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# BRYOFLORA OF THE SPRING FEN "MAKĄTY" IN NORTH-WESTERN WIELKOPOLSKA REGION

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ABSTRACT. Spring fens are rare elements in the lake district landscape of western Poland. The paper presents bryological and habitat studies conducted on Makąty fen situated in the Puszcza Notecka (the Notecka Primeval Forest area). Flora of bryophytes in the investigated area comprises 75 taxa, including 10 species of liverworts, as well as 63 species and two varieties of mosses. Three species, i.e. *Helodium blandowii*, *Paludella squarrosa* and *Tomentypnum nitens*, belong to the group of rare boreal mosses considered to be glacial relics. The population of *Hamatocaulis vernicosus* is also of particular interest, as it is a species from the EU Habitat Directive. Moreover, 22 moss species covered by legal protection in Poland were also observed there. Therefore in terms of bryoflora this object is of major natural value in the Puszcza Notecka (N Wielkopolska). The physico-chemical analyses conducted in eight microhabitats extend the knowledge on rich fens, and show that the spectrum of environmental conditions in ground waters is broad and there is a very high concentration of Ca and Mg.

KEY WORDS: peatlands, bryophytes, spring fens, bryoflora, glacial relics, threatened species, habitat conditions, water chemistry, Puszcza Notecka

## INTRODUCTION

Peatlands are an important element in the landscape shaped by the last glaciation in Poland. They are most densely distributed in the north-western part of the country, where over 60 peatlands per 100 km$^2$ are found (Jasnowski 1975, Żurek 1987, Tobolski 2002). The occurrence and ecological uniqueness of some of them, particularly spring fens, have not been thoroughly investigated to date. It is estimated that the total proportion of biotopes of this type accounts for less than 1% of the total area of peatlands in Poland (Jasnowski 1975). The highest concentration of fen vegetation localities were documented in eastern Poland (e.g. Oświt 1991, Żurek 1993, Łachacz 2000, Pawlikowski 2006). Genesis and development of spring water ecosystems are dependent on the constant inflow of underground waters rich in soluble calcium compounds (e.g. Wołejko 2001, Hájek et al. 2002, 2006). Due to their rare occurrence, well-preserved natural character and the accumulation of threatened, protected and relic species, spring fens are objects with the highest protection priority in the European Union (the Corine List) and species protected within the framework of Natura 2000.

Peatlands and particularly fens are very rare ecosystems in the lake district landscape of the Wielkopolska-Kujawy Region. In the central and southern part of this region the density of open *Sphagnum* lawns is estimated at 5-10 per 100 km$^2$ (Żurek 1987). An exception in this respect constitutes the north-western Wielkopolska region, particularly the Gorzów Basin. The estimated density of mire ecosystems in that mesoregion is 10-25 per 100 km$^2$ (Żurek 1987). They are found in biggest numbers in the Puszcza Notecka and together with the aquatic ecosystems they contribute to an enhancement of biodiversity in the coniferous forest landscape. Peatlands of that area fill the interdune wind-blown troughs, including also shore zones of interdune lakes and less frequently they are connected with watercourses. The woodless peatlands of the Puszcza Notecka, which are biggest in terms of their area, are known and thoroughly investigated. Examples of such ecosystems include the Chlebowo bogs complex (the so-called Bagno Chlebowo) with an area of almost 1284 ha (including 50 ha of *Sphagnum* lawns, e.g. Czubiński and Świtalska 1937, Rusińska and Bocheński 1993, Celka and Szkudlarz 2000, Szkudlarz and Celka 2004), the fens at Lake Rzecińskie near Wronki of almost 30 ha (e.g. Wojterska et al. 2001, Gąbka 2005) and the peatlands


Fig. 1. Lake Makąty (Maconten See) on a map of 1893

complex in the vicinity of the Lake Święte near Miały with an area of approx. 36 ha (Gąbka 2005, Gąbka et al. 2008). Numerous *Sphagnum* lawns of limited area in the Puszcza Notecka are at present objects of detailed interdisciplinary studies on their genesis, functioning and plant cover (e.g. Gąbka 2005, Gąbka et al. 2007, Lamentowicz et al. 2008).

The Bryological Section of Polish Botanical Society organised Bryological Workshops in the Puszcza Notecka in 2008. Among other things, bryoflora of the Makąty spring fen was then inventoried. This object had not been investigated previously in detailed bryological studies, but in the course of a general survey of Natura 2000 habitats in the Międzychód Forest Division (Regional Directorate of State Forests in Szczecin) in 2007 it was selected as an object of natural value since e.g. mosses considered to be glacial relics, i.e. *Helodium blandowii* and *Paludella squarrosa* were recorded there (Rusińska 2007).

The aim of this study was to present the bryophyte flora of that fen and its edges together with the physico-chemical characteristics of ground waters in selected types of microhabitats.

## AREA OF STUDY

Investigations were conducted in the Makąty fen (also called the Kaplin fen), formed at the site of an overgrown lake (*Maconten See*, a German map of 1893, see Fig. 1). At present two small lakes surrounded by a woodless mire are remnants of the former lake basin. The actual vegetation of the investigated object consists of communities of fens and transition bogs from classes *Scheuchzerio-Caricetea fuscae* (Nordhagen 1936) R.Tx. 1937, *Phragmitetea australis* (Klika in Klika and Novák 1941) R.Tx. et Preising 1942 as well as aquatic communities. Around the open water surface a fen with brown mosses is found. At the edge of the former lake spring alderwoods of *Cardamino-Alnetum glutinosae* (Meijer-Drees 1936) Pass. 1968 prevail, and some patches of alder swampy forests *Carici elongatae-Alnetum* Koch 1926 are also found. The peatland is a spring fen in character (percolating mire), it is supplied by rich ground waters, abundant in calcium. At the edges in the alder swamp forest zone numerous spring water seepages are found. The fen is characterised by high moisture levels; in the southern part it is drained by a water course leading towards the Lake Szenińskie.

The examined object is located within State Forests, the National Forest Holding Międzychód Forest Division (the Mokrzec Forest District) and comprises compartments 183d, 183f, 184g, 209a, 209b and 209c (Fig. 2). The total area investigated in this study was 14.75 ha. It needs to be added here that by the decision of the Town Council of Międzychód in November 2004 the central part of the fen (i.e. compartments 183f and 209b) is protected as a special value ecological area "Makąty" which covers an area of 9.13 ha.

The investigated fen is situated approx. 6 km NW of Międzychód and approx. 1 km NW of the village of Kaplin, in the Międzychód county and the Wielkopolskie Voivodeship. In the ATMOS grid (Ochyra and Szmajda 1983) it is contained in grid square Cb 71.

