Biodiversity and Traditional Land Use in South-Central Sweden: The Significance of Management Timing

ANNA DAHLSTRÖM

Department of Economics, Section of Agricultural History
Swedish University of Agricultural Sciences
Box 7013, SE-750 07 Uppsala, Sweden.
E-mail: Anna.Dahlstrom@ekon.slu.se

TOMMY LENNARTSSON

Swedish Biodiversity Centre
Swedish University of Agricultural Sciences and Uppsala University
Box 7007, SE-750 07 Uppsala, Sweden.
E-mail: Tommy.Lennartsson@cbm.slu.se

JÖRGEN WISSMAN

Department of Ecology
Swedish University of Agricultural Sciences
Box 7002, SE-750 07 Uppsala, Sweden.
E-mail: Jorgen.Wissman@ekol.slu.se

INGEMAR FRYCKLUND

The Uppland Foundation,
Box 26074, SE-750 26 Uppsala, Sweden.

ABSTRACT

During the last 50–100 years, large numbers of species associated with semi-natural grassland have declined. One reason for this is the considerable reduction of grassland area. Another possible explanation is the loss of historical management practices. This study addresses changes in the timing of management and its implications for biodiversity, and combines historical data on management timing (eighteenth century) with data on reproductive phenology of vascular plants and butterflies. All data are from south-east and south-central Sweden and demonstrate a considerable loss of grassland area, but an even greater loss of historical management practices. Historically, 21–32 per cent of the semi-natural grassland area was subject to late season management (from early July

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onwards) by mowing or late-season grazing. In 2005, management had ceased in 97–99 per cent of the historically managed grassland, and current management was dominated by all-season grazing. 0.2 per cent of the grassland area was managed by mowing in 2005. Historically, at the time of mowing, 50–80 per cent of the butterfly species and 20–95 per cent of vascular plant species had completed their reproductive cycles, the proportions increasing with the later onset of management. The results suggest that the reduced use of late management is a major cause of the observed decline of grassland organisms.

KEYWORDS

Management timing, biodiversity, historical land use, phenology, semi-natural grassland

INTRODUCTION

In the agricultural landscape of Scandinavia and other parts of Europe before industrialisation, semi-natural grasslands, i.e. unfertilised and uncultivated pastures and hay meadows, constituted the nutrient base for agriculture and dominated the landscape. Today, artificial fertilisers have made crop production independent of livestock manure and have enabled production of winter fodder and pasture on arable fields, and most countries in Western Europe have lost more than 95 per cent of their original grassland areas.[1] The modernisation of agriculture has increased productivity enormously but as a consequence, large numbers of species associated with semi-natural grassland have declined during the last 50–100 years and are now red-listed and threatened by extinction. Species are red-listed based on observed negative trends in, for example, the number of populations, population sizes and population connectivity, according to the IUCN criteria for red-listing.[2] In Sweden, changes in the agricultural landscape, in particular the loss of semi-natural grasslands, has been identified as the cause of decline for about 50 per cent of the red-listed species.[3] By ratification of the Convention of Biological Diversity, Sweden and other countries have agreed 'to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level'.[4] In practice, a considerable decline in biodiversity is accepted before species meet the criteria for red listing and the decline becomes subject to conservation efforts.[5] Preservation of unfertilised semi-natural grasslands has been identified as one of the most important conservation measures to halt biodiversity loss in Europe's open landscapes.[6] Consequently, substantial financial resources are allocated to European subsidiary programs to manage the remaining semi-natural grasslands.

