THE FOCUS ON PLANT DIVERSITY: RESTORATION AND MANAGEMENT, Lessons from boreal hay fens

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Abstract: Succession in boreal plant communities and population dynamics of plants in hay fens have been studied in permanent plots in two nature reserves in central Norway for more than four decades. The main aim has been to document the effects of management activities, such as mowing, trampling, burning and cattle grazing. The long-term data allows us to quantify effects of climate change. The pleurocarpous, prostrate bryophytes (e.g. Campylium stellatum) are favoured by mowing, whereas acrocarpous and ‘hummock-building’ bryophytes are reduced. Overall, mowing leads to a reduction in woody plants and herbs, whereas the proportion of graminoids has increased. The reduction of aboveground biomass with increased frequency of mowing is not due to an impoverishment of the soil, but due to a high degree of disturbance by regular mowing. The cost of reproduction, summer temperatures and precipitation are important factors affecting the population dynamics of fen and grassland species. Management activities interact with these factors, and climate change will alter the effects of management on population growth rate and population viability.

Keywords: Boreal mires (73XX), Calcareous fens (7210 & 7230), Mountain hay meadows (6520), mowing, population dynamics, sloping fens, succession

Introduction

For centuries, fens (i.e. minerotrophic mires) have been important for production of hay and litter, and used as pastures for domestic stock (e.g. Moen 1990, Middleton et al. 2006). In most countries, including Fennoscandia, the traditional use of the fens ended many decades ago. Fens in Norway cover more than 1 million ha and a large part of this area has been used as hay fens. Scything of fens and grasslands in the uplands went on for several centuries. The relatively intensive mowing, grazing, clearing of trees and shrubs, etc. were important landscape-forming factors, and had created an open and often deforested agro-pastoral landscape over vast areas. During the first decades of the 20th century the utilization of outlying lands gradually declined, and by the end of 1950s the traditional use had ceased. The change in the land use took place on a large scale. The expansion of dwarf shrubs (e.g. Vaccinium spp.), shrubs (e.g. Betula spp., Salix spp.) and trees (e.g. Betula pubescens) had conspicuous effects on landscapes and species distribution in former outlying hay lands and pastures.

Succession in boreal plant communities and population dynamics of plants in outlying hay fens in Norway have been studied on permanent plots in two study areas for more than four decades. The main emphasis has been on brown-moss dominated fens and calcareous fens: a type that includes the most productive hay fens, and therefore, the last areas to be abandoned. These rich fens are species-rich, and include many red listed species and protected vegetation types (Lindgaard & Henrikсен 2011).

The main aims of the long-term study is to identify, quantify and understand the effects of management activities such as clearing, mowing, trampling, burning and cattle grazing on species distribution and population dynamics. This study also enables us to quantify the direct
and indirect effects of climatic variation. In this paper we emphasize the effects of restoration and management, as well as report demographic results for some species.

Figure 1. (A) Scrub-dominated land was cleared with axe during restoration. (B) Burning of trees, scrubs and litter. (C) Mowing with machines on a restored hay fen. (D) A managed sloping hay fen with permanent plots. Photos by A. Moen.

Materials and methods
In the late 1960’s and early 1970’s more than 100 permanent plots were established in former hay fens in two nature reserves in the upper boreal region of central Norway. Sølendet is an inland locality with a rather continental climate (640 mm of annual precipitation); the coastal site Tågdalen has an oceanic climate (1580 mm). Both localities have large areas of sloping calcareous fens and outlying hay meadows. Detailed information on the study areas and the fen vegetation can be found in Moen et al. (2012). In both areas the traditional harvest of hay ceased ca. 1950. At Sølendet restoration and management activities started in 1976, including clearing of shrubs and small trees with axe, and mowing with two-wheeled tractor (Fig. 1). Permanent plot method has been applied to study the changes in plant cover and effects of management activities. Populations of 60 plant species have been monitored since the early 1980’s in the permanent plots, as part of a long-term monitoring programme. Different mowing frequencies (every year, every second year, every fourth year and control plots not mown for more than 30 years) were applied in both study areas. Demographic data from the annual census were analysed using matrix population models. LTRE analysis was used to study the effects of changes in land use and climate on population dynamics.

