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The flora and vegetation of Sosnovets Island, the White Sea

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The flora and vegetation of Sosnovets Island (White Sea Throat, Murmansk Region, Russia) has been studied and described in detail. This is a small island situated within the tundra zone, largely covered by a permafrost peatland with the presence of flarks, a palsa mire, and rock outcrops. Vascular plants of Sosnovets Island include 167 species and subspecies, of which 134 species and subspecies are considered native and 33 species are alien. The number of tundra species is higher and that of boreal species is lower than on the other White Sea islands; a few species with eastern distributions in East Europe are present; 6 protected species are recorded. Alien species were mostly transported from Arkhangelsk Region but partly from Central Russia; main pathways were forage, construction and gardens; one species (*Alchemilla cymatophylla*) was likely introduced as a polemochore. The vegetation of Sosnovets Island is represented by a complex of lichen, dwarf-shrub, cottongrass-sphagnous and sedge-sphagnous communities of the peatland, which covers the major part of the island, as well as dwarf-shrub and lichen tundras, coastal vegetation, willow thickets, dwarf cornel (*Cornus suecica*) and secondary anthropogenic meadows and grasslands. A palsa mire, marshes with *Calamagrostis deschampsioides*, highly dissected peatlands with cloudberry-crowberry-lichen communities on elevated sites and cottongrass-sphagnous communities in depressions are the unique features of the island's vegetation.

Introduction

Insular ecosystems have a certain level of peculiarity because of their restricted size and isolation, which makes them suitable for testing ideas and principles of ecology and evolution but also leads to their vulnerability under climatic changes and anthropogenic pressure (Drake et al. 2002). The biogeographic context of such studies concerns species richness and distribution, and also regionalization patterns of target study groups. Island biogeography (MacArthur & Wilson 1967) has been developed when the biodiversity of insular ecosystems is studied (Haila et al. 1982; Patiño et al. 2017); its results are of special interest when larger archipelagoes, harbouring many endemic species, are examined (e.g. Bramwell 1976), but may also reveal important dependencies when smaller and minor insular groups are considered (e.g. Rebassoo 1987).

Vascular plants of the White Sea islands were included into larger studies in Murmansk Region (Gorodkov 1953–1954; Pojarkova 1956–1966), Karelia (Kravchenko 2007) and Arkhangelsk Region (Schmidt 2005), although their particular descriptions and analyses are far from being comprehensive. Nevertheless, there is a long tradition of biodiversity studies of the White Sea, including numerous islands along its coasts.

Ivan I. Lepekhin was the first naturalist to visit the White Sea islands. In June 1772, upon completing his four-year journey across various provinces of the Russian Empire, he visited the Solovetsky Islands and provided a brief description of them (Lepekhin 1805). Almost a century thereafter, in 1861, the islands were visited by Karl Emil Inberg, an entomologist, and Gustaf Selin, a botanist, as a group of the Finnish expedition to Russian Lapland supported by *Societas pro Fauna et Flora Fennica* and the Consisto-

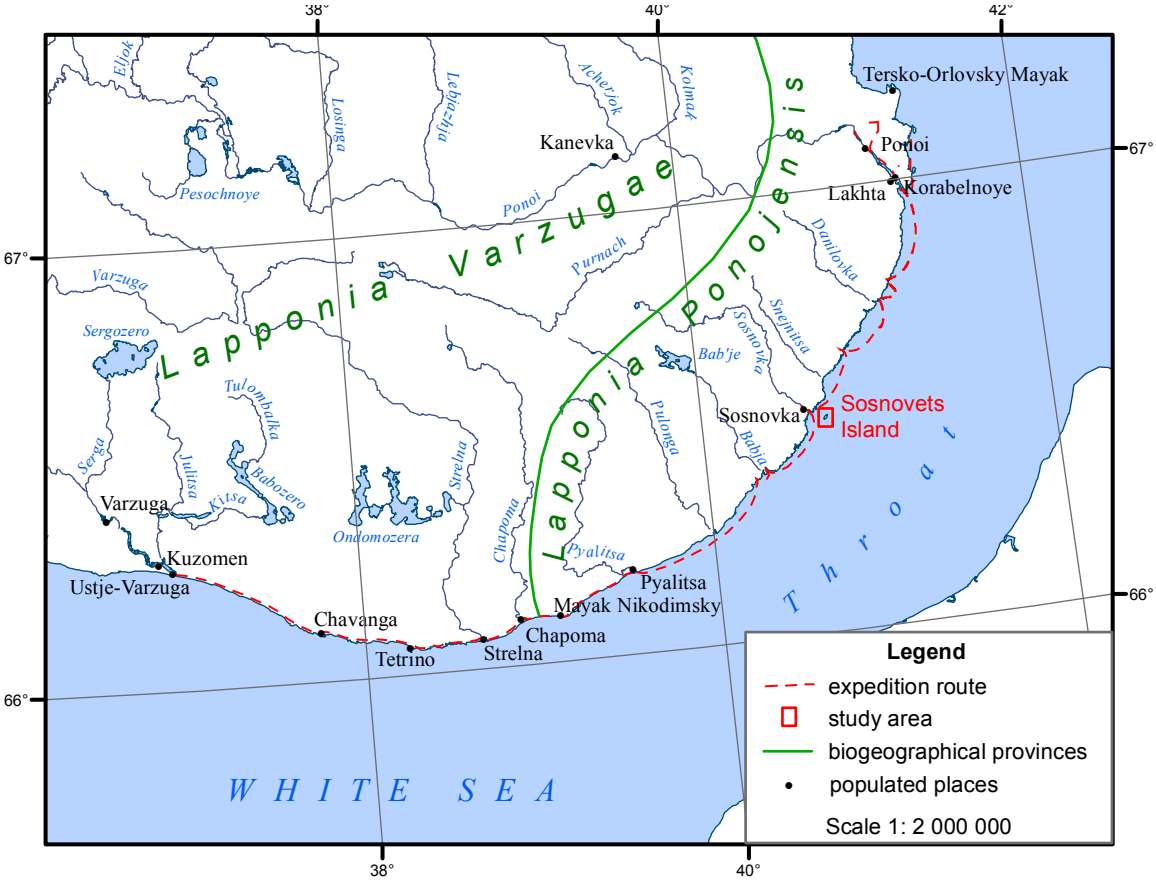

Figure 1. Sosnovets Island as a study area, and the route of our botanical expeditions to the south-eastern coast of the Kola Peninsula, July–August 2015–2016.

ry of the University of Helsinki. They stayed on the islands for two weeks, 11–25 July, and prepared the first scientific collections (insects and plants) from the White Sea islands (Sennikov & Kozhin 2018). For a certain period, further floristic studies on the White Sea islands were sporadic and non-organized (Lindberg 1914; Pobedimova et al. 1960; Uotila 2013).

When the Kandalaksha Strict Nature Reserve was founded in 1932, regular studies of the flora and vegetation had been established on the islands. A number of insular systems in the Kandalaksha Bay were explored, first floristic checklists (e.g. Bogdanova & Vekhov 1969a, 1969b; Vorob'eva 1986, 1989, 1996b; Zherikhina & Moskvicheva 2006), descriptions and classifications of their flora and vegetation (Breslina 1987; Vorob'eva 1996a; Kozhin 2011) were compiled. The flora of the Solovetsky Islands, the largest archipelago situated in the outer part of the Onega Bay, was regularly studied by the Moscow State University in 1980–2000 (e.g. Kiseleva et al. 1997), with later additions from other researchers (e.g. Savinov & Semashko 2014). Minor islands at the border of Murmansk Region and Karelia were explored by student expeditions from Moscow (Shipunov & Abramova 2006). Since 2000, the floras of the other Onega Bay islands have been studied by Karelian Research Centre of the Russian Academy of Sciences (Kravchenko et al. 2002, 2008, 2015). Recently, the information on the island floras of the Dvina Bay was published based on an expedition of the Northern (Arctic) Federal University in 2012 (Churakova et al. 2016).

As a result of these activities, numerous annotated check-lists, vegetation descriptions and analyses of human and natural dynamics of the island floras were published. However, all the previous studies were performed in the taiga zone and mainly in the western part of the White Sea. To extend the studies into the tundra zone, we have started a new initiative that aimed at revealing the flora and describing the vegetation of the islands situated along the north-eastern coast of the White Sea.

On this way, Sosnovets Island was selected as a case study. We described its complete flora and plant communities in order to provide insights into the features of the northern islands' species composition, the vegetation of the tundra zone and its anthropogenic transformation.

Study area

Sosnovets Island (Figs. 1, 2) is located 8 km south of the Arctic Circle near the south-eastern part of the Tersky Coast in the White Sea Throat, at 66° 29′ N, 40° 41′ E. The island has an area of 40.6 ha, a length of 1385 m, a width of 445 m, and a perimeter of ca 3.5 km. The summit plain is about 10–15 m above sea level and the maximum elevation situated in the southern part of the island

Figure 2. General view of Sosnovets Island from a powered paraglider. Photo: Boris B. Vakhmistrov.

is 16.2 m above sea level. The Sosnovets lighthouse is located in the central part of the island. The southern shore is lower and flatter than the northern and western ones. The tideland width comprises from 10 to 90 m. Sosnovetskaya Salma Strait with the depth of 6–11 m separates the island from the mainland. The minimal distance to the mainland is 3.3 km from the cape on the left side of the Sosnovka River mouth.

The geological structure of the Tersky Coast is formed by the eastern margin of the Baltic Shield. The island is formed by Neoarchean granite-gneisses, gneisses, migmatites and amphibolites, which belong to the Purnach Block near its border with the Tersky Block (Pozhilenko et al. 2002). The island's basement rock is overlaid with soft, mostly sandy deposits of the early Holocene marine terrace. Along with the eastern part of the Kola Peninsula, Sosnovets Island is undergoing tectonic subsidence (Koshechkin 1979). The sea-level rise leads to continuous erosion of loose deposits on the island's periphery. The abrasion of the Holocene deposits results in steep shore slopes as well as basement rock exposure.

The major part of the island, namely its summit plain and some slopes, is covered by a heavy layer of peatland with a thickness of 1–2 m. Such peatlands were termed 'arctic bog' by Zinserling (1934). The surface of the peatland is undulate; its elevated and marginal parts are divided by cracks into polygonal blocks with an area of 1–10 m^2, whereas flarks are formed in the lowest parts with a relatively small area. According to macrofossil analysis, the island's peat deposit belongs to the raised-bog (ombrotrophic) type; its higher layer consists of loose, dwarf-shrub peat, while the lower one is composed of denser, cottongrass peat (Kutenkov et al. 2018). The flarks are filled with fen sedge peat. Permafrost peatlands cover the major part of the island with a seasonal thaw depth of about 50–60 cm. In the central part of the island, north of the weather station, the peatland topography is more prominent and approaching that of palsa bogs. The southern part of the island is characterized by an undulating relief, stone and sand deposits with rock outcrops, the absence of permafrost and a considerably thinner peat layer.

The study area has a subarctic climate with long mild winters and cool summers, and a considerable impact of the White Sea. In the eastern part of the Tersky Coast, the climate is most severe among all the other regions of the Sea (Yakovlev 1961). As observed at the Sosnovets weather station (ID 22355), the average annual temperature during a long-term observation period accounted for –0.66°C. However, due to the trend towards temperature rise in the last two decades the average annual temperature has reached +0.24°C (www.rp5.ru; Novakovsky & Elsakov 2014). The average long-term annual frostless period comprises 150 days. The annual precipitation equals ca. 400 mm mostly occurring in the warm season with the recent tendency to increase. The snow layer with a depth of 10–20 cm, seldom 30 cm, usually does not cover the entire land surface. The air humidity is constantly high throughout the year, varying from 85.9 (May) to 91.8 (August), with the average value of 88.2%. High tides are typical of the study area, comprising 3.5 m on average and reaching 4.3 m in syzygy. Tidal currents are widespread in the White Sea Throat; in Sosnovetskaya Salma Strait, the high tide current is directed southwards, whereas the low tide current is directed northwards with a stream velocity of 1–2 knots (Anonymous 1954).

Attributing the study area to the existing vegetation divisions

Sosnovets Island is located on the limit between the tundra and forest-tundra zones, which accounts for the ambiguity in attributing it to a particular unit of vegetation division. According to the vegetation map of Murmansk Region (Chernov 1956), a narrow stripe along the coasts of the Barents and White seas from the Sem' Ostrovov to the Ponoi River mouth belongs to the 'typical tundra'. Besides, the islands situated along this stripe and further south (including Sosnovets Island) were attributed to the 'typical tundra' as well. In later vegetation studies, all the tundra areas of Murmansk Region were referred to as the southern tundra subzone, which was reflected on vegetation maps of Murmansk Region and the USSR. In particular, the vegetation of the White Sea coast in the vicinity of Sosnovka Village and the adjacent islands was classified as dwarf shrub

tundra (Chernov 1971; Isachenko & Lavrenko 1975).

According to the scheme of vegetation zones of the Nonblack-Earth Region of Russia, which includes the boreal and tundra regions of the European part of the USSR (Alexandrova & Yurkovskaya 1989), Sosnovets Island occupies an intermediate position between the Iokanga-Ponoi vegetation district, Kola subprovince, European and West Siberian tundra province, and the Ponoi-Tersky vegetation district, Kola-Karelia subprovince, North European taiga province. According to the vegetation zones of north-western Europe (Ahti et al. 1968), the coastal area and the islands in the White Sea Throat south of the Ponoi River mouth do not belong to the tundra zone. This delimitation of tundra is accepted in Alexandrova (1977). In Safronova et al. (1999), the eastern part of the Kola Peninsula is attributed to the East Scandinavian (Kola) vegetation district of the southern hypoarctic tundra subzone. In the up-to-date circumpolar map of the Arctic (CAVM Team 2003; Walker et al. 2005), the Kola Peninsula has been excluded from the low-shrub tundra subzone. However, a recent analysis of the vegetation and climate patterns by Koroleva (2006b) and Virtanen et al. (2015) suggested that the scheme of Walker et al. (2005) may need revision.

Based on our flora and vegetation knowledge, we accept the attribution of Sosnovets Island to the south subarctic tundra of Alexandrova (1977), otherwise called the south tundra in Chernov & Matveeva (1979). A more precise zonation of the Kola Peninsula is outside the scope of the present paper.

Field work and data analysis

The research material was collected during our botanical expedition to the south-eastern coast of the Kola Peninsula from the Varzuga River mouth to the Rusinga River (*Lapponia Varsugae* and *Lapponia Ponojensis*) in July – August 2015 and 2016. The expedition proceeded largely along the coastline near Sosnovka Village, Danilov Island, Danilovskaya Bay, the Ponoi River mouth, abandoned Ponoi Village, Goryainov Island, Aldobinskaya Guba Bay, the Tri Ostrova Archipelago and Rusinga Bay (Fig. 1). The field work on Sosnovets Island was performed in two days, 7–8 August 2016.

