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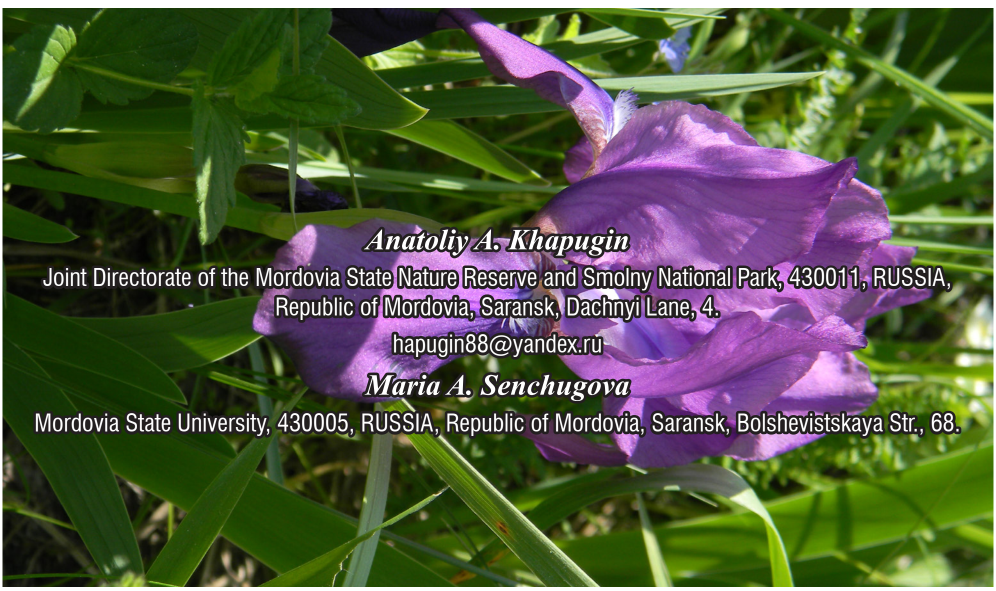
The floristic lists as a source to characterize environment conditions of habitats using phytoindication methods: A case study for *Iris aphylla* (Iridaceae) and *Lilium martagon* (Liliaceae) in central Russia

Las listas florísticas como fuente para caracterizar las condiciones ambientales de habitats usando métodos de fitoindicación: un caso de estudio para *Iris aphylla* (Iridaceae) y *Lilium martagon* (Liliaceae) en Rusia central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Abstract

Floristic lists are often considered only as a source of information for general comparison of floras in different localities or for comparison of flora within the same locality at different times. However, pure floristic lists may be useful to estimate environmental conditions in natural habitats using phytoindication methods. We showed here that if we have a set of floristic lists of certain region, we can use phytoindication methods to establish coenotical confinement of certain species and environmental factors which are most important for its existence. As example, we showed that it is possible to separate habitats with favourable and unfavourable environmental conditions for certain plant species (*Iris aphylla*) using phytoindication methods. We also proposed three recommendations for regional researchers which will contribute qualitatively to data collection and further analysis of existing floristic lists. At first, each floristic list must be confined to separate plant communities. Secondly, in order to increase accuracy of results, sampling should be carried out as much as possible. At third, botanists should add qualitative data in floristic lists: e.g., projective cover percentage of each species.

Keywords: ecological scale, environment factor, floristic lists, *Iris aphylla*, *Lilium martagon*, phytoindication.

