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Seedling recruitment in peat bogs in contrasting hydrologic conditions

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Abstract: The study examined the effect of variation in hydrology on seedling recruitment of shrubs, trees and herbs in peat bogs. The establishment of plants and hydrologic conditions were followed in two peatlands in the Polesie Zachodnie region, Eastern Poland. Meteorological conditions in the study sites ranged from very dry (2006) to very wet (2007) and strongly affected ground water level in the bogs. The emergence of woody species typical for advanced vegetation succession was higher in forest-bog, while the recruitment of typical peat bog plants was higher in open bog. Disturbance in the vegetation positively influenced emergence of typical peat bog species and *Betula pubescens*, but the effect was only found in the dry year. Only in *Pinus sylvestris* did recruitment increase in wet seasons. The results suggested that an increase in the number of woody species in peat bogs may be enhanced during relatively wet seasons and that disturbance in the vegetation cover are not required for seedling recruitment of these plants.

Additional key words: *Betula pubescens*, disturbance, ground water level, *Pinus sylvestris*.

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Introduction

Hydrological conditions affect the distribution of plant species and the direction of vegetation processes in peat-forming ecosystems (Haraguchi 1991; Pellerin and Lavoie 2003). Successional transformations of vegetation, the development of shrubs and trees in peatlands are often caused by a decrease of ground water level due to human activity (Laine et al. 1995; Frankl and Schmeidl 2000). Such changes in vegetation may also occur as a result of the natural variation in water level between years, especially during long periods of natural droughts (Noryśkiewicz 1978). The development of woody vegetation changes crucial environmental conditions for plants, e.g. insolation in the vegetation canopy, temperature and moisture of soil (Breshears et al. 1997, 1998). As a consequence typical peat bog species decrease due

to tree growth on previously unforested bogs and they may finally become extinct in these localities (Laine et al. 1995).

The emergence of new species is often limited in plant communities. The vegetation canopy is considered as a barrier for the process of succession (Grubb 1977). The recruitment of seedlings is often restricted by the litter layer and dense vegetation cover (Borkowska 2004; Overbeck et al. 2003). Disturbances in the vegetation structure can provide opportunities for seed germination and seedling recruitment (Harper 1977).

Many plants in peat bogs including woody species are clonal and their recruitment from seeds is rather scarce (Ejankowski 2008). Sexual reproduction in clonal species can be expressed in favourable years and can play a significant role in the long-term dynamics of a population (Weppler et al. 2006). Repro-

duction from seeds in peat bogs may be advantageous for plants, because it determines the immigration potential enabling the colonization of bare sites (Campbell et al. 2003). However, after dispersion seeds must find favourable conditions to break dormancy, germinate and grow. The emergence of typical peat bog plants may be constrained by harsh climatic conditions, e.g. high temperature of peat and long periods of droughts, while more tolerant species are favoured (Cooper et al. 2004; Lavoie et al. 2005).

Small-scale natural disturbances caused by the activity of animals and the anthropogenic impact of peat extraction are common in peat bogs. Disturbances in vegetation canopy can enable the emergence of new individuals and new species that affect species richness in different habitats (Grubb 1977).

Besides propagule availability soil conditions are the major factor determining the pattern of revegetation on bare peat surfaces (Salonen 1987, 1994; Cooper et al. 2004). The prediction of responses of desirable and undesirable species to critical environmental conditions is important for protection planning and restoration measures in peat bogs (Campbell and Rochefort 2003). From this point of view knowledge of the conditions and mechanisms that affect the establishment of trees and other woody species are needed.

The objectives in this study were to determine the effect of year-to-year variation in environmental conditions in peat bogs on the emergence of early life-history stages of woody species compared to typical peat bog plants and to examine the role of disturbance in seedling recruitment in contrasting hydrologic conditions.

Methods

The study sites were situated near town Włodawa in the Polesie Zachodnie region in Eastern Poland (Kondracki 2002). The study centred on two nutrient-poor, rain-fed ombrotrophic bogs, Małe (51°25' N, 23°30' E) and Żłobek (51°29' N, 23°31' E). The two peat bogs differed in their vegetation cover. Małe is an open bog with vegetation comprising *Sphagnum* mosses, perennial herbs and shrubs. Woody vegetation occupied only the margins of this bog. Żłobek is a forest-bog covered by shrubs and trees with raised and transitional bog vegetation (Fijałkowski and Pietras 1990). Plant communities with Scots pine (*Pinus sylvestris* L.) and pubescent birch (*Betula pubescens* Ehrh.) predominate the vegetation of this bog.

