Conference Paper

Gradients of Taxonomic Diversity among Local Floras in the Russian Arctic

O. V. Khitun[1], S. V. Chinenko[1], A. A. Zverev[2], T. M. Koroleva[1], V. V. Petrovsky[1], I. N. Pospelov[3], and E. B. Pospelova[4]

[1]Komarov Botanical Institute of the Russian Academy of Sciences, 197376 St Petersburg, Russia
[2]Tomsk State University, 634050 Tomsk, Russia
[3]A. N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, 119071 Moscow, Russia
[4]Taimyrsky State Nature Reserve, 663305 Norilsk, Russia

Corresponding Author:
O. V. Khitun
khitun-olga@yandex.ru

Received: 12 September 2018
Accepted: 15 October 2018
Published: 29 October 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the Ecology and Geography of Plants and Plant Communities Conference Committee.

Abstract

Latitudinal and longitudinal changes in taxonomic variables were analyzed in 319 local floras in the Russian Arctic. Within the studied segment of latitudinal gradient, most changes can be described in terms of linear regression with negative coefficients (a number of species, genera and families), or positive coefficients (a proportion of the leading families and genera). However, the mean number of species in a family or genus almost does not change with increasing latitude, although it slightly increases as one moves eastward. The proportion of monocots does not correlate with latitude, but slightly decreases as one moves eastward. Proportions of various families change asynchronously. Although correlation with longitude was less pronounced, mean species richness was specific to many subprovinces, even within a certain subzone. These differences reflect both the diversity of landscapes and the history of flora formation.

Keywords: the Arctic, local floras, latitudinal and longitudinal gradient, floristic subprovinces

1. Introduction

Although the latitudinal trend for a decrease in biodiversity as one moves from the equator to the poles is well known, the geographical variation of species richness and the role of factors underlying diversity gradients (climate, history, evolution) need further investigation [1–5]. There is no unanimous approach to studying the spatial distribution of taxonomic variables. Most commonly, taxonomic richness is compared between rather large territories, such as grid squares of given size or administrative units. In both cases, these units are filled with species according to regional flora books or species distribution maps [1, 6, 7]. The method of concrete or local floras [8, 9] gives reliable data about species presence in certain localities and can be useful for the study of biodiversity changes [3].

On a global or continental scale, biodiversity changes in the Arctic are characterized by a sharp decrease of taxonomic variables: however, usually only species richness is taken into account. The expression of the latitudinal gradient varies within its different segments [1, 3, 12]. The first attempt to analyze changes in various taxonomic characters in three sectors of the Asian Arctic was made under guidance of B. A. Yurtsev [11] without any statistical treatment. The aim of this work is to test statistically the changes of the various taxonomic variables of local floras (LFs) in the Russian Arctic as a whole and within different subprovinces. Knowledge of these natural variations is important because Arctic biota is under threat from global climate change and increasing anthropogenic pressure [13].

2. Methods

More than 250 checklists of LFs studied by the researches of the Komarov Botanical Institute RAS and their coauthors from the 1950s to the present and about 70 species lists of LFs published by other botanists have been inputted into the integrated botanical information system IBIS v.7.2 [14]. IBIS provided the taxonomical spectra of LFs and data sets for the following statistical treatment in Statsoft Statistica v.8.0 [15]. In total, 319 LFs from all subprovinces of the Russian Arctic and Subarctic were analyzed. We follow the scheme of the floristic subdivision of the Arctic [16], with addition of the Kola subprovince, which includes the northern coast of the Kola Peninsula [17, 18]. Several LFs from forest-tundra and northern taiga territories adjacent to the Arctic are also included in the database. Comparative analysis demands the unification of nomenclature: therefore, we follow *The Arctic Flora of the USSR* [19] with regards to the volume of species, genera and families. In the Panarctic Flora checklist [20], the volume of several genera in such families as *Caryophyllaceae* and *Polygonaceae* is different.

