ISSN 1067-4136, Russian Journal of Ecology, 2018, Vol. 49, No. 3, pp. 201–208. © Pleiades Publishing, Ltd., 2018.
Original Russian Text © A.S. Tretyakova, D.V. Veselkin, S.A. Senator, Ya.M. Golovanov, 2018, published in Ekologiya, 2018, No. 3, pp. 165–173.

Factors of Richness of Urban Floras in the Ural–Volga Region

A. S. Tretyakova[a, *], D. V. Veselkin[b, **], S. A. Senator[c, *], and Ya. M. Golovanov[d, ****]**

[a] *Ural Federal University, Yekaterinburg, 620083 Russia*
[b] *Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, Yekaterinburg, Russia*
[c] *Institute of Ecology of the Volga River Basin, Russian Academy of Sciences, Tolyatti, 445003 Russia*
[d] *Botanical Garden-Institute, Ufa Scientific Center, Russian Academy of Sciences, Ufa, 450080 Russia*
**e-mail: Alyona.Tretyakova@urfu.ru*
***e-mail: denis_v@ipae.uran.ru*
****e-mail: stsenator@yandex.ru*
*****e-mail: jaro1986@mail.ru*

Received November 10, 2017

Abstract—Original data on 14 urban floras in the Ural–Volga region have been analyzed to estimate the effect of the geographic location, topography, climate, size, and age of a city on the species richness of its flora. This parameter in different cities varied from 288 to 973 species, with the proportion of alien species varying from 21 to 41%. Factors of flora richness were estimated by multiple linear regression using principal component estimates obtained by factor analysis of 13 city characteristics as predictors. It has been confirmed that the richness of urban floras depends primarily on the city size, which accounts for greater proportions of variation in the number of native species (56%), the number of alien species (91%), and the total number of species (71%). In addition, variation in the number of native species is determined by terrain elevation (22%), increasing at higher elevations. The proportion of alien species in the urban flora does not depend on the size of the city and is negatively correlated with terrain elevation.

Keywords: biodiversity, urbanization, urban flora, plant species richness, native species, alien species, determinants of species richness

DOI: 10.1134/S1067413618030098

Studies on the plant component of urban ecosystems and factors determining the richness and structure of urban floras are highly relevant in the context of active urbanization [1, 2] and the necessity to search for the methods of sustainable urban development allowing the conservation of biological diversity.

Urban floras are usually richer than the floras of the surrounding areas [3–6], which is due to the location of cities in hotspots of plant species richness from the time of their founding, as well as to the spatial heterogeneity of the urban environment and high enrichment of urban floras with alien species [1, 3, 5, 7–9]. On the other hand, urbanization leads to decrease in the diversity of native species; stenotopic (forest, aquatic, and wetland) species are the first to disappear because of degradation and transformation of habitats [9–12].

The accumulation of data on urban floras has made it possible to initiate the search for general explanation of their richness and structural features. It has been proven many times that the richness of urban floras is subject to the fundamental "area–species number" correlation: as a city grows in size, the number of species in its flora increases [1, 7, 13–16]. In addition to this basic regularity, the richness of urban floras is determined by different natural and climatic factors; however, these correlations are less strict. For instance, the richness of native species can be negatively correlated with longitude [7], while the average air temperature, longitude, and latitude can serve as significant predictors for the richness of alien species [7, 17]. The proportion of alien species in urban floras does not depend on the urban size; however, it is negatively correlated with latitude and positively correlated with the annual average temperature [7, 18]. In addition, integrative studies on urban floras in Europe [7] and North America [17] have shown that the numbers of native and alien species in these floras are determined by different factors. The issue concerning the contribution to the richness of urban floras from anthropogenic factors proper, such as the degree of development of transport communications, has been discussed repeatedly [1, 15, 19], although this parameter strongly depends on the size of a city.

Analysis of 89 urban floras in the Russian Federation revealed factors that have the most significant influence on their richness [20]. In particular, the number of native species in the cities was almost exclusively determined by the size of the city, while the number of alien species was also determined by the level of anthropogenic transformation of regions and by the age of the city (positively) and climate severity (negatively). However, the quality of prediction in the corresponding multiple regression models was not very high: $R^2 = 0.43–0.58$ for different features. This is possibly due to a wide variability of urban characteristics and differences in approaches to the study of urban floras used by different researchers.

