
The Structure and Functional Features of *Sphagnum* Cover of the Northern West Siberian Mires in Connection with Forecasting Global Environmental and Climatic Changes

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Introduction

Changes in structural and functional features of *Sphagnum* cover may be very sensitive indicators of climatic shift in Western Siberia. The spread of raised *Sphagnum* bogs in the West Siberian Plain is limited by low temperatures and the presence of a permafrost earth layer in the north, and by precipitation in the south. It is expected that global warming and increases in ambient CO₂ concentrations may shift bioclimatic zones northward. Comparative ecophysiological analysis of *Sphagnum* indexes for contrasting bioclimatic zones is very important in order to forecast possible changes in northern peatlands and to estimate the tolerance range of *Sphagnum* species.

Western Siberia is located in the central part of the Eurasian continent, covering a vast area from the Urals to the Yenisei River. The extent of the territory is more than 2500 km in the meridional direction; therefore the climate in Western Siberia is very diverse. Within the bounds of the plain territory (West Siberian Plain, WSP) the latitudinal bioclimatic zones (tundra, forest tundra, taiga, forest-steppe and steppe) are very well distinguished. They replace each other to the south in accordance with temperature and moisture gradients (Richter 1963).

Boggy soils are characteristic of the plain territories. Such types of soils can be explained by the surface slope to the north, high relative humidity, and weak drainage. However, the spread of mires to the north is limited by the presence of

Table 15.1. Base wetland types and percentage of the paludal area

Bioclimatic zone	Wetland types	Paludal area	
		10 ⁶ ha	% of zone area
Tundra	Polygonal mires	7.1	13
Forest-tundra	Flat- and big-hummock (frozen) palsas	3.8	28
Northern taiga		17.8	31
Middle taiga	Patterned (ridge–hollow) and domed	19.5	35
Southern taiga	oligotrophic <i>Sphagnum</i> bogs	17.7	25
Forest–steppe and steppe	Eutrophic and mesotrophic mires dominated by sedges and rushes	0.7	< 9

Source: Kosykh *et al.* (2008).

a permafrost layer. Its southern extent is located at about 61–62°N. The mires do not violate the general latitudinal and zone pattern and naturally fit into the complex mosaic of forest–swamp landscapes, as well as carrying out an important accumulative function. Within the West Siberian Plain several swamp zones can be distinguished, which differ in intensity of boggy pedogenesis, typology of swamps, typical vegetation, and structure of the *Sphagnum* layer (Kats 1948; Romanova 1977; Liss & Berezina 1981; Liss *et al.* 2001). The total area of swamps in Western Siberia, according to the evaluations of different authors, is 58–102 million hectares (Vomperski 1994; Yefremov & Yefremova 2001; Vaganov *et al.* 2005; Velichko *et al.* 2007; Peregon *et al.* 2008). It should be noted, however, that the accuracy of such evaluations greatly depends on the selected cartographic basis and the calculation method. The areas covered by swamps, and the characteristic types of swamps within different bioclimatic zones, are presented in Table 15.1. The bog-forming process is especially well expressed in the forest zone (northern and middle taiga).

In the forest zone (middle and southern taiga) the swamps of atmospheric and mixed atmospheric-ground water sources prevail. Thus, oligotrophic and mesotrophic peat bogs with *Sphagnum* peat occupy more than 65% of boggy soils. For steppe and tundra zones, eutrophic swamps (rich fens) dominated by a vegetation structure consisting chiefly of large sedges are characteristic. In transition zones, such as forest–tundra and forest–steppe, the spreading of *Sphagnum* swamps is limited by unfavorable environmental conditions.

The vegetation cover of raised *Sphagnum* bogs of the middle and southern taiga is represented by pine – dwarf shrub – *Sphagnum* communities (ryams) in drained landscape areas, and sedge–*Sphagnum* communities in waterlogged hollows. The term "ryam" is a synonym for a raised bog with stunted pine

trees. The dense moss cover in ryams is mostly composed of *Sphagnum fuscum* (Schimp.) Klingg. Similar vegetative communities include the patterned ridge–hollow complex bogs. Separate hummocks and intervening local depressions are often covered with *Sphagnum magellanicum* Brid. and *Sphagnum angustifolium* (Russ. ex Russ.) C. Jens. True mosses are represented by *Pleurozium schreberi* (Brid.) Mitt. and *Polytrichum strictum* Brid.

