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The Richness and Cover of Alien Plants in the Undergrowth and Field Layer of Urbanized Southern Taiga Forests

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Abstract

The aim of the work is to compare the richness (the number of species in 400 m^2) and cover of alien plants in the undergrowth and field layer of a large city forest. The research was carried out in 2016–2017 in the southern taiga subzone of the Eurasian boreal zone, specifically in the urban forests of the industrial city of Ekaterinburg (the Central Urals, Russia) and the area around it. 235 plots have been analyzed. The number and cover of alien species in the undergrowth and field layer are contrastively different. The richness and cover of alien herbaceous species are much less than the richness and cover of alien woody plants (shrubs and trees) in the undergrowth. Thus, the undergrowth layer has transformed much more comprehensively as a result of alien plant invasions than the field layer. This conclusion is valid both for analysis on the scale of individual plots and for the analysis of complete species lists in urban and suburban forests. This statement is also true for the analysis of the cover of alien plants. This result appears to be unexpected.

Keywords: plant invasions, invasiveness of communities, urban forests, woody plants, herbaceous plants

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1. Introduction

The biota of urbanized areas is transformed by different processes: (i) fragmentation and degradation of habitats due to different forms of pollution and other impacts; (ii) the distribution of alien species [1]. These processes are interdependent and occur not only in cities, but also in most landscapes on the Earth. However, in cities they are more pronounced than in non-urbanized territories. Cities are centers of alien plant naturalization and distribution. In Russia, floristic works predominate in this direction. In our estimates, the richness of urban floras is known for at least 89 Russian cities [2].

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In this article, we have made an assessment of the invasiveness of communities [3]. Alien plants are predominantly naturalized in habitats with low stress levels and high frequency or intensity of disturbances, in particular in anthropogenically transformed and fragmented habitats [3]. Managed urban forests or forest parks provide an example of intensively violated and highly invasive communities. Their common feature is increased plant diversity due to active invasions [4–7]. With increasing urbanization, the diversity of native plants can either decrease [6, 8, 9] or increase [4, 10] in different situations.

The aim of the work is to compare the richness (number of species) and cover of alien plants in two layers of urban forests – the undergrowth and field layer. We investigate whether the field layer and undergrowth have been transformed to an equal degree due to plant invasions. This work is a part of a comprehensive project to study urban forests in Ekaterinburg [11–13].

2. Methods

2.1. Study area

Ekaterinburg is a city in the Central Urals in Russia with a population of 1.5 million. It is located in the southern taiga subzone of the boreal forest zone. Typical forests in the region are herbaceous, herbaceous–dwarf shrub and green moss pine forests with larch.

Urban forests are described with reference to the forest park Yugo-Zapadnyi (Southwestern). The pine stands of the forest park have a natural origin. These are the remnants of natural forests. Wild forests still existed when this area fell into the construction zone. These forest areas were included in the city line in the 1950–1960s, 60–70 years ago. The stands of urban forests generally belong to the same age group; the age of the main generation trees is 90–120 years old [11–13]. Suburban forests are described around the cities of Sysert' and Aramil' and the villages of Mednyi and Severka. These sites are located 13–40 km from Ekaterinburg and 0.5–4 km from the nearest settlements. The plots in the suburban forests were selected in such a way that they would be as comparable as possible to urban forests in terms of characteristics of the relief and tree stand, the history of forest exploitation and the type of plant communities.

2.2. Data collection

128 plots in urban forests were described in 2016, while 107 plots in the suburban forests were described in 2017. The plot square is 400 m^2 (a circle with a radius of 11.27 m with a *Pinus sylvestris* L. tree at the center of each plot). The number of plant species in the field layer and in the undergrowth was recorded, as well as the plant cover of the above-ground organs of each plant species (as a percentage). What we were interested in was the characteristics of the species richness of different plant groups: in other words, the species density, the number of species per 400 m^2.

The following terms are used to refer to the vegetation components. The field layer is a layer of herbaceous plants and other low plants (forbs, graminoids, dwarf shrubs, semi-shrubs, ferns, horsetails). Mosses are not included in the field layer. This meaning of the term has been used in other studies of urbanized boreal forests [14]. The undergrowth is a layer of shrubs and low trees not included in the first layer of the stand (canopy cover). The term 'woody plants' is used to refer to the plants of this layer. Native and alien plants were subdivided according to regional summary reports [15–16].

2.3. Data analysis

To compare the values, one-way ANOVA was used. When describing the results of ANOVA, the value of the *F*-test of Fisher (*F*) and its significance level (*P*) are indicated. When ANOVA was performed for the indicators expressed in fractions, the arc sine conversion was used, but the untransformed data are discussed in the figures and in the text. The standard deviation is indicated by the ± symbol. The calculations were conducted in STATISTICA 10.0.

