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LINEAR INCREMENT OF *SPHAGNUM* MOSSES ON KARELIAN MIRES (RUSSIA)

ЛИНЕЙНЫЙ ПРИРОСТ СФАГНОВЫХ МХОВ НА БОЛОТАХ КАРЕЛИИ (РОССИЯ)

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Abstract

Linear increment of *Sphagnum majus, S. fallax*, *S. balticum*, *S. obtusum*, and *S. subsecundum* was examined in 2001-2010. The study was carried out in the mid-taiga subzone, in Koivu-Lambasuo mire conservation area (61° 48' N and 33° 35' E), Karelia, Russia. The greatest linear increment was observed for all of the *Sphagnum* mosses studied during favorable vegetation periods with warm spring and warm, humid summer. The growing seasons in 2002 and 2010 showed a significant decrease in growth for *S. balticum, S. fallax* and *S. obtusum*. Such a decline is likely to result from dehydration of moss capitula.

Резюме

Линейный прирост *Sphagnum majus, S. fallax*, *S. balticum*, *S. obtusum*, *S. subsecundum* изучался в период 2001-2010 гг. в подзоне средней тайги на территории болотного заказника Койву-Ламбасуо (61° 48' с.ш. и 33° 35' в.д.), республика Карелия, Россия. Наибольший линейный прирост отмечен у всех исследуемых сфагновых мхов в благоприятные вегетационные периоды с теплой весной и теплым влажным летом. В вегетационные периоды 2002 и 2010 г.г. наблюдалось значительное снижение прироста *S. balticum, S. fallax, S. obtusum*. Вероятно, это произошло в результате обезвоживания головок мха.

KEYWORDS: *Sphagnum*, annual increment, mire, Karelia

INTRODUCTION

In Karelia, mires occupy an area of 3.63 million hectars. *Sphagna* form a continuous cover on various types of oligotrophic and mesotrophic mires, where they act as vegetation edificators.

Mire ecosystems play a unique role in the control of the Earth's carbon balance. They bind large volumes of carbon dioxide in accumulating peat and remove it from the substance turnover over thousands of years. On many mires of the taiga zone, *Sphagnum* mosses behave as essential producers and peat-formers. They exhibit an unlimited apical growth and absorb water with nutrients by entire surface. Therefore, their linear growth increment is closely related to the soil-ground water level, climatic conditions during their growing season, moss species and the nutrient supply of their habitats. In addition, *Sphagnum* mosses have a high regenerative capacity. Hence, they are promising as producers of organic matter in artificial cultivation and recultivation of cut-over and unnecessarily drained peatlands, as shown by foreign experience (Ferland & Roschfort, 1997).

Katz *et al*. (1936) were the first to present a review of papers on linear increment of *Sphagnum*. A number of works on this subject were published subsequently (Clymo,1970, 1973; Ilomets, 1974, 1981; Grabovik & Antipin, 1982; Maksimov, 1982; Grabovik, 1994, 1995; Kosykh, 2008; Moore, 1989; Pakarinen, 1978; Pedersen, 1975; Lindholm; 1990; Lindholm & Vasander, 1990). However, the above data on moss growth increment are either fragmentary or cover short periods of 1-2 years, and are not linked to the climatic and hydrological conditions in the study areas. In contrast, we have been studying the functioning of *Sphagnum* cenopopulations in southern Karelia with regard to climatic and phytocenotic conditions for 30 years (Grabovik, 2002, 2003).

The present paper deals with a linear increment pattern of *Sphagnum* in different environmental groups growing under natural mire biotope conditions. It is aimed at studying long-term relationships between growth intensity of *Sphagnum* and climatic conditions during growing seasons.

MATERIALS AND METHODS

The study was conducted at the Kindasovo Forest-Mire Experimental Station of the Karelian Research Centre, RAS, in the Koivu-Lambasuo conservation area located in the mid-taiga subzone (61° 48' N, 33° 35'E).

The Permanent Research Facility area displays a heavily paludified lacustrine and lacustrine-glacial plain landscape dominated by pine habitats (Gromtsev, 2000).

