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Salt marsh flora and vegetation of the Russian Arctic coasts

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Abstract

The flora of open coasts and the estuaries of rivers is an important element of the Arctic flora and represents the littoral halophytic floristic complex. The salt marsh flora includes 113 species of vascular plants (12% of the total amount of Arctic flora), belonging to 62 families. Due to geographical conditions, the partial floras of coastal wetlands of the Russian Arctic have similar taxonomic and typological structure. In the geographical structure of flora-coenotic complex, the Arctic circumpolar species dominate. The Arctic coastlines are subjected to frequent disturbances associated with frost action, storms and ice pressure ridges that affect species richness and the ability of human populations to exploit coastal resources successfully. The dynamic changes of salt-marsh plant communities are site-specific: 1) in the initial stages, vegetation development mostly depends on the physical-chemical substrate properties and tidal action, 2) the spatial-temporal processes of successional change over a long time result in the environment development and changes in edaphic conditions. The time scale of these changes brought about by disturbances is biologically important as there must be sufficient time to allow genetic adaptation in plant and animal populations.

Key words: Salt marsh plants, flora, vegetation

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Introduction

The length of the Arctic coast is about 50 000 km. The Arctic coast of Russia makes up half of this length and is divided into the Barents, the Kara, the Laptev, the East-Siberian, the Chuckchi, the Bering shelf sea, and the semi-landlocked one (the White Sea). All they belong to the Arctic Ocean. The distribution of plant coastal species differs in different parts of the Arctic zone. The coastal zone is an interface through which land-ocean exchanges in the Arctic are mediated. It is the site of most human settlements and activity in the Arctic. Arctic coasts are highly variable and their dynamics are a function of interactions between environmental forcing, coastal geology, biology, and human activity. The zone is extremely vulnerable to environmental change. The changes that occur recently, *i.e.* a decrease in the extent

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and thickness of sea ice, a rise in sea level, increased storm frequency, loss of biodiversity, and an increase in anthropogenic impacts, have already been predicted.

The coastal flora of open coasts and the estuaries of rivers is an important element of the Arctic flora and represents the littoral halophytic floristic complex (Sergienko 2008). Salt-marsh communities are sensitive to environmental change, including a rise in sea level and erosion from storm surges. Studies on the interactions between abiotic and biotic processes enable to determine recent state of coastal biogeocoenosis (development of the ecosystem) and make predictions of future changes. Ecological data of salt-marsh communities, including soil processes and anthropogenic use enable us to place the development of these coastal wetlands in an historical context including changes during the post-glacial period.

Material and Methods

The work was performed within a complex floristic, geobotanical studies and soils sampling (Galanin 1991). The collection of field data was held from 1972 to 2011. Personally, the author has investigated 36 partial local floras, on the shores of the White, the Barents, the East-Siberian, the Chukchi and the Bering Seas. In the herbarium materials [Herbarium of the Komarov Botanical Institute, Saint-Petersburg, Russia (LE), Herbarium of the Department of Botany and Plant Physiology of the Petrozavodsk State University (PTZ), Herbarium of the Botanical Museum of the University of Oslo (O), the National Herbarium of the Netherlands, Leiden (L)], all coastal species from the Russian Arctic have been checked up by the author. In this study, published data on the composition and structure of vegetation cover of the above mentioned seas, the Kara, and the Laptev seas were used. Descriptions of the plant communities were made within the limits of a natural contour of phytocoenosis (Galanin 1991). Non equal distance scale by B. M. Mirkin (Mirkin et al. 1989) has been used for the estimation of the projection cover of the plants.

Results

The total amount of Arctic species of higher plants was 1691, belonging to the 99 families and 435 genera (Sergienko 2008). The total amount of the Arctic coastal species was 113 species, belonging to the 32 families and 62 genera. Particular amount of the coastal species in the different Arctic regions was not more than 68 species on the White Sea coast, 72 species in the Bering sea, 47 species on the Barents sea, 37, 35 and 39 species were found on the shore of Kara, the Laptev and the East-Siberian seas coasts. On the Chukchi sea coasts, 57 species were found (*see* Fig. 1).

