has long been developed: in addition to a dense network of railroads and settlements, there are many agricultural lands and very intensive forest cutting, all of which determines active

invasion of alien species. According to our studies, 9% of alien species were found in the floristic list of the Ustyanskaya Station, which is consistent with the data collected on the Nyandomsky floristic region. A similar situation is observed in Emetsky floristic region, while in Vychegodsky and Lachsky regions the share of alien species is smaller, about 4%, with the lowest (1%) share observed in Severo-Dvinsky region (Table 2), which could be due to low density of settlements, railroad and roads and rather highly swamped area.

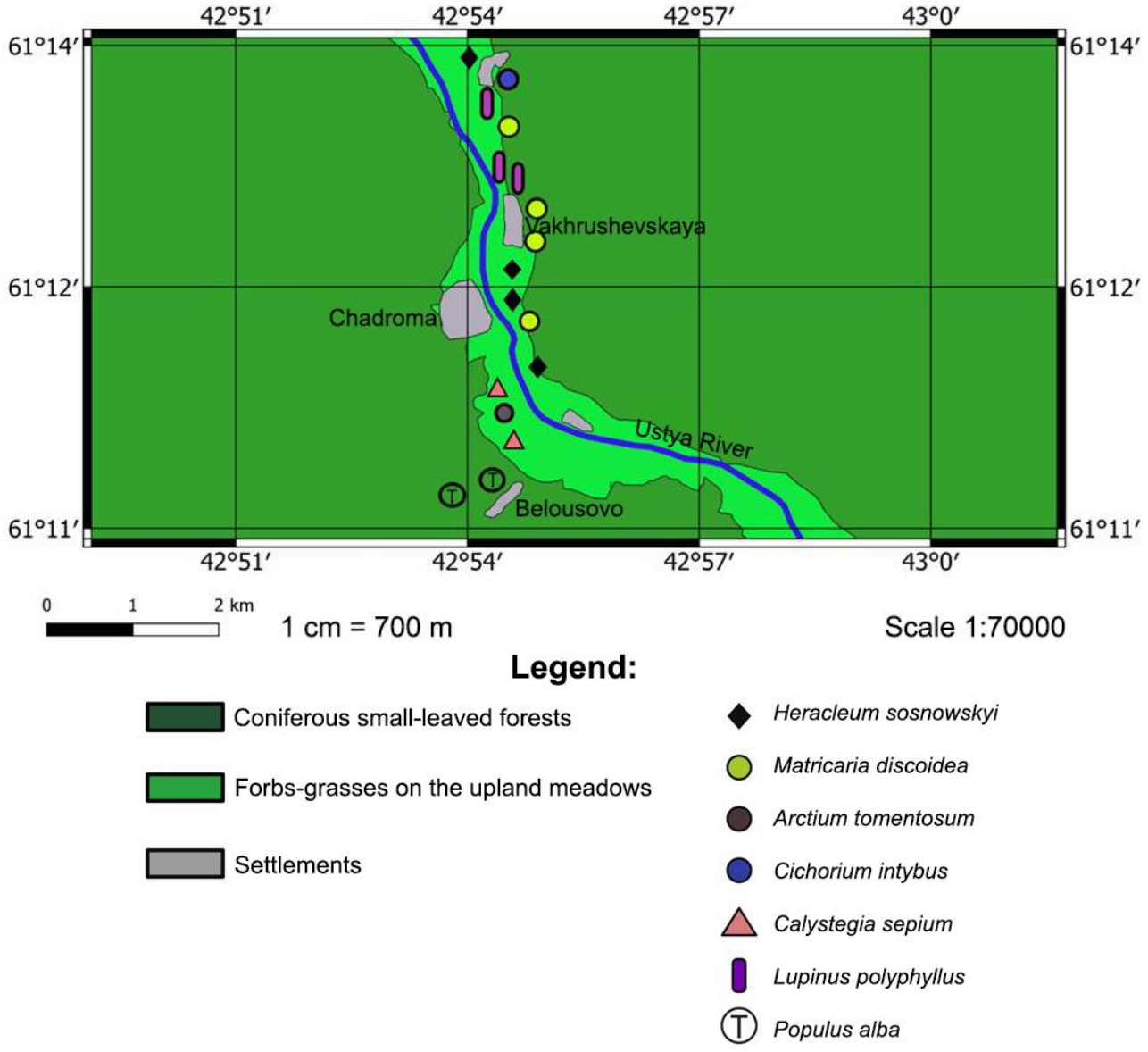

Fig. 7. Map of abundance of alien plant species within the territory of the Chadromsky key site of the Ustyansky Station.

Conclusions

The study of the composition and characteristics of alien species of vascular plants is very important and piques interest of many specialists, from ecologists and biologists to botanical geographers. Despite the large number of publications on this subject, vast regions of Russia, especially taiga regions, such as the Arkhangelsk Region, are barely covered by those studies. The research that we conducted in the Ustyanskaya Educational and Research Station of the

Geography Department of the M.V. Lomonosov Moscow State University allows us to make a contribution to the better understanding of invasive species in the central part of the European middle taiga and to draw some conclusions.

We identified 48 alien species in the study area, which is 9% of the floristic list of this region. The taxonomic spectrum of the alien flora is dominated by Asteraceae, Fabaceae and Brassicaceae.

