VILNIUS UNIVERSITY

NATURE RESEARCH CENTRE, INSTITUTE OF BOTANY

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POSSIBILITIES OF ECOLOGICAL RESTORATION OF RAISED BOG PLANT COMMUNITIES IN DEGRADED PARTS AND IN A CUTOVER PEATLAND OF AUKŠTUMALA RAISED BOG

Summary of doctoral dissertation

Biomedical sciences, botany (04 B)

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VILNIAUS UNIVERSITETAS

GAMTOS TYRIMŲ CENTRO BOTANIKOS INSTITUTAS

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AUKŠTAPELKIŲ AUGALŲ BENDRIJŲ EKOLOGINIO ATKŪRIMO GALIMYBĖS DEGRADAVUSIOJE AUKŠTUMALOS PELKĖS DALYJE IR IŠEKSPLOATUOTAME DURPYNE

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INTRODUCTION

Peatlands occupy about 3% (4 × 106 km^2) of the global land surface and contain about 30% of the terrestrial soil carbon (GORHAM, 1991; JOOSTEN, CLARKE, 2002; GORHAM, ROCHEFORT, 2003). Active drainage for agriculture, forestry and commercial peat harvesting during the last century was the main cause of pristine peatlands' losses. Since 1800's, the global area of peatlands has been reduced at least by 10–20% (JOOSTEN, CLARKE, 2002; MACDONALD et al., 2006). Herewith, valuable ecosystems, which are vitally important in the global carbon cycle for protection of biodiversity, soil, preserving water supply and its quality, and other functions of ecosystem services, are being lost. Lithuania has lost about two thirds of its total peatland area during the 20th century (MIERAUSKAS et al., 2005; JUKONIENE et al., 2009). To date, about 70% of the inventoried peatlands in Lithuania are anthropogenically damaged (POVILAITIS et al., 2011; TAMINSKAS et al., 2011), and 1.6–2.5 mln. tons of carbon are lost every year as a result of intensified peat mineralization (MINAYEVA, SIRIN, 2009). Despite of the fact that active raised bogs are usually rather stable ecosystems, their further development towards degradation often follows as human activity accelerates succession processes and turns them into bog woodlands or degraded raised bogs (JOOSTEN, CLARKE, 2002). Changes in these abiotic factors are inevitably reflected in plant species composition: for example, in drained bogs of the north-temperate climate zone of Europe, typical raised bog species are commonly replaced by forest vegetation.

Such changes are also observed in one of the largest and most famous Lithuanian peatlands – Aukštumala raised bog (western Lithuania), where in its drained areas typical open raised bog vegetation is replaced by forest species including trees and shrubs. First negative changes in the vegetation cover and intensified decomposition of the peat layer of Aukštumala raised bog were noticed by a German naturalist and botanist C. A. Weber already in the beginning of the 20th century (WEBER, 1902). Weber's monograph was the first scientific publication dedicated to the main concepts of the raised bog ecology and botany, geology and paleogeography in the world. To date, about two-thirds (2.417 ha) of the former Aukštumala raised bog have been turned into peat harvesting fields, and only in 1995, the remaining least affected part (1.285 ha) was declared as a Telmological Reserve (TR). Although the reserve status has protected western part of Aukštumala raised bog from further peat harvesting, it did not safeguard this area from a negative influence of draining. Areas adjacent to peat harvesting fields are drained most intensively by deep water-collecting ditches; although a network of smaller primary ditches across the territory of the Aukštumala TR has also a certain negative effect on hydrology and the state of ecosystems in the raised bog.

The aim of the study was to assess the state of raised bog plant communities and hydrological regime in the Aukštumala Telmological Reserve, and to study the potential of restoration of plant communities in the parts of Aukštumala raised bog, degraded by drainage and the fire, and in the cutover peatland.

The main objectives of the research:

1. to assess the state of degradation of raised bog plant communities and to perform inventory of EU habitats in the Aukštumala Telmological Reserve;
2. to evaluate drainage-caused changes in hydrological and hydrochemical properties of Aukštumala raised bog, and to define relationships among those factors identifying optimal conditions for restoration of raised bog plant communities;
3. to study natural regeneration of raised bog plant communities in fire-damaged areas of Aukštumala raised bog;
4. to assess effectiveness of three different means of hydrological regime regulation: i) polyethylene membrane; ii) "peat lock" system (a barrier made of a highly decomposed peat); and iii) peat dams;
5. to investigate the potential of ecological restoration of raised bog plant communities in the cutover peatland by artificial reintroduction of *Sphagnum* mosses.

Theme relevance

Anthropogenically disturbed peatlands are getting less and less resilient in the face of the environmental change: the peatlands lose their capability to resist negative impacts what in the future will accelerate decline of their sensitive ecosystems (JOOSTEN, CLARKE, 2002). Importance of restoration of peatland ecosystems and a need for further investigations is stressed by researchers from all over the world (PRICE, 1998, 2003; GRONEVELD, ROCHEFORT, 2002; JOOSTEN, CLARKE, 2002; SCHIPPER, 2002; QUINTY, ROCHEFORT, 2003; ROCHEFORT et al., 2003; KOZULIN et al., 2010; TOMASSEN et al., 2003; VASANDER et al., 2003; GONZÁLEZ et al., 2014). In the present study, we performed investigation of raised bog habitats with different degree of degradation and assessed effectiveness of measures applied to improve the state of those habitats in the Aukštumala Telmological Reserve; moreover, we studied the possibilities to restore raised bog plant communities in the cutover peatland of Aukštumala raised bog. These studies are important not only on a country-wide scale, but also on a global scale as the fate of this unique delta-type peatland interests researchers from many countries. Almost every peatland is unique in its properties and each need to be dealt individually. Even within a single peatland variation will occur, which may demand different approaches (ANONYMOUS, 2010).

Herein, we discuss effectiveness of three types of measures of hydrological regime restoration aiming to offer optimal means for protection of Aukštumala raised bog from further effect of the drainage, and preventing degradation of the vulnerable peatland ecosystem. An experiment of introduction of donor fragments of raised bog plant cover into the cutover peatland of Aukštumala raised bog has been initiated within the frame of this dissertation project, which results will allow evaluation of possibilities to restore already devoured Lithuanian peatlands. In the present work, a valuable material of the performed research on self-regeneration of plant communities in fire-damaged raised bog, on coherence of the raised bog plant communities and individual plant species with dynamics of ground water level and hydrochemical water properties (pH, electrical conductivity) is presented. The obtained results are by no doubt relevant to researchers and practioners working in the field of peatland ecosystem restoration all over the world.

Scientific novelty of the research

The dissertation provides new summarized data on the state of plant communities, distribution of EU natural habitats, and assessment of the impact of three measures of water level regulation on the hydrological regime and the potential to restore raised bog plant communities in the Aukštumala Telmological Reserve. For the first time in Lithuania, we initiated an experiment of introduction of donor fragments of raised bog plant cover into a cutover peatland, which results will provide novel information on possibilities to apply such restoration measure in exploited Lithuanian peatlands. The preliminary results suggest an approach different from previously used practices to recultivate exploited and abandoned parts of peat harvesting fields (full or partial restoration of peatland ecosystems), which may facilitate artificial regeneration of raised bog plant communities. Another important problem addressed that still lacks attention by the Lithuanian researchers – investigation of dynamics of post-fire raised bog plant communities. The results obtained during three investigation years in the eastern part of Aukštumala raised bog allowed evaluation of changes in the raised bog plant communities following peatland fire of 2011.

Scientific and practical importance of the research results

The results of the present work complement our knowledge about hydrological properties of Lithuanian raised bogs and reveal the potential of their ecological restoration. The hydrological and phytocenotic data compiled during this study allow providing detailed overview of anthropogenically induced changes that have occurred in Aukštumala raised bog, the world's first thoroughly investigated peatland (WEBER, 1902). Five locations of occurrence of plants included into the Lithuanian Red Data Book were inventoried during the field studies in the Telmological Reserve. It was demonstrated that ground water level is the main factor determining the occurrence and distribution of raised bog plant communities, the structure and physical as well as chemical properties of the peat stratum. The data obtained during eight investigation years allowed rather precise determination of a limit between conditions favourable for peatland formation and drainage-induced peatland degradation processes. Moreover, testing and approval of effectiveness of several measures to restore hydrological regime will allow adapting best practices in other Lithuanian raised bogs irrespective of regional differences. Restoration of ground water level is particularly important problem of present times to which we attach while trying to solve questions associated with degradation of peatland habitats and increased emissions of greenhouse gas.

The defended statements:

1. Plant species atypical to ombrotrophic bogs occupy disturbed raised bog habitats of the Aukštumala Telmological Reserve; fens and transitional peatlands have vanished from the surroundings of the raised bog because of drainage;
2. Mean water table depth not less than 30 cm below the peat surface during vegetation season is the most important factor ensuring natural raised bog development;
3. The number of plant species atypical to ombrotrophic bogs in the fire-damaged parts of Aukštumala raised bog are decreasing in the course of time; a rising water table in burned areas disturbed by drainage induces regeneration of the raised bog plant communities;
4. Polyethylene membrane, "peat lock" system (a barrier made of highly decomposed peat), and blocking of old drainage system by peat dams can stop direct water runoff from the raised bog to peat harvesting fields, and may help to effectively restore hydrological regime favourable for peatland formation, which in its turn facilitates regeneration of plant communities typical to raised bogs;
5. Optimal water table depth during vegetation season is the main factor to ensuring introduction of donor fragments of raised bog plant cover into cutover peatlands.

Approbation of the results

The results of the present study were presented in six scientific papers, of which two – in international journals included into *Thomson Reuters Master Journal List* (one – with impact factor). The research results have also been presented in the theses of six scientific conferences. See end of the summary for full list of publications.