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Table 1. Characteristics of Nenazvannoe Mire sites

Type of mire	Species	Microrelief	Groun water level, cm	Projective cover, %	Moisture regime
Meso-oligotrophic 'Sphagneta majusi+Sphagneta papillosi'	*S. majus*	hollow	–1 — –5	80	Watered, stagnant
Eu-Mesotrophic 'Sphagneta obtusi + Sphagneta subsecundi'	*S. obtusum*	Swamp	–5 — –13	60	Poorly lotic
	S. subsecundum	Swamp	–1 — –5	30	Abundantly watered
Mesotrophic 'Sphagneta fallaxi + Sphagneta riparii'	*S. fallax*	Mat	–10 — –15	90	Poorly lotic
Oligotrophic 'Sphagneta fusci + Sphagneta baltici'	*S. balticum*	Mat	–7 — –10	70	Stagnant

Its geological basement is composed of crystalline rocks represented mainly by Lower Proterozoic amphibolite, schist, magnetite, quartzite and metadiabase. These rocks form a N-S-trending multiple-dislocated synclinal structure bounded on the west and east by granitoid rocks of Archaean and Proterozoic age (Ekman, 1968). A detailed study of topography and Quaternary deposits showed that glacial, lacustrine-glacial and lacustrine-mire deposits are the oldest (Elina & Lak, 1980). The study area is part of the Southern Agroclimatic Province, the Southern Lacustrine Subprovince (Atlas…, 1989). The mean annual air temperature is +2.1°C and the long-term mean temperature in the vegetative season is 11.9°C. The mean annual precipitation is 565 mm.

According to the geobotanical zoning proposed by Yurkovskaya (1993), the Permanent Research Facility area is part of the Suojдrvi Mid-Taiga District. 71% of its area is covered by forests, 52% of which are made up of dry valley forests. Coniferous forests predominate (76%). Secondary birch and aspen forests have replaced spruce and pine mossy forests. Mires occupy 29% (60% within the nature conservation areas) and are represented by grass-*Sphagnum* mesotrophic, South Karelian aapa and *Sphagnum* oligotrophic types (Elina *et al.*, 1984).

The 2001-2010 growing seasons witnessed extremely high values of temperature and humidity. The 2002 and 2005 growing seasons were very warm and dry; precipitation deficit was apparent in June-July. The distinctive feature of the growing season in 2010 was extremely hot summer with air temperatures up to +30-+35°C. Precipitation was highly uneven and clearly insufficient over most of the growing season. In May-June it exceeded normal values, while in July-early August precipitation deficit was obvious. In other growing seasons, average monthly air temperatures and precipitation were close to average long-term values.

The monitoring was carried out at four sites of Nenazvannoe natural mire (544 ha) of eutrophic-mesotrophic type, where mosses dominate in various environments, which somewhat differ in mineral nutrition and moisture regime. The study of the linear increment and its dependence on climate in 2001-2010 involved *Sphagnum majus* (Russow) C.E.O. Jensen, *S. fallax* (H.Klinggr.) H.Klinggr., *S. balticum* (Russow) C.E.O. Jensen, *S. obtusum* Warnst., and *S. subsecundum* Nees.

All *Sphagnum* are hydrophilous, but some species may survive a rather long drying-out and variable moisture regime on hummocks, while others endure only mild short-time drying-out and only moderate moisture fluctuation. According to Lopatin (1973), *S. fallax* belongs to a subpsychrophilous mat group and can stand mild short-time desiccation, whereas *S. balticum, S. majus, S. obtusum,* and *S. subsecundum* belong to a bog hollow hyperhydrophilous group and cannot withstand drying-out (Table 1). Results of Maksimov (1982) and Grabovik (2003) confirm this (cf. Table 1).

Linear increment was studied by a tying-up method. In May, microcenoses dominated by *Sphagnum* species under consideration were sampled from all mire sites, and the mosses (50 samples of each species) were tied up at 1 cm below the apex. Next May, the mosses were cut off and their linear growth increment was measured. During the entire study period the mosses were tied up at the same sites, but the ties were slightly shifted towards their previously untouched parts.

