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Factors affecting the diversity of vegetation of chosen lakeland and riverine peatlands of SE Poland

Czynniki warunkujące różnorodność roślinności wybranych torfowisk przyjeziornych i przyrzecznych Polski południowowschodniej

SUMMARY

The aim of the study was to present the diversity of peatland vegetation of two regions in south-eastern Poland. We also aimed to determine the relationship between particular edaphic factors as well as the structure of peatland communities and their diversity. The study was conducted in the lakeland peatlands of the Łęczna-Włodawa Lakeland and in riverine peatlands in the river breaks of the Central Roztocze Highlands. The lakeland peatlands are characterized by lower species richness and diversity expressed by the Shannon-Wiener index; yet, they exhibit greater phytocoenotic diversity in comparison to the riverine peatlands of Roztocze. Increased tree density in lakeland peatlands reduces the number of species and renders the communities less diverse. Such physico-chemical properties as soil acidity and content of Ca, and Na ensure species richness in *Caricetum lasiocarpae* phytocoenoses in the lakeland peatlands.

Keywords: diversity, species richness, Shannon-Wiener index, peatlands

STRESZCZENIE

Celem badań było przedstawienie zróżnicowania roślinności torfowisk dwu regionów Polski południowowschodniej oraz określenie zależności pomiędzy wybranymi czynnikami edaficznymi i strukturą zbiorowisk torfowiskowych a ich różnorodnością. Badania przeprowadzono na torfowiskach przyjeziornych Pojezierza Łęczyńsko-Włodawskiego oraz na torfowiskach przyrzecznych w przełomowych odcinkach dolin rzek Roztocza Środkowego. Torfowiska przyjeziorne cechują się mniejszym bogactwem gatunkowym i mniejszą różnorodnością wyrażoną współczynnikiem Shannona-Wienera, ale równocześnie większą różnorodnością fitocenotyczną w relacji do torfowisk przyrzecznych Roztocza. Wzrost zwarcia drzew na torfowiskach przyjeziornych ogranicza liczbę występujących gatunków i sprawia, że zbiorowiska są mniej różnorodne. Spośród właściwości fizyczno-chemicznych gleb to głównie kwasowość oraz zawartość Ca i Na warunkują bogactwo gatunkowe fitocenoz *Caricetum lasiocarpae* w obrębie torfowisk przyjeziornych.

INTRODUCTION

Peatland ecosystems are particularly susceptible to changes occurring in abiotic factors. They are not only storages of organic carbon, but also a mainstay for many rare species, which contribute to local biodiversity (4, 12, 38). The groundwater level, acidity, and nutrient content are factors that exert a significant effect on the diversity of peatland vegetation (11, 14, 15, 24). Anthropopressure has a great impact as well, and its consequences include desiccation, eutrophication, habitat fragmentation, and decreased biodiversity (5, 19, 20, 23, 40).

The species diversity of peatland communities depends, among others, on the share of plant life forms occurring in the area. The share of bryophytes is affected by both the density of the shrub layer and the cover of its representing species (2, 33, 35). Interspecies relations result in changes in the cover of particular components of plant communities, but also disappearance of some, also rare, taxa as well as changes in species richness (15, 25, 35). Diversity of life forms may vary due to effects of various factors. The richness of vascular plants may decline, whereas bryophyte richness may increase (15). This results from, among others interactions between vascular plants and bryophytes (18, 24).

Plant species richness is significantly correlated with a number of topographic, geographic, historical, and edaphic factors (22). The acidity and calcium concentration are the major factors controlling species distribution of mire plants and species richness especially between individual mires or among different vegetation types (16, 34, 36, 37). Our studies focused on the relation between species diversity and abiotic parameters among the patches of one type of mire plant community. The aim of the present study was presentation of the vegetation diversity in peatlands located in two regions of southeast Poland. Another objective was to identify the relationships between edaphic factors and the structure of peatland communities and their diversity.

