Aquatic Botany 147 (2018) 24–33

Contents lists available at ScienceDirect

Aquatic Botany

journal homepage: www.elsevier.com/locate/aquabot

Potential changes of elemental stoichiometry and vegetation production in an ombrotrophic peatland in the condition of moderate nitrogen deposition

Marek Kruk*, Katarzyna Podbielska

Department of Tourism, Recreation and Ecology, University of Warmia and Mazury, 10-957 Olsztyn, Poland

ARTICLE INFO

Keywords:
Ombrotrophic peatland
N:P stoichiometry
Vegetation production
Sphagnum
Structural equation modelling

ABSTRACT

Our study aims to elucidate how decreases in peatland above-ground net primary production (AG-NPP) might be explained by a network of relationships between some nutritive elements and the N:P ratios in different plant groups. We focused on three functional groups of peatland plants with different growth form: *Sphagnum* mosses, shrubs, and non-woody vascular plants (NW-VP) in an ombrotrophic peatland in northeastern Poland affected by moderate N deposition. We measured AG-NPP and elemental stoichiometry (C, N, P, Ca, Fe) in different plant species belonging to these functional plant groups, and growing within different microhabitats: *Sphagnum* bog hummocks and hollows, and *Sphagnum* mat. The functional groups significantly differed only in AG-NPP, but not in nutrient contents within the study sites. *Sphagnum* mosses had the highest mean production (247.6 g/m^2), while it was lower in NW-VP (71.7 g/m^2) and shrubs (49.4 g/m^2). The plant groups had a comparable N:P ratio. The N:P ratio was correlated with K, Ca, and Fe, but not with N in *Sphagnum* mosses. In NW-VP and shrubs, we observed an increased N:P ratio with increasing plant N content. However, increased N:P ratio was only negatively correlated with C content in *Sphagnum* mosses. Based on these data, we performed an analysis of elemental and production relations in peatland vegetation at the ecosystem level. Structural equation modelling (SEM) suggests that an increase of the N:P ratio in the vegetation, induced by higher N concentration, plus indirect effects of Fe, might explain a lower carbon concentration in plant production. As an outcome of this network of interactions, the AG-NPP of the entire peatland vegetation might be reduced.

1. Introduction

Despite ecological research conducted in recent years on the responses of plants to increased atmospheric N deposition in ombrotrophic peatland ecosystems (Aerts et al., 1992; Limpens and Berendse, 2003; Larmola et al., 2013; Wu et al., 2015), the effect of this on vegetation production is still an open question. The ombrotrophic peatland environment, which is poor in available biogenic elements, affects the ratios between N and P in plants, thus determining their vitality, growth, and reproduction. Some authors conclude that enhanced supplies of N may alter C cycling in peatland ecosystems by lowering the level of its sequestration (Bubier et al., 2007; Limpens et al., 2011; Kivimäki et al., 2013; Larmola et al., 2013). This might also influence the production of *Sphagnum* mosses (Breeuwer et al., 2009). However, the elemental interactions that determine changes of peatland vegetation production at the ecosystem level, and the role of plant functional groups (Dorrepaal, 2007) accompanying *Sphagna* in these habitats remain unclear. Understanding the multi-factorial mechanisms of vegetation response to air pollution is increasingly important for making better prognoses and organizing the management of peatland ecosystems.

The concept of this study stems from the theory of ecological stoichiometry (Sterner and Elser, 2002), which underscores the importance of interactions between nutrients in explaining the condition and status of organisms and linking them with nutrient ratios in the environment. As for peatland vegetation, the C:N:P or N:P ratios were of particular interest, including their variations and effects on plant production (Verhoeven et al., 1996; Güsewell and Koerselman, 2002; Jiroušek et al., 2011; Kaštovská et al., 2017). Some authors included other nutrients, such as potassium, in these stoichiometric interactions (Hoosbeek et al., 2002; Breeuwer et al., 2009; Wang and Moore, 2014). There are, however, no studies on peatland vegetation that combine N:P ratios with other nutrients (K, Ca, Fe) in the network of elemental interaction and its effect on vegetation production at the ecosystem scale in the context of N deposition. The present study intends to fill this gap, as this is essential to understanding and predicting possible changes in peatland vegetation under conditions of global change (Wang and Moore, 2014).

* Corresponding author.
E-mail address: mkruk@uwm.edu.pl (M. Kruk).

https://doi.org/10.1016/j.aquabot.2018.03.004
Received 7 November 2017; Received in revised form 18 March 2018; Accepted 24 March 2018
Available online 26 March 2018

