Salt marsh vegetation of the southern tundra subzone of Western Siberia: An example of the Baydaratskaya Bay coasts in the Kara Sea

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Abstract

The study is focused on the description of the vegetation and the general environment all characteristics of the salt marshes along coasts in the Baydaratskaya Bay there are of the Kara Sea in the southern tundra subzone of Russian Arctic. In tidal salt marsh habitats, several successional stages and types of communities depending on part of tidal zone. The plant communities study areas located close to research stations were represented by 50 species of vascular plant, 15 mosses and 3 lichens. The coastal vegetation tends to be floristically intermediate between the species composition of typical salt marshes communities (obligate and facultative halophytes) and species from adjacent tundra plains which can be able to tolerate occasional flooding by salt water. Zonation of salt marsh vegetation and floristic diversity were compared with the data for northern area of Kara Sea coasts.

Key words: salt marsh, species composition, succession, Baydaratskaya Bay, Russian Arctic

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Introduction

In the coastal zone of the Russian Arctic formed habitats (salt marsh on oozy drainage coasts and in the river estuaries) which overgrown by specific plant communities and characterized by unique structural-functional continuity. The leading factor in their formation is the daily fluctuation of the abiotic and biotic environmental factors associated with tidal dynamics (Sergienko 2012).

The vegetation of shoreline habitats was examined and systematically sampled along different parts of the Russian Arctic coasts (Sergienko 2008, 2011; Sergienko et Shreders 2009), but the data about species diversity and plant communities of the Baydaratskaya Bay coasts practically were not considered. A notable exception is the work of Rebristaya (1997) describing the floristic composition of the Kara Sea coasts in the northern subarctic and Arctic tundras of the Yamal and Gydan Peninsulas, but not considering the features of similar ecotopes in the southern sub-arctic tundra subzone.

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Material and Methods

The study was conducted in coastal marsh in southern subarctic tundra subzone on the North of Western Siberia along coasts of Baydaratskaya Bay of the Kara Sea. Salt marsh vegetation was investigated in five stations in estuarine areas of rivers and streams that flow into the Bay (Fig. 1). We chose sites representing a range from little or no plant cover to the sites with well-established plant cover.

In the studied estuaries on the Yamal Peninsula, an alternation of small plane parts of land with a large number of small round-oval shallow ponds containing salt and salty water was typical for secondary marches (Fig. 2). Vegetation is concentrated between the ponds and streams. It is composed mainly of specific halophytic grass species and belongs to the meadow vegetation type (Gorodkov 1935, Taylor 1981). However, in elevated sites with low levels of soil salinity to them mixed with tundra and wetland species with wide ecological amplitude. Low-lying sites of marshes are swampy, coasts of ponds and streams are often very boggy.

On the Urals coast of Baydaratskaya Bay the landscape of marshes is quite different. Ponds and lake have another form, not so numerous, and the width of the line of shoreline vegetation is much narrower.

Vegetation sampling was conducted during July and August, 2006-2009, using the sampling format by methods of ecological profiling and geobotanical description. At each station, five-ten 5 x 5 m plots were laid out perpendicular to the shoreline. Geobotanical descriptions were made in all visually allocated vegetation belts – successional stages of vegetation at altitudes 0-3 m above sea level. Each ecological profile was considered as an ecological-dynamical series of vegetation (Sergienko 2008).