MATERIALS AND METHODS

Five minerotrophic and ombrotrophic peatlands (lakeland peatlands = LP) were selected in the Łęczna-Włodawa Lakeland. The peatlands are connected with five lakes (Lake Miejskie, Lake Kleszczów, Lake Czarne Gościnieckie, Lake Długie, and Lake Moszne). The area of the peatlands ranges from 8 ha to 32 ha.

The eutrophic and calcium-rich peatlands (riverine peatlands = RP) are located in four river valleys in the Roztocze Highlands region (the Jeleń river, the Sopot river, the Szum river and Potok Łosiniecki stream). The area of these peatlands is very small and ranges from 0.5 ha to 1.5 ha.

The study was carried out in 1998–2003. Phytosociological relevés were made in the study peatlands (93 in the LP and 55 in the RP), using an eleven-degree scale, with the + symbol for the species cover below 5%, 1 – for the cover of 5–10%, 2 – for 10–20%, …, 10 – for 90–100%. The area of each phytosociological relevé (15–25 m^2 in forestless areas and 200–400 m^2 in shrub and forest communities) represented the species composition, species richness and vertical structure of the communities. For each relevé, the following parameters were determined: the number of tree and shrub species (NTS), the number of herb species (NHS), the number of bryophyte species (NBS), the total number of species (TNS), the Shannon-Wiener index (H) and the evenness index (E).

Samples of topsoil (0 to 20 cm) were taken in each of the 37 *Caricetum lasiocarpae* patches located in the Łęczna-Włodawa Lakeland, where the phytosociological relevés were made. The pH of dried samples was analysed in distilled water and in 1 mol $KCl \cdot dm^{-3}$. Organic matter was determined by loss ignition at 550°C in a muffle furnace. The content of Ca, Na, Mg, Fe, extracted in 0.5 mol $HCl \cdot dm^{-3}$ was measured spectrophotometrically.

The Detrended Correspondence Analysis (DCA) was applied (value of the gradient length >4 SD) to describe the relationships between the structure of the study peatland communities and the main environmental gradient, which is understood as a continuous change in plant communities and environmental conditions. Relationships between the parameters of community diversity and the first two DCA axes and between parameters of community diversity and soil properties were established based on the calculated Spearman's rank correlation coefficients (*r*). All data analyses were carried out in MVSP and Statistica version 5 programs. The classification and association nomenclature were given after Matuszkiewicz (26). Vascular plants nomenclature followed Mirek et al. (27), bryophytes names followed Ochyra et al. (29).

RESULTS AND DISCUSSION

We recorded 427 plant species in the study peatland patches. The riverine peatlands exhibited distinctly greater species richness – 329 taxa (Fig. 1). Despite the significantly smaller area covered by these peatlands and a smaller number of phytosociological relevés analysed, as many as 33 tree species, 220 herbaceous plant species and 76 species of bryophytes were found in this area, whereas the lakeland peatland communities comprised 16, 177 and 63 taxa, respectively.

The distribution of the phytosociological relevés representing the study phytocoenoses in the ordination space is illustrated in Figure 2. The eigenvalues of the first two axes were 0.70 and 0.36, which indicates two main trends in species composition variability. The first DCA axis is significantly correlated with the number of herbaceous species, number of bryophytes, the total number of species, and coefficients H and E (Fig. 2). It reflects the gradient progressing towards communities with higher species richness, diversity, and evenness. The phytosociological relevés from the riverine peatlands are grouped on the right side and in the centre of the ordination space; the large space covered by them demonstrates higher species richness, higher diversity and evenness, compared to the lakeland peatlands. The second DCA axis is also correlated with the parameters studied (TNS, NHS etc.), the correlation coefficients are however low.