To gain a deeper insight into the patterns of formation of the composition of urban floras, it is necessary to compare the species richness of cities along different gradients. We analyzed factors of flora richness in 14 cities located in three natural zones of the Ural–Volga region, in which, along with the latitudinal gradient, the longitudinal gradient is also pronounced. All these floras were studied using the same methodological approaches and criteria, assuming that the use of an aligned array of estimates can improve the quality of interpretation of their characteristics.

The purpose of this study was to assess the influence of characteristics concerning the geographic location, topography, climate, size, and age of cities on the richness of urban floras in the Ural–Volga region. Two hypotheses were tested: (1) in addition to the "area–species number" correlation, the richness of urban floras is determined by climatic and topographic features; (2) the richness of the native and alien fractions of urban floras is determined by different factors.

MATERIAL AND METHODS

Array of estimates. We analyzed the estimates of species richness in the floras of 14 cities in the Urals and Middle Volga region (51°46′–58°02′ N, 48°22′–63°42′ E (Table 1). The cities are located in the southeast of the East European Plain (Dimitrovgrad, Zhigulevsk, Novoulyanovsk, Sengilei, and Tolyatti), the Cis-Ural region (Krasnoufimsk, Kumertau, Meleuz, Salavat, Ishimbay, and Sterlitamak), the mountain part of the Urals (Yekaterinburg), and the Trans-Ural region (Kamensk-Uralsky and Turinsk), in the steppe, forest–steppe, and taiga zones. They include four small towns with a population of up to 50000), four medium cities (up to 100000), three large cities (up to 250000), two major cities (up to 1 million), and one city with the population of over 1 million. The age of the cities varies from 58 to 400 years.

Indices of urban flora richness. We analyzed the original data on the richness of urban floras that were partially published [11, 21–25] and supplemented by our results. The species composition was studied by the method of route censuses that covered all the main variants of natural and anthropogenic habitats within the administrative boundaries of the cities. We used the unified, consistent approach to estimating the indices of urban flora richness: total number of species (N_{total}), the number of species in the native (N_{native}) and alien (N_{alien}) fractions, and the proportion of alien species (P_{alien}) (Table 1). The total number of urban flora species is the aggregate of all vascular plant species that grow within the administrative boundaries of a city and pass through their entire life cycle or its initial part without human involvement. The native fraction is the group of species that have appeared and grow in a region independently of human activities. The alien fraction is the group of species whose appearance in a region is a result of anthropogenic activity rather than of processes of natural florogenesis. Alien species include all species that were accidentally introduced in cities and those introduced species for which seed or vegetative reproduction has been revealed or which have been found outside cultivation sites.

City characteristics. Thirteen city characteristics were used as predictors for interpreting the richness of urban floras (Table 1). *Geographic location characteristics*: (1) latitude, (2) longitude. *Climate characteristics*: (3) annual average temperature, (4) annual precipitation, (5) Gorchinsky index of continentality. *City age and size characteristics*: (6) size of city area, (7) population, (8) population density, (9) age of city (the number of years since the official year of founding). *Topographic features*: (10–12) minimum, maximum, and mean terrain elevation above sea level; (13) relief complexity (the difference between the minimum and maximum terrain elevations). Features (3) and (4) were determined according to the Climate Data for Cities Worldwide website [26], features 10–12 were determined using the Google Maps Find Altitude tool [27], and features 5 and 13 were calculated.

Data analysis. The strength of correlation between two variables was estimated using the Pearson correlation coefficient (r). Factor analysis was performed by the principal component method with the threshold minimum eigenvalue of components taken as 1. The influence of several independent variables on the resultant was estimated using multiple linear regression without selecting variables. Prior to the analysis, we found the logarithms of the city area, population, and population density, and the P_{alien} feature was arcsine transformed.

RESULTS

The main factor of urban flora richness is the city size. An increase in the number of residents leads to an increase in the number of native ($r = 0.82$, $P = 0.0003$) and alien ($r = 0.93$, $P < 0.0001$) species and, accordingly, the total number of species in the urban flora ($r = 0.89$, $P < 0.0001$) (Figs. 1a–1c). The city area is less closely related to the indices of absolute richness of urban floras ($r = 0.82–0.86$, $P < 0.0004$ in all cases). The population density is even more poorly correlated with the richness of urban floras: $r = 0.58$,