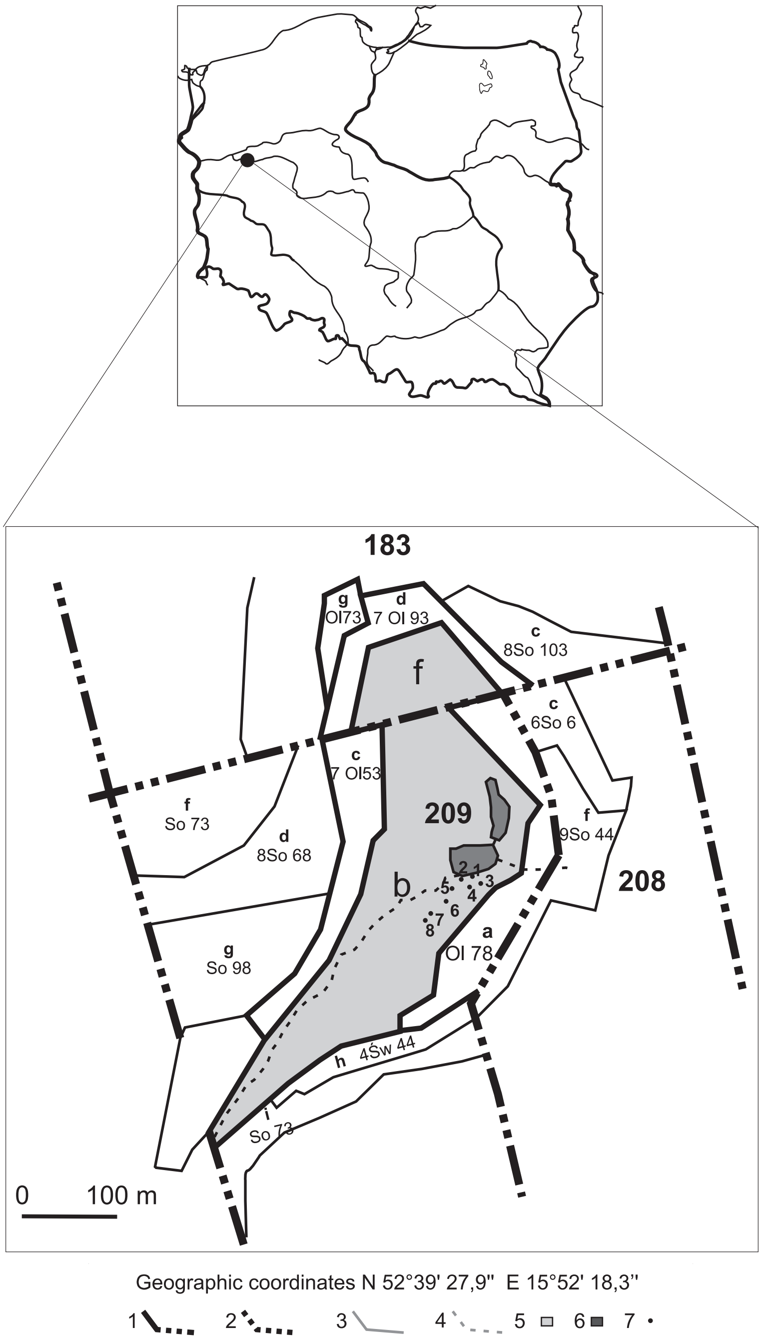


Fig. 2. The Makąty spring water mire together with the location of vegetation plots (points 1-8), in which physico-chemical parameters of water, as well as the structure of vegetation was analysed in detail: 1 – boundaries of forest compartments, 2 – boundaries of area of the study, 3 – boundaries of subcompartments, 4 – water courses, 5 – small lakes, 6 – boundaries of special value ecological area "Makąty", 7 – vegetation plots (1-8)

## MATERIAL AND METHODS

Field studies were conducted in the period of May--June 2008. Mosses were collected from the entire area of the fen and surrounding wet woodlands. Bryoflora was listed on the basis of almost 200 records by different researchers. In the description of the occurrence of each species the basic characteristics of the habitat the character of phytocenoses and the frequency of species were included (the type of substrate).

Additionally in the south-eastern part of the Makąty fen complex eight vegetation plots were established (Fig. 2). The best developed, woodless part of the fen was analysed. The species composition and the structure of vegetation was investigated in the specially established plots reflecting the variation of the microhabitats into: floating mats, fragments of mire, *Sphagnum* lawns and low hummocks. Vegetation was described from an area of 1 m$^2$ using a classical phytosociological method by Braun-Blanquet (Dierschke 1994). In each vegetation plot the depth of water table (DWT), pH, conductivity, soluble oxygen and oxygen saturation were determined. Moreover, from each vegetation plot three samples of ground water were collected to plastic containers for laboratory analyses. The first sample was preserved adding 1 ml concentrated nitric acid, while the second – by adding 1 ml 95% chloroform. The third sample was not preserved. Ten parameters of water were analysed at the laboratory: colour, $NH_4^+$, $NO_3^-$, $PO_4^{3-}$, $SO_4^{2-}$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $K^+$ and total Fe. Physicochemical analyses were performed using the standard methods (Hermanowicz et al. 1999).

In order to illustrate the main environmental gradients for the distribution of bryophytes and vascular plants the detrended correspondence analysis (DCA) was applied (ter Braak and Šmilauer 1998).

Nomenclature of mosses was adopted after Ochyra et al. (2003), that of liverworts after Szweykowski (2006), while nomenclature of vascular plants was given after Mirek et al. (2002). Names of plant communities were adopted after Brzeg and Wojterska (2001) and Pawlaczyk (2004).

## RESULTS

*A list of species*

The list of liverwort and moss species is given in the alphabetical order, with the numbers of compartments of the Międzychód Forest Division. Abbreviations of the names of the authors of the collection are given in brackets. The following abbreviations were used:

AR – Anna Rusińska, AS – Adam Stebel, ASa – Anna Salachna, EF – Ewa Fudali, GW – Grzegorz Wolski, JZG – Joanna Zalewska-Gałosz, MS – Mirosław Szczepański, MSK – Monika Staniaszek-Kik, MW – Marcin Wilhelm, PG – Piotr Górski, PP – Paweł Pawlikowski, RZ – Robert Zubel, SR – Stanisław Rosadziński, WP – Włodzimierz Pisarek.

Abbreviations of names of plant communities:

C.-A. – *Cardamino-Alnetum glutinosae*, C. e.-A. – *Carici elongatae-Alnetum*, C. l. – *Caricetum lasiocarpae*, C. p. – *Caricetum paniculatae*, S.-C. r. – *Sphagno apiculati-Caricetum rostratae*, T.-P. – *Thelypterido--Phragmitetum*.

Other abbreviations:

183f, 209a – denotations of subcompartments

S. p. – Strictly protected species

P. p. – Partially protected species.

Category of threat (according to Żarnowiec et al. 2004): (E) endangered, (V) vulnerable.

