Analysis of the peculiarities of the expansion of invasive plant species in the south-west of the middle Russian Highland (Russia, The Belgorod Region)

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Abstract
The study of the characteristics of the expansion of groups of invasion species in various types of natural and anthropogenic habitats of the south-west of the Central Russian Highland (Russia, the Belgorod region) by traditional and statistical methods has allowed to expose the features of selective colonization by plants of different ecotopes. The application of cluster analysis of correlation matrices obtained on the basis of Jaccard's coefficients provide the differentiation of three groups of species (clusters) that are characteristic of steppe, forest and anthropogenic areas. In the group of plants of steppe ecotopes, the group of invasive species that have intruded into communities that form in chalk habitat areas is somewhat separate. The groups of plants colonizing the steppe habitats turned out to be the most dispersed. The paper presents the data related to the structure of invasive species in various ecotopes and the analysis of plants by categories: mono-, oligo-, polychores.

Keywords: invasive species, distribution, analysis

INTRODUCTION

The biological encroachment of alien plant species is global (Tokhtar 2018, Tokhtar et al. 2017, Vinogradova et al. 2010) and leads to reduction in natural biodiversity (Lisetskii et al. 2016). Currently, one of the most important theoretical problems in the study of non-indigenous plant species is to identify the main patterns of their dissemination and invasion into various ecotopes of the regions (Tokhtar et al. 2016).

An important task of studying the expansion of alien plants is to identify the characteristics of the dispersion of both individual invasive species and their groups in natural and anthropogenic habitats (Tokhtar 2018). The solution of this problem involves the study and assessment of the occurrence of specific species in different habitats of the region, the study of the spatial differentiation of the invasive component of flora and a comparative analysis of groups of species colonizing various types of ecotopes using statistical analysis.

To understand the characteristics of dispersion of specific invasive species in various types of natural and anthropogenic habitats (Reshetnikova and Vinogradova 2016), in the course of route-floristic surveys of ecotopes of the south-west of the Central Russian Highland, we determined the quantitative assessment of their presence.

OBJECTS AND METHODS

The objects of study were invasive species of the flora of the south-west of the Central Russian Highland, common in various types of natural and anthropogenic habitats. Their expansion was analyzed according to the habitat classification proposed by Reshetnikova and Vinogradova (2016). The authors examined the following main types of natural and anthropogenic ecotopes of the region: railway embankments, fields and arable land, quarries, forest belts, forest parks, banks of reservoirs and river beds, steppes, chalk outcrops, deciduous and coniferous forests, as well as a quantitative assessment of the presence of invasive species in them was determined (Tokhtar et al. 2018).

For groups of invasive species observed in various ecotopes, Jaccard's coefficients of similarity were determined. The correlation matrices obtained in this way were analyzed via cluster analysis (Tokhtar 2016).

According to the classification proposed by Hejny and Jehlik (1972), all invasive species according to their spreading in the region were divided into monochores (propagated in the region by only one main way), oligochores (disseminated by several ways, one of
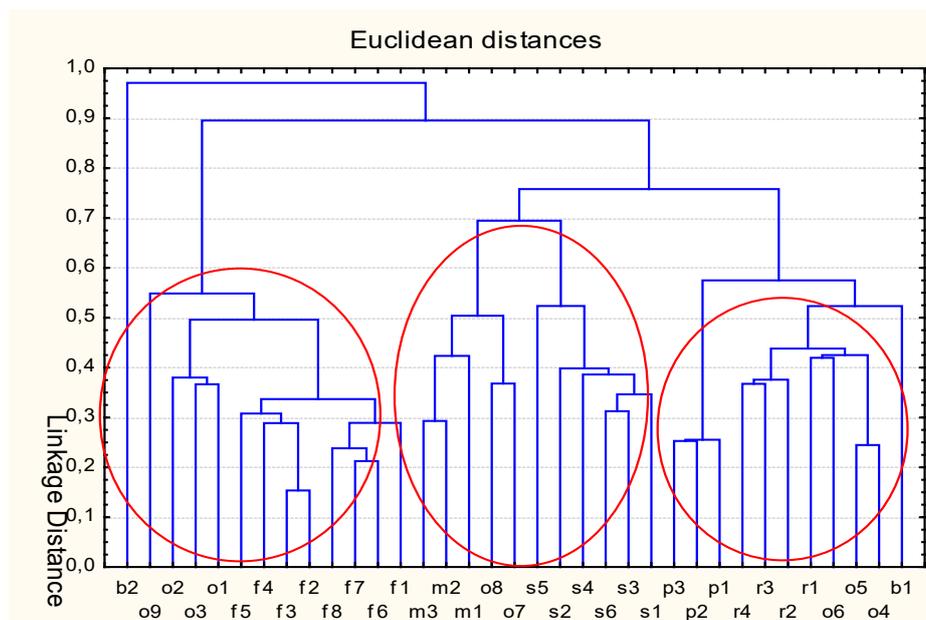
Fig. 1. Cluster analysis of the distribution of groups of alien species in various ecotopes of the region, built on the basis of using Jaccard's similarity coefficients, symbols: b1-b2 – banks of water bodies and river banks, m1-m3 – chalk outcrops, f1-f8 – forest habitat areas, o1- o9 – gully systems, p1-p3 - parks, r1-r4 – railways, s1-s6 – steppe areas