Table 1. Characteristics of cities and indices of urban flora richness

Characteristic	City													
	Meleuz	Salavat	Sterlitamak	Ishimbay	Kumertau	Zhigulevsk	Tolyatti	Dimitrovgrad	Novoulyanovsk	Sengilei	Kamensk-Uralsky	Krasnoufimsk	Yekaterinburg	Turinsk
North latitude	52°57′	53°22′	53°38′	53°27′	52°46′	53°24′	53°31′	54°14′	54°09′	53°58′	56°24′	56°37′	56°50′	58°02′
East longitude	55°56′	55°56′	55°57′	56°02′	55°47′	49°30′	49°25′	49°35′	48°23′	48°48′	61°56′	57°46′	60°35′	63°42′
Natural zone	Steppe zone		Forest zone										Taiga zone	
Mean air temperature, °C	4.6	3.6	4.0	3.3	3.5	3.6	5.1	4.8	4.6	4.7	2.4	1.4	3.0	1.7
Annual precipitation, mm	415	413	497	421	428	440	492	522	505	500	467	534	537	481
Index of continentality	50.3	53.8	52.7	54.3	54.0	50.4	46.2	49.2	48.3	49.2	46.5	48.3	46.3	48.5
City area, km^2	36	106	109	104	170	61	315	103	31	6	144	48	490	28
Population, 1000 ind.	59	156	279	66	62	55	712	117	15	6	171	40	1430	17
Year of city founding	1958	1954	1781	1940	1947	1949	1953	1698	1957	1666	1702	1736	1723	1600
Elevation a.s.l., m:														
minimum	169	135	122	133	255	35	45	53	52	50	117	197	245	59
maximum	190	180	184	250	346	202	110	121	160	107	183	305	322	108
average	175	146	161	168	309	180	92	93	72	68	154	265	265	97
Elevation difference, m	21	45	62	117	91	167	65	68	108	57	66	108	77	49
Numbers of species in urban flora:														
total, N_{total}	645	722	694	689	663	526	919	448	379	372	753	607	973	288
native species, N_{native}	470	509	464	546	488	345	624	269	223	244	525	422	661	190
alien species, N_{alien}	175	213	230	143	175	181	295	179	156	128	228	185	312	98
Proportion of alien species, P_{alien}, %	27.1	29.5	33.1	20.7	26.4	34.4	32.1	39.9	41.1	34.4	30.2	30.4	32.0	34.0