Phytocoenoses classified into 28 associations and 5 communities were recorded in the studied peatlands (Fig. 3). The peatlands of the river valleys in the Roztocze Highlands were characterized by lower area and by lower phytocoenotic diversity (15 associations were recorded) compared to peatlands connected with lakes (20 associations and 5 plant communities were recorded). No raised bog communities from the class *Oxycocco-Sphagnetea* were reported from these areas. In turn, moss-sedge communities from the class *Scheuchzerio-Caricetea nigrae* (not reported from the lakeland peatlands), e.g. *Caricetum davallianae* and *C. paniceao-lepidocarpae* as well as bog alder forests of *Ribeso nigri-Alnetum* and *Sphagno squarrosi-Alnetum* associations, and even the spring forms of riparian forests *Fraxino-Alnetum* were found here (8, 9). The syntaxa found in both study areas included *Rhynchosporetum albae* and *Caricetum limosae*. The species richness and phytocoenotic diversity of the peatlands in both areas are related to the diverse origin of the peatlands and the nature of the feeding waters (7, 8, 17). The fragments of lakeland peatlands that are away from the lake shores have an ombrotrophic character, while those located closer to the shores are fed with lake waters that are fairly rich. Riverine peatlands are often fed with waters that are rich in Ca and Fe ions (8); the moss species (*Helodium blandowii*, *Tomentypnum nitens*) reported from these areas are typical components of alkaline peatlands, which are the localities of numerous rare and endangered species and which play an important role in conservation of the local biodiversity (21, 39). The location in the DCA diagram ordination space of the Sopot and Jeleń river valleys away from the other two objects (Szum, Potok Łosiniecki) and all the lakeland complexes is conditioned by the occurrence of alder and ash-alder riparian forests. Moreover, the fragments of the valleys analysed are characterized by large forest cover – ca. 95% (10).

Negative correlations between the tree layer density and the number of herbaceous species, the total number of species, and coefficient H (Tab. 1) were found in the *Caricetum lasiocarpae* phytocoenoses from the lakeland peatlands. Increased tree density, particularly of *Betula pendula* or *B. pubescens*, contributes to increased shading and, consequently, leads to appearance of shade tolerant species (11, 29). Rare peatland species are replaced with common forest species

