ЭКСПЕРИМЕНТАЛЬНЫЕ РАБОТЫ

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NOTES ON THE PHENOLOGY OF FUNGI IN OMBROTROPHIC BOG

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Observations of fungal fruiting and micro-climate were done during a two-year time period in bog habitats near Khanty-Mansiysk town (middle taiga of West Siberia). Air and soil profile temperature regimes of two bog habitats (treed bog, sphagnum lawn) were compared to forest one. Precipitation was measured in one location at the bog (during two years of observations). Fruiting of larger fungi was recorded in 2013 by counting at plots placed in two bog communities (additional information on fruiting was collected in 2012 by random sampling).

Quantitative registrations of larger fungi were done only in August-September, the time of abundant fruiting. Sporocarp abundance was growing during this period and reached its maximum in the middle of September for both years. Mean number of species at plots was remaining constant (totally fruiting of 59 species observed). Earlier fruiting of larger fungi at bogs was scarce, four species were noticed with earlier appearance. Microfungi on plant litter were observed during the entire vegetation season in 2013. Periodicity in fruiting of 40 species was registered.

The three studied habitats differ in micro-climates in spite of their geographical proximity. The bogs have highest daily amplitude and temperature range within the 0-5 cm layer. Soil surface in treed bogs is more subjected to frosts, lawn has lower number of frost hours at the surface and forest has intermediate position. The longevity of the vegetation period (period with temperatures >5°) at the surface is the shortest in treed bog but at 5 cm depth is the shortest in forest.

Fungi settled in the litter (0-5 cm) experience more extreme climatic conditions in the treed bog environment and, to a lesser extent in the lawn habitat. The fruiting pattern registered in 2013 at Mukhrino bog seems to be corresponding to autumn downshift mean soil and minimum air temperatures. The influence of precipitation on fruiting was not very pronounced.

Key words: bog, fungi, macromycetes, phenology, microclimate.

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INTRODUCTION

The life cycle of fungi, and thus their function in ecosystems, is influenced by climatic conditions of the region. This influence is connected with processes of different scales from global climate to microclimatic conditions of micro-habitats. Temperature and moisture content of the substrate are two important climatic factors influencing fungal activity. The optimum temperature for fungal growth is generally considered to be approximately 25°C, with minimum and maximum being 5 and 40°C [Magan, 2008]. Individual responses of different species are variable. The water availability for fungi (expressed through water potential) depends on the presence of solutes (osmotic potential) and pore system of substratum (matric potential). Terrestrial fungi grow at an optimum water potentials of about -1 MPa, and can slowly growth at -14.5 MPa. When it comes to extreme consitions, xerotolerant species can handle as low as -40MPa in their surroundings. In the case of undecayed wood and leaves, -1Mpa corresponds to weight water content about 40% [Dix, Webster, 1995]. Different stages of life cycle of species could require different conditions. Thus, the formation of fruit bodies of fleshy larger fungi needs extra water.

Temporal changes in fruiting of larger fungi have always been of particular interest to researchers due to their edible properties. To some extent, fruiting pattern also corresponds to mycelium dynamics inside the substrate. Fruiting pattern characterized by periodicity, e.g. changes in presence of particular species during only limited period of the year, and fluctuations, e.g. differences in sporocarp density and species composition between different years [Arnolds, 1981]. Most species of larger fungi fruit in late autumn, but the time and longevity of this event, as well as abundance could depend on different reasons. In the regions with a long vegetation period, several peaks of fruiting could appear in spring, summer and autumn, the last being still most abundant. Some species may have their internal intra-annual cycle with fruiting once in several years [Arnolds, 1981; Baptista et al., 2010; Straatsma et al., 2001]. The most important external factors influencing fruiting are temperature and rainfall. Fruiting of mycorrhizal species could depend on physiology of the host. High temperature may inhibit sporocarp formation, creating drying of surface litter layers and desiccation of fruit-bodies [Dix, Webster, 1995; Pinna et al., 2010]. Critical minimal temperatures also limit fruiting, with nearly all fleshy sporocarps collapsing at temperature below -5° [Arnolds, 1981]. Temperature range ("cold shock") is shown to influence fruiting initiation *in situ* [Pinna et al., 2010; Kotilová-Kubičková et al., 1990a] and in experimental conditions [Kües, Liu, 2000]. The amount and distribution of rainfall have major effects at two stages of mushroom formation: 1. the initiation of primordia (a dry period in the spring may prevent the development of primordia) and 2. their subsequent expansion [Dix, Webster, 1995]. Since fruit-body formation takes some time, rainfall is followed by fruiting with some delay. Rainfall range also has effect, thus autumns with high fruiting often preceded by dry summers [Arnolds, 1981]. The conditions of macroclimate of the area may be additionally influenced by microclimatic factors, providing different patterns of fruiting in different mycocoenoses [Arnolds, 1981]. The most common factors are: canopy structure, thickness and structure of litter layer (A_L), moss and herb cover, relief and others [Burova, 1986]. Micro-climatic observations are very important for modeling and predictions of fungal fruiting [Arnolds, 1981].

Bog landscapes have micro-climate characteristics which differ from the nearby forests or other open landscapes. Some major factors causing these differences are: absence of dense tree canopy at the bog, presence of highly saturated peat soil or even open water bodies, presence of frost in peat layer for longer time, and sphagnum covered surface. Hojdova et al. [2005] observed higher daily temperature amplitude in bogs compared to forests as well as lower air humidity in bogs. These authors explain high amplitude in the case of bogs by: 1. shallow root systems of bog plants creating poor transpiration, 2. dry *Sphagnum* surface creating high albedo, 3. dry *Sphagnum* layer lowering the heat conductivity, preventing heat from passing from lower horizons at night.

Mycological studies in the middle taiga of West Siberia have been lasting for about 30 years and mostly presented by inventories. Research in the field of myco-ecology and on the phenology in particular is not developed enough. Yuriy Gordeev was a first amateur mycologist working in the region, who had described fungal seasonal fruiting near the Khanty-Mansiysk town in scientific and popular form [Gordeev, 2007; Gordeev, 2010]. Otherwise information on time of fungal fruiting available only from collection annotations in checklists.