Resumen

Las listas florísticas son a menudo consideradas solo como fuente de información para comparaciones generales de floras de diferentes localidades o para la comparación de la flora dentro de la misma localidad en diferentes épocas. Sin embargo, las listas florísticas por sí solas pueden ser útiles para estimar las condiciones ambientales en hábitats naturales usando métodos de fitoindicación. Mostramos aquí que si tenemos un grupo de listas florísticas de cierta region, podemos usar métodos de fitoindicación para establecer el confinamiento ecológico de cierta especie y los factores ambientales que son más importantes para su existencia. Como ejemplo, mostramos que es possible separar hábitats con condiciones ambientales favorables y desfavorables para cierta especie de planta (*Iris aphylla*) usando métodos de fitoindicación. También propusimos tres recomendaciones para investigadores regionales, las cuales contribuirán cualitativamente a la recolección de datos y a análisis posteriores de listas florísticas existentes. En primer lugar, cada lista florística debe ser confinada separando comunidades de plantas. En segundo lugar, para incrementar la precisión de resultados, el muestreo debería llevarse a cabo tanto como sea possible. En tercer lugar, los botánicos deberían agregar datos cualitativos en las listas florísticas: por ejemplo, porcentaje de cobertura proyectado de cada especie.

Palabras clave: escala ecológica, factor ambiental, listas florísticas, *Iris aphylla*, *Lilium martagon*, fitoindicación.

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Introduction

Floristic lists are often the only source of botanical information for a particular area and may serve as basis for more detailed study. Such lists may be used for comparison of floras in different localities, or that of the same locality at different times (Keith, 1988; Benson & Melrose, 1993; Pinheiro & Monteiro, 2006; Ferreira *et al*., 2013; Khapugin, 2016; Martínez-Calderón *et al*., 2017).

Floristic lists can be prepared with

or without data on quality parameters such as vegetation cover (projective coverage for each species). However, in future researchers would not be able to understand and estimate completely the structure of phytocoenosis or environment conditions in a studied site. Thus further analysis of vegetation cover will be limited. Unfortunately, many researchers and researcher groups of botanists conduct floristic studies without indicating of species' projective coverage (Reshetnikova & Berezutskiy, 2013; Antipina & Rokhlova, 2015; Rodríguez *et al*., 2017). In contrast to them, there are many floristic studies accompanied by data on species' projective cover (Bezsmertna *et al*., 2015; Bystriakova *et al*., 2015; Dítě & Elias, 2016; Piwowarczyk *et al*., 2016), ecology or morphometrics of plants (Aguirre *et al*., 2017; Beltrán *et al*., 2017; Puchnina, 2017) in studied sites. Consequently, these data are much more appropriate to further obtaining of data on conditions of habitat(s). However, pure floristic lists may also be useful for estimation of environment conditions of habitats using phytoindication methods.

The concept of species' ecological tolerance is the key principle for conducting the phytoindication studies. That requires quantitative estimation of the dimension of species' ecological amplitude, and this needed for elaboration of appropriate ecological scales (Didukh, 2011). Nowadays there are many scales reflecting the relation of plant species to various ecological factors. There are no unified methods of scale construction. Different authors use different approaches for this operation. Many types of ecological scales exist. However, several approaches can be distinguished: method of nicks (Ramensky *et al*., 1956), method of limitation (Ramensky, 1938; Hundt, 1966; Tsyganov, 1983) and method of mean values (Landolt, 1977; Ellenberg *et al*., 2001).

In case of the absent of data on species' projective cover, the method of limitation looks the most appropriate. This is the search of amplitude in factor's values, which limits the possibilities of particular species growth. Although this method is mathematically less precise, this is very important during the construction of ecological scales of coenophobic species which represents about 50% of floras (Didukh, 2011). Therefore, these ecological scales are the most appropriate in case when pure floristic list are only available. In conditions of middle belt of European Russia, ecological scales of Tsyganov (1983) look as most appropriate.

