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Modern pollen–vegetation relationships in traditionally mown and unmanaged boreal rich-fen communities in central Norway

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ABSTRACT

Knowledge of the relationship between vegetation and modern pollen deposition is necessary to improve the interpretation of fossil pollen samples. We compared the cover of plant species and the modern pollen deposition in surface moss samples in 49 plots in rich-fen vegetation from the boreal vegetation zone in Norway in two areas (one oceanic and one more continental). These rich fens were used for traditional hay cutting until ca. 1950. Three management regimes are used: 1) biennial mowing, 2) quadrennial mowing and 3) unmown. The unmown areas were traditional hay fens, with no management since the 1950s. Of the 89 plant taxa and corresponding 65 taxa of pollen and spores, 29 and 22, respectively, were sufficiently represented in both vegetation and as pollen, to allow direct comparisons of the two data sets. Most of the plant and pollen taxa were found in the plots from both study areas and in plots with different mowing frequencies. Therefore, quantitative differences in vegetation cover and pollen percentages were the main focus in this investigation of plant–pollen relationships in mown and unmown vegetation. The relative difference in plant cover was largest between biennially and unmown plots. 12 species showed a significant positive correlation with difference in plant cover between mown and unmown areas ($p < 0.05$; Wilcoxon signed rank test), most pronounced for *Molinia caerulea* (most common in unmown plots), and *Carex dioica* and *Thalictrum alpinum* (most common in mown plots). A significant positive plant–pollen correlation (Spearman rank-correlation) was found for 10 pollen taxa. *Thalictrum alpinum* is a very good pollen indicator, and Cyperaceae, *Eriophorum*-type and *Pedicularis*-type are good pollen indicators of mowing. Poaceae/*M. caerulea* and *Succisa pratensis* are negatively correlated with mowing. The impact of mowing on species composition was similar in both study areas. Mown and unmown areas were differentiated in the vegetation data and could be identified by modern pollen data. These results will improve the interpretation of past land-use practices using pollen analysis of rich-fen vegetation.

1. Introduction

All over northern Europe fens have, for centuries, been important for production of hay for winter fodder. The fertile infields were often of limited extent, so the outfields were of great importance for haymaking, grazing and summer farming (e.g. Ellenberg, 1988; Hjelle et al., 2012; Solem et al., 2012). This long-term regular harvesting has influenced the fens, turning large areas into open semi-natural landscapes. The traditional use of the fens ceased many decades ago in most countries in western and central Europe, including southern Fennoscandia. In parts of central boreal Norway the traditional use of fens, including our study areas, lasted until the 1950s (Moen, 1990; Tretvik and Krogstad, 1999).

Cultural landscapes leave contemporaneous traces in the form of pollen assemblages in accumulating deposits. Pollen analysis is thus a widely used approach for reconstructing the history of past cultural practices and landscapes (e.g. Berglund, 1991). Investigations of the modern local plant–pollen relationship in areas with documented land-use regimes are a basis for reconstructing these practices back in time. The taphonomy of pollen in modern moss samples is comparable to pollen analytical data from peat cores. Pollen assemblages from vegetation dominated by dwarf-shrubs, graminoids or herbs reflect local sources of non-tree pollen (NAP) and thus small-scale vegetation variations (Hjelle, 1999a; Bunting, 2003; Bunting and Hjelle, 2010; Pardoe, 1996). The relationship between number of deposited pollen grains and the corresponding plant cover is complex (e.g. Sugita, 1994), and

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the pollen taphonomy must be taken into account when interpreting pollen assemblages (e.g. Fægri and Iversen, 1989).

Mowing leads to disturbance and changes in available resources and competition between species (Crawley, 1997; Grime, 2001). Species resilient to mowing will be favoured and plants with low and rosette growth forms, with meristems close to the ground or clonal growth, are tolerant to mowing (Klimešová et al., 2008). In addition, stress-tolerant species are less affected by mowing (Grime, 2001; Øien and Moen, 2001). Thus mowing affects the composition of vegetation and species abundance. For example the plant cover of *Thalictrum alpinum* and several *Carex* and *Eriophorum* species increases with mowing in boreal fens (Moen, 1995).

In order to reconstruct past vegetation communities from pollen data the relationship between the vegetation community and the pollen produced and deposited within it must be known. If good pollen–plant relationships exist and the plant community is reflecting a type of land use today, pollen types/species may be identified as indicator taxa for that land-use (cf. Behre, 1981). The present study aims to produce indicator taxa for mown fens which may be of international value when interpreting pollen diagrams. Also the whole pollen assemblage may be used in a comparative approach (Birks and Birks, 1980) to aid in the identification of past vegetation communities or land-use practices. The results from the present study will be combined with plant–pollen data from mown and grazed vegetation types in Western Norway (Hjelle, 1999a) to form a larger data set. This data will aid the interpretation of possible land-use practices (e.g. Gaillard et al., 1994; Hjelle, 1999b) for pollen diagrams from the rich fens in Tågdalen and Sølendet. The data set should also be useful as part of future pollen–plant databases, e.g. the European Pollen Database (http://www.europeanpollendatabase.net/index.php).

