Littoral vegetation of estuarine rivers of the southern part of Vaygach Island and the Yugorsky Peninsula

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Abstract

The saline tidal estuaries of two small rivers of Vaygach Island, the Krasnaya and the Varkulyakha, and one in the area adjacent to the Yugorsky Peninsula, the Nikolskaya River, contribute to the occurrence of salt marshes that are home to halophytic vegetation. In terms of marine exposure, the studied area comprises three types of habitats – low marshes, middle marshes and high marshes, each with a specific composition and structure of the vegetation cover. Along with salt marshes, the study has identified more habitats of smaller area and with specific vegetation, among them lowland wetlands in marsh-tundra ecotones, pebble-sand beaches, rubble beaches, salt lakes, and microdepressions. The marshes of Vaygach Island are classified Vaygachas Arctic type, as evidenced by the presence of halophytic communities dominated by Arctic and hypoarctic species, represented by three associations: *Caricetum subspathaceae herbosum, Caricetum glareosae potentillosum egedae* and *Caricetum glareosae arctantemosum polarae*. In our study, the estuarine vegetation has been discovered to comprise a fourth association, *Plantaginetum schrenkii*. Using the metric scaling method, we provided evidence that the studied estuaries support different vegetation types. While the communities of Vaygach Krasnaya and Varkulyakha estuaries tend to be similar in species composition and structure, the vegetation of the Nikolskaya River estuary appears to be markedly different. The differences relate mostly to the geomorphology of the three estuaries, consisting mainly in the fact that the Vaygach estuarine marshes occupy much larger areas compared to the tidal flats available to halophytic vegetation in the Nikolskaya estuary. The paper proposes a classification of the estuarine vegetation based on ecological and phytocenotic descriptions. Abandoned mines located at the mouth of the Krasnaya River, where polymetallic ores were previously mined, are unlikely to influence the composition and structure of halophytic vegetation. A variety of phytocenoses have formed in this area, as in the mouth of the Varkul'yakha River, where no mining activity has occured.

DOI: 10.5817/CPR2025-1-4

Received December 23, 2024, *accepted* April 30, 2025.
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Acknowledgements: The work of D.S. Moseev and I.V. Miskevich at the mouths of the Krasnaya and Varkulyakha rivers on Vaigach Island was carried out with the support of the Russian Fundamental Research grant No. 23-27-00225. The works of D.S. Moseev and I.V. Miskevich at the mouth of the Nikolskaya River were carried out on the topic of state assignment No. FMWE-2021-0006. The work E. Churakova was carried out within the framework of the state task (125021902594-4). The authors would like to express their special gratitude to Alexander E. Yakovlev, Chief Researcher at the Russian Academy of Sciences' P.P. Shirshov Institute of Oceanology – Northwest Branch for his assistance and contribution to organizing field expeditions.

Key words: Barents Sea, Yugorsky-Shar Strait, tidal estuaries, marshes, estuarine vegetation

Introduction

The Yugorsky Shar, a narrow strait 1.5 to 4 km wide and 24 km long, connects the Barents and Kara seas, separating Vaygach Island from the Yugorsky Peninsula. Within the tidal estuaries of small rivers (*Note:* A small river is a watercourse with a basin area of up to 2,000 km^2 or with an average flow rate at the mouth of the river of up to a few tens of m^3/sec, Reimers 1990) flowing into the strait and the lagoons adjacent to the Barents Sea, where the land meets the sea, cenoses of halophytic vegetation form. Halophytic vegetation is primarily found in salt marshes and narrow tidal flats. A salt marsh is defined as a low-lying accumulative coast formed by suspended solids brought to the foreshore by tides and wind-induced surges, inhabited by hygrophilous, salt-tolerant or halophytic vegetation (Leont'ev et al. 1975, Sergienko 2008). Saltmarshes are considered an intrazonal biocenosis type and are home to halophytes, waterfowl, semiaquatic birds, invertebrates (predominantly soil species), and microorganisms (Adam 1990, Bakker 2014). According to Odum (1966), saltmarshes are a type of marine ecosystem. The halophytic vegetation of the Yugorsky Shar Strait has never been the object of a dedicated study. Previously, the species of halophytes were mentioned merely in connection with vascular plant records from Vaygach Island (Kuliev 2007, Lavrinenko et al. 2016b, Morozov and Kuliev 1994). As inhabitants of the entire SE Barents coast, halophytes have been recorded in many studies (Matveeva and Lavrinenko 2011, Lavrinenko et al. 2012, Lavrinenko and Lavrinenko 2018, Moseev and Sergienko 2020, Moseev et al. 2022a, b). Compared to other regions within the Barents Sea, such as the Pechora Bay, the Cheshskaya Bay and the Indiga estuary, the saltmarshes of the estuarine zones of Vaygach Island and within the Kara Sea near the Yugorsky Peninsula occupy a relatively small area. This is due to the lower tidal range, which averages here between 0.3 and 0.5 m (Miskevich et al. 2024b), and the geomorphology of the estuaries. The small halophyte communities occur on sand-and-pebble beaches, a type of accumulative coasts distinctive to the Yugorsky-Shar coast.

As early as the 1930s, polymetallic ores were mined near the mouth of the Krasnaya River. Currently, the mine is abandoned (Miskevich et al. 2024a). However, ore dumps may still impact the environment (Miskevich et al. 2024b). Therefore, studies of phytocenoses in estuaries are important for assessing the ecological condition of Vaygach Island estuarine ecosystems.

This paper aims to investigate local vegetation and habitats as well as provide a classification of the halophyte vegetation occurring in small estuaries of the Yugorsky-Shar Strait and to explore its communities across salinity gradient.

Material and Methods

Field work was conducted in late July to early August 2023 and covered the estuarine zones of the Krasnaya and Varkulyakha rivers at the southern sector of Vaygach Island, and the Nikolskaya River estuary in the Yugorsky Peninsula (Fig. 1).

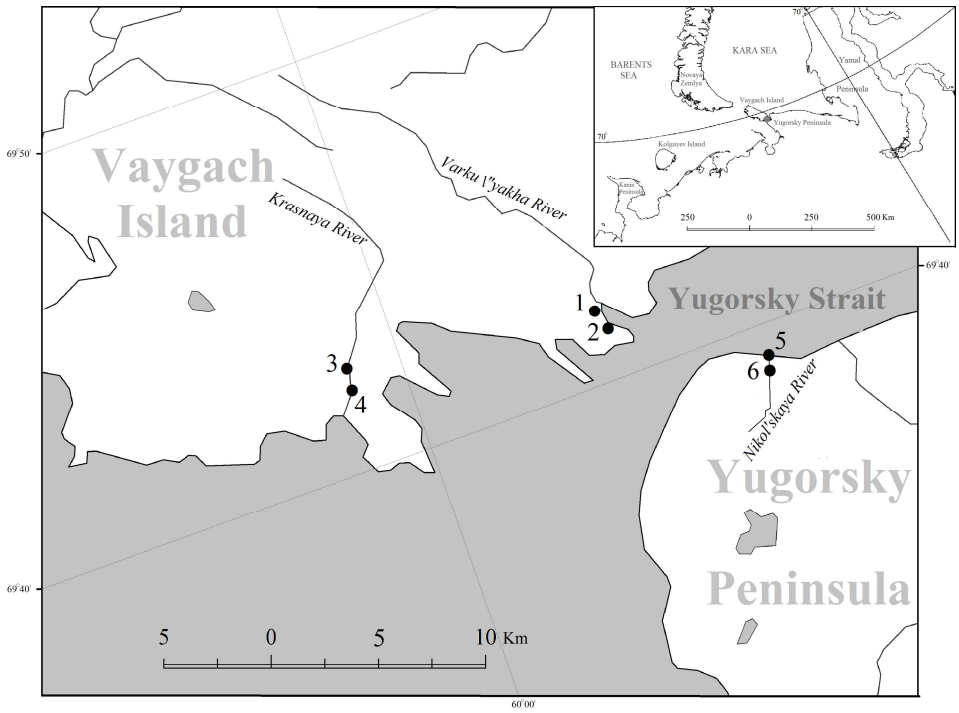

Fig. 1. Map-scheme of the study area: 1,2 – mouth of the Varkul'yakha River; 3,4 – mouth of the Krasnaya River; 5,6 – mouth of the Nikolskaya River.