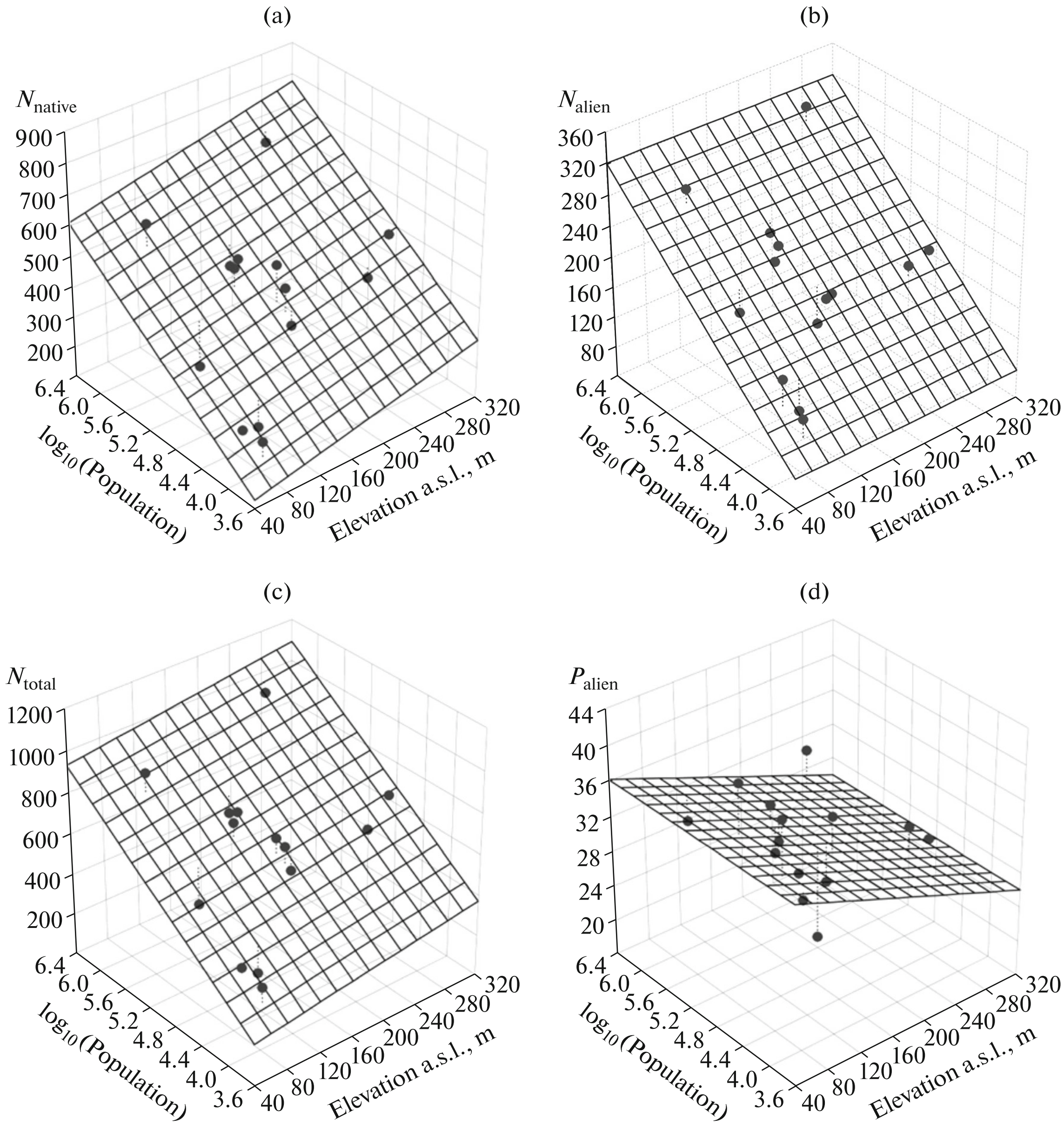

Fig. 1. Dependence of the numbers of (a) native species, (b) alien species, (c) all species and (d) of the proportion of alien species in urban floras on city population size and mean terrain elevation.

$P = 0.0308$ for N_{native}; $r = 0.79$, $P = 0.0007$ for N_{alien}; and $r = 0.67$, $P = 0.0093$ for N_{total}. Therefore, the population size explains the richness of urban floras better than the other characteristics of the urban size.

We were interested mainly in revealing the secondary factors of urban flora richness, additional to the city size. However, it was found that, along with the city size, N_{native} shows a weak correlation only with the minimum terrain elevation ($r = 0.58$, $P = 0.0282$).

Different indices of urban flora richness increase from small towns to big cities approximately to the same extent: N_{native} increases from 190–220 to 620–660 species, i.e., by a factor of 2.8–3.5; N_{alien} increases from 100–130 to 300–310 species, i.e., by a factor of 2.3–3.1; and N_{total} increases from 290–370 to 920–970 species, i.e., by a factor of 2.5–3.3. Therefore, the P_{alien} index is not related to the urban size (see Fig. 1d; $r = -0.16$, $P = 0.5752$ for the population size) and varies from 21 to 41%, being, on average, 32%. Analysis of pairwise coefficients of correlation between the city characteristics and P_{alien} suggests that the degree of adventization can be related (but weakly) to only two characteristics: annual precipitation ($r = 0.59$, $P = 0.0250$) and minimum elevation above sea level ($r = -0.57$, $P = 0.0342$).

Table 2. Structure of correlations between city characteristics

Characteristics of cities and regions	Factor loads*			
	principal component 1: "city size"	principal component 2: "latitude"	principal component 3: "terrain elevation"	principal component 4: "relief complexity"
(1) Latitude	−0.076	0.934	0.187	−0.177
(2) Longitude	0.022	0.429	0.629	−0.590
(3) Average annual temperature	0.281	−0.571	−0.666	0.160
(4) Yearly amount of precipitation	0.231	0.787	−0.160	0.314
(5) Continentality	−0.309	−0.750	0.316	−0.150
(6) City area	0.823	−0.053	0.392	0.091
(7) Population	0.954	0.004	0.217	−0.049
(8) Population density	0.864	0.097	−0.134	−0.259
(9) City age	−0.130	0.831	−0.078	−0.297
Elevation a.s.l.:				
(10) minimum	0.228	−0.077	0.874	−0.154
(11) maximum	0.116	−0.085	0.932	0.252
(12) average	0.170	−0.068	0.936	0.128
(13) Elevation difference	−0.212	−0.028	0.250	0.862
Proportion of explained variance	0.21	0.25	0.29	0.12

* Varimax-rotation was used.