A permanent sample plot was used in each of the study site. The experimental transect was 0.5 m wide and 17.5 m long in Małe bog and 0.5 m wide and 18.5 m long in Żłobek bog. Each linear transect consisted of alternating undisturbed and disturbed sites (0.5 m × 0.5 m) separated by blind area of the same size. A

total of 35 experimental quadrats were marked out in the field. In disturbed sites all plants and the upper peat layer (0–5 cm) were removed in every season before the vegetation season started to imitate the effects of animal activity. Seedling emergence and the number of juvenile plants in each of the study sites were recorded every month between April and November in years 2006–2008. Mosses and vegetative ramets of vascular plants were regularly removed in the disturbed quadrats. At the end of each season juvenile plants with at least two mature leaves were taken out from the ground and collected. The samples were cleaned, identified and counted in the laboratory. Identification of plants was carried out using Csapody (1968) and Muller (1978). The nomenclature of plants followed Mirek et al. (2002). Emergent plant species were classified into two groups following Matuszkiewicz (2001), (1) typical peat bog plants characteristic of *Oxycocco-Sphagnetea* and related classes, and (2) woody species characteristic of the class *Vaccinio-Piceetea* and other types of forest and bushy vegetation.

The water level was measured every month from April to November between 2006 and 2008 using a ruler and two perforated pipes situated in the vicinity of the experimental transects in each of the study sites. The depth of the water table was followed in relation to the ground level. Precipitation data of the half-year from January to June for the town of Włodawa located 3 km N away from Żłobek and 6 km N away from Małe were taken into consideration when the hydrological conditions were compared. Data for the study period originated from the NOAA Satellite and Information Service.

A two-way ANOVA (Sokal and Rohlf 1995) was performed to test the effects of disturbance and differences of environmental conditions between years on the emergence of woody plants. Normality was tested by Levine test, and the homogeneity of variance was tested by the Shapiro-Wilk test, prior to analysis. All the data were transformed ($\log_{10} x + 1$) to meet the assumptions of parametric tests. Calculations were performed using Statistica ver. 8.0.

Results

Meteorological conditions in the Polesie Zachodnie region varied considerably between years. In the first half-year (January–June) in 2006–2008 precipitation was 161 mm, 349 mm and 292 mm, respectively. The hydrological conditions in both peat bogs reflected precipitation in particular years. The ground water table in the study sites in 2006 was mostly below ground level, and it was much lower than in 2007 and 2008 (Fig. 1). The decreased water level in 2006 was especially marked in the forest-bog (on average –346 mm). In the open bog the water table was 38 mm above

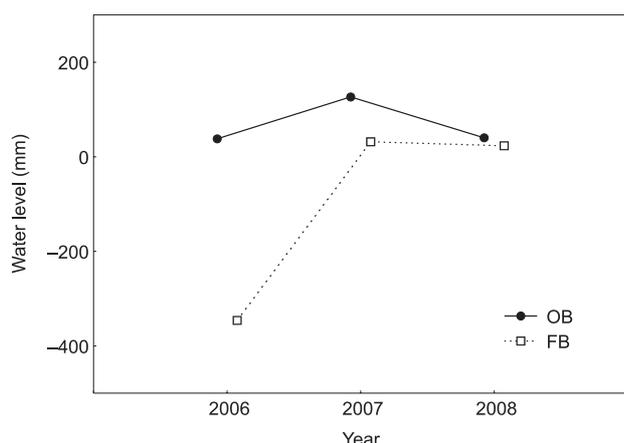


Fig. 1. Changes of ground water level from April to November in peat bogs in the Polesie Zachodnie region, Eastern Poland. Signatures: OB – open bog, FB – forest-bog. Circles and squares indicate mean values

ground level. During the summer periods in the years 2007 and 2008 each study site was waterlogged.

