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Original Articles

Environmental traits determining plant species distribution in selected midforest bogs

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ABSTRACT

The investigations were carried out in six small mid-forest peat bogs with active peat-forming processes, all situated in the Lublin region (Eastern Poland). The bogs represented two floristically different types of peatland: raised bogs and transitional mires species composition analysis and specific chemistry analysis (pH, Eh, carbon content, N, P, Mg, Na, Ca, Mn, Fe, dehydrogenase activity and water level) were performed. The plant associations/communities of the peat bogs represented three phytosociological classes: *Scheuchzerio-Caricetea nigrae, Oxycocco-Sphagnetea*, and *Vaccinio-Piceetea*. The analysis of redox potential measured in the different communities revealed differences in the Eh values between these phytocoenoses ($p < 0.001$). Assotiations representing *Vaccinio uliginosi-Pinetum* were found in areas characterised by the highest redox potential. Redox potential values in these communities were significantly higher than the values recorded in bog communities and mosaic associations. Seasonal variability of the redox potential was noted as well. The current research indicates that soil chemical parameters: pH, Eh are closely related with water table level and plant distributions.

1. Introduction

In recent years, peatland investigations have been focused on determining the distribution along environmental gradients of plant and animal species inhabiting peat bogs (Hàjkova and Hàjek, 2004; Mitchell et al., 2004; Hàjek et al., 2006, 2007). In Western Europe, plant distribution is analysed based on three main environmental gradients, namely the pH/calcium gradient defined by the pH value and Ca^{2+} content, the fertility gradient associated with the availability of biogens (nitrogen and phosphorus), and the hydrological gradient (Bridgham et al., 1998; Bragazza et al., 2005; Hàjek et al., 2006).

Vitt and Wieder (2009) have suggested that the pH/calcium gradient in minerotrophic fens does not show correlations with the fertility gradient. An analysis of hydro-chemical parameters has revealed a greater similarity of transitional mires to bogs than to fens (Rydin and Jeghum, 2006). In the case of transitional mires and bogs, the pH reaction of the surface layers shows that the habitat is highly acidic with low contents of mineral ions. This is determined by the high content of humic acids produced during decomposition of Sphagnum remnants. Such conditions limit the availability of many ions, in particular nitrogen and phosphorus (Rydin and Jeghum, 2006; Vitt and Wieder, 2009). Hence, in this type of peat bogs, the pH/calcium gradient plays a key role, whereas the hydrological and fertility gradients have a minor importance (Hàjek et al., 2002).

The hydrological gradient determines the distribution of vegetation in peat bogs, since the water table undergoes considerable seasonal fluctuations (Tobolski, 2004; Bragazza et al., 2005; Dwire et al., 2006). Changes in moisture content are accompanied by a number of changes in the physico-chemical properties of soil, e.g. oxygen, nitrogen, and phosphorous availability, or changes in the redox potential.

Plants are characterised by varied tolerance to changing oxido-reduction conditions (Eh) and soil pH. Investigations conducted by Dwire and co-workers on riparian meadows (2006) have shown a high correlation of floristic diversity with the hydrological gradient and soil redox potential. As indicated by Pennington and Walters (2006), natural plant communities can be used for characterisation of aerobic conditions in moor soils. Vascular plants and mosses are highly adapted to nutrient- and oxygen-poor habitats through a variety of means, such as aerenchymatic tissue, internal recycling of N and a short root system (Aldous, 2002).

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There are many studies describing relationship between vegetation types in mountain and boreal mires and the environmental factors of a habitat (Wheeler and Proctor, 2000; Økland et al. 2001; Hàjek et al., 2002; Wojtuń et al. 2013). In contrast, relationships between environmental factors and vegetation have not been well described in the literature for wetlands in Eastern Poland (Wassen and Joosten, 1996; Pawliskowski et al., 2013). From the physiological-ecological point of view, the redox potential indicates what chemical compounds essential for plant growth and in what form are present in the habitat. For instance, 0 mV soil Eh points to oxygen and nitrate depletion as well as availability of iron and manganese forms as electron acceptors. A redox potential of 400 mV indicates the presence of oxygen in the environment despite strong hydration of soil (Armstrong, 1967; DeLaune et al., 1990). Pezeshki et al. (1996) reported that under controlled experimental condition net photosynthesis and biomass of cattail and sawgrass was lower at Eh below 250 mV and net photosynthesis decreases to zero at 200 mV in sawgrass, while cattail maintained photosynthesis even at 200 mV. This knowledge is particularly important when activities focused on renaturalisation of degraded peat bogs are undertaken.

The research hypothesis investigated in this paper is that there exists an Eh gradient which determines the presence of particular vegetation communities in selected bogs and transitional mires in the Lublin region in Poland.

2. Material and methods

In the present study, we analysed the vegetation of bogs and transitional mires and the physico-chemical parameters of these habitats, in particular pH, redox potential, nitrogen and phosphorus content, and dehydrogenase activity (DHA).