RESULTS

Linear growth measurements showed considerable variations both within one microcenosis across different years, as well as within one growing season across different environments (Table 2). Basing on long-term averages in linear growth, we subdivided *Sphagnum* communities into three groups: 1) *S. obtusum* which displays the highest increment and grows on highly lotic swamp sites; 2) *S. majus, S. subsecundum* and *S. fallax* exhibiting medium growth increments and growing on poorly lotic inundated swamps; 3) the lowest linear growth increment was shown by *S. balticum*, which grows in shallow bog hollows and on mats under stagnant moisture conditions (Table 2).

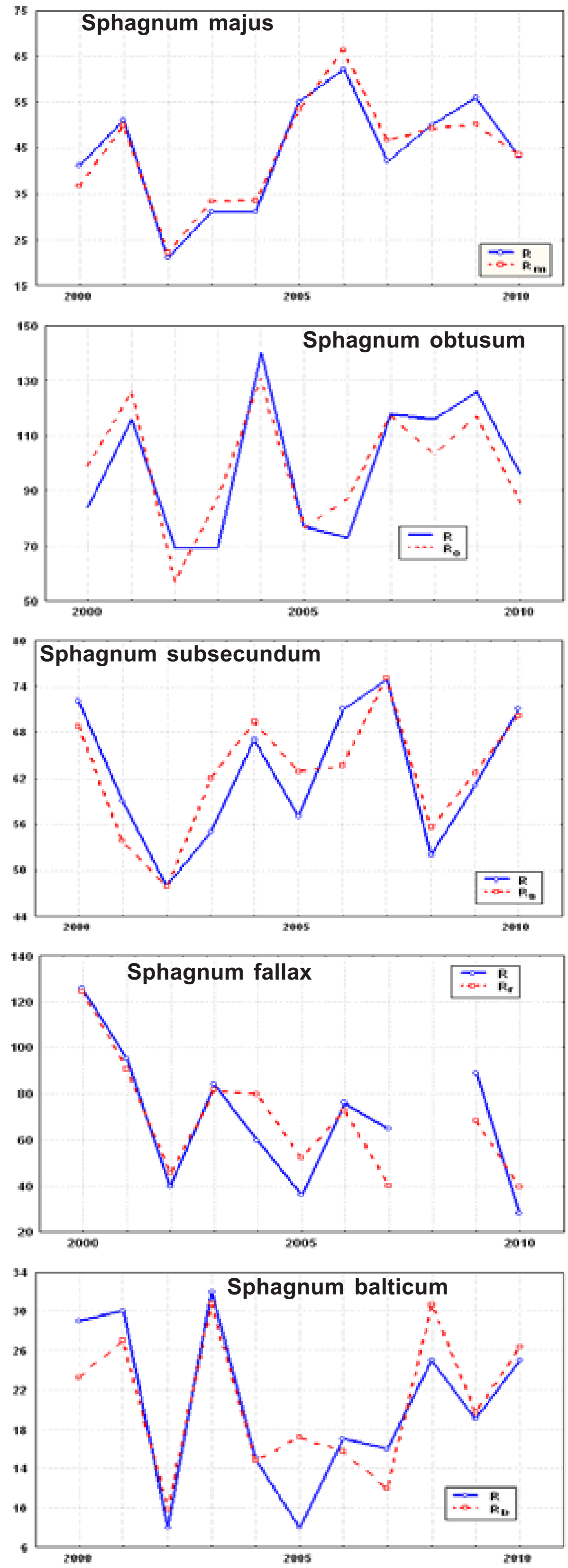
Maximum growth was shown in 2001 by *S. fallax* and *S. obtusum* (Table 2), while other species have different years when their increment reached maximum.