3. Results

The average density of woody species was about 30% higher in urban forests than in suburban ones (Figure 1). In contrast, the average density of herbaceous species in urban forests was approximately 30% lower.

The increase in the density of undergrowth species in urban forests, as compared to suburban ones, is only due to an increase in the number of alien species. On average, 3–5 alien woody plants are registered on each plot in the urban forests, and 0–2 species on each plot in the suburban forests. The percentage of alien shrub species in the urban forests (30%) is higher than in the suburban forests (12%). Alien woody plants in the urban forests were represented by both adults and small specimens that appeared as a result of regeneration. Such small specimens predominated numerically among many species. Some of the adult alien plants may have been artificially planted in the urban forests. The average species density of native woody plants between urban and suburban forests did not differ.

The average density of alien herb species per plot was very low. On average, there was less than one alien species per plot both in urban and suburban forests. The average density of alien herb species did not differ between urban and suburban forests. The percentage of alien herb species per 400 m^2 plot was very low – less than 1% in both urban and suburban forests. This is an unexpected result.

When analyzing the complete species lists, we also found a large proportion of alien plants in the undergrowth compared to the field layer (Figure 2). Out of the 55 species of woody plants recorded in urban forests, 29 species (or 53%) are alien plants. Among the 46 species of woody plants recorded in the suburban forests, the number of alien species is 13 (or 28%). The transformation of the field layer's general composition is significantly lower: 10 species (5%) of the 186 total numbers of species in urban forests and 19 species (9%) of 221 species were registered outside the city.

Only the undergrowth of urban forests is heavily transformed in terms of the cover of alien plants (Figure 3). There, alien woody plants formed 17% of the total cover. Outside the city, the cover of alien woody plants was less than 1%. The field layer is little transformed in terms of the cover of alien plants. The cover of alien herb species was less than 1% both in urban and suburban forests.

In some respects, our results are expected. They coincide with the general patterns of the transformation of urban forests described in other regions. For example, it is expected that the diversity and cover of alien woody plants are higher in urban forests than in suburban ones. Similar results were published for European and North American forests [4–7]. We demonstrate that this pattern is also true for the intracontinental coniferous forests of Eurasia.

Some other published data indicate the possibility of very different effects for the diversity of native plants in urban habitats. For example, the diversity of native plants may decline with increasing urbanization [6, 8, 9]: this is exactly the effect we have observed for the field layer on the scale of gamma-diversity. However, there is also evidence of an increase in the diversity of native plants with an increase in urbanization [4, 10].

