**SPHAGNUM MOSSES IN VEGETATION COVER OF HIGHLANDS IN THE SUB-POLAR URAL, KHANTY-MANSIYSK AUTONOMOUS DISTRICT**

СФАГНОВЫЕ МХИ В РАСТИТЕЛЬНОМ ПОКРОВЕ ВЫСОКОГОРИЙ ПРИПОЛЯРНОГО УРАЛА, ХАНТЫ-МАНСИЙСКИЙ АВТОНОМНЫЙ ОКРУГ

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Abstract

Species diversity of *Sphagnum* was studied in the mountain highlands (areas above a timber-line) in the Sub-Polar Urals within the Khanty-Mansiysk Autonomous District (64°27’ – 64°35’ N; 59°35’ – 59°46’ E). This work was conducted in 2013 and 2015 and revealed 19 species. Their distribution along the altitudinal profile from 300 m alt. in the upper forest belt to 1200 m in mountain tundra belt has been studied. Only one species, *S. compactum*, was found to occur mostly in the mountain tundra belt, although with a low abundance. The most common and widespread species above timber-line were found to be *S. girgensohnii* and *S. russowii*, which grow in a wide range of habitats. Several primarily bog species, including *S. fuscum*, *S. balticum*, *S. capillifolium*, *S. lindbergii*, *S. teres*, and *S. contortum* are confined in the highlands of the Sub-Polar Urals to the dwarf shrub-sedge-*Sphagnum* mires, concentrating there in less than 1% of total in surveyed area. A number of species of *Sphagnum* occur in a wider variety of the vegetation types, while three species, *S. fallax*, *S. flexuosum* and *S. jensenii* grow up to the tree-line, but never exceed it in the study area. The altitudinal distribution and frequency of *Sphagnum* species in the Sub-Polar Urals and other mountains of the Northern Eurasia are compared.

Keywords: *Sphagnum*, highlands, altitudinal distribution

INTRODUCTION

Sub-Polar Urals (SPU) is the widest and most elevated part of the ancient Ural Mountains. The mountain range here is up to 150 km wide (at 65° N), and some peaks are higher than 1800 m above sea level. Being hard to access, SPU as a whole and especially its highlands are poorly studied for the biodiversity, including bryophytes. The highlands are defined here as above the upper limit of close forests regardless of the altitude elevation; vegetation is affected there by severe conditions,

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and forests are substituted by other vegetation types, such as subalpine ("sub-goltsy") open forests and shrubs, subalpine meadows, and mountain tundra. An extensive areas near the top have primarily rock fields.

The upper limit of closed mountain forest is situated at 400–450 m a.s.l., and above this altitude a subalpine vegetation occurs. It is represented by larch-dominated open woodlands, secondary low birch forests, alder tick-ets and subalpine meadows. Since 500–600 m, mountain tundra forms the belt, which is succeeded by rock fields with only scattered and fragmentary vegetation at the level above 800–900 m. However, due to the highly dissected relief, location of the upper limit of the subalpine wood communities is very variable in the SPU. They may occur up to 650 m a.s.l. in deep valleys and on steep slopes.

Previous exploration of this area was mainly conducted on the forested mountain slopes and on neighboring water-logged plain lands, both on the west and east slopes (Lapshina et al., 2015). The data on Sphagnum from numerous publications (Pohle, 1915; Ivanovsky, 1917; Zinserling, 1935; Ghaze, 1930; Sochava, 1930; Gorchakovskiy, 1958, 1975; Kuvaev, 1970) were summarized by Dyachenko (1995); in total, 27 species were recorded in this area.

The aims of our study were to determine the species composition of Sphagnum on the eastern macroslope of SPU, with special emphasis on vegetation of higher elevations, above the tree line, and to estimate the occurrence and abundance of Sphagna species in different habitat types.

