Intralandscape differentiation of the local flora in the central part of the Gydansky Peninsula (West Siberian Arctic)

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Abstract

The paper aims to describe Russian approaches to inventory of vascular plants diversity in the Russian Arctic. In the study, the local flora method is used. It provides comparable data for spatial comparisons between different locations. The method includes the study of species distributions within a landscape, therefore the concept of "partial flora" was elaborated. A complex estimate "activeness" allows to assess a species role within the landscape. These theoretical concepts are applied at the local flora of a hardly accessible central part of the Gydansky Peninsula. The local flora numbers 191 vascular plant species. Altogether, 18 habitat types were distinguished with partial floras numbering from 15 to 75 species. The highest alfa-diversity was recorded on steep slopes, many rare species occurred there as well. These habitats occupied less than 10% of the area but provided almost 75% of local flora. Although the morphology of relief was better developed at this locality compare to the others at the Gydansky Peninsula, the intralandscape structure of flora is continuous, showing a low beta-diversity and high similarity of species composition between different habitats. It is explained by a high proportion of "active" species, which occur in many different habitat types. Along the zonal gradient within the Gydansky Peninsula, a decrease of species richness at local flora level was found but no change at partial floras level.

Key words: vascular plants, local flora, habitat types, species richness, beta-diversity, Arctic

Abbreviations: local flora (LF), joint partial flora (JPF), landscape activeness (LA)

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Introduction

The Gydansky Peninsula is located in the north of West Siberia. It is one of the regions poorly studied by botanists. Several expeditions of B. N. Gorodkov in the 1920-1930-s (Gorodkov 1928, 1935, 1944), sampling at several sites along the coast by the expedition of the Arctic and Antarctic Research Institute in the beginning of 1970-s (Sisko 1977) and herbarium vouchers collected during the surveys of reindeer pastures were the only sources of the floristic data. Relatively recently, West Siberian sector of the Russian Arctic was mainly known for its "negative" features, *i.e.* gaps in the knowledge on distribution of many species (Yurtsev et al. 1978, [1] Arctic flora of the USSR 1960-1987). During the field work in the late 1980-s, many species which were previously considered as absent, were found (Khitun et Rebristaya 1998, Khitun 2002, 2003). However, expanded areas in the central and north-eastern parts of the Gydansky Peninsula have not been surveyed by botanists yet. Gas and oil exploration activities ongoing in the region increase, there is a danger that some species may disappear even before full assessment of the flora of this region is done.

The "local flora method" elaborated by Tolmatchev (1931, 1974) and his disciples (*see* Rebristaya 1977, Yurtsev 1975, 1982, 1987, Yurtsev et Semkin 1980) is broadly used in Russia for the studies focused on plant biodiversity, especially in the vast Arctic wilderness areas. Local flora (LF) theory was recently presented for international readers (Khitun et al. 2016). The LF method strives to determine the total vascular plant flora in a specific locality by thorough inspection of all of all habitat types found in the locality. It allows find many rare and small in size species, which otherwise could be missed. Empirically it has been shown that the representative area for such study in lowland Arctic is approximately 100 km^2 (Khitun et al. 2016).

By determining a flora as a system of local populations of species, Yurtsev (1982) expanded hierarchical approach to floristic studies. Following the classification of geosystems (Sochava 1978), planetary, regional and intralandscape spatial levels of floristic systems can be distinguished. These views match very well with LF methodology which describes species assemblages in different habitats. These assemblages are floras of intralandscape level and it was suggested (Yurtsev 1982, 1987) to call them "partial floras". The study of partial floras provides information about biodiversity distribution within particular landscape and allows find the most valuable habitats.

As an estimate of species behavior, Yurtsev (1968; also Yurtsev et Petrovsky 1994) introduced a special parameter – "activeness". It can be evaluated both at landscape and intralandscape levels. A five-score scale of "landscape activeness" of species was expertly elaborated according to different combinations of four components: (1) the diversity of habitats where the species occurs, *i.e.* its ecological range; (2) species constancy and (3) abundance in these habitats; (4) rarity or commonness of the habitats where the species occurs (Table 1).

For evaluation of species behaviour in each habitat type, *i.e.* at intralandscape level, partial activeness is used. To estimate it, different authors use either only mean species cover (Marina 2000) or its combination with species constancy in a certain habitat type (Galanin 1980, Teljatnikov 1998, Khitun 2002). The gradation of cover values used for estimation varies between different authors and bioclimatic zones. In plant communities of the West Siberian Arctic, many species have a low cover values and, therefore, I used more fine gradation for them. However, only few species have cover >50%, therefore, I reduced this part of the scale. Abundance scales of Braun-Blanquet (1964) and Barkman (Barkman et al. 1964), modified by van der Maarel (1979) were used as a base with some my adjustments (Table 2). The scores of partial activeness were estimated expertly. In the West Siberian Arctic, many species have very low partial activeness, dominants usually have the score ranging 5-6. Therefore, the scores 3 and 4 should be considered as high, showing the important role of the species in the vegetation cover of given habitat type.

The aim of this paper is to give the characteristics of the flora of the central part of the Gydansky Peninsula which has not been visited by any botanists previously. The other aim is to compare the two following methodological approaches: (1) traditional for Russian floristic, analyzing the relevés that were initially grouped subjectively, but also (2) a matrix with all the relevés that is analyzed in detrended correspondence analysis.

Species abundance	Percentage of habitat types where species occurs from all present in the area types									
	> 80%		50-80%		21-49%		< 20%			
	Species constancy in its habitats						Common habitats		Rare habitats	
	Ew	*Sp*	*Ew*	*Sp*	*Ew*	*Sp*	*C*	*Nc*	*C*	*Nc*
Abundant	V	V	IV	IV	III	II	III	II	II	I
Sparse	IV	IV	III	III	III	II	III	I	I	I
Solitary	III	II	II	II	II	I	II	I	I	I

Table 1. Determination of scores (I-V) of landscape activeness (after: Yurtsev et Petrovsky 1994): V, especially active; IV, highly active; III, moderately active; II, low active; I, non-active. *Symbols*: *Ew* - Everywhere, *Sp* - Sporadic, *C* - Constant, *Nc* - Non-constant.

Species cover (score, %)	Constancy (score, %)				
	1 (1-20%)	2 (21-40%)	3 (41-60)	4 (61-80%)	5 (81-100%)
1 (< 1 %)	1	1	2	2	2
2 (1–2 %)	1	2	3	3	3
3 (2–5 %)	1	2	3	4	4
4 (5–15 %)	2	3	4	4	5
5 (16-25 %)	2	3	4	5	5
6 (25–50 %)	3	4	5	6	6
7 (> 50 %)	3	4	6	7	7

Table 2. Determination of partial activeness scores of a species based on its constancy and modal projective cover within the habitat types (after: Khitun 2002).