which is dominant) and polychores (several ways, of which two at least are dominant).

MAIN PART

To understand the patterns of propagation of specific invasive species in various types of natural and anthropogenic habitats, we determined the quantitative assessment of their presence in the route-floristic surveys of ecotopes of the south-west of the Central Russian Highland and singled out the groups of plants according to the intensity of their dissemination in the region.

The analysis of the presence of invasive species in various types of habitat areas allowed to differentiate three groups of plants according to the degree of intensity of their spreading in the region. The group of actively propagating plants comprehended eight species that were found in almost all natural and anthropogenic ecotopes of the region and showed a high level of presence in them. Species belonging to plants that are actively distributed in the region are also characterized by a high degree of occurrence: *Erigeron annuum* (0,7)*, Acer negundo* (0,6)*, Erigeron canadensis* (0,6)*, Fraxinus pennsylvanica* (0,5)*, Robinia pseudoacacia* (0,5).

It should be noted that in the group of active spreading plants, 6 out of 8 species belong to kenophytes of North American origin, in the group of moderately spreading species, 23 species belong to kenophytes, 5 to archaeophytes, and 4 to eukenophytes. In the group of weakly spreading invasive species, the majority of species account for kenophytes (16 species), eukenophytes occupy the

second place (14 species). Archaeophytes account for only three species.

Based on the obtained data, it can be concluded that the most active invasive species in terms of time for dissemination into the region are kenophytes of North American origin. Archaeophytes, apparently, slow down the rates of their distribution, while eukenophytes, at present, are represented mainly in the group of weakly dispersed invasive plants, noted mainly in anthropogenically disturbed sites.

For particularization of spreading of invasive non-indigenous plants we have studied the invasive species expanding in various natural and anthropogenic habitat areas along the gradient of reducing effect of the anthropogenic factor railways, parks, forests, steppe areas, ravine ecotopes, chalk outcrops and others

For groups of invasive species observed in various ecotopes, Jaccard's coefficients of similarity were determined. The correlation matrices obtained in this way were analyzed applying cluster analysis, which made it possible to study the features of the spread of invasive species in different habitat areas (**Fig. 1**). **Fig. 1** shows that invasive species are quite clearly divided into three groups (clusters): species that spread to steppe, forest and anthropogenic ecotopes. In the group of plants of steppe areas, the group of invasive species that have been invaded into communities that are formed in chalk habitats is in somewhat isolation. The groups of invasive species of ravine-gully ecotopes are distributed more extensively and are represented in different clusters. This is apparently due to the presence in their composition of common for a number of groups of habitats of arboreal species, including introducents.

The groups of invasive species of anthropogenically transformed ecotopes (parks, railways) are located nearby and form a common cluster due to the similarity in the species composition of alien invasive plants (**Fig. 1**). The groups of plants colonizing the steppe habitat areas turned out to be the most dispersed. The similarity of species compositions between these groups of alien plants is determined by the commonality between the species.