Republic of Mordovia covers area of 26,200 km^2. It is located on the border of the forest and forest-steppe zones in Central Russia (Fig. 1). Flora of the Republic of Mordovia is considered as one of the most studied floras in Central Russia, and includes more than 1400 species (Silaeva *et al*., 2010). Amongst them, both target species are distributed exclusively *Lilium martagon* L. (Iridaceae) or primarily *Iris aphylla* L. (Iridaceae) in forest-steppe landscapes of Eastern Mordovia (Senchugova *et al*., 2016; Khapugin *et al*., 2017a). Both taxa were included in regional Red Data Book (2017) as vulnerable (rarity category 2) species. As a result of recent IUCN assessment of protected plant species of Mordovia, *Iris aphylla* and *Lilium martagon* were estimated as Near Threatened (NT C2a(i)) taxa (Khapugin *et al*., 2017c). Additionally, 73.9% (17 of 23) and 90.9% (3 of 33) populations of *Iris aphylla* and *Lilium martagon* respectively are located outside of current Protected Areas Network of the Republic of Mordovia (Khapugin *et al*., 2017b). All these facts show relevance of study these species and conditions of their habitats.

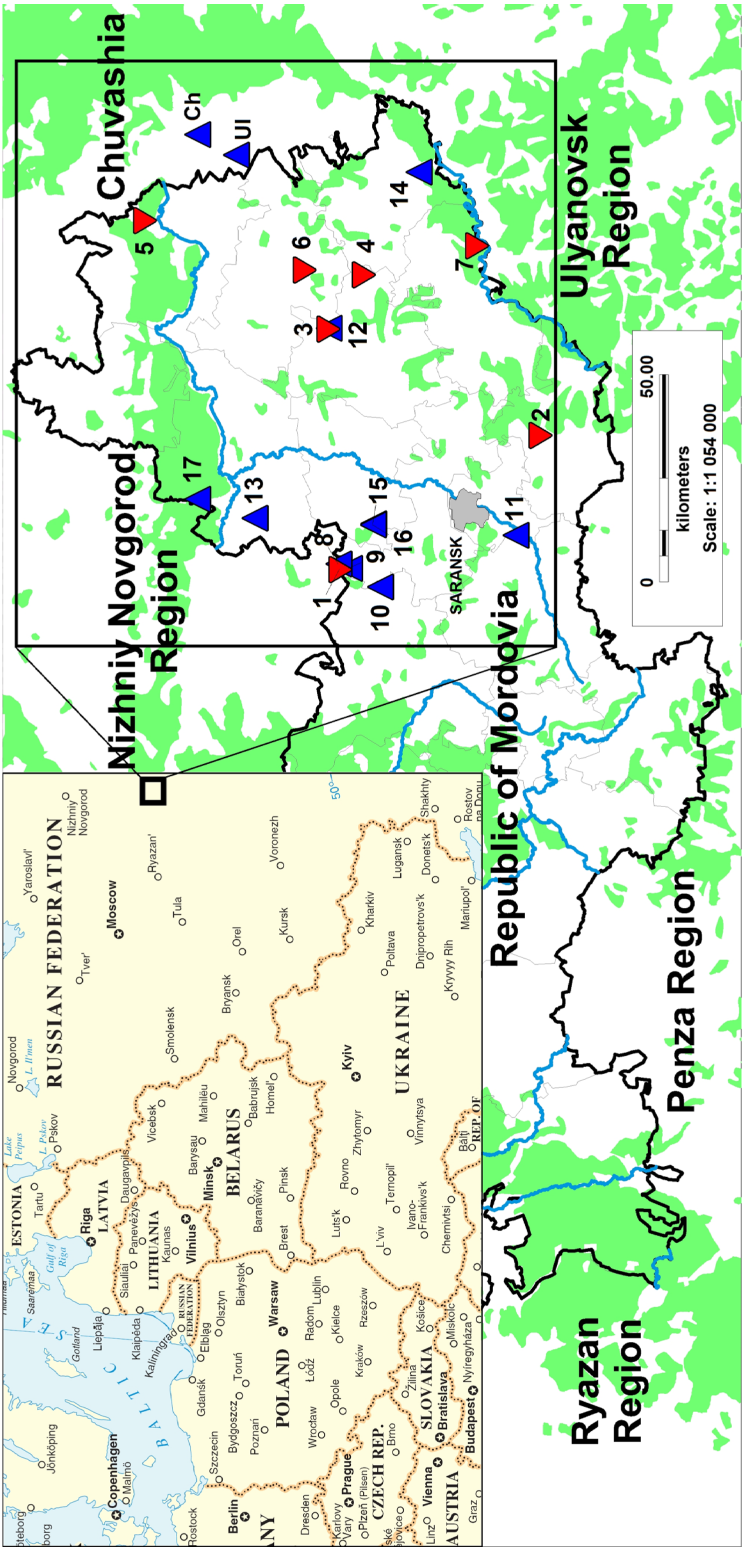

Fig. 1. Locations of study sites in the Republic of Mordovia and in Europe (Map of Europe with modifications from web-site United Nations Geospatial Information Section: http://www.un.org/Depts/Cartographic/english/htmain.htm). On the map of Mordovia, blue triangles indicate localities of *Iris aphylla*, and red inverted triangles-localities of *Lilium martagon*. Numbers indicate names of the localities as in Table 1.

Founders of intensive floristic studies in Mordovia, Vladimir N. Tikhomirov and Tatyana B. Silaeva, and their followers have collected large number of pure floristic data available in handwritten form at the Department of Botany, Physiology and Ecology of Plants of the Mordovia State University. This is a great database of plant species distribution in the region. But till date no study has been focused on the environmental factors affecting the distribution of plant species in the region.

Therefore, aim of this study was to show the opportunity and methods of applications of pure floristic lists to obtain data on environment conditions in study sites with participation of two rare plants (*Iris aphylla* L. and *Lilium martagon* L.) using phytoindication methods.

Material and methods