Material and Methods

The study area

The field work was carried out in August of 1987 in the central part of the Gydansky Peninsula (Western Siberian Arctic), at the upper reaches of the Ngarka-Ngynyangse River (70º 30′ N, 77º 15′ E). Hereafter we refer this locality as "Ngynyangse" (*see* Fig 1). The area of approximately 100 km^2 was thoroughly inventoried. The region is formed mainly by Late Pleistocene sediments but the highest interfluve hills are formed by the Middle Pleistocene marine sediments ([2] Atlas of Tjumen Region 1971). Altitude of the region varies from 30 to 100 m a.s.l. (almost the highest value found at the peninsula). Flat or gently rolling watershed's hills are intersected by narrow creeks valleys and ravines. The nearest weather station is located in the Gyda village. Local climate is typical by mean July temperature of 8.1°C, and sum of mean temperatures above 5°C reaches the value of 731°C. Annual precipitation is 311 mm ([WP1]; also: [4, 5] Climate of the USSR 1965, 1968). According to the scheme of bio-climatic zonation ([3] CAVM Team 2003) the study area is located in the subzone D, which coincides with the subzone of northern hypoarctic tundra in the scheme of Yurtsev (1994). Zonal vegetation is represented by nontussock, sedge, dwarf-shrub, moss tundra with dwarf birch and low willows ([3] CAVM Team 2003).

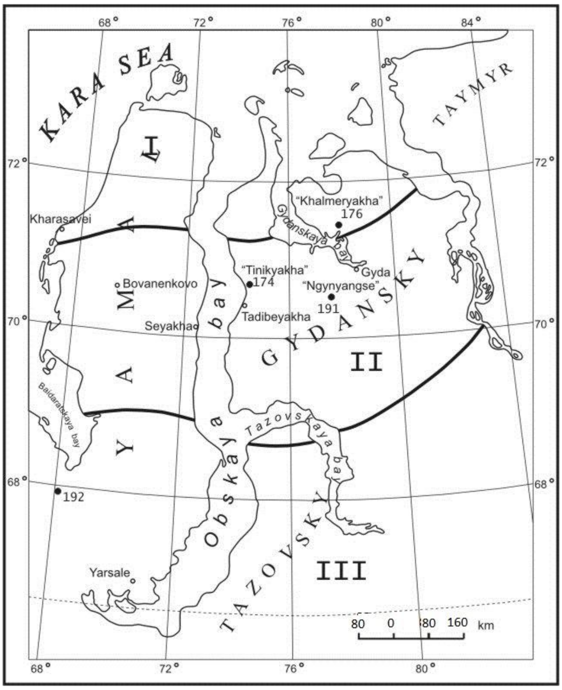

Fig. 1. Location of the study site "Ngynyangse". Two other localities where local floras were investigated are also shown: "Tinikyakha" and "Khalmeryakha". Species richness of the local floras is indicated below their names. Boundaries of bioclimatic subzones are drown (CAVM team 2003): III, subzone E; II, subzone D; I , subzone C, (the southern border of the latter in reality is northerner than it is shown on the map and vegetation in "Khalmeryakha" is typical for subzone D).

The method

The LF method means the area of approximately 100 km^2 around base camp is thoroughly examined by radial routes of about 5-7 km long over 2-3 weeks, compiling species lists of all habitat types (HT) that can be distinguished. To achieve that, the relevés in 10 x 10 m plots were done in at least 5 replicates in common habitats and as many as they were met in the rare habitats. Herbarium vouchers were collected for all species and in every case when the determination in the field was doubtful.

In relevant literature, there is some discrepancy in understanding and distinguishing various habitat types (compare: Tolmatchev 1932, Pospelova et Pospelov 1998, Khitun 1998, Zanokha 1987). I distinguished habitat types according to the expert evaluation of the similarity in topography, soil moisture and drainage, soil type, snow regime and vegetation cover (Khitun 1991, 1998, 2002). The distinguished habitats were very different in size because I evaluated with the main focus on vegetation cover. For example, I considered the extended (several hundred square meters) but relatively homogenous by conditions plateaux of the watershed hills as a single habitat type. On the other hand, relatively small by area (8-20 m^2) components of tundra-mire complexes (high centred polygons and troughs) that dramatically differed in conditions, I distinguished as two different types. Slopes were initially divided also according to their aspect, but as species lists of southern slopes included all other variants, they were joined in one habitat type. Hills formed by sandy and loamy sediments are covered by the thick layer of peat and therefore they also practically do not differ by species composition and thus were joined in one type.

In the West Siberian Arctic, I distinguished 22 habitat types (Khitun 1998), 18 of which are present in “Ngynyangse” (Table 3). Totally, 121 relevés were done. Total vegetation cover, as well as the cover of various plant functional types (mosses, lichens, graminoids, dwarf-shrubs and low shrubs) and of each vascular species were estimated visually as a percentage of the total plot area as observed projection from above. Joined Partial Floras (JPF) of each habitat type were comprised by joining the species lists from the relevés done in the same habitat type. Only lists of vascular species are considered in this paper. The work resulted in the production of the check-list of the local flora with detailed information of the species distribution within the habitat types, and estimation of the landscape and partial activeness of each species (Appendix 1).

Statistical analysis

As a measure of beta-diversity (Whittaker 1972), which reflects the differentiation of species distribution along the environmental gradients, similarity coefficients were used (Magurran 1989). Sørensen’s similarity index (*see* Eqn. 1) and Simpson’s inclusion index (*see* Eqn. 2) based on numbers of shared species were calculated between JPFs of different habitat types:

(*Eqn. 1*) $K_{AB} = \frac{2C}{A+B}$ and (*Eqn. 2*) Max of $K_{AB} = \frac{C}{A}$ and $K_{AB} = \frac{C}{B}$

where A is the number of species in JPF A; B is the number of species in JPF B and C is the number of species common for two JPF. Integrated Botanical Information System (IBIS) and its supplement BIOSTAT (Zverev 1998, 2007) was used as a database and for performing the calculations. Linkage by WPGMA in hierarchical agglomerative cluster analysis was performed in Statistica for Windows 8.0 (Hill et Lewicki 2007).

The methods of multivariate statistic are broadly used in analysis of vegetation cover by western scientists (Qian et al. 1999, Kade et al. 2005). The change of ecological conditions along the environmental gradients is the reason for the change of species composition between different communities. The methods of ordination, in particular, detrended correspondence analysis (DCA) help to explain the directions of variation in vegetation cover (Økland 1990). I used DCA modified for CANOCO, version 4 (Ter Braak et Šmilauer 1998). The analysis was performed during my visit to Tromsø University in 2000 but never published.