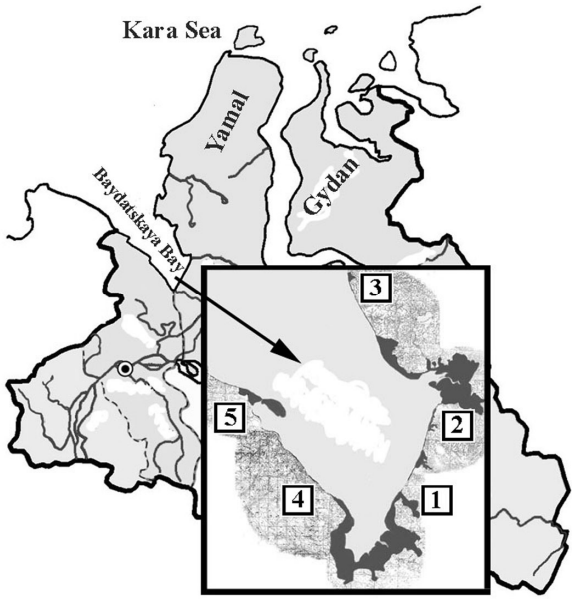

Fig. 1. Location of research stations along the coasts of the Baydaratskaya Bay of Kara Sea in Russian Arctic: 1. Erkuta-yakha River; 2. He-yakha River; 3. Yara-yakha River; 4. Ngoyu-yakha River; 5. Levdiev Island.

Results

Salt marshes vegetation successions

Formation of salt marshes vegetation from the sea surf begins slowly, without typical vegetation communities on the sandy beach. There are some individuals of halophyte plant species that can form sparse groups from one- or a few species. Apart from the surf species, composition and structure of these vegetation groups is complicated. On the sector from the sandy beach to the typical tidal salt marshes, located in 50-250 m from the sea line, visual become differentiated several intergrading plant communities (successional stages) with width from 2 to 10 m. The typical vegetation changes or vegetation zone in relief were characterized in the estuary of the Yara-yha River on the Yamal peninsula:

1) The low sandy shoreline is usually devoid of vegetation, although it can grow single plants and small patches of *Puccinellia phryganodes* and *Honkenia peploides*. Less usual *Tripleurospermum hookeri*.

2) Sparse plant groups on the slope of sandbar facing to the sea. Typical sparse monospecific plant groups of *Honkenia peploides*. The width of this zone is 2-4 m and percent cover in community about 10-20%. Patulent rosettes of *Honkenia* often covered with a thin layer of sand. Additionally low shrubs of *Salix reptans* can be found sporadically.

3) Sparse plant groups (*Festuca cryophila / Honkenia peploides*) on sandbar. Vegetation of this community formed a sparse mat with coverage averaging 30%. *Honkenia peploides* is dominant species. *Festuca cryophila, Dupontia psilosantha, Rumex graminifolius* are associate with coverage about 5%. *Stellaria humifusa*, *Tripleurospermum hookeri, Armeria maritima, Cerastium* and ponds. Herb species (*Potentilla egedii, Rhodiola arctica, Arctanthemum arcticum, arvense, Salix reptans* are present sporadically and diffusely.

4) Sedges-grass plant groups (*Festuca cryophila / Carex mackenziei*) on the slope of sandbar facing from the sea with projective coverage about 40% and provides by high abundance of *Festuca cryophila* (30%). *Carex mackenziei* and *Calamagrostis deschampsioides* are the principle codominant species with coverage 5%; *Deschampsia borealis, Pedicularis sudetica* s.l., *Salix reptans, Arctanthemum arcticum, Rumex graminifolius, R. aureostigmaticus, Armeria maritima, Tanacetum bipinnatum* are the constant species. *Polytrichum* mosses are conspicuous element of the community.

5) Sedge-grass-shrub communities (*Carex / Festuca cryophila / Salix reptans*) are common for the bottom of sandbar. Visually different from the previous zone by high abundance of *Salix reptans* and in increase of total projective coverage to 50-60%. On moist depressed areas appeared such species as *Carex rariflora, C. subspathacea, C. ursina*.

6) Typical halophytic marshes between the numerous ponds, lakes and streams and is best developed in lagoons and estuary with gently sloping shorelines. They are characterized by high cover (an average 90-100 %) at the height of the grasses about 8-10 cm. The stands of *Salix reptans* with coverage ranging from 20% to 30% and height up to 15 cm are clearly visible among grasses by grey colour. Such species as *Carex subspathacea*, *C. mackenziei, C. ursina, C. rariflora, C. concolor, Calamagrostis deschampsioides* and *Dupontia psilosantha* are dominant and constant. The thin mat from *Puccinellia phryganodes* have covered everywhere the dried-up shores of streams *Stellaria humifusa, Cochlearia groenlandica* et al.) are found singly or scat-

tered, but can form sporadically cover up to 15-20%. *Plantago schrenkii* can be found in these communities very at the foot of the hills and outliers of marine terraces very rarely with percent cover about 1-5%.