*Liverworts*

***Calypogeia muelleriana*** (Schiffn.) Müll. Frib. – **209a**: swampy alderwood C. e.-A., moist peat [AS, ASa, PG]

***Chiloscyphus pallescens*** (Ehrh. ex Hoffm.) Dumort. – **183d** and **183f**: swampy alderwood C. e.-A., moist peat [RZ]; **209a**: swampy alderwood C. e.-A., moist peat [PG, WP, JZG]; **209c**: swampy alderwood C. e.--A., peat [RZ]; **209d**: alderwood C. e.-A., moist peat [AR, SR]

***Chiloscyphus polyanthos*** (L.) Corda – **209a**: peat in spring alderwood C.-A. [AS]; log in: swampy alderwood C. e.-A. [MW]

***Lophocolea bidentata*** (L.) Dumort. – **209a**: swampy alderwood C. e.-A., stump [ASa, EF, GW], rotting wood [WP], moist peat [PG]; **209b**: fen [WP]; **209c**: swampy alderwood C. e.-A., rotting log [MSK]; **209d**: swampy alderwood C. e.-A., moist peat [AR, SR] and rotting wood [MSK]

***Lophocolea heterophylla*** (Schrad.) Dumort. – **183d**: swampy alderwood C. e.-A., rotting trunk of *Alnus glutinosa* [RZ]; **183f**: swampy alderwood C. e.-A., moist peat and rotting wood [RZ]; **209a**: swampy alderwood C. e.-A., base of an *Alnus glutinosa* trunk to a height of 30 cm and rotting stumps and branches [ASa, EF, GW, MW, PG, WP, JZG], moist peat [AS]; **209b**: swampy alderwood C. e.-A.: moist peat [AS], rotting logs [PP], fen [WP]; **209c**: swampy alderwood C. e.-A., peat [RZ]; **209d**: swampy alderwood C. e.-A., moist peat [AR, SR] and bark of rotting trunk [MSK]

***Marchantia aquatica*** (Nees) Burgeff – **183d**: swampy alderwood C. e.-A., peat in a depression [RZ]; **209a**: swampy alderwood C. e.-A., moist peat [PG, WP, MW] and decaying stump [JZG]; **209b**: peat in a sedge community C. p. [AR, SR], fen [PP]; transition bog, patch of C. l. [AR], on a *Sphagnum* hummock [RZ]; **209c**: swampy alderwood C. e.-A., peat [AR, SR]

***Pellia endiviifolia*** (Dicks.) Dumort. – **183d**: swampy alderwood C. e.-A., peat at the base of an *Alnus glutinosa* stem [RZ]; **209a**: swampy alderwood C. e.-A., moist peat [PG]

***Pellia epiphylla*** (L.) Corda – **209a**: swampy alderwood C. e.-A., a little hollow between hummocks [AS, ASa, JZG]; **209b**: spring alderwood C.-A., peat [AS]

***Ptilidium ciliare*** (L.) Hampe – **209a**: swampy alderwood C. e.-A., trunk of *Alnus glutinosa* at a height of 1 m [EF, GW] **P. p.**

***Ptilidium pulcherrimum*** (Weber) Vain. – **209a**: swampy alderwood C. e.-A., base of an swampy alderwood C. e.-A., an *Alnus glutinosa* trunk [AS]; **209d**: swampy alderwood C. e.-A., rotting log [MSK]

*Mosses*

***Amblystegium juratzkanum*** Schimp. – **209c**: swampy alderwood C. e.-A., rotten branch [MSK]

***Amblystegium serpens*** (Hedw.) Schimp. – **209a**: swampy alderwood C. e.-A., wood of decaying logs, *c. spor.* [EF, GW, AS, WP]

***Atrichum undulatum*** (Hedw.) P.Beauv. – **209a**: swampy alderwood C. e.-A., mineral soil in a depression left by a windthrown tree [EF, GW, WP]

***Aulacomnium androgynum*** (Hedw.) Schwägr. – **183f**: spring alderwood C.-A., peat [MS]; **209a**: swampy alderwood C. e.-A., protruding roots and bark of *Alnus glutinosa* to a height of 1 m and rotting wood of a log [EF, GW, AS, WP]; base of an *Alnus glutinosa* trunk [AS]; **209d**: swampy alderwood C. e.-A., bark of a rotting trunk [MSK]

***Aulacomnium palustre*** (Hedw.) Schwägr. – **209a**: swampy alderwood C. e.-A., decaying stump [JZG] **209b**: fen [PP], transition bog with *Sphagnum teres* [PP, MS]; transition bog, patch of C. l. [AR] **P. p.**

***Brachytheciastrum velutinum*** (Hedw.) Ignatov & Huttunen – **209a**: swampy alderwood C. e.-A., slope of a hummock, peat [AS]

***Brachythecium mildeanum*** (Schimp.) Schimp. – **209b**: patch of C. p. [AR]

***Brachythecium rivulare*** Schimp. – **209a**: spring alderwood C.-A., peat [WP]; **209c** and **209d:** spring alderwood C.-A., peat [AR, SR]

***Brachythecium rutabulum*** (Hedw.) Schimp. – **183f**: spring alderwood C.-A. [MS]; **209a**: swampy alderwood C. e.-A., moist peat [EF, GW], rotting logs [AS, WP], an alder trunk [MW], fen, decaying logs [AS]; **209b**: fen [PP, WP], swampy alderwood C. e.-A., rotting log [MSK], spring alderwood C.-A. [MS]; **209c**: patch of C. p., peat [AR, SR]; **209d:** spring alderwood C.-A., peat [AR, SR]

***Brachythecium salebrosum*** (Hoffm. ex F. Weber & D. Mohr) Schimp. – **209a**: swampy alderwood C. e.-A., wood of a rotting stump [EF, GW]

***Bryum pseudotriquetrum*** (Hedw.) P. Gaertn., B. Mey & Scherb. – **209b**: peat in a patch of C. p. [AR, SR], fen [PP]

***Calliergon cordifolium*** (Hedw.) Kindb. – **209b**: fen [AS], spring alderwood C.-A. [MS]; **209f**: patch of T.-P. [AR, SR]

***Calliergonella cuspidata*** (Hedw.) Loeske – **183f**: swampy alderwood C. e.-A. and T.-P. [MS], forest depressions, in water [RZ]; **209a**: spring alderwood C.–A., peat [AS]; swampy alderwood C. e.-A., little hollows [PP, MW, WP, JZG]; **209b**: fen [AS, PP, WP, MS], patch of C. p., between hummocks [AR, SR], fen, in water depressions [RZ]; **209c** and **209d**: spring alderwood C.-A., peat [AR, SR], swampy alderwood C. e.-A., peat [MSK]; **209f**: patch of T.-P., in water [AR, SR], fen [MSK]. **P. p.**

***Campylopus introflexus*** (Hedw.) Brid. – **209b**: fen, patch of C. p., hummock [WP]

***Ceratodon purpureus*** (Hedw.) Brid. – **209a**: swampy alderwood C. e.-A., wood of rotting trunk [EF, GW], slopes of hummocks, peat [AS]; **209b**: fen, hummocks in C. p. [WP]

***Climacium dendroides*** (Hedw.) F. Weber & D. Mohr – **183f**: spring alderwood C.-A., peat [MS]; **209a** and **209b**: swampy alderwood C. e.-A., moist peat [AS, MW, WP, MS, JZG], bases of alders and rotting logs [PP]; **209c**: swampy alderwood C. e.-A., peat [RZ]. **P. p.**