For our study, we have used our own collected data and available floristic lists at the Department of Botany, Physiology and Ecology of Plants containing information on *Iris aphylla* and *Lilium martagon* (Iridaceae) in the Republic of Mordovia. We also chose some data from adjacent regions (Chuvashia, Ulyanovsk region) to compare with that from Mordovia. In some cases localities of the one target species were situated in the immediate vicinity (within 0.3–1.5 km) of the second species' localities (see Tab. 1) and, it would seem, conditions should differ slightly. Therefore, they were given special attention. Also, we deliberately selected one locality (16: Salma) where *Iris aphylla* is observed in unfavourable conditions.

We compared the compositions of pure floristic lists in studied localities. For this purpose, we calculated a Jaccard's similarity index $JS = 100 \times C/(A + B - C)$, where *A* = number of species in locality *A*; *B* = number of species in locality *B*; *C* = number of species shared between two (*A* and *B*) localities (Jaccard, 1901).

Alternatively, based on composition of the same pure floristic lists, values of environmental factors in studied habitat were calculated. Calculations were carried out according to Tsyganov's (1983) scale where ecological indicator values are arranged as intervals. It means that for each plant species we can define the range of its existence in relation to environmental factors, for instance, soil nitrogen, moisture etc. Mean ecological indicator values were calculated using algorithm suggested by Buzuk & Sozinov (2009). Ten ecological scales have been used: termoclimatic (TM), climate continentality (KN), climate humidity (OM), kryoclimatic (CR), soil moisture (HD), soil trophicity (TR), soil nitrogen (NT), soil pH (RC), shading (LC), soil moisture variability (FH).

In order to assess limiting factors, we used the principal component (PCA-analysis). This method makes it possible to assess the role and importance degree of each environmental factor, its significance in plant community and its distribution. Obtained significance quantitative data, converted into coefficients, can be used in assessment of cumulative effect on the character of community differentiation (Didukh, 2011). Thus, we tried to define main factors influencing differences between all studied localities of both target species.

Statistical analyse was carried out using PAST 3.15 (Hammer *et al*., 2001) and Microsoft Excel.