Results

Our work resulted in producing the checklist of the LF "Ngynyangse" with indication of species distribution within the landscape. 191 species from 96 genera and 36 families were found in LF "Ngynyangse" (Appendix 1). For the majority of species there were no previous records from the central part of the Gydansky Peninsula. LF "Ngynyangse" was the richest of the three LF studied in the subzone D in the Gydansky Peninsula (Fig.1). The set of the ten richest (by number of species) families is typical for the Arctic floristic region (Tolmatchev 1974): *Poaceae* (26 species), *Asteraceae* (19 species), *Cyperaceae* and *Caryophyllaceae* (15 species in each), *Ranunculaceae* (12), *Brassicaceae* and *Salicaceae* (11 species in each), *Saxifragaceae* (10), *Rosaceae* (9) and *Scrophulariaceae* (8 species). Although the average number of species per genus in this LF is almost the highest for the Yamal-Gydan region (5.5), it is lower than such values in Taimyr (5-8) or, especially, in Chukotka (up to 11) (Yurtsev et al. 2002). The richest (by number of species) genera in this LF are the same as in the other localities in this subzone: *Salix, Carex, Ranunculus, Saxifraga, Taraxacum, Eriophorum, Luzula, Poa, Pedicularis* and *Draba*. Comparison of the species composition of LF "Ngynyangse" with the other LF studied in the Gydansky Peninsula ("Tinikyakha" and "Khalmeryakha") showed 84% and 78% similarity. High similarity was found also between LF in other subzones in this region (Khitun 1998).

The species richness of the JPFs varied from 15 to 75 and it was within exactly the same range which was found in the other localities in this region (Khitun 1998, 2002, 2003) (Table 3). The JPFs (and respective habitat types) were joined in groups with similarity more than 65%. This threshold was chosen arbitrary and used it in all the other Yamal-Gydan localities. The grouping is slightly different if we use Sørensen or Simpson indexes (Fig. 2), because the former has very low values if we compare floras essentially differing by richness (Fig. 2A). In such cases Simpson inclusion index (poorer flora into richer one) was accounted (Fig. 2B).

The highest similarity (80%) was found between the habitats with flat surfaces with the vegetation of zonal type. The flat plateaus of watershed hills (1) and their gentle slopes (4) are the most expanded by area habitat types, but they are relatively poor by number of species (Table 3). Communities of sedge (including *Eriophorum vaginatum*)–dwarf-birch–moss *Polytricum strictum* and *Dicranum* spp.) tundra with low willows (*Salix glauca, S. pulchra* are wide spread on tops and slopes of 40-60 m a.s.l. interfluves, whereas on higher hills (usually with sandy sediments) dwarf-shrub (*Dryas punctata, Ledum decumbens*) –willow–sedge–grass–moss–lichen communities predominate. Lingonberry (*Vaccinium vitis-idaea)* is abundant in all above mentioned communities.

HT id-number as in Fig. 2	**Subzone**	**E**	**E**	**D**	**D**	**D**	**C**	**C**
	Name of the locality	**Lai**	**Poi**	Ngy	**Tin**	**Kha**	**Kho**	**Mat**
	Number of species in local flora	**215**	**185**	191	**172**	**176**	**174**	**156**
	Name of the habitat type	**Number of species in JPF in respective locality**						
1	Flat tops of interfluves with zonal communities	49	34	**37**	47	53	48	67
2	Convex edge parts of the hills with little snow in winter	35	32	**34**	44	42	48	62
3	Slightly elevated and better drained parts of river terraces	43	34	**37**	39	46	60	60
4	Long gentle slopes of interfluve hills	43	33	**55**	46	68	57	65
5	Foot parts of the hills with some mineral enrichment	30	32	**43**	55	53	55	56
6	Peat high centered polygons in polygonal mires	25	30	**21**	29	27	36	33
7	Wet oligotrophic troughs in polygonal mires	20	16	**15**	20	22	28	22
8	Steep short (<10m), often sandy hill slopes	70	45	**57**	50	68	61	45
9	Steep, long (20-30m) clayey or sandy well-drained slopes	70	54	**76**	65	75	73	69
10	Drained parts of floodplain (more mesophytic)	55		**56**	37	49	37	
10a	Drained parts of floodplain (more xerophytic)		51	**56**	-	-		49
11	Sand beaches, sand blow-outs on hills with sparse vegetation	32	24	**30**	33	-	37	-
12	Steep sandy failures of active banks of the rivers. (Absent in Ngy!)	-	33	**-**	-	-	47	30
13	Bottoms of wide hollows, concaves on long slopes	54	57	**58**	42	57	39	35
14	Little hollows on slopes and at their foots with snow beds	69	61	**68**	43	58	55	58
15	Clayey landslides with pioneer vegetation	36	42	**46**	43	47	48	37
16	Old entirely recovered landslide scars	56	-	**56**	-	-	39	-
17	Wet depressions in the valleys with mires or wet meadows	52	40	**34**	33	36	37	37
18	In the water or on permanently wet muds	17	17	**21**	15	18	12	16

Table 3. Number of species in joint partial floras (JPF) of different habitat types (HT) distinguished at “Ngynyangse” and other studied localities.
Notes: Ngy - Ngynyangse, Tin - Tinkyakha, Kha - Khalmeryakha (Fig. 1), Lai - Laiyakha, 68° 04′ N, 74° 50′ E and Poi - Poilovayakha, 68° 15′N 76° 25′ E in the Tazovsky Peninsula, Kho - Khonorasale, 71° 25′ N, 73° 10′ E and Mat - Matjuisale 71° 56′ N, 76° 32′ E in the north of the Gydansky Peninsula.

PF of somewhat elevated surfaces within flood plain and on lower river terraces (type 3) and on basal parts of hills (type 5) are joined with the tops due to high floristic similarity. They are occupied by willow-grass-moss and herb (*Cardamine bellidifolia, Eutrema edwardsii, Saxifraga nelsoniana, Pyrola grandiflora*)-willow (*Salix reptans*)-moss communities. The above mentioned herbs and the presence of *Tomentypnum nitens* in moss cover at the base of the hills in this region may indicate certain mineral enrichment (Rebristaya 2013).