In the partial flora of all types of estuarine and coastal biotopes of the all Russian Arctic coasts (salt marshes on the river's estuaries, sandy and pebble beaches of the coasts), the number of the leading families consisted of *Poaceae* (26 species, accounting for 23.4% of the total number of species), *Cyperaceae* (17 species - 15.3%), *Asteraceae* (8 species - 7.2%), and *Chenopodiaceae* (7 species - 6.3%), *Caryophyllaceae* (6 species - 5.4%). Two families, *Brassicaceae*, *Apiaceae* had 4 species in their structure (3.6%); fam. *Juncaceae, Primulaceae, Rosaceae, Plantaginaceae* had only 3 species.

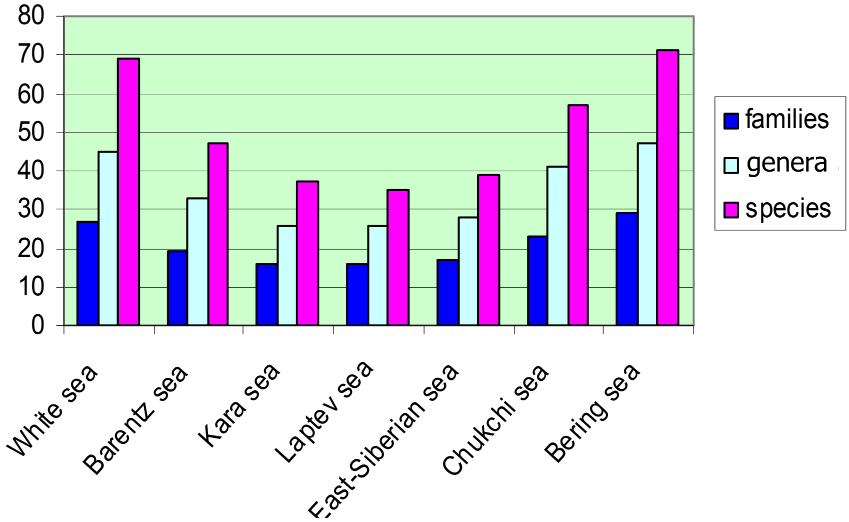

Fig. 1. Number of the coastal species in the Russian Arctic.

Species structure depended on the zonal region positions. Therefore, there was the absence of the species with plurizonal areas in the Barents, the Kara, the Laptev, the East-Siberian and the Chukchi Seas coasts. Proportions of latitudinal geographical elements in the salt floras of the Russian Arctic showed the absolute dominance of species with circumpolar range around the Arctic coast of Russia. The predominance of species with the boreal area of distribution was marked on the shores of the White, the Barents and the Bering Seas coasts.

The amount of the circumpolar species was almost the same in the Arctic zone. The only exception was the Lena region where it equaled to 15, due to the plain landscapes and recent deliverance from the ice cover. The species with the European ranges were spread only to the Taimyr Peninsula. Species with the Eurasian ranges were absent in the Kolyma regions. The absolute predominance of the Chukotian species was observed in the Far East regions of the Arctic zone.

On the Arctic coasts, the specific ecological conditions (tides, low temperatures and structure of the soil layer) determine the uniqueness of biological variety of salt marsh communities. The spatial heterogeneity on different level is the distinctive feature of the majority of salt march communities of the coasts of the Russian Arctic. A specific variety is limited by the species that have developed adaptive responses. However, their high specialization has increased the risk of their disappearance in case of loss of the coastal habitats. Relatively low taxon variety of plants, growing on the salt marshes in the conditions of high environmental variability and relative isolation, causes the formation of morphotypes in the majority of coastal species.

Development and formation of the salt marsh vegetation at the coasts of the Russian Arctic regions is caused by daily fluctuation of abiotic and biotic environmental factors associated with tidal dynamics. Primacy and stability of salt marsh communities is proved by a significant variation of dynamics of final stages at rather identical initial stages. Primary stages of overgrowing of muddy coasts are identical at all Arctic coast of Russia. The greatest distinctions are observed in final stages of overgrowing which depend on the longitudinal location of studied territories.