***Cratoneuron filicinum*** (Hedw.) Spruce – **209a**: spring alderwood C.-A., moist peat [AS, WP]; **209d**: spring alderwood C.-A., peat [AR, SR]

***Dicranella heteromalla*** (Hedw.) Schimp. – **209a**: swampy alderwood C. e.-A., slope of a hummock, humus soil [AS], peat [MS]; **209d**: swampy alderwood C. e.-A., rotting wood [MSK]

***Dicranoweisia cirrata*** (Hedw.) Lindb. – **183d**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* [RZ]; **209a**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* to a height of 3 m, *c. spor.* [EF, GW, AS, MS], a trunk of *Pyrus communis* [AS]; **209d**: swampy alderwood C. e.-A., bark of a lying log of *Alnus glutinosa* [MSK]

***Dicranum polysetum*** Sw. ex anon. – **183d**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* [RZ]. **P. p.**

***Dicranum scoparium*** Hedw. – **183d**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* [RZ]; **183f**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* [RZ]; **209a**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* and wood of a rotting stump [EF, GW], rotting logs [AS, WP]; **209b**: swampy alderwood C. e.-A., hummock [MS]; **209d**: spring alderwood C.-A., a trunk of alder [AR, SR]. **P. p.**

***Drepanocladus aduncus*** (Hedw.) Warnst. – **209b**: transition fen, floating mat [MS]

***Drepanocladus polycarpos*** (Blandow ex Voit) Warnst. – **209b**: fen [PP], patches of S.-C. r. [AR], edge of a small peatland lake [WP]; **209f**: patch of T.-P., in water [AR, SR]

***Hamatocaulis vernicosus*** (Mitt.) Hedenäs – **209b**: fen, along animal paths [PP, AR], transition bog with *Sphagnum teres* [PP, WP, MS]. **S. p., assumptions of 2nd Habitat Directive Natura 2000**

***Helodium blandowii*** (F. Weber & D. Mohr) Warnst. – **209b**: patches of C. p., between hummocks [AR, SR], fen [PP, WP, MS], transition bog with *Sphagnum teres* [PP, RZ], floating mat W of edge of small lake [PP], transition bog, patch of C. l. [AR], edge of swampy alderwood C. e.-A. [AR]; **209f**: patch of T.-P. [AR, SR], fen [MSK]. **S. p. (E)**

***Herzogiella seligeri*** (Brid.) Z. Iwats. – **209a**: swampy alderwood C. e.-A., wood of rotting trunk, *c. spor.* [EF, GW, JZG], rotting log [AS]

***Hylocomium splendens*** (Hedw.) Schimp. – **209a**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* [AS]. **P. p.**

***Hypnum cupressiforme*** Hedw. var. ***cupressiforme*** – **183d**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* [RZ]; **209a**: swampy alderwood C. e.-A., trunks of *Alnus glutinosa* to a height of 50 cm [EF, GW, AS], rotting logs [AS, PP, WP]; **209b**: swampy alderwood C. e.-A., rotting logs [PP, MS]; **209d**: spring alderwood C.-A., roots of alder [AR, SR], swampy alderwood C. e.-A., bark of a rotting log of *Alnus glutinosa* swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* to a height of 50 cm [EF, GW, AS], bark of a rotting log [AS]

***Hypnum cupressiforme*** Hedw. var. ***filiforme*** Brid. – **209a**: alder forest: trunk of *Alnus glutinosa* up to 50 cm above ground [EF, GW, AS], lying logs [AS]

***Hypnum pallescens*** (Hedw.) P. Beauv. – **209a**: swampy alderwood C. e.-A., base of *Alnus glutinosa* [AS]

***Mnium hornum*** Hedw. – **183d** and **183f**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* [RZ]; **209a**: swampy alderwood C. e.-A., wood of a rotting trunk [EF, GW, AS, JZG], moist peat [AS, WP], base of a trunk of *Alnus glutinosa* [AS, MW]; **209b**: spring alderwood C.-A. [MS]; **209d**: spring alderwood C.-A., peat [AR, SR], rotting wood [MSK]

***Orthodicranum montanum*** (Hedw.) Loeske – **183d**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* [RZ]; **209a**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* [EF, GW, JZG]; a trunk of *Betula pubescens* [AS]

***Orthodontium lineare*** Schwägr. – **209a**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* [AS]

***Oxyrrhynchium hians*** (Hedw.) Loeske – **209a** and **209d**: spring alderwood C.-A., peat [WP, AR, SR]

***Oxyrrhynchium speciosum*** (Brid.) Warnst. – **209a**: spring alderwood C.-A., moist peat [AS]

***Paludella squarrosa*** (Hedw.) Brid. – **209b**: transition bog, patch of C. l. [AR], among *Sphagnum* [RZ]; **209b**: transition bog with predominating *Sphagnum teres*, along animal paths [PP, WP, MS], patch of S.-C. r. [AR]. **S. p. (E)**

***Plagiomnium affine*** (Blandow ex Funck) T.J. Kop. – **183d**: swampy alderwood C. e.-A., peat [RZ]; **209a**: swampy alderwood C. e.-A., moist peat [EF, GW]; **209c** and **209d**: swampy alderwood C. e.-A., peat [RZ, MSK]

***Plagiomnium cuspidatum*** (Hedw.) T.J. Kop. – **209a**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* at a height of 1 m [EF, GW]

***Plagiomnium elatum*** (Bruch & Schimp.) T.J. Kop. – **183d**: swampy alderwood C. e.-A., peat [RZ]; **209a**: swampy alderwood C. e.-A., forest swamp [AS], base of *Alnus glutinosa* [MW], peat [WP, JZG]; **209b**: transition bog, patch of C. l. [AR], fen [MS]; **209c**: spring alderwood C.-A., peat [AR, SR]; **209c**: swampy alderwood C. e.-A., peat [RZ]; **209d**: spring alderwood C.-A., peat [AR, SR]

***Plagiomnium ellipticum*** (Brid.) T.J. Kop. – **209b**: fen [PP, WP, MS], floating mat at the edge of a small lake and a hummock of willows [PP]; **209c**: patches of C. p. and T.-P., peat [AR, SR]; **209d**: spring alderwood C.-A., peat [AR, SR]; **209f**: patch of T.-P., peat [AR, SR]

***Plagiomnium undulatum*** (Hedw.) T.J. Kop. – **209a**: swampy alderwood C. e.-A., moist peat [EF, GW, JZG]; spring alderwood C.-A., moist peat [AS]; **209b** and **209d**: spring alderwood C.-A., moist peat [MS, AR, SR]

***Plagiothecium curvifolium*** Schlieph. ex Limpr. – **209a**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* and wood of a rotting stump [EF, GW]

