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RESEARCH PAPER

Notes on distribution and habitat preferences of *Sphagnum inexspectatum* and *S. mirum* in Western Siberia

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ABSTRACT

New records of two rare moss species, *Sphagnum inexspectatum* Flatberg (4) and *S. mirum* Flatberg & Thingsgaard (9) are reported from Western Siberia, and discuss them in context of their habitat preferences in region as well as general range. Their distribution in Russia is considered and re-assessed. Geobotanical relevés of plant communities with *Sphagnum inexspectatum* and *S. mirum* from Western Siberia are presented. It is shown that in the taiga zone *S. inexspectatum* occurence is closely related to communities of the alliance *Stygio-Caricion limosae* Nordhagen 1943, class *Scheuchzerio-Caricetea nigrae* Tx. 1937, and similar *Sphagnum* carpets in meso-oligotrophic mires, where it grows as single stems among other peat mosses in poor conditions on slightly acidic substrates. In forest tundra and southern tundra this species occurs only in communities of the alliance *Caricion stantis* Matveyeva 1994. More diverse communities with *S. mirum* are assigned mainly to the alliance *Sphagno-Caricion canescentis* Passarge (1964) 1978, which comprises sedge-*Sphagnum* vegetation located in fens and transitional bogs in a wide variety of habitats from moderately poor to moderately rich in mineral nutrients and with slightly acidic substrate. This species occurs both with low (as single stems) and high abundance (frequently being dominant) in moss layer.

Keywords: rare species, *Sphagnum* mosses, habitat, ecology, plant communities, distribution, Western Siberia, Russia

РЕЗЮМЕ

Лапшина Е.Д., Максимов А.И., Ламковски П. Заметки о распространении и предпочитаемых местообитаниях *Sphagnum inexspectatum* и *S. mirum* в Западной Сибири. Сообщается о 13 новых находках двух редких в России видов сфагновых мхов – *Sphagnum inexspectatum* Flatberg (4) и *S. mirum* Flatberg & Thingsgaard (9) в Западной Сибири. Рассмотрено и уточнено их распространение в России. Приведены геоботанические описания растительных сообществ с участием *Sphagnum inexspectatum* и *S. mirum* из Западной Сибири. Показано, что *Sphagnum inexspectatum* в таежной зоне тесно связан с сообществами союза *Stygio-Caricion limosae* Nordhagen 1943 класса *Scheuchzerio-Caricetea nigrae* Tx. 1937 и близкими к ним сообществами сфагновых ковров мезоолиготрофных болот комплексного строения, где он растёт рассеяно отдельными экземплярами среди других сфагновых мхов в условиях бедных обменными основаниями со слабокислой реакцией среды. В лесотундре и южной тундре вид встречается только в сообществах союза *Caricion stantis* Matveyeva 1994. Сообщества с участием *S. mirum* более разнообразны и соответствуют в основном союзу *Sphagno-Caricion canescentis* Passarge (1964) 1978, который включает осоково-сфагновые сообщества низинных и переходных болот, охватывающие широкий диапазон местообитаний от умеренно бедных до умеренно богатых элементами минерального питания и слабокислой реакцией среды. Вид встречается как единичными экземплярами, так и в большом обилии, нередко доминируя в моховом покрове.

Ключевые слова: редкие виды, сфагновые мхи, местообитание, экология, растительные сообщества, распространение, Западная Сибирь, Россия

Sphagnum mosses are one of the most typical and attractive groups of Bryophyta, which play the leading role in vegetation of peat bogs and in paludified forests in the boreal and subarctic zones of the Holarctic. In spite of the large size and abundance of *Sphagnum* mosses in Western Siberia, their species diversity and distribution pattern are poorly understood. The past years have seen some publications on new records of *Sphagnum* moss species unknown earlier in Western Siberia (Yurkivskaya & Maksimov 2009, Lapshina & Maksimov 2014, Lapshina et al. 2018, Ellis et al. 2018, Safronova et al. 2018).

Of special interest are two rare *Sphagnum* moss species – *S. inexspectatum* Flatberg and *S. mirum* Flatberg & Thingsgaard. Our knowledge of their distribution and ecology is very limited.

Sphagnum inexspectatum Flatberg occurs in British Columbia, in Alaska, in Russia and in the mountains of Japan (Flatberg 2005). In Russia, it is known from scarce records in Chukotka, the Yakutia, Jewish Autonomous Region, Amur Region, Primorye Territory, Koryak Autonomous Area, Kamchatka Territory (with the Commander (Bering) Islands) and the Kuriles (Iturup Island) (Flatberg 2005, Czernyadjeva et al. 2009, Czernyadjeva 2012, Fedosov et al. 2012, Ignatov et al. 2014, Maksimov 2016, Sofronova et al. 2016, Cherdantseva et al. 2018, Bakalin et al. 2019, Afonina et al. 2022). In Western Siberia, the species was first

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collected in 2005 near Novy Urengoy city (Yamal-Nenets Autonomous Area), but relevant data were published much later after checking the definition of the species (Ellis et al. 2018). At about the same time, evidence for new habitats of the species in Surgut Poles'e and on two mires in "Numto" Nature Park, located in the north of Khanty-Mansi Autonomous Area (Ellis et al. 2018, Lapshina et al. 2018), was made available. In total 21 localities of *Sphagnum inexspectatum*, 4 of which are in Western Siberia, have been known in Russia before this study (Fig. 1).

Sphagnum mirum Flatberg & Thingsgaard was first described by K. Flatberg, from one locality in the Bethel area, Subarctic Alaska (Flatberg & Thingsgaard 2003). It was then recorded only for Alaska, Canada, and surroundings of Naryan-Mar town in Nenets Autonomous Area, north of European Russia (Laine et al. 2016).

When revising a moss collection in MW and LE herbaria, *Sphagnum mirum* was found on Eastern Taimyr and in the Trans-Baikal Territory, Asian Russia (Flatberg et al. 2016) as well in the eastern spurs of the Polar Urals in Yanganape area (pers. comm. Lamkowski 2017). The species was collected recently in Zeya Nature Reserve, Amur Region (Dudov et al. 2018), on Novaya Zemlya (Czernyadjeva et al. 2020a), and on southern part of Iturup Island, Kurile Islands (Czernyadjeva et al. 2020b).

By now, 23 localities of *Sphagnum mirum* have been found in Russia, including 17 in the north of Western Siberia boreal zone (Ellis et al. 2018, Lapshina et al. 2018, Safronova et al. 2018). The occurrence search via GBIF (GBIF.org, 2023) shows that, although *S. mirum* with its 23 localities in Russia is considered as rare, outside Russia only four localities from North America (Alaska and Quebec) are known. Therefore the worldwide conservation of *S. mirum* depends on the success of its habitat preference assessment.

The scarcity of records of *Sphagnum inexspectatum* and *S. mirum* and meagre (with few exceptions) information about their habitats on labels limits assessment of their ecology, which is essential for detecting their other potential habitats. Therefore, it is particularly important to describe their habitats phytocoenotically in order to address the ecological requirements of these species to certain types of plant communities. The present study aims at filling this gap of knowledge by the documentation of recurrent records of these two *Sphagnum* moss species in Western Siberia.

MATERIAL AND METHODS

Sphagnum inexspectatum and *S. mirum* distribution maps (Figs 1, 2) were compiled on the basis of literature data, original new records from Western Siberia (Appendix 1) and additional records of *S. inexspectatum* revealed in the course of revision of *Sphagnum contortum* Schultz specimens stored in the LE (Appendix 2).

To address ecological requirements of the two species, we analyzed original geobotanical relevés completed in Western Siberia between 2005 and 2022 with *Sphagnum inexspectatum* and *S. mirum* in moss cover. We used both the relevés made in localities known earlier (Ellis et al. 2018, Lapshina et al. 2018, Safronova et al. 2018) and those of newly-found and not earlier published ones.

A total of 6 locations of *Sphagnum inexspectatum* and 23 locations of *S. mirum* have been found in Western Siberia (Appendix 1), where 18 and 41 vegetation relevès respectively have been involved in the analysis of their habitat preferences.

The localities in Western Siberia where specimens of *Sphagnum inexspectatum* (*S. inexsp.*) and *S. mirum* were taken with vegetation relevés (rel.) and without ones (point) are given below. Their coordinates and reference to the first publication are shown in parentheses.

Yamal-Nenets autonomous Area:

2005. Purovsk District, surroundings of Novy Urengoy city (65.99°N 70.70°E), *S. inexp.* – 1 point (Ellis et al. 2018);

2017. Priuralskiy Disctrict, northern and western plains surrounding the Yanganape Plateau (67.73°N 67.87°E; 67.70°N 67.76°E; 67.75°N 67.81°E), *S. mirum* – 3 points (pers. comm. Lamkowski 2017; present publication).