The Krasnaya River is a 23 km long lowland river. Flowing from north to south, it falls into a small bay on the Yugorsky-Shar western border on the main water area of the Barents Sea. The Krasnaya estuary classifies as a lagoon-type estuary and is composed of the approximately 1 km long outfall offshore; 1.6 km long and 0.7-1 km wide lagoon; 1 km long, funnel-shaped tidal mouth; and 0.8 km long sea reach. The Varkulyakha River has a length of 25 km and flows from north to south, falling into the Yugorsky-Shar Strait. Its estuary represents a deltaic lagoon composed by the ~1 km long tidal mouth; about 0.6 km long and 0.3–0.5 km wide lagoon; 1.5 km long, poorly braided delta; and ~1.4 km long sea reach. The Nikolskaya River is 10 km long, flowing from south to north into the Yugorsky-Shar Strait. Its estuarine part has a length of ~5 km and includes the 1.5 km long funnel-shaped tidal mouth at confluence to the sea, and the sea reach with a length of 3.5 km. The estuaries of these three rivers experience a tidal range of 0.3–0.5 m (Miskevich at al. 2024b). Salt marshes can be found on all the estuarine shores, and their lagoons are rounded by sandbars at the confluence with the sea.

The Yugorsky Shar coast is known as having a severe climate. Winters are long and cold, lasting 7 to 8 months. Spring begins in early or mid-May and continues until August, followed by the autumn rains from August to September. According to the Amderma weather station, situated ~40 km from Vaygach Island in the subzone of the northern hypoarctic tundra Vaygach (WMO ID number 23022, 69.76°N, 61.66°E), the average January temperature is –17.3°C, with February being the cold-

est month (–17.7°C). The warmest month is July, with an average temperature of +8.0°C. Snow cover persists from October to late June. The prevalent wind direction is from north to south and southwest in winter, and from south to north in summer[1]. Ice begins to form in the Yugorsky-Shar Strait in November and breaks up in early July.

For the purposes of geobotanical descriptions (a total of 126), performed in July-August 2023, a set of 2×2 m^2 sample plots was established within communities with homogeneous growth conditions. Each sample plot was studied for species composition; general projective cover (GPC); species-specific projective cover (SSPC); tier arrangement (tier height and position in phytocenosis); meso-, micro- and nanorelief; soil texture; and tidal influence (water level and timing). The vegetation classification is based on the ecological-phytocenotic approach (Neshataev 2001). The descriptions operate at two syntaxonomic ranks: 1) formation, identified based on edificator species; and 2) association, identified by dominant species of the upper and lower tiers, defined as 'category-diagnosing species' (Moseev et al. 2022a). Where a community clearly had one dominant species (monodominant community), the association would be named according to such a dominant, considered as a diagnostic species. To differentiate plant communities by habitats, the classification considered the following habitat types: beaches, salty and brackish marshes, salt lagoon lakes within marshes, narrow rubble-clay tidal flats, marsh, and high marsh ecotones. Low level salt marshes are flooded twice daily and correspond to the middle horizon of the littoral zone. Mid-level salt marshes occupy the tidal shore between the middle and upper littoral zone boundaries. Upper level brackish marshes are affected only by storm surges (Belikov et al. 2011, Moseev et al. 2022a). All geobotanical descriptions were georeferenced using a Garmin GPSmap 62S navigator.

To assess the effect of tides on vegetation, one hydrologic-hydrochemical observation station was installed at each estuary. During a tidal cycle (12 hours), measurements were taken every two hours, including tidal height and salinity. Salinity was also measured along the estuaries at high tide and in salt lakes forming part of the marshes. Salinity was measured using the *Multi 3420* multiparameter analyzer. Tidal heights were measured using hydrometric rails with reference to a designated zero level.

The compositional analysis of vascular plant and moss species involved a series of variance matrix calculations using Euclidean distance. The ordination of the obtained geobotanical descriptions used nonmetric multidimensional scaling (Grohlina and Hanina 2015). We used R Core Team 2019 for calculations and ggplot2 (Wickham 2016) for data visualization.

The taxonomic rank names used in is paper are according to S. K. Cherepanov's checklist (Cherepanov 1995).

Taxonomic names of vascular plants are given in accordance with the systematic summary of S.K. Cherepanov (1995). Species names of mosses are given according to the list of Eastern Europe and Northern Asia (Ignatov et al. 2006), names of algae taking into account modern ideas about the systematics of microalgae AlgaeBase[2].

Results

According to Chapman's (Chapman 1977) classification of marshes, which is based on geographical criterion, the salt marshes of Vaygach Island can be classified as Arctic type. The communities of the identified associations have been found to occur in the

following habitats: 1 – beaches; 2 – low level salt marshes; 3 – middle level salt marshes; 4 – high-level brackish marshes; 5 – salt lakes and microdepressions within marshes; 6 – low-lying wetland vegetation in marsh-tundra ecotones; 7 – clay wind-driven in estuaries.

1. Beaches

A species dominant on the beach ridges is seaside sandwort *Honckenya peploides.* The communities dominated grass *Leymus arenarius* are rare.

***Honckenyeta peploidis*,** formation
This formation is composed by one association, *Honckenyetum peploidis*, involving the succulent seaside sandwort *Honckenya peploides* of the circumpolar Arctic distribution. The monodominant communities of the formation occur on the SE coast of the Barents Sea, superseding the formation *Leymeta arenarii* with *Leymus arenarius* as a dominant species on the beaches of the Arctic islands in the Barents Sea (Moseev et al. 2024).

***Honckenyetum peploidis*,** association
Composition and structure: The association includes pioneer communities of beach halophytic vegetation, consisting of a single species, *Honckenya peploides*. It forms clumps of 40-50 cm in diameter, which can be noticed from a great distance due to their light green color.
Ecology and distribution: The communities of *Honckenya peploides* inhabit the sand- and shingle beach ridges in the estuaries of the Nikolskaya and Krasnaya rivers. In the supralittoral zone, they are exposed to storm surges. The communities occur also on flat sections and beach ridge foots along the White Sea coast, as well as on the Barents coast within the Indiga estuary. The community of *Honckenya peploides-Lactuca tatarica*, defined from the perspective of its floristic composition and ecological characteristics as similar to the association *Honckenyetum peploidis*, is also known from the White Sea coast (Sorokin and Golub 2007).

***Leymeta arenarii*,** formation
Leymeta arenarii represents the most common formation occurring on beach ridges of the White and Barents seas. Its distinctive species is the sea lyme grass ***Leymus arenarius***, a psammophilic tallgrass of the boreal European Arctic distribution.
***Leymetum arenarii honckenyetum peploidis*,** association
Syn.: ***Honckenyo diffusae–Leymetum arenarii*** R. Tüxen 1968
Composition and structure: This community has two dominant species, its upper tier formed by *Leymus arenarius* and the lower one by *Honckenya peploides*.
Ecology and distribution: On the Yugorsky Peninsula, within the estuary of the Nikolskaya River, this association has been found on the NE border of its range, occupying the sand-and-shingle estuarine ridge exposed to storm surges.

The association commonly occurs on the SE coast of the Barents Sea, precisely in the Pechora Bay (Moseev et al. 2022a) and the Indiga estuary. Its communities in the White Sea's Mezen Gulf (Moseev and Sergienko 2020) and Dvina Gulf (Moseev and Sergienko 2016) have been described in terms of phytocenotic and ecological approach. Communities of similar composition are known to occur on the western and southeastern coasts of the White Sea (Sorokin and Golub 2007), along the White and Barents coasts

on the Kola Peninsula (Sorokin and Golub 2007, Koroleva et al. 2011) and on the Rybachy Peninsula (Popova et al. 2017), and received floristic and ecological descriptions.

In communities dominated by *Leymus arenarius* along the White Sea coast, a number of nitrophilous species, such as *Atriplex littoralis*, *A. nudicaulis*, *A. praecox*, *Lactuca tatarica*, *Sonchus humilis*, is often present: Sorokin and Golub (2007), Moseev and Sergienko (2020). However, none of these species were found in the current study area, as their northern distribution limits lie further south. This results in a poorer species composition of psammophyte communities in the Yugorsky Shar Strait compared to those on the White Sea coast and the mainland coast of the Barents Sea.

2. Low salt marsh vegetation

Puccinellieta phryganodis, formation
This formation comprises *Puccinellia phryganodes*, a hygrophilous obligate halophyte of the circumpolar Arctic distribution, whose creeping shoots stand out well against the background of the silty sandy flats of the low-lying marshes. Being a common inhabitant of marshes of the Arctic coast, *Puccinellia phryganodes* can be found in many areas (Thannheiser and Willers 1988, Sergienko 2008, Matveeva and Lavrinenko 2011, Martini et al. 2019).