In spite that weather stations network is working in the region for about 100 years, the long-lasting microclimate observations of regional ecosystems there still absent. The climate parameters influencing a particular ecosystem processes therefore are missing. For that reason a series of micro-climate observations was started at Mukhrino field station of Yugra state university since 2010 [Egler et al., 2012]. The parameters monitored include: air temperature, soil profile temperature, wind speed and direction, solar radiation, photosynthetic active radiation, soil humidity, heat flux through the soil, bog water table, atmospheric pressure and others; mainly in the bog ecosystem and less in nearby mixed forest. Having this set of micro-climate observations it is important to relate them to dynamics of biota.

We decided in this introductory paper to describe several parameters of micro-climate monitored at Mukhrino field station. We have chosen those data series, which were important in relation to fungal community phenology, and which data were complete enough (not all loggers are properly work presently). These micro-climate observations are valuable in themselves as a description of conditions in which the fungal community functions. The other goal of present report was to make description of fruiting phenology of macro- and microfungi in bog communities. The description is based on plot observations during one year (2013), and additional data from random sampling in 2012. The correlation between weather conditions and fungal fruiting cannot be statistically performed at present since short longevity of plot observations and for this reason, the paper has introductory nature.

Phenological observations are important part of climate change monitoring and mitigation. They are included in a series of observations on the environmental monitoring stations [Egler et al., 2012]. Fungal fruiting patterns have been changing during the last 20 years as was shown by different authors based on long-lasting monitoring [Buntgen et al., 2011; Gange et al., 2007; Kauserud et al., 2012]. Since that, the beginning of such observations at our station has been started.

Climate characteristics of the region

The study site is located in the zone of subarctic climate and boreal (taiga) zonobiome of West Siberia. The climate there is generally characterized by a long cold season (lasts more than 6 months). Mean year temperature near Khanty-Mansiysk equals minus 1.3°C. Mean temperature of the coldest month (January) is minus 19.8°C. The mean temperature of the warmest month (July) is +18.0°C. Relative air humidity doesn't change significantly from year to year with a mean value of 77% (autumn and winter months have mean values about 80%). Mean sum of precipitation near Khanty-Mansiysk equals 553 mm and varies from 385 m to 704 mm. Maximum precipitation (70%) falls in warm period from May to October. Mean snow depth is 54 cm, the snow cover forms in the middle of October and melts at the beginning of May. Summer (the period between spring and autumn frosts) in the area lasts for 113 days on the average. On average, the last frost occurs on the 26th of May [Bulatov et al., 2007; Dikunez et al., 2005]. General climate characteristics by months are summarized in table 1 in the climate-diagram (fig. 1).

Table 1. General climate characteristics (air temperature) near Khanty-Mansiysk based on 30-years observation [Tryaszyn, 2007]

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Mean	**-20**	-18	-9	-1	6	15	**18**	14	8	-1	-11	-16	-1,3
Absolute Max	4	3	10	25	30	33	**34**	32	27	20	7	3	34
Absolute Min	**-49**	-46	-38	-31	-15	-3	4	1	-8	-29	-42	-47	-49
Daily amplitude	7,9	8,5	9,7	9,4	9,9	9,3	8,9	8,6	7,5	5,8	6,9	8,3	7,7
Relative humidity	83	80	75	71	66	66	71	79	81	84	85	83	77
Precipitation, mm	30	22	21	30	47	68	76	72	58	54	41	35	553
Precipitation days	24	20	18	18	19	17	16	20	19	24	23	24	241

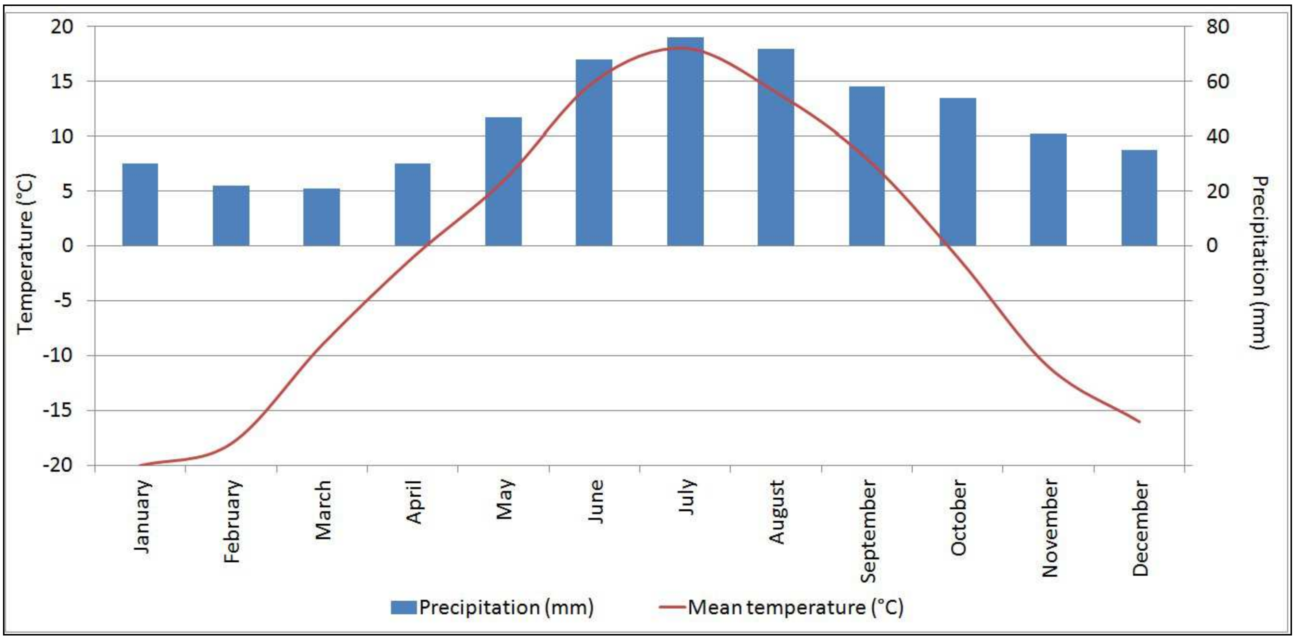

Figure 1. Khanty-Mansiysk climate-diagram (based on 30-years observation data in Tryaszyn [2007])

METHODS

Two micro-climatic parameters were chosen for analysis in the study: soil profile temperature, and precipitation. Soil profile temperature was measured by System for environmental condition autonomous monitoring "APIK" [Kurakov et al., 2012] with an interval of an hour during a year (2013). Four stations located at a distance about 500 m were chosen for the analysis: conifer – Aspen forest (N60.89458 E68.70920), *Pine* – dwarfshrubs – *Sphagnum* treed bog (N60.89487 E68.89847), another location in treed bog (N60.89471 E68.68407) and graminoid – *Sphagnum* lawn of bog (N60.89223 E68.68176) (fig. 2). Soil profile temperature was measured at depths: 0, 2, 5, 10, 15, 20, 30, 40, 60, 80, and 120 cm. Precipitation was measured by automatic rain gauge (HOBBO RG3-M model) at a single location of the bog during two years (2012, 2013). Only data for vegetation period from May to October were involved in the analysis.