In the coastal area of the deep and on the bottom of shallow ponds, there monospecific community of *Hippuris tetraphylla* is found. In shallow ponds, are formed large clones from *Ranunculus tricrenatus*.

In different parts of typical salt marshes, the ratio between dominant species varies with moisture and soil salinity. With increasing elevation in local relief on 30-40 cm the salt marshes vegetation have changes on zonal tundra vegetation – grass-moss tundras and grass-sphagnum bogs. Dominant status gain to species of zonal type of tundra: *Eriophorum polystachion, E. scheuchzeri, E russeolum, E. vaginatum, Poa arctica* et al. Solitary these species come in halophytic communities that adjacent to such elevation of relief.

On the Urals coast of Baydaratskaya Bay, salt marshes formed in the same way. However, in the mouths of small rivers and streams, where we spend our research, the profile from the line of surf up to typical salt marshes communities is much shorter. Only four successional stages can be allocated there. Plant groups and salt marshes communities are formed by the same species of plants as on the coasts of Yamal Peninsula. The features in structure of salt marshes relate primarily to the relief of the marine coasts: the sandbar did not formed and plane sandy beach beginnings by ledge, which rise above the surf level at low tide on 1 m. The pioneers in regrowth of shoreline are the same species *Honkenia peploides* and *Puccinellia phryganodes*. In the belt from sand costal ledge up to 20 meters, these species can be found rarely and other vegetation is absent.

The first belt of vegetation from the edge of the coastal ledge is represented by **primary grass-sedge groups** with a relatively high level of percent cover (50%). *Puccinellia phryganodes* is the dominant species (20-30%). *Carex subspathacea* and *Dupontia psilosantha* are codominants and their coverage may reach 15%. *Calamagrostis deschampsioides, Rhodiola arctica, Arctanthemum arcticum, Stellaria humifusa, Cochlearia groenlandica* cover is about 1%. The belt width ranges from 2 up 10 meters. This plant group is changed with increasing complexity of phytocoenoses.

Cotton-sedge-grass community with willow is formed at the next stage of ecological-dynamical series of vegetation. It is characterized by joint growth of typical plant from salt marshes and zonal types of tundras and bogs. The cover is about 80-90%. In the structure of community with constant coverage of *Dupontia psilosantha*, an increase in the cover of *Calamagrostis deschampsioides* up to 30% and decrease in the coverage of *Carex subspathacea* down to 5% could be found. The tundra species are registered in the community as codominant (*Eriophorum polystachion, Carex rariflora, Salix reptans* with percent cover about 15%) and uncommon species (*Eriophorum russeolum, E. scheuchzeri* with percent cover less than 1%). On depressed areas, the abundance of *Carex mackenziei* is higher, and cover moss is increased up to 50%.

At the estuary of a large river, where the low-lying seashores are more pronounced and occupy wider lagoons, not only the belts, but the zones of regrowth can be found. For example in the estuary of the Erkuta-Yakha River on western coast of Baydaratskaya Bay, the following zones can be distinguished on shoreline:

1) Sand beach with width of about 100-150 meters for with large deposits of silt. Vegetation is absent, only rare shoots of *Puccinellia phryganodes* can be found.

2) In the second zone, (width raging from 50 to 100 m) plant communities form spots of different diameters (*Puccinellia phryganodes* with coverage ranging from 20 to 40%).

3) In the third zone, (width about 300-400 m), vegetation are formed by *Puccinellia phryganodes* and *Carex subspathacea* with relative cover of about 70-100%. On the banks of streams and more drained sites, spots of *Cerastium arvense* grow. This zone differs from typical salt marshes by the absence of mosses and *Salix reptans*.