***Puccinellietum phryganodis*,** association
Composition and structure: The association comprises the communities heavily dominated by *Puccinellia phryganodes* (SSPC 10%-90%). Many geobotanical descriptions in the low-lying salt marshes of the studied estuaries reveal poor species composition (Sergienko 2008). The obligate halophytes *Stellaria humifusa*, *Carex mackenziei* and the yellow-green algae *Vaucheria* (SSPC 10%-30%) are among the co-occurring species. The latter were mostly sterile, precluding precise species identification.
Ecology: In the estuaries and lagoons of the Krasnaya and the Varkulyakha rivers, the communities of ***Puccinellietum phryganodis*** occupy a vast silty to sandy flats within low-lying marshes, where they are flooded with saline tide waters (24.8-25.4‰). Located closest to the shoreline, these communities represent the initial stage of the marshes overgrowing. Ecological and floristic descriptions have been provided of the Puccinellietum phryganodis communities inhabiting the estuaries of the Chizha and the Chesha Rivers on the Kanin Peninsula, where their species composition is described as more diverse, with a separate community involving *Tipolium vulgare* (Moseev and Sergienko 2020). The communities are known to occur on the Pechora Bay coast (Moseev et al. 2022a) and along the SE coast of the Barents Sea (Matveeva and Lavrinenko 2011, Lavrinenko and Lavrinenko 2018), the northern coast of the White Sea and the western coast of the Barents Sea (Koroleva et al. 2011). Communities with the species composition similar to those in the Vaygach estuaries occur in southern Greenland and the Svalbard archipelago (Hadač 1989, Molenaar 1974).

***Cariceta subspathaceae*, formation**
This formation is composed of halophilic sedge *Carex subspathacea* of the circumpolar Arctic distribution. Its communities are commonly found along the Arctic coast and are most numerous within the marshes of the SE Barents coast (Moseev et al. 2024). Earlier studies discovered this formation on the Chukchi Peninsula (Sergienko 2008). Commu-

nities with similar species composition are known to occur along the entire White Sea coast (Babina 2002, Koroleva et al. 2011, Moseev and Sergienko 2020, Volkova et al. 2008), the Norwegian Sea coast, the Svalbard Archipelago (Thannheiser 1975, 1991), and the Atlantic coast of Canada (Thannheiser 1975, 1991, Thannheiser and Hellfritz 1989). The formation is often described as consisting of two associations *Caricetum subspathacaea herbosum* and *Caricetum subspathacaea potentillosum egedei*. With a slightly different composition of dominant species, these associations typically inhabit low to mid tidal marshes (Moseev et al. 2024). In the Vaygach estuaries, the communities are markedly dominated by *Carex subspathacea*, with *Potentilla egedei* as a subdominant species (SSPC 10% to 20%). There are many other halophytes in communities with *Potentilla egedei*, making it difficult to separate them into a separate association. We therefore consider such communities as belonging to the association *Caricetum subspathaceae herbosum*.

***Caricetum subspathaceae herbosum*, association**

Composition and structure: This association comprises monodominant, occasionally oligodominant, communities composed of 1 to 6 species, with *Carex subspathacea* being a dominant (SSPC 60% to 100%), *Stellaria humifusa* constant (SSPC 5% to 10%), and *Arctantemum polare, Dupontia fisheri* and *Potentilla egedei* commonly occurring species. These communities are home to halophytes – *Carex glareosa, Calamagrostis deschampsioides, Dupontia psilosantha, Puccinellia phryganodes, P. pulvinata, Plantago schrenkii* – and to minor occurrences of mosses *Distichium cf. capillaceum* and *Bryum rutilans*, and the *Vaucheria* algae.

Ecology and distribution: The *Caricetum subspathaceae herbosum* communities inhabit the silty-sandy and loamy sections of the marshes experiencing two tides per day of 23.3-24.8‰ salinity. In the Krasnaya and the Varkulyakha estuaries and lagoons, *Carex subspathacea* tends to form extensive communities, whereas in the funnel-shaped estuary of the Nikolskaya River it occurs on relatively small areas at the confluence to the sea. During high tide, the salinity within these habitats varies only slightly between 24.1‰ and 25.2‰. *Caricetum subspathaceae herbosum* represents a distinctive community within the marshes of the SE Barents coast. Ecological and phytocenotic descriptions was presented by Moseev et al. (2022a), who explored this association within the Indiga estuary and the Pechora Bay. Communities with similar ecological and floristic characteristics can be found in other parts of the SE coast of the Barents Sea (Leskov 1936, Matveeva and Lavrinenko 2011, Lavrinenko and Lavrinenko 2018, Moseev and Sergienko 2020).

The *Caricetum subspathaceae herbosum* communities are known to occur within the estuaries of the Kyanda and the Keret' rivers in the White Sea (Moseev et al. 2022b), along the Chukchi and the Bering coasts (Sergienko 2008), the Korfa Bay in the Bering Sea (Neshataeva et al. 2014), and the Canadian Arctic Islands (Thannheiser 1975).

3. Middle salt marsh vegetation

Cariceta glareosae, formation

The formation is composed of the obligate halophyte *Carex glareosa*. Occurring commonly along the circumpolar Arctic coasts, *Carex glareosa* is known to inhabit also the Chukchi and the Bering coasts in the high latitudes (Sergienko 2008). Descriptions of its communities cover the southeastern coast of the Barents Sea (Lavrinenko and

Lavrinenko 2018, Moseev and Sergienko 2020, Moseev et al. 2022a), the White Sea coast (Babina 2002, Sergienko 2013), the Scandinavian Peninsula and the Pacific coast of Canada (Thannheiser and Hellfritz 1989, Saarela et al. 2020). In the studied area, this formation comprises two associations – *Caricetum glareosae arctantemosum polarae* and *Caricetum glareosae potentillosum egedei*, each with a specific dominant species composition but occupying the homogeneous habitats.

***Caricetum glareosae arctantemosum polarae ass. nov.*,** association
Composition and structure: The association comprises oligodominant communities of 2-6 species, with *Carex glareosa* (SSPC 50% to 80%) as a dominant and *Arctantemum maritimum* subsp. *polare* (SSPC 10% to 30%) as co-dominant. The latter is easily recognizable by its white anthodia contrasting against the background of the halophytic vegetation of these marshes. Constant in this association is *Dupontia psilosantha* (SSPC 5% to 20%); other halophytes include *Calamagrostis deschampsioides, Carex subspathacea, Potentilla egedei, Puccinellia phryganodes, P. coarctata, Stellaria humifusa* and some salinity-tolerant species including *Festuca richardsonii* and *Rhodiola rosea.*
Ecology and distribution: These communities occupy the middle marshes of the estuarine and lagoon sections of the Krasnaya and the Varkulyakha rivers, where they are exposed to syzygial tides and water salinity, measured throughout July-August 2023, of 23.3-24.8‰. Occurring on clay and loamy soils, they form dense vegetation.
Remark: The communities involving *Carex glareosa* and *Arctantemum maritimum* subsp. *polare* occur most commonly on the SE coast of the Barents Sea, but, judging from the obtained descriptions, not all of them involve *Arctantemum maritimum* as a dominant species.

Caricetum glareosae potentillosum egedae, association
Composition and structure: This association is composed by oligodominant communities consisting of 2-5 species, the dominant one being *Carex glareosa* (SSPC 40% to 80%) and the co-dominant *Potentilla egedei* (SSPC 10% to 50%). The latter is easily recognizable by the abundance of its yellow flowers contrasting against the overall background and forms a distinctive feature of this association as compared to the previously described one. Some descriptions mention as abundant in these communities the obligate halophyte *Stellaria humifusa* (SSPC 10% to 30%). One more species, *Festuca richardsonii*, occurs with III-degree constancy but develops rather a small projective cover degree of 10%.
Ecology and distribution: Caricetum glareosae potentillosum egedae has been found to inhabit the middle marshes of the Krasnaya estuary. Its ecological and phytocenotic characteristics describe it as occurring on the SE coast of the Barents Sea within the Indiga estuary (Moseev et al. 2024) and the Pechora Bay (Moseev et al. 2022a), as well as in the estuarine waters of the Kanin Peninsula (Korchagin 1935). Previous studies provide ecological and floristic descriptions of the *Carex glareosa* communities with *Potentilla egedei* as members of diverse syntaxa occurring on the SE Barents Sea coast within the Kanin Peninsula (Moseev and Sergienko 2020), Malozemelskaya tundra (Matveeva and Lavrinenko 2011) and Bolshezemelskaya tundra (Lavrinenko and Lavrinenko 2018).