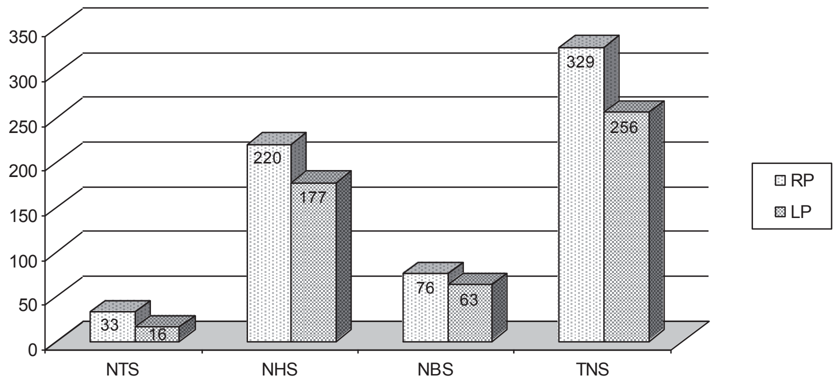


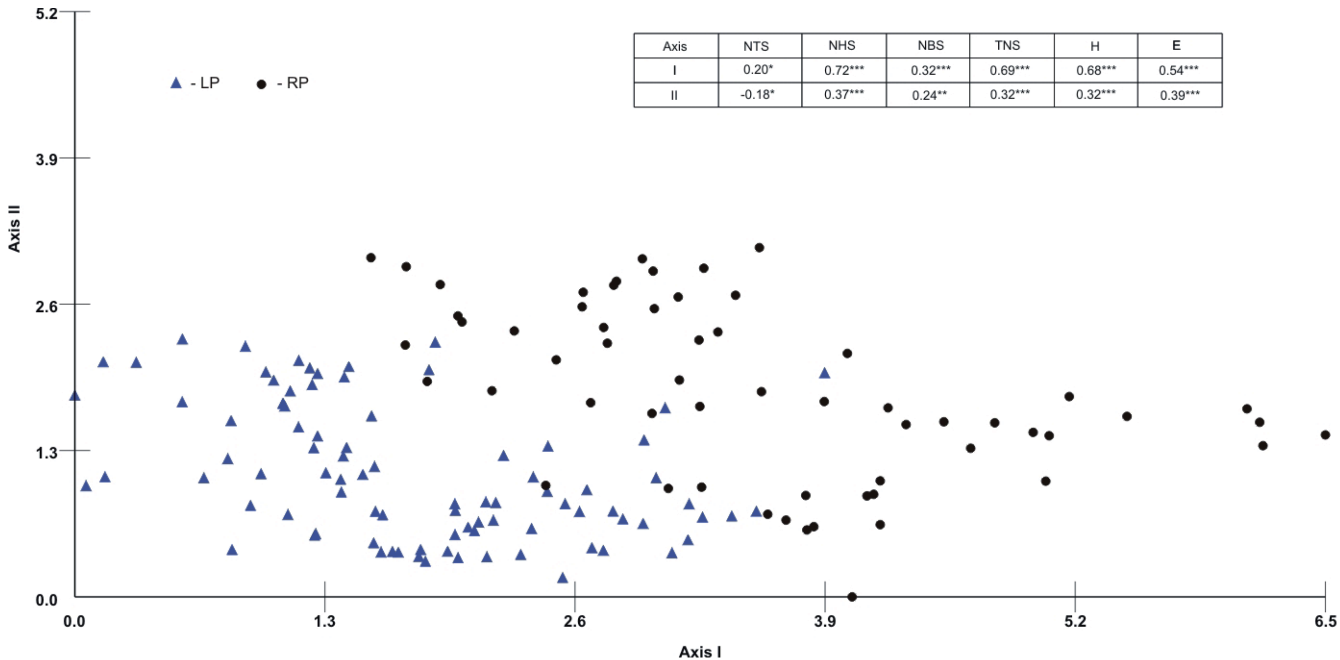
Fig. 1. Species richness of studied peatlands of SE Poland; LP – lakeland peatlands, RP – riverine peatlands, NTS – number of tree and shrub species, NHS – number of herb species, NBS – number of bryophyte species, TNS – total number of species

Table 1. Statistically significant correlation coefficients between cover of particular layers and parameters of diversity of *Caricetum lasiocarpae* association; for details see Fig. 2

Cover of layer	NTS	NHS	NBS	TNS	H	E
Trees		-0.74*		-0.81*	-0.78*	
Shrubs						
Herbs						
Bryophytes	0.35*		0.38*		0.36*	0.41*

(31). The species composition changes, while the species richness declines (1, 13, 15). Additionally, in the present study, a relatively low correlation between the density of the bryophyte layer and the number of trees and shrubs, number of bryophytes and coefficients H and E was found (Tab. 1).

The analysis of the correlations between floristic and habitat data obtained in the *Caricetum lasiocarpae* association patches demonstrated an effect of edaphic factors on species richness and diversity coefficients (Tab. 2). It is unquestioned that there is an increase in species richness from very acidic to somewhat less acidic sites (32), but usually among individual mires (16, 30, 34, 36). In our study the habitats of phytocoenoses characterized by greater species richness exhibited higher pH values. High values of the Spearman's rank correlation coefficient were found also between pH(KCl) and the total number of species (r=0.53, 0.001<P≤0.01) and coefficients H (r=0.56, P≤0.001) and E (r=0.54, 0.001<P≤0.01) were found. In terms of the same relationships, lower values of the correlation coefficient



Axis	NTS	NHS	NBS	TNS	H	E
I	0.20*	0.72***	0.32***	0.69***	0.68***	0.54***
II	-0.18*	0.37***	0.24**	0.32***	0.32***	0.39***