4) Zone of typical salt marshes. On the soil surface there are well developed carpets of mosses (*Polytrichum alpinum* var. *fragile*, *P. jensenii, Sanionia uncinata* et al.). *Puccinellia phryganodes* and *Carex subspathacea* are dominant, but *Calamagrostis deschampsioides* and *Dupontia fischeri* have also high prominence value high prominence value has also. With the average cover about 5% can be found *Empetrum subholarcticum*. Occasionally in the salt marshes composition *Plantago schrenkii* invaded suitable areas.

The transition from the communities of salt marshes to zonal vegetation was investigated in the estuary of the Yara-yakha River on Yamal peninsula. Successional changes occur through the formation of several belts which are characterized by the specific composition of species. Communities among themselves qualitatively and quantitatively are separated by a predominance of one or another species of herbs. Six different belts are distinguished on the slope from the foot up to top of outcrop of marine terrace on the profile about 30-35 meters in length:

1) *Carex subspathacea* + *Stellaria humifusa* + *Plantago schrenkii* + *Calamagrostis deschampsioides* salt marsh community;
2) *Carex subspathacea* + *Potentilla egedii* + *Calamagrostis deschampsioides* community;
3) *Carex subspathacea* + *C. mackenziei* + *Rhodiola arctica* + *Potentilla egedii* + *Stellaria humifusa* community;
4) *Plantago schrenkii* + *Puccinellia phryganodes* community;
5) *Honckenia peploides* + *Plantago schrenkii* sparse community;
6) Grass-dwarf shrub-lichen-moss tundra, which different from zonal type of tundra only by presence of halophyte species *Plantago schrenkii.* The constant species are *Empetrum subholarcticum* and *Festuca cryophila* with percent cover about 20%, *Salix nummularia*, *Deschampsia borealis*, *Plantago schrenkii*, *Rumex graminifolius, Armeria maritima,* which abundance did not exceed 1-5%.
7) Dwarf shrub- lichen-moss polygonal tundra with soil deflation on the top of outcrop of marine terrace.

Salt marshes species diversity

Species diversity in the localities close to research stations (*see* Fig. 1 and Appendix) is ranging from 17 to 35 species of vascular plants on individual site. Maximum species number in salt marshes communities can be found from the middle July to the third decade of August. Species diversity of halophytic meadows was significantly higher on sandy soils than on dirty sand and clay

loam. On silty lowlands of sea coasts, many common species of salt marshes are not found.

In total, 50 species of vascular plants belonging to 30 genera and 18 families (without species from typical zonal tundra's, Table 1; Appendix) were found in the localities of all stations along a shoreline of the Baydaratskaya Bay. In species list of salt marshes flora of the Baydaratskaya Bay coast, the share of obligate and facultative halophyte consists of only 46%. However, in tundra species dominated those that are resistant to the conditions of soil salinity. In composition of salt marshe communities, also 15 species of mosses and 3 taxons of lichens were revealed. The mosses and lichens are not halotorerant. They are sporadically found in the typical marsh zone on the highest parts of microrelief.

Family	Number of genera	Number of species
Poaceae	8	13
Cyperaceae	2	9
Caryophyllaceae	3	4
Asteraceae	3	3
Polygonaceae	1	3
Salicaceae	1	2
Ranunculaceae	1	2
Juncaceae	1	2
Juncaginaceae	1	2
Scrophulariaceae	1	2
Brassicaceae	1	2
Other family	7	7
Total:	30	51

Table 1. Taxonomic structure of vascular plants of salt marsh vegetation on Baydaratskaya Bay coasts

Number of	Southern Subarctic Tundra	Northern Subarctic and Arctic Tundra	Number of common units
	Yamal Peninsula	Yamal and Gydan Peninsulas	
	The data of authors	Rebristaya, O.V. (1997)	
Family	18	18	9
Genera	30	37	19
Species	51	57	32

Table 2. Systematic structure of salt marsh floristic composition in subzonal aspect

Fig. 2. ➞ General view of typical salt marshes habitats on the Baydaratskaya Bay coasts:
A – Photo of salt marshes in Erkuta-yakha river estuary in early summer (the end of June); B – Photo of salt marshes in He-yakha river estuary (August); C – View on shoreline vegetation from helicopter in in Erkuta-yakha river estuary.