2019. Nadym District (67.76°N 75.56°E; 67.80°N, 75.36°E), *S. inexp.* – 4 rel.; (64.25°N 71.06°E; 64.37°N 75.61°E; 64.38°N 71.46°E; 64.35°N 71.26°E; 65.58°N 73.07°E), *S. mirum* – 9 rel. (present publication);

Khanty-Mansy Autonomous Area:

2007. Sovetskiy District, Nature Reserve "Kondinskie Lakes" (60.81°N 63.55°E), *S. mirum* – 1 rel. (Ellis et al. 2018);

2016. Surgut District, Surgut Poles'e (62.01°N 71.17°E), *S inexp.* – 1 point (Ellis et al. 2018);

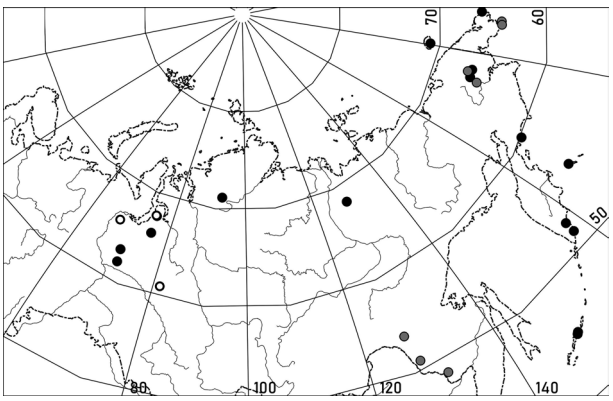

Figure 1 Distribution of *Sphagnum inexspectatum* Flatberg in Russia: open circles – newly found localities of the species in Western Siberia; grey circles – re-examined specimens; solid circles – localities known earlier

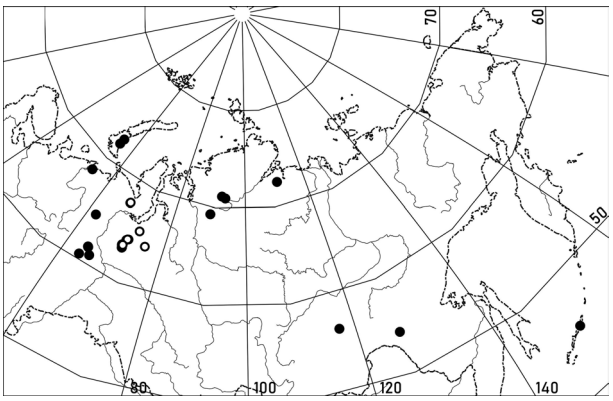

Figure 2 Distribution of *Sphagnum mirum* Flatberg & Thingsgaard in Russia: open circles – newly found localities of the species in Western Siberia; solid circles –localities found before 2016

2016. Sovetskiy District, Nature Reserve "Malaya Sosva" (61.82°N 64.46°E; 61.86°N 64.35°E; 61.84°N 64.43°E), *S. mirum* – 5 rel. (Ellis et al. 2018);

2017. Beloyarsk District, southern part of "Numto" Nature Reserve (63.24N 70.69E), *S. inexp.* – 2 rel. + 1 point (63.37°N 70.89°E; 63.36°N 70.86°E; 63.62°N 70.72E°; 63.60°N 70.64 °E; 63.66°N 70.61°E), *S. mirum* – 6 rel. (Lapshina et al. 2018);

2018. Surgut District, surroundings of Lyantor city (61.51°N 72.17°E; 61.50°N 72.18°E), *S. mirum* – 9 rel. (Safronova et al. 2018);

2018. Surgut District, East-Surgut oil field (61.38°N 73.72°E), *S. mirum* – 1 point (Safronova et al. 2018);

2018. Berezovsiy District, Khulga River basin in its middle course (64.94°N 61.70°E), *S. mirum* – 1 rel. (Safronova et al. 2018);

2018. Sovetsiy District, Potanay oil field (61.19°N 65.48°E), *S. mirum* – 4 rel. (Safronova et al. 2018);

2021. Nizhnevartovsk District, Mestyg-Egan River basin, left tributary of Vakh River in its upper course (61.14°N 81.41°E), *S. inexp.* – 5 rel. (present publication);

2022. Beloyarsk District, central part of "Numto" Nature Reserve, *S. mirum* – 7 rel. (present publication).

We identified all species (vascular plants, mosses, and lichens) on 5×5 m plots and estimated the coverage in percent for the major plant growth forms, as well as cover abundance of each species. To classify communities and their belonging to higher syntaxa (alliance, classes), the floristic classification developed by Braun-Blanquet approach (Westhoff & van der Maarel 1978, Mirkin & Naumova 1998) was used. The nomenclature of the higher vegetation units follows Mucina et al. (2016).

The pH and electroconductivity (EC) were measured in the field to describe the mire-water properties. The Combo portable tester (HI 98129 COMBO) was used for measurements. In some cases for poor sites two devices (Hannah Instruments HI98303 EC and HI98128 pH) were used for better resolution. Comparison of the environmental conditions of mire habitats in relative units was made based on L.G. Ramenskiy method of ecological scales (Ramensky et al. 1956). Ecological indices (grades) of water supply and nutrient condition for each relevé were calculated.

The nomenclature of the species follows Cherepanov (1995) for vascular plants; Ignatov et al. (2006) for mosses, with regard to the latest taxonomic assessments (Ignatov et al. 2022), Konstantinova et al. (2009) for liverworts.

RESULTS

Typical habitats and phytocoenotic preferences

Sphagnum inexspectatum was collected in an aapa mire in the middle taiga subzone of the eastern part of Khanty-Mansi Autonomous Area and at two sites in the southern tundra subzone in the Yamal-Nenets Autonomous Area. *Sphagnum mirum* has been found repeatedly in more or less noticeable abundance in mires of northern taiga subzone within the Nadym River basin (Yamal-Nenets Autonomous Area), and in central parts of "Numto" Nature Reserve, northwestern Khanty-Mansi Autonomous Area. The labels of new records are shown in Appendix 1.

Sphagnum inexspectatum

Processing the tables of geobotanical relevés has shown that *S. inexspectatum* is associated with different types of mire communities in different bioclimatic zones. The classification of plant communities showed that in the middle and north taiga subzones of Western Siberia's boreal (forest) zone the species occurs in the communities of the alliance *Stygio-Caricion limosae* Nordhagen 1943, class *Scheuchzerio palustris-Caricetea nigrae*. The alliance combines oligotrophic to meso-oligotrophic sedge- and sedge-moss (*Warnstorfia*-liverworts-*Sphagnum*) communities occurring on the quagmires and hollows of transition, aapa and flat palsa mires in the Boreal and Subarctic zones of Eurasia, which develop under poor nutrient conditions with a slightly acidic reaction of the substrate (Peterka et al. 2017, Lapshina et al. 2022). The typical species of this alliance are: *Carex limosa*, *Drosera obovata*, *Gymnocolea inflata*, *Juncus stygius*, *Rhynchospora alba*, *Sphagnum platyphyllum*, *S. subsecundum*, *S. perfoliatum*, *Sarmentypnum exannulatum*, *Warnstorfia fluitans*, *Utricularia minor*, and *U. ochroleuca*. The communities of the alliance typically occur in the northern taiga zone, spreading as a slightly impoverished form as far as the southern boundary of the middle taiga southwards and the forest-tundra zone northwards.

In the middle taiga subzone, at its southern distribution boundary in Western Siberia, *S. inexspectatum* is restricted to a narrow (contact) zone between low *Sphagnum* ridges and the waterlogged hollows of patterned meso-oligotrophic mires (Fig. 3A, B) of European Russia and Scandinavia such as aapa mires (Table 1, 1–8; Fig. 4).

The habitat of *S. inexspectatum* is represented by *Menyanthes-Rhynchospora*-sedges-*Sphagnum* as well as *Menyanthes*-sedge (*C. rostrata*)-*Sphagnum* communities, commonly dominated by *Sphagnum papillosum*, which grow on low ridges. A low dwarf shrub layer, if present, is formed by *Andromeda polifolia* (Table 1, 8). A sparse grass layer consists of *Menyanthes trifoliata* and *Carex limosa*, above which stems of *Carex rostrata* and *Eriophorum angustifolium* rise, except for sites where grass layer is dominated by *Rhynchospora alba*, which can dominate up to 50–60 %. The moss cover of ridges is dominated by *Sphagnum papillosum* mixed with *S. divinum*, and *S. russowii*. The highest levels of ridges on West Siberian aapa mires are occupied by *Sphagnum fuscum* accompanied by sparsely abundant *Drosera rotundifolia*, *Eriophorum vaginatum*, and *Oxycoccus microcarpa* – species of the class *Oxycocco-Sphagnetea*. *Sphagnum inexspectatum* occurs as individual plants in a narrow marginal zone, where ridges transition into carpets dominated by *S. papillosum* with admixture of *S. jensenii* and *S. subsecundum*. The mire water level in this zone is at a depth of 3–5(7) cm from the moss cover surface.