As grassland area has declined, management has ceased, and this has been acknowledged as an important cause of the decline of grassland biodiversity.[7] In contrast, suboptimal management of the remaining grasslands has attracted less attention,[8] despite the fact that, as grassland areas are reduced and become more fragmented, it becomes increasingly important to optimise management of the remaining patches. Field experiments have shown that management regimes have profound effects on grassland biodiversity, and have also indicated that the present management may not provide sufficient conditions for threatened species.[9]

The majority of semi-natural pastures and hay meadows, and their biodiversity, are the result of a long history of management.[10] Therefore, grassland biodiversity on a local scale should be favoured by management that is as similar as possible to the local traditional management regimes (here defined as the grassland management used in pre-industrial agricultural systems of northern Europe).[11] The current management methods can be assumed to differ considerably from traditional management, and this difference may be an important, but little studied, cause of the ongoing decline of biodiversity in the agricultural landscape.[12] Today's grassland management differs from the traditional land use in terms of, for example, type, timing, intensity and temporal variability of management.[13] This study addresses the timing of management, by comparing historical and present land use data with ecological data on reproductive phenology.

One important change in the timing of management is the widespread shift from mowing to grazing.[14] Another change is the decreased use of late season grazing. Historically, some areas were fenced together with hay meadows and arable fields,[15] and could not be grazed until after harvesting.

One major ecological effect of late management by mowing or grazing is that the vegetation is left undisturbed in the early summer. This is advantageous for seed production,[16] especially in plants with early reproduction,[17] but may be negative for germination and seedling establishment due to tall vegetation.[18] In general, however, early management of grasslands has been shown to have negative effects on grassland biodiversity,[19] especially when grazing is intense.[20] Consequently, several studies have shown the strong positive effects of mowing compared to grazing on grassland biodiversity.[21]

Late management increases floral richness, which in turn also favours insects dependent on pollen or nectar, for example, rare bee species.[22] In many regions, semi-natural grasslands are the major sources of pollen and nectar in the landscape.[23] Pollen- and nectar-feeders are, therefore, affected by early grassland management through reduction of resources. Seed predators and phytophagous insects, e.g. butterflies, are also strongly affected by the timing of grazing and mowing.[24] Many species in these groups are directly affected since they are killed when their host plant is grazed.

The aim of this study is to analyse the decline of semi-natural grasslands, in terms of both area reduction and loss of traditional management, and to

discuss the ecological significance of timing in the management of semi-natural grasslands. The study combines data on land use and management timing, both historical and present, with ecological data of timing of reproduction of vascular plants and butterflies. Specifically, we address the following questions: (1) What was the historical timing of management in different types of semi-natural grasslands, and how were large proportions of the grasslands managed late? (2) To what degree are the different historical land use management types (in terms of timing of management) preserved in the present day management of semi-natural grasslands? (3) To what degree are historical land use strategies practised in historical locations today? (4) How much has the area of semi-natural grassland declined in some Swedish landscapes? (5) How does the historical and current timing of management correspond with the phenology of reproduction of grassland plants and butterflies?

MATERIAL AND METHODS

Timing of management in traditional land use

Large scale cadastral maps[25] from the eighteenth century were used to map different land use in 64 villages in four landscapes in south-central Sweden, covering a total of 16,700 hectares. The four landscapes were chosen to represent both farmland plains (the island of Selaön and the parish of Fornåsa) and upland regions (the parishes of Kristberg and Alseda). All land in the villages was assigned to one of the following types of land use: (1) *permanent pasture*, available for grazing through the entire growth season; (2) *pasture fenced with hay meadow*, grazed after harvesting of hay; (3) *pasture fenced with arable field*, grazed after crop harvest or before autumn sowing; (4) *hay meadow*, mown in the summer; (5) *hay meadow fenced with arable field*, mown in the summer and grazed after crop harvest, except for years of autumn sowing; (6) *arable fields*. Except for the arable fields all of these are semi-natural grassland habitats. The pastures consisted of more or less forested areas on till or similar low-productive soils, whereas hay meadows and arable fields were mainly situated on clay and other more productive soil types. For each landscape, a mean hectarage of each land use type was calculated as the average of the villages in the landscape.