MATERIAL AND METHODS

Field surveys were carried out in 2013 and 2015 at mount Ner-Oyka and in the upper course of the Puiwa River (64°27’ – 64°35’ N; 59°35’ – 59°46’ E), in the altitudinal range of 380 to 1200 m above sea level.

In two chosen key sites, 176 vegetation relevés were done, attempting to cover most types of vegetation and habitats, and to reveal species diversity. Sphagnum species were found in 62 studied plots (35% of the whole amount). A preliminary species lists and their abundance have been drafted in situ. Identification of most specimens was checked later in the laboratory, except for easily recognizable species, such as S. fuscum, S. squarrosum, S. compactum, etc. All herbarium samples collected during the field work are stored in the herbarium of the Yugra State University (YSU) and M. Noskova’s private collection in St.-Petersburg, and duplicates were delivered to the Museum of Nature and Man in Khanty-Mansiysk.

For the analysis of species distribution patterns and their frequencies, the diversity of habitats in the SPU highlands and upper forest belt was structured into 14 large categories (groups). Sphagnum mosses were found in ten of them (Table 1). Habitats, in which Sphagnum species were not found, include young karst sinkholes, calcareous rock remnants, subalpine meadows, and disturbed habitats (roads, waste rock heaps, abandoned settlements).

For the comparison of the altitudinal distribution of Sphagnum species in SPU and in other mountain regions of North Asia, we used published data with sufficiently detailed information regarding altitudinal distribution and/or occurrence in the vegetation types above tree line. Their frequency of occurrence were scored by five grade scale (Table 2).

RESULTS

In total, 218 Sphagnum specimens were collected and identified under microscope; the whole set includes 300 records.

In these collections, 19 Sphagnum species were identified (Table 1). Among them, Sphagnum fallax, S. flexuosum and S. jensenii were collected only within the forest belt, in meso-oligotrophic sedge-Sphagnum mire, situated in the Puiva River valley at 390 m a.s.l. The rest 16 species were found above the tree line, in smaller or greater amounts.

Rock outcrops and rock fields (kurumniks) (Table 1, column 1). Sphagnum species are rare in rock fields and grow mostly on soil under big rocks, on fine earth filling flat moist recesses, at groundwater outcrops between rocks, or sometimes spread on rock surfaces on steep slopes to the narrow creek canyons, where air is very humid. The most frequent is S. girgensohnii; it forms pure extensive mats, rarely with admixture of S. russowii. On wet soil under rocks, small tufts of S. aongstrostomii and S. squarrosum were found, while S. compactum grew on dry moss litter between rocks of rock field. S. lindbergii was once observed at the bottom of rock field, at the edge of late snow bed, between rocks, in water running from melting snow.

Tundra vegetation. Sphagnum species are absent in most tundra sites, except for few ones. We studied 19 dwarf shrub-lichen-moss and herbaceous-green moss tundra communities, and Sphagnum mosses were noted in only three of them (Table 1, column 2). Thus, mountain tundra vegetation, which occupies no less than 70% of the study area, is poor in Sphagna. Only two species, S. girgensohnii and S. compactum, occurred in tundra itself, both being quite rare. They were found in moderately drained sites in dwarf shrub-lichen-moss and herb-moss tundra. The former species formed small cushions directly on mineral soil, and the latter one grew in flat patches up to one meter in diameter.

Late snowmelt sites and nival meadows. Sphagnum avoids sites with late snowmelt (Table 1, column 3), where only not abundant (1–3%) Sphagnum girgensohnii and S. russowii were observed once as an admixture to liverworts Neoorthocaulis floerkei, Lophozia wenzelii and green mosses Kiaeria starkei and Ologotrichum hercinium.