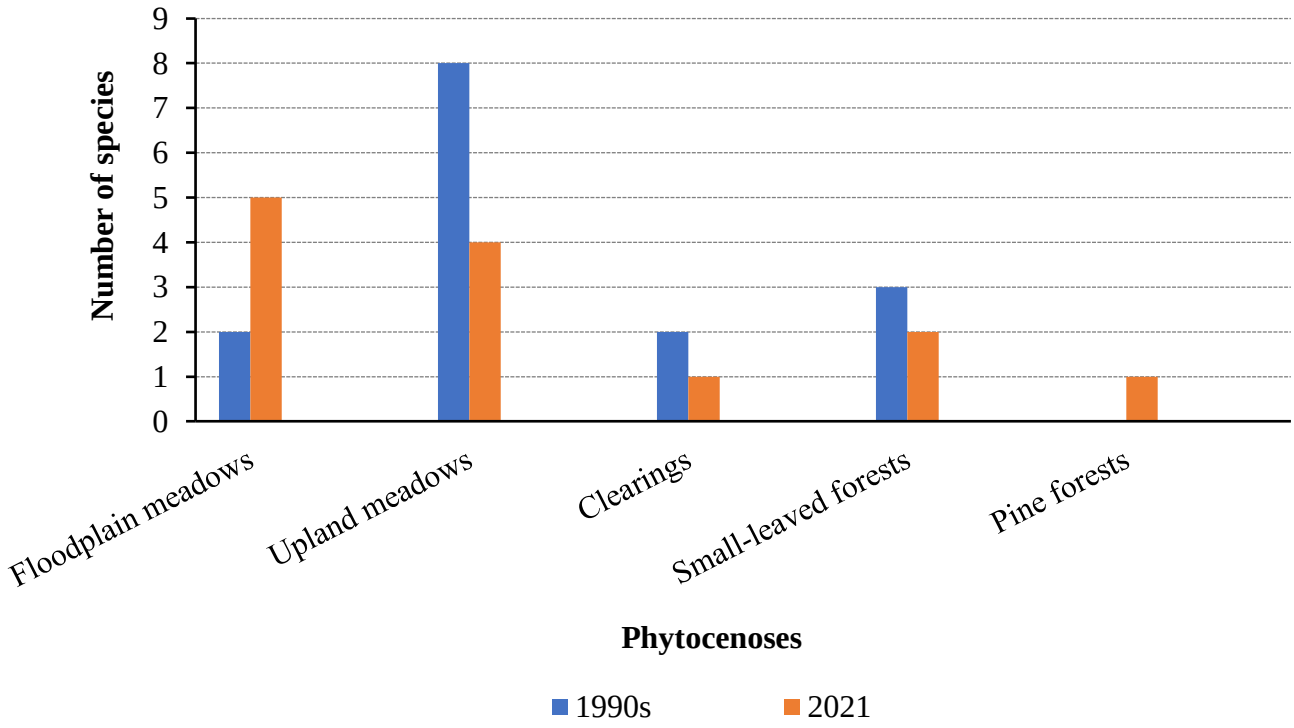

Fig. 8. Number of alien plant species in different phytocoenoses in the 1990s and 2021.

Table 2. Proportion of alien species in the flora of floristic regions of the middle taiga of the Arkhangelsk region (Schmidt, 2005; Morozova, Tsarevskaya, 2010).

Floristic region	Total number of vascular plant species	Number of alien species	Share of alien species, %
Kozhozersky	694	112	16
Emetsky	661	50	8
Severo-Dvinsky	672	8	1
Lachsky	592	22	4
Nyandomsky	631	51	8
Vychegodsky	618	25	4

About half of these species are widespread, and their natural range covers several continents, with 23% of the species sourcing from North America and 20% sourcing from Asia.

The characteristics of alien species that were identified using the ecological scales are mainly mesophytic and rather demanding to soil richness, which determines their role in the vegetation cover of the middle taiga. They can easily spread in natural communities of floodplain meadows

and upland meadows, fallow lands, and secondary forests. The residential areas and roadsides also create favorable conditions for the spread of alien species and their invasion into new areas.

The analysis of the coenotic role of alien species revealed that most of them were inactive and, therefore, were introduced to this territory intentionally. Out of the total 48 alien species of the territory, only 15 had entered into natural communities. According to the Black Data Books, only 2 species (*Heracleum sosnowskyi* and *Lupinus polyphyllus*) act as transformer species that change natural communities.

The distribution of alien species in rather severe biological and climate conditions of the middle taiga is possible due to the migration paths along the valleys of large rivers, railroads that compose a developed network, and due to a highly developed agriculture in Nyandomsky, Emetsky, and Kozhozersky floristic regions.