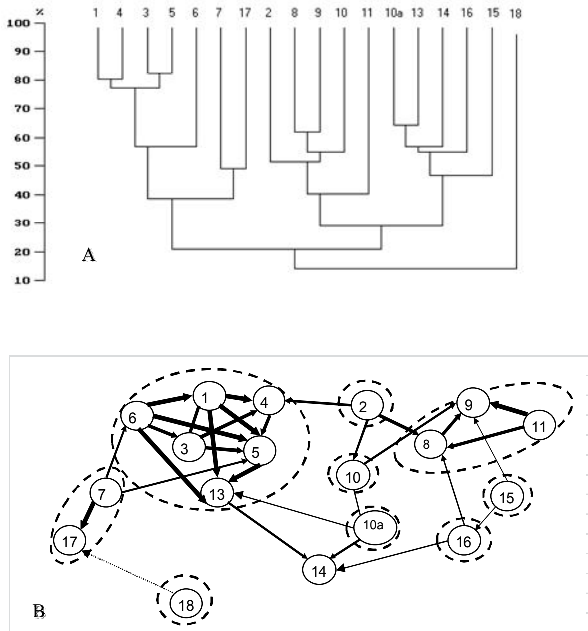

Fig. 2. Tree (A) and graph (B) of partial floras similarity by species composition based on Sørensen similarity index (A) and Simpson inclusion index (B) in local flora "Ngynyangse". Arabic numerals above the tree and in circles on the graph are the id-numbers of habitat types as in Table 3. Thickness of arrows on the graph indicates the values of Simpson index, the thickest is >70%; thinner= 65-69%

Intralandscape structure at all locations in the West Siberian Arctic is rather continuous because species compositions of many JPFs are very similar. However, there is some variation between different locations both in grouping of habitats and even in distinguishing of certain habitats. For example, in Ngynyangse, rich JPF of relatively well-drained depressions between hills (type 13) "pulled" to itself the whole group of poorer JPFs from flat and gently sloping surfaces. However, the same results we got earlier in LF from the subzone C (Khitun et Rebristaya 1998).

Edge parts of the hill-tops, where snow is blown away in winters (type 2), is unfavorable for plants habitat occupied by frost boil dwarf-shrub tundra with *Salix nummularia, Dryas punctata*, *Vaccinium vitis-idaea, Ledum decumbens*. Both from topographical and species composition point of view, this JPF occupies transition between flat surfaces and slopes. Slopes are the most favorable habitats with the richest JPF. Short steep slopes (type 8) are occupied by forb-grass (*Calamagrostis neglecta, Hierochloë alpina, Festuca ovina*)-dwarf-shrub (*Vaccinium uliginosum, Salix nummularia)* communities. Many southern species were found here at their northernmost location in this region (*Equisetum pratense*, *Lycopodium clavatum, L. alpinum, Linnaea borealis, Rubus arcticus*). Long steep slopes (type 9) are occupied by colorful meadow-like communities with abundance of forbs, such as *Potentilla stipularis, P. kuznetzovii, Erigeron eriocalyx, Bistorta elliptica, Poa alpigena* subsp. *alpigena, Astragalus alpinus* subsp. *arcticus, Hedysarum arcticum* and others. This JPF is therefore the richest in Ngynyangse (76), as well as in the all other studied localities (Table 3). Additional enrichment comes from the communities on sandy slopes with psammophytes, such as *Oxytropis sordida, Eremogeone polaris, Aconogonon ocreatum, Thymus reverdattoanus*. Ngynyangse is the only location in the Gydansky peninsula where *Carex supina* subsp. *spaniocarpa* and *Silene samojedora* were found. These species are relics of Pleistocene cryo-steppe communities (Yurtsev 1972). JPF of sand scars and blow outs (type 11) is joined with slopes due to high inclusion index.

Dry parts of flood plain on the higher bank of the river in Ngynyange were represented by two distinct habitats: more mesophytic with willow thickets (*Salix lanata, S. glauca, S.reptans*, up to 60 cm high) and well developed herbs layer (type 10) and more xerophytic with forb-dwarf-shrub communities (type 10a). Each of these habitats was found at the other locations, however, here both were present (Fig. 2). On more mesophitic river terraces (10) in willow copses, a number of boreal or hypoarctic species were found at their northern limit (few of them were found also in Khalmeryakha), such as, *Trollius asiaticus, Ranunculus monophyllus, Potentilla gelida* subsp. *boreo-asiatica, Veronica longifolia, Veratrum lobelianum, Equisetum palustre, Salix reticulata, Pedicularis compacta.*

Landslides (type 15) at few other locations were joined with slopes (Khitun 1991, 2002) but both in Khalmeryakha (Khitun 2003) and in Ngynyangse they were in distinct group. That was due to a group of species found only there (*Arctagrostis arundinacea, Poa alpigena* subsp. *colpodea, Puccinellia sibirica, Phippsia concinna, Juncus castaneus, Descurainia sophioides, Tripleurospermum hookeri*). Especially interesting was the fact, that we found halophytes *Carex maritima* and *C. glareosa* on landslides, these species were indicating saline marine deposits.

In river valleys and lake depression (type 17) various variants of sedge (including Cotton-grass)-moss (*Calliergon stramineum, Warnstorfia sarmentosa, Hamatocaulis vernicosus, Limprichtia revolvens, Paludella squarrosa, Polytrichum jensenii, Sphagnum* spp.) mires occur. The poorest (15 species) JPF of wet troughs between polygons (type 7) is joined with the mires due to high inclusion index. The JPF of high centered polygons (type 6) in such tundra-mire complexes is another very poor habitat. Although in Ngynyangse they were rare habitats, usually they are very common in the West Siberian Arctic but their JPFs are always among the poorest (Table 3). As in all other localities aquatic habitats (type 18) are very distinct from all others.

In order to compare the results, DCA-ordination was performed on all 121 relevés with default options. The lists of species from aquatic habitats were excluded both because they were clearly distinct and also as they often number just 2-3 species (they were not counted as relevés). The analysis of the distribution of relevés on the ordination diagram shows connection of the first axis with moisture conditions: mires and hollows at one end and sand blow-outs at the opposite. Eigenvalue was 0.61, length of the gradient was 6.1 of SD. The second and third axis are most likely reflected snow gradient and soil composition (sand-loam), with eigenvalues 0.47 and 0.26 and lengths of the gradient 3.5 and 2.8 SD. However, the majority of relevés were pulled together in diffuse conglomerate (Fig. 3). The three most important axes explain only 16% of variation. In general, the picture is similar to Fig. 2 and it confirms high similarity of floristic composition on different parts of relief. Similar regularity was found at all previously studied sites in the West Siberian Arctic (Khitun 1991, 1998, 2002, 2003).