***Plantagineta maritimae*,** formation
This formation is composed of the communities of related obligate halophytes *Plantago maritima, P. subpolaris* and *P. schrenkii*, occurring on the coasts of Europe and North America. While previously these three taxa listed in the international database The Plant List as subspecies synonymous to *Plantago maritima*, according to the latest records they appear on The Plant List (accessed on 17.08.23) as three separate species. Since the communities involving the related halophilic coastal species of *Plantago* genus occur in very similar ecological conditions, it is expedient to bring them under one formation, but on condition that the associations dominated by genus-specific species are recognized as separate. Consequently, we bring all the *Plantago schrenkii*-dominated communities occurring on the Yugorsky Peninsula and Vaygach Island under one association.

***Plantaginetum schrenkii ass. nov.*,** association
Composition and structure: This association comprises the communities consisting of 1 to 7 species and is dominated by *Plantago schrenkii* (SSPC 15%-30%). Its frequently occurring species include *Puccinellia coarctata* (PC 1%-5%), *Festuca richardsonii* (SSPC 3%-10%), *Rhodiola rosea* (SSPC 1%-5%) and *Allium schoenoprasum* (SSPC 1%). Other members include *Cochlearia arctica, Poa alpigena, Puccinellia phryganodes, Silene acaulis*.
Ecology and distribution: These communities occupy clay-gravelly flats within the Nikolskaya and Krasnaya estuaries, where vegetation forms at early stages of succession. A circumpolar hypoarctic species, here on the northern coasts *Plantago schrenkii* forms part of many other halophyte communities as a subdominant or species with a small projective cover. Descriptions of the *Plantago schrenkii* communities were provided by D.S. Moseev who explored them within the Zolotitsa River estuary on the Onega Peninsula in the White Sea (Moseev 2017). Within the estuaries under study, *Plantago schrenkii* is a cenosis-forming species. Its association represents a newly discovered association and should be recognized as such from the perspective of the ecological and phytocenotic approach.

The association *Plantaginetum schrenkii* has been further found to consist of two sub-associations – *Plantaginetum schrenkii herbosum* in the Krasnaya estuary and *Plantaginetum schrenkii purum* in the Nikolskaya estuary.
Along with minor occurrences of halophytes *Cochlearia arctica, Puccinellia coarctata* (PC 1%-5%) and *P. phryganodes*, the sub-association ***Plantaginetum schrenkii herbosum*** is composed by glycophytes *Allium schoenoprasum, Festuca richardsonii*, *Poa alpigena, Rhodiola rosea*, *Silene acaulis.* The number of glycophytes as high as this may indicate a slight degree of soil salinization in the habitat, exposed to minor flooding by brackish waters of syzygial tides.

The sub-association ***Plantaginetum schrenkii purum*** is heavily dominated by *Plantago schrenkii* (PC 15%-30%) and has just two other members – *Puccinellia coarctata* (PC 1%-5%) and *Puccinellia phryganodes*. Its communities are exposed not only to syzygial tides, but also to the daily salt water flooding with an average tide range of 0.5 m and salinity of 20.4‰-23.5‰.

***Puccinellieta distansae*,** formation
This formation is composed by communities of halophytes with latitudinal Arctic distribution and close relation to *Puccinellia distans – Puccinellia coarctata, P. capillaris, P. pulvinata*. These three species currently list in the international database The Plant List as synonymous to *Puccinellia distans*. Based on polytypic species concept, we,

however, view *Puccinellia coarctata* as a separate species. The information on communities with *Puccinellia* as a cenosis-forming species is limited. However, they are not rare on the White and Barents coasts, often forming part of other communities (Babina 2002, Lavrinenko and Lavrinenko 2018, Moseev and Sergienko 2020). According to the unpublished data from D.S. Moseev, *Puccinellia coarctata* occurs in the *Plantago maritima* communities inhabiting the estuary of the Kuloy River in the White Sea's Mezen Gulf, being a dominant species, alongside *Puccinellia pulvinata* and *Puccinellia capillaris*, in the microdepressions of the White Sea's marshes on the Onega Peninsula.

***Puccinellietum coarctatae*,** association
Composition and structure: This association comprises mono- and oligodominant communities composed of 2 to 7 species, the dominant being obligate halophyte *Puccinellia coarctata* (SSPC 20%-30%). In the studied estuaries, these communities vary greatly in terms of species composition. *Plantago schrenkii* and *Carex subspathaceae* (SSPC 30%) are common, with Honckenya peploides occurring near the beach. One marsh in the Nikolskaya estuary is inhabited by obligate halophytes *Stellaria humifusa* and *Potentilla egedei*, and the one in the Krasnaya estuary is covered almost entirely by *Puccinellia coarctata*. Even so, we place the communities to one association, given the previous descriptions of their diversity (Popova et al. 2017) in the estuaries other than the ones described herein.
Ecology and distribution: The *Puccinellietum coarctatae* communities occur on pebbly mudflats of the middle marshes in the Nikolskaya and Krasnaya estuaries. Their ecological and floristic descriptions define them as inhabiting the Rybachy Peninsula coast of the western Barents sector (Popova et al. 2017), the coasts of northern Norway (Nordhagen 1954) and the Atlantic coast of Canada (Thannheiser and Willers 1988).

Puccinellia coarctata* + *Carex subspathacea, community type
Composition and structure: Alongside *Puccinellia coarctata* and *Carex subspathaceae*, the lower tier has among its dominant species *Distichium cf. capillaceum*. Moderately abundant are glycophytes *Salix reptans* and *Saxifraga hirculus*.
Ecology and distribution: The phytocenosis occupies a site exposed to waterlogging from syzygial tides in the ecotone between the marsh and tundra, where it supersedes the association ***Caricetum subspathaceae herbosum*.**

4. Higher marsh vegetation

The geomorphology and hydrological features of the higher estuarine marshes under study make them a less pronounced landform. Here, the height of syzygial tides does not exceed that of the valley flats or slopes, where the vegetation cover shows features of marshes and tundra (ecotones).

Festuceta richardsonii, formation
This formation is composed of communities dominated by the Arctic circumpolar species *Festuca richardsonii*. A salinity-tolerant species, *Festuca richardsonii* is found commonly in tundra ecotopes (Rebristaya 2013) but can form communities on higher marshes, co-dominating with halophytes (Moseev et al. 2022a).

Festucetum richardsonii herbosum, association
Composition and structure: From the perspective of the ecological and phytocenotic approach, we classify all the *Festuca richardsonii*-dominated communities occurring in the area under study as belonging to one association. Despite some variance in species composition, from 2 to 5 as cited in the available descriptions, *Festuca richardsonii* represents in this association a diagnostic species. The *Festucetum richardsonii herbosum* association comprises mono- and oligodominant communities of 2 to 5 species, with *Festuca richardsonii* as cenosis-forming one. Abundant in some of these communities are *Carex glareosa, Deschampsia borealis*, *Dupontia fisheri, Rhodiola rosea.* Many of the communities involve *Cochlearia arctica, Potentilla egedei, Salix reptans, Tripleurospermum maritimum.*
Ecology and distribution: These communities inhabit the loamy bottoms of the higher marshes, where exposure to marine waters occurs solely during surges. Communities of similar species composition and structure are widespread on the SE coast of the Barents Sea (Lavrinenko and Lavrinenko 2018, Moseev et al. 2022a, Moseev et al. 2024).

Saliceta reptantis, formation
This formation is composed by dwarf creeping willow *Salix reptans* of the circumpolar Arctic distribution. Its glaucous color stands out well against the background of the grassy vegetation of this marsh-tundra ecotone. The communities occurring on the coast of the Pechora Bay tend to be much more species rich than those on marshes and beaches (Moseev et al. 2022a). However, those found on the Yugorsky-Shar coast have approximately the same number of species as the communities inhabiting the middle marshes. There are two associations within this formation, each with its own set of dominants.

Salicetum reptantis herbosum, association
Composition and structure: This association comprises mono- and oligodominant communities consisting of 5 to 9 species. Its diagnostic species *Salix reptans* dominates with the projective cover of 15%-30%. Abundant are *Calamagrostis neglecta*, *Calamagrostis deschampsioides, Carex parallela, Carex stans, Deschampsia borealis, Festuca richardsonii, Salix polaris, Poa alpigena.* The ground cover shows large occurrences of mosses – *Bryum pseudotriquetrum, B. salinum, Warnstorfia exannulata, Drepanocladus aduncus, D. polygamus, Sanionia uncinata*.
Ecology and distribution: These communities are found on higher marshes near the valley sides within the Krasnaya and Nikolskaya estuaries, forming on loamy and peaty soils.