In this article, we will discuss the correlation of the quantitative floristic variables of LFs of the Russian Arctic (Table 1) with geographical position (latitude, longitude) along the latitudinal gradient from 64° to 82° N and the longitudinal gradient from 28° E to 168° W. It is well known that latitudinal position is strongly correlated with temperature, while longitude reflects the oceanity—continentality gradient [3]. As datasets of taxonomic variables (n = 319) fulfill the normal distribution demand (the Kolmogorov–Smirnov criteria), we used Pearson's linear correlation analysis and linear model for regression. To test the significance of differences in species richness between the different subprovinces, the non-parametric Mann–Whitney criterion was used.

3. Results

The studied variables and the expression of their latitudinal and longitudinal variation within the Russian Arctic as a whole and in the separate subprovinces are summarized in Table 1. In the set of all 319 LFs, negative correlations with latitude (we discuss here only statistically significant coefficients) were found for a number of species, genera and families, which confirms the presence of a zonal gradient of decreasing diversity as one moves northward at all taxonomical levels. The strongest correlation was shown at the level of families. According to the regression analysis, on average, per 1 degree latitude northward, LFs diversity decreases by 16.7 species, 7.9 genera and 2.6 families. On the Central Siberian Plateau within the latitudinal segment from 54° to 73° N, a similar value was calculated for the species – a decrease by 16.3 per 1° [1]. In the European part of Russia, in the segment between 50° and 80° N, changes in diversity were described by a logistic curve [10], with a rather gentle northern part and a steep increase (up to 44 species per 1°) at the border of the southern taiga subzone, however, Arctic LFs were poorly represented in that study.

A positive correlation with longitude was found only for a number of species, and it is weaker than that with latitude (Table 1). The longitudinal gradient is essentially longer and the range of variation in richness is not as great as along the zonal gradient, but this depends heavily on landscape and geological diversity. Comparisons within the separate subzones revealed the differences between many subprovinces (not shown here). In the subzone of the southern Arctic tundra, LFs on Wrangel Island are significantly richer than anywhere else. In the northern Hypoarctic tundra, species diversity grows as one goes eastward (with the exception of the Yana–Kolyma subprovince). In the southern Hypoarctic tundra, LFs of the Kola Peninsula, Taimyr and continental Chukotka have a similar level diversity, one that is higher than in the other regions.

Table 1: Coefficients of correlation between the floristic variables and geographical position of the local floras in the Russian Arctic as a whole and in various subprovinces.

Variable	Subprovinces or their joinings								
	All	KK + KP + SF	KP	UZ	YaG	T	AO + Kh	YaK	CC + CW + CS + CB
Number of LFs	319	63	47	14	27	59	38	20	98
	Coefficients of correlation with latitude								