S. inexspectatum also occurs as single plants in the waterlogged hollows of aapa mires occupied by *Menyanthes-Scheuchzeria*-sedge and *Menyanthes*-sedge-*Utricularia* communities (Table 1, 1–5). Their well-defined grass layer is composed of *Carex limosa* and *Menyanthes trifoliata* consistently mixed with *Eriophorum angustifolium*, *Scheuchzeria palustris*, and *Rhynchospora alba*, less often *Juncus stygius*. *Carex lasiocarpa* and *Equisetum fluviatile* are occasionally

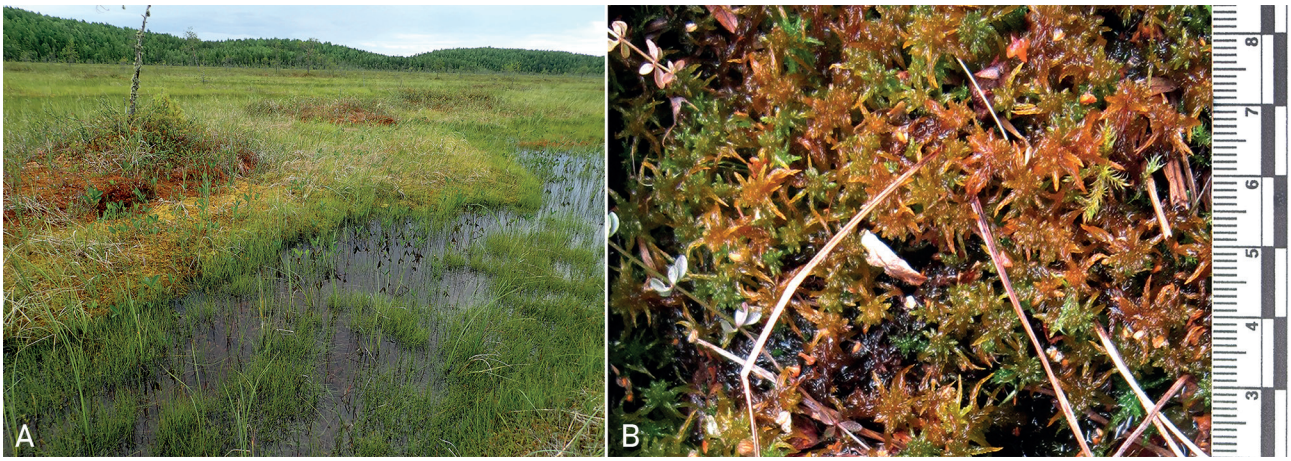

Figure 3 General view of aapa mire with the typical habitats of *Sphagnum inexspectatum* in the contact zone between low *Sphagnum* ridges and waterlogged hollows (A); *Sphagnum inexspectatum* (B)

encountered in the upper sublayer. A moss cover is very sparse or missing in such communities, and *Utricularia ochroleuca* grows on the bare peat surface. The bog water level during the growing season remains at or 1–8 cm above the surface (pH=4.8–5.7, EC=20–60).

In the north taiga subzone *Sphagnum inexspectatum* was revealed in the sedge (*Carex limosa*)-*Menyanthes*-liverwort communities of the same alliance *Stygio-Caricion limosae* in the highly inundated, nutrient-poor quagmires and hollows of patterned meso-oligotrophic mires, where the typical species of the alliance are best-represented (Table 1, 9–12; Fig. 4). Noteworthy, *Rhynchospora alba*, a typical species of this alliance in the middle taiga communities of the forest zone, does not occur in the north taiga of Western Siberia.

The grass layer (percent coverage varies from 5 to 45 %) of communities with *Sphagnum inexspectatum* and contains of variable proportions of *Carex limosa* and *Menyanthes trifoliata*. *Carex chordorrhiza*, *C. rotundata*, *Drosera obovata*, *D. anglica*, *Eriophorum angustifolium*, *E. russeolum* and *Juncus stygius* are less abundant. The moss cover (5–90 %) is patchy. *Gymnocolea inflata* forms black liverwort backgrounds, which are sometimes mixed with small amounts of *Scapania paludicola*. Also patches of the mosses like *Sarmentypnum exannulatum* and *Warnstorfia fluitans* separate small patches of the *Sphagnum* mosses: *S. compactum*, *S. inexspectatum*, *S. papillosum* or *S. subsecundum*. The mire water level is either near the surface or 1–3 cm above it.

In the forest-tundra and south tundra subzone, all records of *Sphagnum inexspectatum* originate from communities of the alliance *Caricion stantis*, which combines sedge-moss hollow vegetation of flat-palsa mires of the central portions of polygonal mires, as well as homogeneous sedge-moss vegetation of valleys and wide rills in Eurasian and North American Arctic (Matveyeva 1994, 1998). In general, these habitats display a moderate enrichment by mineral nutrients and slightly acidic to neutral reaction of the substrate due to a considerable dilution effect caused by precipitation. The typical species of the alliance in the south of the tundra zone are *Calliergon richardsonii*, *Carex aquatilis* s. l., *Cinclidium subrotundum*, *Drepanocladus arcticus*, *Dupontia fischeri*, *Leiocolea rutheana*, *Meesia triquetra*, *Pedicularis sudetica* s. l., *Polytrichum jensenii*, *Sphagnum squarrosum*, *Scorpidium revolvens*, and *Sarmentypnum sarmentosum*.

In the forest-tundra and southern tundra of Western Siberia, *Sphagnum inexspectatum* was found in communities

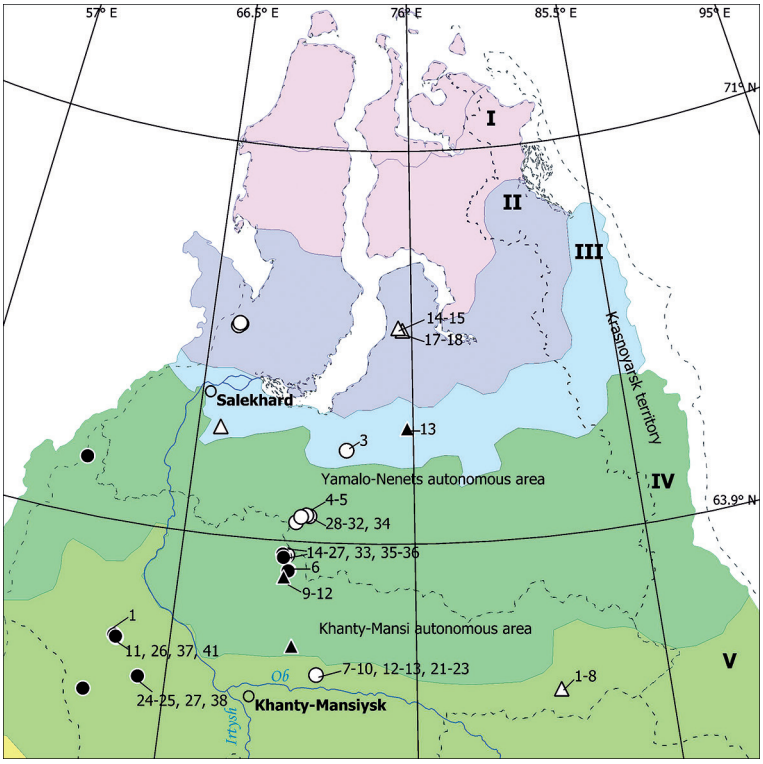

Figure 4 Distribution of *Sphagnum inexspectatum* (triangle) and *S. mirum* (circles) in Western Siberia in context with bioclimatic gradient: open symbols – newly found localities of the species (this paper); black symbols – localities known earlier. Bioclimatic zones and subzones: I – typical tundra, II – southern tundra, III – forest-tundra, IV – northern taiga , V – middle taiga. Arabic numerals are the relevés numbers in Table 1 (*Sphagnum inexspectatum*) and Table 2 (*S. mirum*), respectively

Table 1. Communities with *Sphagnum inexspectatum*

Alliance ***Stygio-Caricion limosae***
1–5: waterlogged *Menyanthes*-sedge (*Carex limosa*)-*Utricularia* hollows
6–8: *Rhynchospora-Sphagnum* (*S. papillosum*) low ridges and carpets
9–12: *Menyanthes*-sedge (*Carex limosa*)-liverwort (*Gymnocolea inflata*) hollows

Alliance ***Caricion stantis***
13–16: sedge (*Carex aquatilis* s. l.)-moss (*Sarmentypnum exannulatum, Sphagnum* spp.) communities
17–18: low shrub (*Salix* spp., *Betula nana*)-moss (*Aulacomnium palustre, Sphagnum* spp.) communities