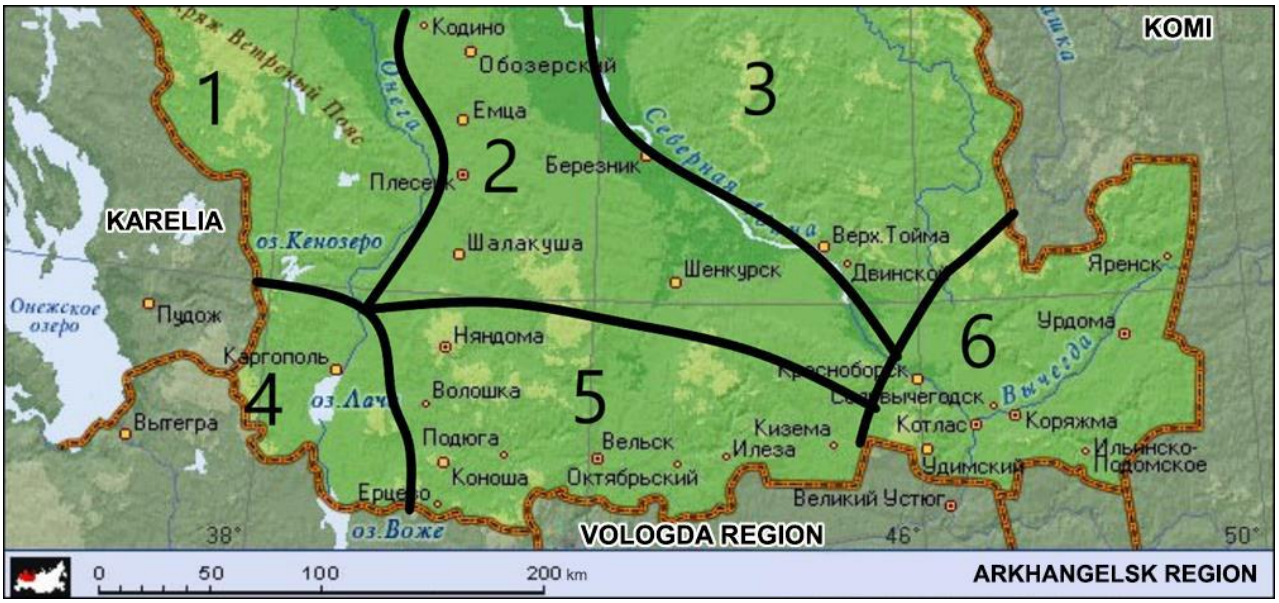

Fig. 9. Floristic zones of middle taiga in the Arkhangelsk Region (Schmidt, 2005). *Legend:* 1 – Kozhozersky, 2 – Emetsky, 3 – Severo-Dvinsky, 4 – Lachsky, 5 – Nyandomsky, 6 – Vychegodsky.

At the local level, our study shows that the foci of alien species distribution are livestock farms, tree and shrub plantings in settlements, especially near schools and dirt roads, where the concentration and diversity of these species was found to be at their maximum.

In recent years, the influence of alien species in the study region has increased, and they have a negative effect on local flora and vegetation, transforming natural ecosystems. If these studies are continued, it will allow us to clarify and possibly to expand the knowledge on composition of alien species, because a greater coverage of different types of communities and habitats will be available. It will also help to track changes in the coenotic role of those alien species and to identify potentially dangerous ones.

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ЧУЖЕРОДНЫЕ ВИДЫ СОСУДИСТЫХ РАСТЕНИЙ В ФИТОЦЕНОЗАХ СРЕДНЕЙ ТАЙГИ АРХАНГЕЛЬСКОЙ ОБЛАСТИ*

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В статье рассмотрена актуальная проблема распространения чужеродных видов в растительном покрове среднетаежной территории Архангельской области, до настоящего времени не исследованной подробно в этом отношении. Использованы данные многолетних биогеографических исследований на Устьянской учебно-научной станции географического факультета МГУ имени М.