Structure of the dissertation

The dissertation consists of the following chapters: Introduction, Literature Review, Study Object, Materials and Methods, Results and Discussion, Conclusions, Reference List (190 sources). The dissertation consists of 108 pages and includes 36 figures and 11 tables. The dissertation is written in Lithuanian with English summary.

MATERIALS AND METHODS

Investigation area. Aukštumala raised bog (total area 3.702 ha) is situated in the Nemunas delta plain (western Lithuania; 55°24′ N; 21°20′ E). In this region, large-scale land reclamation works were implemented already in the 19th century to regulate water regime in fertile lands of the delta, which were readily used for agriculture (BASALYKAS, 1958). Almost two-thirds of the former Aukštumala bog area is now used for intensive peat harvesting (Fig. 1). This area is surrounded by deep water-collecting ditches to prevent rising of the water level in the industrial area. The rest territory of the bog has relatively recently (in 1995) been declared as a Telmological Reserve (TR), yet large part of this area is still negatively affected by an old drainage system (created in about 1970s) and by significant water runoff into water collecting ditches surrounding peat harvesting fields. The old drainage system in the Aukštumala TR consists of 1–2-m-wide and up to 1-m-deep ditches with an average distance of 20–30 m from each other. The system is located in the eastern part of the TR and is currently not maintained. The contact zone of the Aukštumala TR and peat harvesting fields is about 6 km long (Fig. 1); therefore about 30–60 ha of the TR is under continuous influence of the intensive drainage (PAKALNIS et al., 2009). In June 2011, a large fire devastated 270 ha of the Aukštumala TR (the north-eastern part).

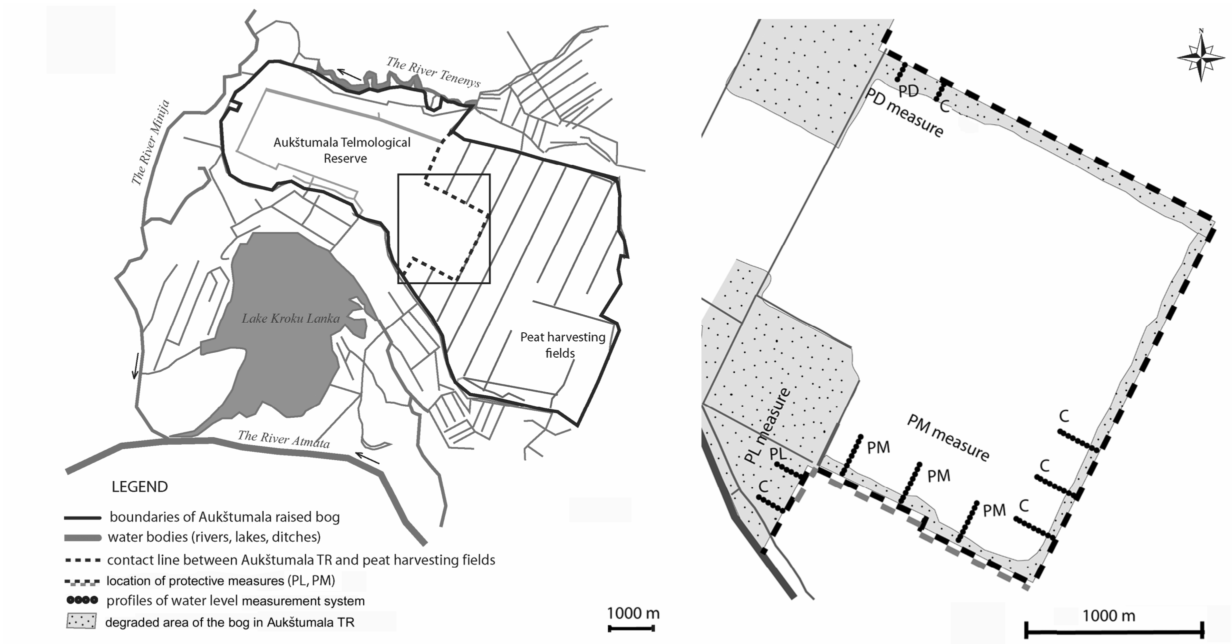


Fig. 1. Map of Aukštumala raised bog. Left: raised bog divided into the Aukštumala Telmological Reserve (TR, north-western part) and peat harvesting fields (south-eastern part). Right: enlarged area of investigations in the Aukštumala TR with indicated locations of the applied treatments (PM, PL and PD measures) and water level monitoring profiles. C – control profiles (untreated area) associated with the respective measures.

Studies on vegetation in the Aukštumala Telmological Reserve. The scale of disturbance and degradation of plant communities and vascular plant species diversity in the Aukštumala TR was evaluated in 2010–2014. A total of 130 phytocenotic relevés of raised bog vegetation were performed applying the principles of Zürich-Montpellier phytosociological vegetation research approach (BRAUN-BLANQUET, 1964) using a route survey method; of this number, 84 relevés were made close to installed water level measurement wells in ten water level monitoring profiles (Fig. 1; see below for detailed information about water level monitoring system). To assess the influence of water table depth (WTD) on raised bog plant communities more accurately, in addition, 1 × 1 m investigation plots (N = 84) were established by each water level measuring well. The Sorensen similarity indices (C_S) were calculated to assess differences between plant communities (BRAY, CURTIS, 1957; KENT, 2012), and modified TWINSPAN classification (HILL, 1979) was used to define the types of habitats according to composition of plant communities. Evaluation of the habitats was carried out after the List of Habitats of European Importance in Lithuania (RAŠOMAVIČIUS, 2012).

Phytosociological relevés of the vegetation in the burned area were made in 2012–2014 in five permanent investigation plots (10 × 10 m in size) established along the 180-m-long transect (at 40 m distances from each other, profile PD, Fig. 1), perpendicular to the margin of the Reserve (profile PD, Fig. 1). Each investigation plot was divided into nine trial plots of 1 × 1 m for the evaluation of relative coverage by each species.

Measures to prevent direct water runoff from the raised bog. Two types of measures were applied to isolate the raised bog of the Aukštumala TR from adjacent peat harvesting fields (Fig. 1):

1) polyethylene membrane (PM). In November 2006, a 3-m-wide and 0.5-mm-thick polyethylene membrane was installed vertically in a 1-km-long, 3-m-deep and 1.5-m-wide trench excavated along the contact zone of peat harvesting fields and the TR. Immediately after installation of the membrane, the trench was filled up with the excavated raised bog peat;

2) "peat lock" (PL) system. A 0.3-km-long, 3-m-deep and 1.5-m-wide trench was excavated along the contact zone of peat harvesting fields and the TR and filled up with highly decomposed peat excavated from a bottom layer of the bog. This peat is characterized by a very low water filtration rate (ČEBATORIOVAS, 1983). The measure was installed in November 2010.

Both measures were installed along the edge of the TR (Fig. 1). To prevent runoff of the surface water, a 50-cm-high protective embankment was formed on top of each measure using excessive peat excavated from the trenches.

Blocking of old drainage system in Aukštumala TR. In order to reduce the negative effect of the old drainage system, twenty 2-m-wide bog peat dams (further referred to as PD measure) were built in November 2012 on four drainage ditches closest to the contact zone with 50 m intervals. Five dams were built per ditch. The dams were made of decomposed peat, and squeezed down.

Assessment of efficiency of the applied measures. To assess efficiency of the applied measures and to perform studies on the effect of WTD on plant communities, a hydrological monitoring system was installed (Fig. 1). Ten profiles, consisting of water level measurement wells, were installed perpendicularly to the contact zone of the Telmological Reserve and peat harvesting fields. The first well of each profile was installed at a 10 m distance from each water insulation measure (either PM or PL) (Fig. 1). The distance between wells in each profile was 20 m and the number of wells per profile varied from six to nine. For installation of the wells, PVC tubes were inserted 1.8

m into a peat deposit. Measurements of water table depth (WTD) were carried out with monthly intervals during vegetation season (from April till October).

To monitor effectiveness of the PM measure, three parallel 170-m-long profiles, each consisting of nine water level measurement wells, were installed in March 2007 in the "influence zone" of the protective measure. For control, three identical profiles were installed in the untreated area (Fig. 1). To monitor effectiveness of the PL measure, two parallel 110-m-long profiles, each consisting of six water level measurement wells, were installed in March 2011: one in the treated and one in the untreated area (Fig. 1). Effectiveness of the PD measure was assessed by installation of two parallel 70-m-long profiles (each consisting of four water level measurement wells). The profiles were installed in March 2011, two vegetation seasons before the setting of the PD measure: one in the area assigned for damming and one in the control area.

In addition, a dendrochronological method (Stravinskienė 1994, 2002) was applied to assess the effectiveness of the PM measure to restore hydrological regime unfavourable for tree growth. In March 2014, a total of 50 wood cores were extracted using Pressler's increment borer from 50 pine (*P. sylvestris*) trees growing in a 20-m-wide stripe stretching along the contact line: 25 trees were sampled in the PM-treated area and 25 trees – in the untreated area adjacent to the PM-treated area. Dendrochronological method was not applied to assess the efficiency of PL and PD treatments because of too short period of these measures being in force.

Introduction of donor fragments of raised bog plant cover into the cutover peatland. In September 2011, to restore the abandoned cutover peatland of Aukštumala raised bog, a total of 130 square patches (5–7-cm-thick and 0.4 × 0.4 m in size) of naturally growing cover of typical raised bog plants were collected from a donor site (selected in a degraded part of the raised bog). Following their cutting, the donor fragments were immediately placed onto wet peat substrate (flooded with up to 9-cm-thick layer of water) in an abandoned cutover peatland site designated for the vegetation restoration experiment. The introduction of the fragments was carried out in 13 parallel transects with a 3 × 3 m spacing. To assess efficacy of the raised bog ecosystem restoration experiment, development of vegetation cover in the experimental field was monitored each July from 2011 to 2014 in 1 × 1 m investigation plots which centres matched the donor fragment centres.