The island flora was recorded and described during field excursions. Firstly, we walked around the island twice to study the shore habitats in detail. Secondly, we studied the whole island by a network of parallel routes paying particular attention to specific natural and human-influenced habitats. As a result of visiting all the habitats throughout the island, the entire checklist was compiled and the occurrence of species was assessed using a five-grade scale: Un (unique) – one or two occurrences of a species on the island; Rar (rare) – rare plants (less than 10 individuals) observed in several locations; Sp (sparse) – plants are quite abundant but occupy less than 1/20 of the island; Fr (frequent) – plants cover from 1/20 to 1/2 of the island; Com (common) – plants are widespread and cover more than a half of the island. The checklist included all the natural and alien species. When detecting alien species, particular emphasis was placed on their habitat type and degree of naturalization. The checklist with species attributions to particular habitat types is placed in Appendix 1.

Phytosociological data were collected according to the relevé method of vegetation sampling (Yunatov 1964) at sites with homogeneous microtopography and moisture. Plots of 25 m^2 were used for large-scale communities, mostly in tundra, whereas small-scale communities, mostly in flarks and on meadows, were described in their natural limits. When compiling phytosociological relevés, precise geographical coordinates (WGS-84) as well as meso-relief position and micro-relief features were recorded; species abundance according to Braun-Blanquet scale or cover was estimated. Phytosociological data covered all types of the island's vegetation. In total, 76 relevés were obtained.

A map of the island's vegetation was compiled according to the authors' field observations and a set of relevés. The vegetation was visually interpreted using open-access satellite high resolution images. The plant community classification was based on the dominant (ecological-phytocoenotic) approach (Alexandrova 1969). To identify plant communities, dominant species and species-indicators of environmental conditions

were taken into account. In homogeneous vegetation, the main mapping units were community types, corresponding to association, subassociation or variant of local hierarchy. For heterogeneous vegetation that may be difficult to visualize as separate contours, with regular alternations in a certain topographic site, complexes (in case of peatland vegetation) and ecological series (in case of shore meadows) were used as mapping units. The legend consists of 24 basic units and 4 extensions marked with an asterisk, which denote the communities found with the basic ones. The map and its legend are placed in Appendix 2.

Collected specimens of vascular plants, mosses, liverworts and lichens were deposited in the Herbaria of Moscow State University (MW), University of Helsinki (H), Forest Research Institute of Karelian Research Centre (PTZ), Kandalaksha State Nature Reserve and Polar-Alpine Botanical Garden-Institute (KPABG).

History of botanical studies

In the early 19th century, scientists started exploring the coast and the islands of the White Sea Throat. The first expeditions to the area were directed by the Imperial Saint-Petersburg Academy of Sciences.

In 1837, naturalist Karl von Baer, botanist Alexander Lehmann and draughtsman Karl von Röder travelled from Arkhangelsk to Novaya Zemlya. They reached the Kola Peninsula in the vicinity of Pyalitsa Village on 2 July and stayed there for a few days. Then they passed by Sosnovets Island and arrived at the Ponoi River mouth and later at the Tri Ostrova Archipelago and further proceeded to Novaya Zemlya via the Barents Sea (Raikov 1961). On the way back the expedition vessel anchored near Sosnovets Island at the beginning of September and stayed here for several days due to foul weather. They explored the nearest vicinities of the Sosnovka River mouth, a place populated by the Saami. They provided several naturalistic descriptions and noted that the local forest almost reached the coastline, which is untypical of the south-eastern part of the Tersky Coast (Baer 1837a, 1837b).

In 1839, the Academy organized an expedition to Eastern Lapland with participation of Alexander von Schrenk, a plant collector of the Botanical Garden in Saint-Petersburg, and Wilhelm Boehtlingk, a geographer and geologist. On their route the naturalists travelled near Sosnovets Island (Fellman 1869). In 1840, the expedition of Baer with Alexander Theodor von Middendorff as a zoologist and student Pankevich as a collecting assistant explored the Kola Peninsula. Their vessel landed near Sosnovka Village on 15 June, and foul weather made them stay there for four days, during which the naturalists explored the neighbouring territories (Raikov 1961).

In 1841, the route of Franz Josef Ruprecht's expedition to Malozemelskaya tundra ('terra Samojedorum': Ruprecht 1845) passed near Sosnovets Island, where he stopped and collected several specimens probably on the adjacent mainland.

Botanical collections of these academic expeditions, supplied with extremely brief labels, were deposited in Komarov Botanical Institute (LE). To determine whether the specimens from 'Sosnovets' were actually collected on the mainland or on the island poses unavoidable difficulties as in the 19th century the village and the island were known under the same name (Baer 1837). We assume that, most likely, the island was not visited by these early expeditions.

The first naturalists known to visit Sosnovets Island were entomologist Johan [John] Reinhold Sahlberg and botanist August Johan Malmberg (later Aukusti Juhana Mela) supported by *Societas pro Fauna et Flora Fennica*. In 1870, they travelled across Russian Lapland and obtained vast collections of vascular plants (Uotila 2013). Sahlberg and Malmberg arrived at the island on 26 August and collected a few specimens of *Arctanthemum arcticum* subsp. *polare*, *Stellaria humifusa* and *Tripleurospermum maritimum* (deposited in H).

In 1889, Alfred Oswald Kihlman (later Kairamo) visited Sosnovka Village ('Sosnovets'), explored the vicinities and went upstream the Sosnovka River to Babozero (Akjawr) Lake in 12–18 August. He studied the adjacent tundra, paludified places and marshes (Kihlman 1890). Kihlman never visited the island itself; all his specimens deposited in H and attributed to 'Sosnovets' refer to the village rather than the island.

In 1913, Constantin Regel travelled across the Kola Peninsula and stayed at Sosnovka Village ('Sosnovets') in 12–18 August. Following the previous researchers, he studied the tundra, marshes and riparian vegetation on plains and small hills in the vicinities of the village; Regel also visited Babozero (Akjawr) Lake and the Babja (Akjok) River (Regel 1927). He never reached the island either.

In 1926, the first phenological observations were conducted on the island by B. Vorontsov, a staff member of the weather station (Smirnov 1927). He was also interested in botany and was the first to detect the larch on the Kola Peninsula near Sosnovka Village (Tolmatschev 1925; Kozhin & Sennikov 2016). The following year, an expedition of the Botanical Garden in Saint-Petersburg directed by Yuri D. Zinserling studied the island. Zinserling (1934) described the island's peatlands as 'arctic bog', a bog type that seldom occurs in the north-west of the European part of the USSR. He recorded permafrost peatlands throughout the island, which were thawing to depths of 30–40 cm at the end of summer, and *Empetrum nigrum* subsp. *hermaphroditum* and *Rubus chamaemorus*-dominated oligotrophic bogs with patches of crust-lichen vegetation, which he found widespread.

More than half a century after Zinserling, in July and August of 1986, the Kola geobotanical expedition from the Polar-Alpine Botanical Garden-Institute of Russian Academy of Sciences, directed by Irina P. Breslina, worked in the southeast of the Kola Peninsula (Breslina 1986). The landscape of Sosnovets Island was described by the expedition, several relevés were obtained, a preliminary checklist of vascular plants was compiled, and a substantial number of herbarium specimens (deposited in KPABG and MW) were collected. A quantitative and qualitative analyses of the island's flora was planned but this study had not been eventually completed, and even a draft floristic checklist had not been preserved in the archives. In 2000–2002, Natalya R. Kirillova (Kaneva), a student of the Kola Branch of the Petrozavodsk State University, visited the island and collected field material for her diploma thesis (Kaneva 2002).

As we see, botanists have repeatedly visited Sosnovets Island since the middle of the 19th century. Nevertheless, the results of these studies were left unpublished and the available data remained scarce. The name 'Sosnovets' was frequently mentioned in historical literature and on herbarium labels (Ruprecht 1845; Hjelt 1895, 1902, 1926), but this information was uncertain because the village and the island were known under the same name in early usage. In herbarium collections, this name may refer to the mainland part of the locality, i.e. Sosnovka Village (the collections of Baer, Kihlman and Schrenk), or to the island (the collections of Malmberg and Sahlberg).

Human occupation

Sosnovets Island is situated in the White Sea Throat near the sailing lines from the west and north to Arkhangelsk. Sosnovetskaya Salma Strait is the sole safe roadstead for vessels in the White Sea Throat, which attracted seafarers after crossing the White Sea from the Summer and Winter coasts to the Tersky Coast and helped them to avoid storms and wait out foul weather. On the western shore of the island several wooden crosses were installed to facilitate marine navigation. Because of this feature, Sosnovets Island commonly passed under the name of 'Cros ilond', or 'Krestovii' on early foreign maps and in travelogues (Reineke 1850; Komaritsin et al. 2001).

In 1822, a navigation watchtower was constructed on the island at the direction of Arkhangelsk Marine Service. The tower was fitted with wooden planks and painted red. Saami, who lived near the Sosnovka River mouth, were in charge of maintaining the tower, whereas the island remained uninhabited (Reineke 1850).

In 1862, a new lighthouse was constructed, with five buildings erected on its southern side for the lighthouse keeper and seven maintenance staff, and for food and kerosene supply. Since that year, meteorological data were regularly recorded by the lighthouse keeper. In 1896, Russian Hydrographic Service organized a separate weather station on the island to continuously obtain meteorological and hydrological data. In 1909, the lighthouse area was reconstructed, a new lighthouse was built, with a chapel, two dwelling houses, an alarm flagpole, two fog guns

and a weather box. In 1920, the weather station was handed over to Meteorological Service of the Russian Soviet Federative Socialist Republic. At that time the station already had a separate house and its own staff. In addition to the other activities, rock blasting and drilling were conducted on the island to construct a tide gauge in the 1930s (Komaritsin et al. 2001).

Consequently, a permanent population and a number of residential and technical buildings have been present on the island for more than one and a half centuries. At present, most of the buildings have not been used for a long time and are currently abandoned. Food supply and fuel to maintain the weather station and the lighthouse are annually delivered to the island from Arkhangelsk. Noteworthy is that the weather station and the lighthouse have always belonged to marine and weather services of Arkhangelsk and almost all the cargoes have been carried from the remote Summer Coast in Arkhangelsk Region rather than from the neighbouring Tersky Coast in Murmansk Region.

Vegetation

The vegetation of the island is represented by a complex of lichen, dwarf-shrub, cottongrass-sphagnous and sedge-sphagnous communities of the peatland, which covers the major part of the island, as well as dwarf-shrub and lichen tundras, coastal vegetation, willow thickets, dwarf cornel (*Cornus suecica*) and secondary anthropogenic meadows and grasslands (Appendix 2).

The summit plain of the island is largely covered with a permafrost peatland in its northern part. It is weakly dissected in the north and northeast: flat surface areas of the summit plain alternate with round gently elevated sites separated by wide and shallow depressions; dells draining the peatland, shallow and low-branched, are directed from the centre of the island to its east and west shores (Fig. 3.1). The permafrost peatland is more dissected in the western and especially southern parts of the island, near the lighthouse village; the dells are also directed mainly to the eastern and western shores of the island, where they become deeper, longer and forming a highly branched network. Round and elongated frost peat mounds with a diameter of 15–40 m and a height of up to 2 m are located among the dells (Fig. 3.2). On its southern margin, near the weather station, the peatland is morphologically similar to palsa mire and is treated as such (Fig. 3.3). Small pools occasionally occur in highly dissected parts of the peatland. South of the weather station, where the summit plain gradually decreases towards its southernmost tip, the central part of the island is covered with a thin discontinuous layer of dry peat without permafrost; the relief of the peatland is smooth, lacking mounds and expressed depressions (dells).

The vegetation cover of the permafrost peatland is represented by several community types distributed across different topographic sites. Peat mounds, flat surfaces, round gently elevated sites with indistinct wide depressions in between, characteristic of weakly dissected parts of the peatland, are occupied by **cloudberry (*Rubus chamaemorus*)-crowberry (*Empetrum nigrum* subsp. *hermaphroditum*)-lichen communities** (Fig. 3.4). Species composition of their herb layer (cover of up to 40–50%) is extremely poor; these communities often lack species other than dominants: *Empetrum nigrum* subsp. *hermaphroditum* and *Rubus chamaemorus*. Sometimes *Vaccinium vitis-idaea* and some other species may occur in such communities. In the lichen cover, *Cladonia arbuscula*, *C. rangiferina*, *Flavocetraria nivalis* and *Cetraria islandica* dominate and some chionophobous species (*Bryocaulon divergens*, *Alectoria ochroleuca*, *Gowardia nigricans*, *Sphaerophorus globosus*) are constant. The cover of mosses (*Dicranum elongatum* and *Pohlia nutans*, typical of dry peatlands) and liverworts (*Ptilidium ciliare*, *Sphenolobus minutus*) does not exceed 1%. The tops of mounds and gently elevated sites are cracked into polygonal blocks when drying. In their centres, lichen patches of crustose *Ochrolechia frigida* and cup-shaped *Cladonia* species (*C. deformis*, *C. borealis*, *C. squamosa*, *C. fimbriata* etc.) sporadically occur (Fig. 3.1); patches of bare peat are uncommon.

In the north and east of the island, the lichen abundance markedly decreases in the peatland margin near the shore slopes and **cloudberry-crowberry communities** are formed, similar to those described above but with the increased participation of *Empetrum nigrum* subsp. *her-*

maphroditum (75–90%) and the reduced cover of lichens (5–10%) (Fig. 3.5). We frequently observed this negative correlation between the lichen and crowberry abundances in the shore parts of islands and on remote islets also in the other regions of the White Sea. Apparently, this trend may result from the greatest values of surface air moisture at such sites, which favours active crowberry growth (Tybirk et al. 2000; Vasilevich & Bibikova 2011).

Similar cloudberry-crowberry communities occur also in the inner part of Sosnovets Island, around the lighthouse village and the weather station, as well as on a thin peat layer without permafrost. These communities are characterized by the presence of herbs including meadow and weedy species: *Chamaenerion angustifolium*, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Solidago virgaurea* subsp. *lapponica*, *Avenella flexuosa*, *Festuca ovina* and *Equisetum arvense* subsp. *alpestre*. In the herb layer, *Cornus suecica* is occasionally co-dominant; the cover of *Vaccinium vitis-idaea* is increased; in the moss layer, *Polytrichum hyperboreum* is present. The low abundance of lichens and the presence of herbs in these communities is more likely to be connected with constant trampling, not only by people but also by horses which used to be kept there, as well as with other types of long-term human disturbance rather than with habitat features.