To find the dates of onset and end of management in different areas we used the responses garnered from ethnological questionnaires about peasant culture. The questionnaires were sent to countryside people by *Nordiska muséet* in the 1930s, and requested information on, for example, daily chores related to agriculture in the 1880s.[26] Of the 33 replies available, 13 from southern Sweden were used in this study. The information in the replies consists of both general descriptions and exact dates for when different types of work were performed. Dates for the onset and end of management of semi-natural grasslands (permanent pasture, pasture in field and hay meadow) were noted.

Timing of management in present land use

The current management in the four landscapes was extracted from national records of semi-natural grasslands subject to environmental subsidies[27] during 2005.

Phenology of seed production of vascular plants

The development of reproductive organs, from bud to mature fruit, was followed for vascular plant species in one semi-natural pasture in Harpsund, situated close to the island of Selaön (59°05'N 16°29'E). To allow monitoring of reproductive phenology without disturbance from grazing, the cattle were fenced out of a four hectare area during the study. Twenty 1x1 m permanent plots were established and the numbers of buds, flowers, immature fruits, and mature fruits were counted in all plots at approximately two-week intervals during the summer. The date of fruit maturation of a species was defined as the average date for 50 per cent of the produced fruits being mature. Data are reported only for the 33 species occurring in at least 15 plots.

Phenology of reproduction of red-listed butterflies

Nationally and regionally red-listed grassland butterflies[28] were searched for on their host plants at suitable sites in the administrative province of Uppsala, in eastern Sweden, during 1996–2001. This province is located in the same climatic region as the island of Selaön and has a similar species pool. The first and last observation dates for larvae, pupae, and imagos were noted, to give the approximate period during which the butterfly is stationary on the host plant for the 66 observed species. Eggs were rarely observed, but instead the approximate date of oviposition was estimated based on observations of imago butterflies. The field observations were complemented with information on host plants and phenology of Swedish butterflies compiled by Svensson (1993).[29]

RESULTS

Historical land use

During the eighteenth century the semi-natural grasslands, open, semi-open or forested, covered all land that was not listed as arable fields, gardens or roads. Thus, semi-natural grasslands comprised between 67 and 79 per cent of the land area in the two plain landscapes, and 94–95 per cent in the more hilly upland landscapes (Table 1).

Permanent pastures were historically the dominant group of habitats in all four landscapes, comprising 63–73 per cent of all grasslands (Table 1). They were

TABLE 1. Mean per village area and percentage of semi-natural grassland subject to different management regimes in four landscapes. Standard errors are given in brackets.

Landscape and period	Selaön (1697–1805)	Fornåsa (1696–1776)	Kristberg (1689–1795)	Alseda (1785–1803)
Landscape area	3682 ha	1604 ha	3185 ha	8204 ha
Number of villages	27	9	10	18
Permanent pasture	78.7 ha (7.7) 72.9%* (2.0)	83.5 ha (20.8) 63.2%* (3.5)	217.0 ha (58.7) 68.4%* (4.9)	340.4 ha (88.4) 72.8%* (2.4)
Permanent hay meadow	18.0 ha (2.0) 17.8%* (1.2)	34.9 ha (3.3) 33.3%* (3.3)	69.0 ha (19.0) 27.5%* (4.4)	51.5 ha (10.8) 17.4%* (3.0)
Hay meadow in arable field	1.2 ha (0.3) 0.2%* (0.1)	2.8 ha (1.8) 1.5%* (1.0)	4.3 ha (1.0) 0.9%* (0.4)	44.1 ha (12.0) 9.6%* (1.1)
Pasture in hay meadow	1.1 ha (0.3) 1.0%* (0.2)	0.3 ha (0.3) 0.3%* (0.3)	5.0 ha (4.0) 0.2%* (0.2)	0.03 ha (0.02) 0.03%* (0.02)
Pasture in arable field	11.2 ha (2.1) 10.1%* (1.5)	1.9 ha (0.8) 2.2%* (1.0)	6.5 ha (2.2) 3.2%* (1.7)	0.9 ha (0.8) 0.1%* (0.1)
Total grassland	110.2 ha (9.7) 79.4%† (1.4)	123.4 ha (23.8) 66.8%† (2.9)	301.9 ha (76.1) 93.9 %† (1.4)	436.9 ha (106.2) 94.9%† (0.4)
Arable fields	26.0 ha (2.3) 20.5%† (1.4)	53.3 ha (6.8) 31.9%† (2.5)	16.9 ha (4.9) 5.7%† (1.0)	18.7 ha (3.7) 5.0%† (0.4)

