Decomposition of plant matter on peat bogs in the southern taiga of western Siberia

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Abstract. The article discusses the dynamics of decomposition of dominant plant species in mire complexes of the southern taiga of Western Siberia. The decomposition of plant remains in bogs occurs in the warm season, when the level of bog water decreases, and oxygen freely penetrates into the upper layer of the peat. The highest rate of decomposition is observed for Menyanthes trifoliata L., both leaves and rhizomes, losses of up to 80% of the initial mass during two years of experiment. The roots and stem bases were slowest to decompose: a 20% loss during two years. Sphagnum mosses lose from 20 to 40% of the initial mass in the same period.

1. Introduction
Peat bogs are unique natural ecosystems that have the ability to accumulate dead plant material in the form of peat. They are directly related to maintaining the atmospheric gas composition, performing a buffer role in global climate change processes, and they are accumulate organic carbon in the form of peat or release it in the form of carbon-containing gases (carbon dioxide and methane) [1]. The increase in the concentration of these gases, which are greenhouse gases, contributes to the climate warming on our planet. Stationary studies of current rates of production and destruction in bogs are necessary to indicate the processes of climate change. The results of the study of decomposition in bogs are presented in a number of papers [2-11].

2. Materials and Methods
Experiments to determine the decomposition rate of plant residues of dominant species in the peat layer of oligotrophic bog complexes were carried out on the territory of the soil station of the Institute of Soil Science and Agrochemistry of the SB RAS in the northeastern part of the Great Vasyuganskoye Mire (southern taiga) within the Tomsk Region. To determine decomposition rate and main patterns of individual peat formers, the litter bag technique was applied [8]. The plant material was laid in peat to a depth of 5, 15 and 25 centimeters. In addition, the fallen leaves of bog shrubs and grasses were laid on the surface of the moss cover, since their decomposition begins on the surface, then continues in peat. The rate of decomposition was studied in four species of shrubs, six species of grasses and five species of Sphagnum mosses in five bog ecosystems of different trophicity. During the growing season, the dynamics of the phytomass and mortmass and its fractional composition were studied. The primary production of mosses, shrubs and herbs, both green parts, and their roots to a depth of 30-40 cm was evaluated. The investigated ecosystems were located along a transect through the scots pine – dwarf shrub – Sphagnum bog (ryam), sedge – Sphagnum bog, ridge-pool complex.
The first ecosystem (ryam) was a scots pine – dwarf shrub – Sphagnum bog. The crown density was 0.1, the height of the trees (Pinus sylvestris L.) ranged from 0.5 to 3.0 m, the diameter of the trunks was 3-8 cm. The dwarf shrub - grassy layer was a microassociation with dominance of Chamaedaphne calyculata (L.) Moench and Ledum palustre L. on hummocks of 50-80 cm height and Eriophorum vaginatum L. in hollows, and Andromeda polifolia L., Rubus chamaemorus L. and Oxycoccus palustris Pers were rare (coverage of shrubs and grasses were 40-50%). The moss layer was dominated by Sphagnum fuscum (Schimp.) Klinggr. (covering 60%), Sph. magellanicum Brid. (covering 10%) on hummocks and Sph. angustifolium (Russ. ex Russ.) C.Jens. (covering 30%) in hollows. Hummocks were well defined and occupied 70% of the total surface.

The second ecosystem (transition zone) was a dwarf shrub – sedge - Sphagnum bog with Eriophorum vaginatum. The vegetative community was mosaical. On hummocks, dominate species were Chamaedaphne calyculata, Andromeda polifolia, Ledum palustre, Oxycoccus microcarpus Turcz. ex Rupr. and Eriophorum vaginatum with rarely growing Betula nana L. The height of hummocks ranged from 20 to 50 cm and they occupied about half of the area. Coverage of dwarf shrubs and Eriophorum vaginatum on hummocks was 60%. In hollows, Carex rostrata Stokes and Oxycoccus palustris dominated, their coverage was 40-50%. The moss layer was represented by Sph. fuscum (30%), Sph. magellanicum (50%), Sph. angustifolium (20%) on hummock, and Sph. balticum (Russ.) Russ. ex C.Jens. (50%), Sph. fallax (Klinggr.) (35%), Sph. angustifolium (15%) on hollows.