***Plagiothecium denticulatum*** (Hedw.) Schimp. – **209a**: swampy alderwood C. e.-A., wood of a rotting stump [EF, GW], litter at the base of an *Alnus glutinosa* trunk [AS], peat [WP]; **209d**: spring alderwood C.-A., peat [MSK]

***Plagiothecium laetum*** Schimp. – **183d**: swampy alderwood C. e.-A., overdried peat [RZ]; **209a**: swampy alderwood C. e.-A., bark and wood of rotting stump [EF, GW, JZG], base of a trunk of *Alnus glutinosa* [AS]; **209b**: swampy alderwood C. e.-A., lying rotting log [PP]; **209c**: swampy alderwood C. e.-A., peat [RZ]

***Plagiothecium ruthei*** Limpr. – **209a**: swampy alderwood C. e.-A., moist peat [EF, GW], forest swamp [AS]; **209b**: swampy alderwood C. e.-A. [MS]; **209d**: spring alderwood C.-A., peat [AR, MSK, SR]

***Pleurozium schreberi*** (Willd. ex Brid.) Mitt. – **209a**: swampy alderwood C. e.-A., forest road, soil and rotting wood of a stump [EF, GW], lying rotting log [AS], peat [PP]. **P. p.**

***Pohlia nutans*** (Hedw.) Lindb. – **209a**: swampy alderwood C. e.-A., soil between protruding roots of *Alnus glutinosa* (*c. spor.*) and rotting wood of a stump (*c. spor.*) [EF, GW], rotting log [PP]; **209b**: patch of C. p., rotting wood of a stump [AR, SR], overdried hummocks of *Carex paniculata* [WP], swampy alderwood C. e.-A., peat around a trunk of *Alnus glutinosa* [MS]; **209d**: spring alderwood C.-A., rotting wood [MSK]

***Polytrichastrum formosum*** (Hedw.) G.L. Sm. – **209a**: swampy alderwood C. e.-A., a trunk of *Alnus glutinosa* at a height of 30 cm [EF, GW], rotting log and stump [MW, JZG], peat [MW]; **209b**: spring alderwood C.-A. [MS]

***Polytrichastrum longisetum*** (Sw. ex Brid.) G.L. Sm. – **183d**: swampy alderwood C. e.-A., among *Sphagnum* [RZ]; **209a**: spring alderwood C.-A., moist peat [AS], swampy alderwood C. e.-A., peat [MW, WP, JZG]; **209b**: patch of C. p., peat [AR, SR], transition bog, among *Sphagnum* [RZ], fen [WP]; **209d**: spring alderwood C.-A., peat [AR, SR]

***Polytrichum commune*** Hedw. – **209a**: swampy alderwood C. e.-A., peat [WP]; **209b**: swampy alderwood C. e.-A. [MS]. **P. p.**

***Polytrichum juniperinum*** Hedw. – **183d**: swampy alderwood C. e.-A., base of a trunk of *Alnus glutinosa* [RZ]

***Polytrichum strictum*** Menzies ex Brid. – **209b**: transition bog [PP, MS]. **P. p.**

***Pseudoscleropodium purum*** (Hedw.) M. Fleisch. ex Broth. – **209b**: swampy alderwood C. e.-A., moist peat [AS] **P. p.**

***Rhizomnium punctatum*** (Hedw.) T.J. Kop. – **183d**: swampy alderwood C. e.-A., a layer of peat on a rotten stump [RZ]; **209a**: swampy alderwood C. e.-A., peat [MW, JZG], spring alderwood C.-A. [WP]; **209b**: swampy alderwood C. e.-A. [MS]; **209d**: spring alderwood C.-A., base of *Alnus glutinosa* [AR, SR] and peat [MSK]

***Rhytidiadelphus squarrosus*** (Hedw.) Warnst. – **209b**: swampy alderwood C. e.-A., mineral soil at the edge of forest [AS, MS]. **P. p.**

***Sciuro-hypnum oedipodium*** (Mitt.) Ignatov & Huttunen – **209c**: spring alderwood C.-A., rotting log [MSK]

***Sphagnum angustifolium*** (C.E.O. Jensen ex Russow) C.E.O. Jensen – **209b**: transition bog, patches of C. l. and S.-C. r. [AR]. **S. p.**

***Sphagnum fallax*** (H. Klinggr.) H.Klinggr. – **209 b**: *Sphagnum* lawn, patch of S.-C. r. [AR]; **209f**: patch of T.-P., peat [AR, SR]. **P. p.**

***Sphagnum fimbriatum*** Wilson – **209a** and **209b**: swampy alderwood C. e.-A., forest swamp [AS, MW, WP, MS, JZG]; **209b**: patch of C. p., peat [AR, SR]; **209c**: spring alderwood C.-A., peat [AR, SR]; **209f**: patch T.-P. [AR, SR]. **S. p.**

***Sphagnum palustre*** L. – **209b**: swampy alderwood C. e.-A., [MS]; **209d**: spring alderwood C.-A., peat [MSK]. **S. p.**

***Sphagnum russowii*** Warnst. – **209b**: transition bog, patch of C. l. [AR]. **S. p.**

***Sphagnum squarrosum*** Crome – **209a**: swampy alderwood C. e.-A., swamp [MW], peat [WP]; **209b**: swampy alderwood C. e.-A. [PP, MS]; **209a**: patch of C. p., peat [AR, SR]; **209c**: spring alderwood C.-A., peat [AR, SR]; **209f**: patch of T.-P., peat [AR, SR]. **P. p.**

***Sphagnum teres*** (Schimp.) Ångstr. – **183f**: fen [MS]; **209b**: transition bog [PP, WP], fen [MS], **209b**: transition bog, patch of C. l. [AR]; **209f**: patches of T.-P., peat [AR, SR, MSK]. **S. p.**

***Tetraphis pellucida*** Hedw. – **183f**: swampy alderwood C. e.-A., rotting wood [MS], rotting base of a live trunk of *Alnus glutinosa* [RZ]; **209b**: swampy alderwood C. e.-A., rotting log [MS]; **209d**: spring alderwood C.-A., rotting wood [MSK]

***Tomentypnum nitens*** (Hedw.) Loeske – **209b**: fen [PP, WP, MS]. **S. p. (V)**

*Characteristics of bryoflora and general conditions of its occurrence*

The flora of bryophytes in the investigated area comprises 75 taxa, including 10 species of liverworts and 63 species as well as two varieties of mosses. It consists of both bryophytes connected with the ecosystems of woodless mires and with moist alder carrs. They overgrow peat, bark of trees (mainly alder) as well as rotting stumps and branches. Some of them, particularly peat mosses, in several places form a mat fen and floating vegetation mat. Almost 35% of bryoflora (26 species) consisted of sporadic species, found only in single localities in the Makąty peatland.

Among liverworts only *Lophocolea heterophylla* was found commonly in the investigated area. It grows mainly on rotting stumps and branches, as well as on peat in spring and swampy alderwoods, and is accompanied by a rarer species *Lophocolea bidentata*. In communities of hollows and mires, e.g. in *Caricetum paniculatae* and on a peat floating mat *Marchantia aquatica* is found in abundance. The other liverwort species were recorded only occasionally.