The core of the invasive component in different habitat areas of the region is formed by different species. Within the valleys and floodplains of rivers, these species are: *Acer negundo*, *Acorus calamus* L., *Bidens frondosa*, *Echinocystis lobata*, *Fraxinus pennsylvanica*, *Impatiens glandulifera*, *Populus alba*, *Xanthium albinum*. The core of invasive species in forests is comprehended by: *Acer negundo*, *Caragana arborescens, Cerasus vulgaris*, *Fraxinus pennsylvanica, Lonicera tatarica, Malus domestica*, *Sambucus racemosa*, *Ulmus pumila* and others. Within the bounds of embankments of railways the following are widely dispersed: *Acer negundo*, *Amaranthus retroflexus*, *Ambrosia artemisiifolia*, *Anisantha tectorum*, *Atriplex tatarica*, *Cyclachaena xanthiifolia*, *Erigeron canadensis*, *Lepidium densiflorum*, *Oenothera biennis*, *Oxybaphus nyctagineus* and others. The flora of parks is formed by introduced plants, accidentally disseminated adventive species, and the florae of "remnants" that have survived since the creation of parks and squares: *Acer negundo*, *Aesculus hippocastanum*, *Parthenocissus inserta*, *Populus alba*, *Pyrus communis*, *Robinia pseudoacacia* and others. On chalk outcrops the following are observed: *Acer negundo*, *Hyppophaë rhamnoides*, *Kibera gallica*, and over ravines and slopes there are *Armeniaca vulgaris*, *Arrhenatherum elatius*, *Caragana arborescens*, *Elaeagnus angustifolia*, *Erigeron canadensis*, *Fraxinus pensylvanica*, *Lonicera tatarica*, *Malus domestica*, *Robinia pseudoacacia*.

The analysis of the expansion of invasive plants and the structure of life forms in groups of alien species in different habitat areas of the region indicate that the nature of their distribution in different ecotopes is uneven. Within the bounds of transport arteries, for example, there propagate mainly herbaceous plants belonging to terophytes (47.7%). Among them are xenophytes (66.0%), kenophytes (74.0%) and epecophytes (48.0%), meso- (50.0%) and oligotrophs (36.4%), eumeophytes (45.4%) and xeromesophytes (36.4%), belonging to the Asteraceae, Brassicaceae and Poaceae families. Introduced species belonging to ergaziophytes (57.0% in parks, 75.0% in woodland belts), phanophytes (25.0% in parks, 78.3% in woodland belts), terophytes (62.5% in parks), mesotrophs (56.6% in woodland belts), megatrophs (45.8% in parks) from the families of Fabaceae, Rosaceae prevail in the formation of the invasive component of parks and woodland belts.

According to the classification developed by Hejny and Jehlik (1972), all of the invasive species in the region are divided by distribution method into monochores (only by one way in the region), oligochores (in several ways, one being dominant) and polychores (spread in many ways, of which at least two are dominant) (Hejny and Jehlik 1972).

The analysis of the characteristics of the spread of invasive species suggests that 49 species (58.3% of the total number of invasive species) of which are monochores, 23 species (27.4%) are oligochores and 12 species (14.3%) – polychores.

CONCLUSION

As the result the study by means of cluster analysis, three groups of invasive plant species have been differentiated according to the degree of their dissemination. It is established that the most active of them are kenophytes of North American origin. Cluster analysis of groups of alien plants colonizing various types of ecotopes of the southwest of the Central Russian Upland leads to identification of three groups of species that are selectively dispersed in steppe, forest and anthropogenic areas. The analysis of the structures of life forms in groups of invasive species in different habitats of the region suggests that the pattern of their distribution in different ecotopes is uneven. Within the bounds of transport arteries, for example, there prevail herbaceous plants belonging to terophytes (47.7%). The introduced species belonging to ergaziophytes (57.0% in parks, 75.0% in forest belts), phanerophytes (25.0% in parks, 78.3% in forest belts), terophytes (62.5% in parks) are dominant in the formation of the invasive component of parks and forest belts. Most of the invasive species belong to monochores (49 species, 58.3% of their total number), oligochores are slightly less represented (23 species, 27.4%), 12 species (14.3%) of plants are referred to polychores.

SUMMARY

1. In order of intensity of dissemination in the region, three groups of plants are distinguished. The group of actively propagating plants includes eight species, which are found in most natural and anthropogenic ecotopes and showed a high level of spreading. 6 out of 8 species of this category are kenophytes of North American origin.

2. Cluster analysis of alien plants colonizing various types of ecotopes of the southwest of the Central Russian Highland allowed to single out three groups of species that selectively spread to steppe, forest and anthropogenic area.

3. Most species (85.7%) belong to mono- or oligochores, which are distributed in the region in one or several dominant ways.

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