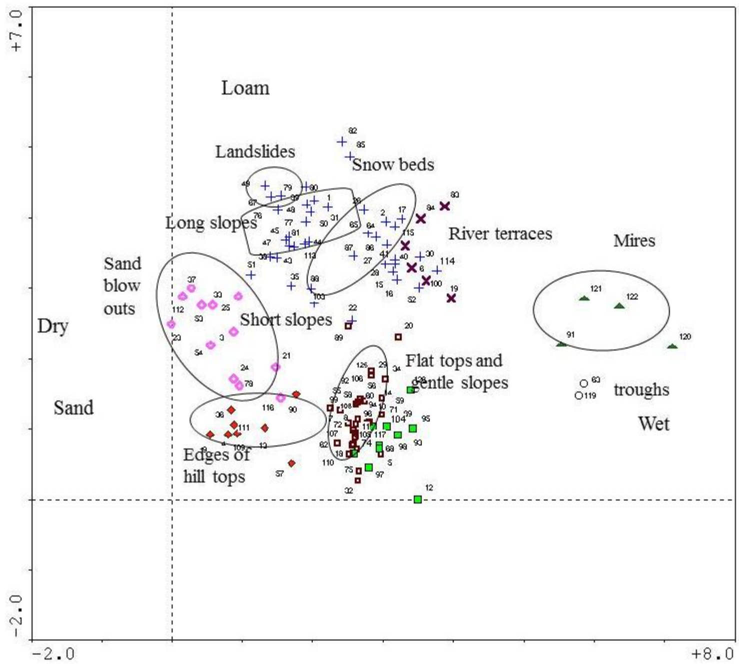

Fig. 3. DCA ordination diagram obtained from the matrix which contained all relevés made in "Ngynyangse". Some relevés were marked manually with different symbols showing to which habitat type they belong.

Discussion

Although the Arctic is not considered as a biodiversity hotspot, its unglaciated regions in Beringia have relatively high floristic diversity compared to the rest of the Arctic (Walker et al. 2016). In opposite, the West Siberian sector is known for its very low (even for the Arctic) diversity (Rebristaya 2013). There are at least two main reasons for it. During the Pleistocene, the land experienced several marine transgressions (the biggest was the Yamal transgression in the mid-Pleistocene), when most of the surface was covered by the water (Khotinsky 1977, Svedsen et al. 1999). Transgressions alternated with regressions, when the land was re-inhabited by plants migrating both from the south and along the shelf (Rebristaya 2013). So, the time of flora formation was relatively short. Additionally, a wide spread of acidic peaty soil, which were not favourable for Arctic species prevented their spread to the south. Proportion of arctic and arctic-alpine phytogeographical groups is lower in the Yamal-Gydansky LFs compare to the Taimyr ones in the subzones D and E (compare: Rebristaya 2013, Khitun 1998, 2002, 2003 and Matveeva 1998). It was shown earlier that the LF richness values were increasing from the Yamal Peninsula eastwards (Yurtsev et al. 2002): in the subzone D, LF from the Yamal Peninsula included approximately 140-155 species (Rebristaya 2013), LF from the Gydansky Peninsula compriced 165-186 (Khitun 2002, 2003) and LF from Taimyr numbered 190-200 species (Matveeva 1998). Data from LF “Ngynyangse” confirmed this regularity

The differences in the species richness of partial floras reflected the favourability of conditions in the habitat (in terms of warmth, drainage and nutrients). Range of 15-20 species in the poorest habitats and 60-70 in the richest was exactly the same in all LFs which were studied in this region, independently of their subzonal position. Everywhere, the richest are the warmest habitats – steep slopes and the poorest are the most specific habitats – aquatic or dry sands. Interestingly, some increase in the number of species in the partial flora of flat hill tops was noted from subzone E to C. Along with the dropping out of the hypoarctic shrubs and dwarf- shrubs which were dominant in subzone E, penetration of herbaceous species belonging to the arctic and arctic-alpine phytogeographic groups take place (Khitun 1998). This trend is the most pronounced in the arctic tundra subzone (subzones C and B) (Matveeva 1998). The trend, however, starts in subzone D.

Intralandscape structure is typical for the West Siberian sector. The most evident is a connection of the species composition with moisture conditions (*see* Fig. 3). Some change in the grouping of habitat types happens practically at all studied sites and reflects the local specificity. That is because of the fact that topographically similar habitats in different localities are not identical in physical environmental conditions. Comparison of ecotopological structure of local floras in different subzones shows the tendency of decrease in number of such groups: from 12 in southern tundra (Khitun 1991) to 8-10 in northern hypoarctic and 6 in the arctic (Khitun et Rebristaya 1998). The reason is certain levelling (unification) of the microclimatic differences between the habitats with the increase of general climate severity to the north along with the relative increase of the proportion of the species with broad ecological amplitude which occupy all suitable habitats and increase the similarity of partial floras (the formal reason for joining habitat types in one class).

Analysis of distribution of species by the scores of activeness demonstrated that non-active species (LA=I) were the most numerous at “Ngynyangse”, comprising almost the half of the LF (Appendix 1, Fig. 4). That is in contrast to the two other LFs, studied in the same subzone, where low active (LA=II) species were predominating. Specificity of the curves of distribution of species by activeness grades in different subzones was shown in the Taimyr (Matveeva 1998). There was found a trend of decreasing the proportion of non-active (LA=I) species to the north. Our previous data also confirmed this conclusion (Khitun 1998, 2002, 2003). However, in the Yamal Peninsula, Rebristaya (2013) did not find the correlation between the shape of the activeness-grades distribution curve and the subzonal position. In opposite, she noted that in areas with more the diverse relief proportion of non-active species increased. The same result we obtained in “Ngynyangse”. There are many rare species, relics or species at their northern limit in this locality. Most of them were found in low abundance, once or twice and got LA score=I.

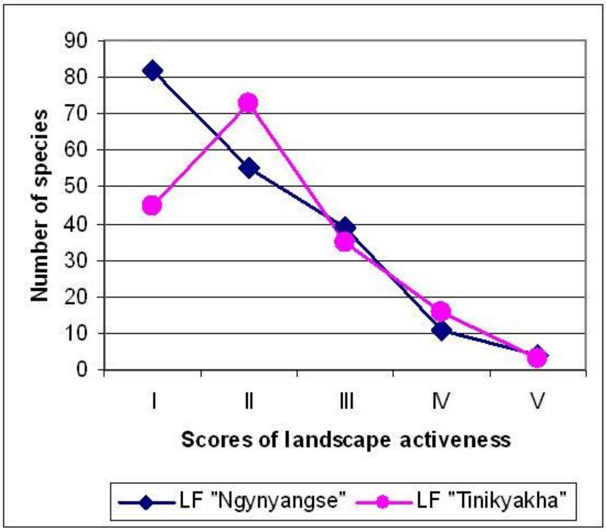

Fig. 4. Distribution of species in local flora by the scores of landscape activeness.