Oligotrophic hollows are covered by sedge–*Sphagnum* and cottongrass–*Sphagnum* communities with *Carex limosa* L. and *Eriophorum russeolum* Fries. In the dense *Sphagnum* cover of hollows, *Sphagnum balticum* (Russ.) Russ. ex C. Jens. and *Sphagnum papillosum* Lindb. prevail. On the edges of large boggy areas, poor fens with *Carex rostrata* Stokes, *Sphagnum jensenii* H. Lindb., *S. fallax* (Klinggr.) Klingg., and *S. majus* (Russ.) C. Jens. occur.

To the north of the forest zone on frozen hummocks *S. fuscum* loses its prevailing position, which is then taken by the lichens *Cladonia rangiferina* (L.) Web. and *Cladonia stellaris* (Opiz.) Brodo. The latter two species, together with *Pleurozium schreberi* and *Dicranum* sp., force *S. fuscum* to the edges of hummocks. Relatively favorable conditions for *Sphagnum* moss remain in oligotrophic hollows that thaw down to the mineral bottom, and in places that lowered due to thermokarst subsidence of lakes, in “hasyreis,” i.e., drained lakes, in the communities of *Carex rostrata* – *Eriophorum polystachion* – *Sphagnum riparium* Aongst., *S. jensenii* and *Carex limosa* – *Eriophorum russeolum* – *Sphagnum balticum*, *S. lindbergii* Schimp. ex Lindb.

Raised *Sphagnum* mires also occur in the forest–steppe zone. They have formed under the influence of pine – dwarf shrubs – *Sphagnum* and birch – dwarf shrubs – *Sphagnum* phytocoenoses. *Sphagnum fuscum* and *S. capillifolium* (Ehrh.) Hedw. are predominant in the moss layer. However, raised *Sphagnum* mires in this region are vulnerable and fragment because the locality is at the limit of the range and physiological tolerance of *Sphagnum*. They do not form any substantial mire areas, but are represented as separate small islands. This is especially true for the mires located near settlements and subject to anthropogenic influence (fires, deforestation, excavation of turf, etc.). Certain types of *Sphagnum* and the degree of *Sphagnum* cover in mire ecosystems are sensitive indicators of ongoing changes happening in the environment. Thus studies of structural and functional characteristics of the *Sphagnum* cover of mires, and the assessment of their ecological condition, represent valuable scientific and practical avenues of research, particularly in relation to recent climatic trends.

Subjects and methods of research

In this study the moss density, linear *Sphagnum* growth, net primary production, moss production efficiency, and total dark respiration were

analyzed in relation to geographical latitudes and ecological factors. These included permafrost, temperature, water table level, and hydrological regime.

This work was mostly carried out from 1995 to 2005, and occasionally from 2006 to 2008. The subjects of research were different species of *Sphagnum* moss growing in the West Siberian Plain from tundra to forest–steppe. They were identified according to the keys in Savich-Lyubickaya and Smirnova (1966) and Mul'diyarov (1990).

There are several methods of analysis of the structure and functional state of vegetation. In this work we applied the approach based on distinguishing several ecogroups of *Sphagnum* moss similar in their habit, production potential, and morphophysiological characteristics. Normally such species occupy similar ecological niches and carry out the same functions in the community.

We have distinguished three basic groups of *Sphagnum* with respect to moisture. In doing this we have taken into account microrelief peculiarities of habitats and conditions of mineral nutrition. The first group includes the species that prefer habitats with relatively low levels of bog water, well-drained hills, beds, and hummocks, which sometimes form rising *Sphagnum* “cushions.” Normally the representatives of this group relatively easily sustain short desiccation periods and quickly restore their physiological functions after being wetted (*S. angustifolium*, *S. magellanicum*, and *S. capillifolium*), or form dense sod cover (*S. fuscum*), retaining moisture for a long time, which can also be regarded as an adaptation to desiccation. Compared with other species of this group *S. fuscum* is characterized by its ability to form isolated communities with absolute dominance on hills, beds, and moss “cushions” in forest zone swamps.

Sphagnum species inhabiting oligo- and mesotrophic hollows (*S. balticum*, *S. fallax*, *S. majus*, *S. riparium*, and others), are sharply different in their habit, morphophysiological characteristics, and production potential. Normally the water table level in such habitats during wet periods reaches *Sphagnum* capitula (and sometimes immerses them), and during dry periods it can recede 7–10 cm lower, very rarely 15 cm. These species are typical hygrophytes and we classified them into the second group. It is interesting to note that the representatives of the first and the second groups, which were studied in the southern taiga of Western Siberia (Yefremov & Yefremova 2000), are considerably different in their contents of chlorophylls *a* and *b*, and in the correlation between them. The first group had higher values of these pigments.