In order to understand the pattern of changes in soil profile temperatures from a station to another one the interpolation of the temperature data has been performed according to 1) the depth of soil profile (vertical axis) and according to 2) the transect (horizontal axis). As the kriging method is relevant to interpolating climate data and allows to smooth the patterns [Hartkamp et al., 1999] it has been chosen here. It gives an idea of the spatial distribution of the temperatures in the soil profile but its accuracy depends on the available data. Then, the information should be taken carefully, especially when a long distance lies between two stations.

The fruiting observations of macromycetes (the term is generally accepted for fungi with visible by naked eye fruiting structures [Lodge et al., 2004]) were done on two bogs in the vicinity of the Khanty-Mansiysk town during two years (2012–2013). We used the method of route collection in the first year and the resulting data on the fruiting period (August–September) come from the number of collections per day. A plot based study by mycocoenological approach was initiated in 2013. Data on sporocarp density per 1000 m^2 in two types of habitats (treed bog and sphagnum lawn) were collected from August until the end of September. The full observation during all season was not performed due to scarce fruiting in earlier time and other activities (work with microfungi on litter). Observations of fruiting of micromycetes (fungi with spore-producing structures up to several mm in size) were done during the entire vegetation season of 2013 on Mukhrino bog. Litters of 12 bog plants were collected regularly (4–5 times per season), examined under lens, and found species were processed in collection. Identification was done based on European floras [Hansen and Knudsen, 1997, 1992, 2000] and taxon monographs, but since lack of regional treatments and of specialists some taxa remained under-identified. The fungal authorities provided based on Index Fungorum [http://www.indexfungorum.org/].

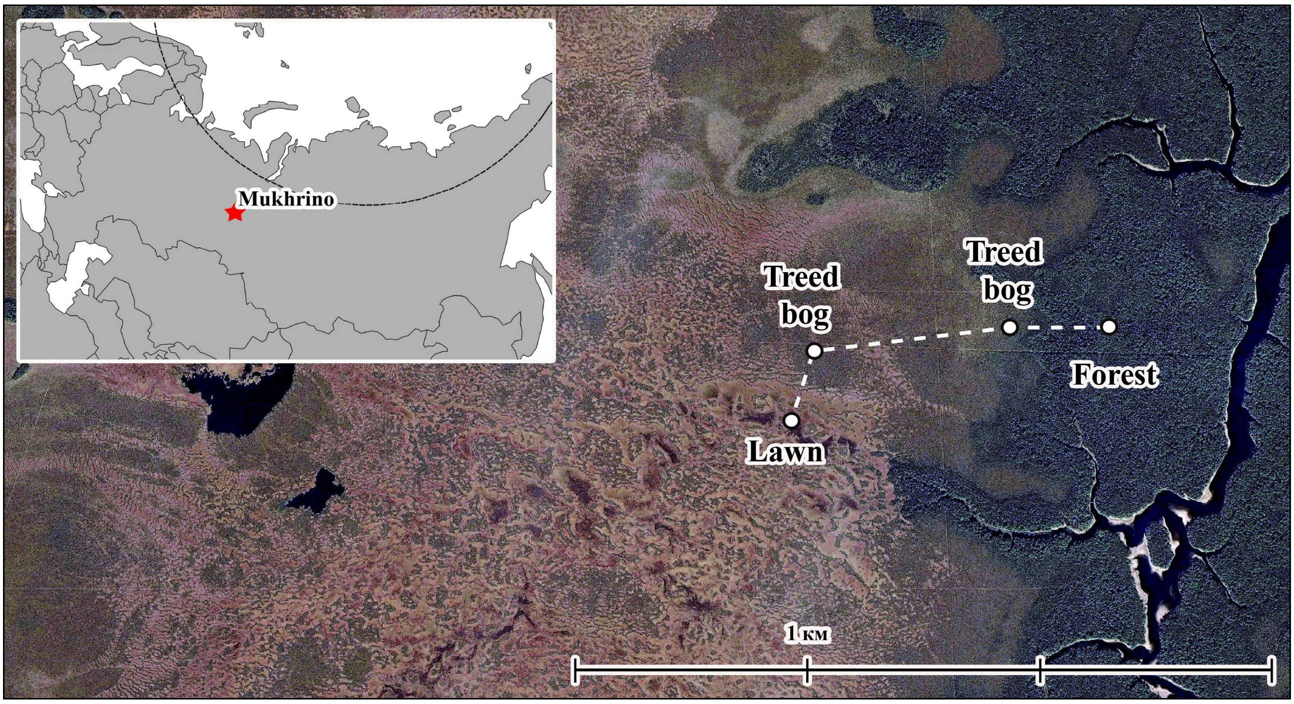

Figure 2. Position of the location near Khanty-Mansiysk, transect of the soil profiles and distances of the selected stations to the Forest one

RESULTS AND DISCUSSIONS

Micro-climatic conditions of habitats

Mean temperature of vegetation season (May–October) at the soil surface was nearly the same in the three habitats, temperature increases from forest to sphagnum lawn by 1.3° (table 2). At 5 cm depth in soil profile treed bog is the coldest, and forest is the warmest habitat with difference by 2.1°. The range of daily temperature at the soil surface and at the 5 cm depth considerably differs in the three habitats: bogs experience higher temperature extremes compared to forest (fig. 3). The sum of hours with the temperature >5 °C at the surface is the highest in lawns and the lowest in treed bogs, but at 5 cm depth forest has the smallest number. Vegetation season at 5 cm depth based on this measure is longer in bogs for nearly 6 days.