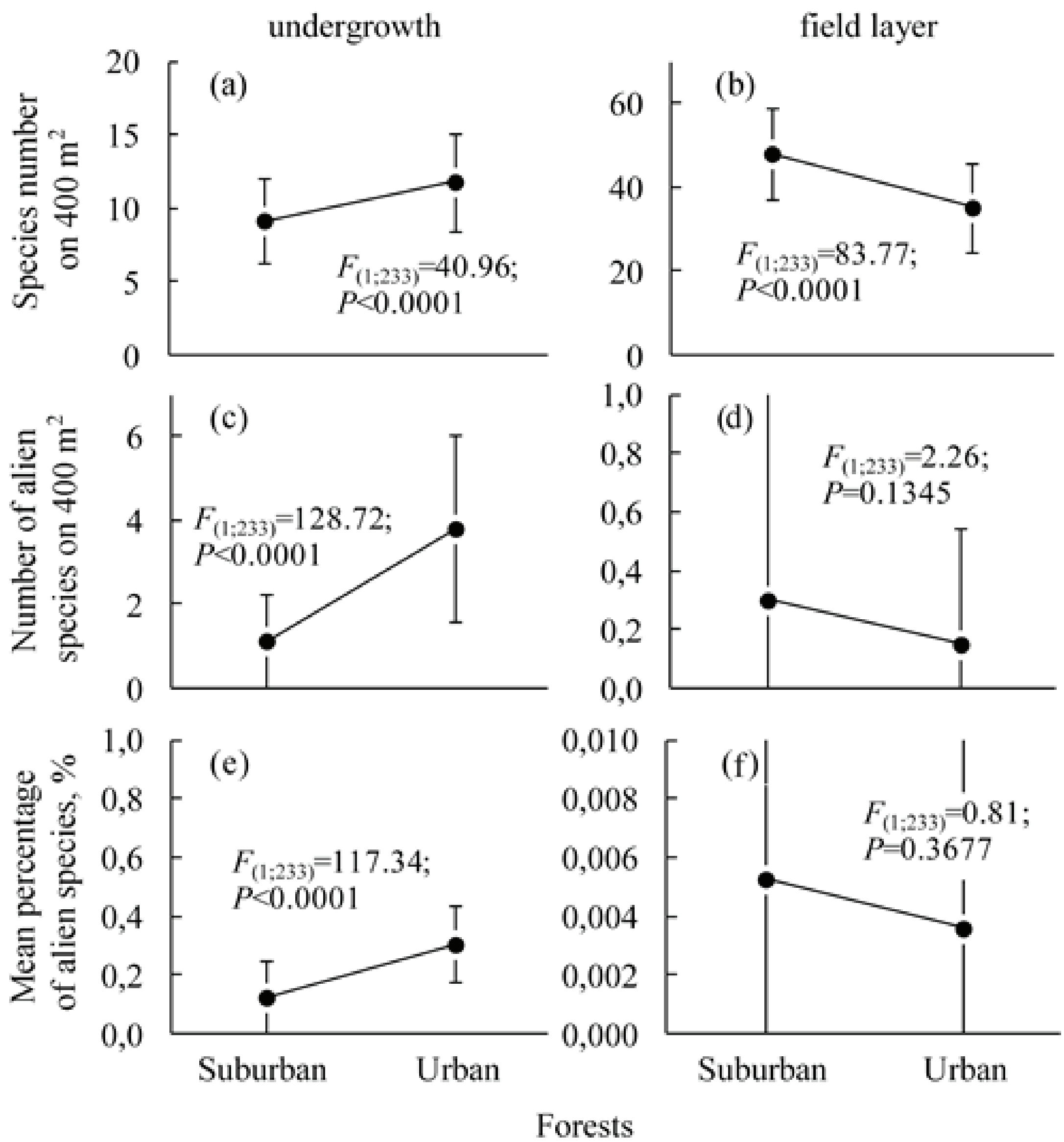

Figure 1: Density of species (a, b), density (c, d) and percentage (e, f) of alien woody plants (a, c, e) and species of field layer (b, d, f) in suburban and urban forests. Mean ± standard deviation. Note the difference in scales in the adjacent figures. Source: Authors' own work.

In general, our results show that the diversity and cover of alien plants in the undergrowth and the field layer of the studied forests are contrastively different. As a result of invasions, the undergrowth is transformed much more substantially than the field layer. It is interesting to note that this conclusion is valid for both urban forests and suburban ones. Unfortunately, we cannot compare our results with other estimates, since relevant publications are not known to us.

The large number of alien woody plants observed in urban forests can easily be explained. Most of these species were artificially planted to enhance the aesthetic value of urban forests. In particular, the following species were planted: *Acer ginnala*

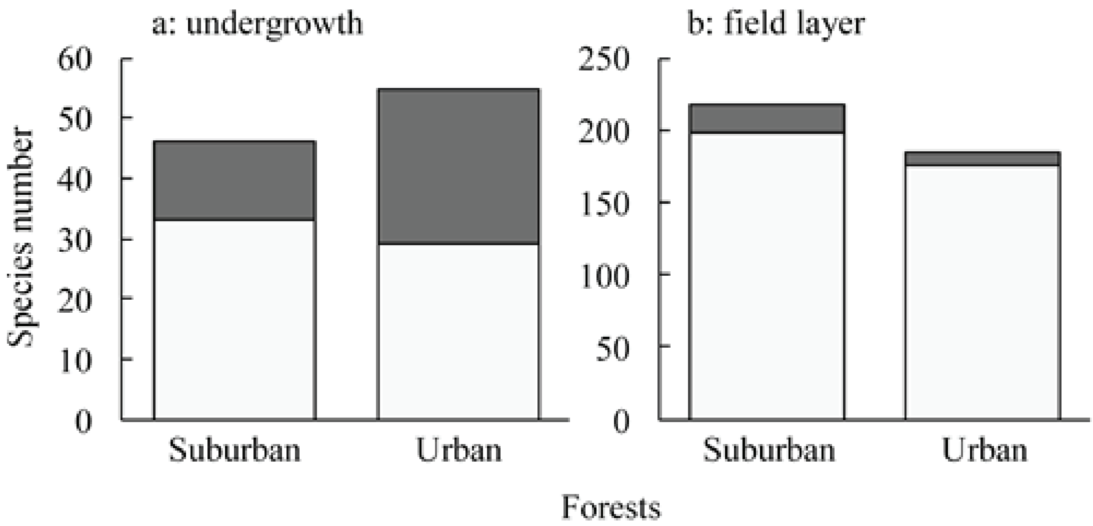

Figure 2: The number of alien (shade fragments) and native (open fragments) species in the total species composition of the undergrowth (a) and field layer (b) of suburban and urban forests. **Source:** Authors' own work.