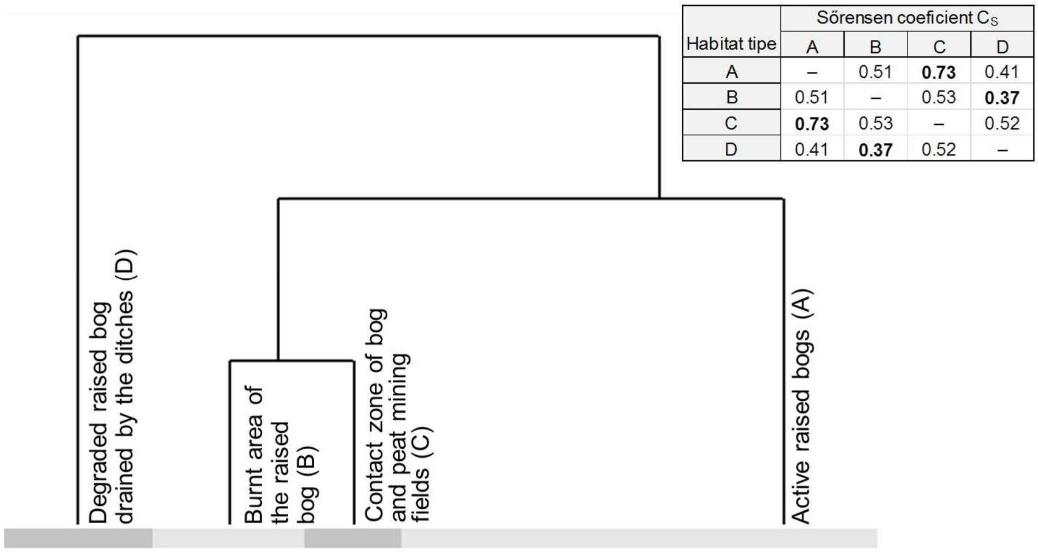
RESULTS AND DISCUSSION

Assessment of the state of raised bog habitats in the Aukštumala Telmological Reserve

Five EU habitats and 201 plant species were inventoried in the territory of the Aukštumala TR. It was found out that 38.2% (489.8 ha) of the habitats were significantly modified or degraded and did not meet the requirements for habitats of the European importance. These belt-shaped habitats (40–500-m-wide) with dominant woody vegetation cover stretch along the margins of the TR where impact of the anthropogenic activities is the most prominent. The largest area of the Reserve's territory is covered by the habitats of Active raised bogs (code 7110*) – 48.3% (621 ha), and by Degraded raised bogs still capable of natural regeneration (code 7120) – 11.6% (148.8 ha). Bog woodlands (code 91D0*) and Natural dystrophic lakes and ponds (code 3160) cover about 1% of the territory each. Some small fragments (< 0.1 ha) of Depressions on peat substrates of the *Rhynchosporion* (code 7150) were identified in the areas affected by the peatland fire of 2011. Natural vegetation cover in the Aukštumala TR has changed due to anthropogenic activities – a gradual shift of the plant communities towards eutrophication and establishment of tree and dwarf-shrub layer is being observed in the most damaged parts of the raised bog. This shift has accelerated changes in a systematic spectrum of the resident plant families: *Cyperaceae, Ericaceae and Droseraceae* are being replaced by *Asteraceae, Poaceae, Rosaceae, Onagraceae*, etc.

Analysis of vegetation cover

In the 84 phytosociological relevés made close to the water level measurement wells, a total of 76 plant species were recorded, 43% of which were typical to raised bogs. Based on TWINSPAN cluster analysis, four clusters were distinguished and named after relatively predominant habitat type: i) active raised bog (55 relevés); ii) degraded raised bog drained by the ditches (11 relevés); iii) the contact zone of the bog and peat mining fields (7 relevés) and iv) burned area of the raised bog (11 relevés) (Fig. 2). First two habitat types were qualified as the habitats of the European importance: 7110 *Active raised bogs; 7120 Degraded raised bogs still capable of natural regeneration.



Habitat tipe	Sõrensen coeficient C_S			
	A	B	C	D
A	–	0.51	**0.73**	0.41
B	0.51	–	0.53	**0.37**
C	**0.73**	0.53	–	0.52
D	0.41	**0.37**	0.52	–

Fig. 2. Types of habitats in Aukštumala raised bog based on TWINSPAN cluster analysis. A – active raised bog; B – burned area of the raised bog; C – contact zone of the bog and peat mining fields; D – degraded raised bog drained by the ditches.

In the zone of active raised bog (zone A), 43 plant species were recorded (Fig. 3). Of these, 72% were typical to ombrotrophic raised bogs. This type of habitats was represented by the ass. *Sphagnetum magellanici* (Malc. 1929) Kästner et Flössner 1933, and characterized by treeless plant communities with well-expressed *Sphagnum* moss (73 ± 14.4%) and sparse herb (33 ± 16%) coverage. In this zone, the mean WTD was –26 ± 8.4 cm (Table 1) and fluctuated from -15 cm in treeless communities to -49 cm in communities with well-expressed tree coverage. The mean water pH was 4.4 ± 0.2, falling into the range of pH values typical to ombrotrophic bogs. The mean electrical conductivity (EC) value was 60 ± 10 µS m^{-1} (Table 1).

Forty one plant species were recorded in the degraded raised bog drained by the ditches (zone D, Fig. 3). Trees and shrubs were abundant in this zone, whereas the moss layer was sparse (38 ± 24.1%). The mean WTD there was -52 ± 20.2 cm, mean water pH was 4.6 ± 0.61, and mean EC value was 84 ± 21.9 µS m^{-1} (Table 1). At the driest sites, the lowest recorded WTD was -93 cm, while water pH and EC values were above average: 6.2 and 140 µS m^{-1}, respectively.

In the contact zone of the bog and peat mining fields (zone C), 25 plant species were recorded. Of these, 80% were typical to ombrotrophic bogs (Fig. 3). Communities with dense *Pinus sylvestris, Calluna vulgaris* and *Empetrum nigrum* cover and sparse moss coverage (10% ± 10.5) have penetrated into the raised bog along a narrow (20–60 m wide) stripe. The mean water level was -52 ± 16.0 cm, mean water pH was 4.6 ± 0.38 and mean EC value was 74 ± 24.1 µS m^{-1} (Table 3). At the driest sites, the lowest recorded water level was -80 cm, while water pH and EC values also were above average: 5.5 and 127 µS m^{-1}, respectively.

In 2013, two years after the fire, a total of 29 plant species were recorded in the investigated area of the burned bog (zone B). Only 52% of the inventoried species were typical to ombrotrophic raised bogs (Fig. 3). Pioneer moss species *Marchantia polymorpha* and *Funaria hygrometrica* were dominant in plant communities of this zone. The mean WTD here was -44 ± 22.5 cm, mean water pH was 4.6 ± 0.24, and mean EC value was 79 ± 14.4 µS m^{-1} (Table 1). At the driest sites, the lowest recorded WTD value was -93 cm, while water pH and EC values also were above average: 5.0 and 97 µS m^{-1}, respectively.

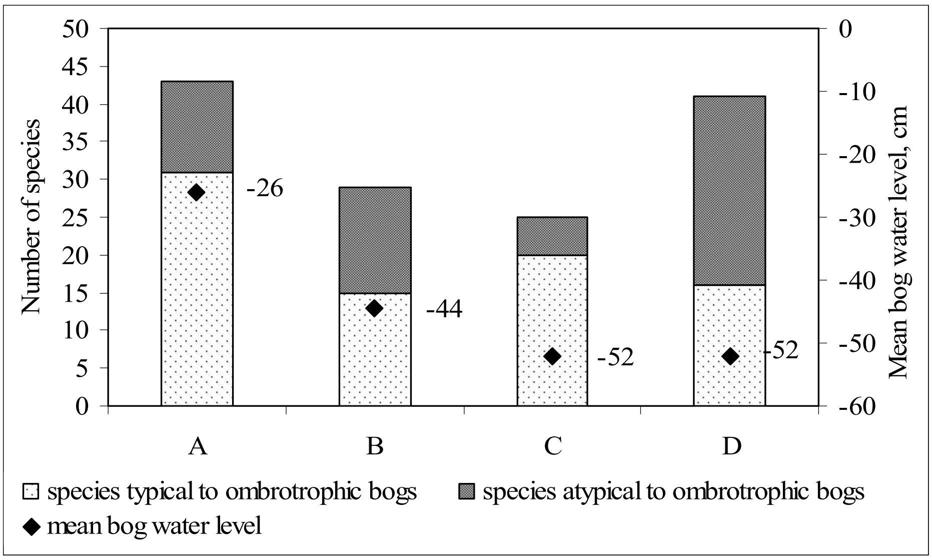


Fig. 3. Number of plant species typical and atypical to ombrotrophic bogs and mean water level (WTD, water table depth) in four habitats distinguished in the Aukštumala Telmological Reserve. For definition of the habitat types A, B, C and D see Fig. 2.

Table 1. Water table depth (WTD), pH and electrical conductivity (EC) of water, measured in four different habitats identified in the Aukštumala Telmological Reserve. Within lines, values labelled with different letters are significantly different from each other at $p < 0.05$; n.s. – non-significant difference (Tukey HSD test, ANOVA). ± SD – standard deviation. For definition of the habitat types see Fig. 2

Parameter	Habitat types							
	A		B		C		D	
Number of relevés	55		11		7		11	
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
WTD, cm	-26 a	8.4	-44 b	22.5	-52 b	16.0	-52 b	20.2
pH	4.4 n.s.	0.17	4.6 n.s.	0.24	4.6 n.s.	0.38	4.6 n.s.	0.61
EC, $\mu S \cdot cm^{-1}$	60 a	9.7	79 b	14.4	74 ab	24.1	84 b	21.9

To investigate influence of WTD on raised bog plant communities more accurately, the cover of *Sphagnum* mosses and dwarf-shrub *Calluna vulgaris* was studied in the 1m^2 investigation plots located close to the water level measurement wells. It was found out that cover of *Sphagnum* spp. exceeded 50% of the investigation plot area when WTD values did not exceed -30 cm, whereas the cover of *Calluna vulgaris* increased significantly when WTD values reached -30 cm and more (Fig. 4).