Variable	Subprovinces or their joinings								
Number of species	**−0.62**	**−0.76**	**−0.90**	**−0.89**	**−0.66**	**−0.79**	−0.05	**−0.47**	**−0.45**
Number of genera	**−0.71**	**−0.82**	**−0.91**	**−0.92**	**−0.84**	**−0.86**	**−0.35**	**−0.63**	**−0.68**
Number of families	**−0.76**	**−0.92**	**−0.88**	**−0.94**	**−0.93**	**−0.87**	**−0.42**	**−0.70**	**−0.70**
The proportion of the 10 leading genera	**0.78**	**0.98**	**0.80**	**0.98**	**0.76**	**0.80**	**0.40**	**0.67**	**0.67**
The proportion of the 10 leading families	**0.80**	**0.98**	**0.80**	**0.99**	**0.91**	**0.89**	**0.64**	**0.71**	**0.72**
The proportion of Monocots	0.05	0.08	**0.54**	**0.70**	0.37	0.05	**−0.42**	−0.15	−0.12
	Coefficients of correlation with longitude								
Number of species	**0.28**	**−0.37**	**−0.36**	0.23	**0.49**	0.21	0.25	**−0.54**	0.23
Number of genera	0.03	**−0.35**	**−0.41**	0.42	0.25	0.12	0.31	**−0.61**	0.01
Number of families	−0.01	−0.29	**−0.49**	0.34	0.08	0.11	0.20	**−0.47**	−0.12
The proportion of the 10 leading genera	−0.02	0.14	**0.40**	−0.30	0.10	−0.03	−0.18	**0.46**	0.13
The proportion of the 10 leading families	−0.01	0.18	**0.52**	−0.39	−0.03	−0.05	−0.17	0.18	0.09
The proportion of Monocots	**−0.30**	−0.05	**0.39**	−0.14	−0.37	**0.28**	**−0.82**	0.09	**−0.26**
Number of species in the family:	Coefficients of correlation with latitude								
Poaceae	**−0.41**	**−0.70**	**−0.59**	−0.26	−0.32	**−0.61**	0.26	−0.42	0.05
Cyperaceae	**−0.62**	**−0.74**	**−0.85**	**−0.88**	**−0.52**	**−0.78**	**−0.49**	−0.37	**−0.56**
Asteraceae	**−0.65**	**−0.78**	**−0.86**	**−0.94**	**−0.65**	**−0.80**	−0.01	−0.39	−0.16
Caryophyllaceae	**−0.41**	**−0.64**	**−0.70**	**−0.75**	0.11	**−0.73**	0.29	−0.22	**−0.28**
Brassicaceae	0.05	−0.21	**−0.63**	0.09	**0.66**	**−0.26**	**0.49**	−0.14	**−0.22**
Ranunculaceae	**−0.48**	**−0.82**	**−0.78**	**−0.65**	−0.14	**−0.74**	0.07	0.0	**−0.29**
Rosaceae	**−0.64**	**−0.69**	**−0.87**	**−0.77**	**−0.60**	**−0.73**	−0.25	**−0.54**	**−0.40**
Salicaceae	**−0.67**	**−0.84**	**−0.51**	**−0.88**	**−0.84**	**−0.81**	−0.13	**−0.56**	**−0.48**
Saxifragaceae	0.06	**0.60**	**0.49**	−0.51	**0.71**	−0.05	**0.75**	0.35	−0.11
Scrophulariaceae	**−0.49**	**−0.78**	**−0.81**	**−0.83**	**−0.73**	**−0.71**	−0.05	−0.29	**−0.23**
Juncaceae	**−0.63**	**−0.62**	−0.10	**−0.62**	**−0.75**	**−0.73**	0.06	−0.07	**−0.67**
Fabaceae	**−0.40**	**−0.64**	**−0.87**	**−0.83**	−0.27	**−0.62**	0.05	**−0.54**	−0.11
Ericaceae	**−0.76**	**−0.87**	**−0.68**	**−0.89**	**−0.93**	**−0.83**	−0.29	−0.39	**−0.81**
Source: Authors' own work.									
Note: Subprovinces: KK, Kola; SF, Svalbard and Franz Josef Land; KP, Kanin–Pechora; UZ, Ural–Novaya Zemlja; YaG, Yamal–Gydan; T, Taimyr; AO, Anabar–Olenek; Kh, Kharaulakh; YaK, Yana–Kolyma; CC, Continental Chukotka; CW, Wrangel Chukotka; CS, Southern Chukotka; CB, Beringian Chukotka. Statistically significant ($P < 0.05$) values are indicated in bold.									

The high portion of species in the 10 (and, moreover, in 20) leading families is a characteristic feature of Arctic floras [8]: it increases as one goes northward, both in the Arctic as a whole and in each of the subprovinces (Table 1). This portion in LFs in the High Arctic reaches 94–98%: it decreases to 77–86% in the northern Arctic tundra and to 62–76% in the southern Arctic and in the two Hypoarctic tundra subzones. In the northern taiga, it is always below 60% (55–59%). Correlation with latitude for this parameter is the strongest in the Ural–Novaya Zemlya subprovince, as there both the northern taiga and the High Arctic floras were represented. Correlation with longitude was not found except in Kanin–Pechora. However, in the latter, this is likely a reflection of the asymmetry in the LF set (the studied northern taiga LFs were located in the western part of this subprovince, while the majority of the tundra ones were in the eastern part).