Results

Analysis of floras in studied localities has demonstrated that species composition may be highly similar for habitats of one target plant, as it seems for localities 2, 3 and 6 for

Table 1. Localities of *Iris aphylla* and *Lilium martagon* listed in analysed floristic lists

Localities' designation	Nearest settlement	Species	Coordinates	Habitat	Number of individuals
1	Dalniy	*Lilium martagon*	54.4817 N 44.9709 E	Aspen (*Populus tremula* L.) forest with *Aegopodium podagraria* L. in herb layer	31
2	Kochkurovo	*Lilium martagon*	54.0484 N 45.4696 E	Steppificated broad-leaved forest with *Corylus avellana* L. in shrub layer	92
3	Sabur-Machkasy	*Lilium martagon*	54.5068 N 45.8639 E	Steppificated broad-leaved forest	56
4	Sorliney	*Lilium martagon*	54.4313 N 46.0651 E	Steppificated broad-leaved forest with *Corylus avellana* in shrub layer	21
5	Oktyabrskiy	*Lilium martagon*	54.9034 N 46.2664 E	Mixed (coniferous-broad-leaved) forest	46
6	Atyashevo	*Lilium martagon*	54.5589 N 46.0825 E	Steppificated broad-leaved forest with *Corylus avellana* in shrub layer	60
7	Simkino	*Lilium martagon*	54.1863 N 46.1732 E	Moist mixed (*Pinus sylvestris* L., *Quercus robur* L., *Populus tremula*, *Betula pendula* Roth, *Alnus glutinosa* (L.) Gaertn.) with *Phragmites australis* (Cav.) Steud., *Filipendula ulmaria* (L.) Maxim. in herb layer	21
8	Dalniy	*Iris aphylla*	54.4844 N 44.9913 E	Steppe slopes	96
9	Dalniy	*Iris aphylla*	54.4612 N 44.9756 E	Steppificated meadow on slopes	21
10	Ingener-Pyatina	*Iris aphylla*	54.3945 N 44.9064 E	Feather-grass meadow-steppe on slopes	38
11	Levzhenskiy	*Iris aphylla*	54.1015 N 45.0981 E	Shrub steppe on slopes	33
12	Sabur-Machkasy	*Iris aphylla*	54.5054 N 45.8670 E	Feather-grass meadow steppe on slopes	51
13	Lobaski	*Iris aphylla*	54.6664 N 45.1621 E	Feather-grass meadow steppe on slopes	47
14	Engalychevo	*Iris aphylla*	54.3114 N 46.4466 E	Feather-grass steppe on slopes near the forest	102
15	Salma	*Iris aphylla*	54.4089 N 45.1412 E	Steppificated plot on the edge of forest	84
16	Salma	*Iris aphylla*	54.4098 N 45.1374 E	Plot under artificially planted forest (*Pinus sylvestris* + *Larix sibirica* Ledeb.) cover	21
17	Smolny	*Iris aphylla*	54.7898 N 45.2314 E	Plot on the edge of forest	13
Ch	Stemasy	*Iris aphylla*	54.7901 N 46.5851 E	Feather-grass meadow steppe on slopes	31
Ul	Zhdamirovo	*Iris aphylla*	54.7060 N 46.5095 E	Feather-grass meadow steppe on slopes	60

Lilium martagon and for localities Ul and 13 for *Iris aphylla* (Tab. 2). It is easily explained by similar conditions favourable for the same plant species. In contrast, Jaccard's similarity index is extremely lower (up to 0.0) for localities different from each other. However, some localities of *Iris aphylla* are similar (Jaccard's similarity index more than 10%) to localities of *Lilium martagon* despite the differences in coenological confinement of both target species. These pairs of localities are: 2 and 15, 2 and 8, 3 and 8, 3 and 12, 2 and 14. In one case, this picture may be explained by presence of forest plants in *Iris aphylla* habitats in transitional communities – forest edges, as well as by large species number in a sample. In another case, analysed habitats may be closely located to each other (e.g., localities 3 and 12). Locality of *Iris aphylla* № 16 demonstrated high similarity with localities of *Lilium martagon* and slight similarity with localities of *Iris aphylla* except closely located habitat № 15. Although floristic composition of locality 16 is different of other localities of *Iris aphylla*, viability of species' individuals is very low here (Senchugova *et al*., 2017). Thus, due to presence of forest species in forest edges, as well as penetration of meadow and forest-edge plants into forest communities, the same species can be found in accompanying floras of both target species.