The third group includes the species occupying the lower parts of slopes and edges of local hills, beds, and hummocks (*Sphagnum compactum* DC. in Lat. et DC. (= *S. capillifolium*), *S. nemoreum*, *S. rubellum* Wils., and *S. papillosum*). They often inhabit transitional zones, from elevated swamp areas to waterlogged depressions. However, they do not take the prevailing positions in *Sphagnum* communities.

For the assessment of the functional state of *Sphagnum* moss we used several parameters: the reserve of green phytomass, G (g dry mass m^{-2}), the annual linear increase, L (mm yr^{-1}), the density of *Sphagnum* sod, D (capitula m^{-2}), the annual net production, ANP (g $m^{-2}yr^{-1}$), and the intensity of dark respiration, R (mg CO_2 $g^{-1} h^{-1}$). In addition, we determined the dry mass of capitula of each species of *Sphagnum*. We selected all samples and carried out all measurements locally, on homogenous areas of *Sphagnum* cover.

The linear increase of *Sphagnum* moss was evaluated by using the method of "individual markers." For this we carefully fixed a thin wire ring with a label under the plant's capitulum, as shown in Fig. 15.1. The label was located 5–10 cm away from the plant. When using this method it should be noted that the wire ring should lie freely on the upper twigs and should not move down at will. A year later we recorded the increase by taking all *Sphagnum* from 100 cm^2 areas, in the centers of which the marked species were located. The distance between a and b , between the capitulum and the ring, was measured with a ruler. The new growth portion of the stem was cut off and dried completely; the dry masses of the capitulum and the recent stem growth were determined separately. The data were recorded from 5–10 locations for each habitat.

The moss cover density was evaluated according to the number of capitula of *Sphagnum* on randomly situated surface areas. Under field conditions we made digital photographs of the standard area, 10 $cm \times 10$ cm of homogenous moss cover. The border areas of the plots examined were marked with a scale frame. The photographs were processed by means of a software image analysis program. For this we marked the *Sphagnum* capitula and counted them automatically (Fig. 15.2). Using this method implies that the annual moss production can be calculated by multiplying the average annual increase of one plant by moss cover density. Thus, the method of digital photography allows us to substantially simplify the calculation of the number of *Sphagnum* plants per unit area.

The intensity of dark respiration of *Sphagnum* moss was measured by two different methods, static and dynamic, using an infrared gas analyzer (IRGA) Infralit-5 (0–0.01 v/v CO_2 , Germany). The observations were carried out mostly in the summer. The plant material for evaluations was taken from the areas with homogenous *Sphagnum* cover. For the dynamic method we cut out 15 $cm \times 15$ $cm \times 15$ cm monoliths from the upper layer and delivered them to the field laboratory. Changes in dark respiration were measured in an open gasometric system with IRGA under the open-air temperature (Voznesenski 1990). For experiments we used only living phytomass, the upper pigmented (autotrophic) and the lower (heterotrophic) *Sphagnum* parts. Before the measurement the moss was carefully separated from the turf and placed in an 0.5 l exposure chamber. Each sample was measured for 10–12 min.

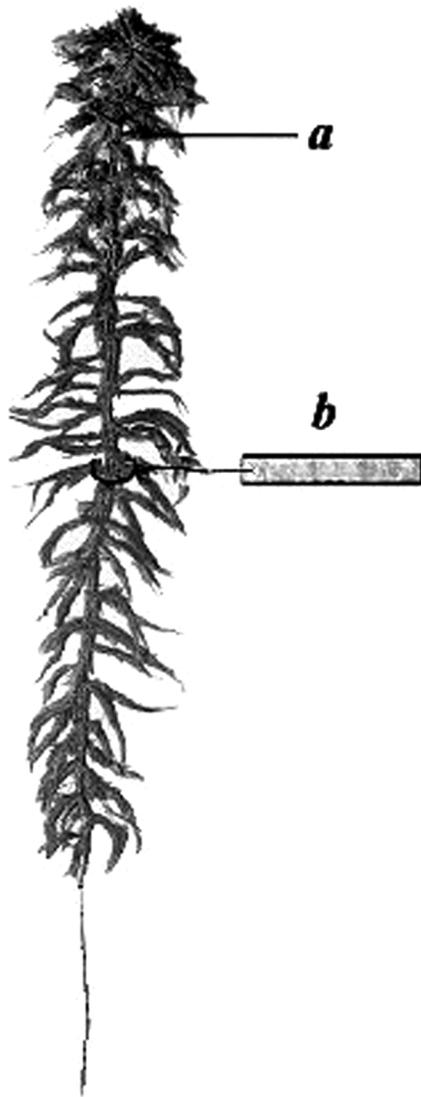


Fig. 15.1. Positions (a and b) of the individual marks on *Sphagnum* plants at the linear metering; a–b represents a linear gain in length, rectangle represents the aluminum foil tag.