The last frost (mean daily minimum temperature below zero) at 5 cm depth was in May (the 5th, the 13th and the 19th for lawn, treed bog and forest accordingly), the first frost in autumn was 17.09, 11.10, and 25.11 (the same order) (table 2).

The pattern of the average minimum and maximum temperature in the soil profile is shown in figure 4. It demonstrates that the treed bog habitats experience the highest maximum temperatures and the lowest minimum temperatures, and very stable temperatures in depth. The forest habitat shows a narrower thermal range but is warmer in depth, like the sphagnum lawn habitat which shows the warmest soil profile.

Thus, the three studied habitats differ in the number of parameters of vegetation, soil structure, humidity and others. This determines complex differences of their micro-climates which exist in spite of their geographical proximity (only 500 m). The treed bogs have the highest temperature range within the 0-5 cm layer, since they have open canopy and dry surface. The sphagnum lawns are generally warmer in depth since the conductivity of water saturated substrate, in the same way amplitude in depth in lawns is maximal. The treed bog is the coldest habitat as defined by number of hours with temperature >5°C at soil surface, but both bog habitats are warmest at 5 cm depth by this parameter. It appears that the fungi settled in the litter (0-5 cm) experience more extreme climatic conditions (daily temperature range) in the bog compared to forest. Then, this habitat could present more favorable conditions for the fructification as wide variations of soil temperature in the litter (0–5 cm) are argued to be an important factor for the onset of the fungi fructification [Pinna et al., 2010]. The longevity of suitable for growth temperatures (>5°) at 5 cm soil depth (relevant to mycelium development) is highest in two bog habitats.

Total volume of precipitation from May until middle October was higher in 2012 (317 mm) than in 2013 (244 mm). Both numbers are some smaller than mean value for this period based on 30 years observation (about 350 mm). Rainfall distribution over time was not equal by months and by years (fig. 6). There was quite dry beginning of summer and wet autumn in 2012, but in 2013 half of precipitation fell in July (during three days).

Table 2. Temperature characteristics in studied communities from May to October 2013

	Parameter	**Treed bog**	**Lawn**	**Forest**
Soil surface	Daily mean temperature, °C	8.8	9.0	7.7
	Mean maximum temperature, °C	16.6	13.3	11.0
	Mean minimum temperature, °C	2.6	4.4	5.2
	Mean temperature range, °C	13.9	8.9	5.5
	Number of hours with T>5 °C	2770.0	2972.0	2842.0
	Dates of the last and first frosts	13.05/11.10	5.05/17.09	19.05/25.11
Soil at 5 cm depth	Daily mean temperature, °C	7.5	8.9	9.6
	Mean maximum temperature, °C	10.7	12.9	7.6
	Mean minimum temperature, °C	4.7	4.8	6.1
	Mean temperature range, °C	6.0	8.1	1.5
	Number of hours with T>5 °C	2867.0	2862.0	2728.0

Fruiting observations

The first collections of larger fungi in 2012 were done on the 12th of August, the maximum number of collections occurred at the beginning of September, and the end of fruiting period was registered around the 20th of September. Registrations of larger fungi at plots in 2013 started on the 22nd of August and were finished the 21st of September. Some registrations on appearance of larger fungi were made out of plots by random observations in earlier summer: *Pseudoplectania sphagnophila* was collected at the end of June (24), *Omphalina sphagnicola* started to appear in the middle of July, and *Tephrocybe palustris*, *Galerina tibiicystis* were fruiting at the end of July – beginning of August. These four species seem to represent earlier aspect of bog fungi, and started to wither away by the time of plot study. Other species of macrofungi of bog communities (totally 59 species registered) were fruiting lively during the mentioned time period (22.08 – 21.09) (table 3). Sporocarp abundance was growing in both habitats (treed bogs, lawns) until its maximum in the middle of September. First visited plots yielded about 5 times lesser abundance in sphagnum lawns and 9 times in treed bogs in August compared to September. At the same time, mean number of species at plots was remaining constant during this period. The end of fruiting was set by frosts (the first temporal snow cover was on the 10th of October).

Fruiting of micromycetes on plant litter was lasting during the whole observation period from May until October. The species of this group do not require long time for the formation of fruiting structures and some of them were registered immediately after the snow melt. At the same time, seasonal periodicity was also observed for many species (early summer, summer or autumn fruiting). It is not possible to draw any conclusions about the phenology of a large part of the species listed in this group since the registrations are scarce and the taxonomy of part species is uncertain. But for the identified species with constant occurrence some phenological notices are presented in table 4.

Table 3. Species list of larger fungi of bogs and time of fruiting (*): 1 – earlier summer, 2 – summer, 3 – late summer and autumn

