ARPHA Proceedings

Proceedings BDI-2020, 51-65
doi: 10.3897/ap.2.e56848

III Russian National Conference
"Information Technology in Biodiversity Research"

An overview of the alien flora of the Yamal-Nenets Autonomous Area (Russia)

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Abstract

From eight years, 2012–2019, of field research, critical work in herbariums and literature reviews, we have established and identified as alien in the Yamal-Nenets Autonomous Area (YaNAA) a list of 216 vascular plant species from 144 genera and 35 families. The set of the ten richest families, by the number of species, alters in that the alien flora includes such families as Fabaceae, Polygonaceae and Chenopodiaceae, whereas the Cyperaceae, Salicaceae and Juncaceae families are absent from it. The richest by the number of species genus in the alien flora of the YaNAA is *Chenopodium*. We have classified the non-native species by the degree of naturalization, means of introduction and frequency of occurrence. We considered all alien species as kenophytes. For some arrival into the region can be traced back to 17th century, but most of them appeared at, or since, the end of 20th century or later. We distinguished three groups according to the naturalization degree: ephemerophytes (70%), kolonophytes (15%), and epekophytes (15%). Life history strategies and growth forms of the alien species differ from the native ones, with absolute dominance of herbaceous forms and a high proportion of annuals among them. By means of introduction, xenophytes prevail (82%), the remainder being number of ergasiophytes and xenoergasiophytes.

Keywords: alien species, degree of naturalization, Far North, indigenous species, life history strategies, means of introduction, vascular plants, Western Siberia

Published by Ural Federal University and peer-reviewed under responsibility of BDI-2020 (III Russian National Conference "Information Technology in Biodiversity Research")

Introduction

Yamal-Nenets Autonomous Area (YaNAA) is one of the primary regions in Russia for gas and oil production. Industrial development, and the associated expansion of transport infrastructure in this region, has significantly transformed the environment

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and in particular facilitated the migration of non-native species into the local flora. Immigrant alien species first appear at and then spread along the roadsides and road pads, railway pads, ruderal sites, around airports and railway stations; also at river's alluvium. The results of the invasion of aggressive alien species can be catastrophic for native ecosystems, while on the other hand the appearance of new species is an enrichment of local floras, which, in the West Siberian North, are normally very species poor. Monitoring of alien species should become a part of future regional floristic studies.

There is significant information in the literature about the diversity of vascular plants in the YaNAA, including non-published herbarium collections (Pismarkina 2014a). "Flora of Western Siberia" (Krylov 1927–1964), "The Arctic Flora of the USSR" (Tolmachev 1960–1987) and "Flora of Siberia" (Krasnoborov et al. 1987–1997; Malyschev et al. 2003) are the most valuable sources, though even in such fundamental works information about alien species is minimal. In "Conspectus florae Sibiriae" (Baikov 2005) and "Conspectus florae Rossiae Asiaticae" (Baikov 2012), mainly based on the material from "Flora of Siberia", there is very limited information about the distribution of species within the individual administrative units. Books summarizing the results of the inventory and analysis of the flora of several regions within the YaNAA were devoted to the Polar Urals (Knyazev et al. 2006), the Yamal Peninsula (Rebristaya 2013), the Upper Taz State Reserve (Neshataev et al. 2002) and the floodplain of the Taz River (Titov and Potokin 2001). However, these also provide little information about non-native species. The most useful information about the synanthropic component of flora was found in the monograph of Dorogostayskaya (1972) and papers by Trotsenko (1990), Vilchek and Kuznetsov (1996), Ishbirdin et al. (1996) and Khozyainova (2007).

Plant specimens from the YaNAA are preserved in the Herbarium of Komarov Botanical Institute RAS (LE), the D.P. Syreishchikov Herbarium of the Moscow State University (MW), the P.N. Krylov Herbarium of the Tomsk State University (TK), the Herbarium of the Main Botanical Garden of the Russian Academy of Sciences (MHA), and I.P. Borodin Herbarium of the St. Petersburg State Forest Technical University (KFTA).

Although much floristic information has been achieved for more than a century, summary publication about the flora of the YaNAA is still absent. The totality of non-native species that has entered the region has not been a subject of any special investigation.

Methods

The YaNAA is situated in the North of West Siberia. The northernmost point of the YaNAA lies at approximately 73°20′N and the southernmost at 62°N. The region stretches throughout the three bioclimatic zones: tundra (including Arctic tundra, Northern and Southern Hypoarctic tundra subzones), forest-tundra and taiga (including northern and middle taiga subzones) (Larin 2004).