Projective cover, %	**Alliance *Stygio-Caricion limosae***												**Alliance *Caricion stantis***					
shrubs	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	40	25
dwarf shrubs	0	0	0	0	0	1	1	30	0	0	0	0	0	0	0	0	5	5
herbs	40	20	35	65	10	70	65	10	40	25	10	10	40	30	20	80	10	10
bryophytes	1	1	2	3	1	100	95	100	40	80	35	15	90	55	60	90	100	90
Number of species	9	10	12	12	10	15	14	10	16	18	14	10	19	13	9	13	33	42
Relevé nr.:																		
by author	069E21me	068E21me	070E21me	072E21me	008F21me	090E21me	092E21me	012F17nu	310E17nu	309E17nu	007F17nu	077F17nu	209E05nr	253F19ya	254F19ya	264E21bt	413E19ya	449E19ya
in the table	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Diagnostic species of the *Stygio-Caricion limosae* and *Scheuchzerio-Caricetea*																		
Eriophorum angustifolium	2	1	1	3	1	1	1	5	·	+	5	1	30	15	1	·	+	+
Menyanthes trifoliata	3	5	10	13	3	5	2	·	15	20	·	·	·	·	·	·	·	·
Carex limosa ***St-C. l.***	30	8	20	23	5	·	1	·	7	10	1	1	·	·	·	·	·	·
Utricularia intermedia ***St-C. l.***	10	5	20	15	1	·	·	·	·	·	·	·	·	·	·	·	·	·
Scheuchzeria palustris	5	10	5	5	3	·	1	·	·	·	·	·	·	·	·	·	·	·
Rhynchospora alba ***St-C. l.***	1	2	3	50	1	65	60		1	·	·	·	·	·	·	·	·	·
Sphagnum papillosum	·	·	1	1	+	90	90	90	+	1	+	·	1	·	·	·	·	·
Sphagnum jensenii	·	1	+	2	·	1	1	·	·	·	+	·	·	·	·	·	·	·
Sphagnum subsecundum ***St-C. l.***	·	·	1	·	·	+	+	·	·	5	·	·	·	·	·	·	·	5
Drosera anglica ***St-C. l.***	·	·	·	4	·	1	·	·	·	1	·	·	·	·	·	·	·	·
Carex rostrata	·	·	·	·	·	2	2	3	·	·	·	1	·	·	·	·	·	·
Drosera rotundifolia	·	·	·	·	·	3	1	+	·	·	·	·	·	·	·	·	·	·
Andromeda polifolia	·	·	·	·	·	1	1	30	·	+	·	·	·	·	·	·	·	·
Sphagnum fallax	·	·	·	·	·	·	·	10	·	·	·	·	·	·	·	·	·	·
Eriophorum russeolum	·	·	·	·	·	·	·	3	5	+	·	·	·	·	·	·	·	·
Diagnostic species of the *Stygio-Caricion limosae*																		
Drosera obovata	·	·	·	·		·	·	·	5	1	+	+	·	·	·	·	·	·
Juncus stygius	2	·	·	5	1	·	·	·	1	2	·	+	·	·	·	·	·	·
Gymnocolea inflata	·	·	·	·	·	·	·	·	30	50	30	10	·	·	·	·	·	·
Trichophorum cespitosum	·	·	·	·	·	·	1	·	+	2	·	·	·	·	·	·	·	·
Warnstorfia fluitans	·	·	·	·	·	·	·	·	3	+	·	·	·	·	·	·	·	·
Sphagnum compactum	·	·	·	·	·	·	·	·	5	3	+	·	·	·	·	·	15	·
Utricularia ochroleuca	·	·	·	·	·	·	·	·	3	3	5	3	·	·	·	·	·	·
Carex rotundata	·	·	·	·	·	·	·	·	3	·	+	1	·	·	·	·	·	·
Carex chordorrhiza	1	·	·	·	·	·	·	1	·	2	+	5	+	15	5	·	·	1
Diagnostic species of the *Caricion stantis*																		
Sarmentypnum exannulatum	·	·	·	·	·	·	·	·	·	+	1	·	20	20	50	70	1	·
Carex aquatilis	·	·	·	·	·	·	·	·	·	·	·	·	15	·	15	40	·	·
Sphagnum squarrosum	·	·	·	·	·	·	·	·	·	·	·	·	20	·	+	·	1	10
Sphagnum lindbergii	·	·	·	·	·	·	·	·	·	·	·	·	30	·	·	·	·	·
Scapania paludicola	·	·	·	·	·	·	·	·	1	·	+	·	10	·	·	·	·	·
Polytrichum jensenii	·	·	·	·	·	·	·	·	·	·	·	·	25	·	·	·	30	·
Calliergon richardsonii	·	·	·	·	·	·	·	·	·	·	·	·	·	10	·	25	·	1
Cinclidium subrotundum	·	·	·	·	·	·	·	·	·	·	·	·	+	25	·	1	·	10
Scorpidium revolvens	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	·	·	10
Straminergon stramineum	·	·	·	·	·	·	·	·	1		·	·	·	·	·	20	·	1
Warnstorfia sarmentosa	·	·	·	·	·	·	·	·	·	·	·	·	·	+	+	·	·	5
Comarum palustre	·	·	·	·	·	·	·	·	·	·	·	·	+	1	·	40	·	3
Meesia triquetra	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	1	·	5
Differential species of the shrub-moss communities with *Sphagnum inexpectatum*																		
Betula nana	·	·	·	·	·	1	·	3	·	·	·	·	·	·	·	·	35	20
Aulacomnium palustre	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	30	20
Sphagnum obtusum	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	10	5
Salix glauca	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5	2
Vaccinium uliginosum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5	5
Sphagnum warnstorfii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3	5
Aulacomnium turgidum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	1
Schljakovia kunzeana	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4	1
Sanionia uncinata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	+	1
Carex rariflora	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	10	·
Dicranum spadiceum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5	·
Sphagnum girgensohnii	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5	·
Tritomaria quinquedentata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	10
Salix myrtilloides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5
Sphagnum teres	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5
Bryum pseudotriquetrum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5

Note. Species found in 1–2 relevés: *Blepharostoma trichophyllum* (18 +), *Brachythecium mildeanum* (18 +), *Breidleria pratensis* (18 +), *Bryum neodamense* (14 +), *Carex lasiocarpa* (2 1, 3 1), *C. magellanica* (13 +), *Cephalozia pleniceps* (18 +), *Cetraria* sp. (17 +), *Chiloscyphus pallescens* (18 +), *Cladonia cornuta* (17 +), *Cladopodiella fluitans* (4 1, 13 +), *Equisetum fluviatile* (2 1, 3 2), *Eriophorum medium* (16 1), *Ledum palustre* (17 3), *Loeskypnum badium* (17 +), *Lophozia longiflora* (17 2), *Mylia anomala* (17 1), *Odontoschisma elongatum* (18 +), *Oncophorus wahlenbergii* s. l. (14 +, 17 +), *Oxycoccus palustris* (6 1, 7 1), *Paludella squarrosa* (14 +, 18 1), *Pedicularis labradorica* (17 +), *P. palustris* (5 1), *P. sudetica* (18 1), *Pohlia nutans* (16 1, 17 +), *Polytrichum strictum* (17 +), *Ptilidium ciliare* (18 1), *Riccardia latifrons* (18 +), *Sphagnum alaskense* (18 1), *S. aongstroemii* (17 +), *S. capillifolium* (6 +, 18 1), *S. fimbriatum* (13 5, 17 2), *S. majus* (11 +, 17 3), *S. platyphyllum* (15 5, 18 1), *S. riparium* (13 +), *S. russowii* (6 5), *Stereocaulon* sp. (17 +), *Tomentypnum nitens* (18 1).

Characteristic species (next to the name of the taxon): ***St.-C. l.*** – ***Stygio-Caricion limosae***.

dominated by *Carex aquatilis* and *Eriophorum angustifolium* with admixture of *Carex chordorrhiza* in the grass layer (Table 1, 13–16; Fig. 4). The moss cover displays a patchy structure built by variable proportions of *Sarmentypnum exannulatum*, *Sphagnum squarrosum*, *S. lindbergii*, *Scapania paludicola* and characteristic moss species of the alliance.

Sphagnum inexspectatum was found recently in a similar habitat in the south tundra subzone of Taimyr Peninsula (Table 1, 16) (Lapshina et al. 2022b).

Special cases are shrub (*Salix* spp., *Betula nana*)-moss and shrub-sedge (*Carex rariflora*)-moss tundra-mire communities with *Sphagnum inexspectatum*. They form in regularly flooded transition zones along the periphery of paludified lake basins ("khasyreys"), which replaced former lakes. A variable humidity regime contributes to the formation of a well-defined shrub layer consisting of *Betula nana*, the willow species *Salix glauca* and *S. myrtillus*, as well as *Vaccinium uliginosum*. The ground layer displays a combination of various moss and liverwort species such as *Aulacomnium palustre*, *A. turgidum*, *Sphagnum obtusum*, *S. warnstorfii*, *Tritomaria quinquedentata*, *Schljakovia kunzeana*, *Sanionia uncinata* and *Dicranum laevidens*, which contribute to the greater species diversity of these communities (Table 1, 17–18; Fig. 4).

Sphagnum mirum

Until now, records of *Sphagnum mirum* in Western Siberia have been mainly made in the northern part of the forest zone within the middle and north taiga subzones with three records in the southern tundra subzone (Fig. 4).

Our results show that most records of *S. mirum* are related to the plant communities of the alliance *Sphagno-Caricion canescentis*. The alliance combines the mesotrophic and meso-oligotrophic sedge-*Sphagnum* and sedge-herb-*Sphagnum* communities of transition mires covering a wide range of habitats from nutrient poor to moderately rich ones with acidic to slightly acidic substrate reaction (pH=4.3–5.2, EC=10–60).

Data showed the highest frequency of *S. mirum* in the mesotrophic sedge (*Carex limosa*)-herb (*Menyanthes trifoliata*, *Comarum palustre*)-*Sphagnum* fens (Table 2, 8–38) evolving in river and brook valleys, less commonly at the base of low hills, and in poor groundwater discharge sites (Fig. 5).