Species	*	Species	*
Amanita porphyria Alb. &Schwein.	3	*Gymnopus androsaceus* (L.) J.L. Mata & R.H. Petersen	3
Arrhenia sphagnicola (Berk.) Redhead, Lutzoni, Moncalvo&Vilgalys	2	*Gymnopus dryophilus* (Bull.) Murrill	3
Arrhenia onisca (Fr.: Fr) Quel.	3	*Hebeloma incarnatulum* A.H. Sm.	3
Ascocoryne turficola (Boud.) Korf	3	*Hygrocybe cinerella* (Kühner) Arnolds	3
Clavaria sphagnicola Boud.	3	*Hypholoma capnoides* (Fr.) P. Kumm.	3
Collybia cirrhata (Pers.) Cumm.	3	*Hypholoma elongatum* (Pers.) Ricken	3
Cortinarius cf. *albovariegatus* (Velen.) Melot	3	*Hypholoma eximium* (C. Laest.) Rald	3
Cortinarius caperatus (Pers.: Fr.) Fr.	3	*Hypholoma udum* (Pers.) Quél.	3
Cortinarius flexipes (Pers.) Fr.	3	*Laccaria proxima* (Boud.) Pat.	3
Cortinarius cf. *flos-paludis* Melot	3	*Lactarius helvus* (Fr.) Fr.	3
Cortinarius huronensis Ammirati & A.H. Sm.	3	*Lactarius rufus* (Scop.) Fr.	3
Cortinarius cf. *obtusus* (Fr.) Fr.	3	*Lactarius* sp. 1	3
Cortinarius pholideus(Fr.: Fr.) Fr.	3	*Leccinum holopus* (Rostk.) Watling	3
Cortinarius scaurus var. *sphagnophilus* Fr. (Fr.)	3	*Lichenomphalia umbellifera* (L.) Redhead, Lutzoni, Moncalvo&Vilgalys	3
Cortinarius semisanguineus (Fr.) Gillet	3	*Mycena concolor* (J.E. Lange) Kühner	3
Cortinarius cf. *vibratilis* (Fr.: Fr.) Fr.	3	*Mycena epipterygia* (Scop.: Fr.) S.F. Gray	3
Cortinarius stillatitius Fr.	3	*Mycena galopus* (Pers.) P. Kumm.	3
Cortinarius sp. 1	3	*Mycena megaspora* Kauffman	3
Cortinarius sp. 2	3	*Omphaliaster borealis* (M. Lange &Skifte) Lamoure	3
Cortinarius sp. 3	3	*Psathyrella* cf. *sphagnicola* (Maire) J. Favre	3
Entoloma fuscomarginatum (Fr.) P. Kumm.	3	*Pseudoplectania sphagnophila* (Pers.) Kreisel	1
Galerina allospora A.H. Sm. & Singer	3	*Psilocybe turficola* (Lasch) Gillet	3
Galerina cerina A.H.Smith& Singer	3	*Russula paludosa* Britzelm.	3
Galerina paludosa (Fr.) Kühner	3	*Sphagnomphalia brevibasidiata* (Singer) Redhead, Moncalvo, Vilgalys&Lutzoni	3
Galerina sphagnicola (G.F. Atk.) A.H. Sm. & Singer	3	*Suillus sibiricus* Sing.	3
Galerina sphagnorum (Pers.) Kühner	3	*Suillus variegatus* (Sw.) Kuntze	3
Galerina tibiicystis (G.F. Atk.) Kühner	2	*Tephrocybe palustris* (Peck) Donk	2

Species	*	Species	*
Geoglossum glabrum Pers.: Fr.	3	*Thelephora terrestris* Ehrh.	3
Gymnopilus fulgens (J. Favre & Maire) Singer	3	*Xeromphalina cornui* (Quél.) J. Favre	3
Gymnopilus penetrans (Fr.) Murrill	3		

Table 4. Fruiting time of some microfungi on litter

Species	Month	Species	Month
Allophylaria basalifusca Graddon	7–9	*Hysteropezizella diminuens* (P. Karst.) Nannf.	8
Cistella cf. *acuum* (Alb. & Schwein.) Svrček	7, 8	*Lophodermium eriophori* (Henn.) P.R. Johnst. & Scheuer	9
Coccomyces cf. *coronatus*	9	*Lophodermium oxycocci* (Fr.) Duby	8
Coccomyces duplicarioides Sherwood	9	*Mollisia ramealis* (P. Karst.) P. Karst.	6, 7
*Colpoma ledi (*Alb. & Schwein.) B. Erikss	7, 8	*Mollisia retincola* (Rabenh.) P. Karst	8
Coronellaria caricinella (P. Karst.) P. Karst.	7, 8	*Monilinia oxycocci* (Woronin) Honey	5
Dasyscyphella cassandrae var. *cassandrae* Tranzschel	6–8	*Mycosphaerella bacillifera* (P. Karst.) Lind	5
Gibbera cassandrae (Peck) M.E. Barr	6, 8	*Mycosphaerella* cf. *chamaemori*	5
Gnomoniella nana Rehm	6 – 8	*Myriosclerotinia dennisii* (Svrček) J. Schwegler	6
Gnomoniopsis chamaemori (Fr.) Berl.	5	*Nimbomollisia eriophori* (L.A. Kirchn.) Nannf.	8
Godronia cassandrae f. *cassandrae* Peck	6–8	*Niptera* cf. *fuscoparaphysata*	6, 7
Helotium schimperi Navashin	7	*Physalospora vaccinii* (Shear) Arx & E. Müll.	7, 8
Hyaloscypha fuscostipitata (Graddon) Baral & Huhtinen	7	*Rhytisma andromedae* (Pers.) Fr.	5–9
Hyaloscypha leuconica var. *bulbopilosa* (Cooke) Nannf.	6–8	*Roeslerina media* Y.J. Yao & Spooner	6
Hyaloscypha secalina var. *paludicola* Huhtinen	8	*Rutstroemia chamaemori* L. Holm & K. Holm	8
Hymenoscyphus salmanovicensis Svrček	6	*Rutstroemia paludosa* (E.K. Cash & R.W. Davidson) J.W. Groves & M.E. Elliott	6
Hypoderma cf. *alpinum* Spooner	8	*Typhula chamaemori* L. Holm & K. Holm	8
Hysteronaevia advena (P. Karst.) Nannf.	7	*Vibrissea obconica* (Kanouse) A. Sánchez	6
Hysteronaevia olivacea (Mouton) Nannf.	8, 9	*Wentiomyces sibiricus* (Petr.) E. Müll.	7, 8

Relation between soil temperature, precipitation and fungal fruiting

According to Moore et al. [2008], *in vitro* cultivated fungi need a downshift of the temperature to fruit. In natural conditions the daily mean soil temperature at 5cm depth and the daily minimum air temperature turn out to be decisive for the fruiting onset [Kotilova-Kubickova et al., 1990a] as the best correlation with production of new fruit bodies is obtained when the soil temperature (5 cm depth) goes under 12.5°C and the minimum air temperature is between 1 and 5.5°C during 1 or 2 days [Kotilová-Kubicková et al., 1990b]. The data collected in the Mukhrino area in 2013 seem to follow this pattern (fig. 5). The mean soil temperature at 5 cm depth dropped below 12.5°C on the 20th of August and the minimum air temperature reached the 1–5.5°C temperature range on the 15th and the 16th of August for both treed bog and sphagnum lawns while the fruiting started with a little delay. Indeed, the onset was on the 22nd of August in the treed bog and on the 26th in the lawn habitat. Moreover, the mean soil temperature at 5cm depth goes durably below 12.5°C after the 26th of August, while the number of fruitbodies gets high (above 500) from the 2nd of September.

The influence of precipitation on fruiting was not very pronounced (fig. 6). Though triggering rains which precede fruiting onset by one-two weeks could be traced in both years, probably precipitation may be not important factor given high humidity of peaty soils in bogs.