The high latitude location of the YaNAA, its remoteness from warm air and water masses and the plain topography determine its sharply continental climate. Winters last almost eight months with minimum temperatures as low as –59°C. Summers though short and cool may have some days, in the southern part of the region, with temperatures as high as +30–34°C. Summer isotherms follow latitudinal direction and

change from a mean July temperature of +4°C in the north to +16°C in the south. Winter isotherms have meridional direction and the mean January temperature changes from –22°C in the western part of the region to –27°C in the eastern part (Larin 2004). Permafrost underlain the terrain.

We studied the alien fraction of the YaNAA flora from 2012 to 2019, carrying out flora surveys in the majority of towns (Salekhard, Labytnangi, Nadym, Novy Urengoi, Gubkinskii, Noyabrsk, Tarko-Sale) and in several bigger settlements of the region (Pangody, Priozernyi, Yagelnyi, Tazovskii, Korotchaevo, Aksarka, Kharp, Novy Port, Bovanenkovo) (Fig. 1). We carried out 22 expeditions and examined approximately 20 000 herbaria specimens of alien and native species. Field investigations were performed in the form of daily excursions, commonly designed by the route method (Scherbakov and Mayorov 2006).

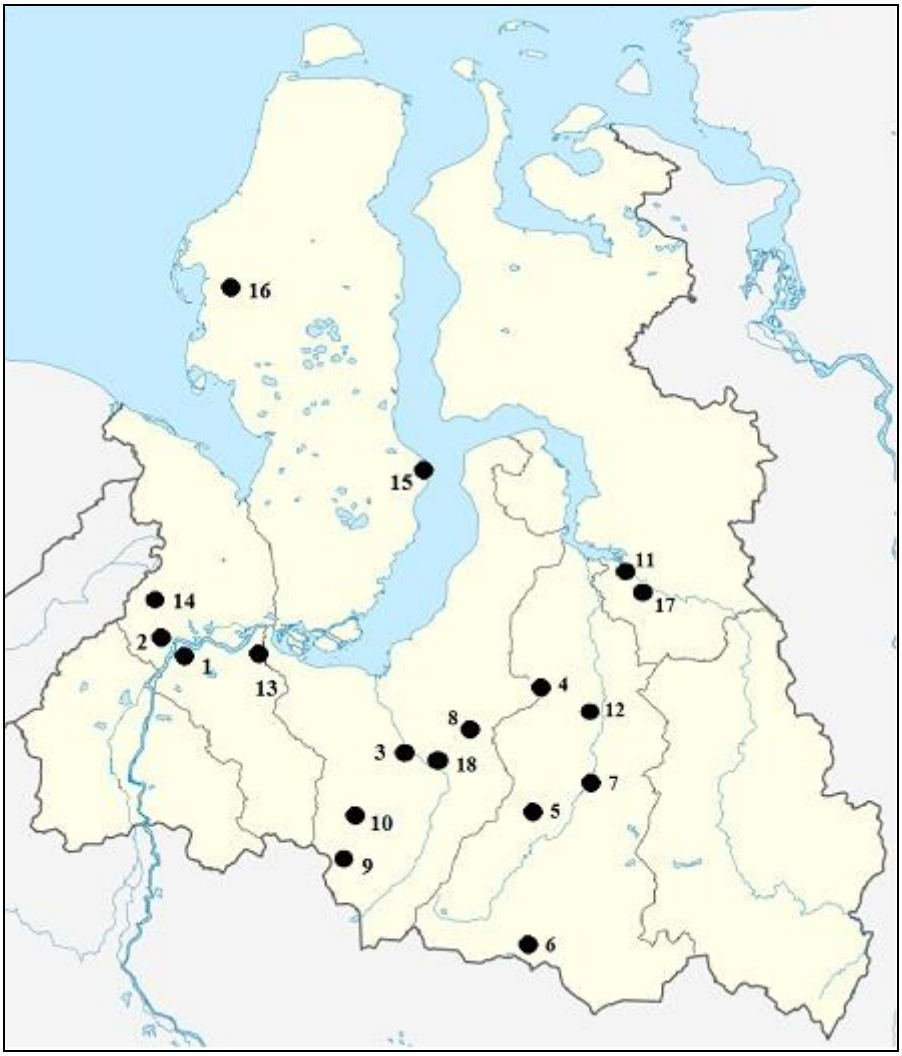

Figure 1. Location of the study sites on the map Yamal-Nenets Autonomous Area: 1 – Salekhard, 2 – Labytnangi, 3 – Nadym, 4 – Novy Urengoy, 5 – Gubkinsky, 6 – Noyabrsk, 7 – Tarko-Sale, 8 – Pangody, 9 – Priozerny, 10 – Yagelny, 11 – Tazovsky, 12 – Korotchaevo, 13 – Aksarka, 14 – Kharp, 15 – Novy Port, 16 – Bovanenkovo, 17 – floodplain of the Nuny-Yakha river, 18 – Pravokhettinsky.