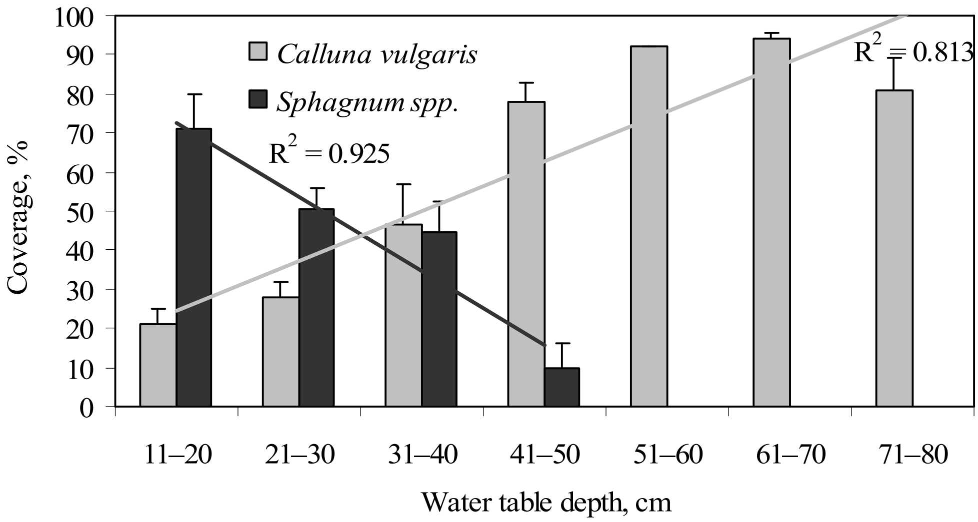


Fig. 4. Correlation between water table depth and coverage of *Calluna vulgaris* and *Sphagnum* spp. in the Aukštumala Telmological Reserve.

In all 84 water level measurement wells, the WTD ranged between -15 and -94 cm; pH ranged between 4.0 and 6.2, and EC between 44 and 140 μS cm^{-1}. WTD moderately negatively correlated with EC ($r = -0.57$; $p < 0.05$), while the correlation between WTD and pH was weaker, yet still significant ($r = -0.38$; $p < 0.05$). The comparison of hydrological and hydrochemical parameters in four types of plant habitats showed that water level in the active raised bog habitat was significantly higher ($p < 0.05$) than in other three habitat types, while among the rest three types the differences were insignificant ($p > 0.05$) (Table 1). EC values in active raised bog habitat were significantly (at $p < 0.05$) lower compared to degraded raised bog and burned area habitats. Significant differences in mean pH values between different habitats were not found (Table 1). Deep bog water level accelerates peat mineralization processes (WITTE et al., 2004). Electrical conductivity measurement is a convenient proxy for a total ionic concentration assessment. Increased values of the EC indicate accelerated mineralization process in peat bogs (RYDIN, JEGLUM, 2006). Electrical conductivity within raised bog waters is usually less than 80 µS cm^{-1} (BANAŚ, GOS, 2004).

The most constant vegetation-season WTD was recorded in active raised bog habitat, where mean seasonal water level fluctuation amplitude was as low as 12 ± 6.4 cm. In the rest three habitat types, seasonal bog water level amplitude was higher with the largest fluctuation recorded in the degraded raised bog habitat (Table 3). Moreover, monthly bog water level values in active raised bog (A) habitat were in most cases significantly higher ($p < 0.05$) compared to the rest three habitat types (B, C, D). Our results correspond with the data presented by other researchers (BALYASOVA, 1974; EGGELSMANN, 1984) showing that seasonal water level fluctuations in undisturbed bogs of Europe may be within 20–30 cm (Table 2).

Table 2. Bog water level fluctuation amplitudes during vegetation season (May–October) of 2013 in the Aukštumala Telmological Reserve. Within lines, values labelled with different letters are significantly different from each other at $p \leq 0.05$ (Tukey HSD test, ANOVA). ± SD – standard deviation. For definition of the habitat types see Fig. 2

Months	Habitat type							
	A		B		C		D	
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
	Mean water level fluctuation amplitudes							
May–October	12 a	6.4	21 a	14.0	18 a	8.8	34 b	15.5
	Mean bog water level during the vegetation season (May–October)							
May	-23 a	7.7	-41 b	25.1	-44 b	16.1	-36 ab	14.0
June	-25 a	7.0	-50 b	27.2	-49 b	15.9	-45 b	17.3
July	-26 a	7.1	-49 b	21.9	-55 b	18.7	-48 b	16.7
August	-29 a	8.6	-50 b	21.3	-56 b	14.1	-57 b	24.6
September	-29 a	11.7	-39 a	19.5	-58 b	14.0	-69 b	23.6
October	-23 a	7.6	-38 ab	19.9	-47 bc	16.9	-56 c	24.7
Mean	-26 a	8.4	-44 b	22.5	-52 b	16.0	-52 b	20.2

Regeneration of raised bog vegetation in fire-damaged part of the Aukštumala Telmological Reserve

In the area of 270 ha, raised bog vegetation was strongly affected by a fire that took place in the Aukštumala TR in 2011. The fire mainly disturbed the habitats of active raised bogs (code 7110*) and degraded raised bogs (code 7120). During the first three post-fire years (2012–2014), 44 plant species were inventoried in the investigation plots established in the burned area. Fifteen (34%) of the inventoried plant species were typical to ombrotrophic bogs and 29 (66%) species were atypical.

The results of the study on vegetation dynamics in the burned area showed that during the first post-fire year, the habitats of degraded raised bog were rapidly colonized by atypical to raised bogs species such as *Marchantia polymorpha* (up to 20% in the total plant cover), *Funaria hygrometrica* (up to 12%), *Chamerion angustifolium*, *Conyza canadensis*, *Molinia caerulea, Caluna vulgaris*, etc. The predominance of the atypical species was evident in the areas where vegetation cover was completely destroyed by the fire. This effect was particularly noticeable at the north-eastern margin of the Reserve, where 50–70-m-wide zone is still influenced by old drainage system (WTD in dry seasons may reach up to -0.4– -0.5 m). None of *Sphagnum* species in this zone could be found, whereas atypical plant species occupied up to 40% of the investigated plots. Dominant post-fire pioneer species *Marchantia polymorpha* covered up to 20% and *Funaria hygrometrica* – 12% of the investigation plot. In 2014, the coverage of these species decreased to 0% and 1%, respectively. The recovery of *Calluna vulgaris* under dry conditions was quite rapid: coverage increased from 20–34% in 2012 to 69–77% in 2014 (Fig. 5).

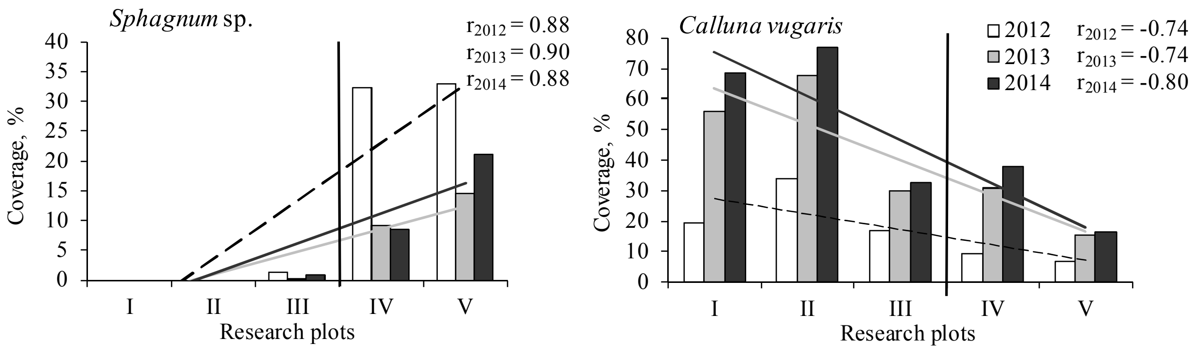


Fig. 5. Regeneration of the coverage of *Calluna vulgaris* and *Sphagnum* spp. in the study plots in the burned area of the Aukštumala Telmological Reserve.

In the burned habitats of the active raised bog (mean WTD was between -0.2 and -0.3 m), typical raised bog species *Rhynchosphora alba, Oxycoccus palustris, Andromeda polyfolia* gradually regenerated. However, three-year studies indicated that the most evident changes occurred only in *Calluna vulgaris* cover (it increased from 7–17% in 2012 to 16–31% in 2014) and *Rhynchosphora alba* cover (from 1–7% in 2012 to 9–22% in 2014). Whereas regeneration of *Sphagnum* cover was poor during all observation period even in the areas not affected by the drainage. Apparently, the *Sphagnum* cover was killed by heat rather than by burning, and the damage induced on tissues was stronger. The full regeneration of strongly affected *Sphagnum* cover may take up to 20 years (FOSTER et al., 1986).

Assessment of effectiveness of the applied hydrological regime regulation measures

Effectiveness of polyethylene membrane (PM)

Dendrochronological analysis showed that mean annual radial increment of pines growing in the PM-treated area started to decrease in 2008, i.e. one year after the installation of this measure, continued to decrease till 2010 and then levelled out to about 2 mm per annum. Radial increment of pines sampled in control area showed the opposite trend: increased in 2007–2010 and then started to slightly decrease (Fig. 6). Nevertheless, during the period from 2009 to 2013, the annual increment of control pines remained significantly ($p < 0.05$) larger compared to that in the treated area.