Common mosses in the analysed area include *Brachythecium rutabulum* and *Calliergonella cuspidata*. The former grows mainly in alderwoods on different substrates (e.g. peat, rotting wood), it is also found in patches of fens. *Calliergonella cuspidata* is found in flooded localities – both in fen and the surrounding alderwoods. In small water bodies the presence of clusters of *Chara globularis* threatened in Poland (Siemińska et al. 2006) was also recorded.

The group of species widely distributed over the whole area included also an epiphytic, epixylic *Hypnum cupressiforme*, as well as *Pohlia nutans*, *Polytrichastrum longisetum*, *Plagiomnium elatum* and *P. ellipticum*, with the latter being recorded mainly in patches of fen communities (*Sphagno-Caricetum rostratae*, *Caricetum paniculatae*) and rush vegetation (*Thelypterido-Phragmitetum*). The most commonly found peat mosses are *Sphagnum squarrosum* and *S. teres*. *Sphagnum fallax* and *S. angustifolium* formed large clusters and were the main components of the peatland.

In spring alderwoods, classified as *Cardamino-Alnetum*, only two species were commonly found: *Brachythecium rivulare* and *Cratoneuron filicinum*. They were less frequently accompanied by *Climacium dendroides* and *Plagiomnium undulatum*. Patches of swampy alderwoods *Carici elongatae-Alnetum* are well-distinguished by presence of *Dicranum scoparium* growing on rotting wood, as well as of occasionally found other coniferous forests mosses, i.e. *Dicranum polysetum, Hylocomium splendens, Pleurozium schreberi, Dicranella heteromalla* and *Pseudoscleropodium purum*. There can be also most frequently found *Mnium hornum* and *Plagiomnium affine*.

Worth stressing in the Makąty peatland is the presence of a group of rare boreal mosses considered to be glacial relics, forming the basis of the spring fen. The most common among them, *Helodium blandowii*, forms vast clusters particularly in the northern and western part of the fen (compartments 209b and 209f), being a component of floating mats with *Sphagnum teres*, as well as patches of sedge communities: *Caricetum lasiocarpae*, *C. paniculatae* and rush vegetation *Thelypterido-Phragmitetum*. The other relic mosses, i.e. *Paludella squarrosa* and *Tomentypnum nitens*, grow in the central part of compartment 209b, south of two small lakes, where they form relatively small clusters, mainly in patches of community *Sphagno-Caricetum rostratae*. They are accompanied by *Hamatocaulis vernicosus*, a moss from the Habitat Directive Natura 2000. It occupies the moistest localities, most often paths treaded by animals visiting the peatland.

A locality of *H. vernicosus* in the Makąty fen is one of the nine presently recorded in the Wielkopolskie Voivodeship (Rusińska 2008). This species and above mentioned glacial relics are strictly protected (Ordinance of the Minister of the Environment of 9 July 2004) and three of them are included in the Red Book of threatened species in Poland (Żarnowiec et al. 2004), with categories E (endangered) and V (vulnerable). The other mosses covered by strict protection are peat mosses: *Sphagnum angustifolium*, *S. fimbriatum*, *S. palustre*, *S. russowii* and *S. teres*. Moreover, in the fen and its edges 14 species of bryophytes were recorded which are covered by partial protection. These include *Ptilidium ciliare*, *Aulacomnium palustre*, *Calliergonella cuspidata*, *Climacium dendroides*, *Dicranum polysetum*, *D. scoparium*, *Pleurozium schreberi*, *Hylocomium splendens*, *Polytrichum commune*, *P. strictum*, *Pseudoscleropodium purum*, *Rhytidiadelphus squarrosus*, *Sphagnum fallax* and *S. squarrosum*.

*Habitat conditions for the occurrence of fen bryophytes*

In the south-eastern part of the Makąty peatland complex eight study plots were marked out, in which vegetation type and chemical parameters of ground water were determined in the fen. In these places a total of 15 moss species (three peat mosses and 12 brown mosses) were determined, as well as 23 species of vascular plants.

The analysed microhabitats represented four vegetation types, exhibiting zonal distribution, ranging from the floating mat to peatland with dominating *Sphagnum*. The following were analysed: (I) floating vegetation mat and low hummocks with rush vegetation, (II) rich fen, (III) *Sphagnum* lawns and (IV) a small hummock of *Sphagnum*. Species composition and quantitative ratios of vegetation in peatlands microhabitats are presented in Table 1.

TABLE 1. Vegetation of sampled microhabitats: I – floating mat, II – rich fen plots, III – *Sphagnum* lawn, IV – hummocks

| No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Microhabitat types | I | I | II | II | II | II | III | IV |
| **Bryophytes and algae** | | | | | | | | |
| *Drepanocladus polycarpos* | **3.3** | **4.4** | . | . | . | . | . | . |
| *Paludella squarrosa* | . | . | **4.4** | **5.5** | 1.1 | 2.2 | . | . |
| *Calliergonella cuspidata* | 1.1 | 2.2 | r | 1.1 | **3.3** | 2.1 | . | . |
| *Plagiomnium ellipticum* | . | 1.1 | r | r | 2.1 | **4.4** | . | . |
| *Helodium blandowii* | . | 1.1 | 2.2 | . | . | . | . | . |
| *Marchantia aquatica* | . | . | 2.2 | 1.1 | 2.2 | 2.2 | . | . |
| *Sphagnum teres* | . | . | 1.1 | 2.2 | . | 1.1 | . | 1.1 |
| *Aulacomnium palustre* | . | . | 1.1 | 1.1 | . | + | . | . |
| *Hamatocaulis vernicosus* | . | . | . | + | 2.2 | 1.1 | . | . |
| *Brachythecium mildeanum* | . | + | . | . | . | . | . | . |
| *Brachythecium rutabulum* | . | . | . | + | . | . | . | . |
| *Sphagnum fallax* | . | . | . | . | . | 1.1 | . | . |
| *Sphagnum angustifolium* | . | . | . | . | . | . | **5.5** | **4.4** |
| *Sphagnum squarrosum* | . | . | . | . | . | . | . | 1.1 |
| *Bryum pseudotriquetrum* | . | . | . | . | . | . | . | + |
| *Spirogyra* sp. | 1.1 | . | . | . | . | . | . | . |
| **Vascular plants** | | | | | | | | |
| *Lemna minor* | 3.2 | . | . | . | . | . | . | . |
| *Thelypteris palustris* | 2.2 | 2.2 | 3.3 | 1.1 | 2.2 | 1.1 | . | 1.1 |
| *Carex pseudocyperus* | . | 1.1 | . | + | 1.1 | . | . | . |
| *Epilobium palustre* | + | 1.1 | . | r | . | . | . | . |
| *Cardamine amara* | . | + | . | . | . | . | . | . |
| *Carex paniculata* | . | . | . | 2.2 | . | 1.1 | . | 1.1 |
| *Typha latifolia* | . | . | + | + | . | . | . | . |
| *Lysimachia thyrsiflora* | . | . | + | . | . | . | . | . |
| *Galium palustre* | . | . | + | 1.1 | . | + | . | . |
| *Cirsium palustre* | . | . | 1.1 | 1.1 | . | . | 1.1 | 1.1 |
| *Drosera rotundifolia* | . | . | 1.1 | . | . | . | + | + |
| *Utricularia minor* | . | . | . | 1.1 | + | . | . | . |
| *Equisetum palustre* | . | . | . | . | 2.2 | . | . | . |
| *Agrostis canina* | . | . | . | . | 1.1 | 1.1 | 3.3 | 3.3 |
| *Alnus glutinosa* | . | . | . | . | 1.1 | . | . | 2.2 |
| *Myosotis palustris* | . | . | . | . | + | . | . | r |
| *Ranunculus lingua* | . | . | . | . | + | . | . | . |
| *Stellaria palustris* | . | . | . | . | . | 1.1 | . | . |
| *Carex rostrata* | . | . | . | . | . | 1.1 | 2.2 | 2.2 |
| *Eriophorum angustifolium* | . | . | . | . | . | . | 1.1 | . |
| *Carex nigra* | . | . | . | . | . | . | 1.1 | . |
| *Dactylorhiza incarnata* | . | . | . | . | . | . | 1.1 | . |
| *Comarum palustre* | . | . | . | . | . | . | + | . |