The mean number of species in a family slightly increases as one goes southward. Our previous research did not reveal this tendency, but, in longer gradients in the European part of Russia, this correlation was found and it was expressed stronger [3, 10]. The same regularity was found for the mean number of genera in a family. No correlation with latitude was found for the mean number of species in a genus. These variables vary essentially at the same latitude in different sectors of the Arctic. All the aforementioned parameters exhibit correlations with longitude. The number of species in a genus reaches 3.6–3.8 in the Chukotkan LFs, whereas in the European LFs it is only 2.4–2.9. The number of species in a family is 11.3–12.8 versus 7.2–10.2, respectively. The increase of these parameters eastward expresses the fact that many Arctic genera (*Potentilla, Astragalus, Oxytropis, Artemisia, Taraxacum*) have a speciation center in Beringia. The relative stability of flora proportions within one subprovince can be explained by removing single species families and replacing some boreal species with Arctic ones.

The proportion of monocots along the longer gradient, crossing several biogeographical zones, decreases as one goes northward [3, 10]. However, our data does not support this regularity because in different sectors changes in the proportion of monocots to dicots take place at various latitudes. There is a slight decrease in the proportion of monocots as one moves eastward.

The parameters of biodiversity in various subprovinces exhibit similar tendencies in correlation with latitude, although coefficients vary. High coefficients in the Kanin–Pechora and Ural–Novaya Zemlya subprovinces are caused by a large amplitude of values on a relatively short gradient. In the former, the richness of LFs varies from 450 species in the northern taiga to 120–140 in the northern hypoarctic tundra; in the latter, it varies from 240–260 species in forest-tundra to 59 in the northern Arctic LF. A relatively high correlation between the number of species and longitude was recorded in the Yamal–Gydan sector, reflecting the differences we have already reported [21] in the richness between the Yamal and Gydan LFs exhibited in all subzones.

The absolute number of species in almost all 20 leading families decreases as one goes northward and slightly increases as one moves eastward. However, the correlation with latitude was not found in the families *Brassicaceae* and *Saxifragaceae.* The reason for this is a large number of Arctic species in the genera *Draba* and *Saxifraga*, which in some subprovinces are present in floras only in the Arctic tundra subzone. For example, in Yamal and Gydan an obstacle to their presence in the hypoarctic tundra is widespread acidic peaty soils: these species prefer mineral ground. In the family *Papaveraceae*, an even slighter positive correlation with latitude was found, probably for the same reason. The correlation between the number of species in various families and latitude varies between families and subprovinces from very strong to non-significant (Table 1). In terms of the proportion of various families, both negative and positive correlations were found (an increase in the proportion of *Poaceae, Caryophyllaceae, Brassicaceae, Saxifragaceae, Papaveraceae* and *Ranunculaceae* in LFs as one goes northward). In these families, along with the tendency of species to drop out as one goes northward, the opposite trend is also present – the appearance of new species in the following genera (*Cerastium, Minuartia, Ranunculus, Puccinellia, Draba*, *Saxifraga)* and even the appearance of new genera (*Pleuropogon, Phippsia*). Interestingly, proportions of the same families do not change with longitude (not shown here). In other families, longitudinal correlations are weaker or absent. The strongest positive correlation with longitude was found in the *Salicaceae* family: this reflects the increase in mountain willow species in Asia and, especially, in Chukotka.

4. Conclusions

Linear regressions with negative coefficients describe the latitudinal changes in vascular plant diversity at all taxonomical levels throughout the entirety of the Russian Arctic and in individual subprovinces. However, the expression of this trend varies in different groups and in different subprovinces. Various parameters (f. ex., number of species vs. proportion of species in 10 leading families) exhibit contradictory trends. Various families and genera change in different ways both along the latitudinal and longitudinal gradients. Correlations with longitude are generally weaker or are not found for many variables. Local conditions (the presence of mountains, exposed bedrock, the presence of a thick peat layer) and the history of the region influence taxonomic diversity in an essential way.

Acknowledgement

This work was completed within the research project of the Komarov Botanical Institute RAS 'Variation of the plant cover in the Far North in space and time'.

References

[1] Malyshev, L. I. (1994). Floristic richness of the USSR, in *Actual Problems of the Comparative Study of Floras*, pp. 34–87. St Petersburg: Nauka.