Bogged dwarf shrub-moss tundra. Species diversity and abundance of Sphagna sharply rise in boggy dwarf...
Sphagnum mosses in vegetation cover of mountain highlands in the Sub-Polar Ural

Sphagnum mosses in vegetation cover of mountain highlands in the Sub-Polar Ural shrub-moss tundra communities, represented in tundra belt (Table 1, column 4). Such type of tundra develops in shallow depressions and on poorly insolated north-facing slopes. Mosses form here a layer up to 15–20 cm thick. First stage of Sphagnum expansion includes S. girgensohnii, occurring as an admixture to other mosses, and S. aongstroemii, forming pure tufts in small depressions. On further stages, as can be assumed from higher Sphagnum abundance, S. russowii and S. angustifolium appear. Total cover of Sphagna in boggy tundra is up to 20–40%.

**Dwarf shrub-sedge-Sphagnum mires.** The highest diversity of Sphagnum mosses (13 species) was detected in high-mountain dwarf shrub-sedge-Sphagnum mires (Table 1, column 5). These mires varied in size, from several square meters to 1–2 ha, however, in total occupying not more than 1% of the territory. Sphagnum mosses cover was up to 95% of the surface of such mires. Various combinations of Sphagnum species dominated there, i.e., Sphagnum russowii, S. capillifolium, S. angustifolium and S. warnstorfi, often with a notable contribution of S. balticum, S. fuscum, S. teres and S. girgensohnii. Sphagnum aongstroemii was quite common at early stages of mire development. In the course of microrelief differentiation, hollows are formed, where Sphagnum lindbergii gained the absolute dominance. Rarely Sphagnum contortum and S. majus were also observed in these high-mountain mires.

**Fens and waterlogged willow carrs.** Sphagnum warnstorfi was the only fairly constantly present species of this genus in mineral-rich fens and waterlogged willow carrs. It grew on peat and peat-mineral soil at groundwater outcrops (Table 1, column 6); however, its cover rarely exceeded 10–20%. Its occasional and non-abundant companions were S. squarrosum, S. girgensohnii and S. aongstroemii.

**Alder thickets and larch open forests.** Woody communities close to the tree line in subalpine belt were most poor in Sphagna. The only species constantly present there, though in small quantity, was Sphagnum girgensohnii (Table 1, column 7). It grew in small pure tufts in the ground layer and on mossy rocks, among Hylocomium splendens, Pleurozium schreberii, Rhytidiadelphus squarrosum and Sciuro-hypnum reflexum. The diversity of Sphagnum species noticeably increased in the mountain forest belt, especially in wet conditions in waterlogged forests in river valleys (Table 1, column 9).

**Banks of rivulets and streams** in highlands did not have a distinctive species diversity of Sphagnum mosses compared to those in forest belt (Table 1, columns 8-t and 8-f). Most Sphagnum species, which were found on the banks of rivulets and streams, occurred up to the upper bounds of the mountain tundra belt. The exception was Sphagnum riparium, which did not exceed the sub-goltsy belt. Species composition depended on the type of sub-
Table 2. Altitudinal distribution and frequency of *Sphagnum* species in mountains of Northern Eurasia (arranged from West to East): **Lav:** Lavana-Tundra mountains, Murmansk Province (Likhachev & Belkina, 1999); **Khi:** Khibiny Mountains (Schljakov, 1961); **NU:** North Urals, Vishera Nature Reserve (Ignatova et al., 1996); **SPU:** Sub-Polar Urals (present paper); **PU:** Polar Urals (GhaZe, 1930; Czernyadjeva, 1994); **Put:** Putorana Plateau (Czernyadjeva, 1990, 1992); **Say:** Sayan Mountains (Bardunov, 1974); **Alt:** Altai (Ignatov, 1994); **M-Kh:** Mus-Khaya Mountain, Yakutia (Ignatova et al., 2011); **Kam:** Kamchatka Peninsula (Czernyadjeva, 2012). Frequency is indicated as: **com** – common, **fr** – frequent; **sp** – sporadic, **rr** – rare, **un** – unique, + – present with unknown frequency. Frequency of species found only in the forest belt is given in parentheses.