В. Ломоносова в Архангельской области и собственные полевые материалы, собранные в 2019-2022 гг. Выявлен состав чужеродных видов растений, произрастающих на территории исследования, проанализированы их таксономическая принадлежность и эколого-географические характеристики. Использованы традиционные методы полевого ботанико-географического обследования и камеральной обработки материалов с привлечением широкого круга научных публикаций по оценке роли чужеродных видов в сообществах, проведен анализ экологических ареалов видов на основе экологических шкал Д.Н. Цыганова, составлены карты массового произрастания наиболее распространенных чужеродных видов на ключевых участках территории. Проведенное исследование выявило, что чужеродные растения в растительном покрове средней тайги Архангельской области в настоящее время составляют около 9% флористического списка, при этом большая их часть занесена на территорию преднамеренно – в ходе сельскохозяйственного природопользования. В таксономическом спектре чужеродных видов преобладают представители семейств Asteraceae, Fabaceae, Brassicaceae, преимущественно выходцы из Северной Америки и Азии. В ценотическом отношении они распространяются главным образом в сообществах пойменных и суходольных лугов и залежей, во вторичных лесах, а также в антропогенных ценозах в пределах селитебных территорий и вдоль дорог. Показано, что в среднетаежных районах области значимая доля чужеродных видов во флоре обусловлена наличием долин крупных рек, развитой сетью железных дорог и степенью сельскохозяйственной освоенности.

Ключевые слова: чужеродные виды растений, таксономический состав, эколого-ценотический состав, географические элементы, экологические шкалы, растительные сообщества.

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