The static method of exposure in closed chambers was used to measure the respiration of living *Sphagnum* and samples of the upper turf layer directly in field conditions under habitat temperature *in situ*. In the course of experiments the chambers with samples were placed into the moss sod cover. The temperature in the middle part of the moss layer was measured with a mercury thermometer. Air samples from the chambers were taken with syringes every

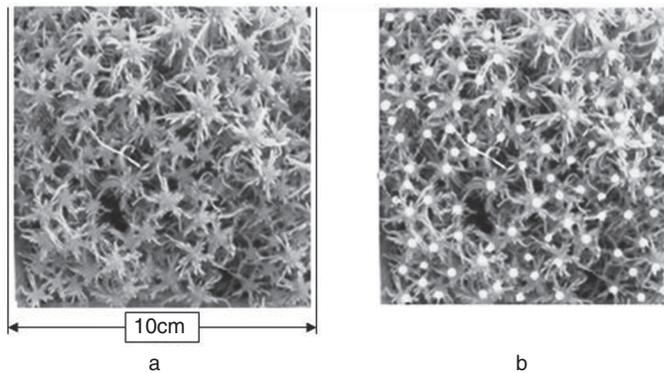


Fig. 15.2. Original (a) and processed (b) pictures of *Sphagnum* cover.

4–5 min and analyzed in a field laboratory by means of IRGA, precalibrated by means of an impulse method with pure CO₂. In the tables the average values of results and their standard deviations, calculated per unit of dry mass, are shown. Both methods showed comparable results.

Results and discussion

Sphagnum species carry out important establishment functions as part of the vegetation of oligotrophic and mesotrophic mires of Western Siberia. They usually dominate the moss layer and determine the qualitative composition and properties of the upper turf. They are especially widespread in the taiga zone. To the north and south of this zone, owing to the change in climatic conditions, the occurrence of *Sphagnum* bogs in the landscape mosaic decreases. How does the change of climatic factors influence morphophysiological characteristics, production potential, and bog building functions of the representative *Sphagnum* species? The answer to this question is of obvious scientific and practical interest because it may throw light on the current and future dynamics of the natural environment of a large (on the global scale) region of the planet.

The diversity of *Sphagnum* moss species in the region examined is relatively high. Out of 43 species registered in the plant guides for the territory of the former USSR in Western Siberia there are 31 described species (Savich-Lyubickaya & Smirnova 1966; Mul'diyarov 1990; Liss *et al.* 2001; Lapshina 2003). By comparison, in the mires of western Canada (Alberta, coniferous forest area) 21 species of *Sphagnum* moss can be found (Vitt & Andrus 1977).

We studied the mass of capitula (heads) of *Sphagnum* moss, growing in different conditions (Fig. 15.3). The analysis of the primary data, including about 650 records, made it possible to assess considerable variation in this parameter

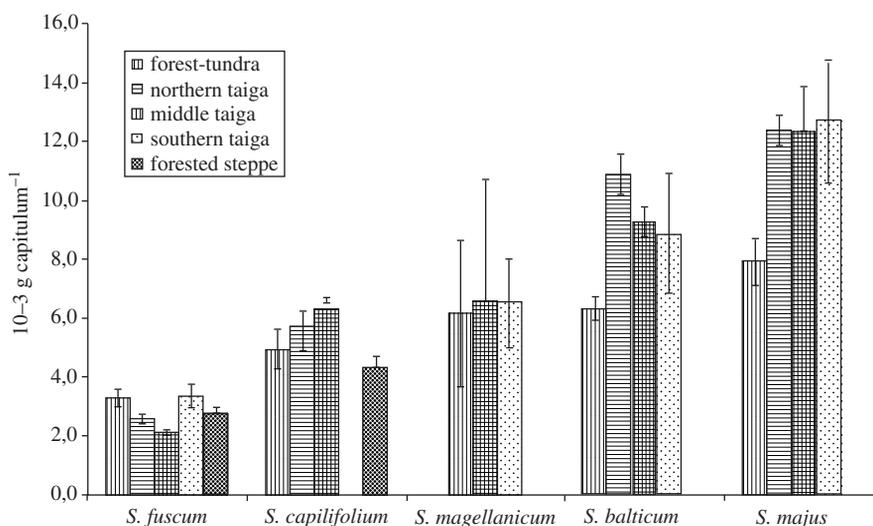


Fig. 15.3. Capitulum biomass of five species of *Sphagnum* in five regions.

within representatives of different groups. Capitulum mass was highest in the typical hygrophytes *S. balticum* and *S. majus*. They had the largest and the heaviest apical segment. *Sphagnum fuscum* had the highest capitulum mass in the moss layer of the pine – dwarf shrub – *Sphagnum* oligotrophic bogs; it is characterized by a shortened stem and a much lighter head.