Fig. 2. Ordination diagram of 148 phytosociological relevés on the two first DCA axes and correlation coefficients between DCA axes and parameters of plant communities diversity; LP – lakeland peatlands, RP – riverine peatlands, NTS – number of tree and shrub species, NHS – number of herb species, NBS – number of bryophyte species, TNS – total number of species, H – Shannon-Wiener index, E – evenness index

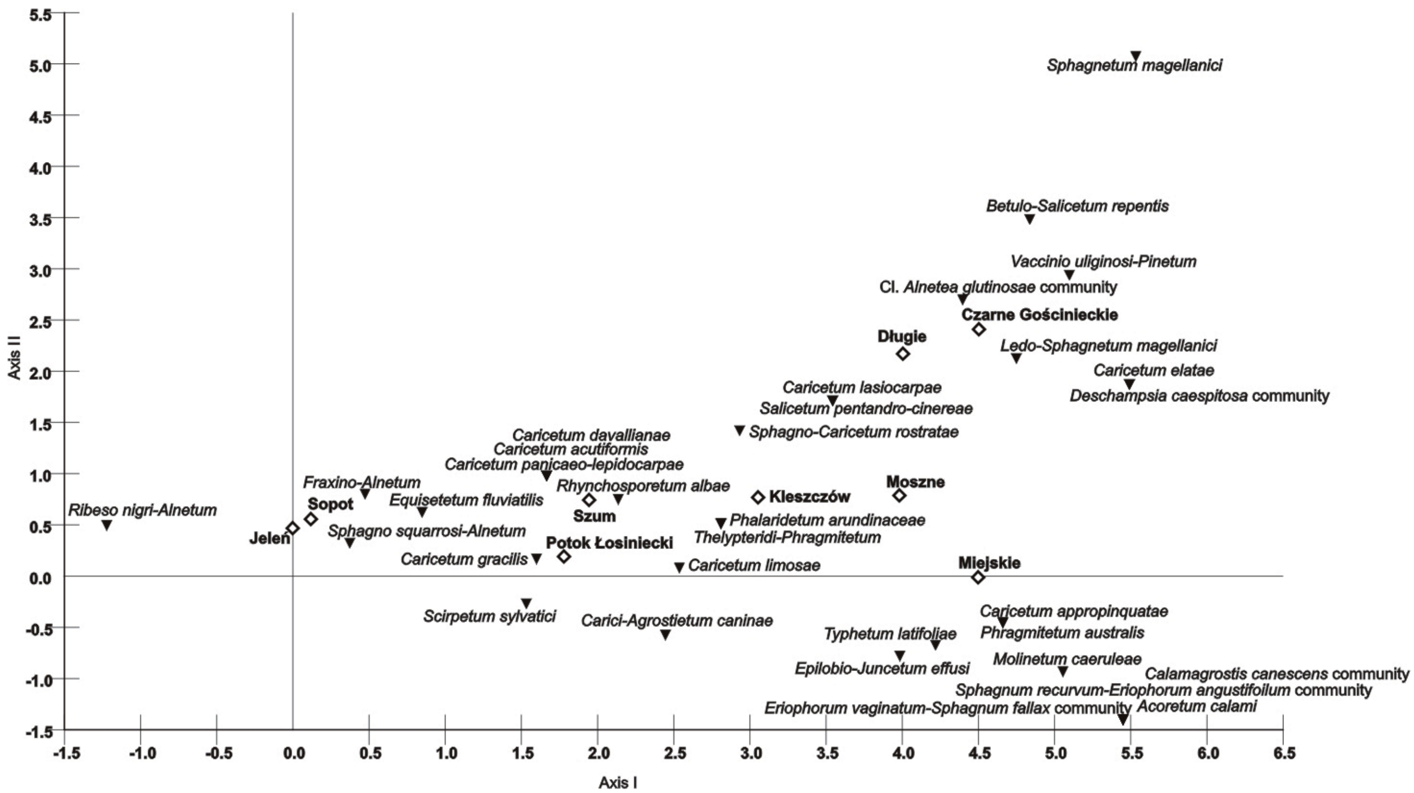


Fig. 3. Ordination diagram of plant communities (0–1 base) on the two first DCA axes; diamonds – peatlands connected with lakes and located in the river valleys, triangles – plant communities