Salicetum reptantis-Parnassiosum palustris, association
Composition and structure: This association is composed by oligodominant communities of 5 to 8 species. Based on the studies conducted earlier in the Pechora Bay, we identify two diagnostic species within the said association – *Salix reptans* and *Parnassia palustris* (Moseev et al. 2022a). The creeping shoots of *Salix reptans* propagate in the ground cover, developing a projective cover of 30% to 50%. Contrasting against its background are the white flowers of hygrophilous *Parnassia palustris* (SSPC 20%-30%), the stems and inflorescence of the rampant *Festuca richardsonii* (SSPC 15%-30%) and patches of *Rhodiola rosea* (SSPC 10%). These communities involve *Dupontia fisheri, Polygonum viviparum* and major occurrences of mosses *Drepanocladus polygamus, Aulacomnium palustre, Bryum* sp.

Ecology and distribution: These communities occur in well irrigated, waterlogged parts of the high marshes within the Varkulyakha estuary, where they form on loamy and peaty soils.
Known to occur in the Khylchuyu estuary along the coast of the Pechora Bay (Moseev et al. 2022a), the diverse variants and sub-associations of the *Parnassio palustris-Salicetum reptantis* association have received sufficient ecological and floristic descriptions (Matveeva and Lavrinenko 2011, Lavrinenko and Lavrinenko 2018).

5. Salt lake and microdepression vegetation

Hippurideta tetraphyllae, formation
This formation is composed by communities of hydrophilic obligate halophyte *Hippuris tetraphylla* of Eurasian-American hypoarctic distribution, for Alaskan distribution, *see* Hampton-Miller et al. (2022). Found in microdepressions of marshes, mudflats, salt lakes and saline hollows within tidal areas, they are known to occur on the Chukchi and Bering coasts (Sergienko 2008, Neshataeva et al. 2014), the White Sea coast (Babina 2002, Sergienko 2013, Moseev and Sergienko 2020) and, more prevalently, on the Barents coast (Koroleva et al. 2011, Leskov 1936, Matveeva and Lavrinenko 2011, Lavrinenko and Lavrinenko 2018, Moseev and Sergienko 2020, Moseev et al. 2022a).

Hippuridetum tetraphyllae purum**,** association
Syn.: ***Scirpeto-Hippuridetum tetraphyllae*** **subass. inops Matveeva Lavrinenko 2011**
Composition and structure: This association comprises monodominant communities consisting of 1 to 3 taxa (species, genera, green algae type), with *Hippuris tetraphylla* as cenosis-forming species (SSPC 5%-30%). The single-species communities of *Hippuris tetraphylla* are common in the estuaries of Vaygach Island. Occurring in this association are *Carex mackenziei, Ranunculus hyperboreus, Puccinellia phryganodes*. Some of the *Hippuris tetraphylla* communities have been found to include yellow-green algae of the genus *Vaucheria* and the blue-green algae *Lingbia*.
Ecology and distribution: The *Hippuridetum tetraphyllae purum* communities occur in the Krasnaya and Varkulyakha estuaries, where they grow on muddy bottoms of the smaller salt lakes with an area of less than 1 ha and a depth of 10 to 50 cm that often dry up in summer. These lakes form within low and middle marshes under the tide influence. High-water salinity ranged from 19.7‰ to 26.5‰, but is subject to significant seasonal and tidal fluctuations. Meltwater and rain desalinate these ponds significantly in spring and summer, but the saline waters get brought back with every tide and wind-induced surge, exposing *Hippuris tetraphylla* to wide diurnal and seasonal salinity variations. Its communities are widespread on the SE Barents coast (Leskov 1936, Matveeva and Lavrinenko 2011, Lavrinenko and Lavrinenko 2018, Moseev et al. 2022a) and are known to inhabit the Bering coast (Sergienko 2008) and its Korfa Gulf (Neshataeva et al. 2014). Communities of similar structure but inclusive of boreal species *Bolboschoenus maritimus, Eleocharis uniglumis, Triglochin maritimum* and *Tipolium vulgare*, are found along the entire White Sea coast (Babina 2002, Bragin et al. 2021, Koroleva et al. 2011, Sergienko 2013, Moseev and Sergienko 2016) and were originally described as occurring in Northern Norway (Nordhagen 1954).

***Ranunculus hyperboreus*,** community type
Composition, structure, ecology and distribution: This community involves the hygrophilous species *Ranunculus hyperboreus* subsp. *Tricrenatus* and is found in the Varkulyakha River delta, where it occurs on silt-loam soils of an episodic microdepressions of the middle marsh.
Communities dominated by *Ranunculus hyperboreus* are quite widespread in the tundra zone. However, due to insufficient descriptions of *Ranunculus hyperboreus subsp. tricrenatus*, it is not possible to identify an independent association.

Vaucherieta, formation
The species of *Vaucheria* DC. are widely distributed within the studied area; however, these algae commonly occur in sterile condition that preclude precise identification. In those cases, when fertile specimens were found, only *V. velutina* C. Agardh was identified (Kotkova et al. 2024). Here, we describe single association under *Vaucherieta*, a formation dominated by *Vaucheria*. It can be easily recognized by bright or dark green, velvety patches of densely intertwined erect filaments attached to sandy or muddy sediments by rhizoids (*cf.* Polderman 1979).

Vaucherietum velutinae, association
Composition and structure: Vaucheria velutina was found to be dominant in Community 42Kc. The communities of sterile *Vaucheria*, which may belong to *V. velutina* or another species, also involve the halophyte *Puccinellia phryganodes* and blue-green alga *Lyngbya* cf. *aestuarii* Leib. ex Gom. The *Vaucheria* communities have been found to involve also blue-green algae of the genus *Lyngbya*.
Ecology and distribution: The association occurs in silty, waterlogged microdepressions of the middle marshes and salt lakes within the Krasnaya River estuary, where salinity measured 24.8‰.The communities of *Vaucheria velutina* were also reported from the White Sea (Moseev et al. 2022c) and are known also from Europe (Knutzen 1973, Polderman 1979).

The community described below, *Ulva prolifera,* is defined by us as a type, since descriptions are too scarce to identify it as a separate formation or association. At the same time, this green algae's common presence in many estuarine bays of the White Sea, for example Sukhoe More Bay (Moseev et al. 2022b), allows us to identify, within *Ulva prolifera*- dominated communities, syntaxons of a higher rank.

Ulva prolifera, community type
More research is needed to refine the classification of the algae communities of the genus *Ulva (=Enteromorpha)* occurring on the White and Barents Sea coasts. As their species composition and structure remain poorly studied, we refer to the communities below as a type.
Composition, structure, ecology and distribution: These communities occur on mud flats in the tidal zone of the Krasnaya estuary and have as their cenosis-forming species *Ulva prolifera*, which dominates with the projective cover of 10%-20%. According to D.S. Moseev, the *Ulva prolifera* communities are found in the Kuloy estuary in the White Sea's Mezen Gulf, in the Sukhoe More Bay and the Una Bay of the White Sea (Moseev et al. 2022b).

6. Low-lying wetland vegetation in marsh-tundra ecotones

Magnocariceta, formation
This formation is dominated by freshwater species: *Carex aquatilis, C. acuta, C. rostrata, C. vesicaria*. Since *Carex stans* (= *Carex concolor*) is considered to be morphologically close to the circumpolar hypoarctic subspecies *Carex aquatilis* subsp. *stans,* we view these communities as composing the ***Magnocariceta*** formation**.**

Caricetum stantis, association
Composition and structure: This association is composed of monodominant communities consisting of 2 to 11 species, the cenosis-forming one being *Carex stans,* a large hygrophilous sedge that develops here a projective cover of 50%-70%. The association commonly involves *Eriophorum scheuchzerii* (SSPC 5%-20%) and occurrences of mosses *Warnstorfia exannulata* (SSPC 5%-20%) and *Aulacomnium palustre* (SSPC 10%). Found under the canopy of *Carex stans* are also *Caltha arctica, Carex lachenalii, Nordosmia frigida, Polygonum viviparum, Ranunculus pallasii, Trisetum sibiricum, Saxifraga hirculus* and *Stellaria* sp. Noticeable amid the vegetation background are the shrub willows *Salix glauca* and *Salix lanata*, which grow here along ponds amid sedge tussocks.
Ecology and distribution: These communities occupy the hummocks of the lower wetlands lying in the transition area between marshes and low-height accumulative terrace, the latter inhabited by the moss-lichen tundra species. In these low-lying areas (microdepressions), the standing water forms 0.5 m deep lakes with muddy bottoms. Its high mineralization rate – 426 mg/l – indicates regular exposure to storm surge.