A
B
C

Discussion

In this study, peculiarities of ecological-functional series of shoreline vegetation in different parts of Russian Arctic were studied. They fit to the results of earlier studies Sergienko (2008, 2012). The results of our studies of salt marsh vegetation in southern subarctic tundra of the Western Siberia are comparable and supplemented all data about flora and vegetation of Russian Arctic. Low species diversity, the presence of specific floristic complex, and typical zonation of marshes vegetation are reflected in general similarity of environmental conditions of shoreline vegetation of the Western Siberia with other costal regions of the Arctic.

For a detailed comparison of salt marsh vegetation of the Baydaratskaya Bay southern coasts, only the nearest Arctic regions in the Northern Subarctic and Arctic Tundras on the Yamal and Gydan peninsulas were chosen. According to Rebristaya (1997), vegetation of the sea cost habitats formes same zones, the number of which varies from 1 to 5, with the distance from the line of surf. Moreover, the area of coastal vegetation is limited by the upper storm line which is marked by the presence of driftwood. In our southern stations (investigated locations) included in this study, the line with driftwoods is absent on all five profiles.

Comparison of salt marsh species composition in two subarctic subzones along the coasts of the Baydaratskaya Bay and the Kara Sea revealed the similarity of their systematic structure and the close floristic diversity (Table 2). However, it also revealed a significant difference in composition of particular floras. A number of common species is about 62% of total salt marshes species diversity in the Southern Subarctic tundra subzone and 56% of floristic diversity of halophyte flora in the Northern subarctic and Arctic tundra's subzones.

For the same numbers of families in the comparable lists of species only nine are general. In the Northern Subarctic and Arctic areas on the Yamal and the Gydan Peninsulas, the species from five families (*Limoniaceae, Plantaginaceae, Empetraceae, Parnassiaceae, Rosaceae*) was not present at both peninsulas. In the Southern Subarctic tundra subzone, species from four family were absent (*Polemoniaceae, Equisetaceae, Saxifragaceae, Portulacaceae*).

The intertidal-halophytic floristic complex of the Baydaratskaya Bay coast was formed up by the same species of obligate halophytes as in subzones of the Northern Subarctic and Arctic tundra: *Puccinella phryganodes, Honckenia peploides, Carex subspathacea, C. ursina, Stellaria humifusa, Calamagrostis deschampsioides, Hippuris tetraphylla, Arctanthemum arcticum* ssp. *polare, Ranunculus tricrenatus, Triglochin maritimum, T. palustre*. In Southern Subarctic coasts, we can not find only *Carex minuscula*. However, the coastal vegetation as a whole tends to be floristically intermediate between the species composition of typical salt marshes communities and adjacent tundra plains.

The most significant differences in the floristic lists are related to the distribution of species in the zones along shoreline vegetation and its frequency in investtigated stations (locations). It was shown for the northern subarctic tundra that *Honckenia peploides* grows only behind the tidal zone (Rebristaya 1997). In southern subarctic tundra, however, the species occurs only in the first zone of salt marsh vegetation and can be considered as pioneer species on sand beach and soils. *Arctanthemum arcticum* ssp. *polare* is more widespread in the southern subarctic

tundra subzone than in the northern subarctic tundra. In all researched stations (locations), its relative cover in salt marsh communities varied from 1 to 10%. *Rhodiola arctica* Boriss. (= *R. rosea* L. by O.V. Rebristaya (1997)) is typical for the salt marshes vegetation in the southern subarctic tundra subzone. Its relative cover in communities is ranging from 1-5 up to 20%.

Concluding Remarks

In the shoreline vegetation of the Baydaratskaya Bay coasts, three obligate halophyte: amphioceanic species *Potentilla egedii* Wormsk., europian species *Plantago schrenkii* C. Koch. (= *Plantago maritima* subsp. *borealis* (Lange) Blytt et Dahl) and Atlantic species *Triglochin palustre* L. were found for the first time. These floristic additions suggest similarity of salt marshes species composition of the Western Siberian Arctic to the floristic composition of the European Arctic and the Chukchi Peninsula. On the one hand, the analysis of species diversity and community's distribution along intertidal habitats showed the similarity of ecotopes of shoreline lowlands in subarctic and arctic tundra zones, but reflected the subzonal features of plant coastal habitats. Obviously, many species of salt marshes vegetation increase their abundance in the geographic gradient from north to south. In southern locations, also their frequencies and abundance are higher and more apparent than in northern areas. They grow in the earlier successional stage.