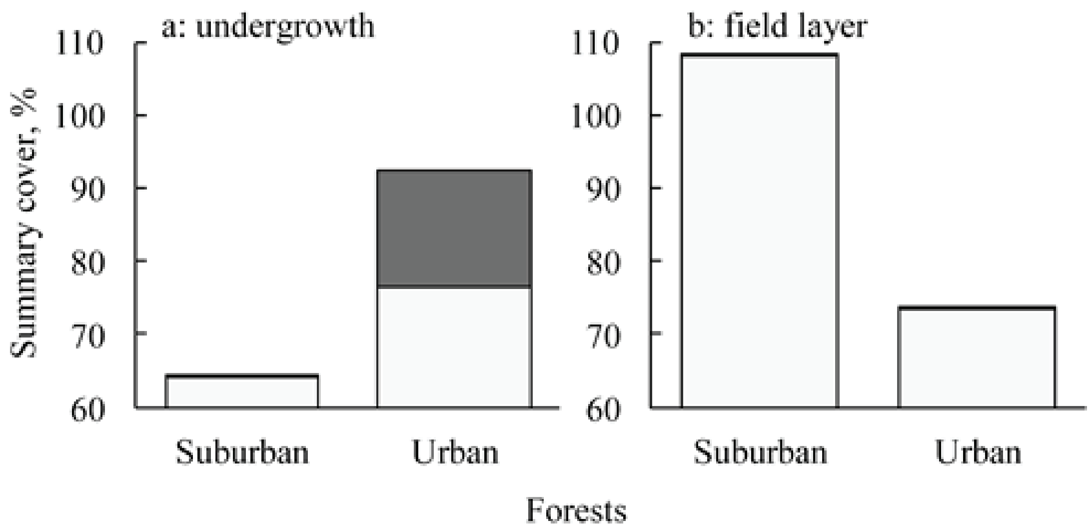

Figure 3: The summarized cover of alien (shade fragments) and native (open fragments) species in the undergrowth (a) and field layer (b) of suburban and urban forests. **Source:** Authors' own work.

Maxim., *A. negundo* L., *A. platanoides* L., *Amelanchier spicata* (Lam.) C. Koch, *Aronia mitschurinii* A. Skvorts. et Maitul., *Berberis vulgaris* L., *Cotoneaster lucidus* Schlecht., *Euonymus europaeus* L., *Fraxinus pennsylvanica* Marsh., *Lonicera tatarica* L., *Malus baccata* (L.) Borkh., *M. domestica* Borkh., *Padus maackii* (Rupr.) Kom., *P. virginiana* (L.) Mill., *Physocarpus opulifolius* (L.) Maxim., *Populus balsamifera* L., *Pyrus ussuriensis* Maxim., *Quercus robur* L., *Ribes aureum* Pursh, *Sorbaria sorbifolia* (L.) A. Br., *Syringa josikaea* Jacq. fil. ex Reichenb., *S. villosa* Vahl, *Ulmus laevis* Pall. According to our observations, almost all these trees and shrubs in the forest parks are being renewed.

However, the hypothesis of alien woody plants originating only from artificial planting is not comprehensive. It does not explain the strong transformation of the undergrowth of suburban forests as a result of invasions. It is more difficult to explain why, due to invasions, it is the undergrowth of the investigated forests that is strongly transformed, not the field layer.

In the regional lists of alien and invasive plants, the number of herbaceous species is many times higher than the number of woody species. For example, out of 360 alien species of Sverdlovsk region only 48 (13%) are represented by woody plants, and the remaining 312 (87%) are herbaceous and other species [17]. Among the 100 invasive and potentially invasive plants of Sverdlovsk region, 10 are woody plants and 90 are non-woody plants [18]. Thus, based on the alien and invasive species pool estimates, it would be more likely to detect the opposite trend, that is, a strong transformation of the field layer. The result is rather unexpected.

Therefore, some special studies are required to explain why invasive processes result in a high degree of undergrowth layer transformation on the one hand and a low level of field layer transformation on the other.

4. Conclusion

In the urban and suburban forests of Ekaterinburg, the richness and cover of alien species in the undergrowth and field layer strongly contrast. The richness and cover of alien herbs in the field layer are much less than the richness and cover of alien shrubs and trees in the undergrowth. This conclusion is valid for both the analysis on the scale of plots, the analysis of complete species lists and the cover analysis. This result appeared to be unexpected, as it could not be predicted *a priori*.

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