The ***Caricetum stantis*** communities are common in the tundra zone and known to occur on the Yamal (Rebristaya 2013) and the Taimyr Peninsula (Matveeva 1998).

Cariceta rariflorae, formation
This formation is composed by *Carex rariflora*, a salinity-tolerant species of the circumpolar Arctic distribution. Like *Carex stans*, *Carex rariflora* acts here in the tundra zone, and especially in its waterlogged habitats, as a cenosis-forming species (Matveeva 1998, Lavrinenko et al. 2016a).

***Caricetum rariflorae subpurum*,** association
Composition and structure: The communities of *Caricetum rariflorae subpurum* are composed by 2 to 6 species, the dominant being *Carex rariflora* (SSPC 30%-50%). Other members include *Eriophorum scheuchzerii, Polygonum viviparum, Stellaria* sp. The moss layer is composed by *Warnstorfia exannulata, Aulacomnium palustre, Plagiomnium ellipticum, Calliergonella lindbergii*. Noticeable amid the grassy background are the shoots of *Salix glauca* (SSPC 15%).
Ecology and distribution: These communities occur here on peaty soils of lowland wetlands.

Like *Caricetum stantis*, they are common in the tundra zone (Matveeva 1998, Lavrinenko et al. 2016a) and are known to occur on higher coastal marshes (Sergienko 2008).

7. Vegetation of clay wind-driven in estuaries

With the exception of the area where the estuary meets the sea, the Nikolskaya River estuary on the Yugorsky Peninsula lacks well-developed marshes. Instead, halophytic vegetation is represented by narrow, discontinuous strips that occasionally become denser, interspersed with broad bare patches.
Due to the limited availability of geobotanical descriptions and ecological data on communities dominated by the hygrophilous species *Juncus arcticus*, it would be premature to classify *Junceta arctici* as a separate formation. However, it is appropriate to recognize these communities at the rank of association.

Juncetum arctici, association
Composition and structure: This association is composed by monodominant communities of 1 to 4 species, the cenosis-forming one being the hygrophilous *Juncus arcticus* (SSPC 15%-30%). Occurring in these communities are *Deschampsia borealis, Eriophorum scheuchzerii* and mosses *Drepanocladus polygamous* and *Sanionia uncinata*.
Ecology and distribution: The *Juncetum arctici* communities occupy clay-gravelly microdepressions on the estuarine flat of the Nikolskaya River. These microdepressions remain wet for most of the year, the water starting to accumulate in them in spring. In the summer of 2023, however, a period of unusually hot weather caused these microdepressions to dry up and the *Juncus arcticus* shoots to turn yellow. Minor occurrences of *Juncus arcticus* are found also on the Pechora Bay coast (Moseev et al. 2022a) and in the Mezen Bay (Moseev and Sergienko 2020).

***Deschampsieta borealis*,** formation
This formation is composed by communities dominated by the Arctic races of the plurizonal species *Deschampsia cespitosa – Deschampsia borealis, D. glauca* and *D. brevifolia*. Commonly occurring in humid Arctic habitats – Franz Josef Land (Safronova et al. 2019), Severnaya Zemlya and Wrangel Island (Kholod 2020) – they tend to inhabit localities prone to erosion, both natural and anthropogenic.

***Deschampsietum borealis*,** association
Composition and structure: We identified communities dominated by the circumpolar Arctic species *Deschampsia borealis* as a separate association. They show major occurrences of *Carex parallela, Festuca richardsonii, Salix reptans* and *Saxifraga aizoides,* involving also *Polygonum viviparum, Salix polaris* and *Silene acaulis*.
Ecology and distribution: The *Deschampsia borealis* communities occur in humid areas of tidal flats within the Nikolskaya River estuary, where they form on rubble-loam soils. The species *Deschampsia borealis*, grows on Severny Island (Novaya Zemlya archipelago) in the valley of a stream flowing into Russkaya Gavan Gulf, where it forms communities (Moseev and Sergienko 2017). Communities of similar composition are known to occur on the territory of the Russian Arctic National Park and have received ecological and floristic descriptions (Kholod 2020).

Discussion

A total of 16 associations and 14 formations of estuarine vegetation have been identified in the Yugorsky-Shar Strait (*see* Table 1).

Biotop	Beaches		Low level salt marshes		Mid-level salt marshes						Salt lakes and microdepressions on the marches				Higher marsh vegetation			Low-lying wetland vegetation in marsh-tundra ecotones		Clay wind-driven in estuaries	
Association/subassociation, community types	H. p.	L. a. h. p.	P. ph.	C.s.	C. g. arct. p.	C. g. p. e	Pl sh. h.	Pl sh. p.	P. c.	P. c. + c. s.	H. t	R. h.	V.	U. pr.	S. r. h.	S. r. p. p.	F. r. h.	C. st.	C. r. s	J. a	D. b.
Number of species	1	2	6	15	11	7	9	3	4	8	8	1	3	1	27	8	11	24	10	7	8
Syntaxa number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Diagnostic species																					
Honckenya peploides	4^{10-15}	1^{20}	-	-	-	-	-	-	1^{1-5}	-	-	-	-	-	-	-	-	-	-	-	-
Leymus arenarius	-	1^{50}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Puccinellia phryganodes	-	-	V^{5-80}	I^{5}	I^{10}	I^{1}	-	I^{1}	-	-	II^{5-10}	-	2^{1-1}	-	-	-	-	-	-	-	-
Carex subspathacea	-	-	-	V^{50-80}	I^{10}		-	-	-	30	-	-	-	-	-	-	-	-	-	-	-
Carex glareosa	-	-	-	I^{20-30}	V^{50-80}	V^{40-80}	-	-	-	-	-	-	-	-	-	-	1^{10}	-	-	-	-
Arctantemum maritimum	-	-	-	I^{5-30}	V^{5-50}	I^{10-10}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla egedei	-	-	-	II^{10-20}	II^{5-10}	V^{10-50}	-	-	1^{5}	-	-	-	-	-	-	-	2^{5-10}	-	-	-	-
Plantago schrenkii	-	-	-	I^{1-15}	-	-	3^{20-30}	V^{15-30}	-	5	-	-	-	-	-	-	-	-	-	-	-
Puccinellia coarctata	-	-	-	-	I^{10}	-	1^{1}	III^{1-5}	3^{20-30}	30	-	-	-	-	-	-	-	-	-	-	-
Hippuris tetraphylla	-	-	-	-	-	-	-	-	-	-	V^{10-30}	-	-	-	-	-	-	-	-	-	-
Ranunculus hyperboreus	-	-	-	-	-	-	-	-	-	-	I^{5}	20	-	-	-	-	-	-	-	-	-
***Vaucheria* sp. str.**	-	-	I^{10-20}	I^{10}	-	-	-	-	-	-	I^{10}	-	-	-	-	-	-	-	-	-	-
Vaucheria velutina	-	-	I^{10-10}	-	-	-	-	-	-	-	-	-	1^{15}	-	-	-	-	-	-	-	-
***Vaucheria* sp. str. +**	-	-	I^{10-30}	-	-	-	-	-	-	-	I^{30}	-	2^{10-20}	-	-	-	-	-	-	-	-
Ulva prolifera	-	-	-	-	-	-	-	-	-	-	-	-	-	2^{10-20}	-	-	-	-	-	-	-
Salix reptans	-	-	-	-	-	-	-	-	-	1	-	-	-	-	V^{15-30}	3^{30-50}	1^{10}	I^{1}	-	-	2^{5-15}
Parnassia palustris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{1-5}	3^{15-30}	-	-	-	1^{1-1}	-
Festuca richardsonii	-	-	-	I^{5}	II^{5-5}	III^{10-}	3^{3-10}	-	-	-	-	-	-	-	III^{10-}	3^{15-30}	4^{20-50}	-	-	-	1^{15}
Carex aquatilis* subsp. *stans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{20}	-	1^{20}	V^{50-70}	-	-	-
Carex rariflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2^{30-50}	-	-
Juncus arcticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	-	-	1^{15-}	-
Deschampsia borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{10-10}	-	-	-	-	1^{1}	2^{30-30}
Other species																					
Stellaria humifusa	-	-	I^{10}	III^{5-10}	I^{10}	II^{30-30}	-	-	1^{5}	-	-	-	-	-	-	-	-	-	-	-	-
Carex mackenziei	-	-	I^{1-5}	-	-	-	-	-	-	-	I^{5}	-	-	-	-	-	-	-	-	-	-
Calamagrostis deschampsioides	-	-	-	I^{5-10}	II^{5-10}	-	-	-	-	-	-	-	-	-	I^{5-20}	-	-	-	1^{10}	-	-
Dupontia fisheri	-	-	-	II^{5-10}	III^{5-20}	-	-	-	-	-	-	-	-	-	-	$2^{10,15}$	1^{30}	-	-	-	-
Puccinellia pulvinata	-	-	-	I^{10}	-	-	-	-	-	-	-	-	-	-	-	$2^{10,10}$	-	-	-	-	-
Rhodiola rosea	-	-	-	-	I^{1-1}	II^{1-5}	3^{1-5}	-	-	-	-	-	-	-	II^{1-5}	-	1^{15}	-	-	-	-
Allium schoenoprasum	-	-	-	-	-	-	2^{1-1}	-	-	-	-	-	-	-	I^{1}	-	-	-	-	-	-
Poa alpigena	-	-	-	-	-	-	1^{1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silene acaulis	-	-	-	-	-	-	1^{1}	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cochlearia arctica	-	-	-	-	-	-	1^{1}	-	-	-	-	-	-	-	-	-	1^{1}	-	-	-	-
Saxifraga hirculus	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	I^{10}	-	-	-
Salix polaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{10-15}	-	-	-	-	-	2^{5-5}
Polygonum viviparum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	$2^{10,10}$	-	I^{10}	-	-	2^{1-5}
Calamagrostis neglecta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{30}	-	-	-	-	-	-
Carex parallela	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{5-15}	-	-	-	-	-	-
Tripleurospermum maritimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1^{5}	-	-	-	-