In all studied floras (and also in the Yamal and Taimyr ones), the proportion of "especially active" (LA=V) species is very low. Two arctic-alpine herbs (*Poa alpigena* and *Bistorta vivipara*) got this score in the all three studied localities, and moreover, they had such LA score also in localities studied in subzones E and C (Khitun 1998). In the Gydansky Peninsula these species are growing practically everywhere (except for aquatic habitats) and in rather big abundance (at least, sparse). In LF "Ngynyangse" also two hypoarctic shrubs (*Betula nana* and *Salix glauca*) had LA=V, which is rather unusual for this subzone. Probably, it reflected the fact, that mean temperature of July and August is approximately 1-1.5°C higher in the central part of the peninsula compare to the coast ([4] Climate of the USSR 1965). At the two other sites ("Tinikyakha" and "Khalmeryakha") the arctic species *Salix reptans* got LA score =V. Hypoarctic and Arctic-Boreal species prevail among the species with LA=IV. The species with higher landscape activeness (III-V) accounted for less than 30% of the LF composition but their presence in many partial floras provided that tightly connected intra-landscape structure which was described above.

Approximately 60% of the partial floras are comprised by species with low partial activeness, playing minimal coenotic role in plant cover. Such regularity in phytocoenology is characterised as "excessive diversity" ("сверхразнообразие") (Vasilevich 1992) and is important for restoration ability in succession. Proportion of species with PA=3 or 4 in various JPFs is usually 20-40%. The highest proportion of species with increased PA were found in partial floras of slopes and mesophytic river terraces. Species with high LA score had also the highest PA scores in the majority of habitats where they occur, being dominants or co-dominants in the plant cover. It corresponds with the idea of "superdominance" (Matveeva 1998) when the most adapted and competitive species occupy all suitable habitats and became dominant.

Our study provided new information about the distribution of vascular plant species in the central part of the Gydansky

Peninsula and suggested the explanation for the high continuality of the intralandscape structure of flora, which was found both in traditional for Russian floristics analysis and in DCA. High proportion of species with increased landscape activeness in various partial floras is the reason for high similarity between them and, therefore, a low beta-diversity in this region.

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Appendix 1. Vascular plants of local flora “Ngynyangse” with indication of their landscape activeness (LA) and partial activeness (PA) in habitat types where species occur.

Note. Scores of LA (I-V) and PA (1-7) are determined according to Tables 1 and 2 respectively. Species nomenclature follows the Arctic flora of the USSR(1960-1987), updated according to Elven 2007. Species are listed in the order of decreasing LA. Within one step of LA, species are listed in alphabetic order. Species with LA=II and LA=I are listed below the table, with habitat type indicated by numeral in fat style, followed by PA in brackets. PA=1 is not shown.

	Partial activeness of species in various habitat types (habitats **1-18** as in Table 3)																	
Species with LA=V	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10a**	**11**	**13**	**14**	**15**	**16**	**17**	**18**
Betula nana L.	5	4	5	5	5	5	1	3	1	1	2	-	4	1	-	1	1	-
Bistorta vivipara (L.)S.F.Gray	2	2	2	3	3	2	-	3	4	5	5	-	4	4	2	4	2	-
Poa alpigena (Blytt) Lindm. subsp. *alpigena*	2	1	3	2	2	2	-	3	4	5	3	-	3	4	3	5	2	1
Salix glauca L.	5	2	4	5	5	1	1	2	2	5	3	1	5	4	3	3	-	-
Species with LA=IV																		
Carex bigelowii subsp. *arctisibirica* (Jurtzev) A. Löve & D. Löve	5	2	5	5	5	-	-	2	-	-	2	-	2	1	-	-	-	-
Equisetum boreale Bong.	1	2	-	1	1	-	-	5	4	4	3	3	3	4	3	4	-	1
Festuca ovina L.	2	3	3	2	1	1	-	5	5	1	4	1	3	4	2	2	-	-
Hedysarum hedysaroides subsp. *arcticum* (B.Fedtsch.) P.W.Ball	-	1	2	1	1	-	-	2	4	4	5	-	1	1	2	3	-	-
Petasites frigidus (L.) Fr.	2	-	2	1	3	1	1	1	1	3	-	-	3	3	2	4	2	-
Poa arctica R. Br.	3	-	4	3	4	3	1	2	-	-	-	-	1	1	-	2	1	-
Salix lanata L.	-	-	3	1	3	-	-	-	2	5	3	-	4	3	1	3	-	-
Salix polaris Wahlenb.	3	-	1	3	2	-	-	2	2	3	-	-	4	5	-	4	-	-
Salix reptans Rupr.	3	-	4	2	2	-	-	-	1	-	5	1	-	-	4	4	1	1
Vaccinium vitis-idaea subsp. *minus* (Lodd.) Hult.	5	4	4	4	2	3	-	5	2	-	2	-	1	-	-	-	-	-
Valeriana capitata Pall. ex Link.	3	-	2	3	3	-	-	1	2	2	2	-	3	1	1	1	-	-
Species with LA=III																		
Alopecurus alpinus Sm.	2	1	1	1	1	-	-	1	1	1	1	-	1	-	3	3	-	-
Arctagrostis latifolia (R.Br.) Griseb.	4	-	4	4	3	-	-	-	-	1	1	-	2	-	1	-	1	-
Artemisia tilesii Ledeb.	-	-	-	-	-	-	-	1	2	2	1	-	1	2	4	4	-	-
Astragalus alpinus subsp.*arcticus* Lindm.	-	-	-	-	-	-	-	2	4	-	2	-	1	1	2	2	-	-
Calamagrostis neglecta (Ehrh.) Gaerth., Mey. et Scherb.	-	-	-	-	-	-	-	4	-	3	2	-	4	3	1	4	1	-
Calamagrostis holmii Lange	4	4	4	5	4	5	1	-	-	-	-	-	-	-	-	-	-	-
Cardamine pratensis L.	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	2	3	-
Calamagrostis lapponica (Wahlenb.) C.Hartm.	-	3	-	-	-	-	-	2	1	-	2	-	1	-	1	-	-	-
Carex. concolor R.Br.	-	-	2	-	2	-	4	-	-	4	-	-	4	2	-	-	5	1