As “alien” (synonyms: exotic, introduced, non-native, non-indigenous, adventive) we consider species, which appearance in the study region was not connected with

natural flora genesis, but is the result of human economic activity, primarily anthropogenic disturbance of plant and soil cover. The absence of natural predators (phytophagous insects and pathogens) often enables exotic species (Tuganaev and Puzyrev 1988; Burda 1991).

While working with literature and herbarium specimens we took into account information about the presence of the species in natural or anthropogenic habitats within YaNAA borders and adressed the following questions:

1) Is the presence of a species in any specific locality connected with any anthropogenic activity?

2) Is the species adventive throughout the whole YaNAA territory?

If the species is native in one part of the region, and in another part, usually northwards, it is obviously adventive, we did not include it in the alien fraction. To evaluate the modern range of the species of the regional flora, along with literature, we used also internet resources (Afonin et al. 2008; GBIF 2020a, 2020b, 2020c; Pismarkina 2018–2019).

For the analysis of the alien flora by the degree of naturalization and the means of introduction, we used the classification by F.G. Schroeder (Schroeder 1969; Ignatov et al. 1990).

For the analysis of alien flora by the species occurrence frequency, we used the following scale:

- solitary: species found in one locality in the YaNAA;
- very rarely: species found in 2–5 localities;
- rarely: species found in 6–10 localities;
- often: species is known from 11–15 localities;
- commonly: species found in 16 or more localities.

Our field work in the YaNAA in 2012–2019 is reported in a number of publications (Byalt et al. 2017, 2020; Byalt and Egorov 2019a, 2019b; Pismarkina 2014a, 2014b, 2019; Pismarkina and Khitun 2019; Pismarkina and Bystrushkin 2019, 2020; Pismarkina et al. 2019). Our data, critical check of the herbaria specimens in the mentioned above herbariums (LE, MW, SVER, TK) and literature references, followed by nomenclature control according to the website “Plants of the World Online” (POWO 2019), allow us to present a list of 216 species from 144 genera and 35 families in the alien fraction of the regional flora of the YaNAA. Previously, we wrote about 190 alien species (Pismarkina et al. 2018), an additional 26 species appeared due to new findings, new identifications and re-identifications of herbaria specimens. In 2019–2020, we reviewed the list of the alien species and only information that was confirmed by a possession of a herbaria specimen was used. Therefore, species known in the YaNAA only from literature reference were not included in our list.

Results

The alien species portion contributes only 20.3% of total regional flora. There are several reasons for such a low proportion, compared to regions that lie further south:

1) Geographical position in the north of West Siberia. Here, not only naturalization, but even encroachment of new species (mainly originated from more southern regions), is difficult due to the climatic and biological barriers;

2) Relative “youth” of synanthropic component of regional flora;

3) The limited number of publications devoted to adventive plants since the work of Dorogostayskaya (1972).

Taxonomic structure

The following 11 families are the richest, in terms of the number and proportion (%) of species in the non-native fraction of the YaNAA regional flora: Asteraceae (31 species, 14.8%), Poaceae (28 species, 13.0%), Brassicaceae (22 species; 10.2%), Fabaceae (19 species; 8.8%), Caryophyllaceae, Polygonaceae and Chenopodiaceae (12 species, or 5.6% in each); Apiaceae (10 species, 4.6%); Rosaceae (9 species; 4.2%), Lamiaceae and Plantaginaceae (7 species, or 3.2% in each). The Boraginaceae, Ranunculaceae, and Scrophulariaceae families contain 4 species, or 1.9% each; Rubiaceae, Solanaceae, Urticaceae contain 3 species (1.4%) each); the Cucurbitaceae, Geraniaceae, Onagraceae, Papaveraceae, Typhaceae families contain 2 species (0.9%) each, and Equisetaceae, Amaranthaceae, Cannabaceae, Convolvulaceae, Cuscutaceae, Dipsacaceae, Euphorbiaceae, Hydrophyllaceae, Malvaceae, Primulaceae, Violaceae, Alliaceae, Lemnaceae are represented by a single species.

The positions of the richest families, in terms of the number and proportion of species, differ in the indigenous and alien flora (Table 1). For example, Asteraceae in the native part of flora occupies the second place. The proportion of such families as Brassicaceae and Polygonaceae increased in the non-native fraction compared to aboriginal. Families, which in the indigenous flora are represented by 1 to 7 species (Plantaginaceae, Boraginaceae, Lamiaceae), in the alien flora are among the ten richest. Rosaceae keeps its position, whereas proportion of Ranunculaceae and Caryophillaceae decreased in the alien fraction compared to the indigenous flora. In the alien flora, we did not find representatives of Cyperaceae, Juncaceae and Saxifragaceae, whereas these families are among the richest twelve in the native fraction. In the indigenous flora Chenopodiaceae is absent, while within the alien flora it is represented by 12 species.