Explaining the properties of urban flora based a limited number of predictors selected by analyzing pairwise correlation coefficients is an unjustified simplification. Many geographic, climatic, and other characteristics of cities are interdependent, since they may correlate with each other or causally determine each other. Therefore, the contribution of different predictors to the determination of urban flora properties can be correctly revealed only by simultaneously taking into account the contributions of all or, at least, several key urban characteristics. To this end, we used factor analysis and then calculated multiple regression using principal component estimates as predictors.

At the outset, we investigated the structure of correlations between the variables using the principal component analysis (Table 2). We distinguished four principal components that were orthogonal to each other and together explained 87% of the variance of initial features. The first component included three characteristics of the city size with the highest contribution from the population size variable. The second principal component is formed by the geographic latitude, annual precipitation, city size (positive indices) and the Gorchinsky index of continentality (negative index). Taking into account the highest contribution of the geographic latitude, it is most convenient to designate this component as "latitude" and interpret it as an integrated geographic factor that provides a generalized description of changes in different conditions along the latitudinal gradient. The third component is formed by three topographic characteristics: the minimum, maximum, and mean terrain elevations (all positive). The fourth principal component is easily interpreted as a characteristic of relief complexity.

Multiple regression based on the estimates of the four principal components makes it possible to explain 75–91% of variation in the N_{native}, N_{alien} and N_{total} indices and 47% of variation in the P_{alien} index (Table 3). The following predictors are significant: city size (the contribution to the total explained variance is approximately 68%) and terrain elevation (26%) for N_{native}; city size alone for N_{alien} (97%); city size (80%) and terrain elevation (17%) for N_{total}; terrain elevation alone for P_{alien} (59%). Since N_{native} and, accordingly, N_{total} increase with an increase in the terrain elevation, P_{alien} decreases in this case.

DISCUSSION

We were able to obtain regression dependences that provide a good explanation to the richness of urban floras on the basis of city characteristics (R^2_{adj} = 75–91%). The percentages of explainable variance that we obtained for the same urban flora indices using the same methods were 40–65% for 65 European cities [7] and 49–

Table 3. Results of calculation of multiple regressions describing the dependence of indices of urban flora richness on principal component estimates

Urban flora characteristic	Principal component								R^2_{adj}
	(1) "city size"		(2) "latitude"		(3) "terrain elevation"		(4) "relief complexity"		
	β	pR^2	β	pR^2	β	pR^2	β	pR^2	
N_{native}	0.746***	0.56	–0.215	0.05	0.465**	0.22	–0.077	0.01	0.75
N_{alien}	0.953***	0.91	0.069	0.00	0.124	0.02	0.110	0.01	0.91
N_{total}	0.841***	0.71	–0.140	0.02	0.385**	0.15	–0.025	0.00	0.82
P_{alien}	0.003	0.00	0.413	0.17	–0.614*	0.38	0.295	0.09	0.47

Designations: β, standardized partial regression coefficient; R^2_{adj}, the coefficient of determination adjusted for the number of parameters; pR^2, the proportion of variance explained by variable associated with predictor. Levels of significance of β-coefficients: *$P < 0.05$, **$P < 0.001$, ***$P < 0.001$.

58% for 89 Russian cities [20]. Therefore, the use of a geographically and methodically aligned data array makes it possible to improve the quality of interpretation of urban flora indices. The contributions of predictors "latitude" and "relief complexity" to the interpretation of urban flora indices are small and can be neglected. Therefore, all interpretations can be reduced to the analysis of one- or two-parameter dependences shown in Fig. 1.

It is quite expectable that features N_{total}, N_{native}, and N_{alien} are most significantly determined by the urban size: the growth in the species richness with increase in the study area is a universal regularity that holds for both natural floras and anthropogenically transformed areas [1, 7, 13–16, 28–30]. Factors contributing to the formation of high plant diversity in the cities include preservation of sites with natural communities, as well as an intensive introduction of alien species and a high patchiness of habitats providing for the coexistence of ecologically dissimilar species [7, 9, 13, 16, 18, 31, 32].

We revealed no correlation between the indices of urban flora richness and climatic (temperature and precipitation) and geographic (latitude and longitude) characteristics. This is possibly due to a relatively small size of the study region (extending for 5 degrees of latitude and 15 degrees of longitude) and, accordingly, a narrow range of conditions. A limited influence of climate was observed for the cities of Central Europe located along the transect extending for 1000 km from oceanic to continental areas [18, 31], although in other studies the number of native and alien species in urban floras were found to correlate with average air temperature and with longitude and latitude [7, 17].