CONCLUSIONS

We have presented the description of micro-climate factors (soil temperature and precipitation) related to fungal development in bog ecosystem in middle taiga of West Siberia. These data could be valuable information about ecology of the species and dynamics of decomposer community of bog ecosystems. Some biologically valuable parameters (temperature range, number of days with temperature >5°C) considerably differ between two bog habitats (treed bogs and *Sphagnum* lawns) and the forest. The bog has higher daily temperature range and thus could represent more extreme environment for fungal development. The temperature extremes, on the other side, could trigger fungal fruiting in the bog to more extent than in the forest. Number of vegetation hours (when temperature exceeds 5°C) at 5 cm soil depth in the bog is higher than in the forest. Thus, the bog have longer time for mycelium functioning than the forest.

We have summarized the results of one-year fruiting observations of macro- and microfungi in the bog. For macromycetes, maximum of carpophore formation was shown in September. Some species had earlier fruiting at the beginning and mid-summer. The species of micromycetes had different fruiting patterns during the vegetation season.

The relations between micro-climate parameters and fruiting patterns were made in descriptive way (no statistical analysis was accomplished at this point). The beginning of macromycetes fruiting in the bog could be related to downshifts of mean soil and minimum air temperatures. The relation between rainfall and fruiting was not showed, which probably explains lesser importance of rains for fruiting in saturated conditions of the bog.

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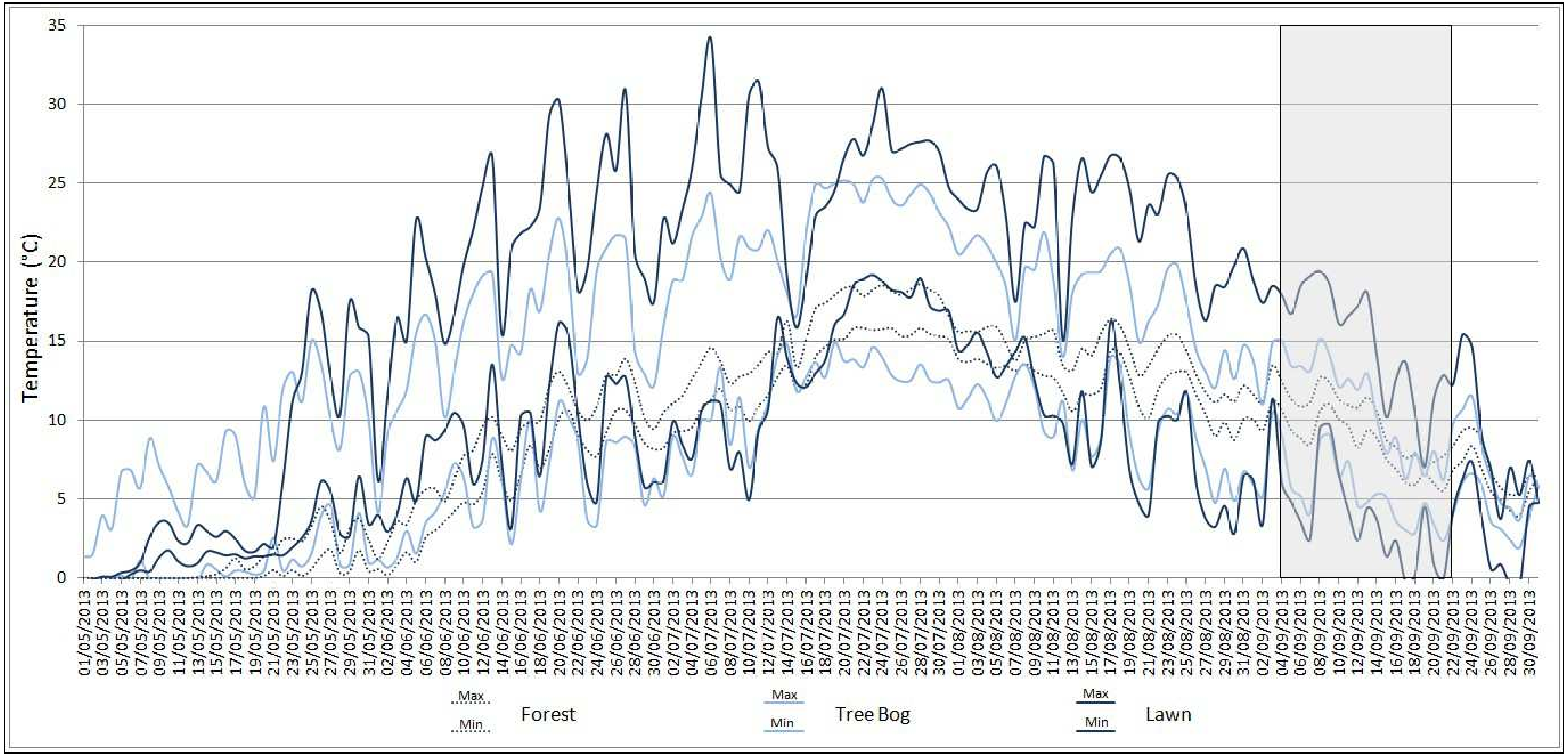

Figure 3. Daily minimum and maximum soil temperature course (5 cm below the surface) from May to October 2013 in forest, treed bog and lawn, and period of maximum fruiting of macromycetes in bog in 2013 (gray part)