2.1. Study site

The term midrofest peat bog in our research means small peat bogs that occur in small hollows without runoff surrounded by forest associations (*Vaccinio uliginosi-Pinetum, Molinio-Pinetum*, *Lecobryo-Pinetum*) growing on mineral soil. The investigations were carried out in six midforest peat bogs – Macoszyn, Osowa, Stulno, Józefów, Aleksandrów, and Tarnowola, which are located in protected areas (Landscape Park or Natura 2000 area). In physical and geographical terms, the first three sites are located on the Łęczna-Włodawa Plain, which is a mesoregion of Western Polesie. The other three sites are situated on the Biłgoraj Plain (Kondracki, 2002). Peat bogs in Łęczna-Włodawa Plain are older and deeper (data not presented) than peat bogs in Biłgoraj Plain (Table 1).

The climate is temperate with a mean annual temperature of 8.9 °C in 2012, 8.5 °C in 2013, 9.5 °C in 2014. The coldest month was February with temperature -7.7 °C and the warmest month was July with 22.6 °C. Average annual total rainfall amounted of 530 mm in 2012, 620 mm in 2013, 735 mm in 2014 (Włodawa, Zamość stations).

2.2. Research design

Floristic and phytosociological investigations allowed us to determine the species composition of the plant associations/communities present in the analysed peat bogs. The mapping of existing plant communities was performed on each studied object. A route method was used to determine the ranges of plant patches (Faliński 1990) using the GPS location system. Within the scope of each identified community, homogeneous places were designated, according to commonly used Braun-Blanquet method [1964]. Passing zones of one phytocoenosis to the other and unrepresentative places were omitted. The cover of species in each phytosociological relevés was given according to the Braun-Blanquet scale [1964]: 5 - any number of individuals, covering more than 75% of the phytosociological relevés area; 4 - any number of individuals, covering 50–75% of the phytosociological relevés area; 3 - any number of individuals, covering 25–50% of the phytosociological relevés area; 2 – large number of individuals, covering 5–25% of the phytosociological relevés area; 1 - large number of individuals (5–50 individuals), coverage not exceeding 5% of the phytosociological relevés area; + - small number of individuals (2–5 individuals), slight cover; r - very small number of individuals (1 individual), negligible coverage. A total of 94 phytosociological relevés were taken at studied objects. Plant species were recorded during the spring and summer of 2012 at each location in 25 m^2 plots. The phytosociological classification and nomenclature of the plant communities were based on a paper by Matuszkiewicz (2012). The nomenclature of vascular plants was adopted from Mirek et al. (2002) and that of bryophytes followed Ochyra et al. (2003).

Based on our plant species inventory and phytosociological classification, a detailed lithological identification of the sediments of each peat bog was carried out on a grid of geological drilling. Drilling was performed with an INSTORF probe at all sites to reach the mineral bottom. We selected 19 boreholes for permanent monitoring of environmental factors (pH, Eh, DHA, water level) across 11 vegetation types, 3 boreholes in each object and additional one in Osowa. The boreholes were localized in central part of peatlands along orthogonally oriented transects (NS; WE) at 50 m intervals. The distribution of plots was not randomized. During three seasons (spring, summer and

Table 1
Site characteristics.

Locality	Surface area of the locality (ha)	Max. depth of peat deposits (mean)	Predominant plant communities	Form of protection
Macoszyn 51o23′26.5″ N 23o27′36.2″ E	2.0	250 cm (160 cm)	*Sphagno-Caricetum rostratae* STEFFEN 1931, *Eriophorum vaginatum-Sphagnum fallax* HUECK 1928	Natura 2000 Lasy Sobiborskie PLH 60043
Osowa 51o24′58.2″ N 23o33′48.9″ E	2.9	300 cm (260 cm)	*Sphagno-Caricetum rostratae* STEFFEN 1931, *Eriophorum vaginatum-Sphagnum fallax* HUECK 1928	Sobibór Landscape Park
Stulno 51o22′57.7″ N 23o36′56.8″ E	2.7	250 cm (195 cm)	*Sphagno-Caricetum rostratae* STEFFEN 1931, *Rhynchosporetum albae* KOCH 1926, *Eriophorum vaginatum-Sphagnum fallax* HUECK 1928	Sobibór Landscape Park
Józefów 50o29′12.7″N 23o01′15.4″E	1.5	90 cm (75 cm)	*Caricetum lasiocarpae* KOCH 1926, *Rhynchosporetum albae* KOCH 1926, *Eriophorum vaginatum-Sphagnum fallax* HUECK 1928	Natura 2000 Roztocze PLB060012
Aleksandrów 51°28′41.8″ N 22°48′55.2″ E	22.5	200 cm (170 cm)	*Caricetum lasiocarpae* KOCH 1926, *Vaccinio uliginosi-Pinetum* kleist 1929, *Eriophorum vaginatum-Sphagnum fallax* HUECK 1928	Natura 2000: Uroczyska Puszczy SolskiejPLH060034 and Puszcza Solska PLB060008
Tarnowola 50°29′46.6″ N 23°00′40.2″ E	0.4	90 cm (65 cm)	*Sphagno-Caricetum rostratae* STEFFEN 1931, *Vaccinio uliginosi-Pinetum* kleist 1929, *Eriophorum vaginatum-Sphagnum fallax* HUECK 1928	Natura 2000 Roztocze PLB060012