Table 1. The numerically richest plant families in the indigenous and alien flora of the YaNAA.

Family	Number (n) and proportion (%) of species			
	Indigenous flora		Alien flora	
	n	%	n	%
Poaceae	93	11.0	28	13.0
Asteraceae	85	10.5	32	14.8
Cyperaceae	83	9.8	0	0
Caryophyllaceae	54	6.4	12	5.6
Ranunculaceae	51	6.0	4	1.9
Brassicaceae	37	4.4	22	10.2
Rosaceae	37	4.4	9	4.2
Scrophulariaceae	35	4.1	3	1.4
Salicaceae	32	3.8	0	0
Juncaceae	25	2.9	0	0
Polygonaceae	22	2.6	12	5.6
Saxifragaceae	20	2.4	0	0
Fabaceae	17	2.0	19	8.8
Apiaceae	15	1.8	10	4.6

The richest by the number of species genus in the alien flora of the YaNAA is *Chenopodium* (10 species). It is followed by *Plantago* (7 species), *Trifolium* (6 species), *Rumex* (5 species), *Lolium* (5 species). Genera *Amaranthus*, *Artemisia*, *Centaurea*, *Helianthus*, *Sonchus*, *Brassica*, *Galeopsis*, *Polygonum*, *Galium*, and *Urtica* contain 3 species each. Genera *Bidens*, *Cirsium*, *Lactuca*, *Lappula*, *Barbarea*, *Camelina*, *Lepidium*, *Raphanus*, *Sinapis*, *Sisymbrium*, *Coccyganthe*, *Dianthus*, *Gypsophila*, *Silene*, *Medicago*, *Melilotus*, *Epilobium*, *Fagopyrum*, *Aquilegia*, *Geum*, *Potentilla*,*Veronica*, *Solanum*, *Alopecurus*, *Avena*, *Echinochloa*, *Elymus*, *Hordeum*, *Poa*, and *Typha* contain 2 species each. More than a half of genera in the alien flora of the YaNAA are monotypic (contain 1 species): *Equisetum*, *Carum*, *Cenolophium*, *Chaerophyllum*, *Conium*, *Coriandrum*, *Eryngium*, *Kadenia*, *Pastinaca*, *Seseli*, *Achillea*, *Arctium*, *Carduus*, *Cichorium*, *Conyza*, *Cota*, *Galinsoga*, *Leontodon*, *Lepidotheca*, *Leucanthemum*, *Picris*, *Senecio*, *Jacobaea*, *Tripleurospermum*, *Tussilago*, *Echium*, *Anchusa*, *Armoracia*, *Berteroa*, *Bunias*, *Catolobus*, *Descurainia*, *Erysimum*, *Neslia*, *Thlaspi*, *Cannabis*, *Agrostemma*, *Cerastium*, *Spergula*, *Spergularia*, *Stellaria*, *Viscaria*, *Atriplex*, *Beta*, *Convolvulus*, *Cucumis*, *Cucurbita*, *Cuscuta*, *Knautia*, *Euphorbia*, *Anthyllis*, *Astragalus*, *Cytisus*, *Lathyrus*, *Lotus*, *Lupinus*, *Onobrychis*, *Pisum*, *Vicia*, *Erodium*, *Geranium*, *Phacelia*, *Glechoma*, *Nepeta*, *Origanum*, *Prunella*, *Malva*, *Chelidonium*, *Papaver*, *Fallopia*, *Persicaria*, *Primula*, *Leptopyrum*, *Ranunculus*, *Argentina*, *Rosa*, *Rubus*, *Sorbaria*, *Linaria*, *Pedicularis*, *Hyoscyamus*, *Viola*, *Allium*, *Lemna*, *Agropyron*, *Anisantha*, *Apera*, *Bromus*, *Dactylis*, *Panicum*, *Phalaris*, *Phleum*, *Puccinellia*, *Secale*, *Triticum* (totally 98 genera).

Frequency of occurrence and degree of naturalization

The majority of the alien species were found in the YaNAA one to five times (i.e., "solitary" or "very rarely"), there are 87 and 80 species respectively in these categories, and thus 77.3% of the alien species we found. Thirty species we categorized as occurring "rarely" (13.9%). Species recorded as "often" and "commonly" (11 and 8 species respectively) contributed only 8.9% of the alien flora.

Extensive introduction of alien species to the north of West Siberia started concurrently with the migration of people from European Russia (17th century onwards), but it became more intensive during the period of gas and oil exploration and industrial development. Therefore, all non-native species in the flora of YaNAA are kenophytes, including the oldest grains and the weeds accompanying them, which in European part of Russia and in the south of Siberia are considered as archaeophytes (e.g., *Hordeum vulgare* L., *Chenopodium album* L., *Triticum aestivum* L., *Chenopodium rubrum* L., *Centaurea cyanus* L.).