The type of microhabitat – floating mat, was mainly represented by *Drepanocladus polycarpos*. Moreover, such species as *Calliergonella cuspidata* and scarce vascular plants e.g. *Lemna minor, Thelypteris palustris* and *Carex pseudocyperus*, were also recorded. In one of the microhabitats (plot 1) macroscopic green algae (*Spirogyra* sp.) were found. These plots are adjacent to a water course (plot 1) or are located in the vicinity of a small water body (plot 2).

Rich fen covered the central part of the peatland. A total of four patches were analysed with dominance of such species as *Paludella squarrosa* (two plots), *Calliergonella cuspidata* (one plot) and *Plagiomnium ellipticum* (one plot). Localities were characterised by a high plant cover and diversity of bryophytes (e.g. *Marchantia aquatica*, *Hamatocaulis vernicosus* and *Aulacomnium palustre*). Peat mosses were scarce: *Sphagnum teres* and *S. fallax*. The rich layer of vascular plants was formed by species of rush vegetation (e.g. *Equisetum palustre*, *Typha latifolia*, *Galium palustre*) and peatland species (e.g. *Agrostis cannina*, *Drosera rotundifolia* and *Utricularia minor*). A considerable proportion of *Thelypteris palustris* and *Carex paniculata* was recorded in some of the analysed areas.

*Sphagnum* lawn (plot 7) was characterized by a strong development of the moss layer formed by *Sphagnum angustifolium* and of some vascular species: *Carex rostrata*, *Agrostis cannina*, *Drosera rotundifolia* and *Cirsium palustre*.

A small hummock, poor in terms of species composition, and formed by *Sphagnum angustifolium* was also examined (plot 8). The central part of the hummock was occupied by *Alnus glutinosa*. *Sphagnum*-dominated peatlands developed in the farthest south-eastern part of this complex.

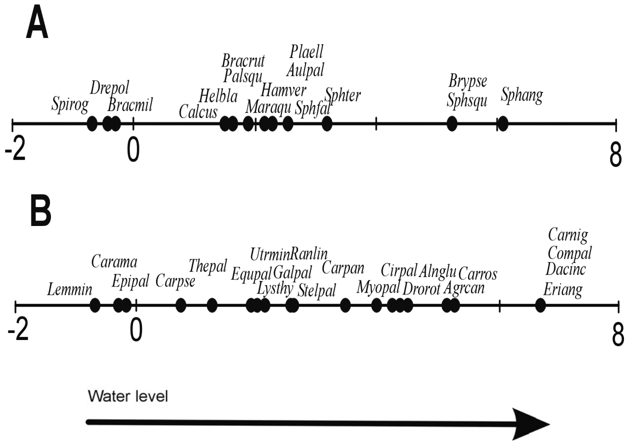


Fig. 3. Optima of individual species: bryophytes (A) and vascular plants (B) along the first DCA axis of the species sample composition. Species name: *Agrostis cannina* (*Agrcan*), *Alnus glutinosa* (*Alnglu*), *Aulacomnium palustre* (*Aulpal*), *Brachythecium mildeanum* (Bracmil), *Brachythecium rutabulum* (*Bracrut*), *Bryum pseudotriquetrum* (*Brypse*), *Calliergonella cuspidate* (*Calcus*), *Cardamine amara* (*Carama*), *Carex nigra* (*Carnig*), *Carex pseudocyperus* (*Carpse*), *Carex rostrata* (*Carros*), *Cirsium palustre* (*Cirpal*), *Comarum palustre* (*Compal*), *Dactylorhiza incarnata* (*Dacinc*), *Drepanocladus polycarpos* (*Drepol*), *Drosera rotundifolia* (*Drorot*), *Epilobium palustre* (*Epipal*), *Equisetum palustre* (*Equpal*), *Eriophorum angustifolium* (*Eriang*), *Galium palustre* (*Galpal*), *Hamatocaulis vernicosus* (*Hamver*), *Helodium blandowii* (*Helbla*), *Lemna minor* (*Lemmin*), *Lysimachia thyrsiflora* (*Lysthy*), *Marchantia aquatica* (*Maraqu*), *Myosotis palustris* (*Myopal*), *Paludella squarrosa* (*Palsqu*), *Plagiomnium ellipticum* (*Plaell*), *Ranunculus lingua* (*Ranlin*), *Sphagnum angustifolium* (*Sphang*), *Sphagnum fallax* (*Sphfal*), *Sphagnum squarrosum* (*Sphsqu*), *Sphagnum teres* (*Sphter*), *Spirogyra* sp. (*Spirog*), *Stellaria palustris* (*Stelpal*), *Thelypteris palustris* (*Thepal*), *Utricularia minor* (*Utrmin*)