Dominant species of a vegetative cover are Arctic euhalophytes (*Puccinellia phryganodes, Carex subspathacea, Stellaria humifusa, Potentilla egedei*). On coasts, they are at the edge of their continuous natural habitats. However, they exhibit a change in their dynamic behavior. They have different succession status at the coasts of the Barents Sea, the White Sea, the East-Siberian and the Chukchi Seas. Only on the White Sea coasts, the European and Eurasian species 2 - *Bolboschoenus maritimus*, 3 - *Zostera marina*, 5 - *Eleocharis uniglumis*, 7 - *Triglochin maritima*, 8 - *Tripolium vulgare* play a significant role in the composition of vegetation cover altogether (*see* Fig. 2). The diversity of salt marsh plant communities of the White Sea coasts is sufficiently high. Altogether, 20 communities are widespread along the coasts. Communities with *Carex subspathacea* and *Carex ursina* mainly occur on the north. Communities with *Triglochin maritima*, *Tripolium vulgare*, and *Plantago maritima* are common for the west and east coasts of the White Sea. For the Barents Sea, coastal communities with dominance of *Puccinellia phryganodes*, *Carex subspathacea*, *Hippuris tetraphylla*, *Dupontia psilosantha*, *Calamagrostis deschampsioides*, *Plantago schrenkii* are common (*see* Fig. 3). Diversity of salt marsh communities of the Barents Sea coasts is lower than those of the communities with Arctic circumpolar species which play a leading role in the plant cover composition. On the East-Siberian coasts, the landscape structure of salt marsh communities is quite simple. Arctic circumpolar species such as *Carex subspathacea, Carex ursina* and *Puccinellia phryganodes* dominate the vegetation cover (*see* Fig. 4).

The primary stages of overgrowing on the coasts of the Chukchi Sea are the same as to all Arctic Seas. Only in the secondary marches in vegetation cover, the American species *Salix ovalifolia, Carex lyngbyei* and *Rhodiola integrifolia* dominate (*see* Fig. 5).

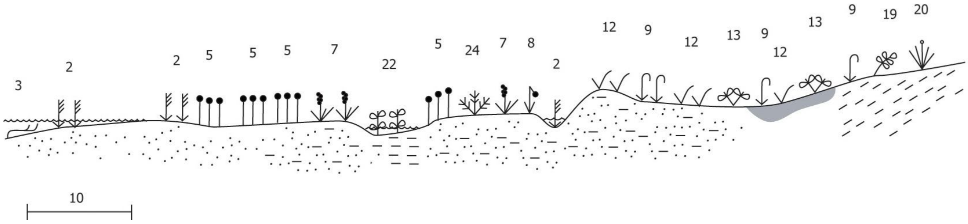

Fig. 2. Landscape structure of muddy region of Pomorsky and Karelian coasts of the White Sea
Species: 2 – *Bolboschoenus maritimus*, 3 – *Zostera marina*, 5 – *Eleocharis uniglumis*, 7 – *Triglochin maritima*, 8 – *Tripolium vulgare*, 9 – *Juncus gerardii*, 12 – *Carex subspathacea*, 13 – *Potentilla egedei* s.l., 19 – *Lathyrus japonicus* ssp. *pubescens*, 20 – *Phragmites australis*, 22 – *Hippuris tetraphylla*, 24 – *Stellaria humifusa*.

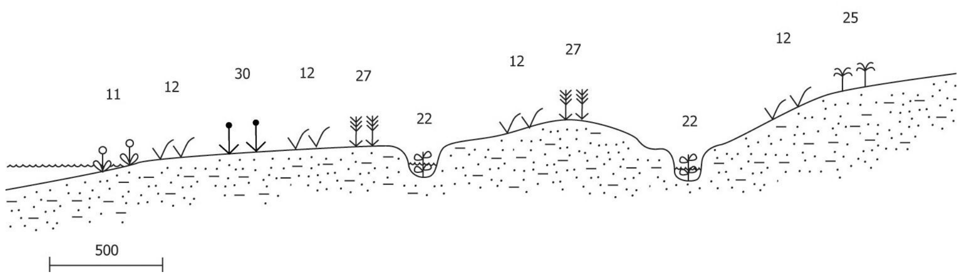

Fig. 3. Landscape structure of coastal wetlands of the Barents Sea
Species: 11 – *Puccinellia phryganodes*, 12 – *Carex subspathacea*, 22 – *Hippuris tetraphylla*, 25 –*Dupontia psilosantha*, 27 – *Calamagrostis deschampsioides*, 30 - *Plantago schrenkii*.