Table 2. Statistically significant correlation coefficients between physico-chemical properties of soils and parameters of diversity of *Caricetum lasiocarpae* association; for details see Fig. 2

Features	NTS	NHS	NBS	TNS	H	E
pH(H_2O)				0.41*	0.47**	0.47**
pH(KCl)	0.38*			0.53**	0.56***	0.54***
OM			0.39*			
Ca	0.40*	0.64***		0.69***	0.67***	0.50**
Na	0.41*	0.62***		0.70***	0.67***	0.49**
Mg		0.36*				
Fe						

were obtained in the case of active acidity. Similar dependencies in ombrotrophic peatlands, where the species richness was determined mainly by acidity, were reported by Gunnarsson (14, 15).

Relatively low values of correlation coefficients were found between the organic matter content and the number of bryophyte species (r=0.39, 0.01<P≤0.05) and between the Mg content and the number of herbaceous species (r=0.36, 0.01<P≤0.05). There were no statistically significant correlations between the Fe content and the analyzed parameters of the community diversity (Tab. 2).

Macroelement availability is an essential factor determining species composition and richness of vegetation in many ecosystems (3). Among the study edaphic parameters, Ca and Na seem to have exhibited the highest correlations. The Ca content displayed the highest positive correlation with the TNS (r=0.69, P≤0.001), NTS (r=0.40, 0.01<P≤0.05) and coefficients H (r=0.67, P≤0.001) and E (r=0.50, 0.001<P≤0.01). Similarly, positive correlations were found between the content of Na and NTS (r=0.41, 0.01<P≤0.05), NH (r=0.62, P≤0.001), TNS (r=0.70, P≤0.001) and coefficients H (r=0.67, P≤0.001) and E (r=0.49, 0.001<P≤0.01).

Soil pH and calcium content are among the most important factors controlling species composition and diversity in plant communities (6, 30). Studies of Tahvanainen (3) indicated impacts of pH, Ca and Na on the species diversity at the regional scale. Our results showed that acidity, calcium and sodium crucially determined species diversity in the narrow range of environmental conditions, in the patches of one type of plant association – *Caricetum lasiocarpae*.

CONCLUSIONS

1. The peatlands in the Łęczna-Włodawa Lakeland are characterized by lower species richness (of all life forms studied) and lower diversity expressed by the Shannon-Wiener index; yet, they exhibited higher phytocoenotic diversity in comparison with the riverine peatlands in Roztocze. Furthermore, the peatlands situated in the river valleys show greater species richness.

2. Increased tree density in the lakeland peatlands limits the number of occurring species (particularly of herbaceous plants) and reduces the plant species diversity.

3. Acidity and the calcium and sodium content are the physico-chemical soil properties that exert an effect on the species richness of the *Caricetum lasiocarpae* phytocoenoses in lakeland peatlands.