Table 2. Physicochemical properties of ground water in habitats of the Makąty peatland. Types of microhabitats: I – floating mat, II – rich fen plots, III – *Sphagnum* lawn, IV – hummocks

| Nr | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Microhabitat types | I | I | II | II | II | II | III | IV |
| Depth to water table (cm) | –4 | –3 | 8 | 5 | 4 | 5 | 15 | 20 |
| Water colour (mg Pt·l$^{-1}$) | 50 | 125 | 172 | 110 | 118 | 113 | 220 | 223 |
| pH | 6.64 | 6.53 | 6.32 | 6.16 | 6.2 | 6.05 | 5.73 | 5.85 |
| Saturation with $O_2$ | 26 | 26 | 8 | 13 | 9 | 13 | 6 | 6 |
| $O_2$ dissolved (mg $O_2$·l$^{-1}$) | 1.9 | 2.7 | 0.6 | 1.5 | 0.6 | 0.7 | 0.2 | 0.2 |
| Conductivity (μS·cm$^{-1}$) | 371.1 | 349.1 | 277.6 | 275.4 | 248.3 | 205.9 | 293.1 | 199.12 |
| $NH_4^+$ (mg N·l$^{-1}$) | 1.27 | 1.37 | 2.31 | 1.78 | 1.66 | 2.16 | 1.79 | 1.55 |
| $NO_3^-$ (mg N·l$^{-1}$) | 0.09 | 0.04 | 0.07 | 0.07 | 0.09 | 0.07 | 0.4 | 0.02 |
| $PO_4^{3-}$ (mg P·l$^{-1}$) | 0.26 | 0.32 | 0.35 | 0.85 | 0.4 | 0.52 | 0.2 | 0.17 |
| Total Fe (mg Fe·l$^{-1}$) | 0.03 | 0.03 | 0 | 0.03 | 0.04 | 0.04 | 0.29 | 0.34 |
| $Ca^{2+}$ (mg Cg·l$^{-1}$) | 67 | 73.2 | 55.6 | 48.7 | 46.1 | 36.4 | 32.9 | 20.6 |
| $Mg^{2+}$ (mg Ma·l$^{-1}$) | 6.6 | 6.6 | 4.9 | 5 | 4.5 | 3.9 | 5.2 | 2.9 |
| $Na^+$ mg Na·l$^{-1}$ | 5.79 | 5.71 | 4.84 | 4.71 | 4.66 | 4.62 | 4.85 | 12.84 |
| $K^+$ (mg K·l$^{-1}$) | 3.61 | 1.73 | 1.26 | 1.59 | 2 | 3.02 | 1.2 | 1.04 |
| $SO_4^{2-}$ (mg $SO_4$·l$^{-1}$) | 14 | 0 | 8 | 1 | 0 | 3 | 4 | 1 |

The microhabitats in the analysed fen complex were characterized by considerable abundance of nutrients, calcium and high conductivity. Localities were arranged along two main habitat gradients, i.e. hydrological dry-moist, and trophic poor-rich. Physicochemical parameters and depth of water table (DWT) measured in the plots are presented in Table 2. Figure 3 presents in detail the bryophytes and vascular plants in relation to the gradient of depth of water table.

The highest level of water table was observed in microhabitats with dominating *Drepanocladus polycarpos*, while the lowest – in *Sphagnum* lawn with *Sphagnum angustifolium* (Table 1, Fig. 3). In habitats of high moisture content of floating mat the highest pH, calcium content, conductivity and water oxygen saturation were recorded, as well as the lowest $PO_4^{3-}$ and total Fe values. The highest levels of nutrients ($NH_4^+$, $NO_3^-$ and $PO_4^{3-}$) were measured at the vegetation plot with the dominance of brown mosses, particularly with *Paludella squarrosa* and *Plagiomnium ellipticum*. A characteristic feature of fen areas in relation to the other microhabitats was connected with intermediate values of measured parameters, particularly colour, pH, Ca and conductivity. In plots with the dominance of *Sphagnum* most parameters (particularly pH, Ca, oxygen saturation, soluble oxygen, conductivity, $NO_3^-$ and $PO_4^{3-}$) exhibited low values in comparison to the other microhabitats, while water colour, total Fe and Na concentrations (plot 7) were high.

## CONCLUDING REMARKS AND DISCUSSION

The Makąty peatland complex, despite its small size (approx. 15 ha), is characterised by a high diversity of bryophyte species – 75 taxa of liverworts and mosses. The recorded diversity of bryoflora is very high in relation to the results of recent studies in selected mires of the Notecka Forest or other regions of western Poland, e.g. the Rzecińskie peatlands (48 species; Górski and Rusińska 2008), fen near the Lake Święte (over 30 species, Rusińska unpublished data, Gąbka et al. 2008), the Chlebowo peatlands (66 species; Rusińska and Bocheński 1993). The number of recorded taxa in the analysed object is comparable to those of the most thoroughly investigated spring water ecosystems of the Wielkopolska region – mire at Lake Mnich (72 species; Lisowski and Szafrański 1964, Rusińska and Gąbka 2008) and the valley of the Rurzyca River (almost 80 species, Jasnowska et al. 1993).

Spring fens of flow-through character and those developing in the complex of the disappearing hardwater lakes need to be treated as areas of special concern, mainly due to the high concentration of rare and threatened plant species. In the bryoflora of the analysed object four species of the endangered species status (E) and vulnerable status (V) in Poland were recorded, as well as 22 species covered by legal protection.

Considerable species diversity of bryophytes in the peatland is related with a small degree of anthropogenic transformation of this object and high variability in environmental conditions in the microhabitat scale. Analysed vegetation plots of the Makąty fens exhibit broad spectra of bryophytes and vascular plants, characteristic of poor and rich fens as well as the transition between aquatic and terrestrial environments (Fig. 3). Very high Ca and Mg concentrations need to be stressed here (Table 2) in the analysed fen microhabitats of the Makąty fen, as well as in the areas occupied by peat mosses. It is also worth mentioning that habitat analyses conducted within this study enrich the state of knowledge we have had to date, concerning rich fens and document in detail habitats of such species as *Hamatocaulis vernicosus*, *Helodium blandowii* and *Paludella squarrosa* (see Łachacz and Olesiński 2000, Hájkova et al. 2004, Hájková and Hájek 2004, Pawlikowski 2006, Štechová and Kučera 2007).

It is believed that at present the specific character of spring water ecosystems is disappearing. This is caused by overdrying, eutrophication and first of all by a change of hydrochemical character of ground waters (e.g. Wołejko 2001, Hájkova et al. 2004, Hájková and Hájek 2004, Pawlikowski 2006, Gąbka and Lamentowicz 2008). The latter factor is connected with the disappearance of supply by rich underground waters and acidification caused by the expansion of species from genus *Sphagnum* (e.g. Limpens et al. 2003). As it is indicated by studies on percolating mires conducted by Wołejko (e.g. 2000, 2001) in north-western Poland, a reduced content of calcium compounds in ground waters in relation with changes in the water balance of the catchment or local habitat changes are the primary reasons of degradation of these ecosystems.

The present status of the vegetation cover, particularly that of bryoflora in the Makąty fen, is connected with the last stage of disappearance and overgrowing of the lake need to be treated as more or less transitory, subjected to dynamic changes. Protection of this fen should first of all consist in the maintenance of the high depth of water table. Moreover, it is necessary to conduct observations and record the process of overgrowing and water saturation of the fen, as well as fluctuations in the water table in small lakes. In case of a drop in the ground water and surface water tables it is necessary to consider the removal of willow thickets and mowing of rush vegetation in the southern part of the peatlands.

The genesis and functioning of the Makąty fen need to be further investigated in detail. It may be assumed that the present fen character of the object is a result of spontaneous restitution of the disappearing lake rich in calcium. The role of man in the formation and functioning of this fen ecosystem is of particular interest.

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