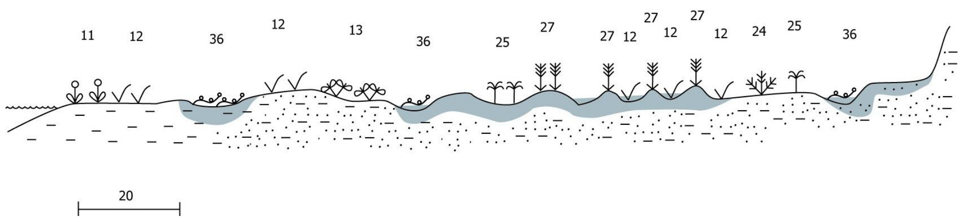

Fig. 4. Landscape structure of the muddy coasts' habitats of the East-Siberian Sea (estuarine zone of the Chukochja River)
Species: 11 – *Puccinellia phryganodes*, 12 – *Carex subspathacea*, 13 – *Potentilla egedei* s.l., 24 – *Stellaria humifusa*, 25 – *Dupontia psilosantha*, 27 – *Calamagrostis deschampsioides*, 36 – *Ranunculus tricrenatus*.

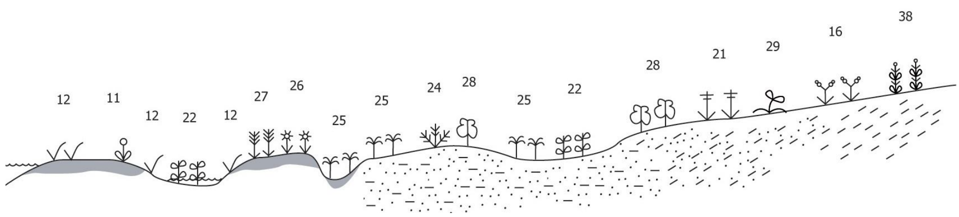

Fig. 5. Landscape structure of coastal wetlands of the Chuckchi Sea (northern coast)
Species: 11 - *Puccinellia phryganodes,* 12 - *Carex subspathacea,* 16 – *Leymus villosissimus,* 21 – *Festuca rubra,* 22 – *Hippuris tetraphylla,* 24 - *Stellaria humifusa,* 25 – *Dupontia psilosantha,* 26 – *Arctanthemum hultenii,* 27 – *Calamagrostis deshampsioides,* 28 – *Salix ovalifolia,* 29 – *Carex glareosa,* 38 – *Rhodiola integrifolia.*

Discussion

For full understanding of ecosystem structure and function, it is necessary to consider historical perspective that includes measurements of the changes in the magnitude of fluxes of physical and biological materials between neighbouring systems, (*e.g.* from river to estuary to shelf). The extent to which the movements have been influenced by humans (*e.g.* river discharge rates, flows of pollutants, invasive species) must be also taken into consideration. The Arctic coastlines are subjected to frequent disturbances associated with frost action, storm surges and an ice pressure ridges that affect species richness and the ability of human populations to exploit coastal resources. The time scale of these changes brought about by disturbances is biologically important as there must be sufficient time to allow for genetic adaptation in plant and animal populations. If the changes are too rapid (decades of years), a population may be unable to adjust to new conditions which may result in its loss and possibly deleterious changes in ecosystem functioning if the species (population) is a keystone species (Löve et Löve 1961).

Azonality is the main peculiarity of the halophytic floristic complexes of marshes wetland of the Russian Arctic coasts (Porsild 1964, Sergienko 2008). Wetland species are highly adaptable to varying climatic conditions (Rozema et al. 1985). Only few cosmopolitan circumpolar species such as *Carex subspathacea*, *Eleocharis uniglumis*, *Potentilla egedei*, *Stellaria humifusa* are the kernel and initial pathfinder of the communities. The changes in the biodiversity of the partial floras on the salt marsh wetlands are related to the historical development of the coenosis, geochemistry of landscape, climate, and, in the modern period, anthropogenous pollutions.