The dwarf shrubs in such mire communities either do not exist or occur occasionally on small patches of 10–15 cm high flat *Sphagnum* hummocks or consists of *Andromeda polifolia*. A grass layer (percent coverage is 20–80 %) is composed of *Carex limosa* and *Menyanthes trifoliata*; *Carex chordorrhiza*, *Comarum palustre*, *Cicuta virosa*, *Epilobium palustre*, *Eriophorum angustifolium*, *E. gracile*, and *Carex canescens*, *C. paupercula*, and *Scheuchzeria palustris* are less abundant. *Oxycoccus palustris* is present on the moss layer. The moss cover displays a simple to spotted structure. *Sphagnum mirum* often prevails (Table 2, 14–27), but commonly is growing together with *S. obtusum* and *S. riparium* (Table 2, 8–20, 30–33) with a small amount of *Straminergon stramineum*. In habitats slightly richer in mineral nutrients *Sphagnum squarrosum*, *S. warnstorfii* dominate, while *Sarmentypnum exannulatum*, *Calliergon cordifolium*, and *Hamatocaulis vernicosus* are less common. *Sphagnum mirum* abundance in such habitats is lower (2–20 %) (Table 2, 34–38). The groundwater level varies from (3–) to 10–15 cm, pH=4.2–5.0, EC=21–44.

The same type of the sedge-*Sphagnum* community *Carex rostrata* of the alliance *Sphagno-Caricion canescentis* dominated or joined by *Sphagnum mirum* has been repeatedly encountered in areas spaced widely apart (Table 2, 4–7; Fig. 4). The total coverage of the grass layer is 60–80 %. The upper 40–60 cm high sublayer is formed of *Carex rostrata*, while the lower sublayer consists of *Comarum palustre*. In addition to *Sphagnum mirum*, *Calliergon cordifolium*, *Helodium blandowii*, *Polytrichum jensenii*, *Sphagnum flexuosum*, *S. obtusum*,

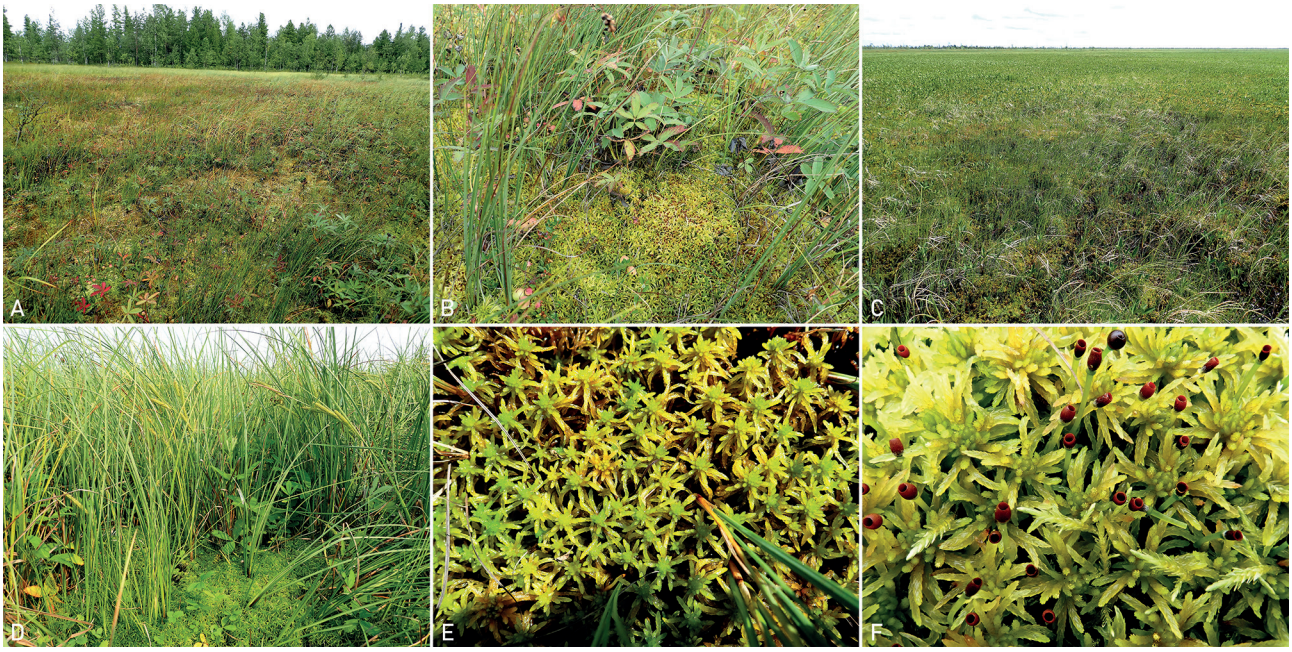

Figure 5 General view of typical habitats with *Sphagnum mirum*: mesotrophic sedge-herb-*Sphagnum* moss (A) and *Comarum palustre*-*Sphagnum* fens dominated by *S. mirum* (B); waterlogged *Menyanthes*-sedge (*Carex rostrata* (C) and low-species tall sedge (*C. rostrata*) communities with an insignificant admixture of *Sphagnum mirum* in the ground cover (D); *Sphagnum mirum* in a vegetative state (E) and with sporophytes (F)

Table 2. Communities with *Sphagnum mirum*

Alliance ***Sphagno-Caricion canescentis*:**
1–3: *Comarum palustre* and herb (*Comarum palustre, Calla palustris*)-*Sphagnum* (*S. obtusum*) communities; 4–7: *Sphagnum* (*S. mirum*)-sedge (*Carex rostrata*) community; 8–31: sedge (*Carex limosa*)-herb (*Comarum plustre, Menyanthes trifoliata*)-*Sphagnum* community: 8–13: variant *Sphagnum obtusum;* 14–29: variant *Sphagnum mirum*; 30–33: variant *Sphagnum riparium;* 34–38: various herb-(hypnum moss)-*Sphagnum* communities

Alliance ***Stygio-Caricion limosae*:**
39–40**:** *Menyanthes trifoliata*-sedge (*Carex limosa*)-liverwort (*Gymnocolea inflata*) community.

Alliance ***Salici pentandrae-Betulion pubescentis*:**
41: shrub (*Alnus incana*)-sedge (*Carex juncella, C. rostrta*)-herb-*Sphagnum* (*S. teres*) birch scrub swamp.