A total of thirteen vascular plant species were recognized in the bogs. Mostly perennial herbs were found: *Carex canescens* L., *C. lasiocarpa* Ehrh., *C. nigra* Reichard, *C. rostrata* Stokes, *C. vesicaria* L., *Eriophorum vaginatum* L., *Juncus* sp., *Lysimachia vulgaris* L., *Peucedanum palustre* (L.) Moench. There were only three shrubs and trees in the study sites: *Pinus sylvestris* L., *Betula pubescens* Ehrh., *Salix* sp. and one dwarf shrub *Oxycoccus palustris* Pers. (Table 1). Common in the forest-bog was only *O. palustris*, whereas the woody species were observed rarely, e.g. *B. pubescens* and *P. sylvestris*. Typical peat bog plants (including all herbs and *O. palustris*) were in the majority.

Over three growing seasons the emergence of these plants in undisturbed quadrats was higher in the open bog, while the recruitment of woody species was higher in the forest-bog, for which these species were characteristic (Fig. 2). The density of woody species was 0.7 m^{-2} in the open bog and 8 m^{-2} in the forest-bog. In comparison, the total number of typical peat bog plants during these three years was very high, 77.8 m^{-2} in the open bog and 1.6 m^{-2} in the forest-bog.

The effect of disturbance was observed in both study sites. More available for seedlings of the typical peat bog species were disturbed quadrats than undisturbed vegetation. These species occurred in all the disturbed sites in the experiment, although plants in the gaps were more numerous in the open bog (751.5 m^{-2}), than in forest-bog (91.6 m^{-2}). The opposite pattern was revealed in the woody species. *Pinus sylvestris* was found more often in the forest-bog than in the open bog and *B. pubescens* was observed only in the forest-bog. Moreover, disturbance limited the emergence of Scots pine. *Pinus sylvestris* was found only in intact vegetation (Table 1 and Fig. 2). In *B. pubescens* the effect of disturbance was not found (Table 1).

Table 1. F-values of ANOVA test of influence of disturbance, year and effect of interaction between them on number of juvenile plants of woody species in peat bogs

Species	Disturbance	Year	Disturbance × Year
<i>Oxycoccus palustris</i> Pers.	19.73***	21.18***	25.83***
<i>Betula pubescens</i> Ehrh.	2.76 n.s.	5.75**	7.48***
<i>Pinus sylvestris</i> L.	4.63*	3.35*	3.61*
<i>Salix</i> sp.	2.31 n.s.	2.31 n.s.	2.31 n.s.

Data were log-transformed ($\log_{10}(x+1)$) prior to analysis. Signatures: P-values * <0.05 , ** <0.01 , *** <0.001 , n.s. – no significant.

In this study emergence varied between seasons. The results indicate that recruitment in the majority of species was affected by differences of environmental conditions between years (Table 1). Generally, recruitment of typical peat bog species including *O. palustris* was the highest in the dry season of 2006. In the consecutive years 2007 and 2008 number of plants was limited in both undisturbed and disturbed sites. An especially strong decrease was observed during the very moist year of 2007 (Fig. 3). The emergence of *O. palustris* was not simply influenced by disturbance and environmental conditions of the peat. Interaction between “Disturbance” and “Year” means that the effect of disturbance on seedling recruitment was related to the year (Table 1). This was confirmed by the negative effect of the very moist 2007, when the number of plants in undisturbed sites was close to the number of plants in the disturbed quadrats (Fig. 3).

Generally, recruitment of typical bog species was high in the very dry year 2006, and it was hampered in relatively wet 2007 and 2008. Scots pine emerged only in 2007 and 2008, and it was absent in the year 2006 (Fig. 3). It was also noticeable that the number of *P. sylvestris* was higher in the very wet year 2007, than in the drier 2008 (Fig. 3). Environmental condi-