The impact of the climatic conditions in the corresponding zones influenced the value of capitulum size among the representatives of the first and the second group of *Sphagnum* species in different ways. The minimum size (mass) of heads of *S. fuscum* was found in the middle taiga, and to the north and south of this zone size increased. Regarding *S. balticum* and *S. majus*, no reliable changes in this parameter within the bounds of the taiga zone were found. However, in the forest–tundra both species were characterized by lower values. *Sphagnum magellanicum*, which we referred to the first group, happened to be closer to hygrophytes regarding its parameters. Nevertheless, attention should be paid to wider dispersion of values inside the sampling areas. We suppose that this fact is related to the adaptive capabilities and the ecological flexibility of this species.

One more important parameter for assessing the functional state of different species of *Sphagnum*, is production potential, i.e., the correlation between the annual dry mass increase and the reserve of green phytomass. We demonstrated the existence of the direct dependence of ANP on G for ecologically different species of *Sphagnum* (Fig. 15.4). It is evident that the angle of the regression line on the graphs characterizes the working efficiency of the assimilation mechanism of plants in certain climatic conditions, and the coefficient of

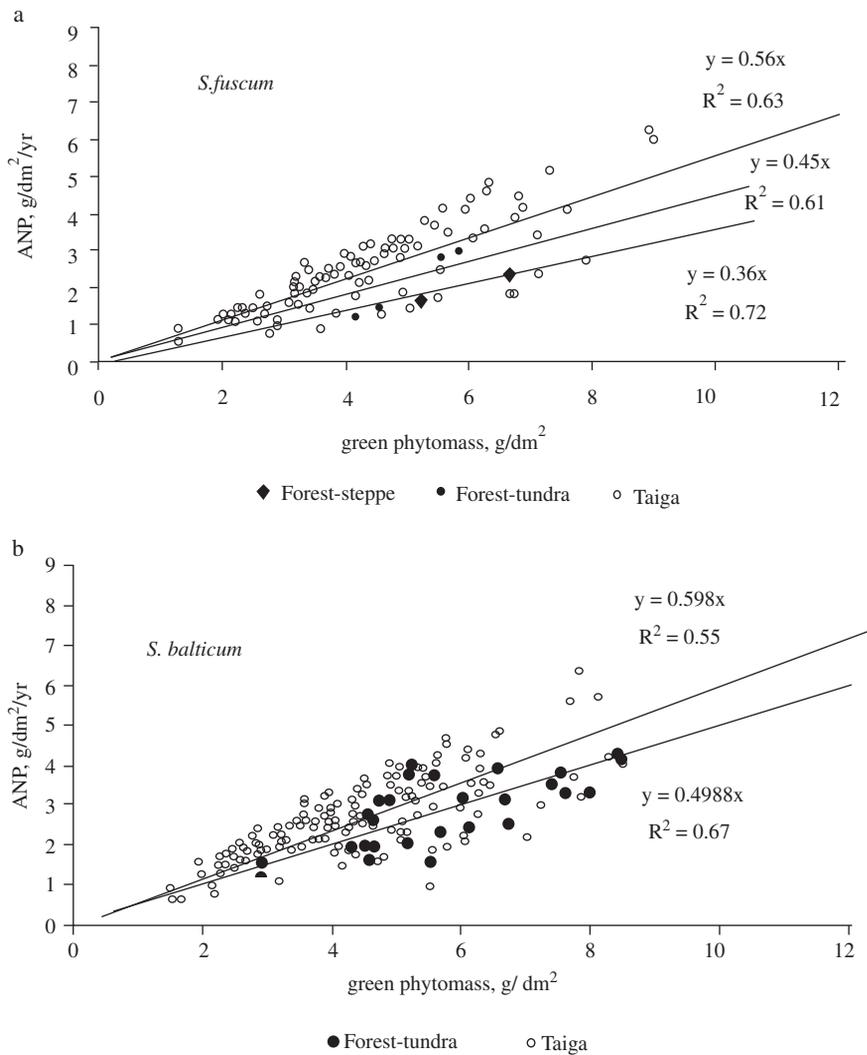


Fig. 15.4. Net production potentials of the photosynthesizing phytomass of *Sphagnum* mosses of dry (a) and wet (b) habitats.