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<th>Species, total</th>
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Species of the whole altitudinal profile, including upper highlands

- *S. compacitum*: sp – fr – sp – sp – – – sp – rr (un) – com
- *S. aongstroemii*: (un) – – (un) – fr – – – un – rr – – sp –
- *S. rubelliil*: – – – (un) – fr – – – un – sp – sp –
- *S. squarrosum*: sp – sp – sp – (fr) + – (sp) – sp – (sp)

Species of forest and subalpine belts, and low part of highlands

- *S. lindbergie*: fr – fr – (rr) – sp – sp – – – un – – sp
- *S. platypyllium*: sp – un – – – – – fr – – (sp)
- *S. subsecundum*: fr – un – (rr) – – – – – un – – sp
- *S. contourt*: – (un) – – un – un – (+) – – un – rr
- *S. jensenni*: rr – sp – (sp) – (un) – – – – rr – – sp
- *S. centrale*: (sp) – (sp) – un – – – un – rr – un – sp
- *S. lenense*: – – – + – fr – (+) – – fr –

Species mostly limited by forest and low part of subalpine belt

- *S. magellanicum*: (un) – (rr) – (fr) – – – (+) – rr – rr – (sp)
- *S. fallax*: (un) – – (rr) – – (rr) – (sp) – rr – rr
- *S. flexuosum*: – – fr – (un) – – – (un) – fr – – (rr)
- *S. majius*: – – (rr) – un – – – – – – (rr)
- *S. subfulvum*: un – (un) – – – – – – – rr –

Species limited by forest belt

- *S. papillosum*: (un) – – (un) – – – – – (un) – sp
- *S. obtusum*: – – – – – – + – – – – – (un) – (rr)
- *S. wulfianum*: – – (un) – – (sp) – – – –
- *S. cuspidatum*: – – – – – – (sp) – – (un)
- *S. palustre*: – – – – – – – (un) – – un
- *S. quinguefarium*: – un – – – – – (un) – (rr) – –

Besides, single mountain moss floras contain: **Lav** – *Sphagnum subnitens*, (rr); **Put** – *S. orientale*, +; **M-Kh** – *S. tundrae*, un; **Kam** – *S. inundatum*, rr; **PU** – *S. subnitens*, un; **Say** – *S. tundrae*, un; **Alt** – *S. tenellum*, (un); **M-Kh** – *S. pulchrum*, (un); **Kam** – *S. inexpectatum*, (un).
Presence of some other *Sphagnum* species above tree line in SPU is quite possible; these are *Sphagnum jense-nii, S. flexuosum* (both detected by us only in the upper part of the forest belt) and *S. centrale*; the latter species was reported from the mountain tundra and the forest belt of the North Urals (Ignatova et al., 1996). All three species are occasionally found in the highlands in many Eurasian mountain systems.

**DISCUSSION**

Our data are generally in good agreement with the patterns of altitudinal and ecological-phytocenotic distribution of species in adjacent parts of the North and Polar Urals and in other mountain systems of Northern Eurasia (Table 2). The total number of *Sphagnum* species varies among individual mountain systems from 13 to 31, being 20–22 species in average. The number of species is the lowest under the harsh conditions of ultra-continental climate (Mt. Mus-Khaya, Yakutia, cf. Ignatova et al., 2011). Mountains of Kamchatka are the richest in *Sphagnum* species, apparently due to the high diversity of habitats and high level of bryological exploration (Czernyadjeva, 2012). Average number of *Sphagnum* species within high mountain vegetation belt ranges within 10–20 species, constituting from 60 to 90% of the total species diversity of *Sphagnum* in the area; though it depends on the covering of these highlands by bryological studies. The respective value in the SPU is over 80%.