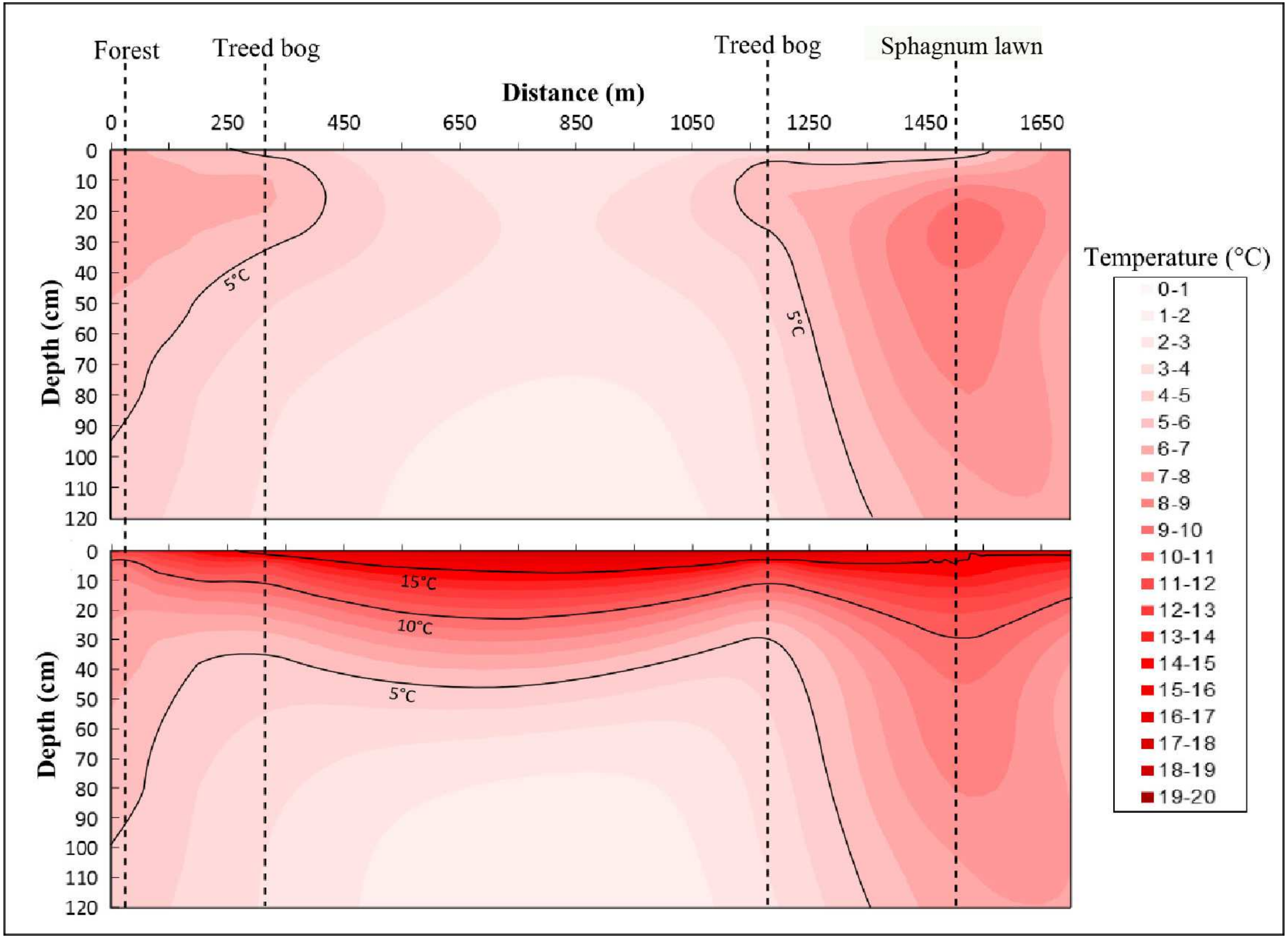

Figure 4. Average minimum (above) and maximum (below) temperatures of soil profile in three studied habitats (May–October)

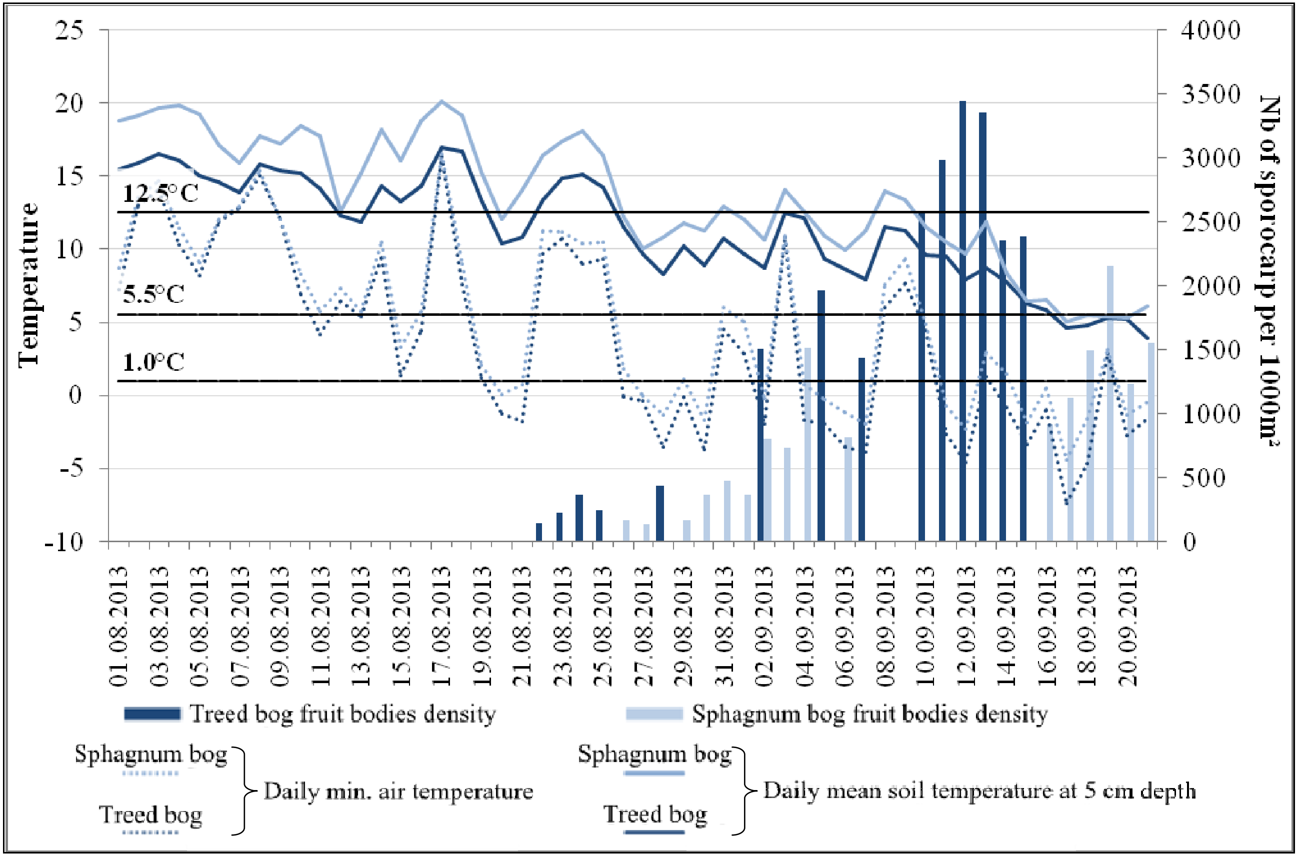

Figure 5. Evolution of the density of sporocarp and the daily minimum and 5 cm depth mean temperatures in the treed bog and sphagnum bog habitats in 2013