proportionality is a characteristic of the living phytomass renewal. Taiga is apparently the zone of the ecological optimum for *S. fuscum*. In forest-tundra and forest-steppe the efficiency of its production process was noticeably lower. The coefficients ANP/G, calculated separately for the southern, middle and northern taiga, nearly coincided at 0.53–0.59. Thus, the renewal of the moss cover of pine – dwarf shrub – *Sphagnum*, dwarf shrub – *Sphagnum* and similar high bogs with prevailing *S. fuscum* takes about two years. The renewal process of hygrophytes inhabiting oligotrophic and mesotrophic sedge-*Sphagnum* bogs in

Table 15.2. Average values and SD (in parentheses) of linear growth, moss cover density and annual production of *Sphagnum* species

L, length; D, density; ANP, Annual net production; Caps, Capitula; WTL, bog water table level; * permafrost; n.m., not measured; FP, frozen palsa; RD, ridge; RM, ryam; OH, oligotrophic hollow; OM, mesotrophic hollow.)

Cluster	Habitat	Species	L, mm yr ⁻¹	D, 10 ³ caps m ⁻²	ANP, g m ⁻²	WTL, cm
<i>Northern taiga</i>						
1	FR	<i>S. fuscum</i>	5 (1)	90 (9)	180 (20)	45*
1	RD	<i>S. fuscum</i>	20 (5)	64 (5)	220 (30)	60
1	RD	<i>S. angustifolium</i>	20 (6)	28 (5)	230 (30)	43
2	OM	<i>S. lindbergii</i>	23 (2)	12.6 (0.9)	220 (19)	7
2	OM	<i>S. balticum</i>	30 (3)	10.6 (0.8)	298 (14)	7
2	MM	<i>S. fallax</i>	106 (14)	19 (1.6)	375 (23)	20
2	MM	<i>S. riparium</i>	61 (6)	14.7 (1)	250 (15)	10
2	MM	<i>S. majus</i>	60 (3)	9.6 (0.5)	200 (20)	4
2	MM	<i>S. jenseni</i>	60 (10)	14.6 (0.9)	250 (50)	0.5
3	RD	<i>S. nemoreum</i>	15(5)	40.8 (4)	150 (20)	n.m.
3	MM	<i>S. compactum</i>	20 (2)	4.4 (1)	208 (15)	15
<i>Middle taiga</i>						
1	RD	<i>S. fuscum</i>	9 (0.9)	76.2 (4.1)	245 (54)	35
1	RM	<i>S. fuscum</i>	19 (2.1)	58.7 (3.2)	390 (50)	40
1	MM	<i>S. angustifolium</i>	30 (2)	17.2 (2.8)	185 (9)	15
2	MM	<i>S. majus</i>	30 (3)	12 (0.5)	290 (20)	4
2	OM	<i>S. lindbergii</i>	37 (4)	12.3 (0.7)	279 (15)	8.5
2	OM	<i>S. balticum</i>	35 (3)	12.9 (1.5)	255 (50)	8
2	MM	<i>S. fallax</i>	87 (5)	12.7 (1.4)	320 (20)	n.m.
2	MM	<i>S. riparium</i>	60 (5)	23.2 (3)	318 (30)	7
3	MM	<i>S. papillosum</i>	28 (3)	12 (2)	320 (50)	9
<i>Southern taiga</i>						
1	RD	<i>S. fuscum</i>	12.1 (1)	54 (1.4)	314 (36)	30
1	RD	<i>S. angustifolium</i>	23 (4)	15 (0.3)	150 (40)	40
1	RD	<i>S. magellanicum</i>	30 (5)	12 (0.2)	170 (20)	30
2	MM	<i>S. majus</i>	70 (10)	10 (1)	250 (20)	12
2	MM	<i>S. balticum</i>	100 (20)	12.8 (2.1)	280 (30)	14
2	MM	<i>S. fallax</i>	130 (15)	12 (2)	300 (25)	14

forest zone, is somewhat faster ($ANP/G = 0.56-0.70$). Our data provide support for the assumption about the lifetime of *Sphagnum* stems in bogs on the southern taiga (Yefremov & Yefremova 2000).