Projective cover, %																																									
shrubs	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	20	0	10	0	0	0	0	0	0	0	0	0	5	40	0	0	0	10
dwarf shrubs	0	0	1	0	0	5	0	0	0	0	0	0	15	1	0	0	10	0	0	0	0	60	0	1	0	0	0	10	15	0	0	0	0	15	<1	5	0	0	0	0	20
herbs	100	30	50	70	80	40	85	35	80	40	70	55	20	55	65	35	35	30	40	70	60	35	25	70	20	60	50	40	30	26	35	40	15	50	85	90	80	50	30	20	50
bryophytes	20	10	30	35	100	80	90	100	100	100	100	100	100	100	100	100	60	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	95	100	95	90	100	60	70	80	95
Number of species	11	16	30	9	3	9	7	7	11	12	11	10	12	14	11	8	14	13	13	15	8	7	4	13	13	8	10	12	16	10	14	15	7	17	18	15	20	18	17	14	26
Relevé nr.: by author	044E16ms	028I18xy	148F19nd	238E19pz	095G19pz	110I17nu	019E18lr	007E18lr	010E18lr	013E18lr	075E16ms	015E18lr	017E18lr	093E22nu	094E22nu	072F22nu	073F22nu	080G22nu	081G22nu	057V22nu	009E18lr	016E18lr	008E18lr	003G18pt	094I18pt	074E16ms	207E18pt	089G19pz	227E19pz	224E19pz	226E19pz	245E19pz	038I17nu	207E19pz	347E17nu	346E17nu	070E16ms	101I18pt	419E17nu	428E17nu	030E16ms
in the table	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**
Diagnostic species of the *Sphagno-Caricion canescentis* and *Scheuchzerio-Caricetea*																																									
Comarum palustre	90	25	10	10	30	+	7	+	+	2	60	1	5	35	35	20	25	15	20	40	2	·	4	5	1	50	1	·	·	·	·	·	·	2	2	20	3	·	·	·	10
Calla palustris	·	·	30	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Carex rostrata	1	3	3	60	50	30	85	·	1	·	2	·	+	·	·	·	1	·	·	5	1	7	·	·	·	2	·	·	·	·	·	+	·	·	·	·	5	·	1	·	5
Sphagnum obtusum	·	+	10	·	·	·	20	95	95	85	60	95	70	5	20	10	30	30	40	30	·	·	·	·	1	·	·	10	40	·	·	·	·	40	20	·	·	10	·	·	·
Sphagnum mirum	5	+	+	10	100	30	60	5	2	7	30	+	20	85	80	80	20	60	40	50	10	80	100	100	99	90	100	30	25	1	5	5	15	2	20	5	10	10	+	+	80
Sphagnum riparium	·	·	1	·	·	·	·	·	·	·	·	5	5	2	2	·	·	·	·	10	·	·	·	·	·	10	·	40	25	95	90	80	80	45	20	15	·	·	·	·	·
Carex limosa	·	·	·	·	·	·	·	7	30	10	4	4	+	10	20	10	1	7	4	3	25	+	10	3	1	5	1	3	5	+	1	1	·	3	15	1	·	25	15	10	·
Menyanthes trifoliata	·	·	·	·	·	·	3	25	25	30	·	50	+	·	·	·	·	·	·	5	35	5	10	25	10	·	20	20	28	20	30	30	·	30	40	·	60	15	25	12	·
Oxycoccus palustris	·	·	·	·	·	10	·	·	·	·	5	·	15	2	1	5	5	3	3	3	·	17	·	7	1	15	·	15	5	5	4	15	10	5	7	5	20	·	·	·	1
Straminergon stramineum	·	+	1	·	·	1	·	·	·	·	·	·	2	2	1	1	1	3	5	5	2	·	·	·	·	2	+	15	10	1	5	1	5	·	10	·	·	+	2	+	·
Carex chordorrhiza	·	1	3	·	·	·	·	·	5	2	·	·	+	4	1	·	1	·	1	1	·	·	·	20	+	·	·	·	+	·	+	·	+	+	+	·	+	1	1	+	1
Eriophorum gracile	·	·	3	·	·	·	·	·	1	1	·	+	·	·	·	·	·	·	·	·	·	·	·	5	1	·	2	·	2	1	2	1	·	5	15	·	·	3	·	·	·
Epilobium palustre	+	·	+	1	·	·	+	+	·	+	+	1	·	1	3	·	·	5	3	·	·	·	·	·	+	·	·	·	·	·	·	·	+	·	+	·	·	+	·	·	·
Eriophorum angustifolium	+	·	·	·	·	·	·	·	·	+	1	1	·	1	·	·	+	1	1	·	·	·	·	·	·	·	·	1	·	+	+	+	·	·	·	+	+	·	+	·	·
Cicuta virosa	·	·	+	·	·	·	·	·	1	1	·	2	·	·	·	·	·	·	·	·	·	·	·	1	·	·	+	·	·	·	+	·	·	·	2	·	·	·	·	·	·
Carex canescens	+	+	·	+	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	3	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Differential species of various herb-(*Calliergon*)-*Sphagnum* communities with *S. mirum*																																									
Sphagnum squarrosum	5	·	+	20	·	·	·	·	·	·	·	·	·	5	·	5	·	·	·	5	·	·	·	·	·	·	·	·	·	·	·	·	·	10	20	40	·	·	·	·	·
Carex paupercula	·	·	+	·	·	1	·	·	·	·	+	·	·	·	·	·	1	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	20	60	5	·	·	·	2
Sphagnum fimbriatum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	20	·	·	·	·	·
Sphagnum warnstorfii	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	5	30	·	·	·	·
Sphagnum angustifolium	+	·	·	·	·	·	·	·	·	·	10	·	·	3	·	5	·	·	·	·	·	20	·	·	·	·	·	·	·	·	·	·	·	·	·	2	50	+	·	·	·
Calliergon cordifolium	1	·	10	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	30	·	·	·
Hamatocaulis vernicosus	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	10	·	·	·
Diagnostic species of the *Stygio-Caricion limosae*																																									
Sarmentypnum exannulatum	·	5	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	10	4	·	+	45	20	·
Gymnocolea inflata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	25	50	·
Cladopodiella fluitans	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	5	10	·
Drosera intermedia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4	4	·
Utricularia ochroleuca	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	4	+	·
Juncus stygius	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	+	·
Scapania paludicola	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	1	2	·
Differential species of *Alnus incana*-sedge-*Sphagnum* birch scrub swamp with *S. mirum*																																									
Betula pubescens	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	30
Carex juncella	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	20
Chamaedaphne calyculata	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	15
Salix myrtilloides	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	6
Alnus incana	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Vaccinium uliginosum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	3
Other species:																																									
Andromeda polifolia	·	·	·	·	·	5	·	·	·	·	·	·	15	1	·	·	10	·	·	·	·	60	·	1	·	·	·	10	15	·	·	·	·	15	+	5	·	·	+	·	·
Helodium blandowii	·	·	5	·	·	50	·	·	·	·	·	·	·	·	·	·	5	2	5	2	·	·	·	·	·	·	·	5	·	·	·	·	·	1	·	·	+	·	·	·	3
Carex diandra	·	5	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	2	1	·	·	·	7	1	·	+	·	·	·	·	·	·	·	·	·	1	3	·	·	·
Betula nana	·	·	+	·	·	·	·	·	·	·	5	·	·	·	·	·	·	·	·	·	·	·	·	20	·	10	·	·	·	·	·	·	·	·	·	5	40	·	·	·	·
Pseudobryum cinclidioides	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2	1	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Scheuchzeria palustris	·	·	·	·	·	·	·	2	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	10	·	30	·	·	·	·	+	·	·	·	·	·	5	·	·	·
Calamagrostis neglecta	·	·	·	1	·	·	·	·	·	·	·	·	·	1	2	·	1	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Equisetum fluviatile	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	+	·	·	·	·	·	·	·	1	·	·	·	·	·	·
Warnstorfia sp.	·	·	·	·	·	·	10	·	5	·	·	·	·	·	·	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Sphagnum flexuosum	·	·	·	·	·	10	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	10	·	·	·	·	·	·	·	·	·
Eriophorum russeolum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·	·	·	·	·	·	·	·	1	·
Stellaria crassifolia	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	1	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	·	·	·	·	·
Cephalozia pleniceps	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	+	·	·	·	·	·	·	·	·	·	·
Plagiomnium ellipticum	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	+	·	·	1
Galium uliginosum	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	1	·	·	·	1
Calamagrostis purpurea	+	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	2
Drepanocladus aduncus	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·	2

Note. Species found in 1–2 relevés: *Amblystegium serpens* (41 1), *Aulacomnium palustre* (3 +), *Bryum bimum* (41 2), *B. pseudotriquetrum* (2 +), *Calliergon giganteum* (2 +), *C. richardsonii* (38 +), *Caltha palustris* (37 +), *Campylium protensum* (41 1), *C. stellatum* (2 +), *Cardamine nymanii* (37 +), *Carex aquatilis* (3 1), *C. cespitosa* (41 +), *C. dioica* (37 +), *Cephaloziella* sp. (40 +), *Chiloscyphus pallescens* (41 +), *Drepanocladus sordidus* (38 +), *Drosera rotundifolia* (28 1), *Galium trifidum* (1 +, 3 +), *Lemna minor* (3 +), *Leptobryum pyriforme* (41 1), *Naumburgia thyrsiflora* (3 1, 10 +), *Parnassia palustris* (2 +), *Pedicularis karoi* (3 +, 29 +), *Poa pratensis* (37 +), *Pohlia nutans* (31 +), *Polytrichastrum longisetum* (3 +), *Polytrichum jensenii* (4 4), *Pyrola rotundifolia* (37 +), *Salix lapponum* (3 1), *Sanionia uncinata* (41 5), *Scapania paludosa* (32 +), *Scapania* sp. (13 +), *Sphagnum centrale* (3 1), *S. compactum* (39 +), *S. fallax* (31 1, 32 5), *S. jensenii* (10 5, 32 1), *S. lindbergii* (40 +), *S. divinum* (38 +), *S. majus* (32 5), *S. platyphyllum* (39 2), *S. russowii* (36 5), *S. subsecundum* (34 1, 35 2), *S. teres* (17 3), *Trientalis europaea* (41 +), *Utricularia intermedia* (25 1, 38 3), *U. minor* (25 +), *U. vulgaris* (3 +), *Viola epipsila* (2 +, 41 +), *Warnstorfia fluitans* (20 2).

S. squarrosum, and *Sarmentypnum exannulatum* occur in moss cover. These highly productive sedge-*Sphagnum communities* can be found on mesotrophic *Sphagnum mires* along the small brooks within the peat deposits in river valleys, which are periodically flooded (pH=5.9, EC=73).

Sphagnum mirum was encountered three times in herb (*Comarum palustre*, *Calla palustris*)-*Sphagnum* communities forming floating mats, which could also be assigned to the alliance *Sphagno-Caricion canescentis* (Table 2, 1–3). They form in depressions occupied by previous oxbow lakes, in river valleys or flood plains, which are flooded by a river and simultaneously supplied by run-off water from nearby mesotrophic *Sphagnum* mire. Grass layer is formed of *Comarum palustre*, sometimes *Calla palustris* is abundant. *Carex canescens*, *C. chordorrhiza*, *C. rostrata*, *Cicuta virosa*, *Epilobium palustre*, and *Eriophorum angustifolium* are less abundant. The patchy moss cover is poorly developed; *Calliergon cordifolium*, *Sphagnum obtusum*, and *S. squarrosum* are most common. Other species, in addition to *Sphagnum mirum*, are *S. centrale*, *S. warnstorfii*, *Straminergon stramineum*, and *Sarmentypnum exannulatum*. The groundwater level is near the surface (pH=4.9, EC=17).