The species featuring the widest altitudinal amplitude and occurrence in the greatest number of habitats in SPU highlands is *Sphagnum girgensohnii*, which is also the most frequent species there, and extremely diverse morphologically. It is the only highest-climbing representative of the genus, which is typical for the alpine belt in European mountains (Dierssen, 2001), whereas the bulk of other species are limited to the forest belt or the lower sub-alpine belt (Gerdol & Bragazza, 1994). *Sphagnum girgensohnii*, along with *S. warnstorffii*, is noted for high frequency of occurrence in nearly all high mountain moss floras of Northern Asia (Table 2). The exception is the local flora of Mus-Khaya Mountain in Yakutia (Ignatova et al., 2011), where these species are practically absent. Remarkably, *S. warnstorffii* in SPU highlands falls somewhat behind *S. russowii* in terms of the range of habitats and frequency of occurrence, probably because of the obvious prevalence of siliceous rocks over very locally appearing calcareous rocks in this area.

*Sphagnum* species occur in different types of habitats in the mountain tundra belt, although some species are relatively infrequent, i.e., *Sphagnum compactum, S. aong stroemii, S. rubellum, S. squarrosum*, and *S. fimbriatum*.

Distribution of *S. fuscum, S. balticum, S. capillifo-lium, S. lindbergii, S. teres* and *S. contortum* in SPU highlands, like in other mountain systems of northern Eurasia, is associated, predominantly or exclusively, with mountain peat mires (Schljakov, 1961; Bardunov, 1974; Gerdol & Bragazza, 1994; Chenyadjeva, 2012). The frequency of peat mires declines rapidly in mountain tundra belt, apparently due to severe climate conditions, which become too cold and dry for the development of at least some types of mires. Thus most *Sphagnum* species closely connected with peat mires are restricted to the forest and subalpine belts, and to the lower part of tundra belt. According to our observations, the ecological-phytocenotic amplitude of *S. angustifolium* and *S. aong stroemii* is somewhat wider, so they have higher frequency. We collected all species mentioned above at much higher altitudes in SPU highlands than it was reported previously: a majority of species grew up to 920–960 m a. s. l., *S. lindbergii* – to 900 m, and *S. contortum* – to 630 m. Furthermore, some species previously known only from plains and lower parts of the forest belt, were found in highlands: *S. fallax, S. flexuosum, S. jensenii* and *S. majus* were collected in the sedge-*Sphagnum* mire close to the tree line, at 390 m a.s.l.; *S. squarrosum* and *S. riparium* grew in a waterlogged willow carr in the upper part of the sub-goltsy belt, at 530 m a.s.l.; some other species were detected even from the upper part of the mountain tundra belt, including *S. fimbriatum* growing along stream bank at 790 m, *S. majus* in a *Sphagnum* mire at 900 m, and *S. squarrosum* on fine earth substrate in a large-boulder stone river, at 980 m a.s.l.

The species diversity of *Sphagnum* mosses in the highlands of the SPU eastern slope is most similar to that in the Vishersky Nature Reserve, which is situated on the western slope of North Urals (Table 2). The higher proportion of species limited in distribution to the forest belt in Vishersky Reserve can be explained by the fact that high mountain habitats were less studied than the forest belt (Ignatova et al., 1996).

Compared to the Polar Urals, some species reach higher elevations in SPU mountains, which is quite explicable. Thus, *Sphagnum teres* and *S. lindbergii* do not get higher than larch open woodland of the sub-goltsy belt in the Polar Urals, but they are sporadically present all along the altitudinal profile in the SPU, up to the upper limits of the mountain tundra belt. *Sphagnum squarrosum* and *S. riparium* occur in the sub-goltsy belt and higher in the SPU, but do not reach further than the forest belt in the Polar Urals. Such species as *Sphagnum fallax* and *S. flexuosum*, being present in the upper part of the forest belt in the SPU, were not found in the Polar Urals (Table 2). On the other hand, *Sphagnum lenense* and *S. rubellum* are quite frequent in the highlands of Polar Urals, but the former species is very rare and the latter one has not been found in the mountains of Sub-Polar Urals.

The collected data can be used in further studies of the moss flora and in environmental monitoring of Sub-Polar Urals highlands based on identification of trends in the altitudinal distribution and phytocenotic activity of *Sphagnum* mosses under the impact of global climate warming.
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