Shallow depressions among elevated sites of permafrost peatland are occupied by **cloudberry (*Rubus chamaemorus*)-dominated communities** (Fig. 3.6), which are either monodominant or with crowberry and dwarf cornel as co-dominants (cover of 15–25%). Other species of vascular plants (*Dryopteris expansa*, *Rumex lapponicus*, *Luzula wahlenbergii*, *Vaccinium vitis-idaea*) and cryptogams (*Dicranum elongatum*, *D. majus*, *Lophozia silvicola*, *Cladonia rangiferina*, *Cetraria islandica* etc.) are represented by single individuals. As the depressions deepened, *Carex rariflora* with a cover of 10%, *Andromeda polifolia* and *Vaccinium uliginosum* appear in the communities. In the moss layer, the abundance of *Dicranum elongatum* increases and sphagnous and other hydrophilous mosses (*Sphagnum lindbergii*, *S. riparium*, *Polytrichum jensenii*, *Warnstorfia fluitans*) and liverworts (*Cephalozia lunulifolia*, *C. bicuspidata*, *Mylia anomala*, *Riccardia latifrons*, *Schistochilopsis incisa* etc.) appear with a cover of up to 7%.

In deep and well-expressed depressions between peat mounds, **cottongrass- and sedge-sphagnous flarks** are formed. The former are typical of relatively narrow depressions. The cottongrass-sphagnous flarks with a small number of species are most frequent. In such communities, *Eriophorum scheuchzeri* dominates with *Carex rariflora* as a co-dominant in the herb layer (Fig. 3.7). Other species of vascular plants are represented by single individuals; yet only cloudberry is constant while the others (*Carex aquatilis*, *C. canescens*, *Cornus suecica*, *Stellaria borealis*) sporadically occur. In the moss layer, *Sphagnum riparium* and *S. lindbergii* are dominant and *S. balticum* and *Warnstorfia fluitans* are common with a cover of up to 5% and less than 1%, correspondingly; liverworts are not regular.

Cottongrass-sphagnous flarks with *Eriophorum angustifolium* as a dominant and *E. scheuchzeri* as a co-dominant are less frequent. They are similar to the abovementioned community type in accompanying species of the herb layer; however, *Sphagnum angustifolium* dominates in their moss layer, whereas the cover of *S. riparium* and *S. lindbergii* does not exceed 1%.

Sedge-cottongrass-sphagnous communities with the dominance of *Eriophorum russeolum* and *Carex rariflora* in the herb layer occur in flarks of the palsa mire near the weather station at slightly less moist sites. In these communities, dwarf shrubs *Andromeda polifolia*, *Empetrum nigrum* subsp. *hermaphroditum* (cover of up to 7%) and *Vaccinium vitis-idaea* (cover less than 1%) are common. Except the dominants, herbs are not abundant yet quite numerous; *Coptidium pallasii*, *Stellaria borealis*, *Epilobium palustre*, *Luzula wahlenbergii*, *Eriophorum angustifolium*, *E. vaginatum*, *Rubus chamaemorus* etc. being most typical. In the moss layer, *Sphagnum flexuosum* dominates whereas *Aulacomnium palustre* and *Straminergon stramineum* are abundant. Apart from the common species like *Sphagnum riparium* and *S. lindbergii*, other mosses (*Sphagnum russowii*, *S. fimbriatum*, *Dicranum laevidens*) and liverworts (*Lophozia silvicola*, *Calypogeia muelleriana*, *Cephalozia* spp.) are present.

***Carex aquatilis*-dominated sedge-sphagnous communities** are characteristic of wide

Figure 3. Plant communities of Sosnovets Island. 1. Weakly dissected permafrost peatland with cloudberry-crowberry-lichen communities in the north-eastern part of the island; in the foreground, on the tops of peatland mounds, patches of crust lichen *Ochrolechia frigida* and cup-shaped *Cladonia* sp. are visible. 2. Highly dissected peatland with cloudberry-crowberry-lichen communities on elevated sites and cloudberry, cottongrass-sphagnous communities in depressions. 3. Palsa mire between the weather station and the lighthouse. 4. Cloudberry-crowberry-lichen community. 5. Cloudberry-crowberry community in the peatland's margin near the shore slope. 6. Cloudberry community in a shallow depression among elevated sites of the permafrost peatland. 7. Flark with the dominance of *Eriophorum scheuchzeri*, *Sphagnum lindbergii*, *S. riparium* among elevated sites of the permafrost peatland. 8. Sedge-sphagnous community with *Carex rariflora* in the herb layer and *Sphagnum fimbriatum*, *S. lindbergii*, and *S. riparium* in the moss layer in the lower part of a dell near the coastline. Photos: 1 – E. I. Kopeina; 2, 3, 7 – M. N. Kozhin; 4, 8 – E. O. Golovina; 5, 6 – S. A. Kutenkov.

flarks; they mainly occur in the palsa mire near the weather station. The cover of *Carex aquatilis* amounts to 40–50%, with other species of the herb layer: *Carex rotundata* (cover of up to 5%), *Epilobium palustre*, *Ranunculus hyperboreus, Rumex lapponicus*, *Luzula wahlenbergii*, *Agrostis mertensii*, *Bistorta vivipara*, *Carex canescens*, *Rubus chamaemorus*, *Montia fontana* etc. Dwarf shrubs, namely *Andromeda polifolia*, *Empetrum nigrum* subsp. *hermaphroditum*, *Vaccinium oxycoccos*, are sparse. *Sphagnum riparium* dominates in the moss layer; *Sphagnum squarrosum*, *Straminergon stramineum*, *Aulacomnium palustre*, *Warnstorfia exannulata*, *Scapania paludicula* are common but not abundant; other species, for example, *Sphagnum lindbergii*, *Polytrichum jensenii*, were found seldom with low cover.

At waterlogged sites, which have degraded as a result of human transformation of flarks, **dense sedge-grass communities** are formed. *Calamagrostis neglecta* subsp. *groenlandica*, *Phleum alpinum* and *Carex aquatilis* dominate in the herb layer, accompanied by *Chamaenerion angustifolium*, *Rumex lapponicus* and *Rubus chamaemorus. Sphagnum* spp. and *Warnstorfia fluitans* are present in the moss layer.

The dells draining the permafrost peatland gradually descend and widen towards the island's shoreline. In these depressions, various **sedge-sphagnous communities** with a peculiar moss layer composition occur. The communities of small depressions are characterized by a polydominant moss-lichen layer. In particular, *Sphagnum fimbriatum*, *S. lindbergii*, *S. riparium*, *Polytrichum jensenii* and *Warnstorfia fluitans* are abundant there, and *Lophozia silvicola* and *Cetrariella delisei* are typical (Fig. 3.8). *Carex rariflora* is the major dominant of the herb layer, sometimes accompanied by *Eriophorum scheuchzeri* or *Carex recta* as a co-dominant. *Cornus suecica*, *Rubus chamaemorus* and *Empetrum nigrum* subsp. *hermaphroditum* are constant; other herbs and dwarf shrubs (*Epilobium palustre*, *Stellaria borealis*, *Arctanthemum arcticum* subsp. *polare*, *Andromeda polifolia*, *Vaccinium uliginosum*) are sparse. Shrub willows, *Salix phylicifolia* and *S. glauca*, sometimes appear in these communities. In larger depressions, the moss layer mostly consists of *Sphagnum balticum* accompanied by *S. flexuosum*, *S. lindbergii* and *Polytrichum jenseni* with a cover of up to 10–15%. The herb layer is represented by *Carex rariflora* as a dominant, as well as dwarf shrubs *Empetrum nigrum* subsp. *hermaphroditum* and *Andromeda polifolia* along with *Rubus chamaemorus* and *Cornus suecica* as co-dominants with a cover of 5–20%. Due to the increase in moisture, sedge-sphagnous communities are formed with the dominance of *Carex aquatilis* and *C. rariflora* in the herb layer and *Sphagnum balticum* in the moss layer, with the absence of dwarf-shrubs and the increasing abundance of *S. riparium*. Larger waterlogged depressions on the western shore of the island are occupied by sedge-sphagnous communities with the dominance of *Carex aquatilis* and *Sphagnum riparium*, similar to those formed in flarks of the palsa mire. Nevertheless, these communities differ by a high abundance of *Carex rariflora* and *Polytrichum jensenii*, as well as by the presence of coastal species such as *Calamagrostis deschampsioides*, *Parnassia palustris*, *Arctanthemum arcticum* subsp. *polare*.

On slopes of the eastern and western shores of the island, large areas are covered with peat deposits. On the eastern shore, which is flatter, the summit plain slope and the adjacent shore line 15–30 m wide are occupied by **dwarf cornell-cloudberry-crowberry community**. Its dense herb layer (cover of about 95%) is represented by *Empetrum nigrum* subsp. *hermaphroditum* as a dominant and *Cornus suecica* (cover of 25–30%) with *Rubus chamaemorus* as co-dominants. *Vaccinium vitis-idaea* (cover of about 10%) is abundant; *Vaccinium uliginosum*, *Luzula wahlenbergii*, *Poa alpigena*, *Equisetum arvense* subsp. *alpestre* are typical; low shrubs of *Salix glauca* are sometimes present. The moss-lichen layer represented by *Cladonia arbuscula*, *C. stellaris*, *Flavocetraria nivalis*, *Dicranum majus* and *Ptilidium ciliare* is fragmentary. The extensive cover of *Cornus suecica* is probably determined by a higher snow accumulation. Along the peatland margin on the western shore, which is steeper, **cloudberry and crowberry-cloudberry communities** similar to those occupying shallow depressions on the summit plain are widespread.

Carex rariflora appears as a co-dominant in paludified crowberry communities on peatlands of shore slopes with slightly moist conditions. In more moist depressions below the sum-

mit plain slope, where snow is accumulated, *Empetrum nigrum* subsp. *hermaphroditum*, *Rubus chamaemorus*, *Carex rariflora* and *Cornus suecica* dominate, and *Rumex lapponicus*, *Stellaria borealis*, *Bistorta vivipara*, *Arctanthemum arcticum* subsp. *polare* are typical, whereas only single thallomes of *Cladonia rangiferina* and single individuals of *Dicranum majus* are present in the moss-lichen layer.

Sedge (*Carex rariflora*)-crowberry communities are formed in marginal parts of the peatland, adjacent to the shore, with a thin peat layer and a constant water inflow (Fig. 4.1). They have a lesser number of vascular plant species: *Rubus chamaemorus*, *Cornus suecica*, *Rhodiola rosea* are present with low abundance in addition to *Empetrum nigrum* subsp. *hermaphroditum* and *Carex rariflora*. The moss-lichen layer is more prominent due to a high abundance of numerous lichen species and their greater cover of up to 3–5%, which may be connected with a lesser moisture and a lesser level of snow accumulation. Along with *Cladonia rangiferina*, other lichens such as *C. arbuscula*, *C. uncialis*, *C. amaurocraea*, *Cetraria islandica*, *Sphaerophorus globosus*, *Flavocetraria nivalis* are present. Sedge-crowberry communities are more widespread on the western shore and in the southern part of the eastern shore, where a peat layer is thinner.

Tundra communities are formed on loose deposits and occupy a limited area in the southernmost tip of the island. Crowberry tundras with a low species number are typical of the summit plain, whereas crowberry-lichen *Flavocetraria nivalis*- and *Cladonia arbuscula*-dominated tundras with the presence of chionophobous *Gowardia nigricans* and *Alectoria ochroleuca* occur at elevated sites. Single individuals of cloudberry are seldom observed in these communities. Crowberry and lichen communities are usually disturbed by anthropogenic impact. Meadow and weedy species such as *Chamaenerion angustifolium*, *Trifolium repens*, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Equisetum arvense* subsp. *alpestre* also appear in these communities. The tundra does not form a continuous cover and alternates with homogeneous groups of *Chamaenerion angustifolium*, *Deschampsia cespitosa* and *Calamagrostis neglecta* subsp. *groenlandica*.

A peculiar dwarf shrub community was once observed on the SE-faced slope of the summit plain in the south of the island. Its species composition is influenced not only by a greater snow accumulation in winter and a sufficient insolation in summer but also by anthropogenic disturbance. Its herb layer is polydominant; *Empetrum nigrum* subsp. *hermaphroditum*, *Vaccinium uliginosum*, *V. vitis-idaea*, *V. myrtillus*, *Cornus suecica* and *Equisetum arvense* subsp. *alpestre* dominate; dwarf shrub *Arctous alpina* and numerous herb species such as *Avenella flexuosa*, *Solidago virgaurea* subsp. *lapponica*, *Hieracium atratum*, *H. nigrescens*, *Euphrasia wettsteinii*, *Phleum alpinum*, *Festuca ovina*, *Lysimachia europaea*, *Luzula multiflora* subsp. *frigida*, *Trifolium repens* are present with low abundance. *Dicranum scoparium* and *Polytrichum juniperinum* dominate; *Pleurozium schreberi*, *Hylocomium splendens*, *Sciuro-hypnum curtum*, *Sanionia uncinata*, *Barbilophozia lycopodioides* are typical in the sparse moss-lichen layer. These species are otherwise rare in dwarf shrub and lichen communities of the island. Lichen-crowberry communities with the presence of dwarf cornel in the herb layer and *Cladonia arbuscula*, *Cetraria islandica*, *Flavocetraria nivalis* in the moss-lichen layer are characteristic of the north-western slope of the summit plain in the southernmost tip of the island. The area of these communities is not large.

Willow thickets with forbs of slopes and valleys shielded from strong winds are widespread in the eastern side of the island's southern part. *Salix phylicifolia*, *S. glauca*, *S. lapponum* form a dense shrub layer with a height of 0.5–1.5 m. The herb layer usually consists of *Calamagrostis neglecta* subsp. *groenlandica*, *Rumex lapponicus*, *Vaccinium uliginosum*, *Empetrum nigrum* subsp. *hermaphroditum*, *Filipendula ulmaria*, *Bistorta vivipara*, *Cornus suecica*, *Veratrum album*, including *Comarum palustre* at waterlogged sites. The sparse moss layer is represented by the cover of *Sanionia uncinata* often containing hygrophilous mosses such as *Calliergon giganteum*, *Bryum pseudotriquetrum*, *Aulacomnium palustre*. Alien species *Deschampsia cespitosa*, *Poa pratensis*, *Vicia cracca*, *Phleum pratense*, *Sagina procumbens* indicate that these communities were partly transformed as a result of human activity in the 20th century.