Sphagnum mirum also occurs in birch-alder (*Alnus incana*)-tussock sedge (*Carex juncella*)-herb-*Sphagnum* scrub swamp communities dominated by *Sphagnum teres* (Table 2, 41). Such vegetation is close to the alliance *Salici pentandrae-Betulion pubescentis* (class *Alnetea glutinosae*), as indicated by its floristic and physiognomic characters. However, the well-developed moss cover, dominated by mesotrophic and meso-oligotrophic *Sphagnum* mosses is similar to the moss composition of the forest-free communities of the alliance *Sphagno-Caricion canescentis*. Birch-herb-*Sphagnum* swamps have a sparse but well-defined 3–4 m high tree layer formed of *Betula pubescens* and a sparse shrub layer made up of *Alnus incana* and *Salix myrtilloides*. Additional dwarf shrubs consisting of *Chamaedaphne calyculata* and *Vaccinium uliginosum* are abundantly growing on near-stem elevations and *Sphagnum* hummocks. The grass layer is formed of low *Carex juncella* hummocks with *Carex rostrata* and *Comarum palustre* growing between. *Rubus arcticus* and *Viola epipsila* commonly grow on mossy elevations near birch stems. Flat 25–30 cm high *Sphagnum* hummocks composed of *Sphagnum teres* make up as much as 70 % of the area, while ground water level remains at surface between the hummocks for the entire season. With average distances to the water level of (0–)10–15 cm *Sphagnum mirum*'s ecological niche is considerably closer to the water table compared to the closely related *S. teres*, which can form hummocks of 60 cm height while *S. mirum* occupies the depressions in between. Other less abundant mosses are *Helodium blandowii*, *Plagiomnium ellipticum*, and *Sanionia uncinata*. Often occurring in such habitats are *Sphagnum centrale* and *S. squarrosum*.

Only in two cases records of *Sphagnum mirum* originate from the *Menyanthes*-sedge (*Carex limosa*)-liverwort-*Sarmentypnum exannulatum* communities of other alliance, namely the *Stygio-Caricion limosae* (more typical for *Sphagnum inexspectatum*), where the species grows as small single turfs (Table 2, 39–40). The communities display a well-defined low grass layer formed of *Carex limosa*, *Menyanthes trifoliata* with *Drosera obovata* and *Juncus stygius*, as well as the dominance of *Sarmentypnum exannulatum* and the liverworts *Cladopodiella fluitans*, *Gymnocolea inflata*, and *Scapania paludicola* in the poorly developed moss cover (pH=5.1, EC=64).

DISCUSSION

New data on records of *Sphagnum mirum* and *S. inexspectatum* in Western Siberia with descriptions of vegetation in their habitats increase our knowledge of their distribution, as well as ecological and phytocoenetic preferences.

Numerous records of *Sphagnum mirum* in Western Siberia, together with its recent records in the Nenets Autonomous Area (Laine et al. 2018) and on Novaya Zemlya (Czernyadjeva et al. 2020), are not consistent with Fedosov's earlier assumption of the "large-scale Berengian" distribution of the species (Ellis et al. 2018). Most likely this species has a wider distribution than "Berengian" with an optimum in the middle and north taiga and regular occurrence in the forest-tundra and south tundra subzones.

According to the literature on the Arctic and Subarctic regions, our knowledge of the species was based on scarce records. In the north of Western Siberia's forest zone, the species is known at 20 localities (Ellis et al. 2018, Lapshina et al. 2018, Safronova et al. 2018) including new data. On 7 mires the species was found repeatedly at several sites and often is abundant or even dominant.

The few number of records for *Sphagnum mirum* from mires in the north of European Russia and Yakutia could be due to the physiognomic similarity of *S. mirum* to the closely related *S. teres* and *S. squarrosum*, which are common in the same biotopes. Most bryologists tend to identify the morphologically close *S. teres* in the field, avoiding "wet growing forms", which have a higher chance to be *S. mirum* and thus the species would be under-recorded. A general tendency of lesser collector's efforts regarding the documentation of presumably very common and easily recognizable species such as *S. teres* should be considered as well.

Gaps in our knowledge of the habitats of *Sphagnum mirum* outside the forest zone in the Subarctic region of Western Siberia are likely to be filled soon, as indicated by records of the species in European Arctic and Subarctic (Laine et al. 2018, Czernyadjeva et al. 2020), in the eastern spurs of Polar Urals (pers. comm. Lamkowski 2017) and the south of Taimyr and on Putorana Plateau (Flatberg et al. 2016, Ellis et al. 2018, Lapshina et al. 2022b).

The distribution of *Sphagnum inexspectatum*, which occurs mainly on plains and in the maritime areas of the Northern Pacific (Flatberg 2005), spreading westwards as far as Western Siberia (Ellis et al. 2018). The species has been recently found in the south tundra of West Siberian plain in two study sites around Yamburg settlement and southern Taimyr in the North Siberian Lowland (Lapshina et al. 2022b). A similar distribution pattern has been shown earlier for *S. steerei* and *S. beringiense* (Maksimov 2007, Maksimov et al. 2016).

New localities of *S. inexspectatum* in the south tundra of Western Siberia (near the Yamburg settlement) are generally consistent with our earlier knowledge of its distribution. Records at the north and middle taiga boundary

in "Numto" Nature Reserve and Surgut Poles'e (63°N and 62°N, respectively) were the southernmost localities in Western Siberia. Newly-found localities of the species in the middle taiga in the Mestyg-Egan River basin in the eastern part of Khanty-Mansi Autonomous Area (61°N) are the southernmost localities of the species known in Western Siberia, since the species has been repeatedly encountered there at various sites of the huge mire massif. It means that this large population is likely to indicate a good representation of the species' environmental requirements.

The possible origin of *Sphagnum inexspectatum*, as a result of the hybridization of *S. subsecundum* and *S. orientale* (Flatberg 2005), or respectively the morphological closely related *S. miyabeanum* from the "pacific clade" Sphagna (Shaw et al. 2008), suggests that the species has spread to Western Siberia's middle taiga zone from the east, where *S. orientale* is common, rather than from the north (Muldiyarov & Lapshina 1990, Ivanova et al. 2005). However, this suggestion needs further investigation.

Based on Ramensky's scales, the ecological ordination of mire vegetation communities with *Sphagnum inexspectatum* and *S. mirum* was performed to compare the ecological features of the habitats of both species and determine their place in the entire range of mire vegetation on the gradient in bioclimatic zones. The environmental and phytocoenotic confinement of communities with these mosses is distinctly seen against the background of the ecological amplitude of the main mire vegetation classes in accordance with Braun-Blanquet approach (Fig. 6). Both species grow in various, mostly waterlogged faintly minerotrophic communities of the class *Scheuchzerio-Caricetea* fed by run-off and poor ground water, being slightly different in their environmental preferences.

In general, the mire communities with *Sphagnum mirum* occur within the broad limits of water supply starting with medium wet (subhydrophylic) shrub-birch swamps and finishing with waterlogged (aerohydrophillic) fens and quagmires (89–99 grades of wetness) (Fig. 6). An important boundary on wetness gradient is the grade 94, which separates moderately moist conditions from those with water level at or above the surface. The ecological amplitude of *S. inexspectatum* habitats with few exceptions is somewhat narrower – from 94 to 98 grades of wetness.

At the same time, the mire communities with *Sphagnum inexspectatum* demonstrate wider ecological amplitude by their nutrient conditions (between 3 and 8 grades) from oligotrophic aapa mire *Sphagnum* carpets and meso-oligotrophic *Menyanthes*-sedge-liverwort communities of the hollows belonging to the alliance *Stygio-Caricion limosae* to mesotrophic shrub-sedge-moss communities of the alliance *Caricion stantis*.

Sphagnum mirum occurs most frequently in mesotrophic (transitional) *Sphagnum* mires in various communities of the alliance *Sphagno-Caricion canescentis*, often dominated in moss cover by *S. obtusum* and *S. riparium* and in the sedge (*Carex rostrata*), herb (*Comarum palustre*, *Calla palustris*) and sedge-herb-*Sphagnum* communities of floating mats flooded periodically by snow melt water or the poor water of small rivers and brooks (6–8 grades of nutrient conditions) It is less common and less abundant in the meso-oligotrophic waterlogged hollow communities of the alliance *Stygio-Caricion limosae* (5–6 grades of nutrient conditions).

Ecological preferences of these two rare *Sphagnum* species are slightly different in various bioclimatic zones. The average value of nutrient condition grades at the middle taiga → southern tundra subzone gradient is 4.39→6.55 in mires with *S. inexspectatum* vs. 6.1→7.0 in those with *S. mirum*. Difference in habitat wetness on this bioclimatic gradient is about 0.5 grades for both species.

Based on our knowledge of their phytocoenetic preferences, more localities, potentially suitable for both of these rare species, should be found. Our experience shows that this increases the probability of finding rare species, which is essential for a better understanding of their distribution and conservation.