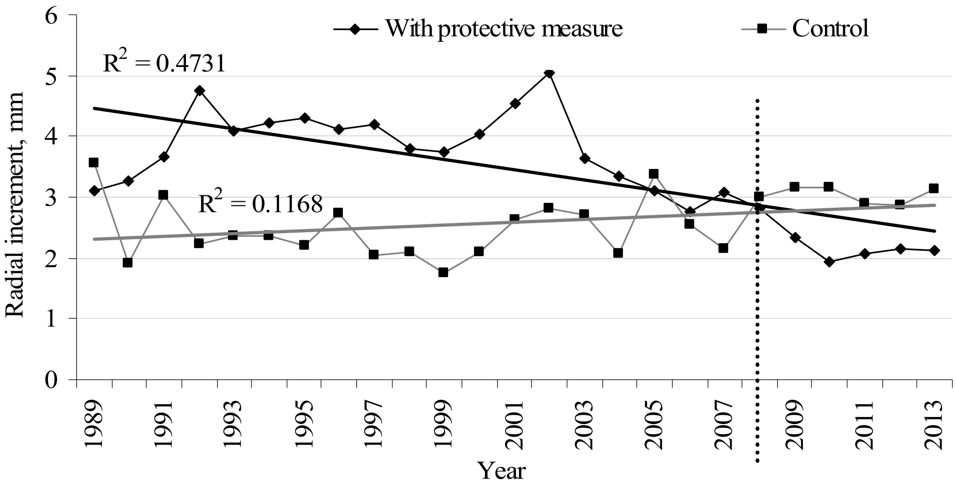


Fig. 6. Annual radial increment of *Pinus sylvestris* trees assessed in the Aukštumala Telmological Reserve following the installation of a protective measure (polyethylene membrane, installed in November 2007)

Positive effect of the applied PM measure was also ascertained by hydrological data obtained in 2007–2014. At a distance of 10–50 m from the contact line of TR and peat harvesting fields, in the treated area, mean vegetation-season WTD was in all cases significantly ($p < 0.05$) lower compared to control (Fig. 7). The greatest difference in mean WTD was observed at a 10 m distance: during first two years after the installation of the PM measure (in 2007 and 2008) this difference reached 65 ± 2.1 and 56 ± 6.1 cm, respectively. In 2009–2014, the differences at this distance were less (yet, remained significant at $p < 0.01$), and, depending on a year, ranged from 28 ± 6.0 to 42 ± 9.7 cm (Fig. 7). On the other hand, mean water table in profiles with the PM measure at 10–50 m distance from the contact line rose up to -34 ± 1.2 cm depth, i.e. to a level which is still regarded too low for peat accumulation and thriving of typical raised bog plant communities (EGGELSMANN, 1984; RUSECKAS, GRIGALIŪNAS, 2008; HAAPALEHTO et al., 2011). At larger distances (≥ 70 m) from the contact line, mean yearly WTD values in the PM-treated area did not differ significantly ($p > 0.05$) from control (Fig. 7).

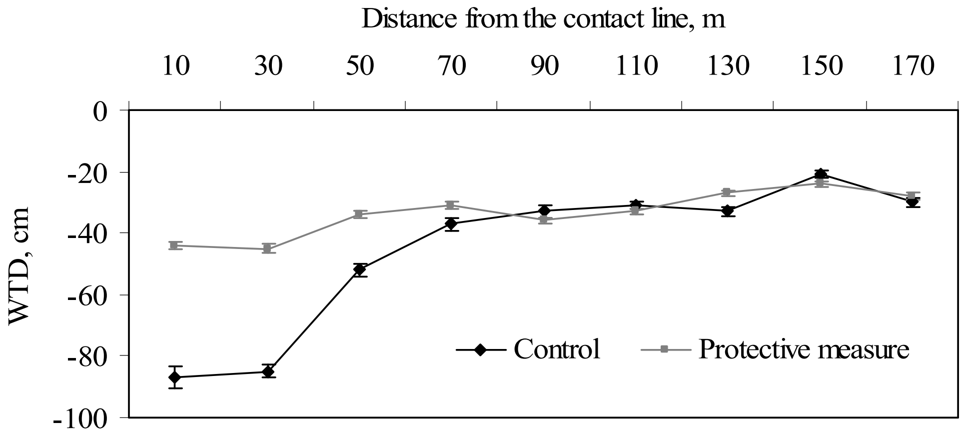


Fig. 7. Mean water table depth (WTD) ± standard error measured in the Aukštumala Telmological Reserve. Presented are values obtained in areas insulated with a polyethylene membrane (protective measure) and without it (control) during vegetation seasons (April–October) of 2007 to 2014.

The effect of the applied PM measure was also noticeable on the amplitude of seasonal water level fluctuation, although this effect could be observed only at 10 m and 50 m distance from the contact line. At the 10 m and 50 m distances, mean respective absolute values of seasonal water level fluctuation amplitude during the whole observation period (2007–2014) in the control area reached 54 ± 4.5 cm and 30 ± 2.4 cm, and were significantly ($p = 0.011–0.033$) higher than in the PM-treated area (38 ± 3.2 cm and 22 ± 2.4 cm). At 30 m distance and distances ≥ 70 m from the contact line, the difference in mean absolute amplitudes between control and treated areas was non-significant ($p > 0.05$) (Fig. 8).

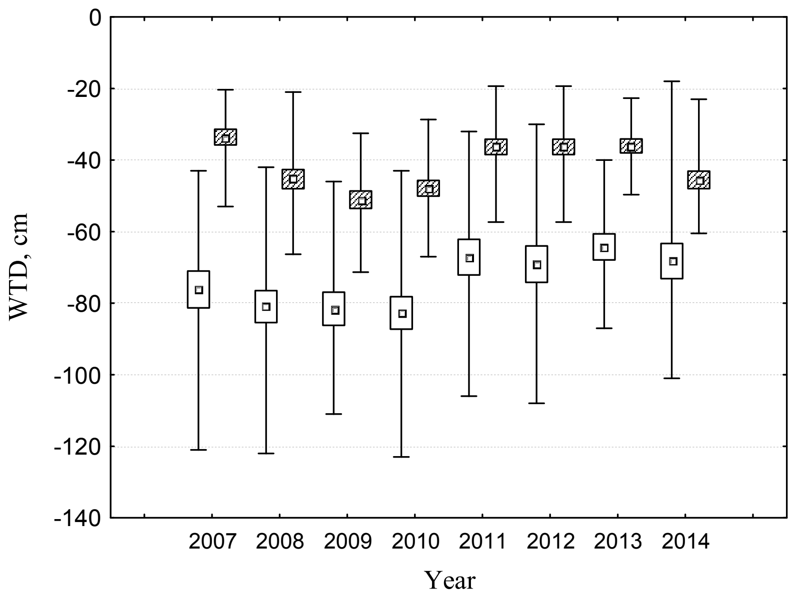


Fig. 8. Amplitudes of monthly water table fluctuations (min-max WTD values) in the area of the Aukštumala Telmological Reserve insulated with a polyethylene membrane (PM, hatched boxes) and in the untreated area (control, empty boxes) during vegetation seasons (April–October) of 2007 to 2014. Presented are values obtained from water level measurement wells at distances of 10, 30 and 50 m from a contact line (combined). Boxes show mean yearly WTD ± standard error.

At short distances from the contact line (10–30 m), seasonal water level fluctuation amplitude in the PM-treated area often exceeded 30 cm keeping conditions for peat accumulation unfavourable (according to BALYASOVA (1974) and EGGELSMANN (1984), in undisturbed bogs of Europe the amplitude should normally be within 20–30 cm). Nevertheless, dendrochronological analysis showed a clear negative effect of the PM measure on radial increment of pines growing in a contact zone of the TR and peat harvesting fields indicating that higher water table is already acting as tree growth limiting factor (STRAVINSKIENĖ, 2002; SMILIJANIC et al., 2014). On the other hand, annual radial increment of pines after the installation of this measure (about 2.0 mm, Fig. 6) was still significantly higher than reported for pines growing in pristine raised bogs of the north-temperate climate zone (annual increment of 0.41–0.87 mm was reported by CEDRO and LAMENTOWICZ (2008), PAKALNIS (2009) and SMILIJANIC et al. (2014).

Effectiveness of "peat lock" measure (PM)

Similarly to PM, the effect of PL measure was noticeable at a relatively short distance (up to about 30 m) from the contact line (Fig. 9). At a 10–30 m distance, the mean observation-period WTD was significantly (p < 0.001) lower in the PL-treated area compared to the control area. Despite this positive effect of the PL measure on bog water retention, mean vegetation-season WTD at the 10–30 m distance was high (ranged between -38 ± 6.5 cm and -67 ± 6.3 cm). At larger distances (≥ 50 m) from the contact line, mean vegetation-season WTD values in the PL-treated area were also comparably high (mean water table never rose higher than -31 ± 3.3 cm) and did not differ significantly (p > 0.05) from control.

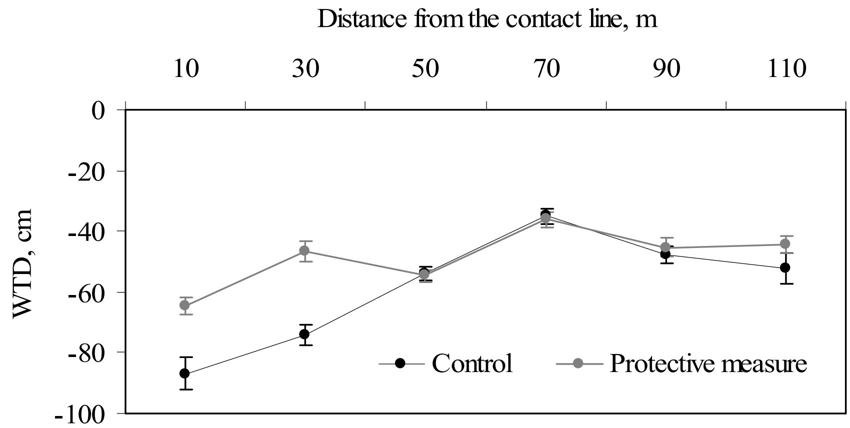


Fig. 9. Mean water table depth (WTD) ± standard error measured in the Aukštumala Telmological Reserve. Presented are values obtained in the areas insulated with a protective "peat lock" measure and without it (control) during vegetation seasons (April–October) of 2011 to 2014.