Dwarf cornel (*Cornus suecica*) communities are the characteristic feature of the island's shore slope vegetation and are usually located in shallow depressions. In these communities dwarf cornel constantly dominates with a high cover, whereas other dominant species are usually absent. *Epilobium palustre*, *Bistorta vivipara*, *Rumex lapponicus*, *Dryopteris expansa*, *Rubus chamaemorus* are typical in the herb layer. Under wetter conditions, sedges appear in these communities: *Carex recta* on the eastern shore, *C. aquatilis* on the western shore, and *C. rariflora* on both shores. *Polytrichastrum alpinum* dominates in the sparse moss layer, whereas other moss and liverwort species (*Dicranum majus*, *Warnstorfia fluitans*, *Polytrichum jensenii*, *Cephaloziella* sp.) are rare. Under drier conditions, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Festuca rubra* subsp. *arctica*, *Cerastium fontanum* subsp. *fontanum*, *Equisetum arvense* subsp. *alpestre*, *Empetrum nigrum* subsp. *hermaphroditum* are common.

Peculiar sedge communities with a sparse or even absent moss layer are located on the shore slopes. **Communities with the presence of halophilous *Carex recta*** are characteristic of the eastern shore. They are situated in shallow depressions on gentle shore slopes and also occur associated with sedge-sphagnous communities in distal parts of the dells passing through the slopes from the summit plain with the permafrost peatland. Sometimes these communities ascend along the cracks reaching the summit plain of the island.

On the one hand, these may be polydominant communities with the dominance of *Carex recta*, *C. rariflora*, *Empetrum nigrum* subsp. *hermaphroditum*, *Rubus chamaemorus* and *Cornus suecica* in the herb layer (Fig. 4.2). While *Rumex lapponicus*, *Comarum palustre*, *Bistorta vivipara* and *Epilobium palustre* are constant, dwarf shrubs *Vaccinium uliginosum*, *V. vitis-idaea*, *Rhododendron tomentosum* and herbs such as *Juncus filiformis*, *Equisetum sylvaticum*, *Dryopteris expansa*, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena* are also present. Sometimes *Eriophorum angustifolium* and *Carex subspathacea*, seldom *Carex aquatilis* are abundant. Tiny plants of an annual herb, *Koenigia islandica*, can be found in moss tufts. The sparse moss layer (cover of up to 40%) consists of *Sphagnum squarrosum*, *S. riparium*, *S. fimbriatum*, *Polytrichum jensenii*, *Dicranum majus* etc.

On the other hand, these communities may be represented by dense stands of *Carex recta* being the single dominant. All the abovementioned herb species occur there while the dwarf shrubs are untypical and the moss layer is almost absent. Being located above the littoral and supralittoral zones, the *Carex recta* communities are exposed to wave run-up during heavy gales. As a result, marine water accumulates there, which favours the growth of *Carex recta*. These communities occasionally alternate with small monodominant groups of *Equisetum sylvaticum*, *Eriophorum scheuchzeri* and *Calamagrostis phragmitoides*. On the western shore, *Carex aquatilis* forms communities similar in accompanying species of the herb and moss layers. *Carex recta* seldom occurs in plant communities of the western shore, mainly in its southern part.

In the northern part of the island, on steep cliffs with drip moisture, which are not directly exposed to the sea, sparse plant communities of **rock vegetation** with herbs (*Carex lachenalii*, *Saxifraga rivularis*) and several tufts of mosses (*Bryum* spp., *Aulacomnium palustre*) occur.

Coastal vegetation is weakly developed on the island and is mostly represented by **sparse plant communities of coastal rock outcrops**. There are rocks, sometimes steep, on almost all the shores of the island. Along cracks of coastal rocks in the wave run-up zone, sparse groups of *Puccinellia capillaris* subsp. *pulvinata*, *Cochlearia arctica*, *Ligusticum scothicum*, *Arctanthemum arcticum* subsp. *polare*, *Tripleurospermum maritimum* subsp. *phaeocephalum*, *Mertensia maritima*, *Carex glareosa*, *Rhodiola rosea*, and separate tufts of *Bryum* sp. occur.

Above the limit of the stony or rocky littoral zone, medium-level coastal meadows stretch narrowly along the shore. They are slightly flooded during ordinary tides, submerged during syzygy and permanently influenced by wave run-up, especially during heavy gales. At well-drained sites on flat rocks, **marshes with *Festuca rubra* subsp. *arctica* and *Sanionia uncinata*** form a dense cover (up to 60–100%). Coastal species such as *Carex glareosa*, *Arctanthemum arcticum* subsp. *polare*,

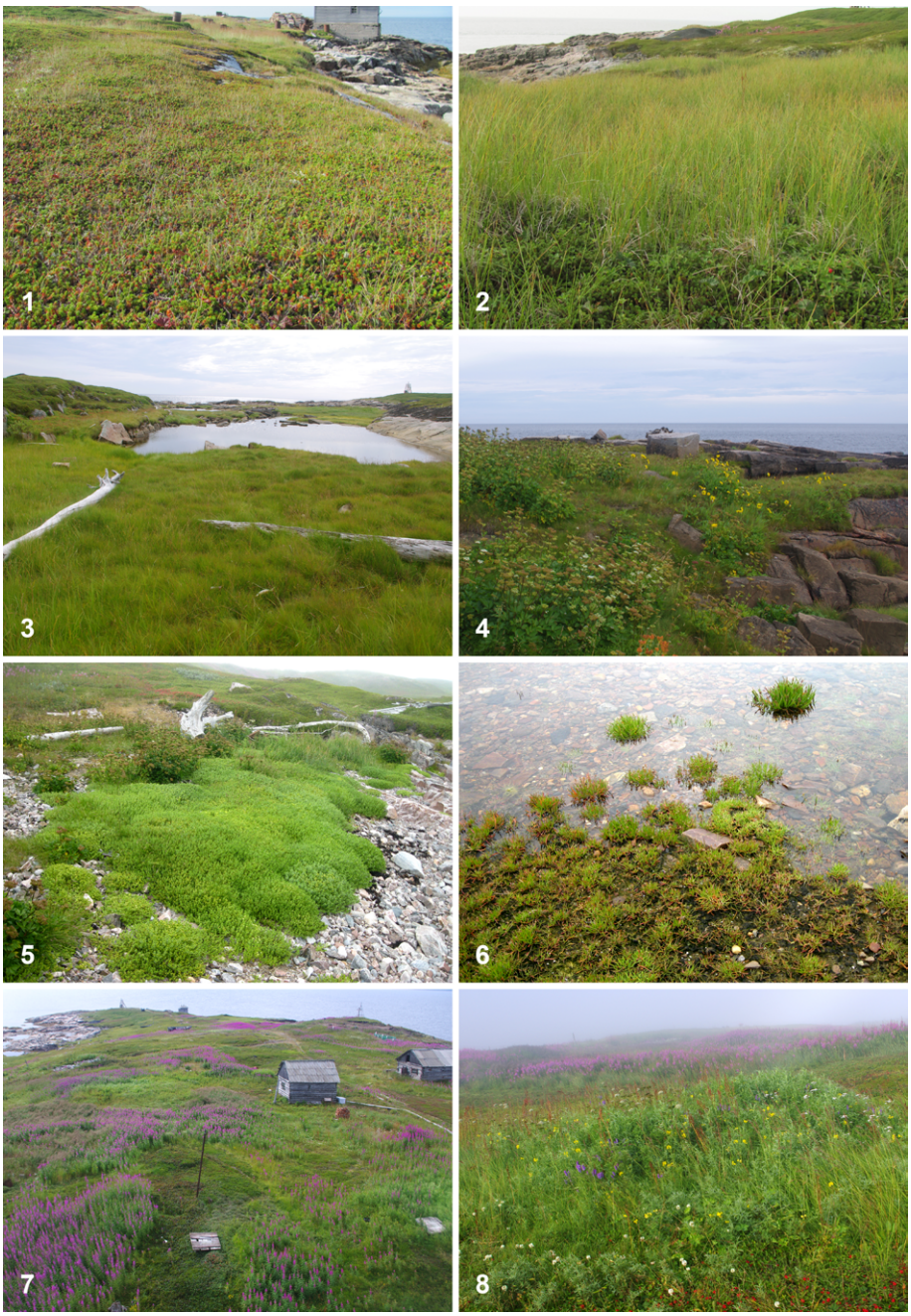

Figure 4. Plant communities of Sosnovets Island. 1. Sedge-crowberry community with *Carex rariflora* on the peatland margin in the western shore of the island. 2. Polydominant community with the dominance of *Carex recta*, *Empetrum nigrum* subsp. *hermaphroditum*, *Rubus chamaemorus* and *Cornus suecica* on the eastern shore of the island. 3. Medium-level marshes with *Festuca rubra* subsp. *arctica*, *Carex glareosa* and *C. mackenziei* in the southern part of the island. 4. Coastal high-level meadow with *Sonchus arvensis* var. *maritimus*, *Ligusticum scothicum*, *Festuca rubra* subsp. *arctica* in the southern part of the island. 5. Separate patches of *Honckenya peploides* subsp. *diffusa* on a cobble shore in the southern part of the island. 6. Coastal low-level meadow with *Plantago maritima* subsp. *borealis* on fine gravel deposits in the southern part of the island. 7. Willowherb (*Chamaenerion angustifolium*) meadows alternating with cloudberry-crowberry communities and crowberry tundra in the southern part of the island. 8. Mesophytic anthropogenic grass-forb meadows with alien species in the foreground and willowherb community in the background. Photos: 1, 2 – E. O. Golovina; 3, 4, 7, 8 – M. N. Kozhin; 5, 6 – E. I. Kopeina.

Argentina anserina subsp. *groenlandica*, *Parnassia palustris* and *Ligusticum scothicum* are typical of these communities (Fig. 4.3).

At moderately drained sites on flat rocks, along the margin of crowberry communities, **marshes of *Carex subspathacea* and *Carex glareosa*** sometimes occur. They are characterized by a relatively small area (from 2 to 10 m^2) and a sparse herb layer. In the sodded rock cracks, *Argentina anserina* subsp. *groenlandica*, *Festuca rubra* subsp. *arctica*, *Calamagrostis deschampsioides* and single tufts of *Bryum* spp. grow.

On shore slopes with some constant inflow of fresh water, **marshes with the dominance of *Calamagrostis deschampsioides* and *Carex rariflora*** are located. They form a relatively dense cover (of 50–95%). Along with coastal species *Stellaria humifusa*, *Arctanthemum arcticum* subsp. *polare,* their herb layer is composed of typical species of paludified places such as *Epilobium palustre* and *Triglochin palustris*. In the southwestern part of the island, a community with a considerable abundance of *Juncus gerardi* subsp. *atrofuscus* apart from the aforementioned species was observed. *Warnstorfia fluitans* and *W. exannulata* usually dominate in its dense moss layer, whereas *Sanionia uncinata* seldom occurs there.

Along elongated rock depressions, on steep and flat shore slopes, **grasslands of *Calamagrostis neglecta* subsp. *groenlandica*** sometimes occur. In the herb layer, narrow small reed dominates and is constantly associated with *Parnassia palustris*, *Festuca rubra* subsp. *arctica*, *Rumex lapponicus*. Sometimes *Allium schoenoprasum* appears in these communities, possibly as a co-dominant. The moss layer (*Sanionia uncinata*, *Sciuro-hypnum curtum* and *Bryum* sp.) is weakly developed.

Supralittoral lime-grass (*Leymus arenarius*) grasslands are present as separate fragments (with an area of 1–2 m^2) in the northern and southern parts of the island. They are usually formed along the shores on loose drift deposits overlaying the basement rock. *Leymus arenarius* conspicuously dominates in these communities but may be replaced by *Lathyrus maritimus*, *Ligusticum scothicum*, *Sonchus arvensis* var. *maritimus*, *Festuca rubra* subsp. *arctica* and *Conioselinum tataricum* (Fig. 4.4). In the moss-lichen layer, lichens *Cetraria islandica*, *Cladonia arbuscula*, *Flavocetraria nivalis* are frequent along with *Sanionia uncinata*. The vegetation cover of these meadows is characterized by mosaic structure, correlated with microtopography conditions, and by a considerable abundance of species from surrounding communities, e.g. *Cornus suecica*, *Empetrum nigrum* subsp. *hermaphroditum*, *Calamagrostis neglecta* subsp. *groenlandica*. These meadows are remarkable due to their highest species diversity among coastal communities.

Below the level of lime-grass meadows, on small areas of supralittoral sand and cobble, separate patches of ***Honckenya peploides* subsp. *diffusa*** (with an area of 1–6 m^2) occur as a narrow discontinuous belt (Fig. 4.5). In the northern part of the island, along the tideline, among heaps of decaying algae, a single patch of five shoots of *Bolboschoenus maritimus* has been observed.

In the southern part of the island, on its eastern side, there is a shallow depression that includes a small sea bay, which is occupied by peculiar coastal meadow and marsh communities. The whole ecological series of low-level coastal meadows, which are flooded daily, and of medium-level coastal meadows, which are flooded only in syzygy, is developed on sandy and silty deposits as well as on sandy and gravelly ones. In the lower level of silty littoral with more stagnant water, a sparse **community of *Puccinellia phryganodes*** was recorded in the only locality on the island. At a level above it, on sandy substrate with fine gravel, **low-level meadows of *Plantago maritima* subsp. *borealis*** occur (Fig. 4.6). Seaside plantain (*Plantago maritima*) forms a homogeneous dense cover, which includes single individuals of *Triglochin maritima* and *Stellaria humifusa*. Further above, they are replaced by a dense tuft of ***Carex subspathacea* communities** with single individuals of *Triglochin palustris*, *Argentina anserina* subsp. *groenlandica*, *Stellaria humifusa*, *Arctanthemum arcticum* subsp. *polare*, and sporadic clusters of *Bryum* sp.

At sites with constant inflow of fresh water, or in flat shallow depressions with stagnant sea water on silty deposits, **marshes of *Carex mackenziei*** are located. The sedge cover reaches 80% and includes single individuals of *Stellaria humifusa* and *Atriplex nudicaulis*, with intrusion of sparse shoots of *Festuca rubra* subsp. *arctica* and *Calamagrostis deschampsioides* from adjacent

medium-level coastal communities. *Carex rariflora* is common at desalinated paludified sites.