	Partial activeness of species in various habitat types (habitats **1-18** as in Table 3)																	
Species with LA=III (cont.)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10a**	**11**	**13**	**14**	**15**	**16**	**17**	**18**
Cerastium jenisejense Hult.	-	-	-	-	-	-	-	-	1	3	2	-	2	2	-	2	2	1
Deschampsia glauca C. Hartm.	-	-	-	-	-	-	-	-	3	-	-	-	-	1	5	4	-	1
Dryas punctata Juz.	3	4	-	2	-	-	-	3	3	-	-	-	-	1	-	-	-	-
Dryas vagans Juz.	2	-	2	3	2	-	-	-	-	-	3	-	1	-	-	-	-	-
Eriophorum angustifolium Honck.	2	-	1	1	2	2	5	-	-	-	-	-	4	-	-	2	4	-
Eriophorum vaginatum L.	5	-	4	4	3	3	-	-	-	-	-	-	1	-	-	-	-	-
Festuca rubra subsp.*arctica* (Hack.) Govor.	-	2	-	-	-	-	-	-	4	3	4	3	-	2	3	3	-	-
Hierochloë alpina (Sw.) Roem. et Schult.	-	3	-	-	-	-	-	4	1	-	-	2	-	-	-	-	-	-
Ledum palustre subsp. *decumbens* (Ait.) Hult.	2	4	2	2	-	3	-	2	-	-	-	-	2	1	-	-	-	-
Luzula confusa Lindb.	-	3	2	1	1	-	-	3	-	-	3	-	-	1	-	1	-	-
Minuartia macrocarpa (Pursh) Ostenf.	1	3	1	1	-	-	-	2	-	-	1	-	-	-	-	-	-	-
Pachypleurum alpinum Ledeb.	-	-	-	-	-	-	-	3	3	3	1	1	-	3	-	-	-	-
Parnassia palustris subsp. *neogaea* (Fern.) Hult.	-	-	-	-	-	-	-	-	2	4	1	-	1	2	-	2	-	-
Parrya nudicaulis (L.) Regel	2	-	3	2	2	-	-	-	-	-	-	-	-	1	-	-	-	-
Pedicularis lapponica L.	3	-	2	3	2	1	-	-	-	-	-	-	1	1	-	-	-	-
Pedicularis sudetica . subsp. *interioroides* Hult.	-	-	1	1	1	-	1	-	-	3	1	-	3	2	1	1	1	-
Poa alpigena subsp. *colpodea* (Th.Fries) Jurtz. et Petrovsky	-	-	-	-	-	-	-	-	-	-	1	2	-	-	5	4	-	1
Polemonium acutiflorum Willd. ex Roem. et Schult.	-	-	-	-	1	-	-	-	1	4	1	-	3	3	-	4	-	-
Ranunculus borealis Trautv.	-	-	-	1	-	-	-	1	4	3	2	-	2	4	2	4	-	-
Rubus chamaemorus L.	2	-	3	2	3	4	-	-	-	-	-	-	2	-	-	-	1	-
Salix nummularia Anderss.	-	5	1	2	-	-	-	5	3	-	4	2	-	-	-	-	-	-
Salix pulchra Cham.	4	-	4	4	3	2	1	-	-	-	-	-	3	-	1	-	3	-
Saussurea tilesii (Ledeb.) Ledeb.	1	1	1	1	1	-	-	4	1	-	1	-	-	-	-	-	-	-
Saxifraga cernua L.	-	-	-	-	-	-	-	-	1	3	1	-	3	1	-	4	1	1
Saxifraga hieracifolia Waldst. et Kitag.	-	-	1	1	1	-	-	-	1	2	-	-	2	2	-	2	-	-
Saxifraga nelsoniana D. Don	3	-	1	3	1	1	-	-	-	1	-	-	2	3	2	-	-	-
Stellaria peduncularis Bunge	2	2	1	2	2	1	-	2	2	2	2	-	2	-	2	-	-	-
Tanacetum bipinnatum (L.) Sch.Bip.	-	-	1	-	-	-	-	1	4	3	4	1	-	2	1	2	-	-
Trisetum spicatum (L.) K.Richt.	-	2	-	-	-	-	-	3	3	2	1	1	1	1	2	-	-	-
Vaccinium uliginosum ssp. *microphyllum* Lange.	2	1	-	2	2	-	-	3	2	-	2	-	1	1	-	-	-	-

Species with LA=II: *Aconogonon ocreatum* (L.) H. Hara **8**(3), **9**(2), **11**(2); *Alopecurus pratensis* subspp.*alpestris* (Wahlenb.)Sel. **10**(2), **13**(3), **14**(2); *Angelica decurrens* (Ledeb.) B.Fedtsch. **10**(3),**10a, 14**; *Antennaria villifera* Boriss. **8**(3), **10, 10a, 14,16;** *Arctophila fulva* (Trin.) Anderss. **17**(2),**18**(2); *Armeria scabra* Pall. ex Roem. & Schult. **2, 8, 9,11**; *Bistorta elliptica* (Willd. ex Spreng.) Kom. ex V.V. Petrovsky, D.F. Murray & Elven **3**(2), **4, 5**(2), **10a**(2); *Bromopsis pumpelliana* subsp. *vogulica* (Soczava) Tzvelev **9, 10, 10a**; *Calamagrostis langsdorffii* (Link) Trin. **10**(3),**13,17**(2); *Caltha arctica* R.Br.**7, 16,17**; *Campanula rotundifolia* L. **2, 8, 9**(2), **10a**(2); *Carex lachenalii* Schkuhr **10, 13, 14, 16**; *Carex rariflora* (Wahlenb.) Smith **13**(2), **6, 7**(3), **17**; *Carex rotundata* Wahlenb. **17**(3); *Castilleja arctica* Kryl. et Serg **9**(3), **8, 10a, 11;** *Cerastium maximum* L. **9**(4), **15**, 10a; *Chrysosplenium alternifolium* subsp. *sibiricum* (Ser. ex DC.) Hult. **10**(3)**,13,14**; *Comarum palustre* L. **7,13,16,17**(2),**18**(2); *Dianthus repens* Willd. **8, 9**(3), **11**; *Draba hirta* L. s.l. **9**(2), **14,16**; *Dupontia fisheri* R.Br. **16**(2), **17**(2), **18**; *Empetrum subholarcticum* V.Vassil. **2**(2), **4, 8**(2); *Erigeron borealis* (Vierh.) Simm. **9**(2), **11,13,10a,16**; *Eriophorum medium* Anderss.**17**(3); *Eriophorum russeolum* Fries **7**(2), **17**(3); *Eriophorum scheuchzeri* Hoppe **14, 15, 16**(4), **18**; *Gentiana tenella* Rottb. **9, 14**(2), **16**(2); *Lloydia serotina* (L.) Reichenb. **2**(2), **8, 9, 10a,14;** *Luzula multiflora* subsp. *frigida* (Buch.) V. Krecz. **8, 9, 10, 14, 16**; *Luzula nivalis* (Laest.) Spreng. **1, 4, 5, 13**; *Luzula tundricola* Gorodk. ex V.Vassil. **1, 2, 4**; *Luzula wahlenbergii* Rupr. **4, 5, 6, 7,17;** *Minuartia rubella* (Wahlenb.) Hiern. **8, 9, 11**; *Myosotis asiatica* (Vesterg.) Schischk. **8**(2), **9**(3), **14,16**; *Oxytropis sordida* (Willd.) Pers. **8(**3), **9, 11**; *Pedicularis verticillata* L**. 9**(4), **10a**(2), **16**(2); *Polemonium boreale* Adams **2, 8**(2), **9, 11**(2); *Potentilla stipularis* L. **9**(4), **15**(2); *Pyrola grandiflora* Radius **1, 3, 4, 5, 13;** *Ranunculus lapponicus* L.**1, 4, 5, 6**(2),**13**(2); *Ranunculus monophyllus* Ovcz. **10**(3), **13**, **14**; *Rumex arcticus* Trautv. **1, 4, 5**(3), **13**; *Salix phylicifolia* L. **5, 10**(3), **13**(3); *Saxifraga bronchialis* L**. 2, 8, 9, 11, 15**; *Silene samojedora* (Sambuk) Oxelman **8**(3), **9**(2), **11**; *Stellaria crassifolia* Ehrh. **7, 10**(2), **13**, **17**(3); *Stellaria palustris* Retz.**13, 16, 17**; *Taraxacum ceratophorum* (Ledeb.) DC. **9**(3),**10, 10a, 15, 16**;*Taraxacum lateritium Dahlst.* **9**(2), **15, 16**; *Taraxacum nivale* Lange ex Kihlm. **10, 13, 14, 16;** *Tephroseris atropurpurea* (Ledeb.) Holub **6,7,14**; *Thymus reverdattoanus* Serg. **8, 9**(2), **11;** *Tripleurospermum hookeri* Sch.Bip. **15**(5), **16**(2),**18**; *Trollius asiaticus* L. **10**(4), **14**(2); *Veratrum lobelianum* Bernh. **10**(3), **10a**(2), **14**(2)