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Appendix

Taxons	Northern subarctic and arctic tundra	Southern subarctic tundra			
		Stations of authors			
	by O.V. Rebristaya (1997)	Eyrkuta-yakha	Heyakha	Yara-yakha	Ngoyu-yakha and Levdiev Island
Poaceae					
Arctophila fulva (Trin.) Anderss.	+		+		+
Calamagrostis deschampsioides Trin.	+	+	+	+	+
Calamagrostis holmii Lange.			+	+	+
Calamagrostis lapponica (Wahlenb.) C. Hartm.					+
Deschampsia borealis (Trautv.) Roshev.	+			+	
Deschampsia glauca C. Hartm.					+
Dupontia fischeri R. Br.	+	+		+	
Dupontia psilosantha Rupr.	+	+	+	+	+
Festuca rubra L.	+				+
Festuca cryophila V. Kruz. et Bobr.				+	+
Poa alpigena (Blytt) Lindm	+				+
Poa arctica R. Br.	+				+
Puccinellia phryganodes (Trin.) Scribn. et Merr.	+	+	+	+	+
Cyperaceae					
Carex glareosa Wahlenb.	+			+	+
Carex mackenziei V. Krecz.			+	+	+
Carex rariflora (Wahleb.) Smith.		+	+	+	+
Carex concolor R. Br.	+	+			+
Carex subspathacea Wormsk. ex Hornem.	+	+	+	+	+
Carex ursina Dew.	+		+	+	+
Eriophorum vaginatum L.			+		
Eriophorum polystachion L.			+		+
Eriophorum scheuchzeri Hoppe.	+			+	+
Salicaceae					
Salix lapponum L.					
Salix reptans Rupr.	+		+	+	+
Polyganaceae					
Rumex arcticus L.					+
Rumex graminifolia Lamb.			+	+	+
Rumex aureostigmaticus Kom.				+	
Caryophyllaceae					
Cerastium arvense L.				+	
Cerastium holosteoides Fries			+	+	
Honkenia peploides (L.) Ehrh. subsp. *diffusa* (Hornem.) Hult.	+	+		+	+
Stellaria humifusa Rottb.	+	+	+	+	+

Asteraceae					
Arctanthemum arcticum ssp. *polare* (Hult.) Tzvel.	+	+	+	+	+
Tanacetum bipinnatum (L.) Sch. Bip.				+	
Tripleurospermum hookeri Sch. Bip.	+			+	
Ranunculaceae					
Ranunculus gmelinii DC.	+				+
Ranunculus tricrenatus (Rupr.) Jurtz. et Petrovsky.	+		+	+	+
Juncaceae					
Luzula parviflora (Ehrh.) Desv.					+
Luzula wahlenbergii Rupr.			+		
Scrophulariaceae					
Pedicularis oederii Vahl.			+	+	
Pedicularis sudetica Willd. s.l.				+	
Limoniaceae					
Armeria maritima (Mill.) Willd. s.l.				+	
Brassicaceae					
Cochlearia groenlandica L.		+		+	+
Cochlearia arctica Schlecht. ex DC. s.l.	+		+		
Empetraceae					
Empetrum subholarcticum V. Vassil.		+			
Hippuridaceae					
Hippuris tetraphylla L. fil.	+	+	+	+	+
Juncaginaceae					
Triglochin maritimum L.	+		+		
Triglochin palustre L.			+		
Crassulaceae					
Rhodiola arctica Boriss.	+	+	+	+	+
Plantaginaceae					
Plantago schrenkii C. Koch.		+		+	
Rosaceae					
Potentilla egedii Wormsk.			+	+	

Table 3. Distribution of vascular plant species on salt marshes along the coasts of Kara Sea.