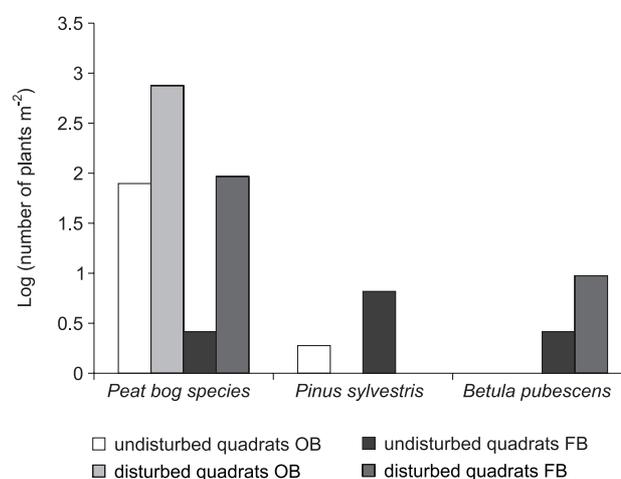


Fig. 2. Number of juvenile plants in two types of peat bogs in the Polesie Zachodnie region (Eastern Poland) during three year period

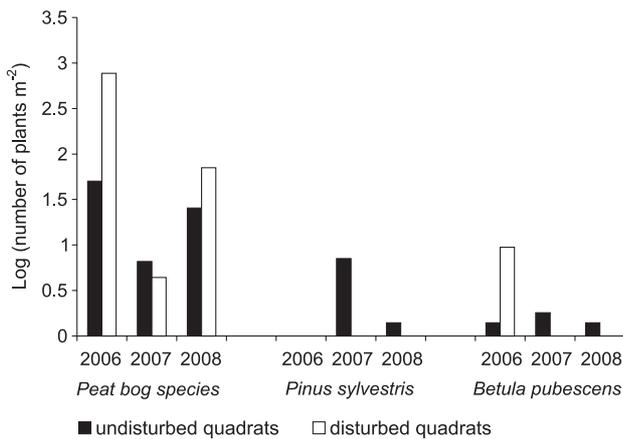


Fig. 3. Number of juvenile plants in peat bogs in the Polesie Zachodnie region (Eastern Poland) in the years 2006–2008

tions positively affected seedling recruitment in this species (Table 1).

The emergence of *Betula pubescens* also varied between years. Number of juvenile plants of pubescent birch was higher in the dry season, than in both the wet seasons (Fig. 3). In this species disturbance influenced the number of plants only in relation to year (Table 1). The number of *B. pubescens* increased in gaps in the dry year, while in wet seasons pubescent birch occurred only in the undisturbed sites, in a similar way to Scots pine (Fig. 3). No effects were found in the other woody plant *Salix* sp., which was found sporadically in the study sites (Table 1). It is likely that a longer time series would be needed to indicate significant correlations in this plant.

Discussion

The effect of type of bog on recruitment was not statistically analysed in this study, however it seems that seedling emergence was in accordance with current vegetation in the study sites. The results suggest that in the open bog emerge mainly plants characteristic for peat bogs, while in the forest bog emerge not only woody species but also typical peat bog plants. Hence, the regeneration potential of swampy forests to development into open bog in suitable hydrologic conditions seems to be relatively high.

A wide range of meteorological conditions occurred during the course of the study between 2006–2008. Using the data on precipitation in the half-year from January to June in the Polesie Zachodnie region, the seasons were classified into three moisture classes according to Kaczorowska (1962), i.e. very dry in 2006, very wet in 2007 and wet in 2008. High year-to-year and season-to-season variability of precipitation and the occurrence of extremely dry and very wet years are characteristic climatic factors in the region (Kaszewski et al. 2009).

Meteorological data and peat hydration revealed that precipitation determined the observed hydrologic conditions in the bogs studied. Changes in ground water and water level in lakes in the area of Polesie are strongly related to precipitation magnitude (Michalczyk 1998). The variation in peat hydration allows the comparison of seedling recruitment of peat bog plants in contrasting hydrological seasons. The presented results suggest that climatic and hydrologic factors in particular years can influence considerably emergence of seedlings in peat bogs.

Seedling recruitment in peaty habitats may be hampered by unfavourable conditions and absence of 'safe sites' for seeds (Cooper et al. 2004). In typical peat bog plants the most appropriate conditions for seedling emergence occurred in the relatively dry season, but it is probable that a similar effect would occur in a climatically normal season. Longer time series would be needed to verify this presumption. Soil moisture during the dry period was suitable for the emergence of characteristic peat bog plants due to high capillary rise in the peat substrate (Schweikle 1990).