Results and discussion
Restoration of the Sølendet Nature Reserve after 30 years of shrub encroachment included clearing of dense scrubs with axe (40 ha) and removal of scattered shrubs and litter with tractor
(16 ha). The rest of the managed area (ca. 84 ha) was not overgrown and the fens were mown with a tractor. The clearing of dense scrub took about 10 years (about 2 man-labour years), and the shrubs and trees were cut slightly below the height of herbaceous vegetation, in order to allow mowing. Mowing with scythe was a traditional way of haymaking. After restoration and management started in 1976, machinery has been used. Mowing with machinery is 7 times faster than with scythe (Table 1), and has the same effect on the vegetation. Gathering and transport of the hay is more time-consuming than mowing. We have used both mechanical rake, sweep rake and other tools for gathering and transport of hay (Table 1).

Table 1. Time spent on various management operations, based on experience gained at Sølendet Nature Reserve (modified after Moen 1995).

<table>
<thead>
<tr>
<th>Description</th>
<th>Hours ∙ ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclamation (completed):</td>
<td></td>
</tr>
<tr>
<td>Clearing of dense thickets</td>
<td>50-100</td>
</tr>
<tr>
<td>Clearing of open thickets</td>
<td>40-50</td>
</tr>
<tr>
<td>Former working methods no longer in use:</td>
<td></td>
</tr>
<tr>
<td>Spreading of hay to dry</td>
<td>20</td>
</tr>
<tr>
<td>Drying, gathering up and removal</td>
<td>30</td>
</tr>
<tr>
<td>Work which has to be done every year:</td>
<td></td>
</tr>
<tr>
<td>Mowing with a scythe or a grass strimmer</td>
<td>30-40</td>
</tr>
<tr>
<td>Mowing with a two-wheeled tractor (with mowing beam)</td>
<td>5</td>
</tr>
<tr>
<td>Mowing with a motor mower (with rotating disc)</td>
<td>3-5</td>
</tr>
<tr>
<td>Gathering up and removal to a road</td>
<td>30</td>
</tr>
<tr>
<td>Gathering into heaps with a mechanical rake and a sweep rake</td>
<td>10</td>
</tr>
</tbody>
</table>

Mowing frequency of every second year in different plant communities resulted in hay crop varying from 5.5 to 17 kg/ha, with an average of 11 kg/ha. Annual mowing reduced the yield by half, which explains why the traditional use was mowing every second year. In the first years after reintroduction of mowing hay crop was about two times larger than the crop of regular mowing every second year. The first harvest, however, contained more than 30 % of litter, compared to 10 % in areas mown regularly every second year. A reduction of yield with mowing frequency was caused by a high degree of disturbance due to mowing and not because of an impoverishment of the soil (Øien & Moen 2001).

The effect of mowing varied considerably among species (Moen et al. 1999). Overall, mowing leads to a reduction in woody plants and herbs, whereas the proportion of graminoids increases. The pleurocarpous, prostrate bryophytes (e.g. *Campylium stellatum*) are favoured by mowing, whereas acrocarpous and ‘hummock-building’ bryophytes (e.g. *Sphagnum* spp.) are reduced.

The cost of reproduction, summer temperature and summer precipitation are important factors affecting the population dynamics of fen species. Management activities interact with these factors. Climate change is likely to alter the effects of management on population growth rates and population viability (Sletvold et al. 2010, 2013). For example, population growth rate of an orchid *Dactylorhiza lapponica* increased with higher summer temperature in both study areas, whereas it declined with higher spring temperature in the continental area and with higher precipitation in the coastal area. There was an interaction between climate and management, as the rate of increase or decrease in population growth differed between control and mown plots in both populations (Fig. 2).

The flowering density of *Eriophorum latifolium*, which is a common species in the study areas, increased with regular mowing every second or every fourth year. The cost of reproduction was the most important factor explaining a large variation in flowering among years. High temperatures in spring had a positive influence on flowering density (Fig. 3; unpublished data).
Figure 2. Interacting effects of climate and management on population viability: growth rate of Dactylorhiza lapponica related to four climatic factors, based on 30 years of demographic data (1981-2010) from rich fens inland and on the coast. Circles indicate the observed climatic data for this period. Results for control (solid line) and mown plots (dashed lines) were shown. From Sletvold et al. (2013).

Figure 3. The effects of different mowing regimes (left) and spring temperature (right) on flowering density of Eriophorum latifolium. Data from 1982-2008. 0: unmown, 0.25: mown every fourth year, 0.5: mown every second year, 1: mown every year. T: Tågdalen, S: Sølendet, C: fen carpet, L: fen lawn, M: fen margin, ETS: effective temperature sum.
References