More understandable and clear arrangement of localities was obtained using principal component analysis of mean values of environment factors revealed for studied habitats. As can be seen from Fig. 2, all these localities are distributed in two main groups with soil moisture (HD), moisture variability (FH), shadiness (LC) as most significant environment factors.

First group, called "open habitats", includes localities on steppe, steppificated and meadow slopes and forest edges. Abundant light, lower soil moisture and higher moisture variability are typical characteristics for this group as compared to localities of the second group. These are localities exclusively of *Iris aphylla*. Open habitats can be separated on three subgroups

Table 2. Jaccard's similarity index calculated for the selected localities (see Table 1).

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Ul	Ch
1	20.6	22.5	20.9	16.7	19.7	10.6	5.0	0.0	1.5	0.0	0.0	4.0	2.3	0.9	4.0	2.3	1.6	0.0
2		34.5	14.1	21.1	38.2	7.6	20.5	0.9	4.0	4.2	5.1	1.5	11.5	13.5	10.8	4.0	3.4	1.3
3			28.3	15.9	33.3	10.0	17.8	8.5	9.3	4.7	11.5	6.2	9.7	6.1	8.5	3.0	2.4	0.9
4				13.6	19.1	13.5	7.3	5.0	3.5	3.8	4.3	3.0	3.4	1.9	5.0	0.0	0.0	0.0
5					20.5	9.8	6.0	0.0	1.2	1.3	0.0	0.0	5.0	9.2	9.8	5.4	1.3	1.9
6						9.5	3.3	3.8	4.3	0.0	2.8	0.0	1.3	3.6	12.5	4.3	3.4	1.7
7							4.5	0.0	0.0	1.9	0.0	0.0	1.7	2.9	7.7	0.0	2.0	1.3
8								12.5	18.6	14.2	14.8	19.2	21.5	20.8	6.4	6.9	18.7	8.3
9									28.3	8.0	18.0	23.6	10.8	7.1	5.0	3.0	18.2	12.5
10										9.2	18.7	19.7	14.8	14.0	1.7	2.0	25.5	10.1
11											13.5	15.9	9.8	8.3	1.9	9.5	20.8	8.1
12												27.3	22.4	12.5	1.4	3.2	24.2	9.9
13													22.1	14.9	1.5	5.3	34.5	12.6
14														26.5	5.1	2.7	23.1	10.2
15															10.5	5.4	23.7	9.9
16																6.3	4.0	3.8
17																	10.0	2.8
Ul																		21.3