The hydrological conditions of the Polesie Zachodnie region were strongly transformed during the second half of 20th century. They are still strongly influenced by human activity (Wilgat et al. 1991) and probably by climatic compounds. It is noticeable that precipitation in Włodawa decreased and mean temperature in the last decades (1951–2006) increased approximately 0.7°C (Kaszewski et al. 2009). Draw-down of water level in this area influenced development of shrubs and forests instead peat bog vegetation, as found in other regions (Laine et al. 1995; Chmielewski 2001; Pellerin and Lavoie 2003). In those swampy forests Scots pine and pubescent birch belong to the most important trees species. They are common in bogs undergoing succession and are the colonizers in disturbed sites after peat mining (Salonen 1994; Matuszkiewicz 2001).

A general pattern in peat bog vegetation can be recognised: higher peat hydration negatively affects the recruitment of typical bog species, but positively affects the recruitment of trees. Unlike the majority of vascular plants characteristic for open bog stage the emergence of *Pinus sylvestris* was enhanced during wet seasons and on the dense vegetation layer. This observation suggests that the development of woody species in well hydrated sites is limited by the high mortality of plants in later age groups, rather than low seedling recruitment. High mortality in Scots pine was found in well hydrated sites by Gunnarsson and Rydin (1998). High water levels may negatively affect the development of trees, especially by root injuries and the reduction of vegetative growth (Kozłowski 1997). The emergence of *Betula pubescens* also responded to peat hydration. Seedling recruitment in

this species was generally higher in the dry season, than in both the wet seasons.

Disturbances in the vegetation canopy stimulated seedling recruitment in the majority of species in this study. Removal of the dense vegetation and litter layer enables the germination of seeds and enhances the survival of plants (Borkowska 2004; Overbeck et al. 2003). However, rooting up the ground by wild boar in forest communities reduced emergence of new seedlings and plants from vegetative reproduction. This effect was caused by vertical movement of seeds and other propagules in the soil after animal activity (Faliński 1986).

It is interesting that in the study, the positive role of disturbances was observed mostly during dry seasons. Disturbed sites in peat bogs were commonly more hydrated than neighbouring intact sites. The number of emerged plants decreased in wet years, especially in more hydrated disturbed sites probably due to waterlogging.

The majority of species in this study emerged in disturbed sites, rather than in intact vegetation. Higher abundance in gaps was observed in e.g. *Oxycoccus palustris*. The reason that few species germinated on the vegetation layer (i.e. *P. sylvestris*) and others emerged only or mainly in gaps (*Betula pubescens*) may be partly explained by the large variation in the seed size of these plants. Seeds of the latter species are small-sized. The probability of these seeds being buried in the peat deposit is seemingly very high. Large seeds probably had more chances to remain on the surface and germinate on intact vegetation. Moreover, seeds of *O. palustris* were also observed stabilized on the *Sphagnum* layer by remnants of its fruits.

It was also suggested that the dense vegetation canopy can limit the emergence and survival of plants, and hence hamper the exchange of species during vegetation succession (Grubb 1977). However, the results show no positive effect of disturbance on the emergence of *P. sylvestris*. The absence of Scots pine in gaps could be caused by unfavourable conditions on bare peat, dryness or waterlogging. On the other hand, repeatable disturbances could remove seeds of this species from upper peat layer. The positive role of disturbance in *B. pubescens* was restricted to the dry season. Generally, a canopy composed of *Sphagnum* did not restrain seedling recruitment of the species typical of forest vegetation, that are important during vegetation succession.

The results are in accordance with the observations of successful recruitment of pubescent birch on bare peat surfaces. High ability to dispersal by wind, and high growth rate in seedlings of the genus *Betula* may explain the later prevalence of this species in severely disturbed bogs (Campbell et al. 2003; Campbell and Rochefort 2003).

In conclusion, the high hydration of peat substrate can stimulate the emergence of the woody species in bogs undergoing succession. On the other hand high-humidity conditions stimulate the development of *Sphagnum* mosses that contribute to the regeneration of peat bogs (Chirino et al. 2006). Typical peat bog species, mostly herbs, regenerate in lower moisture conditions. The results suggest also that the emergence of woody species is not restricted in bogs when the vegetation canopy is dense. Woody species can emerge on undisturbed vegetation that may promote these plants over the other vascular species during successional changes of plant communities.

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