Landscape characteristics are an important factor of biological diversity [29, 33]. In our case, their influence is manifested in an increase of N_{native} and N_{total} with rise in the terrain elevation in the west–east direction within the study region (from the Volga region to the Urals). This may reflect the known regularity that floristic diversity is higher in the mountain regions [29, 33]. The average elevations actually increase from the flatland cities of the Volga region to the Ural cities, although to different degrees: 68–180 m a.s.l. for Ulyanovsk and Samara oblasts; 97–309 m a.s.l. for Bashkortostan and Sverdlovsk oblast. However, the degree of anthropogenic transformation of ecosystems in the region also decreases in this direction, i.e., from the west to the east. For instance, this follows from decrease in population density (from 34–60 ind./km^2 in Ulyanovsk and Samara oblasts to 22–28 ind./km^2 in Bashkortostan and Sverdlovsk oblast) and the proportion of built-up area (from 2.0–2.8% to 1.3–1.4%, respectively) in the same direction [34]. Therefore, it appears impossible to reliably differentiate between the contributions of orographic features, the history of ecosystem development in the region, and the degree of their anthropogenic disturbance in explaining the structure of urban floras based on our data array. Nevertheless, since the increase in N_{native} with rise in elevation is more distinct than the decrease in N_{alien}, it appears more probable that it is topographic features, rather than anthropogenic effects, that have a greater effect on the structure of urban floras.

We did not reveal any relationship between the terrain elevation and the richness of alien species. However, a negative correlation between these parameters was shown for European cities. Presumably, this relationship is indirect and is due to the fact that major cities with a great number of alien species are located mainly in lowland areas, while small towns with a low number of alien species are mainly in the mountains [3, 7, 31].

When verifying the hypothesis of correlation between topographic features and characteristics of urban flora, we used a parameter such as relief complexity, in addition to terrain elevation [33]. At the same time, we assumed that the elevation difference can characterize the degree of environmental heterogeneity, i.e., the degree of habitat diversity in a city. In other words, a high elevation difference may be correlated with an increase in plant species richness. However, contrary to these expectations, the relief complexity had no effect on the richness of urban floras.

On the whole, our first working hypothesis was, in part, confirmed: in addition to the city size, the number of native species in urban floras is also dependent on the terrain elevation. The second hypothesis, according to which the richness of native and alien species in cities is determined by different factors, was also confirmed. Although the leading determinant for both N_{native} and N_{alien} is the city size, a significant additional factor, namely, terrain elevation has a significant effect on N_{native} (Fig. 1a), while the N_{alien} does not depend on this factor. It should also be noted that the richness in alien species depends on the city size more significantly than other urban flora indices.

The P_{alien} index varies in a qualitatively different way than the indices of absolute richness of urban floras: first, the general level of its determinability is markedly lower than that of N_{native}, N_{alien}, and N_{total}; second, P_{alien} does not depend on the city size and decreases with rise in terrain elevation. The negative correlation between the terrain elevation and the proportion of alien species can be interpreted as follows: the richness of native species is higher in Ural cities with a mountain relief than in the cities of the flatland Volga region (certainly, with effects associated with the urban size being eliminated). Therefore, the proportion of alien species in urban floras decreases against the background of general increase in terrain elevation. The explanation of the dynamics of P_{alien} primarily by variation in the number of native rather than alien species is consistent with the fact that the proportion of variation that is not explained by the factor of city size factor is significantly higher for N_{native} than for N_{alien}.

In other regions, the P_{alien} index is also not correlated with the city size [7] but shows a positive correlation with the total level of anthropogenic transformation of ecosystems in the region to which the city belongs [35]. The absence of P_{alien} correlation with the city size, its positive correlation with the degree of anthropogenic transformation of the region and city age, and a negative relation with climate continentality were revealed during analysis of 89 urban floras in Russia [20].

CONCLUSIONS

The richness of urban floras in the Ural–Volga region is determined primarily by the city size: this factor explains 56% of variation in the number of native species and 91% of variation in the number of alien species. The influence of landscape properties, particularly terrain elevation, on the richness of urban floras has been revealed for the first time, with this factor having an effect on the number of native rather than alien species. Therefore, (1) the formation of the native and alien components of urban floras depends in part on different factors, and (2) a natural factor (the terrain elevation in our case) has a significant influence on the richness of the native component of urban flora. This means that natural mechanisms of biodiversity formation continue to function in the cities. Logically, their role as determinants of species richness is more important for the derivative of regional flora rather for the alien component, for which no additional factors except city size were revealed. The high degree of correlation between alien species richness and the size of city area or population size confirms the leading role of direct anthropogenic mechanisms in the dispersal of this plant group. Additional efforts are required for obtaining a more complete picture of the composition and relative importance of these mechanisms for florogenesis in urbanized areas.