REFERENCES

1. Åberg E. 1992. Tree colonisation of three mires in southern Sweden. [In:] Peatland Ecosystems and Man: An Impact Assessment. O. M. Bragg, P. D. Hulme, H. A. P. Ingram, R. A. Robertson (eds), Dept. of Biol. Sci., Univ. of Dundee, Dundee, Scotland, 268–270.
2. Bergamini A., Pauli D., Peintinger M., Schmid B. 2001. Relationships between productivity, number of shoots and number of species in bryophytes and vascular plants. J. Ecol. 89, 920–929.
3. Bobbink R., Hornung M., Roelofs J. G. M. 1998. The effects of air-borne nitrogen pollutants on species diversity on natural and semi-natural European vegetation. J. Ecol. 86, 717–738.
4. Bragazza L. 2006. A decade of plant species changes on a mire in the Italian Alps: vegetation-controlled or climate-driven mechanisms? Climatic Change 77, 415–429.
5. Budyś A. 2008. The synanthropisation of vascular plant flora of mires in the coastal zone (Kashubian Coastal Region, N Poland). Mon. Bot. 98, 55.
6. Chytrý M., Tichý L., Roleček J. 2003. Local and regional patterns of species richness in Central European vegetation types along the pH/calcium gradient. Folia Geobot. 38, 429–442.
7. Czarnecka B. 2005. Plant cover of the Szum river valley (Roztocze, South-East Poland). Acta Soc. Bot. Pol. 74, 43–51.
8. Czarnecka B., Janiec B. 2002. Przełomy rzeczne Roztocza jako modelowe obiekty w edukacji ekologicznej. Wyd. UMCS, 232.
9. Czarnecka B., Janiec B. 2007. Wpływ wód źródlanych na zróżnicowanie roślinności przełomów rzecznych strefy krawędziowej Roztocza Tomaszowskiego. [In:] Źródła Polski. Wybrane problemy krenologiczne. P. Jokiel, P. Moniewski, M. Ziułkiewicz (eds), Wydział Nauk Geograficznych Uniwersytetu Łódzkiego, Łódź, 253–263 + 4 pages with coloured inserts.
10. Czarnecka B., Pelc M. 2007. Biodiversity on the floristic and phytocoenotic levels: the comparison of forest and non-forest landscapes in small river valleys. Ecol. Quest. 8, 37–45.
11. Frankl R., Schmeidl H. 2000. Vegetation change in a south German raised bog: ecosystem engineering by plant species, vegetation switch or ecosystem level feedback mechanisms? Flora 195, 267–276.
12. Gorham E. 1991. Northern peatlands: role in the carbon cycle and probable responses to climatic warming. Ecol. Appl. 1, 182–195.
13. Gunnarsson U., Rydin H. 1998. Demography and recruitment of Scots pine on raised bogs in eastern Sweden and relationships to microhabitat differentiation. Wetlands 18, 133–141.