By the degree of naturalization in the alien flora of the YaNAA we distinguished three groups: ephemerophytes, kolonophytes and epekophytes. We did not find agriophytes, i.e., species that settle in natural habitats. We also analyzed the distribution of species with different degrees of naturalization by occurrence frequency grouping. The aim of this analysis was to illustrate the current distribution of species with different degrees of naturalization in the study region (Fig. 2).

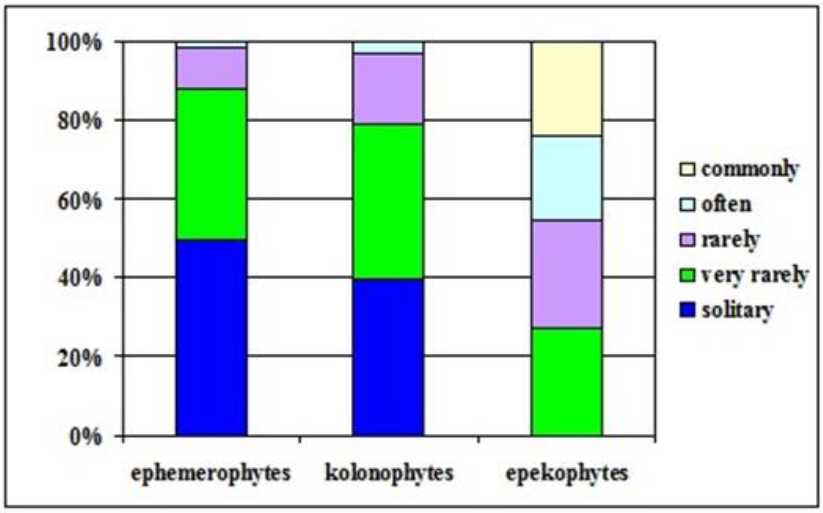

Figure 2. Distribution (%) of the alien species with different degrees of naturalization by the occurrence frequency in the alien flora of the YaNAA.

Ephemerophytes, i.e., species with low ability to naturalization, which occur temporarily in human-made habitats are the most numerous group among the non-native species. We classified 151 species into this group. Almost half of them (75 species) we found only in a single locality. The majority of these species we observed and collected during 2012–2019, often for the first time in the YaNAA: *Amaranthus blitoides* S. Wats., *Cenolophium denudatum* (Hornem.) Tutin, *Chaerophyllum aureum* L., *Conium maculatum* L., *Coriandrum sativum* L., *Kadenia dubia* (Schkuhr) Lavrova et V. Tichom., *Pastinaca sativa* L., *Seseli libanotis* (L.) W.D.J. Koch, *Achillea nobilis* L., *Artemisia dracunculus* L., *Bidens radiata* Thuill., *B. tripartita* L., *Erigeron canadensis* L., *Galinsoga parviflora* Cav., *Helianthus tuberosus* L., *Picris hieracioides* L., *Jacobaea vulgaris* Gaertn., *Sonchus asper* (L.) Hill, *Echium vulgare* L., *Anchusa arvensis* (L.) M. Bieb., *Erysimum canescens* Roth, *Lepidium densiflorum* Schrad., *Neslia paniculata* (L.) Desv., *Sinapis alba* L., *Sisymbrium volgense* M. Bieb. ex E. Fourn., *Silene flos-cuculi* (L.) Greuter & Burdet, *Viscaria vulgaris* Röhl., *Dianthus chinensis* L., *Gypsophila elegans* Bieb., *Chenopodium polyspermum* L., *Ch. desiccatum* var. *leptophylloides* (Murr) Wahl, *Cucumis sativus* L., *Cucurbita pepo* L., *Cuscuta europaea* L., *Knautia arvensis* (L.) Coult., *Lathyrus tuberosus* L., *Onobrychis viciifolia* Scop., *Geranium sibiricum* L., *Galeopsis speciosa* Mill., *Nepeta cataria* L., *Origanum vulgare* L., *Prunella vulgaris* L., *Malva pusilla* Sm., *Epilobium adenocaulon* Hausskn., *Chelidonium majus* L., *Papaver somniferum* L., *Plantago maxima* Juss. et Jacq., *P. major subsp. intermedia* (Gilib.) Large, *Polygonum sabulosum* Worosch., *Rumex obtusifolius* L., *R. rossicus* Murb., *Primula elatior* (L.) Hill., *Aquilegia atrata* Koch, *Galium spurium* L., *Viola arvensis* Murr., *Lemna turionifera* Landolt, *Echinochloa crus-galli* (L.) Beauv., *E. esculenta* (A. Braun) H. Scholz, *Lolium arundinaceum* (Schreb.) Dabrysh, *L. remotum* Schrank, *Panicum miliaceum* L. and *Phalaris canariensis* L. Some other ephemerophytes (*Amaranthus albus* L., *Lactuca sativa* L., *Agrostemma githago* L., *Beta vulgaris* L., *Pisum sativum* L., *Epilobium ciliatum* Rafin., *Fagopyrum esculentum* Moench, *Leptopyrum fumarioides* (L.) Rchb., *Hyoscyamus niger* L., *Bromus tectorum* L., *Hordeum vulgare*, *Poa compressa* L.) were collected in the YaNAA by other authors in the 20th century.