Our results confirm that the proportion of alien species in urban floras is determined in a principally different way than parameters of their absolute richness. In the urban floras of the Ural–Volga region, the proportion of alien species becomes smaller with the general increase in terrain elevation from the west to the east, i.e., from cities on the East European Plain, in regions with a significant anthropogenic transformation of ecosystems, to cities in less densely populated and less transformed regions of the Urals. On the whole, however, geographic variation in the richness of urban floras is low in the Ural–Volga region, where climatic conditions are relatively uniform and the type of agriculture and history of economic development are generally similar. This variation is apparently manifested more clearly in regions with a more contrasting gradient of conditions, where its analysis would be more convincing. Nevertheless, the results of this study show that the use of a geographically and methodologically aligned data array provided a good explanation for changes in the richness of urban floras and made it possible to confirm our working hypotheses.

ACKNOWLEDGMENTS

This study was partly supported by the Russian Foundation for Basic Research (projects nos. 15-44-02160, 16-54-00105, and 17-04-00371) and the Program for Improving the Competitiveness of the Ural Federal University (the decree no. 211 of the Government of the Russian Federation, contract no. 02.A03.21.0006).

REFERENCES

1. Morozova, G.Yu., Zlobin, Yu.A., and Mel'nik, T.I., Plants in urbanized natural environment: Florogenesis, cenogenesis, and population structure, *Zh. Obshch. Biol.,* 2003, vol. 64, no. 2, pp. 166–180.
2. Seto, K.C., Güneralp, B., and Hutyra, L.R., Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools, *Proc. Natl. Acad. Sci. U. S. A.,* 2012, vol. 109, no. 40, pp. 16083–16088.