To analyze the dependency of annual increment of *Sphagnum* on weather conditions, the meteorological data were used for 2000-2010. The quasi-Newton method implemented in Statistica 5 was used, finding extrema

1	*S. majus*	$R_m = -156,79 + 0,86P_{VI} -0,51P_{IX} +7,52T_{VI} +3,76T_{VII} -0,38T_{IX} +3,32T_X$
2	*S. obtusum*	$R_o = -19,95 + 1,72P_{VI} + 0,38P_{VII} -24,03T_V - 2,34T_{VI} + 5,62T_{VII} + 8,7T_{VIII}$
3	*S. balticum*	$R_b = 50,77 – 0,05P_{VIII} + 0,19P_X – 3,23T_{VI} + 1,18T_{VII} – 1,48T_{VIII} + 1,75T_{IX}$
4	*S. fallax*	$R_f = 394,38 + 0,18P_V + 0,05P_{VII} + 0,06P_{VIII} + 0,04P_{IX} – 19,6T_{VIII} - 6,99T_{IX} + 7,46T_X$
5	*S. subsecundum*	$R_s = -40,89 + 0,20P_{VI} + 0,13P_{VII} +0,95T_{VII} +4,56T_{VIII} -1,34T_{IX} + 1,82T_X$

Above: Equations of growth of five *Sphagnum* species: R_i – annual linear increment of a moss species specified, *mm*; P_i – precipitation sum for the *i*-th month, *mm*; T_i – monthly air temperature for the *i*-th month, *°C*. The coefficients of multivariable correlation ranged within 0.86-0.96. See also Fig. 1.

Fig. 1 (right): Annual increments (axis Y, mm) of five species in 2001-2010: *R* measured (blue) and R_i calculated (red) values, cf. above equations.



of the species increments. Fig. 1 demonstrates relationships between the linear increment of different species R_i, monthly air temperature T_i and monthly sums of precipitation P_i, basing on measured increments and predicted values according to the Equations 1-5 (see above) obtaind from quasi-Newton analysis.

The obtained results revealed a strong dependency of Sphagna linear growth increment on air temperature in June-October and, to a lesser extent, on precipitation within the vegetation period. Further research will be aimed at receiving more robust statistics, which would allow using equations 1-5 for the prediction of moss species growth under different weather conditions.

Discussion

Sphagnum mosses start to grow immediately after snow melting. In spring, the mosses are supplied with sufficient moisture, and display a maximum growth increment. Favorable for growth are warm springs and warm humid summers: in the growth equations precipitations of May or June occur for four of five species, while July and August temperture has positive effect on also four of five species, except *S. fallax*. The latter species has strongly negative correlation with the August temperatures according to our results.

In dry 2002, the mire water level decreased greatly because of the anomalously hot periods in July-August. In this year all of the *Sphagnum* species showed a minimum growth increment. This must have resulted from dehydration of the moss apexes. A considerable slowdown in moss growth down to complete termination in dry condition was also noted by Pedersen (1975) and Maksimov (1982).

Dry weather of 2010 strongly reduced the growth of *S. fallax* and *S. obtusum*, speceis from lotic habitats, but had little or no effect on species from more watered sites.

Air temperature in summer months has a greater effect on increment than the atmospheric precipitation does (see above equations). However, individual species differ in response to air temperature and humidity, for example *S. subsecundum,* a hollow species, differs from that of *S. fallax,* which forms mats. The difference is probably due not only to more or less favourable humidification conditions but also to biological characteristics of the species.

Table 2. Annual linear increment (mm) of *Sphagnum* species at Nenazvannoe Mire sites in 2001-2010

Species	Years of investigation											
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2001-2010 mean	φ
S. fallax	95±0.9	40±1.8	84±1.7	60±2.9	34±0.8	76±1.0	65±2.7	63±1.4	69±2.0	18±1.0	60.4±1.6	23.6
S. balticum	31±1.1	8±0.8	16±1.5	15±0.7	8±0.7	17±0.9	16±1.0	25±0.9	19±1.0	8±1.2	16.3±0.9	7.5
S. obtusum	116±2.8	69±2.4	86±2.4	140±3.0	83±4.5	72±3.0	112±5	116±2.0	145±1.0	29±1.4	96.8±2.7	35.6
S. subsecundum	59±2.0	48±2.0	56±1.2	67±1.8	57±3.0	71±2.3	71±2.6	53±3.0	61±1.8	72±2.6	61.5±2.0	8.3
S. majus	50±1.8	22±1.2	32±1.2	30±1.4	53±1.0	62±1.7	42±1.4	47±2.3	56±2.1	43±1.8	50.9±1.6	12.6

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