Stellaria sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1^{10}	II^{1-5}	1^{20}	-	-
Eriophorum scheuchzerii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{3}	-	-	III^{5-20}	1^{10}	1^{5}	-
Rumex arcticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	I^{1}	-	-	-
Caltha arctica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	I^{1}	-	-	-
Pedicularis sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	-	-	-	-
Poa arctica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	-	-	-	-
Rubus chamaemorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{10}	-	-	-	-	-	-
Eriophorum angustifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{1-1}	-	-	-
Comarum palustre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{5}	-	-	-
Salix glauca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{1-1}	1^{15}	-	-
Ranunculus pallasii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{10}	-	-	-
Polemonium boreale	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{5}	-	-	-
Trisetum sibiricum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{5-5}	-	-	-
Carex lachenalii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{5}	-	-	-
Poa alpigena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{5-20}	-	-	I^{5}	-	-	-
Nordosmia frigida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{5}	-	-	-
Salix lanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{10}	-	-	-
Chrisosplenuim tetrandrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{1-3}	-	-	-
Saxifraga hieracifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	-
Saxifraga aizoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1^{15}
Carex parallela	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2^{10-10}
Silene acaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1^{1}
Salix arctica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	I^{1}	-	-	-
Triglochin maritimum				I^{+}																	
Bryum rutilans	-	-	-	I^{5}	-	-	I^{10}	-	-	10	-	-	-	-	-	-	-	-	-	-	-
Bryum sp.	-	-	-	I^{5}	-	-	-	-	-	10	1^{10}	-	-	-	-	-	-	-	-	1^{10}	-
Distichium cf. capillaceum	-	-	-	I^{5}	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-
Warnstorfia exannulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	III^{1-20}	-	-	II^{5-20}	1^{20}	-	-
Drepanocladus polygamus	-	-	-	-	-	-	-	-	-	-	1^{20}	-	-	-	I^{5}	-	-	I^{20}	-	1^{10}	-
Bryum pseudotriquetrum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	II^{5-5}	-	-	-	-	-	-
Aulacomnium palustre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1^{10}	-	-	1^{10}	-	-
Brachythecium salebrosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Sanionia uncinata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1^{+}	-	-	1+	1^{-}	-
Drepanocladus aduncus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Bryum salinum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Plagiomnium ellipticum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	-	-
Calliergonella lindbergii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1+	-	-
Chlorophyta	-	-	I^{3}	-	-	-	-	-	-	-	I^{5}	-	-	-	-	-	-	-	-	-	-

Table 1. Synoptic table of syntaxa the mouth of the river Krasnaya, Varkuts'yakha and Nikolskaya of the Yugorsky Shar Strait. *Abbreviated names of associations:* H. p. – *Honckenyetum peploidis,* L. a. h. p. – *Leymetum arenarii honckenyosum peploidis*, P. ph. – *Puccinellietum phryganodis*, C.s. – *Caricetum subspathaceae herbosum*, C.g. arct. p. – *Caricetum glareosae arctantemosum polarae*, C.g. p. e – *Caricetum glareosae potentillosum egedae*, Pl sh. – *Plantaginetum schrenkii*, P. c. – *Puccinellietum coarctatae*, P. c. + c. s. – *Puccinellia coarctata* + *Carex subspathaceae*, H. t – *Hippuridetum tetraphyllae purum*, R. h. – *Ranunculus hyperboreus*, Vau – *Vaucheria*, U. pr. – *Ulva prolifera*, S. r. h. – *Salicetum reptantis herbosum*, S. r. p. p. – *Salicetum reptantis parnassiosum palustris*, F. r. h. – *Festucetum richardsonii herbosum*, C. st. – *Caricetum stantis*, C. r. s – *Caricetum rostratae subpurum*, J. a – *Juncetum arctici*, D. b. – *Deschampsietum borealis*.

The comparative analysis revealed that the largest similarity in terms of species composition and structure is shown by the vegetation of the accumulative shores of the Krasnaya and Varkulyakha estuaries in the southern sector of Vaygach Island (Table 1). These two estuaries are similar in terms of geomorphology, each forming a lagoon at the confluence with the sea (Figs. 2, 3). The low marshes are occupied by pioneer communities of the *Puccinellietum phryganodis* and *Caricetum subspathaceae herbosum* associations, while the middle marshes are home to vast communities of the *Cariceta glareosae* formation. Salt marsh lakes are characterized by *Hippuridetum tetraphyllae* communities, and microdepressions with area ranging from 4 to 100 m^2 commonly contain *Vaucheria* sp. The high marshes are less pronounced, likely due to fairly large extent of coastal flooding during syzygial tides, when water level barely reaches the valley sides, and the frequent exposure to storm surges from the Barents Sea.

The vegetation of the high marshes includes the coastal meadow association *Festucetum richardsonii herbosum*, dominated by mild salinity-tolerant glycophytes. The transition zone between marsh flats and tundra communities is abrupt. Here large areas are occupied by communities of associations *Salicetum reptantis herbosum* and *Salicetum reptantis parnassiosum palustris*, consisting of species characteristic of wet herbaceous-shrub tundra and bogs, and including some ecotone-specific species such as *Parnassia palustris* and *Rhodiola rosea*.

The vegetation of the Nikolskaya estuary is slightly different from the Krasnaya and Varkulyakha estuaries (Figs. 2, 3). Here, the marsh lies in a short (1.5 km long), funnel-shaped estuary and is inhabited mostly by the communities of *Caricetum subspathaceae herbosum* and *Puccinellietum coarctatae* associations. *Plantaginetum schrenkii* communities, which grow on the clay-gravel bottom of tidal flats, were not found in the Varkul'yakha River estuary, but are found in small areas of 1-4 m^2 in the Krasnaya River estuary. The flats experiencing surge exposure are inhabited by hygrophytic communities of the *Juncetum arctici* and *Deschampsieta borealis* associations.

At the confluence with the sea, sandy and shingle beaches support sparse vegetation. Within the Krasnaya estuary, the beach ridges are 3-5 m high and inhabited by the communities of the *Honckenyetum peploidis* association, while the Nikolskaya estuary is home to the *Leymetum arenarii honckenyosum peploidis* association, occurring in the northern sector. The communities of the *Juncetum arctici* association also occurrs on the northern border of the Nikolskaya estuary.