Totally 58 ephemerophytes were classified in group “very rarely”, i.e., found in 2–5 localities: *Amaranthus retroflexus* L., *Eryngium planum* L., *Artemisia absinthium* L.,

Centaurea jacea L., *Catolobus pendulus* (L.) Al-Shehbaz, *Berteroa incana* (L.) DC., *Brassica napus* L., *Bunias orientalis* L., *Camelina microcarpa* Andrz., *Raphanus raphanistrum* L., *Sinapis arvensis* L., *Cannabis sativa* L., *Atriplex prostrata* Boucher ex DC., *Chenopodium glaucum* L., *Astragalus danicus* Retz., *Lotus corniculatus* L., *Medicago falcata* L., *Erodium cicutarium* (L.) L`Her., *Galeopsis tetrahit* L., *Plantago depressa* Willd., *Rumex crispus* L., *Ranunculus polyanthemos* L., *Argentina anserina* (L.) Lindl., *Galium mollugo* L., *Veronica spicata* L., *Agropyron cristatum* (L.) Gaertn., *Apera spica-venti* (L.) Beauv. and others.

There are 16 ephemerophytes with the frequency of occurrence "rarely" in this region: *Cota tinctoria* (L.) J. Gay, *Centaurea cyanus*, *Barbarea stricta* Andrz. ex Besser, *B. vulgaris* R. Br., *Descurainia sophia* (L.) Webb ex Prantl, *Cerastium fontanum* subsp. *vulgare* (Hartm.) Greuter & Burdet, *Medicago sativa* L., *Trifolium medium* L., *Vicia hirsuta* (L.) S.F. Gray, *Galeopsis bifida* Boenn., *Glechoma hederacea* L., *Rumex longifolius* DC., *R. pseudonatronatus* (Borb.) Borb. ex Murb., *Urtica urens* L., *Avena sativa* L., and *Puccinellia distans* (Jacq.) Parl.

Only two ephemerophytes occur "often", *Brassica rapa* L. and *Dactylis glomerata* L., they are both used in lawn and arable field grass mixtures and therefore are repeatedly introduced into the region.

Kolonophytes are the species that form sustainable populations in the area of invasion. We classified 32 species in this group. There are 13 kolonophytes with solitary occurrence frequency: *Equisetum hyemale* L., *Sonchus oleraceus* L., *Armoracia rusticana* Gaertn., Mey. et Schreb., *Gypsophila paniculata* L., *Cytisus ruthenicus* (Fisch. ex Wol.) Klask., *Lupinus polyphyllus* Lindl., *Rosa glabrifolia* C.A. Mey ex Rupr., *Pedicularis sibirica* Vved., *Urtica angustifolia* Fisch. ex Hornem., *Alopecurus arundinaceus* Poir., *A. geniculatus* L., *Typha angustifolia* L.

A further 13 kolonophytes that were found "very rarely": *Carduus crispus* L., *Scorzoneroides autumnalis* (L.) Moench, *Sonchus arvensis* L., *Tussilago farfara* L., *Euphorbia esula* subsp. *tommasiniana* (Bertol.) Kuzmanov, *Trifolium montanum* L., *Plantago media* L., *Geum aleppicum* Jacq., *G. urbanum* L., *Sorbaria sorbifolia* (L.) A. Br., *Galium album* Mill., *Elymus sibiricus* L. and *Typha latifolia* L. Six kolonophytes occur rarely (*Cirsium arvense* (L.) Scop., *Potentilla intermedia* L., *P. supina* L., *Rubus idaeus* L., *Lolium perenne* L., *Phleum pratense* L.) and only *Lolium pratense* (Huds.) Dabrysh, occurs "often".

Epekophytes are a group of species that spread through human-made habitats. None of 33 species classified as epekophytes in the YaNAA belonged to the occurrence frequency group "solitary". Nine epekophytes occur "very rarely": *Anthyllis vulneraria* L., *Carum carvi* L., *Lactuca tatarica* (L.) C.A. Mey., *Sisymbrium loeselii* L., *Silene tatarica* (L.) Pers., *Chenopodium acerifolium* Andrz., L., *Persicaria maculosa* (L.) S.F. Gray, *Convolvulus arvensis* L., *Linaria vulgaris* Mill. Species in this group behave differently. Thus, *Anthyllis vulneraria* and *Persicaria maculosa*, were found in 2013 and 2014, and they still grow at those same sites but they did not spread to other sites in the region, whereas all other species expanded during the later years of our study to the new settlements. For example, *Sisymbrium loeselii* was first recorded in Noyabrsk in 2013, in 2017 we observed it in many places in Novy Urengoi, and in 2019 – in abandoned lawns and wastelands in Nadym.