Further up, on the supralittoral, medium-level coastal meadows are represented by communities of *Festuca rubra* subsp. *arctica* and *Sanionia uncinata*, which are similar to those described above. However, apart from typical coastal species, *Galium palustre* and *Lathyrus palustris* subsp. *pilosus* were recorded in their composition. In the uppermost part of the supralittoral, the sole stripe of **coastal grassland of *Agrostis stolonifera* subsp. *straminea*** on the island occurs in the inner part of the bay. In this community, *Festuca rubra* subsp. *arctica*, *Cerastium fontanum* subsp. *fontanum*, *Stellaria crassifolia* are present; at wet sites, *Comarum palustre* is also observed. A single patch of *Alopecurus arundinaceus* (with an area of 1 m^2) was found among creeping bentgrass and arctic fescue meadows, although *Alopecurus arundinaceus* communities are quite common on mainland shores and islands of the White Sea.

On the top of a ridge between the weather station and the southernmost tip of the island, **sandy blowouts with sparse plant communities** of small size are found. They may have natural (erosion) or anthropogenic (sand extraction) origin. The vegetation is represented by highly sparse groups (cover of up to 5%) of *Rumex acetosella* subsp. *arenicola*, *Luzula spicata*, *Juncus trifidus*, *Omalotheca supina* and *Poa alpina*. *Bromopsis inermis,* an alien species, was discovered here close to dilapidated buildings.

Intensive anthropogenic activities on the island have already been in progress for one century and a half. The central and southern parts of the island near the lighthouse village and the weather station have been most transformed, with the development of **anthropogenic vegetation**.

***Chamaenerion angustifolium*-dominated anthropogenic meadows** are located on the summit plain and the shore slope; they have the greatest extension at moderately moist, disturbed sites (Fig. 4.7). These meadows are characterized by the absolute dominance of willowherb (*Chamaenerion angustifolium*), which forms continuous pink-coloured stands with a height of 0.7–1.5 m. The herb layer consists of apophytes: *Luzula multiflora* subsp. *frigida*, *Taraxacum repletum*, *Avenella flexuosa*, *Lysimachia europaea*, *Cerastium fontanum* subsp. *fontanum*, *Cornus suecica*, *Empetrum nigrum* subsp. *hermaphroditum*, *Festuca ovina*, *Vaccinium vitis-idaea* and *V. uliginosum*. Alien species, *Deschampsia cespitosa*, *Ranunculus acris* subsp. *acris*, *Stellaria graminea* and *Trifolium repens* are present as single individuals or in groups. The cover of the moss-lichen layer varies from 1 to 45%, which is determined not only by intensive disturbance and succession stage, but also by the density of the willowherb cover. In the moss-lichen layer, *Polytrichum juniperinum* and *Hylocomium splendens* are present, as well as some other species of mosses (*Dicranum majus*) and lichens (*Cetraria islandica*, *Cladonia arbuscula* and *Flavocetraria nivalis*) that are widespread in crowberry and dwarf cornel communities of the island.

Mesophytic **anthropogenic grass-forb meadows** of small size are located in the southern part of the island in the nearest vicinity of the weather station, village buildings and the pier. They are polydominant with irregular species patterns (Fig. 4.8). Alien meadow species such as *Lathyrus pratensis*, *Trifolium repens*, *Alchemilla subcrenata*, *Vicia cracca*, *Ranunculus acris* subsp. *acris* play a considerable role in these communities. However, the greatest species diversity in these meadows comes from the native flora (*Calamagrostis neglecta* subsp. *groenlandica*, *Anthoxanthum alpinum*, *Cornus suecica*, *Conioselinum tataricum*, *Rumex lapponicus*, *Rubus chamaemorus*, *Empetrum nigrum* subsp. *hermaphroditum*, *Achillea apiculata*, *Solidago virgaurea* subsp. *lapponica*, *Carex brunnescens* and *Cerastium fontanum* subsp. *fontanum*).

At waterlogged disturbed sites, on the summit plain and in shallow ravines on slopes in the island centre, ***Deschampsia cespitosa*-dominated anthropogenic grasslands** are most widespread. Such grasslands are similar to true meadows but differ from the latter in degraded species composition and the presence of species otherwise untypical of meadows. They replace cottongrass- and sedge-sphagnous flarks as well as adjacent cloudberry-crowberry communities, which had degraded in the result of permafrost thawing, increased drainage and unstable water regime. These processes destroying natural communities were triggered by human activities in the lighthouse area. In present-day communities, tufted hairgrass (*De-*

schampsia cespitosa) dominates with a cover of over 50%. The herb layer is characterized by mosaic structure and the presence of apophytes, e.g. *Rumex lapponicus*, *Dryopteris expansa*, *Equisetum arvense* subsp. *alpestre*, *Cornus suecica*, *Equisetum sylvaticum*, *Phleum alpinum*, *Cerastium fontanum* subsp. *fontanum* and *Lysimachia europaea.* Alien species such as *Achillea ptarmica*, *Alchemilla subcrenata*, *Phleum pratense* occur in small groups. Sometimes single shrubs of *Salix glauca* and *S. phylicifolia* with a height of up to 0.5 m are present. Since litter covers the surface almost completely, the moss-lichen layer is weakly developed (cover of less than 3%) and represented by *Sanionia uncinata*, *Sciuro-hypnum starkei* and *S. curtum.* Some communities resemble a tussock field, where hairgrass tufts reach a height of 10–15 cm and spaces between the tufts are filled with litter.

On the steep slopes and at their foot in the south-eastern part and near the pier in the western part of the island, vast **grasslands of *Calamagrostis phragmitoides*** are located. They are confined to anthropogenically disturbed sites with constant fresh water inflow. Small-reed forms a dense monodominant (over 70%) cover with a height of 1–2 m. *Comarum palustre*, *Carex aquatilis*, *Ranunculus repens*, *Veratrum album* are present in such communities in the western part, whereas *Dryopteris expansa* and *Phalaroides arundinacea* are found in the south-eastern part of the island.

At the southernmost tip, **severely disturbed vegetation** of various origin is situated. Some of these plant formations resulted from anthropogenic transformation of high-level coastal meadows and dwarf cornel communities, the others appeared by overgrowing of bare man-made lands. These plant groups emerged at sites of coal storage, technogenic waste, abandoned iron constructions and batteries. In this area *Poa alpigena*, *Festuca rubra* subsp. *rubra*, *F. rubra* subsp. *arctica*, *Solidago virgaurea* subsp. *lapponica*, *Chamaenerion angustifolium*, *Empetrum nigrum* subsp. *hermaphroditum*, *Cornus suecica* sporadically occur. *Rumex acetosella* subsp. *tenuifolius* and *Poa pratensis* rapidly overgrow bare soil and coal piles.

Synanthropic vegetation is present only in the closest proximity to residential buildings and is represented by small patches of alien *Trifolium repens* near the weather station at sites exposed to permanent trampling. Otherwise, habitats typical of synanthropic communities are occupied by nitrophilous coastal plants. For example, *Cochlearia arctica* frequently occurs on waste places with a humus substrate, whereas *Tripleurospermum maritimum* subsp. *phaeocephalum* is found on disturbed soils along the paths and near the houses.

Features of the island's vegetation

The vegetation of Sosnovets Island is typical of the tundra zone. Dwarf-shrub (*Empetrum nigrum* subsp. *hermaphroditum*) and lichen (*Cladonia arbuscula*, *Flavocetraria nivalis*) tundras are formed on sandy deposits on the summit plain of the island. They belong to the class ***Loiseleurio procumbentis-Vaccinietea*** Eggler ex Schubert 1960 and are similar to the tundras widespread in the plains and mountains of the Kola Peninsula (Koroleva 2006a). Since the major part of the island is overlaid by peatland, the tundra communities occupy only a small area, i.e. 0.4 ha (1% of the island's area).

Plant communities on drained elevated sites of the permafrost peatland (cloudberry-crowberry-lichen and cloudberry-crowberry) are similar to those described from vast peatlands of the tundra area east of the Kola Peninsula in the alliance ***Rubo chamaemori-Dicranion elongati*** Lavrinenko & Lavrinenko 2015, belonging to the class ***Oxycocco-Sphagnetea*** Br.-Bl. & Tx. ex Westhoff et al. 1946 (Lavrinenko & Lavrinenko 2015). The absence of characteristic species of the class ***Oxycocco-Sphagnetea***, namely *Andromeda polifolia*, *Rhododendron tomentosum* s. l., *Eriophorum vaginatum* and *Sphagnum* spp., is peculiar to these island's communities. This absence distinguishes these communities from those of the same alliance that are situated on the mainland of the Malozemelskaya and Bolshezemelskaya tundras and brings them closer to those of the Barents Sea islands (Vaygach, Kolguev and Dolgii), where these species are also absent or rare (Lavrinenko & Lavrinenko 2015). However, the differences in the species composition do not allow us to attribute these communities of Sosnovets to any

of the associations or subassociations described from the Barents Sea islands, which lay mainly within the subzone of typical tundra.

The majority of cottongrass- and sedge-sphagnous communities of the island belong to the class ***Scheuchzerio palustris-Caricetea fuscae*** Tx. 1937. They are formed in flarks and in wider coastal parts of dells draining the peatland, and can be attributed to the suballiance ***Caricenion rariflorae*** Lavrinenko et al. 2016 of the alliance ***Sphagnion baltici*** Kustova ex Lapshina 2010 due to the presence of the characteristic species of these syntaxa (Lavrinenko et al. 2016): *Sphagnum lindbergii*, *S. balticum*, *Polytrichum jensenii*, *Eriophorum scheuchzeri*. Several sedge-sphagnous communities of palsa mire flarks, which lack the abovementioned species but include *Calliergon stramineum*, *Warnstorfia exannulata*, *Epilobium palustre*, are analogous to communities of the alliance ***Drepanocladion exannulati*** Krajina 1933. The communities of the suballiance ***Caricenion rariflorae*** are widespread in palsa mire flarks of East European tundras, whereas the communities of the northern and high-elevation alliance ***Drepanocladion exannulati*** occur, although rarely, in flarks with flowing water (Lavrinenko et al. 2016).

The coastal vegetation of the island belongs to intrazonal classes ***Juncetea maritimi*** Br.-Bl. in Br.-Bl. et al. 1952 (alliances ***Puccinellion phryganodis*** Hadač 1946, ***Caricion glareosae*** Nordh. 1954, ***Armerion maritimae*** Br.-Bl. & De Leeuw 1936) and ***Ammophiletea*** Br.-Bl. & Tx. ex Westhoff et al. 1946 (alliance ***Agropyro-Honckenyion peploidis*** Tx. in Br.-Bl. et Tx. 1952) and is similar to the vegetation of the Kola Peninsula coast in both the tundra and taiga zones (Koroleva et al. 2011; Popova et al. 2017). The presence of *Calamagrostis deschampsioides*, which has a more eastern distribution in Fennoscandia and is very rare west of *Lapponia Ponojensis*, in some of these communities brings the island's coastal vegetation together with that of the eastern part of the Barents Sea (Matveeva & Lavrinenko 2011).

Although the vegetation of Sosnovets is typical of the tundra zone, it drastically differs from that of the other White Sea islands.

On the one hand, the majority of small islands of the White Sea are located in the Kandalaksha and Onega bays within the boreal zone. Hence, their vegetation significantly differs from that of Sosnovets Island, which is situated in the tundra zone. In the abovementioned bays, a considerable number of islands are also almost completely overlaid with peatland, although the morphology of these peatlands is different: they are formed by a layer of dry peat without permafrost, often cracked into polygonal peat blocks when drying; for this reason, flarks with their sedge-, cottongrass-sphagnous communities, which occur on Sosnovets Island, are absent here. The dominants of plant communities of these dry peatlands (*Empetrum nigrum* subsp. *hermaphroditum*, *Rubus chamaemorus*, *Cladonia arbuscula*, *Flavocetraria nivalis*) are the same as on Sosnovets Island but the other species are partly different due to the presence of several boreal and boreal-nemoral species (*Linnaea borealis*, *Luzula pilosa*, *Platanthera bifolia*) and the absence or rareness of arcto-montane species, mostly in the moss-lichen layer (*Thamnolia vermicularis*, *Alectoria ochroleuca*). On the other hand, the large peatland of Sosnovets Island (29.6 ha, 72.9% of the island's area) is typical of the south tundra and the forest-tundra but is not found on other small islands of the White Sea within the tundra zone.

At the same time, the vegetation of Sosnovets differs from that of the Barents Sea islands, which are also situated in the tundra zone and overlaid with peat. In the peatland's vegetation on the summit plain of the island, the communities with the dominance of fruticose lichens occupy almost 12.0 ha or 29.8% of the total area. The crowberry-dominated communities, natural and anthropogenic, are twice smaller (almost 6.5 ha, or 16.0%). In the vegetation of the summit plain peatlands of the Barents Sea islands, lichen communities are rare or absent, whereas cloudberry-crowberry and cloudberry-fern (*Dryopteris expansa*) communities prevail (Breslina 1969; Parfentieva 1969).

The communities with the dominance of *Carex recta,* a protected species in Murmansk Region, occupy a relatively large area (1 ha, 2.7%) and contribute to the peculiarity of the Sosnovets Island's vegetation.

The anthropogenic vegetation of Sosnovets Island is specific as well. As the island has been populated for more than 150 years, the latter is quite diverse and extensive (5.0 ha, 12.3%),

which is not typical of small islands of the White Sea. The anthropogenic vegetation is predominantly composed of alien meadow species, which form communities according to their ecological preferences: *Deschampsia cespitosa* in degraded wet flarks of the peatland, and the other species at moderately moist sites.

Floristic composition

Vascular plants of Sosnovets Island include 167 species and subspecies from 53 families, of which 134 species and subspecies from 36 families are considered native. In the native flora, Poaceae (21 species), Cyperaceae (19 species) and Asteraceae (13 species) are characterized by the highest species diversity, which is typical of north boreal and south arctic regions. Species composition, distribution across habitat types and frequency are presented in Table 1.