Species with LA=I: *Andromeda polifolia* subsp.*pumila* V.Vinogr. **4,13***;* *Androsace septentrionalis* L. **9, 11**; *Arabis septentrionalis* N.Busch **8,11**; *Arctagrostis arundinacea* (Trin.) Beal **15, 16;** *Arctous alpina* (L.) Nieden. **8**; *Arnica iljinii* (Maguire) Iljin **9**; *Caltha palustris* L. **17**(2); *Cardamine bellidifolia* L**. 4**; *Carex chordorrhiza* Ehrh. **17**;*Carex glareosa* Wahl. **16**(2); *Carex maritima* Gunn. **15, 16**; *Carex supina* subsp. *spaniocarpa* (Steud.) Hult. **9**; *Carex vaginata* subsp.*quasivaginata* (C.B.Clarke) Malysch.**8, 14**; *Cerastium arvense* L. **11**; *Cerastium regelii* Ostenf. **14**; *Cochlearia arctica* Schlecht. **16**; *Crepis nigrescens* Pohle **9**; *Descurainia sophioides* (Fisch. ex Hook) O.E.Schulz **15**; *Diphasiastrum alpinum* (L.) Holub **8;** *Draba glacialis* Adams **14**; *Draba nivalis* Liljebl. **9**; *Draba pauciflora* R.Br. **4**; *Epilobium davuricum* Fisch. **15, 16;** *Epilobium palustre* L. **17**(2); *Equisetum palustre* L. **13**; *Equisetum pratense* Ehrh. **8**; *Eremogone polaris* (Schischk.) Ikonn**. 8, 9, 11;** *Erigeron eriocalyx* (Ledeb.) Vierh. **9**; *Eutrema edwardsii* R.Br. **1, 4**; *Festuca brachyphylla* Schult. et Schult. fil. **4**; *Gastrolychnis angustiflora* Rupr. (*Silene involucrata* aggr.) **9**; *Hierochloë pauciflora* R.Br. **17**; *Hippuris lanceolata* Retz. **18**; *Juncus biglumis* L. **4**; *Juncus castaneus* Smith **15;** *Koeleria asiatica* Domin **9, 11**(2); *Koenigia islandica* L. 14, 18; *Lagotis minor*

(Willd.) Standl. **10a**; *Linnaea borealis* L. **8**; *Lycopodium annotinum* subsp. *pungens* (La Pyl. et Kom.) Hult. **8**; *Lycopodium clavatum* subsp. *monostachyon* (Grev. et Hook.) Seland**. 8, 14**; *Lycopodium selago* subsp.*arcticum* Tolm. **14**; *Minuartia biflora* (L.) Schinz et Thell **14**; *Myosotis palustris* (L.) L. **10**(3); *Oxyria digyna* (L.) Hill. **8**(2), **14**(2); *Pedicularis compacta* Steph. ex Willd. **10**; *Pedicularis hirsuta* L. **1, 2, 4**; *Phippsia concinna* (Th.Fries) Lindeb.**15**; *Poa glauca* Vahl **9**; *Poa pratensis* L. **15**; *Potentilla gelida* subsp. *boreo-asiatica* Jurtz. et Kamel. **10**; *Potentilla kuznetzowii* (Gowor.) Juz. **9,15**; *Primula stricta* Hornem. **14**; *Puccinellia sibirica* Holmb.**15**; *Ranunculus affinis* R.Br. s.l. **4, 5**; *Ranunculus gmelinii* DC.**18** (2); *Ranunculus hyperboreus* Rottb. **18**(2); *Ranunculus nivalis* L. **14**; *Ranunculus pallasii* Schlecht.**18**; *Ranunculus pygmaeus* Wahlenb. **14;** Rubus arcticus L.**10**(2); *Rumex graminifolius* Lamb. **8**, **9**; *Sagina intermedia* Fenzl **4, 14**; *Salix arctica* subsp. *jamutaridensis* Petrovsky **14**; Salix hastata L. **9**; *Salix myrtilloides* L. **17**; *Salix reticulata* L. 10; *Saxifraga cespitosa* L**. 9**; *Saxifraga foliolosa* R.Br. **17**; *Saxifraga hyperborea* R.Br. **9**; *Saxifraga nivalis* L. **2, 9**; *Saxifraga tenuis* (Wahlenb.) H.Smith **9**; *Sibbaldia procumbens* L. **14**; *Sparganium hyperboreum* Laest. **18**; *Taraxacum glabrum* DC. 10; *Taraxacum macilentum* Dahlst. **10a, 14**;*Taraxacum macroceras* Dahlst. **16**; *Tephroseris palustris* subsp. *congesta* (R. Br.) Holub **15**; *Tofieldia coccinea* Richards. **2;** *Veronica longifolia* L.**10**; *Viola biflora* L.**10;** *Viola epipsiloides* Love et D. Love **10**(3).