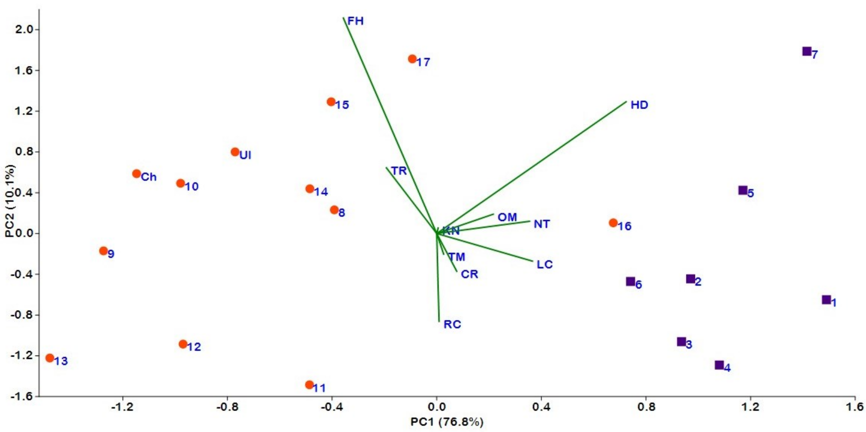

Fig. 2. Principal correspondence analysis (PCA) ordination diagram for localities of *Iris aphylla* (orange dots) and *Lilium martagon* (purple squares), based on mean environmental indicator values according to Tsyganov's ecological scale. Designations of localities are shown in Table 1.

on the basis of environmental conditions. Thus localities 11, 12, 13 characterise by dry conditions and relative higher distance from moist floodplains. Another two localities (15 and 17) are located on the top of ordination diagram. These present a group of habitats at edges of forests. Their location surrounded or on edge of forest reflects in higher moisture variability and moisture availability. Remaining habitats occupy an intermediate position between two abovementioned subgroups.

Second group can be called "afforested habitats". It includes localities of *Lilium martagon* and one (№ 16) – *Iris aphylla*. This group characterises by more shade and moist conditions, as well as lower moisture variability due to the presence of forest canopy cover. Within afforested habitats, habitat 7 is located separately due to the most moist soil conditions and higher shading. Also, localities 5 and 7 are shady habitats with moderately moist soil conditions. Remaining localities are mainly considered as steppificated light forest communities. Locality 16 of *I. aphylla* was separated to this group due to its allocation within forest community. Species' individuals had low viability here while other *I. aphylla* plants at forest edge (in several meters from them) successfully bloomed and fruited (Senchugova *et al*., 2017).

Thus, in order to determine environment conditions of habitats typical for both target species, the phytoindication method usage able to distinguish only habitats where conditions are more or less favourable for certain plants. Otherwise, certain habitat(s) may be defined to another group and individuals of target species here may characterise by low viability.

Absence of correlation between data of similarity indices (in present study – Jaccard's index) and data of statistical analysis for environment factors may be explained by significant differences in environment conditions of studied localities of both target species, as well as transitional nature of most plant communities (forest edges). Usage of data for more or less homogenous plant communities usually provides results characterised by high correlation of similarity indices and results of statistical analyses (Havlová, 2006; Michálková, 2007; Couto *et al*., 2016; Khapugin *et al*., 2016b; Khapugin, 2017).

Discussion

According to our results, establishing of geographic distribution of plant species in certain region is not exclusive applying of pure floristic lists. Numerous data on species' distribution may be used (or not used) for compilation of regional floras. But the same information may be interpreted to understand coenotical confinement of each plant species taking into account as much more large sampling. Phytoindication together with statistical software are considered as the best tool to reveal and keep data of environment conditions of species and plant communities (Zare Chahouki *et al*., 2012; Khapugin *et al*., 2016a; Dakskobler & Surina, 2017), especially when direct measurement of environment factors is not possible.

We can distinguish most significant factors which must be taken into consideration by regional researchers during the accumulation of data to further analysis. (i) Under conditions of mosaic nature of vegetation cover, each floristic list must be fixed in each separate plant community. (ii) In order to analyse revealed floristic data, sampling should be as more as possible, because only large number of samples can provide reliable data (Kuczynski *et al*., 2010).

(iii) Not be limited by compilation of pure floristic lists, but it is necessary to indicate the quality characteristics (e.g., projective cover for each plant species).

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Contribution of the authors

A. K.: Conception, design, collection of data, analysis and interpretation of the results obtained, preparation of the article, & M. S.: Collection of data, analysis of the results obtained, writing of the article. All authors read the final manuscript and approved the revision.

Conflicts of interest

The authors declare not to have conflicts of interests.

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Fig. 1. A. *Iris aphylla*; B. *Iris aphylla*; C. *Lilium martagon*.