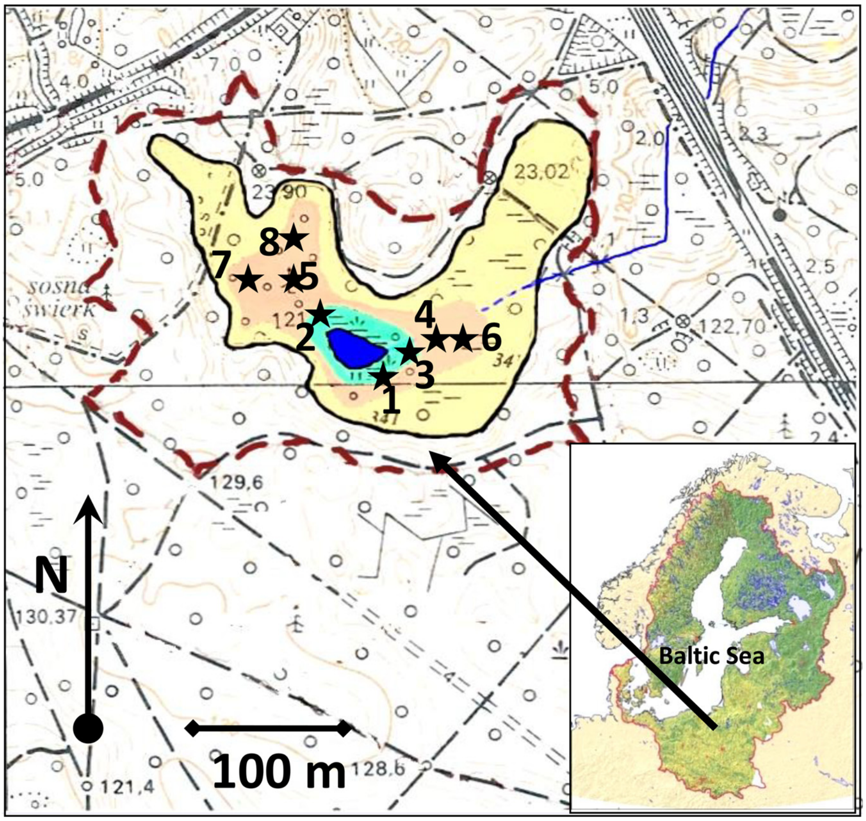

Fig. 1. Topographic and geographical location of studied*Sphagnum* peatland with site numbers and positions (asters). Blue patch – humic lake, green patch – *Sphagnum* mat, orange patch – *Sphagnum* bog, yellow patch - transition zone, dashed line – a range of catchment area (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

Differences in nutrient relationships in the above-ground net primary production (AG-NPP), as defined by Andersen et al. (2013), of peatland plants grouped into growth-form-based types, i.e., *Sphagnum* mosses, shrubs, and non-woody vascular plants (NW-VP) such as graminoids and forbs, have not been compared in depth. *Sphagnum* moss species, peatland graminoids such as *Eriophorum vaginatum* or *Carex limosa*, and shrubs like *Oxycoccus quadripetalus*, *Vaccinium uliginosum* or *Ledum palustre* differ considerably in structure, life cycle, mineral balance and nutrient use efficiency (Aerts et al., 1999). *Sphagnum* mosses are characterized by a slow decomposition rate compared to vascular plants (Dorrepaal et al., 2005), but they have a relatively short life cycle of approximately seven years (Malmer, 1988). Typical perennial vascular plants live much longer by the generation of rhizomes. They are more efficient at photosynthesis than *Sphagna* (Leppala et al., 2008), so they can enhance ecosystem net primary production and C exchange (Laine et al., 2012). They also contain more N and P in their living tissues than do mosses (Wang and Moore, 2014). There are significant differences among graminoids and shrubs in energy and nutrient allocation. The first group mostly allocates these resources to the roots, while shrubs allocate them to woody stems (Hobbie, 1996). Bog shrubs, NW-VP, and *Sphagnum* mosses also differ widely in nutrient resorption effectiveness. For example, N allocation efficiency from senescing *Sphagnum* tissues was 25%, while in *Eriophorum vaginatum* it was 50% and in the shrub *Vaccinium myrtillus,* it was 17% (Kaštovská et al., 2017). Interestingly, shrubs such as the blueberry can stimulate organic matter decomposition and nutrient cycling more than graminoid cotton-grass. This is linked with more stable anoxia conditions in microhabitats where *E. vaginatum* occurs (wet bog hollows) than in typical peatland shrub microhabitats (drier bog hummocks) (Kaštovská et al., 2017). We assumed that these differences among the three functional groups would be reflected in dependencies between N:P stoichiometry and elemental composition in new biomass. Knowledge about nutrient relationships in these plant groups is useful for understanding transformations in peatland vegetation when its environment is affected by anthropogenic factors, especially nitrogen supply from the atmosphere, and climate change effects in general (Güsewell, 2004; Dorrepaal, 2007).

The relevant context of this work was the response of vegetation in nutrient-deficient habitat to anthropogenic processes originating from atmospheric pollution. The predicted annual range of nitrogen deposition until 2020 is 10–14 kg/ha/year in the southern Baltic region (Geels et al., 2012), which exceeds the critical N load for European peatlands set at a value of 10 kg N/ha/year (Bragazza et al., 2004). Such an increased level of N supply is typical for many areas in the temperate zone that are neither primeval nor highly polluted, as is the case of the studied peatland. Identifying the network of relationships among elemental parameters and biomass production under these conditions is essential for a better understanding of the mechanisms responsible for maintaining or modifying the functions that permit rebuilding vegetation structure, because of highly probable increases in air pollution in the future.

The first aim of the present study was to determine how the N:P ratio varies with the Ca, K and Fe content in the AG-NPP of three major functional groups of peatland vegetation. Nitrogen, phosphorus, calcium, and potassium can drive net primary production and are considered deficient in bogs (Hoosbeek et al., 2002; Bragazza et al., 2004). In contrast, reduced Fe, which is widespread in this environment (Gorham et al., 1984), can be toxic to plants (Ernst, 1990).

In this study, we examined the following hypothesis: Under moderate N deposition, increasing N concentration in plant production and a subsequent increase in N:P ratio will lower plant C concentration and indirectly cause a lowering of the AG-NPP of peatland vegetation.

2. Materials and methods

2.1. Study area

The study was conducted in the Olsztyn Lakeland, which is in the western part of the Masurian Lakeland (northeast Poland). The peatland examined lies within a forest complex, south of the city of Olsztyn