The aim of the present study is to assess the modern pollen–plant relationships in rich fens in two study areas. The areas are situated at the transition between the middle and northern boreal vegetation zones, but in different vegetation sections (regional differences oceanity–continentality, Moen, 1999). Both study areas were used for traditional haymaking until ca. 1950. Regular mowing (with a scythe) of permanent plots was reintroduced in the early 1970s and they have been mown regularly for nearly 40 years. The plant communities vary between the study areas, but with the same dominant species, where the impact of mowing on different species is similar (Moen et al., 2012). Further, differences between mowing regimes and unmown areas facilitate various species, giving mainly quantitative differences in plant cover (Moen et al., 2012). We study the correlation between the plants growing in fen vegetation and pollen deposited on a local scale. Three hypotheses are thus put forward: 1) there is a close connection between the taxa in fen vegetation and local pollen deposition, 2) there are small differences in local pollen–plant relationships between the two studied rich fens (regional differences), and 3) differences between mown and unmown vegetation can be detected from the contemporary pollen assemblages. The modern plant–pollen relationship in fens will provide a basis for interpretations of palaeoecological investigations of past land-use in the study areas.

2. Study areas and plant communities

The two study areas (Fig. 1) are both situated at the transition between the middle boreal and northern boreal vegetation zones of central Norway (Moen, 1999). Tågdalen is an oceanic inner-fjord area nature reserve and Sølendet is a continental nature reserve. Tågdalen is part of the markedly oceanic vegetation section while Sølendet is situated on the transition between the indifferent and slightly continental vegetation sections (sensu Moen, 1999). The 20 localities with 49 study plots presented in this paper were established as permanent plots 40 years ago, and vegetation and plant populations dynamics are described in a number of papers (e.g. Moen, 1990, 1995, 2000; Aune et al., 1996; Moen et al., 1999, 2012, 2015; Øien and Moen, 2001; Sletvold et al., 2010; Lyngstad et al., 2016). 10 localities are situated along a line over a distance of 940 m in Tågdalen (Fig. 2a). In Sølendet the 10 localities are situated in an area of just below 1 km^2 (Fig. 2b).

The duration of the growing season is similar in both areas, from the end of May until the first part of September. Tågdalen has an oceanic climate with high annual precipitation and a thick, long-lasting snow cover, while Sølendet has a more continental climate with less precipitation and cold winters (Table 1). The distance between the study areas is 145 km. In both areas calcareous Cambro-Silurian bedrock (Sigmond et al., 1984) is overlaid with base-rich till (Follestad, 1995).

The dominant rich-fen vegetation at Tågdalen and Sølendet forms a mosaic with birch woodland (*Betula pubescens*). Sloping fens (slope > 3°) cover large areas. At Tågdalen the slopes are between 3 and 12° and at Sølendet 3 and 5°. The depth of the underlying peat layer exceeds 50 cm at Tågdalen, and 20 cm at Sølendet. The study areas have the same historical land-use, where the traditional hay cutting declined during the 1930s, and ended in the 1950s. Experimental scything (hereafter called mowing) of permanent plots started in 1973 and was carried out in August, allowing flowering, seed production and dispersal to take place for important species. The localities were established in homogenous fen areas, and the studied plots have been mown regularly biennially or quadrennially since the 1970s, or they have been left unmown for ca. 60 years. The hay crop of the studied communities was estimated to about 110 g/m^2 and 140 g/m^2 (dry matter) in plots mown biennially and quadrennially, respectively (Moen, 1990; Moen et al., 2015; Lyngstad et al., 2016). Biennial mowing represents the traditional practice, where the harvest output was maximized in relation to labour invested. Quadrennial mowing is a possible equivalent to the mowing frequency during periods of extensive mowing, and during the period when hay-cutting was declining.

The terminology of mires follows the Fennoscandia tradition in mire ecology (sensu Sjörs, 1948), separating units related to the main local vegetation gradients. Rich fens are peat-forming mire sites with characteristic vegetation dominated by brown mosses (e.g. *Campylium stellatum*), and with base-rich water (pH above 6). Lawn communities of extremely rich fen vegetation (Sjörs, 1948; Moen et al., 2012; Jiménez-Alfaro et al., 2014) cover the study localities. Phytosociological analyses of the permanent study plots were included in multivariate analyses of 134 rich fen plots from the two study areas (Moen et al., 2012; the plots in this paper mainly belong to their communities II–IV). In the phytosociological classification system (e.g. Dierssen, 1982; Rybníček, 1985), the studied mires belong to the alliances *Caricion davalianae* Klinka 1934 at Tågdalen, and at Sølendet *Caricion atrofuscae* Nordh. 1936. The mean number of species in plots with an area of 12.5 m^2 ranged between 30 and 37 (Table 2 and Supplementary A in Moen et al., 2012). The most common vascular plant species in both areas are *Andromeda polifolia*, *Dactylorhiza* spp., *Equisetum palustre*, *Euphrasia wettsteinii*, *Parnassia palustris*, *Pinguicula vulgaris*, *Potentilla erecta*, *Selaginella selaginoides*, *Succisa pratensis*, *Thalictrum alpinum*, *Tofieldia pusilla*, *Carex dioica*, *Carex flava*, *Carex hostiana*, *Carex lasiocarpa*, *Carex panicea*, *Carex rostrata*, *Eriophorum angustifolium*, *Eriophorum latifolium*, *Molinia caerulea* and *Trichophorum cespitosum*. The bottom layer was dominated by *Campylium stellatum*, with *Aneura pinguis*, *Barbilophozia rutheana*, *Fissidens adianthoides*, *Gymnocolea borealis* and *Scorpidium cossonii* occurring in all or a large majority of the plots. At Tågdalen the western/lowland species *Drosera longifolia*, *Narthecium ossifragum* and *Schoenus ferrugineus* were present in some plots. At Sølendet a number of alpine/inland species were present, the most common being *Pedicularis oederi*, *Saxifraga aizoides* and *Kobresia simpliciuscula*.

3. Material and methods

3.1. Research design and vegetation plots

Ten localities with permanent experimental plots with and without mowing within each study area in similar vegetation units of rich fens were chosen for the present research design (Fig. 3). Each locality