In the YaNAA epekophytes that occur often or commonly are most characteristic of urban landscapes. These groups contain seven (*Pimpinella saxifrage* L., *Leucanthemum vulgare* Lam., *Senecio vulgaris* L., *Melilotus officinalis* (L.) Pall., *Trifolium pratense* L., *Urtica dioica* L., *Hordeum jubatum* L.) and eight (*Matricaria discoidea* DC., *Capsella bursa-pastoris* (L.) Medik., *Stellaria media* (L.) Vill., *Chenopodium album*, *Trifolium repens* L., *Plantago major* L., *Polygonum aviculare* L. s. l. and *Elymus repens* (L.) Gould.) species respectively.

The higher the degree of naturalization, the fewer species achieve it. Long-term observations are necessary to distinguish kolonophytes and ephemerophytes. In contrast to Mayorov et al. (2012), we do not consider all introduced rhizomatous species as kolonophytes. Among the perennial rhizomatous plants, we classified as kolonophytes only those species, that at the time of observation had formed spacious populations and were flowering or fruiting. These are, for example, *Galium album* Mill., *Pedicularis sibirica* Vved., *Urtica angustifolia* Fisch. ex Hornem., *Alopecurus arundinaceus* Poir., *Elymus sibiricus* L., *Lolium pratense*, *L. perenne* L., *Phleum pratense* L., *Typha angustifolia* L., *T. latifolia* L. Taking into account big annual variation in mean temperatures during the vegetation season in the Russian Far North, even such species can die off before managing to form stable autogenous populations.

Epekophytes are clearly distinct in the YaNAA. They are not a transitional group from kolonophytes to agriophytes, when former kolonophytes start successfully spread out, but have not yet manage to encroach new habitats. In this region, as a rule, epekophytes have the highest degree of naturalization among the alien species. We explain this by the specifics of the native ecosystems (taiga, forest-tundra, tundra), which provide harsh phytocoenotic and edaphic barriers to the introduced species. Thick moss and lichen cover; the high acidity, hydrological and thermal regimes of the soil, combine to prevent the settlement of non-native plants. Therefore, exotic plants spread only through anthropogenic habitats. Exceptions do occur such as our 2016 observation of *Hordeum jubatum* in the dry pine forest and *Matricaria discoidea* on the river alluvium in taiga, but such observations are solitary.

Life history strategies and growth forms of alien species

The non-native flora differs from the indigenous by absolute dominance of herbaceous forms and by the very high proportion of annuals among them. Annuals represent almost 41% (88 species) of the alien flora. Other short living plants are less numerous: biennials (15 species, 7.0%); annuals/biennials (9 species, 4.2%); plants, which complete their life cycle in various time, depending on conditions their life span can vary from 1 or 2 years to several years (9 species, 4.2%). However, perennial herbs (91 species, 42.1%) are the largest group, as they are in the indigenous flora. There are only four species of shrubs (1.2 %) in the non-native flora. Mayorov et al. (2012) reported similar proportions for the alien flora of Moscow city and the Moscow region. It is likely, that the selection of growth forms and life history strategies of alien species is similarly throughout the temperate zone.

Species with different life history strategies exhibit different levels of ability to naturalize. Among annuals, we found 76 ephemerophytes, one kolonophyte and 11 epekophytes. Among biennials, there were 11 ephemerophytes, one kolonophyte and three epekophytes. Perennials were represented by 51 ephemerophytes, 24 kolonophytes and 16 epekophytes. Among species where their life span can vary between biennial or perennial, there are two ephemerophytes and one kolonophyte. Among those species,

which can be either annuals or biennials, there are seven ephemerophytes and two epekophytes. Among the plants, which can live 1 to 2 or several years, there are three ephemerophytes, two kolonophytes and one epekophyte. All shrubs (*Cytisus ruthenicus*, *Rosa glabrifolia*, *Rubus idaeus* and *Sorbaria sorbifolia*) we classified as kolonophytes. Distribution of the species with different degrees of naturalization among the groups with different life history strategies is shown on Fig. 3.