The third ecosystem was a sedge - Sphagnum bog with a well-defined grassy layer. Carex rostrata, C. limosa L. and Menyanthes trifoliata L. dominated. In the middle of the bog, a community with Equisetum fluviatile L. was located as a narrow meandering strip. Among dwarf shrubs, Oxycoccus palustris dominated, heath shrubs were found singly. There were also rarely growing Carex chordorrhiza Ehrh., Scheuchzeria palustris L., Drosera rotundifolia L. The moss layer was represented by Sph. fallax, Sph. majus (Russ.) C.Jens., Sph. obtusum Warnst.

The fourth and fifth ecosystems were parts of the ridge-pool complex. On the ridges, pines and dwarf shrubs were more depressed than in the ryam community. Among herbs there were rarely occurred Rubus chamaemorus and Eriophorum vaginatum (covering of shrubs and grasses was 35%). In the moss cover the dominant species was Sph. fuscum (90%), in the hollows on the ridges there were green mosses, lichens and liverworts. In pools, the predominant community was the Eriophorum russeolum - Sphagnum. The dwarf shrub - grassy layer did not exceed 15 cm in height and consisted of only a few species: Andromeda polifolia, Eriophorum russeolium Fries, Scheuchzeria palustris and Oxycoccus palustris, with coverage of not more than 10%. In a small abundance there were Drosera rotundifolia and D. anglica Huds. The moss cover was dominated by Sph. balticum and Sph. papillosum Lindb.

3. Objects and methods
Stocks of living and dead plant matter in the 0-30 cm layer were average 11 tons / ha and fluctuate during the growing season increasing from spring to autumn, and between years in each plant community. The greatest variations were observed in the first ecosystem. The amount of phytomass here increased 1.6 times for three years and amounted to 7.9 t / ha.

The structural composition of the photosynthetic phytomass in ridges and in pools was different: Sphagnum mosses were absolutely dominates (96%) in pools, and in the ryam and ridges they became codominant with shrubs (57% and 42%, respectively). The magnitude of the annual increase was variable and was related to the climatic conditions of the current year. The main contribution to the value of non-photosynthesizing part of primary production was made by roots of grasses and shrubs, which accounted for 60% of the total primary production. The contribution to the primary production of mosses was 21% on ridges and 64% on pools. The novelty of the approach was that not only the productivity of the aboveground and belowground layers was taken into account, but also the rate of decomposition. The analysis of obtained results allowed to estimate the rates of production, dying out and decomposition in bog ecosystems of the southern taiga of Western Siberia.
Figure 1. Plant fraction decomposition: A – in scots pine - dwarf shrub - Sphagnum ryam, B – in transitional dwarf shrub - sedge - Sphagnum bog, C – in sedge - Sphagnum bog.
The destruction of plant matter fractions differed. There were two types:

I type of decomposition was characterized by a medium decomposition rate of fractions in the first year and a high rate in the second year. The first type of decomposition included the following fractions: Rubus chamaemorus dead leaves and leaves of dwarf shrubs.

Decomposition of Rubus chamaemorus was studied in the ryam and the ridge. During the first year, its dead leaves lost 30%, losses during the second year were 10% higher, i.e. 40% (Fig. 1A, 2A). The shrub leaves lost up to 30% of the initial mass decomposing in the first year, and from 25 to 50% in the second year (Fig. 1, 2).

At the II type of decomposition, a high decomposition rate was observed in the first year of the experiment and was of medium or low during the second year. The second type of decomposition included the following fractions: roots and trunks of shrubs; stem bases and roots of Eriophorum vaginatum; dead leaves, roots and rhizomes of Menyanthes trifoliata, sedges and Scheuchzeria palustris; litter of Sphagnum mosses.

Losses in the decomposition of the root mass of shrubs in the first year were about 40%, and a sharp decrease (5%) was observed in the second year.

Leaves, roots and trunks of dwarf shrubs decomposed faster on elevated relief elements such as the ryams, the transition zone and the ridge. In the sedge - Sphagnum bog, Chamaedaphne calyculata decomposed at the minimal rate, leaves and roots of Oxycoccus palustris decomposed at medium rate.

Decomposition of Eriophorum vaginatum was studied in the ryam and in the sedge - Sphagnum bog. Dead leaves was decomposed by one third of the initial mass during the first year, stem bases and roots - by 15%. During the second year, losses were 5%. Dynamics of decomposition of stem bases and roots of Eriophorum vaginatum coincided with the that of shrub shoots (Fig. 1A, B).