3. Pyšek, P., Factors affecting the diversity of flora and vegetation in central European settlements, *Vegetatio,* 1993, vol. 106, no. 1, pp. 89–100.
4. Celesti-Grapow, L., Pyšek, P., Jarošik, V., and Blasi, C., Determinants of native and neophyte species richness in the urban flora of Rome, *Divers. Distrib.,* 2006, vol. 12, no. 5, pp. 490–501.
5. Berezutskii, M.A. and Panin, A.V., The flora of cities: Structure and tendencies of anthropogenic dynamics, *Bot. Zh.,* 2007, vol. 92, no. 10, pp. 1481–1489.
6. Aronson, M.F.J., La Sorte, F.A., Nilon, C.H., et al., A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers, *Proc. R. Soc. B,* 2014, vol. 281, no. 1780, 20133330. doi 10.1098/rspb.2013.3330
7. Pyšek, P., Alien and native species in Central European urban floras: A quantitative comparison, *J. Biogeogr.,* 1998, vol. 25, no. 1, pp. 155–163.
8. Kühn, I., Brandl, R., and Klotz, S., The flora of German cities is naturally species rich, *Evol. Ecol. Res.,* 2004, vol. 6, no. 5, pp. 749–764.
9. Mckinney, M.L., Effects of urbanization on species richness: A review of plants and animals, *Urban Ecosyst.,* 2008, vol. 11, no. 2, pp. 161–176.
10. Ishbirdina, L.M. and Ishbirdin, A.R., Urbanization as a factor of anthropogenic evolution of flora and vegetation, *Zh. Obshch. Biol.,* 1992, vol. 53, no. 2, pp. 211–214.
11. Tret'yakova, A.S., *Flora Ekaterinburga* (The Flora of Yekaterinburg), Yekaterinburg: Ural. Fed. Univ., 2011.
12. Schmidt, K., Poppendieck, H.H., and Jensen, K., Effects of urban structure on plant species richness in a large European city, *Urban Ecosyst.,* 2014, vol. 17, no. 2, pp. 427–444.
13. Pyšek, P., On the richness of Central European urban flora, *Preslia,* 1989, vol. 61, pp. 329–334.
14. Tokhtar', V.K. and Fomina, O.V., Specific features of urban flora formation under different natural climatic and anthropogenic conditions: Factor analysis and data visualization, *Nauch. Vedomosti Belgorod. Gos. Univ., Ser. Estestv. Nauki,* 2011, no. 15, pp. 23–28.
15. Senator, S.A., Kostina, N.V., and Saksonov, S.V., Dependence of the species diversity of urban floras on a series of factors, *Vestn. Udmurt. Gos. Univ., Ser. Biol., Nauki o Zemle,* 2013, no. 2, pp. 23–29.
16. Ceplová, N., Kalusová, V., and Lososová, Z., Effects of settlement size, urban heat island and habitat type on urban plant biodiversity, *Landscape Urban Plan.,* 2017, vol. 159, pp. 15–22.
17. Clemants, S. and Moore, G., Patterns of species richness in eight northeastern United States cities, *Urban Habitats,* 2003, vol. 1, no. 1, pp. 4–16.
18. Lososova, Z., Chytry, M., Tichy, L., et al., Native and alien floras in urban habitats: A comparison across 32 cities of central Europe, *Global Ecol. Biogeogr.,* 2012, vol. 21, no. 5, pp. 545–555.
19. Rat, M.M., Gavrilović, M.T., Radak, B. Đ., et al., Urban flora in the Southeast Europe and its correlation with urbanization, *Urban Ecosyst.,* 2017, vol. 20, no. 4, pp. 811–822.
20. Veselkin, D.V., Tret'yakova, A.S., Senator, S.A., et al., Geographic factors of floristic richness in the cities of Russia, *Dokl. Ross. Akad. Nauk,* 2017, vol. 476, no. 3, pp. 347–349.
21. Rakov, N.S. and Saksonov, S.V., The flora of small cities of Ulyanovsk oblast: 1. Novoulyanovsk, *Fitoraznoobr. Vost. Evropy,* 2008, no. 6, pp. 46–95.
22. Senator, S.A. and Baranova, O.G., Comparative analysis of floras in cities of the Middle Volga region, *Vestn. Udmurt. Gos. Univ., Ser. Biol., Nauki o Zemle,* 2013, no. 4, pp. 37–46.
23. Rakov, N.S., Saksonov, S.V., and Senator, S.A., The flora of small cities of Ulyanovsk oblast: 1. Sengilei, *Samarskaya Luka: Probl. Region. Glob. Ekol.,* 2013, vol. 22, no. 1, pp. 39–79.
24. Senator, S.A., Saksonov, S.V., Rakov, N.S., et al., Vascular plants of Tolyatti and its vicinities (Samara oblast), *Fitoraznoobr. Vost. Evropy,* 2015, vol. 9, no. 1, pp. 32–101.
25. Golovanov, Ya.M. and Abramova, L.M., Comparative analysis of the structure of urban floras in the southern industrial zone of the Cisural region, *Bot. Zh.,* 2017, vol. 102, no. 4, pp. 540–562.
26. Climate Data for Cities Worldwide. http://ru.climate-data.org. Cited August 25, 2017.
27. Google Maps Find Altitude. https://www.daftlogic.com/sandbox-google-maps-find-altitude.htm. Cited August 25, 2017.
28. Tolmachev, A.I., Flora richness as an object of comparative study, *Vestn. Leningr. Univ., Ser. Biol.,* 1970, no. 2, pp. 71–83.
29. Malyshev, L.I., The ecology of floristic richness of Northern Asia, *Bot. Zh.,* 2003, vol. 88, no. 8, pp. 28–36.
30. Govorov, E.V., Yamalov, S.M., and Mirkin, B.M., Effect of the size of a populated area on the parameters of synanthropic vegetation diversity, *Russ. J. Ecol.,* vol. 35, no. 5, pp. 358–360.
31. Lososova, Z., Horsak, M., Chytry, M., et al., Diversity of Central European urban biota: Effects of human-made habitat types on plants and land snails, *J. Biogeogr.,* 2011, vol. 38, no. 6, pp. 1152–1163.
32. Tret'yakova, A.S., Distribution of plant species composition in natural and anthropogenic habitats of Yekaterinburg, *Bot. Zh.,* 2014, vol. 99, no. 11, pp. 1277–1282.
33. Morozova, O.V., *Taksonomicheskoe bogatstvo Vostochnoi Evropy: faktory prostranstvennoi differentsiatsii* (Taxonomic Richness of Eastern Europe: Factors of Spatial Differentiation), Moscow: Nauka, 2008.
34. The Environment and Population Health of Russia. http://www.sci.aha.ru/ATL/ra00.htm. Cited August 25, 2017.
35. Kozhevnikov, A.E. and Kozhevnikova, Z.V., Alien plant species in the flora of the Russian Far East and regional tendencies of their geographic differentiation, *Vestn. Dal'nevost. Otd. Ross. Akad. Nauk,* 2014, no. 3, pp. 12–19.

Translated by D. Zabolotny