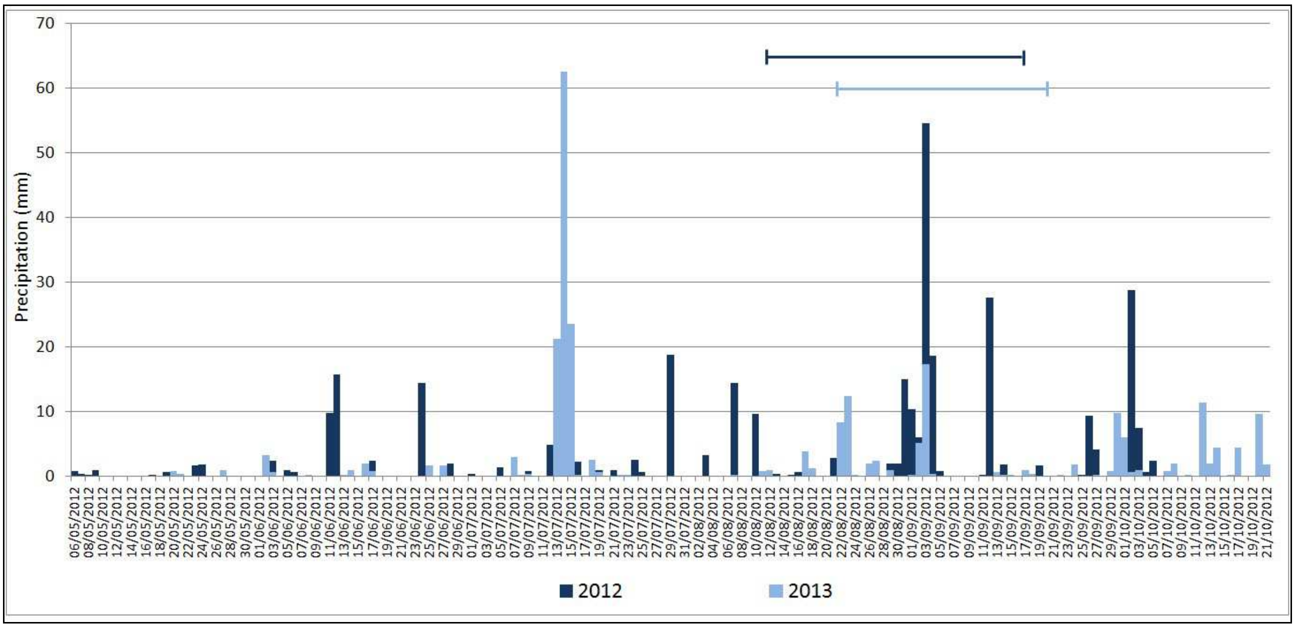

Figure 6. Precipitation (mm) by day and periods of maximum fruiting of macromycetes (bars)

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ФЕНОЛОГИЧЕСКИЕ НАБЛЮДЕНИЯ ЗА ГРИБАМИ ВЕРХОВЫХ БОЛОТ

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В статье приводятся результаты наблюдений плодоношения макро- и микромицетов и микроклиматических параметров на верховом болоте в окрестностях г. Ханты-Мансийска (средняя тайга Западной Сибири). Проанализированы температура воздуха, четыре профиля температуры почвы, расположенные в двух болотных местообитаниях (рям, топь) и в лесу (измерения в течение одного вегетационного сезона). Осадки измерялись в течение двух вегетационных сезонов в одной точке болотного массива. Наблюдения за плодоношением макромицетов проводили маршрутным методом (2012) и учетом на постоянных площадках (2013) в двух болотных сообществах (рям и топь). Учет карпофоров проводился в конце вегетационного сезона, в августе – сентябре (2012, 2013). В первой половине лета плодоношения раннелетних видов были зарегистрированы маршрутным методом. Наблюдение за периодичностью плодоношений микромицетов на растительном опаде продолжалось в течение всего вегетационного сезона (2013).

Обилие карпофоров макромицетов увеличилось в 5 раз (топь) и 9 раз (рям) к концу периода наблюдения (22 августа – 21 сентября, 2013). Дальнейшее плодоношение было остановлено заморозками. Видовой состав в течение этого периода не менялся (всего в двух типах сообществ было зафиксировано 59 видов). Плодоношение в мае – июле зафиксировано у четырех видов, представляющих ранний аспект макромицетов верхового болота. Для 40 видов микромицетов зарегистрирована периодичность плодоношения (приводятся данные по месяцам), заключение о времени плодоношения остальных микромицетов нельзя сделать из-за редкости встреч.

Микроклимат двух местообитаний болота и леса существенно отличается между собой, несмотря на их близость (500 м). Поверхность и верхний слой почвы болота испытывает более глубокие колебания суточной температуры, чем лес (и топи меньше, чем рям). Так, среднесуточная амплитуда вегетационного периода (май – октябрь) составила на поверхности 5,5 в лесу, 13,9 в ряме и 8,9 в топи; на глубине 5 см она была равна 1,5, 6, и 8,1 соответственно. Среднесуточная температура вегетационного периода на поверхности почвы ниже в лесу, а на глубине 5 см ниже в ряме. Число часов с вегетационной температурой (>5° С) на поверхности выше в топи, и на глубине 5 см одинаково выше в топи и ряме.

Наблюдения за плодоношением в течение одного сезона показали возможную связь (статистической оценки не проводилось) между понижением среднесуточных и минимальных температур и началом обильного плодоношения макромицетов. Несмотря на разные режимы выпадения осадков в 2012 и 2013 году, влияния их на сроки плодоношения не было замечено. Вероятно, осадки играют меньшую роль в условиях перенасыщения водой на болоте.

Ключевые слова: болото, верховое болото, микроклимат, грибы, макромицеты, плодоношение, фенология.

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