Dead leaves of sedges lost 25-30% of mass in the first year and about 10% during the second year of the experiment in the sedge - Sphagnum and dwarf shrubs - sedge - Sphagnum communities (Fig. 1B, C). Roots and rhizomes of Carex rostrata decomposed faster than belowground organs of C. limosa, mass losses of these samples was 45% and 29% in the first year, respectively. Decomposition of roots and rhizomes of sedges during the second year did not exceed 5%. The dead leaves and rhizomes of Scheuchzeria palustris decomposed by the same way, during the first year they lost the one third of the initial mass, and during the second year they decomposed only by 3-5% (Fig. 1C, 2B).

Mass loss of Sphagnum litter ranged in the first year of the experiment from 13 to 37%, and in the second year it varied from 2 to 7%. The rate of decomposition of Sphagnum litter varied depending on species and ecosystem type. The highest mass loss among Sphagnum mosses was observed for Sphagnum angustifolium reaching 44% for two years on the ridge (Fig. 2A). Dominant moss species in ryam and ridges, Sph. fuscum, decomposed by an average of 19% for the year, and it lost about 6% more during the next year of the experiment. Average mass loss of Sph. fuscum litter was 25% of the mass.
initial mass for two years of decomposition (Fig. 1, 2). The lowest mass losses of moss litter (15-20% for two years) were observed in the sedge - *Sphagnum* oligotrophic pool (Fig. 2C).

By the rate of decomposition, the fraction of plant matter were divided into 3 groups:

1. **rapidly decomposing** (mass losses for two years were 60% or more): the group included dead leaves and rhizomes of *Menyanthes trifoliata*, dead leaves of *Rubus chamaemorus* and leaves of *Chamaedaphne calyculata*;

2. **medium decomposing** (mass losses for two years were from 30 to 60%): the group included the leaves of three dwarf shrubs (*Andromeda polifolia*, *Ledum palustre*, *Oxycoccus palustris*), roots of dwarf shrubs, roots of *Menyanthes trifoliata*, dead leaves, roots, rhizomes of sedges and *Scheuchzeria palustris*, *Sphagnum angustifolium*;

3. **slowly decomposing** (mass losses for two years were less than 30%): this group included trunks of dwarf shrubs, stem bases and roots of *Eriophorum sp.*, *Sphagnum* mosses (*Sphagnum fuscum*, *Sph. magellanicum*, *Sph. balticum*, *Sph. fallax*).

Studies on the decomposition rate of mire grasses were carried out by Bartsch and Moore in Canada, the province of Quebec [9], as well as in Russia [8, 3, 7]. For the year, mass losses of sedge dead leaves were 26.6% in Canada [9], 24.5% in Karelia [7], and 35% in this study in the southern taiga of Western Siberia. According to Kozlovskaya et al. [8], mass losses during the decomposition of leaves dead leaves of *Eriophorum sp.* were 68.7% for the year; according to Botch [7], it was 23.1% on the Lammin-Suo mire (reserve "Druzhba", Karelia). Our valuation were closer to the data of Botch accounting for 30%. Mass losses of *Rubus chamaemorus* and *Menyanthes trifoliata* in Lammin-Suo amounted to 35.2% during decomposition, and in this study losses amounted to 40%. Lammin-Suo peat bog ecosystems were located in the southern taiga of the European part of Russia [7] and corresponded to the southern taiga of Western Siberia. The rate of grass decomposition was similar in Asian and Europeane southern taiga subzone of Russia and in forest zone of North America.

4. **Conclusion**

Decomposition of *Sphagnum* mosses by the example of *Sphagnum fuscum* was studied by Waddington et al. in a *Sphagnum*-dominated bog in Canada, the province of Quebec [10] and by Hajek in a mountain bog in the Czech Republic [11]. *Sph. fuscum* decomposed most slowly in Canada, and it decomposed at the fastest rate in a mountain bog in the Czech Republic; decomposition rate in ridges of southern taiga was the average. Mass loss after two years of experiment was 13% in the Canadian mire and 10% more in the Czech bog. After three years, the mass loss of *Sphagnum fuscum* in the Canadian bog was as much as two times lower than in the mire ecosystems of the southern taiga.

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