Taxonomic diversity of the native flora

Small islands (9–120 ha) of the Kola Subarctic considerably differ in the native species diversity. On average, the Kandalaksha Bay islands that are similar in size to Sosnovets have floras up to 50 species (or 30%) richer than that of Sosnovets Island. This difference may be explained by several reasons. Firstly, the Kandalaksha Bay islands are located within the boreal zone (north taiga subzone), where the species diversity is higher in general. According to Morozova (2008), the species richness of local floras within the mainland

Table 1. Vascular plant diversity of small (9–120 ha) islands of the White and Barents seas

Island	Area, ha	Taxonomic diversity			Sources
		Total	Native	Alien	
Sosnovets	40.6	167	134	33	original data
Kandalaksha Bay, White Sea					
Ovechii (Olenii Archipelago)	34	181	170	11	Vorob'eva 1996b
Bolshoi Berezovyi	39	190	174	16	Vuzman & Kozhin (pers. comm.)
Bolshoi Kurtyazhnyi	36	160	153	7	Vuzman & Kozhin (pers. comm.)
Tarasikha	50	163	155	8	Vorob'eva 1986
Medvezhii (Por'ya Guba)	57	240	230	10	Kozhin 2016
Bolshoi Asaf'ev	70	201	200	1	Bogdanova & Vekhov 1969a
Berezhnoi Vlasov	106	207	193	14	Vuzman & Kozhin (pers. comm.)
Vachev	107	207	204	3	Vorob'eva 1989
Telyachii (Olenii Archipelago)	120	181	173	8	Vorob'eva 1996b
Onega Bay, White Sea					
Luda Gorelka	9	142	132	10	Kravchenko et al. 2015
Sharapikha	11	120	120	0	Kravchenko & Timofeeva 2008
Lambasluda	15	129	127	2	Kravchenko et al. 2015
Rishluda	26	131	129	2	Kravchenko et al. 2015
Ropaki	36	151	148	3	Kravchenko et al. 2015
Kurich'ya Niloksa	43	106	105	1	Kravchenko & Timofeeva 2002
Oleshin	50	132	131	1	Kravchenko & Timofeeva 2002
Malyi Zayatskii	102	166	160	6	Kravchenko & Timofeeva 2002
Barents Sea					
Bolshoi Gavrilovskii	43	74	73	1	Paneva et al. 2006
Bolshoi Gusenets	11	55	53	2	Paneva et al. 2006
Bolshie Voronukhi	15.5	35	32	3	Paneva et al. 2006
Malyi Ainov	59	74	70	4	Parfentieva & Breslina 1969

part of the boreal zone in Murmansk Region is estimated to be slightly more than 300 species, whereas that of the tundra zone is less than 300 species. We have noted similar patterns in island ecosystems. Secondly, the Kandalaksha Bay is most diverse among the White Sea bays in terms of natural conditions (Bianki 1996), which determines the species richness of its islands. Thirdly, the majority of the Kandalaksha Bay islands have been thoroughly studied by the staff of the Kandalaksha State Nature Reserve, and their floras are consequently better known and more completely revealed.

Unexpectedly, the floristic diversity of Sosnovets Island is comparable to that of the Onega Bay islands of similar size, although the latter are situated in the southern part of the north taiga subzone (Table 1). On the one hand, this low diversity results from severe climatic conditions, mostly strong cold winds, which account for the natural absence of forests on the majority of islands and the peculiarities of their vegetation cover (Zinserling 1934). These were the reasons for Zinserling (1934) to separate this territory as a geobotanical district, the White Sea islands. On the other hand, Zinserling's conclusions were based on relatively short-term expeditions rather than comprehensive studies.

On the contrary, all the Barents Sea islands of similar size have a twice less diverse flora than that of Sosnovets Island. Despite all these islands (Sosnovets and the Barents Sea islands) are located in the same (tundra) zone, a considerable difference in their floristic diversity may stem from several reasons. First and foremost, the Barents Sea islands stretch along the coastline exposed to heavy gales, whereas Sosnovets Island is situated in the White Sea Throat and is therefore shielded against the storms. Notably, the eastern part of the Tersky Coast features the most severe climate of the White Sea, yet the number of days with heavy gales there is 2.5 times lower than on the East Murman Coast (Yakovlev & Kozlova 1971). Secondly, due to proximity to the taiga zone, a few boreal species appear also on Sosnovets Island.

Thus, the native species richness of Sosnovets Island occupies an intermediate position among the Kola Subarctic islands. Comparing the species diversity of Sosnovets Island with that of the other islands of similar size, it is poorer on Sosnovets than in the White Sea and richer than in the Barents Sea.

Phytogeoraphic features of the native flora

Sosnovets Island and the adjacent territories are referred to the tundra zone in this work, but their zonal classification has been debated for a long time. Its flora contains a number of species that are typical of the Hypoarctic phytogeographic belt (Yurtzev 1966), which is an extrazonal territory embracing the southern part of the tundra zone, forest tundra and the north taiga. According to Yurtzev (1966), the Hypoarctic phytogeographic belt is separated from the Arctic by the presence of a certain floristic complex and excludes the 'true' cryophilous tundra, whereas the limit between this area and the Boreal belt is formed by the northern limit of taiga on watersheds.

Irrespective of the classification applied, a specific trait of the vegetation in the north Kola section of the Hypoarctic (Yurtzev 1966), or in the Kola tundras (Safronova et al. 1999), or in the coastal parts of the entire Kola Subarctic (Breslina 1987) is a high abundance of *Empetrum nigrum* subsp. *hermaphroditum*. This is confirmed by our observations on Sosnovets Island, whose area is covered by crowberry for more than three fourth of its total surface.

In comparison with the other White Sea islands studied, the flora of Sosnovets stands out by its high specificity connected with the island's position within the tundra zone and at the easternmost edge of Fennoscandia. In particular, 14 species of its flora are absent from the other White Sea islands. These are predominantly the species of plain and mountain tundra, common to Fennoscandia, namely *Comastoma tenellum*, *Hieracium alpinum*, *H. atratum*, *H. nigrescens*, *Taraxacum hjeltii*, *Koenigia islandica*, *Luzula confusa*, *L. spicata*, *L. wahlenbergii*, *Ranunculus subborealis* subsp. *pumilus* and *Omalotheca supina*. Another set of specific taxa are typical arctic, such as *Arctanthemum arcticum* subsp. *polare*, *Coptidium pallasii*, *Calamagrostis deschampsioides*; and one specific boreal taxon is present, *Lathyrus palustris* subsp. *pilosus*. All these species pene-

trate into Fennoscandia only at its eastern margin, *Lapponia Ponojensis* and *Lapponia Murmanica*.

Another characteristic feature of the island's flora is a low number of typical boreal species. For example, it completely lacks native trees. Apart from widespread tundra shrub willows, woody plants are represented by prostrate shrubs of *Betula pubescens* subsp. *czerepanovii* with a height of up to 0.5 m. Bilberry (*Vaccinium myrtillus*) has a particularly low abundance on the island; its distribution is limited to the places with a higher snow accumulation in winters and a greater insolation in summers. The majority of common boreal species, e.g. *Linnaea borealis* L., *Luzula pilosa* (L.) Willd., *Maianthemum bifolium* (L.) F.W.Schmidt, were not detected on Sosnovets Island although they are widespread on the other White Sea islands studied.

The difference between the flora of Sosnovets Island and floras of the Barents Sea islands is less significant. Firstly, scattered individuals of several boreal species (*Carex paupercula*, *Carex chordorrhiza*, *Vaccinium oxycoccos*) still occur on Sosnovets Island, whereas they are completely absent from the northern Barents Sea islands. Secondly, species with eastern distributions in Fennoscandia (e.g. *Calamagrostis deschampsioides*) seldom reach the Barents Sea islands or are completely absent from the latter. Thirdly, the flora of the Barents Sea islands is considerably poorer due to the decrease in the number of coastal species, which is connected with a harsh climate and frequent heavy gales in the Barents Sea. It is noteworthy that one common arctic species, *Koenigia islandica*, was discovered only on Sosnovets Island and was not recorded on the other Kola Subarctic islands studied; however, this species is not rare in the adjacent mainland tundra.

A considerable number of coastal species as well as a high activity and abundance of crowberry and cloudberry are common features of Sosnovets and the other islands of the White and Barents seas. The absence of *Betula nana* in crowberry communities on dry peatlands on all the other islands of the White and Barents seas is also remarkable. Dwarf birch was observed on mires only on a few islands in the boreal zone, whereas it is widespread and plays a crucial role in the vegetation on the mainland in the tundra zone.

Protected species

There are six vascular plant species included in the Red Data Book of Murmansk Region (Konstantinova et al. 2014), of which one species (*Rhodiola rosea*) is included in the Red Data Book of the Russian Federation (Bardunov et al. 2008). The majority of protected species occur in coastal habitats.

Arctanthemum arcticum subsp. *polare* sporadically occurs on sea shores within the tundra zone of the Kola Subarctic; in particular, the record from Sosnovets is one of the southernmost.

Bolboschoenus maritimus is rare on the White Sea coast; its locality on the island is the easternmost in Murmansk Region and the only one in the tundra zone of the Kola Peninsula. Only four shoots, two of which being reproductive (with spikes), were discovered.

Carex recta sometimes occurs along the coasts of the White and Barents seas. Its population on Sosnovets, estimated at several thousands of reproductive shoots, is possibly the largest in Murmansk Region. This species occupies a vast part of the eastern shore of Sosnovets and penetrates into crowberry communities in the inner part of the island along dells and waterlogged sites.

Comastoma tenellum was recorded in a small number of individuals on forb-grass meadows with minor anthropogenic impact, which are its typical habitats in the east of the Kola Peninsula.

Coptidium pallasii was once recorded in a small number of individuals in flarks of the palsa mire.

Rhodiola rosea sporadically occurs on coastal rocks throughout the island. It is frequent in the east of the Tersky Coast.

Alien species and their origin

The flora of Sosnovets Island includes 33 alien species of vascular plants, which constite 20% of its total species number. This is the highest number of alien species among the islands of similar size in the White and Barents seas (from 9 to 120 ha) (Table 1). This high diversity and wide distribution of alien species is connected with the island being explored and populated for a long time. In particular, a permanent human popula-

tion has been living on the island for more than 150 years, making it the only small island with permanent population in the Kola Subarctic. In the 19th and the 20th centuries, various economic activities took place also on the other islands of small size in the White and Barents seas but these islands remained unpopulated. The pomors used different parts of the White Sea for trap fishing and built small houses to store their fishing equipment, e.g. on Malyi Berezovyi and Luda Gorelka (Nikolsky 1927, Kravchenko et al. 2015). On Medvezhii Island in the Por'ya Guba Bay, silver was mined and barracks for workers were built in the 18th and the 19th centuries (Efimov 1970). In various parts of the Kandalaksha Bay (Bolshoi Kurtyazhnyi and Berezhnoi Vlasov islands) and on the Ainov Islands in the Barents Sea, hayfields were situated (Matsak 2005). On average, 10 alien species were discovered on each of these islands; many of these species began to naturalize also on the other islands. The threefold greater number of alien plants detected on Sosnovets Island can be explained by its long history of diverse economic activities, which drastically differs from that of the other small islands studied in the Kola Subarctic.

Since the village of the lighthouse keepers and the weather station staff had been established on Sosnovets, a regular supply of food, construction materials, and fuel on the basis of the supply system for Arctic polar stations was organized, which had a strong impact on the island's flora.

Five grass species directly used as forage, namely *Phleum pratense*, *Alopecurus pratensis*, *Bromopsis inermis*, *Festuca rubra* subsp. *rubra* and *Elytrigia repens*, were discovered on the island. These species are usually sown on agricultural fields in the boreal zone. Apart from them, a considerable number of plants characteristic of managed or disturbed meadows and abandoned fields were found as accompanying species, such as *Agrostis capillaris*, *A. gigantea*, *Alchemilla subcrenata*, *Deschampsia cespitosa*, *Galium mollugo*, *Geranium pratense*, *Hieracium umbellatum*, *Lathyrus pratensis*, *Leucanthemum vulgare*, *Phalaroides arundinacea*, *Sagina procumbens*, *Ranunculus acris* subsp. *acris*, *R.* aggr. *auricomus*, *R. repens*, *Scorzoneroides autumnalis*, *Stellaria media*, *Trifolium pratense* var. *pratense*, *T. repens*, *Veronica longifolia*, *Vicia cracca*, *V. sepium*. These species appeared on the island as a result of long-term hay supply to feed horses, which were kept there in the 20th century. Plant diaspores dropped from the hay gave rise to populations of alien plants that have established and still remain in disturbed communities. No evidence of these species having been cultivated on the island was observed.

The majority of these species are widespread in the boreal zone and are common on fields and semi-natural meadows in the middle taiga (Parinova 2010), whereas in the tundra zone of the Kola Subarctic they are strictly alien. In the north taiga of Russian Lapland, only a few of these species, namely *Agrostis capillaris*, *A. gigantea*, *Deschampsia cespitosa*, *Hieracium umbellatum*, *Scorzoneroides autumnalis*, *Phalaroides arundinacea*, *Sagina procumbens*, *Trifolium pratense* var. *pratense* and *Veronica longifolia*, may be regarded as native. Apart from the meadow species, a single shrub of *Salix caprea* subsp. *caprea* was recorded, whose diaspores may also have emerged on the island with forage. This mass occurrence of plants typical of middle taiga meadows suggests that the hay was delivered to Sosnovets from Arkhangelsk Region. This conclusion is further supported by the presence of *Achillea ptarmica*, an alien species that is absent from the Kola Peninsula, whereas it widely occurs on floodplain forb-grass meadows, shrub thickets and riverbanks in the middle taiga of Arkhangelsk Region (Schmidt 2005).

Among alien plants typical of meadows, *Alchemilla cymatophylla* is an extraordinary finding as this species was unknown from the eastern part of Murmansk Region despite its presence in the western part (Kurtto et al. 2007). This species cannot have been transported with hay from Arkhangelsk Region because it was only once collected there in a remote area of the Mezen River basin (Schmidt 2005), where it is treated as alien (Kurtto et al. 2007). In Finland, *A. cymatophylla* is considered of polemochore origin, i.e. a war-time immigrant (Heikkinen 1969); it occurs mostly along the present-day Russian border (Piirainen 2019). Its secondary distribution in East Fennoscandia runs largely along the Russian-Finnish border and continues from the northernmost part of Karelian Republic to the western part of Murmansk Region, as do the distributions

of other polemochore species of *Alchemilla* that occur in northern Finland; native distributions of such species are centered in the hemiboreal zone from the Baltic countries to Central Russia (Piirainen & Chkalov 2018). Considering this pattern, we think it possible that *A. cymatophylla* had been brought to Sosnovets as a result of long-distance transportation of hay supply, most likely in the war time when the Russian army required large quantities of hay from Central Russia.

A small population of *Euphrasia stricta* var. *brevipila* was observed on a single spot near the lighthouse tower, on a small meadow with a dense moss cover and other apophytes. This community represents a stage of plant cover demutation, which has been ongoing for decades. The species may have appeared on the island when the lighthouse tower was reconstructed in 1960. In Murmansk Region, *E. stricta* var. *brevipila* occurs at sites with strong anthropogenic disturbance. We think its presence on the island is linked with cargo transportation from Arkhangelsk, since it is widespread on meadows, along roads, on fields and fallow lands in Arkhangelsk Region up to the limit of the north taiga (Schmidt 2005).