The effect of the PL measure was also noticeable on the amplitude of seasonal water level fluctuation, but only at 10 m distance from the contact line the difference between mean absolute observation-period amplitude values in PL-treated (43 ± 8.4 cm) and control (69 ± 5.7 cm) areas was statistically significant (p = 0.041) (Fig. 10).

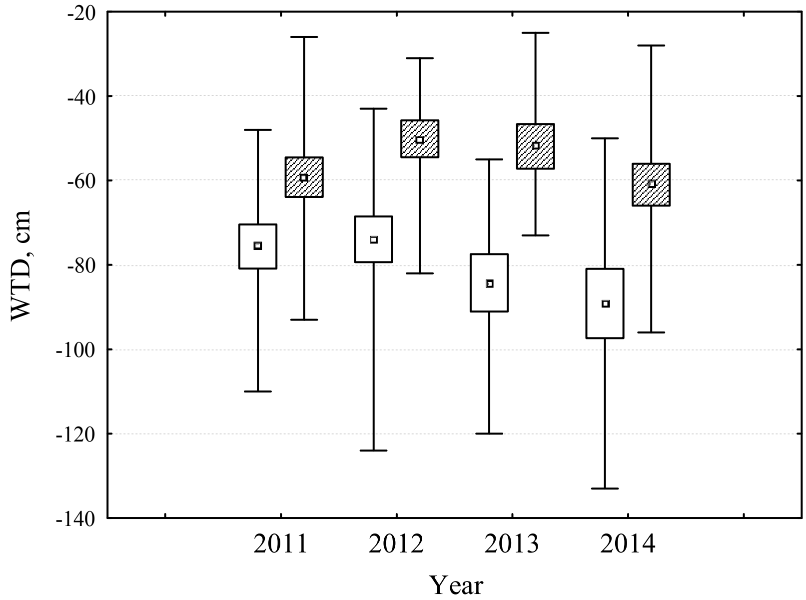


Fig. 10. Amplitudes of monthly water table fluctuation (min-max WTD values) in the area of the Aukštumala Telmological Reserve insulated with a "peat lock" measure (PL, hatched boxes) and in the untreated area (control, empty boxes) during vegetation seasons (April–October) of 2011 to 2014. Presented are values obtained from water level measurement wells at distances of 10 and 30 m from a contact line (combined). Boxes show mean yearly WTD ± standard error.

Effectiveness of ditch blocking using peat dams

WTD measurements made before and after construction of the dams showed that decrease of mean vegetation-season WTD following ditch blocking was noticeable just at a 10 m distance from the contact line. After damming, the differences between treated and untreated areas in mean vegetation-season WTD assessed at a 10 m distance from the contact line became statistically significant at $p \leq 0.01$, whereas at larger distances those differences were in general (with a couple of exceptions) non-significant ($p > 0.05$). At this distance, the difference in mean WTD assessed before (-32 ± 3.8 cm) and after (-19 ± 2.8 cm) the ditch blocking was statistically significant ($p < 0.01$) (Fig. 11).

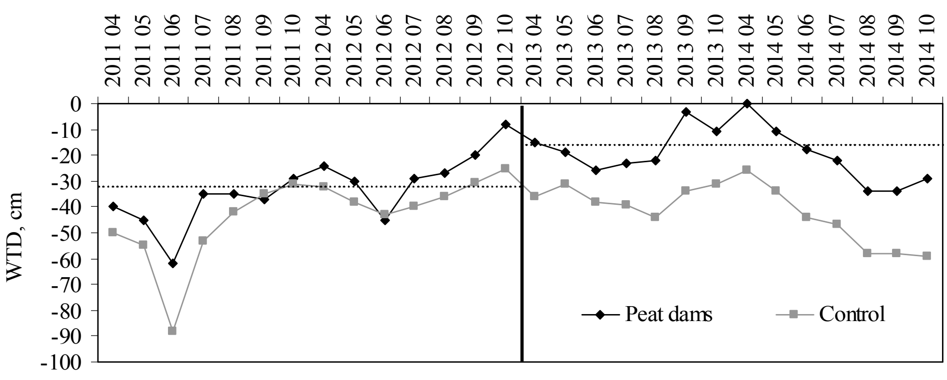


Fig. 11. Monthly water table depth (WTD) fluctuations in the area where old drainage system was blocked with peat dams and in the untreated area (control) of the Aukštumala Telmological Reserve.

Ditch blocking by using peat as a material also proved to be an efficient measure to restore vegetation cover of the raised bog. Typical ombrotrophic species (*Sphagnum* spp. in particular) responded positively to the higher water table in the PD-treated area: a clear shift from domination of *Calluna vulgaris* and *Betula pendula* towards domination of *Sphagnum* spp. was observed near the dammed ditches (at distances up to 5 m) already in two years after the ditch blocking. The cover of *Sphagnum* spp. increased up to 4.7%, whereas the cover of vital *C. vulgaris* individuals decreased up to 11.1% during the investigation period (Fig. 12). The results from Finnish (HAAPALEHTO et al., 2011) and Latvian (PRIEDE, 2013) studies suggest that in raised bog areas rewetted by ditch blocking, the total cover of *Sphagnum* mosses might increase up to 5% in a 10-year period.

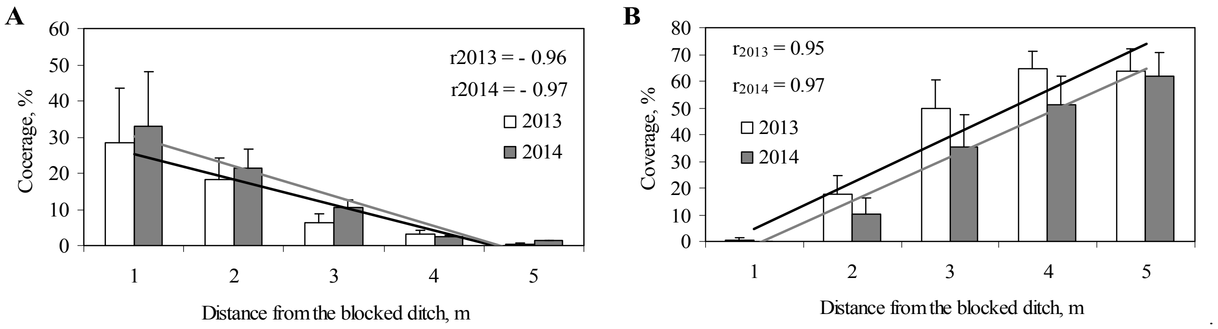


Fig. 12. Changes in *Sphagnum* spp. (A) and *Calluna vulgaris* (B) cover depending on a distance from the ditch blocked by peat dams in the Aukštumala Telmological Reserve during observation period of 2013 to 2014.

Restoration of raised bog habitats in the cutover peatland

The results of the experiment on settlement of donor fragments of raised bog vegetation showed that during the first year 93% of the planted fragments (mostly composed of *Sphagnum* species) recovered successfully. The most significant changes in the cover during the observation period (2011–2013) were ascertained for *Oxycoccus palustris* (Fig. 13). The mean cover of *O. palsutris* increased from 5% in 2012 to 18% in 2013. Whereas the mean cover of *Sphagnum* spp. increased only by 4% during two years of the experiment. No significant changes were observed in the cover of other plant species (Fig. 13).

A total of 22 plant species from 12 families were recorded at the experimental site. About 68% of the recorded species (*Agrostis capilaris*, *Bidens tripartita*, *Frangula alnus*, *Gnaphalium sylvaticum*, *Lycopus europaeus*, *Lysimachia vulgaris*, *Molinia cearulea*, *Salix aurita*, *S. cinerea*, *Taraxacum officinale*, etc.) were atypical to ombrotrophic bogs. This was mainly determined by unfavourable hydrological conditions at the experimental site (WTD during the investigation period varied from -45 to -82 cm). Although the total amount of atypical ombrotrophic bog species increased almost four-fold during the second year of the experiment, the mean coverage of these species remained sparse (24%).

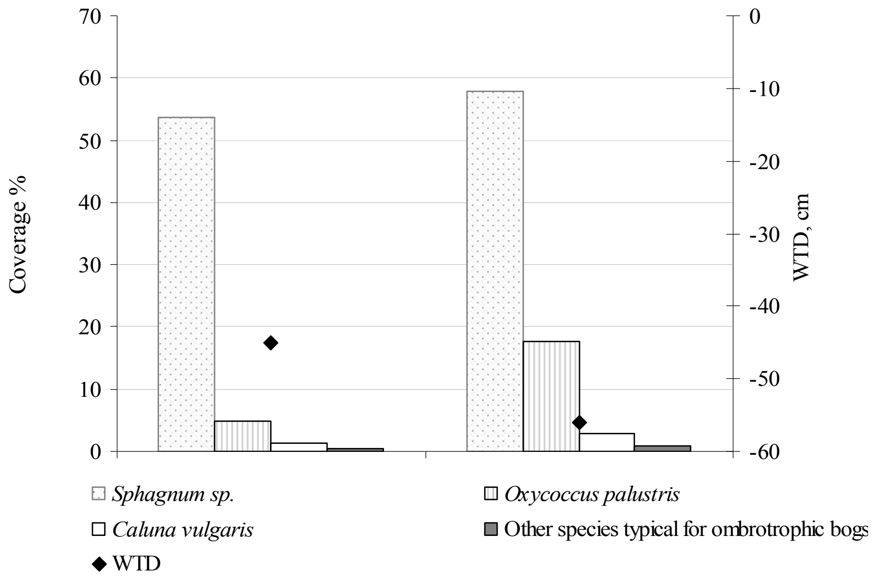


Fig. 13. Coverage of *Sphagnum* spp., *Calluna vulgaris, Oxycoccus palustris* and other plant species typical to ombrotrophic bogs and water table depth in the experimental field established in a cutover peatland of Aukštumala raised bog. Presented are results of the assessments made in July 2012 and 2013.