Halophytic vegetation on Vaygach Island shows substantial similarity with that occurring on the mainland SE coast of the Barents Sea (Pechora Bay, Cheshskaya Bay, Indiga Bay, coasts of Malozemelskaya and Bolshezemelskaya tundra). In both regions, the communities dominated by *Puccinellia phryganodis, Carex subspathacea* and *Carex glareosa* spread over vast areas (Matveeva and Lavrinenko 2011, Lavrinenko and Lavrinenko 2018, Moseev and Sergienko 2020, Moseev et al. 2022a, b; Moseev et al. 2024). These halophytes form associations also on the Bering and the Chukchi coasts (Sergienko 2008).

The similarity within the halophytic vegetation of Vaygach Island becomes less evident as we move focus from the SE Barents coast to the White Sea. On the Kanin Peninsula, the vast marshes in the Mezen Bay's estuaries are inhabited by the cenoses of formations *Cariceta glareosae, Cariceta subspathaceae, Puccinellieta phryganodis* (Korchagin 1935, Moseev and Sergienko 2020). These communities are less common on the SE coast of the White Sea (Moseev and Sergienko 2016).

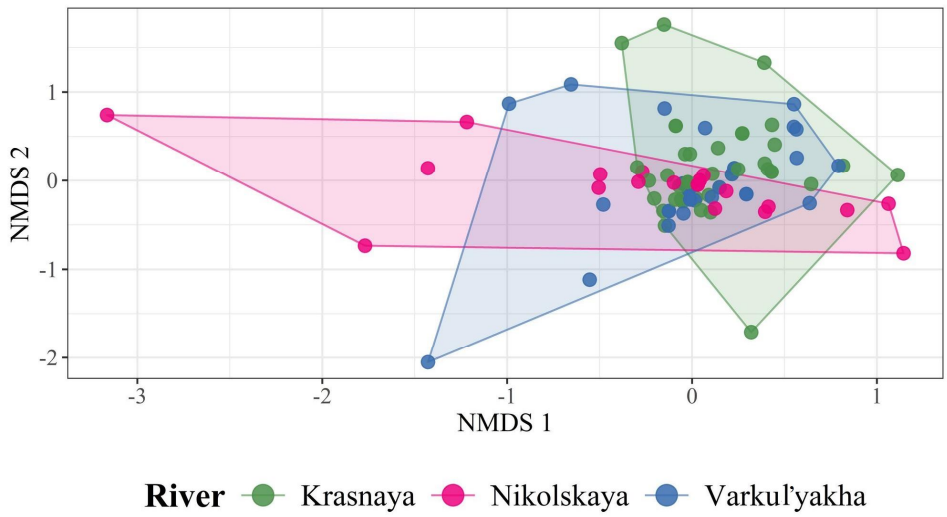

Fig. 2. Graphical interpretation of phytocenoses of halophytic vegetation in the river mouths of the Yugorsky Shar Strait.

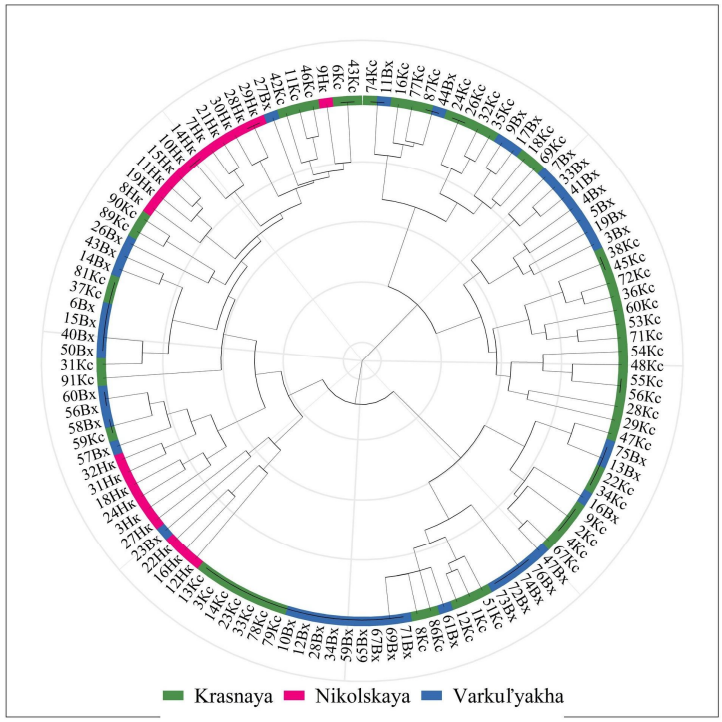

Fig. 3. Cluster analysis of similarity of phytocenoses of halophytic vegetation of the Yugorsky Shar Strait coastline.

In the White Sea, vast communities dominated by sedges *Carex glareosa* and *Carex subspathaceae* occur on the Primorsky and Tersky coasts (Babina 2002, Koroleva et al. 2011). However, the primary halophytic White Sea vegetation is composed of by boreal species *Bolboschoenus maritimus, Eleocharis uniglumis, Glaux maritima, Phragmites australis, Plantago maritima* which have not been found to occur on Vaygach Island. Similarly, there are only rare and minor occurrences of *Hippuridetum tetraphyllae* on Vaygach Island, whereas it occupies vast areas on the mainland Barents and in the White Sea's Mezen Bay.

In the southern sector of Vaygach Island (much farther from the Nikolskaya estuary), vast marshes occupied by the communities of the *Caricetum subspathaceae herbosum* and *Puccinellietum phryganodis* associations reveal substantial similarity with the halophytic vegetation occurring on the Canadian Arctic Archipelago (Thannheiser 1975, Thannheiser and Willers 1988), and the marshes of the Svalbard fjords (Hadač 1989) and West Greenland, Disko Bay (Lepping and Daniëls 2007).

Conclusion

The vegetation cover of the marshes under study allows classifying them as Arctic type, as evidenced by the wide occurrence of communities dominated by Arctic and hypoarctic species of the *Caricetum subspathaceae herbosum*, *Caricetum glareosae arctantemosum maritimae*, *Caricetum glareosae potentillosum egedae*, *Puccinellietum phryganodis* and *Plantaginetum schrenkii* associations. Another characteristic feature of the Arctic marshes is the scarcity of plant associations. On Vaygach Island, not more than ten associations can be distinguished based on ecological and phytocenotic approach. Beach vegetation in the area is notably poor, composed of only two associations, *Honckenyetum peploidis*, involving monospecific communities, and *Leymetum arenarii honckenyosum peploidis,* which numbers two community-forming species. The same is true about the communities of the salt marshes, with species composition limited to 1-7.

Some of the halophytic associations should be identified as newly discovered. These include *Plantaginetum schrenkii ass. nov.*, identified as an association comprising the communities of coastal plantains *Plantagineta maritimae* and *Caricetum glareosae arctantemosum polarae ass. nov.*, which is distinctly separated from the formation *Cariceta glareosae*.

In the studied area, the formation of the halophytic vegetation is often influenced by the geomorphological conditions of tidal estuaries. In the Krasnaya and Varkulyakha estuaries, where estuary mouths form lagoons, salt marshes appear as clearly pronounced landforms shaped by tidal activity and heavy storm surges from the Barents Sea. Contrary, in the Nikolskaya estuary, whose mouth is rather narrow, there form tidal flats and marshes of a smaller size.

Underneath the Krasnaya estuary lie abandoned lead-zinc mines that were active during the 1930s. This area was used as a reference point for the comparison of its vegetation cover, hydrological and hydrochemical parameters, and natural levels of heavy metal pollution with those in the Varkulyakha estuary. The results, however, show no major differences between the current estuarine vegetations of the Krasnaya and the Varkulyakha, indicating these abandoned mines being a source of insignificant influence on the halophytic cenoses.

At the same time, our study revealed elevated content of lead in algae inhabiting the Krasnaya estuary – *Ulva prolifera* and *Fucus distichus* (Miskevich et al. 2024c). For this reason, we recommend measuring heavy metal concentrations also in higher plants occurring in the tidal zone.

The halophytic vegetation of the tidal estuaries of Vaygach Island and the Yugorsky Peninsula forms basis for some rare Arctic marsh biocenoses are highly vulnerable to human impact. These communities play an important role as elements of tidal estuary ecosystems, and their degradation could negatively affect local fauna. In particular, the estuarine marshes are inhabited by numerous migratory waterfowl and semi-aquatic birds. Therefore, we recommend that these communities should be covered by special protection. Given that the studied area is located near the regionally important Vaygach Island Wildlife Sanctuary, which has eco-tourism among its core activities, relevant awareness activities should be organized to inform tourists about the importance of the marsh vegetation for the environment.

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