[2] Rozenzweig, M. L. (1995). *Species Diversity in Space and Time*, p. 436. Cambridge: Cambridge University Press.

[3] Morozova, O. V. (2008). *Taxonomic Richness of Eastern Europe: Factors of Spatial Differentiation*, p. 328. Moscow, Nauka.

[4] Mittelbach, G. G., Schemske, D. W., Cornell, H. V., et al. (2007). Evolution and the latitudinal diversity gradient: Speciation, extinction and biogeography. *Ecology Letters*, no. 10, pp. 315–331.

[5] Kerkhoff, A. E., Moriarty, P. E., and Weiser, M. D. (2014). The latitudinal species richness gradient in New World Woody Angiosperms is Consistent with the tropical conservatism hypothesis. *PNAS*, vol. 111, no. 22, pp. 8125–8130.

[6] Grytnes, J. A., Birks, H. J., and Peglar, S. M. (1999). Plant species richness in Fennoscandia: Evaluating the relative importance of climate and history. *Nordic Journal of Botany*, vol. 19, no. 4, pp. 489–503.

[7] Qian, H. (1999). Spatial pattern of vascular plant diversity in North America North of Mexico and its floristic relationship to Eurasia. *Annals of Botany*, vol. 83, no. 3, pp. 271–283.

[8] Tolmatchev, A. I. (1974). *Introduction to Phytogeography*, p. 244. Leningrad: Leningrad University Print.

[9] Khitun, O. V., Koroleva, T. M., Chinenko, S. V., et al. (2016). Applications of local floras for floristic subdivision and monitoring vascular plant diversity in the Russian Arctic. *Arctic Science*, vol. 2, no. 3, pp. 103–126.

[10] Schmidt, V. M. (1979). Dependence of quantitative indices of some concrete floras in the European part of USSR. On geographical latitude. *Botanicheskii Zhurnal*, vol. 64, no. 2, pp. 172–183.

[11] Yurtsev, B. A., Zverev, A. A., Katenin, A. E., et al. (2002). Gradients in the taxonomical parameters of local and regional floras in Asian Arctic (related to the biodiversity monitoring sites network). *Botanicheskii Zhurnal*, vol. 87, no. 6, pp. 1–28.

[12] Matveeva, N. V. (1998). Zonality in plant cover of the Arctic. *Transactions of Komarov Botanical Institute*, vol. 21, p. 220.

[13] Cramer, W., Yohe, G. W., Auffhammer, M., et al. (2014). *Detection and attribution of observed impacts. Climate Change 2014: Impacts, Adaptations and Vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC*, pp. 979–1037. Cambridge: Cambridge University Press.

[14] Zverev, A. A. (2007). *Information Technologies in the Study of Plant Cover*, p. 304. Tomsk: TML-Press.

[15] *Electronic Statistics Textbook*. Tulsa: StatSoft Inc. Retrieved from http://www.statsoft.com/textbook/

[16] Yurtsev, B. A. (1994). Floristic division of the Arctic. *Journal of Vegetation Science*, vol. 5, no. 6, pp. 765–776.

[17] Koroleva, N. E. (2006). Zonal tundra on the Kola Peninsula – Reality or mistake? *Newsletter of MGTU*, vol. 9, no. 5, pp. 747–756.

[18] Chinenko, S. V. (2008). Local floras of the eastern part of the northern coast of the Kola Peninsula in comparison with local floras of adjacent regions. *Botanicheskii Zhurnal*, vol. 93, no. 1, pp. 60–81.

[19] Tolmatchev, A. I. and Yurtsev, B. A. (eds.). (1960–1987). *Arctic Flora of the USSR, I-X*. Leningrad: Nauka.

[20] Elven, R. (ed.). (2007). *Annotated Checklist of the Panarctic Flora (PAF). Vascular Plants*. Retrieved from http://nhm2.uio.no/paf/

[21] Khitun, O. V. (1998). Comparative analysis of local and partial floras in two subzones in the West Siberian Arctic, in *Study of Biodiversity by the Methods of Comparative Floristics*, pp. 173–201. SPb: NIIFH