In Table 15.2 we present the production values of *Sphagnum* moss in different habitat conditions (within the optimum zone, taiga) in more detail. The

productivity and the moss cover density are largely determined by the conditions of water–mineral supplies of the habitat. The diversity of species and growth conditions of *Sphagnum* moss in Western Siberia made it possible to assess the production potential and the range of change in annual primary production of the basic turf-formers of high bogs. In spite of the obvious differences of the average habitat elevation of different *Sphagnum* species, the value of primary production showed only 1.5–2× variation (separately for each sub-zone). This happened in natural conditions owing to the variation of the density of *Sphagnum* cover from 4.4×10^3 stems m^{-2} for *S. compactum* to 90×10^3 stems m^{-2} for *S. fuscum*. For the whole range of habitats, ANP of the *Sphagnum* moss studied lay between 150 and 375 g dry mass $m^{-2} yr^{-1}$.

Low temperatures and the presence of permafrost had great influence on the linear increase and the density of *S. fuscum*. In bogs of the northern taiga it forms more dense sod on frozen peat hills (so-called palsas) in comparison to thawing beds and hummocks of ridge–hollow mires. The linear increase on frozen substrate was 4 times lower, although the annual production was 1.2 times lower. The same was true for *S. fuscum* on narrow beds (edge effect) in comparison with the spacious ryams.

Studies of respiratory gas exchange of *Sphagnum* moss *in situ* are relatively few. It is hard to apply the assessment of respiration made in the conditions of controlled multifactor experiments in microcosms or in phytotrons to the ecological system in general (Kurets *et al.* 1993, 2000). What remains is the problem of determination of the influence of fungi densely inhabiting the *Sphagnum* layer. The range of values of dark respiration is quite large, and it depends on the experimental conditions and the applied method. Nevertheless, the first stage of accumulating the primary information is absolutely necessary in order to improve the method.

Our experiments took place in bogs of the southern and the northern taiga. We conclude that the contrast of conditions revealed some peculiarities and typical reactions of the prevailing species of the moss and moss–lichen layer on high bogs to changes in environmental parameters. As experiments show, in July and August the intensity of respiration of *Sphagnum* moss was low (Table 15.3). This is caused by the fact that the temperature of the air and of the upper peat layers during that period was gradually declining (during the third ten-day period of July and beginning of August). Under such conditions most of the studied species exhibited a similar rate of gas exchange. *Sphagnum majus* was an exception; the temperature drop by about 3° caused a two-fold decrease in its rate of respiration. The second ten-day period of August was hot, and the temperature at a depth of 10–15 cm from the *Sphagnum* head surface was 24–25 °C. Different species reacted to the change in environmental conditions

Table 15.3. Dark respiration intensity of *Sphagnum* mosses under field conditions in the southern taiga zone.Values are means \pm 1 SE.

Species	Parameter	18 July	7 August	20 August
<i>S. fuscum</i> L.	R, mg CO ₂ g ⁻¹ h ⁻¹	0.43 \pm 0.10	0.43 \pm 0.07	4.03 \pm 0.14
	temperature, °C	16.8	13.7	23.9
	<i>n</i>	3	3	2
<i>S. angustifolium</i> (Russ.) C. Jens.	R, mg CO ₂ g ⁻¹ h ⁻¹	0.18 \pm 0.16	0.17 \pm 0.01	0.44 \pm 0.42
	temperature, °C	16.8	13.7	23.9
	<i>n</i>	2	2	2
<i>S. magellanicum</i> Brid.	R, mg CO ₂ g ⁻¹ h ⁻¹	0.43 \pm 0.12	0.38 \pm 0.04	0.12 \pm 0.05
	temperature, °C	16.8	13.7	24.0
	<i>n</i>	3	3	2
<i>S. majus</i> (Russ.) C. Jens.	R, mg CO ₂ g ⁻¹ h ⁻¹	0.48 \pm 0.10	0.22 \pm 0.05	1.12
	temperature, °C	16.8	13.7	24.0
	<i>n</i>	3	3	1

in a variety of ways. *S. fuscum* and *S. majus* were distinguished by their respiration level. The soil temperature elevation by 10° caused a 6–10-fold respiration increase. The reaction of *S. magellanicum* to the temperature rise was opposite, and this may be connected with greater dehydration of plants during the hot period (McNeil & Waddington 2003). During that period we observed the typical hightening in color of *Sphagnum* heads. We assume that different *Sphagnum* types differ both in the rhythm of the production process and in their physiological reaction to changes in environmental factors. Plants inhabiting areas with variable humidity in transition zones between positive and negative microrelief elements may be subject to higher stress.