14. Gunnarsson U., Rydin H., Sjörs H. 2000. Diversity and pH changes after 50 years on the boreal mire Skattlösbergs Stormosse, Central Sweden, J. Veg. Sci. 11, 277–286.
15. Gunnarsson U., Malmer N., Rydin H. 2002. Dynamics or constancy in *Sphagnum* dominated mire ecosystems? A 40-year study. Ecography 25, 685–704.
16. Hájková P., Wolf P., Hájek M. 2004. Environmental factors and Carpathian spring fen vegetation: the importance of scale and temporal variation. Ann. Bot. Fenn. 41, 249–262.
17. Harasimiuk M., Wojtanowicz J. 1998. Budowa geologiczna i rzeźba terenu Pojezierza Łęczyńsko-Włodawskiego. [In:] Jeziora łęczyńsko-włodawskie. M. Harasimiuk, Z. Michalczyk, M. Turczyński (eds), Lublin, 41–53.
18. Heijmans M. M., Klees H., Berendse F. 2002. Competition between *Sphagnum magellanicum* and *Eriophorum angustifolium* as affected by raised CO_2 and increased N deposition. Oikos 97, 415–425.
19. Herbichowa M. 1988. Ekologiczne studium rozwoju torfowisk wysokich właściwych na przykładzie wybranych obiektów z środkowej części Pobrzeża Bałtyckiego. Wyd. Uniwersytetu Gdańskiego, 119.
20. Herbich J., Herbichowa M. 2002. Szata roślinna torfowisk Polski. [In:] Torfowiska i torf. P. Ilnicki (ed.), Wydawnictwo Akademii Rolniczej im. Augusta Cieszkowskiego w Poznaniu, 179–191.
21. Herbichowa M., Wołejko L. 2004. Torfowiska nakredowe (*Cladietum marisci, Caricetum buxbaumii, Schoenetum nigricantis*). [In:] Poradnik ochrony siedlisk i gatunków Natura 2000 – podręcznik metodyczny, J. Herbich (ed.), Ministerstwo Środowiska, Warszawa, T. 2, 163–171.
22. Huston M. A. 1994. Biological Diversity. Cambridge University Press, Cambridge.
23. Jasnowski M. 1972. Rozmiary i kierunki przekształceń szaty roślinnej torfowisk. Phytocoenosis 1, 3, 193–209.
24. Limpens J., Berendse F., Klees H. 2004. How phosphorus availability affects the impact of nitrogen deposition on *Sphagnum* and vascular plants in bogs. Ecosystems 7, 793–804.
25. Malmer N., Albinsson C., Svensson B. M., Walle´n B. 2003. Interferences between *Sphagnum* and vascular plants: effects on plant community structure and peat formation. Oikos 100, 469–482.
26. Matuszkiewicz W. 2006. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Wydawnictwo Naukowe PWN, Warszawa, 537.
27. Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M. 2002. Flowering Plants and Pteridophytes of Poland. A Checklist. Ser. Biodiversity of Poland I. W. Szafer Inst. Botany, Polish Academy of Sciences, Kraków, 442.
28. Ochyra R., Żarnowiec J., Bednarek-Ochyra H. 2003. Census Catalogue of Polish Mosses. W. Szafer Inst. Botany Polish Academy of Sciences, Kraków.
29. Ohlson M., Økland R. H., Nordbakken J-F., Dahlberg B. 2001. Fatal interactions between Scots pine and *Sphagnum* mosses in bog ecosystems. Oikos 94, 425–432.
30. Pärtel M. 2002. Local plant diversity patterns and evolutionary history at the regional scale. Ecology 83, 2361–2366.
31. Risager M. 1998. Impact of nitrogen on *Sphagnum* dominated bogs with emphasis on critical load assessment. Ph. D. thesis, Dept. of Plant Ecol., Univ. of Copenhagen, Copenhagen, Denmark.
32. Schuster B., Diekmann M. 2003. Changes in species density along the soil pH gradient – evidence from German plant communities. Folia Geobot. 38, 367–379.
33. Sugier P., Czarnecka B. 2010. Vascular plants versus mosses in lakeland and riverine mires in two regions of eastern Poland. Pol. J. Ecol. 58, 637–646.
34. Tahvanainen T. 2004. Water chemistry of mires in relation to the poor-rich vegetation gradient and contrasting geochemical zones of northeastern fennoscandian Shield. Folia Geobot. 39, 353–369.

35. Tomassen H. B. M., Smolders A. J. P., Lamers L. P. M., Roelofs J. G. M. 2003. Stimulated growth of *Betula pubescens* and *Molinia caerulea* on ombrotrophic bogs: role of high levels of atmospheric nitrogen deposition. J. Ecol. 91, 357–370.
36. Vitt D. H. 2000. Peatlands: ecosystems dominated by bryophytes. [In:] Bryophyte Biology. A. J. Shaw, B. Goffinet (eds), Cambridge University Press, Cambridge, 312–343.
37. Wheeler B. D., Proctor M. C. F. 2000. Ecological gradients, subdivisions and terminology of north-west European mires. J. Ecol. 88, 187–203.
38. Wieder R. K. 2001. Past, present, and future peatland carbon balance: An empirical model based on ^{210}Pb-dated cores. Ecol. Appl. 11, 327–342.
39. Wołejko L., Stańko R., Pawlikowski P. 2008. Poradnik utrzymania i ochrony siedliska przyrodniczego 7230 – torfowiska alkaliczne. Klub Przyrodników. Świebodzin–Warszawa, 87.
40. Załuski T., Kamińska A. M. 2000. Plant cover diversity of selected peatlands in the Urszulewo Plain in the aspect of synanthropisation. [In:] Mechanisms of Anthropogenic Changes of the Plant Cover. B. Jackowiak, W. Żukowski (eds), Publications of the Department of Plant Taxonomy of the Adam Mickiewicz University 10, Poznań, 291–298.