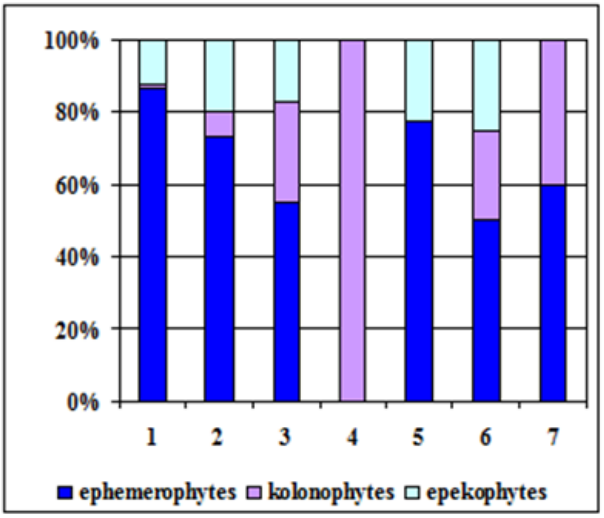

Figure 3. Distribution (%) of the species with different degree of naturalization among life history strategies in the alien flora of the YaNAA. 1 – annuals; 2 – biennials, 3 – perennials, 4 – shrubs, 5 – annuals/biennials, 6 – biennials/perennials, 7 – plants with life span that can vary from 1–2 to several years.

The proportion of ephemerophytes is the largest among annuals – 85.2%, decreasing among the plants with longer life spans. The reason is the inability of annuals and biennials to sustain vegetative reproduction, which decreases their chance to form autogenous populations in the environments of middle and northern taiga with severe continental climate.

Means of introduction

By means of introduction, xenophytes, i.e., unintentionally introduced species, absolutely prevail (177 species, 81.9% of non-indigenous flora). There are also several (15 species, 6.7%) ergasiophytes, i.e., species escaping from cultivation: *Artemisia dracunculus*, *Jacobaea vulgaris*, *Armoracia rusticana*, *Dianthus barbatus*, *D. chinensis*, *Gypsophila paniculata*, *Papaver somniferum*, *Primula elatior*, *Aquilegia atrata*, *A. vulgaris*, *Rubus idaeus*, *Sorbaria sorbifolia*, *Lolium arundinaceum*, *L. pratense* and *L. perenne*. There are few ergasiophytes because agriculture is poorly developed in this region. We referred 24 species to an intermediate group of xenoergasiophytes: *Coriandrum sativum*, *Cyanus segetum*, *Centaurea jacea*, *Brassica napus*, *B. nigra*, *Sinapis alba*, *S. arvensis*, *Cannabis sativa*, *Trifolium hybridum*, *T. pratense*, *T. repens*, *Lotus corniculatus*, *Medicago falcata*, *M. sativa*, *Rosa glabrifolia*, *Allium ampeloprasum*, *Avena sativa*, *Dactylis glomerata*, *Hordeum jubatum*, *H. vulgare*, *Lolium remotum*, *Phleum pratense*, *Poa angustifolia* and *P. compressa*.

A special group in the flora of the YaNAA is formed by species which distribution ranges lie within the territory of the YaNAA and “alien” they are only outside those ranges. These are the following species *Inula britannica* L., *Erysimum*

cheiranthoides L., *Erysimum odoratum* Ehrh., *Silene vulgaris* (Moench) Garcke, *Lathyrus pratensis* L., *Fragaria vesca* L., *Potentilla norvegica* L., *Galium verum* L., *Allium schoenoprasum* L., *A. strictum* Schrad., *Lemna trisulca* L., *Beckmannia eruciformis* (L.) Host, *Calamagrostis epigeios* (L.) Roth, *Phalaris arundinacea* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Poa annua* L. and *P. sublanata* Reverd. In the south and southeast of YaNAA, within the middle taiga subzone, in the Ob River valley, these species grow in the forest and meadow habitats. In the middle and northern part of the region, including peninsulas, they are anthropochores spreading via disturbed sites in settlements and along the roads. We did not include these species in the alien flora.

Conclusion

After appearing in new localities, alien species gradually adapt to their new environments. In the Western Siberian Arctic and Subarctic, it is still too early to speak about phytopollution and bioinvasions but the monitoring of alien species is a matter of necessity. In the Subarctic towns, there are certain positive effects of non-indigenous species in that they make the urban environment more diverse. Among introduced species, there are ornamental, medicinal, fodder plants and food plants. We did not observe spreading of alien species via slightly disturbed natural habitats comparable with such dissemination in more southerly regions. Regarding non-native species becoming detrimentally invasive, we feel that there is currently no imminent or significant threat.

Acknowledgements

The work was fulfilled within the frames of State tasks and research topics of the Institute Botanical Garden of the Ural Branch of the Russian Academy of Sciences; St. Petersburg State University; Komarov Botanical Institute of the Russian Academy of Sciences, Laboratory of Cartography and Geography of Plants (theme AAAA-A19-119030690002-5). Field surveys were conducted with support from the Department of Science and Innovation of the Yamal-Nenets Autonomous District (grant no. 01-15/4, 25.07.2012) and St. Petersburg State University (IAS_18.19.883.2017, Pure ID: 49037045).

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