Abandoned cutover peatlands are characterized with flat surface topography, where bog ecosystem is completely destroyed: the areas are usually lacking vegetation, there is no viable seed bank and hydrological regime is misbalanced. Exposed peat layers have poor water-retaining capacity. Thus, the surface floods in wet weather and can dry out completely during dry periods (PRICE et al., 1998). This may also lead to changes in chemical properties of the peat layer. On the other hand, the acidity of peat at the Aukštumala experimental site varied from pH 4.6 to 5.0, which is in general normal for ombrotrophic bogs. The complete absence of bicarbonate alkalinity below pH 5.5 is a fundamental dividing point in the habitat limits of many peatland species (WIEDER, VITT, 2001). That means that in case of proper management, the experimental site is still capable to develop towards ombrotrophic bog. Restoration of hydrological regime (water availability) is the main condition to meet in peatland restoration projects because cutover peatlands have lost their natural ability to store water and regulate water table fluctuation (QUINTY, ROCHEFORT, 2003). This is why additional measures must be taken to reduce water losses and to ensure water supply for introduced raised bog plant species aiming to get positive results in recovery of the experimental site.

CONCLUSIONS

1. Primeval vegetation cover in the Aukštumala Telmological Reserve has been changed due to anthropogenic activities – a gradual shift of the plant communities towards eutrophication and establishment of tree and dwarf-shrubs layer is being observed in the most damaged parts of the raised bog, this shift has accelerated changes in systematic spectrum of resident plant families: *Cyperaceae*, *Ericaceae* and *Droseraceae* are being replaced by *Asteraceae*, *Poaceae*, *Rosaceae*, *Onagraceae*, etc.;
2. Relatively large areas that don‘t meet the requirements for habitats of European importance and areas of degraded raised bogs (code 7120) (49% of the total area of the Aukštumala Telmological Reserve) clearly indicate the negative impact of long-lasting drainage due to which habitats of fens and transitional mires have vanished from the surroundings of Aukštumala raised bog over the last century;
3. Parts of the raised bog affected by drainage are characterized by low mean seasonal water table depth, increased seasonal water table fluctuation amplitudes, increased values of water electrical conductivity, and changes in the structure of plant communities;
4. Aiming to restore hydrological regime favourable to natural raised bog plant communities, mean water table depth during vegetation season should be upheld above -30 cm;
5. Establishment of plant species atypical to ombrotrophic bogs in the parts of Aukštumala raised bog disturbed by fire is a transient phenomenon: the number of initially abundant atypical plant species during three post-fire years has decreased more than threefold. The fastest regeneration was shown by raised bog plant communities that previously (before the fire) dominated in the areas most distant from the draining ditches;
6. Polyethylene membrane, due to prevented water runoff and significantly (by more than 40 cm) higher mean water table depth at the 50-m-wide contact zone of the Telmological Reserve and peat harvesting fields, should be regarded as rather effective means to restore hydrological regime that creates unfavourable conditions for tree growth;
7. The effectiveness of „peat lock“ system (a barrier made of highly decomposed peat from the bottom layer of the bog) to isolate the Telmological Reserve from peat harvesting fields is conditional, as significant effect of this measure was noticeable at a relatively short distance (up to about 30 m) from the contact line between the Telmological Reserve and peat harvesting fields; however, even in this „effective zone“ mean water table depth was never higher than -30 cm and, therefore, could not ensure good conditions for peatland formation;
8. Blocking of drainage ditches by using peat dams proved to be an effective measure both to restore hydrological regime and vegetation cover typical to raised

bog communities: favourable hydrological conditions for growth of *Sphagnum* mosses were established at up to 5 m distance from the blocked drainage ditches already during the first year of the ditch blocking;

9. Although in the first year, 93% of the planted donor fragments of raised bog vegetation have recovered successfully at the experimental site of cutover peatland of Aukštumala raised bog, the further formation of *Sphagnum* cover stopped due to extremely dry subsequent years (water table was extremely low and thus hydrological regime became unfavourable for peatland formation). The processes may only be re-established if favourable hydrological conditions are ensured by effective regulation measures.

LIST OF PUBLICATIONS

<u>Scientific papers published in impact-factor journals referred in the *Thomson Reuters Web of Science* (WoS) database:</u>

JARAŠIUS L., LYGIS V., SENDŽIKAITĖ J., PAKALNIS R., 2015: Effect of different hydrological restoration measures in Aukštumala raised bog damaged by peat harvesting activities. – Baltic Forestry, **21(2)** (in press).

<u>Scientific papers published in periodicals without impact factor, but included into *Thomson Reuters Master Journal List*</u>

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Vegetation patterns & their underlying processes, 26–30 June. Tartu, Estonia. Abstracts: 97.

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PAKALNIS R., SENDŽIKAITĖ J., **JARAŠIUS L.,** 2014: Previous efforts on reduction of peat mining impact in Aukštumala raised bog. – The International Workshop „Best experiences in conservation and restoration of habitats in raised bogs and mires. Knowledge transfer to Aukštumala Raised Bog”, 11–13 June. Šilutė, Lithuania. Abstracts: 7–8.

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Scientific interests	Telmology, ecosystem ecology, ecological restoration

SANTRAUKA

Dėl žemės ūkio, miškininkystės ir kitų ūkio šakų veiklos vykdomo sausinimo pasaulis neteko beveik 20% pelkių išteklių (GORHAM, 1991; JOOSTEN, CLARKE, 2002; MACDONALD et al., 2006). Lietuva dėl sausinamosios melioracijos XX a. pabaigoje prarado apie du trečdalius pelkių išteklių, todėl kasmet mūsų šalyje netenkama apie 1,6–2,5 mln. tonų anglies (MIERAUSKAS ir kt., 2005; JUKONIENE et al., 2009; MINAYEVA, SIRIN, 2009). Paskutinių apskaitų duomenimis, Lietuvoje inventorizuota 646 tūkst. ha durpinių šlapynių, tačiau iš jų tik 178 tūkst. ha (apie 2,7% Lietuvos teritorijos) yra laikomos natūraliomis pelkėmis (POVILAITIS ir kt., 2011; TAMINSKAS ir kt., 2011).

Šlapynių sausinimo darbai įvairiose Lietuvos dalyse buvo nevienodo masto. Ypač didelį sausinamąjį poveikį patyrė Vakarų Lietuvoje esanti Nemuno delta. Dėl melioracijos čia beveik išnyko žemapelkės, o unikalios šio regiono deltinio tipo aukštapelkės gerokai pakeitė savo pirminę struktūrą (SEIBUTIS, 1961). Ne išimtis ir didžiausia Nemuno deltos regiono aukštapelkė – Aukštumala, kurią sausinti pradėta dar XIX a. pabaigoje. Tačiau didžiausi pokyčiai pelkėje yra susiję su XX a. viduryje prasidėjusia mechanizuota durpių kasyba, kai eksploatacijai buvo parengta apie 2/3 viso pelkės ploto. Pasaulyje Aukštumala žinoma kaip pirmoji monografijoje aprašyta pelkė. Vokiečių botanikas K. A. Vėberis savo 1902 m. pasirodžiusiame leidinyje (WEBER, 1902) išsamiai aprašė Aukštumalos pelkės augaliją, durpės klodo stratigrafiją bei fiziologinius aukštapelkinių augalų prisitaikymo aspektus. Šiuo metu pelkės ekosistemai neigiamą hidrologinę įtaką daro ne tik išlikęs senasis barelinių ir sausinamųjų griovių tinklas, bet ir pelkės kaimynystėje vykdoma durpių kasyba, dėl kurios nuolat žeminamas durpių klodo lygis. Sausinimas pelkėse sukelia neigiamus vandens lygio pokyčius, kurie savo ruožtu lemia oksidacijos ir mineralizacijos procesus bei durpių klodo reakcijos (pH) padidėjimą (LAINE, VANHA-MAJAMAA, 1992; LAVOIE, SAINT–LOUS, 1999; WITTE et al., 2004). Dėl šių priežasčių pelkių augalinėje dangoje įsivyrauja sumedėję augalai, kuriuos ilgainiui gali pakeisti ir visai pelkėms nebūdinga augalija (BARBER, 1981; BARBER et al., 1994; BÈRUBÈ, LAVOIE, 2000; JOOSTEN, CLARKE, 2002; LEUCSCHNER et al., 2002; WITTE et al., 2004; ECKSTEIN et al., 2009).

Nors Lietuvoje šiuo metu saugoma apie 15% visų pelkių ir visi didesni nei 500 ha neeksploatuojami pelkynai (MIERAUSKAS ir kt., 2005; LETUKAITĖ, 2007), tačiau sausinimo ir durpių kasybos paveiktų pelkių ekologinis atkūrimas mūsų krašte vis dar nesulaukia tinkamo dėmesio. Pasaulyje pelkių ir kitų šlapynių spartūs atkūrimo darbai prasidėjo dar XX a. pabaigoje. Lietuva šiuo metu taip pat įgyvendina bent kelis ekologinio pelkių atkūrimo projektus, tačiau XXI a. klimato šiltėjimo perspektyvoje tokių darbų turėtų būti daugiau.

Kitas svarbus ir pakankamai dėmesio nesusilaukiantis klausimas yra Lietuvos išeksploatuotų durpynų likimas. Viena iš augalinės dangos atkūrimo išeksploatuotuose durpynuose priemonių – dirbtinis augalų bendrijų įkurdinimas specialiai įrengtuose eksperimentiniuose laukuose. Aukštumala – viena iš nedaugelio Lietuvos pelkių, kurioje atliekami eksperimentiniai aukštapelkinių augalų atkuriamojo skleidimo darbai ir moksliniai tyrimai, o kai kurios vykdomos hidrologinio režimo atkūrimo priemonės neturi analogų ne tik mūsų šalyje, bet ir daugelyje kitų šalių.