Rumex acetosella subsp. *tenuifolius,* an alien subspecies of anthropogenically disturbed sites, is widespread in the southern part of the island. A few juvenile plants of *Melilotus* sp., which belong to a contemporary ephemeral introduction, were observed on a recent coal pile in the eastern part of the island.

Due to severe climatic conditions, kitchen gardens were little used in the island's village. Only a single depauperate shrub of *Ribes nigrum* (with a height of up to 30 cm) was observed among crowberry communities near the weather station as a relic of cultivation.

Conclusions

Sosnovets Island significantly differs from the other islands of the White and Barents seas in its flora and vegetation.

The native species richness of Sosnovets Island occupies an intermediate position among the Kola Subarctic islands. Comparing the species diversity of Sosnovets Island with that of the other islands of similar size, it is poorer than on islands in the White Sea and richer than on islands in the Barents Sea. Its peculiar features are explained by the eastern localtion of Sosnovets within the Kola Peninsula. There are six protected species in the flora of Sosnovets, of which one species, *Carex recta*, plays a considerable role in the vegetation.

As the island has been populated for more than 150 years, its plant cover was partly transformed. The alien flora of Sosnovets island is most diverse compared with similar-size marine islands of the Kola Subarctic and contains typical meadow species of the middle taiga subzone, which were transported with regular forage supply (hay transportation) from Arkhangelsk Region. The introduction of a few other alien species can be linked with construction activities and war-time long-distance forage supply.

The vegetation of the island is remarkable due to a significant diversity of plant communities, which were developed because of natural conditions (extensive permafrost peatlands and marine severe climate) and anthropogenic impact. The palsa mire, the marshes with *Calamagrostis deschampsioides*, the highly dissected peatland with cloudberry-crowberry-lichen communities on elevated sites and the cottongrass-sphagnous communities in depressions are the unique features of the island's vegetation; among small islands of the White Sea, they were recorded only on Sosnovets.

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Appendix 1. Vascular plant flora of Sosnovets Island, the White Sea.

Status
● – native; ○ – alien.
Main habitats
1. Crowberry tundra on mineral deposits and crowberry- and cloudberry-dominated communities on the peatland.
2. Lichen tundra on mineral deposits and cloudberry-crowberry-lichen communities on the peatland.
3. Dwarf shrub (*Empetrum nigrum* subsp. *hermaphroditum*, *Vaccinium myrtillus*, *V. uliginosum*, *Cornus suecica*) tundra on SE-facing slopes.
4. *Cornus suecica*-dominated communities.
5. Willow thickets.
6. Paludified crowberry communities with *Carex rariflora* and small fens with *C. rariflora*.
7. Paludified coastal community with *Carex recta*.
8. Sedge- and cottongrass-sphagnous flarks.
9. Coastal meadows, grasslands, marshes and rocks.
10. Sandy blowouts.
11. Anthropogenic and synanthropic vegetation and disturbed sites.
Regional protected status is given in accordance with Red Data Book of Murmansk Region (Konstantinova et al. 2014).
Plant names are provided according to FinBIF (2019).

Status	Species	Main habitats										Frequency	Regional protected status
		1	2	3	4	5	6	7	8	9	10	11	
●	*Achillea apiculata* N.I.Orlova	+			+					+		+	Rar	
○	*Achillea ptarmica* L.											+	Rar	
○	*Agrostis capillaris* L.				+							+	Rar	
○	*Agrostis gigantea* Roth											+	Rar	
●	*Agrostis mertensii* Trin.				+				+				Un	
●	*Agrostis stolonifera* L. subsp. *stolonifera*				+					+			Rar	
●	*Agrostis stolonifera* subsp. *straminea* (Hartm.) Tzvelev									+			Rar	
○	*Alchemilla cymatophylla* Juz.											+	Rar	
○	*Alchemilla subcrenata* Buser											+	Rar	
●	*Allium schoenoprasum* L.									+		+	Rar	
●	*Alopecurus arundinaceus* Poir.									+			Un	
○	*Alopecurus pratensis* L.											+	Rar	
●	*Andromeda polifolia* L.	+				+	+						Rar	
●	*Angelica archangelica* L.					+							Un	
●	*Anthoxanthum alpinum* Á.Löve & D.Löve				+					+			Rar	
●	*Arctanthemum arcticum* subsp. *polare* (Hultén) Tzvelev	+			+		+			+		+	Rar	3
●	*Arctous alpina* (L.) Nied.	+	+	+									Rar	
●	*Argentina anserina* subsp. *groenlandica* (Tratt.) Á.Löve									+			Rar	
●	*Atriplex nudicaulis* Boguslaw									+			Rar	
●	*Avenella flexuosa* (L.) Drejer	+		+								+	Rar	
●	*Betula pubescens* subsp. *czerepanovii* (N.I.Orlova) Hämet-Ahti	+	+										Un	
●	*Bistorta vivipara* (L.) Delarbre	+		+	+	+	+	+	+	+			Rar	
●	*Bolboschoenus maritimus* (L.) Palla									+			Un	3
○	*Bromopsis inermis* (Leyss.) Holub											+	Rar	
●	*Calamagrostis deschampsioides* Trin.	+				+				+			Rar	
●	*Calamagrostis neglecta* subsp. *groenlandica* (Schrank) Matuszk.	+			+	+		+	+	+		+	Sol	

App. 1. cont.

Status	Species	Main habitats											Frequency	Regional protected status
		1	2	3	4	5	6	7	8	9	10	11		
●	*Calamagrostis phragmitoides* Hartm.	+	+		+			+		+		+	Sp	
●	*Carex aquatilis* Wahlenb.				+		+	+	+				Sol	
●	*Carex bigelowii* Torr. ex Schwein.					+				+			Rar	
●	*Carex brunnescens* (Pers.) Poir.	+	+		+						+		Rar	
●	*Carex canescens* L.						+	+	+				Rar	
●	*Carex cespitosa* L.											+	Un	
●	*Carex chordorrhiza* Ehrh.								+				Un	
●	*Carex glareosa* Wahlenb.	+								+			Rar	
●	*Carex lachenalii* Schkuhr									+			Un	
●	*Carex mackenziei* V.I.Krecz.									+			Rar	
●	*Carex paupercula* Michx.								+				Un	
●	*Carex rariflora* (Wahlenb.) Sm.				+		+	+	+				Sol	
●	*Carex recta* Boott	+			+		+	+		+			Rar	3
●	*Carex rotundata* Wahlenb.								+				Un	
●	*Carex subspathacea* Wormsk. ex Hornem.	+			+			+		+			Rar	
●	*Cerastium alpinum* L. subsp. *alpinum*	+			+					+			Rar	
●	*Cerastium fontanum* Baumg. subsp. *fontanum*	+		+	+	+	+		+	+		+	Rar	
●	*Chamaenerion angustifolium* (L.) Scop.	+	+	+	+	+		+				+	Sol	
●	*Cochlearia arctica* Schltdl. ex DC.									+		+	Rar	
●	*Comarum palustre* L.					+	+	+					Rar	
●	*Comastoma tenellum* (Rottb.) Toyok.											+	Rar	2
●	*Conioselinum tataricum* Hoffm.				+					+		+	Rar	
●	*Coptidium pallasii* (Schltdl.) Á.Löve & D.Löve						+		+				Un	2
●	*Cornus suecica* L.	+	+	+	+	+	+	+	+	+		+	Sol	
○	*Deschampsia cespitosa* (L.) P.Beauv.				+							+	Sol	
●	*Dianthus superbus* L.			+						+		+	Rar	
●	*Dryopteris expansa* (C.Presl) Fraser-Jenk. & Jermy	+			+		+	+				+	Rar	
○	*Elytrigia repens* (L.) Nevski											+	Rar	
●	*Empetrum nigrum* subsp. *hermaphroditum* (Hagerup) Böcher	+	+	+	+	+	+	+	+			+	Com	
●	*Epilobium palustre* L.				+	+	+	+	+	+			Rar	
●	*Equisetum arvense* subsp. *alpestre* (Wahlenb.) Schönswetter & Elven	+	+	+	+		+	+		+		+	Rar	
●	*Equisetum pratense* Ehrh.		+									+	Rar	
●	*Equisetum sylvaticum* L.	+				+		+				+	Rar	
●	*Eriophorum angustifolium* Honck.				+	+	+	+	+				Rar	
●	*Eriophorum russeolum* Fr.						+		+				Un	

App. 1. cont.

Status	Species	Main habitats											Frequency	Regional protected status
		1	2	3	4	5	6	7	8	9	10	11		
●	*Eriophorum scheuchzeri* Hoppe				+		+		+				Rar	
●	*Eriophorum vaginatum* L.						+		+				Rar	
○	*Euphrasia stricta* var. *brevipila* (Burnat & Gremli) Hartl											+	Un	
●	*Euphrasia wettsteinii* G.L.Gusarova	+		+						+			Rar	
●	*Festuca ovina* L.	+	+	+	+							+	Rar	
○	*Festuca rubra* L. subsp. *rubra*									+		+	Rar	
●	*Festuca rubra* subsp. *arctica* (Hack.) Govor.	+	+	+	+	+	+	+		+		+	Rar	
●	*Filipendula ulmaria* (L.) Maxim.					+							Un	
○	*Galium mollugo* L.											+	Rar	
●	*Galium palustre* L.					+		+					Rar	
●	*Galium trifidum* L.				+	+							Un	
○	*Geranium pratense* L.											+	Un	
●	*Geranium sylvaticum* L.											+	Un	
●	*Hieracium alpinum* L.	+	+									+	Rar	
●	*Hieracium atratum* Fr. s.l.	+	+	+								+	Rar	
●	*Hieracium coniops* Norrl.	+	+									+	Rar	
●	*Hieracium lapponicum* Fr.					+						+	Un	
●	*Hieracium nigrescens* Willd. s.l.			+									Rar	
○	*Hieracium umbellatum* L.											+	Un	
●	*Hierochloë hirta* subsp. *arctica* (J.Presl) G.Weim.									+			Rar	
●	*Honckenya peploides* subsp. *diffusa* (Hornem.) Hultén									+			Rar	
●	*Huperzia selago* subsp. *appressa* (Bach. Pyl. ex Desv.) D.Löve ex Tzvel.											+	Un	
●	*Juncus filiformis* L.				+	+		+	+				Rar	
●	*Juncus gerardi* subsp. *atrofuscus* (Rupr.) Printz									+			Rar	
●	*Juncus trifidus* L.	+									+		Un	
●	*Koenigia islandica* L.							+	+	+			Un	
●	*Lathyrus maritimus* (L.) Bigelow									+			Rar	
●	*Lathyrus palustris* subsp. *pilosus* (Cham.) Hultén					+							Un	
○	*Lathyrus pratensis* L.					+						+	Rar	
○	*Leucanthemum vulgare* Lam.											+	Un	
●	*Leymus arenarius* (L.) Hochst.	+								+			Rar	
●	*Ligusticum scothicum* L.				+					+		+	Rar	
●	*Luzula confusa* Lindeb.		+										Rar	
●	*Luzula multiflora* subsp. *frigida* (Buchenau) V.I.Krecz.		+	+	+			+		+		+	Rar	
●	*Luzula spicata* (L.) DC.	+										+	Rar	

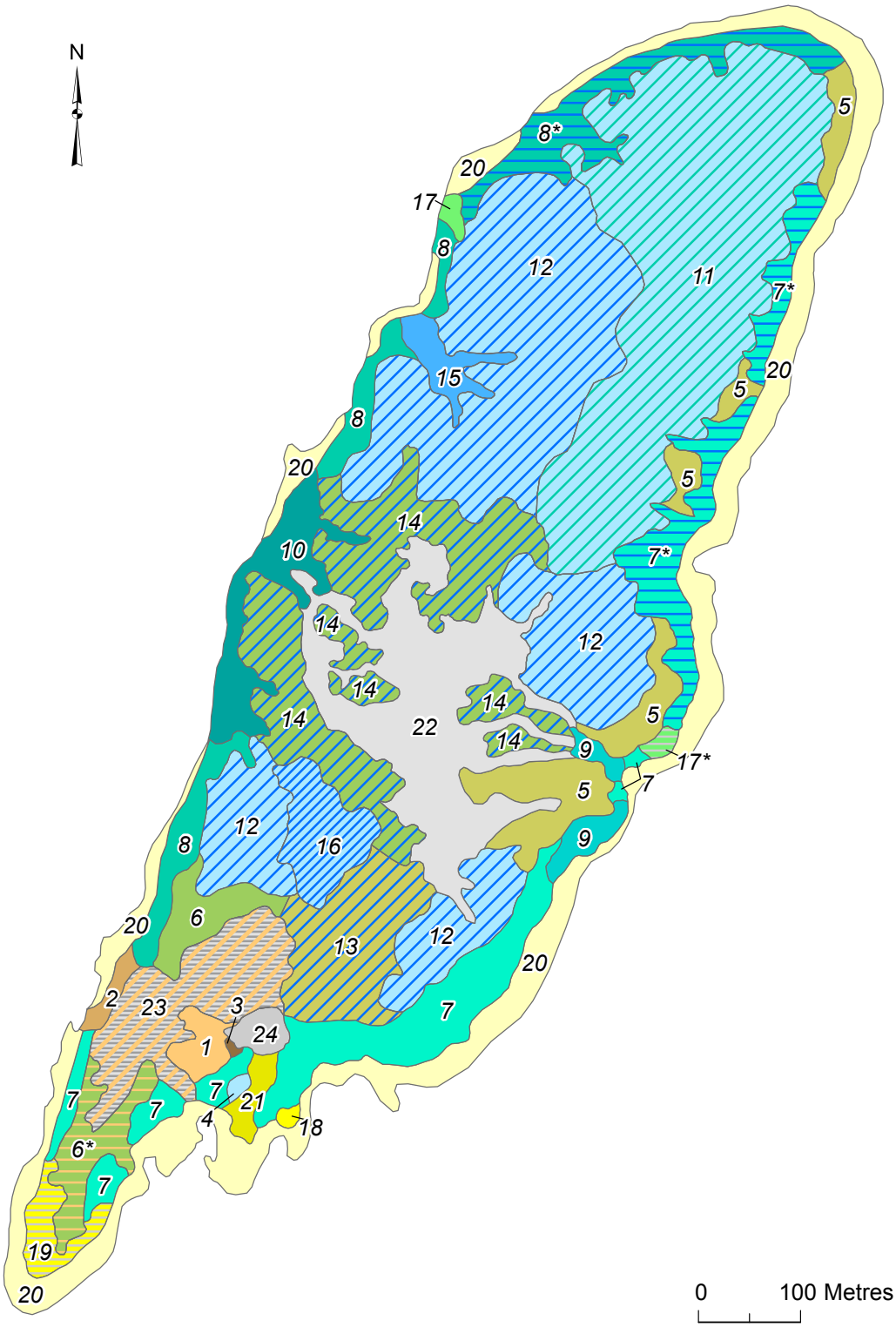
App. 1. cont.