During the Quaternary Period, Beringia was strongly affected by fluctuations in sea level. When the land bridge existed between Chukotka, Alaska and the Canadian Pacific coast, floristic coastal complexes of plant species were present at the end of the last glaciations, but since then, the biodiversity has changed under a changing climate and a rising sea level (Handa et al. 2002). During the marine transgression of Beringia land mass, the coastal ecosystems were isolated and species diverged to give a rise to new species. The ecological and genetic processes that gave a rise formation to these closely related species in the coastal salt marshes of Beringia are mostly unknown and represent a major gap in our understanding of the origin of these species. In this region with the opening of the Bering Strait, seed transfer was made by both fresh-water streams and the sea. Therefore, the amphi-beringian species from the Pacific Ocean probably dispersed to the estuarine zone of northern-western part of America, and circumpolar species dispersed to southern-eastern Asian (Hulten 1964). The survival of populations of these new species depended not only on temperature and other climatic factors, but also on their growth and reproductive strategies (Chapman 1964).

From the time of the opening of Bering Strait, the refugia sites were occupied by the circumpolar floristic complex but Siberian river estuaries were still mostly ice-covered. However, some species migrated from these refugia to the warming Beringia region (Jefferies et al. 2006). Therefore, the biodiversity the Arctic coastal and salt-marsh communities is directly linked to the geological history of the Arctic. In the period of warming at the end of the last Glacial Period, circumpolar plant species became widely distributed over the continental shelf. The species were highly adaptable to varying climatic conditions. Other species probably migrated by the seed dispersed by coastal currents. However, the Taimyr Peninsula and Baffin Land served as barriers against the migration of amphi-atlantic species into the Beringia area. The rivers were also responsible for transfer of southern species into the Arctic ecosystems where, subsequently, genetic changes in populations occurred and lead to their adaptation to rigorous Arctic conditions. During the glaciations, river mouths served as refugia for plant coastal species. The opening of the Bering Strait caused the penetration of boreal Pacific species into the Arctic environment.

Recent species composition of salt-marsh communities of the Chukotka and Alaska Peninsulas reflects not only the migration of different species into the area during the post-glacial period when the Bering Strait was open. It is also a result of the migration of cold-tolerant and thermophilic plants during earlier periods. The salinity of the soil played a dominant role. The ecological amplitude of the species and their ability to compete with other species also played a role. With a loss of salt in older, upper salt marshes, sedges are replaced by grass species in plant communities. Micro-relief across the salt-marsh surface affects local edaphic conditions and species are spatially aggregated in relation to these differences in relief.

Closely-related coastal species growing in south-western Chukotka and along the Pacific coast of Canada are in general typical cold-tolerant Arctic plants that can tolerate changing climatic conditions. There were no ancient thermophilic species in the salt-marsh communities of the Arctic Ocean during the rigorous conditions of the Glacial Period. Sea coast plant communities were destroyed by the extreme climatic conditions. During that period, cold-adapted plant species survived in the estuarine regions of Arctic rivers, where physical conditions were ameliorated by the flow of warmer water from southern regions. The initial colonization by species of the salt-marsh sites along the Chukotka and Canadian coasts occurred after the opening of the Bering Strait, when conditions began to ameliorate. However, conditions on the Chukotka coast were still cold in contrast to the Canadian coast. Number of primary halophytic sea-shore species grew in these new habitats, plant succession, and changes in edaphic conditions resulted in the subsequent establishment of glycophytes. Immigrating species survived thanks only to the availability of suitable ecological niches on the coasts.

Regional geological history and local environmental impacts influenced the species composition of the salt-marsh communities (Moore et al., 1972). Well-adapted species survived in this hostile environment, such as alkaline soil, tidal inundation, short-growing season (Siira, 1987). The basic change of vegetative cover of salt marsh communities connected with the change of the Arctic Seas level and the geostatic rising of coasts is that the area of plant communities with dominance of boreal – European and boreal – Eurasian species on the marshes wetland of the Russian Arctic coasts constantly expands.

The obtained results have shown that the ancient coastal (arising on the Arctic coasts in the Pleistocene, and continuing to present day) circumpolar species *Puccinellia phryganodes, Carex subspathacea, Stellaria humifusa, Potentilla egedei)* play the main role in the formation of halophytic floristic complex. This is proved by the fact that the primary stages of overgrowing ecological time series are the same for the whole Arctic coast of Russia. Atlantic and Bering derivatives are widely represented in the European and Arctic Chukchi longitudinal sectors, but not in the Taimyr Peninsula and the Lena river delta. Similar relations are found in the variation of species richness, genera and families in the partial coastal floras of the Russian Arctic.

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