Darbo tikslas – įvertinti aukštapelkių augalų bendrijų būklę bei hidrologinį režimą Aukštumalos telmologiniame draustinyje ir ištirti pažeistų bendrijų dirbtinio atkūrimo galimybes dėl sausinimo degradavusiose ir gaisro pažeistose Aukštumalos pelkės dalyse bei išeksploatuotame durpyne.

Darbo uždaviniai:

1. Įvertinti aukštapelkių augalų bendrijų būklę (pažeidimo mastą) ir inventorizuoti Europinės svarbos buveines Aukštumalos telmologiniame draustinyje;
2. Įvertinti dėl sausinimo atsiradusius Aukštumalos pelkės hidrologinių ir hidrocheminių rodiklių pokyčius, nustatyti šių rodiklių tarpusavio ryšius ir optimalias aukštapelkių augalų bendrijų atsikūrimo sąlygas;
3. Įvertinti aukštapelkių augalų bendrijų natūralų atsikūrimą gaisro pažeistoje pelkės dalyje;
4. Įvertinti trijų skirtingų hidrologinio režimo reguliavimo priemonių (polietileninės membranos, susiskaidžiusių durpių barjero ir durpinių užtūrų) efektyvumą;
5. Ištirti aukštapelkių augalų (kiminų) bendrijų ekologinio atkūrimo galimybes išeksploatuotame durpyne.

Ginamieji teiginiai:

1. Pažeistose Aukštumalos telmologinio draustinio augalų bendrijose įsikuria aukštapelkėms nebūdingų rūšių augalai, o dėl pelkės sausinimo visiškai išnyksta žemapelkių ir tarpinio tipo pelkių buveinės;
2. Pelkėdarai (aukštapelkinių bendrijų funkcionavimui) optimalus gruntinio vandens lygis, vegetacijos metu ne žemesnis nei 30 cm nuo pelkės paviršiaus, yra svarbiausias natūralią Aukštumalos pelkės raidą užtikrinantis veiksnys;
3. Gaisro pažeistoje Aukštumalos pelkės dalyje įsikūrusių nebūdingų aukštapelkėms augalų rūšių skaičius laikui bėgant mažėja, o gruntinio vandens pakėlimas sausinimo pažeistose vietose skatina aukštapelkių augalų bendrijų atsikūrimą;
4. Polietileninė membrana, susiskaidžiusių durpių barjeras ir senųjų sausinamųjų griovių tvenkimas durpinėmis užtūromis stabdo tiesioginį vandens nutekėjimą iš aukštapelkės į durpyną, padeda efektyviai atkurti pelkėdarai palankų hidrologinį režimą ir aukštapelkių augalų bendrijas;
5. Optimalaus gruntinio vandens lygio užtikrinimas vegetacijos metu yra svarbiausia donorinių aukštapelkės augalų dangos pradmenų įkurdinimo išeksploatuotame durpyne sąlyga.

Darbo mokslinis naujumas. Pirmą kartą Lietuvoje surinkti ir apibendrinti duomenys apie Aukštumalos telmologinio draustinio augalų bendrijų būklę, Europinės svarbos natūralių buveinių paplitimą, trijų gruntinio vandens lygio palaikymo priemonių tipų įtaką hidrologiniam režimui ir aukštapelkių augalų bendrijų atsikūrimo galimybėms. Disertacinio darbo metu pirmą kartą Lietuvoje nuosekliai tirtos aukštapelkių augalų pradmenų paskleidimo ir įsikūrimo galimybės išeksploatuotame durpyne. Pirminiai tyrimo rezultatai leidžia pasiūlyti kitokį, nei iki šiol taikytas, išeksploatuotų ir apleistų durpyno dalių rekultivavimo (pelkės atkūrimo) planą, įgalinantį dirbtinį aukštapelkinių bendrijų atkūrimą. Kita svarbi ir iki šiol Lietuvoje mokslininkų dėmesio mažai sulaukianti problema – aukštapelkinių augalų bendrijų kaita po gaisro. Disertacijoje sukaupta trijų metų tyrimų medžiaga leido įvertinti aukštapelkinių bendrijų kaitą po 2011 m. gaisro Aukštumalos pelkės rytinėje dalyje.

Mokslinė ir praktinė darbo reikšmė. Tyrimų rezultatai papildė žinias apie Lietuvos aukštapelkių hidrologines savybes ir jų ekologinio atkūrimo perspektyvas. Darbo metu sukaupti hidrologiniai ir fitocenotiniai tyrimų duomenys leidžia išsamiai apžvelgti pirmosios pasaulyje išsamiai tyrinėtos ir WEBER (1902) monografijoje aprašytos Aukštumalos pelkės pokyčius, susijusius su antropogenine veikla. Lauko tyrimų metu inventorizuotos 5 Lietuvos raudonosios knygos augalų rūšių radavietės. Nustatyta, kad Aukštumalos aukštapelkės bendrijų tipus, struktūrą bei durpės klodo chemines-fizikines savybes labiausiai veikia gruntinio vandens lygis. Aštuonerius metus rinkti hidrologinių tyrimų duomenys leido gana tiksliai nustatyti ribą tarp pelkėdarai palankių sąlygų ir sausinimo sukeltų pelkinių bendrijų degradacijos procesų, o aukštapelkių hidrologinio atkūrimo efektyvumo tyrimai leis adaptuoti gerąją atkūrimo praktiką kitose Lietuvos aukštapelkėse nepaisant regioninių pelkių skirtumų. Gruntinio vandens lygio atkūrimas – ypatingai svarbi šių dienų problema bandant spręsti su pelkinių buveinių degradacija ir šiltnamio efektą sukeliančių dujų emisijomis susijusius klausimus.

Išvados:

1. Antropogeninės veiklos labiausiai pažeistose Aukštumalos telmologinio draustinio dalyse augalų bendrijos yra pakitusios eutrofizacijos ir medžių bei krūmokšnių ardo įsigalėjimo kryptimi, jose inventorizuota 127 rūšimis daugiau nei sąlyginai natūraliose aukštapelkių buveinėse (54 rūšys), o aukštapelkių florai nebūdingos *Asteraceae, Poaceae, Rosaceae, Onagraceae* ir kt. šeimų rūšys pakeitė sąlyginai natūralių aukštapelkių buveinių augalų šeimų spektre vyravusias *Cyperaceae, Ericaceae, Droseraceae* šeimų rūšis.
2. Santykinai didelis europinės svarbos buveinėms keliamų reikalavimų neatitinkančių ir degradavusių aukštapelkių buveinių plotas (49% draustinio ploto) rodo intensyvią neigiamą daugiametę sausinimo įtaką, dėl kurios per pastarąjį šimtmetį visiškai išnyko Aukštumalos žemapelkių ir tarpinio tipo pelkių buveinės.
3. Sausinimo pažeistos pelkės dalys pasižymi žemu vidutiniu vegetacijos laikotarpio gruntinio vandens lygiu, padidėjusiomis vandens lygio svyravimų amplitudėmis, pakilusiomis vandens elektrinio laidumo reikšmėmis bei pakitusia augalų bendrijų struktūra.

4. Norint atkurti natūralioms aukštapelkių augalų bendrijoms tinkamą hidrologinį režimą, vidutinį gruntinį vandens lygį vegetacijos metu reikia palaikyti ne giliau kaip 30 cm nuo pelkės paviršiaus.
5. Netipingų aukštapelkėms augalų rūšių įsikūrimas gaisro pažeistoje Aukštumalos pelkės dalyje yra trumpalaikis reiškinys, nes per trejus metus po gaisro, pradžioje gausiai augusių aktyvioms aukštapelkėms nebūdingų rūšių skaičius sumažėjo daugiau kaip tris kartus. Greičiausiai atsikuria toliau nuo sausinamųjų griovių nutolusiuose degvietės plotuose augusios aukštapelkių augalų bendrijos.
6. Polietileninė membrana dėl sulaikomo vandens nuotėkio ir reikšmingai daugiau kaip 40 cm pakilusio vidutinio daugiamečio vandens lygio vegetacijos laikotarpiu draustinio ir durpyno kontakto 50 m pločio zonoje laikytina efektyvia hidrologinio režimo atkūrimo priemone, sudaranti nepalankias sąlygas medžiams augti.
7. Iš žemutiniuose pelkės klodo sluoksniuose esančios durpės suformuoto suslėgto barjero efektyvumas izoliuoti draustinį nuo durpių kasybos laukų yra teigiamas, bet nepakankamas, nes reikšmingas poveikis jaučiamas tik iki 30 m atstumu nuo draustinio ir durpyno kontakto linijos, tačiau vidutinis daugiametis gruntinio vandens lygis vegetacijos laikotarpiu šioje arčiau draustinio pakraščio esančioje zonoje nepakilo aukščiau -30 cm ir visais atvejais išliko pelkėdarai nepalankus.
8. Sausinamųjų griovių blokavimas durpinėmis užtūromis pasiteisino kaip efektyvi priemonė tiek atkuriant hidrologinį režimą, tiek augalinę aukštapelkių bendrijoms būdingą dangą: jau sekančiais metais po priemonės įrengimo iki 5 m atstumu nuo patvenktų griovių susiformavo palankios hidrologinės sąlygos kiminams augti.
9. Donoriniai aukštapelkės augalų dangos pradmenys gerai prigijo (93%) išeksploatuotame durpyne, tačiau dėl vėlesniais metais buvusių sausrų ir pelkėdarai nepakankamai aukšto gruntinio vandens lygio kiminų dangos formavimasis sustojo ir gali atsinaujinti tik įrengus efektyvias vandens lygio reguliavimo priemones.