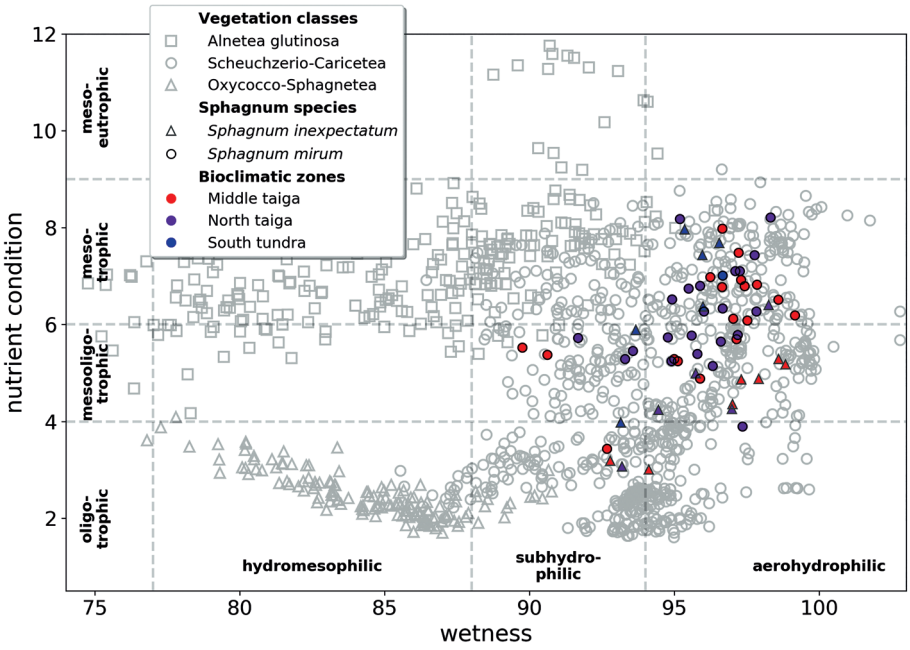

Figure 6 Location of *Sphagnum inexspectatum* (triangle) and *S. mirum* (circles) habitats shown against the ecological amplitude of the phytosociological classes of Braun-Blanquet approach (marked in grey) on Ramenskiy's scales. Phytosociological classes of mire vegetation: 1 – *Alnetea glutinosae*, 2 – *Scheuchzerio-Caricetea*, 3 – *Oxycocco-Sphagnetea*. The color of symbols indicates the belonging of the relevés to the bioclimatic subzones of Western Siberia. Mire habitat types according Ramensky's wetness scale in range from 1 to 120: hydromesophilic (77–88 grades), subhydrophilic (89–94 grades), aerohydrophilic (95–103 grades)

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APPENDIX 1
NEW RECORDS IN WESTERN SIBERIA

Sphagnum inexspectatum

WESTERN SIBERIA

ARC-WSIB Yamalo-Nenetsky Autonomous Area. (1) Nadym District, outskirts of the Yamburg settlement, on the margin of a drained lake depression ("khasyarey"), dwarf birch (*Betula nana*)–sedge (*Carex rariflora*)–moss community, (67.76473°N 75.56400°E), 10.VIII.2019 Лапшина 05239, 05240 [Lapshina] {YSU}. **(2)** ibidem, flat palsa mire complex, shrubs (*Salix*, *Betula nana*)–sedge (*Carex chordorrhiza*)–moss community, on the edge of waterlogged hollow (67.80887°N 75.35857°E), 13.VIII.2019 Лапшина 05241, 05242 [Lapshina] {YSU}; **(3)** Nadym District. Sobty-Yugan Nature Reserve, dwarf shrub (*Chamaedaphne cayculta*)–*Sphagnum* moss mesotriphic fen in river valley (65.85255°N 67.48148°E). 11.VII.2022. Lapshina 05243, det. A.I. Maksimov.

W-SIB Khanty-Mansi Autonomous Area. Nizhnevartovsk District, Mestyg-Egan River basin (left tributary of the Vakh River in its upper reaches), poor aapa mire, along the edge of flat *Sphagnum* ridges and carpets in contact with waterlogged hollows. Single plants among *Sphagnum papillosum* and *S. subsecundum*, (61.14°N 81.41°E), 11.VII.2021, Лапшина, 04308, 04310 [Lapshina] {YSU}

Sphagnum mirum

ARC-WSIB Yamalo-Nenets Autonomous Area. (1) Priuralski District, in a sedge-dominated brook with dominant *Sarmentypnum exannulatum* and abundant *Scorpidium scorpioides*, on the margin to an elevated *Sphagnum lenense*-dominated mire with *S. alaskense* (67.735750°N 67.870278°E), 27.VII.2017, NSIB2017-17 [Lamkowski] {private collection}, **(2)** ibidem, at a sedge-dominated thermokarst lakeshore together with *Sphagnum orientale*, *Paludella*

squarrosa and *Meesia triquetra* (67.700694°N 67.757222°E), 28.VII.2017 NSIB17-22 [Lamkowski] {private collection}, **(3)** ibidem, in a sedge-dominated depression together with dominant *Hamatocaulis lapponicus* and *Sphagnum orientale* (67.751472°N 67.814333°), 30.VII.2017 NSIB17-109 [Lamkowski] {private collection}; **(4)** Nadym District, left low river terrace of Levaya Khetta River valley, left tributary of Nadym River, sedge (*Carex limosa*)–*Menyanthes*–*Sphagnum* mesotriphic mire, small turfs among other mosses *Helodium blandowii*, *Sphagnum obtusum*, *S. riparium*, *Sarmentypnum exannulatum* (64.24759°N 71.06364°E), 20.VII. 2019 05244 [Lapshina] {YSU}; **(5)** ibidem, mesotriphic mire in the Levaya Khetta River valley, Mirovoe Mire, sedge (*Carex limosa*)–*Menyanthes*–*Sphagnum* (*S. riparium*) mire (64.37°N 75.61°E), 22.VII.2019 05245, 05246, 05247 [Lapshina] {YSU}; **(6)** ibidem, mesotrophic mire in the Levaya Khetta River valley, Rastratnoe Mire, sedge (*Carex rostrata*) community (64.38466°N 71.47548°E), 22.VII.2019 05248 [Lapshina] {YSU}; (7) ibidem, mesotrophic mire in the Levaya Khetta River valley, Pestroe Mire, *Menyanthes*–*Sphagnum* (*Sphagnum riparium*) mire (64.35055°N 71.26033°E), 22.VII.2019 05249 [Lapshina] {YSU}; (8) ibidem, along the route Nadym – Pangody, throw flow fen in flat palsa complex, sedge (*Carex rotundata*, *C. limosa*) community in hollow (65.58350°N 73.07422°E), 01.VIII.2019 05250 [Lapshina] {YSU}.

W-SIB Khanty-Mansi Autonomous Area. Beloyarski District, Nature Reserve "Numto", sedge-herb (*Comarum palustre*)–*Sphagnum* mire at the head of the stream (63.64°N 70.79°E), dominant or codominant in combination with *Sphagnum obtusum*, *S. riparium* (63.64555°N 70.79528°E) 13.VIII.2022. 05251 [Lapshina, Filippov, Ganasevich, Verevkina] {YSU}.

APPENDIX 2

SPECIMENS EXAMINED OUTSIDE OF WESTERN SIBERIA

Sphagnum inexspectatum

RUSSIAN FAR EAST

ARC-FE. Chukotka Autonomous Area. (1) Southern Chukotka, N-W part of Pekulney rindge, Baranie Lake (66.90000°N 175.250000°E), sedge–*Sphagnum* tundra, in hollow. 31.VII.1980 O.M. Afonina (LE, duplum PTZ) (*S. contortum*). Rev. A.I. Maksimov 15.III.2015; **(2)** Chukchi Peninsula, southeastern tip, surroundings of Chaplinsky hot springs (64.416667°N 172.500000°W), 31.VIII.1956, B.A. Tikhomirov, V.A. Gavrilyuk (LE, duplum PTZ) (*S. contortum*). Rev. A.I. Maksimov 11.III.2015; **(3)** Gil'mimlinskie hot springs (65.800000°N 173.250000°E), sedge-moss community on the bank of the rivulet, 23.VII.1977, O.M. Afonina (LE, duplum PTZ) (*S. contortum*). Rev. A.I. Maksimov 15.III.2015; (4) Provideniya Bay (64.385035°N, 173.223702°W). Sedge-cotton grass swamp on gentle slope. 24.VIII.2001. O.M. Afonina (LE, duplum PTZ) (*S. contortum*). Rev. A.I. Maksimov A. 9.III.2015.

S-FE. Amur Region. (1) Tom' River basin (50.945196°N 128.167848°E), 9.VIII.1926, Kuzeneva (LE) (*S. contortum*). Rev. A.I. Maksimov. (2) Zeya River basin, Zeya-Pristan' (53.742021°N 127.317952°E), 12.VII.1915, Prokhorov (LE) (*S. contortum*). Rev. A.I. Maksimov.

Jewish Autonomous Region. Sutara River basin (48.814577°N 131.254492°E), 16.IX.1926, Селиванов (LE) (*S. contortum*). Rev. A.I. Maksimov.