The respiration intensity of CO₂ gas exchange of *Sphagnum* in an oligotrophic bog in the northern taiga was considerably lower than in the southern taiga (Table 15.4). These differences are evidently caused by the adaptation of the metabolic system of plants to more severe climate. The rate of carbon dioxide emission by peat samples, taken under different plants, varied from plant to plant. Under the comparatively similar temperature conditions *Sphagnum* moss is able to slow down the peat mineralization by a factor of 3–4, as compared with sedges and lichens. These data confirm the well-known preserving abilities of *Sphagnum* moss. The peculiarities of gas exchange of *Sphagnum* moss were analyzed in more detail in previous publications (Naumov 1997, 2009).

Table 15.4. Carbon dioxide emission of the components of the moss–lichen layer on a ridge–hollow bog (northern taiga)

Material	R, mg CO ₂ g ⁻¹ h ⁻¹	Temperature, °C	
		in chamber	ambient
<i>Ridge</i>			
<i>S. fuscum</i>	0.10	16.2	17.5
<i>S. magellanicum</i>	0.12	17.8	16.0
<i>S. nemoreum</i>	0.15	16.8	16.0
<i>C. rangiferina</i> (dry)	0.03	18.3	17.4
<i>C. rangiferina</i> (wet)	0.03	15.1	14.0
Peat under the lichen	0.08	12.3	10.0
Peat under <i>S. fuscum</i>	0.03	13.7	12.7
<i>Hollow</i>			
<i>S. majus</i>	0.16	17.8	14.7
<i>S. balticum</i>	0.06	15.4	14.7
Peat under the sedge	0.08	13.2	13.6
Peat under (<i>S. majus</i> + <i>S. balticum</i>)	0.02	12.6	10.0

Conclusions

The accumulation of greenhouse gases in the atmosphere, climatic warming, and changes in the functional state of natural systems are drawing special attention from experts and public institutions. The role of bogs in the carbon balance of the biosphere, the condition of *Sphagnum* cover as an indicator of climatic changes, and the forecast of cryolite zone dynamics are currently under examination by researchers from different countries working within the framework of global environmental problems. The recent climatic warming has caused faster thawing of permafrost, appearance of thermokarst effects, and transformation of the landscape structure and carbon balance in regions of spreading northern bogs of taiga and tundra ecosystems in Alaska and Canada (Billings 1987; Halsey *et al.* 1995; Turetsky 2001; Turetsky *et al.* 2002). The northern parts of Western Siberia exhibit similar phenomena (Kirpotin *et al.* 2007).

According to the assessments of RosHydroMet from 1976 to 2006, the temperature change, corresponding to the linear trend, amounts to 1.0 degree (0.32 °C/10 years) for Western Siberia (Anon 2008). Based on the rules that govern of spreading of *Sphagnum* bogs in different climatic zones and known ecological optima for the basic buildup of *Sphagnum* bogs, we assume that further temperature rises will increase the spread of *Sphagnum* and sedge–*Sphagnum* bogs to the



Fig. 15.5. Results of the impact of fire on the upper layer of *Sphagnum* peat in a ryam.

North. The small capacity of peat sediments and proximity of mineral horizons are favorable for formation of mesotrophic communities with participation of the representatives from our second group of *Sphagnum* species (see above).

At the southern border of the range of *Sphagnum* bogs in the forest–steppe zone the environmental situation is also disturbing. Currently, high bogs of the forest–steppe zone under conditions of variable humidity have limited resources for progressive growth. Located at the limit of their natural habitat, they do not form any considerable swamp areas, but are represented in landscapes as separate small islands. That is why they are rather vulnerable (Naumov *et al.* 2009). This is especially true for the subjects located near settlements and spots subject to anthropogenic influence (fires, deforestation, peat development, etc.). They are very sensitive to harsh anthropogenic influences and milder climatic changes. The analysis of photos of this area, found in Google Earth, and reconnaissance activities show that the majority of the rare natural areas, even those designated natural monuments, have been influenced by pyrogenic factors (Fig. 15.5). After fires the *Sphagnum* cover is hardly renewed, and the formation of peat stops. The projective loss of moss cover is 1%–3% per year. The total number of ryam sets (the average area being 1800–2000 ha) comprises only several dozen, and even in relatively favorable conditions this number consists



Fig. 15.6. Raised virgin bog of the “insular” type in forest–steppe zone, Western Siberia.

of only single units (Fig. 15.6). That is why the priority objective, together with conservation activities, should include continuous complex monitoring aimed at forecasting of natural and climatic changes and preservation of these unique natural ecological complexes.

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