Status	Species	Main habitats											Frequency	Regional protected status
		1	2	3	4	5	6	7	8	9	10	11		
●	*Luzula wahlenbergii* Rupr.	+			+	+	+		+				Rar	
●	*Lycopodium clavatum* subsp. *monostachyon* (Grev. & Hook.) Selander		+									+	Rar	
●	*Lysimachia europaea* (L.) U.Manns & Anderb.	+		+	+	+	+	+	+	+			Rar	
○	*Melilotus officinalis* L.											+	Un	
●	*Mertensia maritima* (L.) Gray									+			Un	
●	*Montia fontana* L.							+	+	+			Rar	
●	*Nardus stricta* L.		+										Un	
●	*Omalotheca supina* (L.) DC.										+		Rar	
●	*Parnassia palustris* L.				+					+		+	Rar	
○	*Phalaroides arundinacea* (L.) Rauschert											+	Un	
●	*Phleum alpinum* L.			+	+			+	+			+	Rar	
○	*Phleum pratense* L.											+	Rar	
●	*Pinguicula vulgaris* L.						+						Un	
●	*Plantago maritima* L. subsp. *maritima*									+			Rar	
●	*Plantago maritima* subsp. *borealis* (Lange) Blytt & Dahl									+			Rar	
●	*Poa alpigena* (Blytt) Lindm.	+	+	+	+	+	+	+	+	+		+	Sol	
●	*Poa alpina* L.										+		Rar	
●	*Poa humilis* Ehrh. ex Hoffm.											+	Rar	
●	*Poa pratensis* L.				+	+				+		+	Rar	
●	*Puccinellia capillaris* subsp. *pulvinata* (Fr.) Tzvelev									+			Rar	
●	*Puccinellia phryganodes* (Trin.) Scribn. & Merr.									+			Un	bio
●	*Pyrola minor* L.					+						+	Un	
○	*Ranunculus acris* L. subsp. *acris*											+	Rar	
○	*Ranunculus* aggr. *auricomus* L.											+	Rar	
●	*Ranunculus hyperboreus* Rottb.							+					Un	
○	*Ranunculus repens* L.						+					+	Rar	
●	*Ranunculus subborealis* subsp. *pumilus* (Wahlenb.) Elven	+								+			Rar	
●	*Rhinanthus minor* subsp. *groenlandicus* (Chabert) Neuman									+			Un	
●	*Rhodiola rosea* L.						+			+			Rar	3
●	*Rhododendron tomentosum* Harmaja	+	+					+					Rar	
○	*Ribes nigrum* L.											+	Un	
●	*Rubus chamaemorus* L.	+	+		+	+	+	+	+			+	Fr	
●	*Rumex acetosella* subsp. *arenicola* Y.Mäkinen ex Elven										+	+	Rar	
○	*Rumex acetosella* subsp. *tenuifolius* (Wallr.) O.Schwarz											+	Rar	
●	*Rumex lapponicus* (Hiitonen) Czernov	+	+		+	+	+	+	+				Rar	

App. 1. cont.

Status	Species	Main habitats											Frequency	Regional protected status
		1	2	3	4	5	6	7	8	9	10	11		
○	*Sagina procumbens* L.				+					+		+	Rar	
○	*Salix caprea* L. subsp. *caprea*											+	Un	
●	*Salix glauca* L. subsp. *glauca*	+	+	+	+	+	+	+	+				Rar	
●	*Salix hastata* L.					+							Rar	
●	*Salix lapponum* L.					+	+						Un	
●	*Salix myrsinifolia* subsp. *borealis* (Fr.) Hyl.	+										+	Un	
●	*Salix myrsinites* L.											+	Un	
●	*Salix phylicifolia* L.	+			+	+	+	+				+	Rar	
●	*Saxifraga rivularis* L.									+			Un	
○	*Scorzoneroides autumnalis* (L.) Moench											+	Rar	
●	*Solidago virgaurea* subsp. *lapponica* (With.) Tzvelev	+	+	+	+							+	Rar	
●	*Sonchus arvensis* var. *maritimus* Wahlenb.									+			Rar	bio
●	*Spinulum annotinum* subsp. *alpestre* (Hartm.) Uotila	+										+	Rar	
●	*Stellaria borealis* Bigelow	+	+		+		+	+	+				Rar	
●	*Stellaria crassifolia* Ehrh.				+	+	+		+	+			Rar	
●	*Stellaria fennica* (Murb.) Perfil.											+	Rar	
●	*Stellaria graminea* L.											+	Rar	
●	*Stellaria hebecalyx* Fenzl												Rar	
●	*Stellaria humifusa* Rottb.					+				+			Rar	
○	*Stellaria media* (L.) Vill.											+	Rar	
●	*Taraxacum hjeltii* (Dahlst.) Dahlst.											+	Rar	
●	*Taraxacum repletum* (Dahlst.) Dahlst.									+			Un	
○	*Trifolium pratense* L. var. *pratense*											+	Un	
○	*Trifolium repens* L.			+	+							+	Rar	
●	*Triglochin maritima* L.									+			Un	
●	*Triglochin palustris* L.							+		+			Un	
●	*Tripleurospermum maritimum* subsp. *phaeocephalum* (Rupr.) Hämet-Ahti									+		+	Rar	
●	*Trollius europaeus* L.				+							+	Rar	
●	*Vaccinium myrtillus* L.			+	+	+	+					+	Rar	
●	*Vaccinium oxycoccos* L.						+		+				Un	
●	*Vaccinium uliginosum* L.	+	+	+	+		+	+				+	Sol	
●	*Vaccinium vitis-idaea* L.	+	+	+	+		+	+	+			+	Sol	
●	*Veratrum album* L.				+					+		+	Rar	
○	*Veronica longifolia* L.											+	Rar	
○	*Vicia cracca* L.											+	Rar	
○	*Vicia sepium* L.											+	Rar	

Appendix 2. Vegetation map of Sosnovets Island, the White Sea. Scale 1:6500.



Appendix 2. Legend

	PLANT COMMUNITY	Area ha	Area %
	TUNDRA		
1	Crowberry (*Empetrum nigrum* subsp. *hermaphroditum*) communities in combination with crowberry-lichen (*Flavocetraria nivalis*, *Cladonia arbuscula*) communities at elevated sites	0.25	0.6
2	Lichen (*Cladonia arbuscula*)-crowberry communities	0.12	0.3
3	Bilberry (*Vaccinium myrtillus*)-dwarf cornel (*Cornus suecica*)-crowberry communities	0.01	0.04
	VEGETATION OF PEATLANDS		
4	Cloudberry-crowberry-lichen (*Cladonia arbuscula*, *Flavocetraria nivalis*, *Cladonia rangiferina*) communities	0.04	0.1
5	Cloudberry-crowberry communities	1.56	3.8
6	Cloudberry-crowberry communities including meadow and weed species: *Chamaenerion angustifolium*, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Equisetum arvense* subsp. *alpestre*	0.47	1.2
6*	in combination with crowberry tundra on mineral deposits	0.59	1.5
7	Dwarf cornel-cloudberry-crowberry communities in combination with sedge (*Carex rariflora*)-crowberry and sedge (*Carex recta*) communities, at some sites with willow (*Salix phylicifolia*, *S. glauca*, *S. lapponum*) thickets and tufted hairgrass (*Deschampsia cespitosa*) communities with *Dryopteris expansa* and *Veratrum album* in elongated hollows on slopes	2.00	4.9
7*	in combination with sedge (*Carex rariflora*)-sphagnous (*Sphagnum fimbriatum*, *S. balticum*) communities with *Polytrichum jensenii* and *Andromeda polifolia*	1.28	3.2
8	Cloudberry communities in combination with sedge (*Carex rariflora*)-crowberry communities, at some sites with sedge (*Carex aquatilis*) and small-reed (*Calamagrostis phragmitoides*) communities in elongated hollows on slopes	0.93	2.3
8*	in combination with sedge (*Carex rariflora*)-sphagnous (*Sphagnum fimbriatum*, *S. lindbergii*, *S. riparium*) communities with *Polytrichum jensenii*, *Andromeda polifolia* and *Eriophorum scheuchzeri*	1.02	2.5
9	Estuary sedge (*Carex recta*) communities	0.31	0.8
10	Sedge (*Carex aquatilis*) and small-reed (*Calamagrostis phragmitoides*) communities in combination with sedge (*Carex aquatilis*, *C. rariflora*)-sphagnous (*Sphagnum riparium*) communities with *Calamagrostis deschampsioides* in depressions, and communities of *Calamagrostis neglecta* subsp. *groenlandica* and *Allium schoenoprasum* on dry steep shore slopes	0.90	2.2
	Community complex of weakly dissected peatland		
11	Cloudberry-crowberry-lichen (*Cladonia arbuscula*, *Flavocetraria nivalis*, *Cladonia rangiferina*) communities at elevated sites and cloudberry communities in depressions	6.56	16.2
	Community complexes of peatland highly dissected by dells		
12	Cloudberry-crowberry-lichen (*Cladonia arbuscula*, *Flavocetraria nivalis*, *Cladonia rangiferina*) communities at elevated sites, cloudberry communities and cottongrass-sphagnous (with the dominance of *Sphagnum riparium*, *S. lindbergii*, *Eriophorum scheuchzeri* or *S. angustifolium* and *E. angustifolium*) communities with *Carex rariflora* in depressions	7.87	19.4
13	Cloudberry-crowberry communities at elevated sites; cloudberry communities, cottongrass-sphagnous (with the dominance of *Sphagnum riparium*, *S. lindbergii*, *Eriophorum scheuchzeri* or *S. angustifolium* and *E. angustifolium*) communities with *Carex rariflora* in depressions; small reed (*Calamagrostis phragmitoides*) communities in degraded flarks	1.41	3.5

App. 2. Legend cont.

	PLANT COMMUNITY	Area ha	Area %
14	Cloudberry-crowberry communities including meadow and weedy species: *Chamaenerion angustifolium*, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Equisetum arvense* subsp. *alpestre* at elevated sites; tufted hairgrass (*Deschampsia cespitosa*) and sedge (*Carex aquatilis*)-small reed (*Calamagrostis neglecta* subsp. *groenlandica*) communities in degraded flarks	3.62	8.9
15	Cloudberry communities in shallow depressions and cottongrass-sphagnous (with the dominance of *Sphagnum riparium*, *S. lindbergii*, *Eriophorum scheuchzeri* or *S. angustifolium* and *E. angustifolium*) communities with *Carex rariflora* in deep depressions; sedge (*Carex aquatilis*, *C. rariflora*)-sphagnous (*Sphagnum balticum*, *S. riparium*) communities in the lower part of dells near the shoreline	0.34	0.8
	Community complex of palsa mires		
16	Cloudberry-crowberry-lichen (*Cladonia arbuscula*, *Flavocetraria nivalis*, *Cladonia rangiferina*) and cloudberry-crowberry communities on peat mounds; sedge (*Carex aquatilis*)-sphagnous (*Sphagnum riparium*) and sedge (*Carex rariflora*)-cottongrass (*Eriophorum russeolum*)-sphagnous (*Sphagnum flexuosum*) flarks	0.73	1.8
	DWARF CORNEL (*Cornus suecica*) COMMUNITIES		
17	Forb (*Rumex lapponicus*, *Equisetum arvense* subsp. *alpestre*)-grass (*Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*)-dwarf cornel communities	0.07	0.2
17*	in combination with forb (*Rumex lapponicus*, *Conioselinum tataricum*)-grass (*Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Festuca rubra* subsp. *arctica*) anthropogenic meadows	0.06	0.2
	COASTAL VEGETATION		
18	Fescue (*Festuca rubra* subsp. *arctica*) coastal meadows with *Ligusticum scothicum* and *Argentina anserina* subsp. *groenlandica*	0.03	0.1
19	Coastal meadows with *Festuca rubra* subsp. *arctica*, *Calamagrostis neglecta* subsp. *groenlandica*, *Cornus suecica*, *Ligusticum scothicum* in combination with dwarf cornel communities, and sparse plant communities with *Poa alpigena*, *Festuca rubra* subsp. *rubra*, *Solidago virgaurea* subsp. *lapponica*, *Chamaenerion angustifolium* and *Rumex acetosella* subsp. *tenuifolius* in severely disturbed habitats and on bare man-made lands	0.34	0.8
20	Sparse plants communities of *Puccinellia capillaris* subsp. *pulvinata*, *Cochlearia arctica*, *Arctanthemum arcticum* subsp. *polare*, *Tripleurospermum maritimum* subsp. *phaeocephalum* and *Rhodiola rosea* in combination with medium-level coastal marshes with the dominance of *Festuca rubra* subsp. *arctica* and *Sanionia uncinata* or *Carex subspathacea* and *C. glareosa* or *Calamagrostis deschampsioides* and *Carex rariflora* and high level coastal meadows with *Leymus arenarius* and *Sonchus arvensis* var. *maritimus*, *Ligusticum scothicum*, *Festuca rubra* subsp. *arctica*	4.89	12.0
21	Ecological series of low- and medium-level coastal meadows, grassland and marshes with the dominance of *Puccinellia phryganodes* → *Plantago maritima* subsp. *borealis* → *Carex subspathacea* → *Carex mackenziei* → *Agrostis stolonifera* subsp. *straminea* → *Festuca rubra* subsp. *arctica*, *Sanionia uncinata*	0.18	0.4
	ANTHROPOGENIC VEGETATION		
22	Community complex: tufted hairgrass (*Deschampsia cespitosa*), sedge (*Carex aquatilis*)-small reed (*Calamagrostis neglecta* subsp. *groenlandica*), willowherb (*Chamaenerion angustifolium*) communities and cloudberry-crowberry communities including meadow and weedy species: *Chamaenerion angustifolium*, *Calamagrostis neglecta* subsp. *groenlandica*, *Poa alpigena*, *Equisetum arvense* subsp. *alpestre*	3.32	8.2
23	Willowherb (*Chamaenerion angustifolium*) and grass (*Calamagrostis neglecta* subsp. *groenlandica*, *Anthoxanthum alpinum*)-forb (*Lathyrus pratensis*, *Trifolium repens*, *Alchemilla subcrenata*, *Solidago virgaurea* subsp. *lapponica*) meadows in combination with crowberry tundra on mineral deposits and cloudberry-crowberry communities on a thin peat layer	1.54	3.8
24	Willowherb meadows and small reed (*Calamagrostis phragmitoides*) grasslands	0.18	0.4