* per cent of the total area of semi-natural grassland

† per cent of the total landscape area

grazed from May or early June to October (Table 2). Hay meadows comprised 18–35 per cent of the grasslands (Table 1). The mowing period started in early to mid July, and ended normally in late July to early August, but sometimes as late as in September (Table 2). This implies that some hay meadows could be left undisturbed until early July, others until early August or later. Pastures fenced with hay meadows represented no more than one per cent of the grasslands in any of the landscapes. Pastures fenced with arable fields represented a maximum of 10 per cent of all grasslands. In areas with a two-field system, these pastures were grazed from early September (after harvest) one year and until early August (until autumn sowing) the next year.

In total, 19–35 per cent of the semi-natural grassland area was left undisturbed until July-September every year (hay meadows and pastures fenced with hay meadows), and another 0–10 per cent until August–September every second year (pastures fenced with arable fields).

TABLE 2. Dates of onset and end of management in the 1880s according to replies taken from the ethnological questionnaires.

Parish & county	Accession number	Permanent pasture		Hay meadow		Pastures in fields	
		Onset	End	Onset	End	Grazing until*	Grazing from†
Mo, Västergötland	13932	May 15	.	.	.	.	.
Husby Oppunda, Södermanland	15654	.	.	late June	.	August	Sept
Otterstad, Västergötland	15674	May	.	Jul 01	.	Septem-ber	August-Sept
Fryele, Småland	15762	late June	.	early July	late July	.	10-Sep
Gräsmark, Värmland	15763	May-16	.	Jul 19	29 Sep	.	mid-Sep
Björkö-Arholma, Uppland	16317	.	.	early July	29 Jul	.	.
Huddunge, Uppland	16993	.	.	mid-July	.	.	.
Huddunge, Uppland	16993	May	.	early July	.	mid-August	late August
Huddunge, Uppland	16993	.	.	early July	.	.	early Sep
Huddunge, Uppland	16994	.	.	early July	29 Jul	August	.
Urshult, Småland	20763	late May	late October	early July	late July	.	.
Ålhem, Småland	32365	May 25	.	early July	.	August	Septem-ber
Asby & Torpa, Östergötland	44727	early June	.	early July	early Aug	.	.
Västra Ryd, Östergötland	45042	.	.	early July	mid-July	late August	.
Västra Ryd, Östergötland	45042	.	.	early July	early Aug	late August	August
Väddö, Uppland	3537	early June	October	mid-July	early Aug	late August	early Sep

* in autumn sowing

† in autumn harvesting

Land use changes

In 2005, grazing and mowing had ceased in 97–99 per cent of the historically grazed or mown grasslands (Figure 1). The area of presently managed semi-natural grassland was 82 hectares in the island of Selaön, 10 hectares in the parish of Fornåsa, 44 hectares in Kristberg, and 142 hectares in Alseda (Figure 1).

Grazing, normally from May to September, was the only type of grassland management in 2005 in three of the landscapes. In Alseda, 97 per cent of the remaining grasslands were managed by grazing and four hectares by mowing. Thus, mowing and late grazing were almost entirely extinct as grassland management methods in the studied landscapes. Of the grasslands that are still managed, 0, 11, 64, and 69 per cent used to be hay meadows in the eighteenth century in the four landscapes, respectively, and 0, 0, 0 and 8 per cent used to be pastures fenced with arable fields (Figure 1). Both of these historical land use types had thus experienced a shift of management from late to early management. 100, 89, 36, and 31 per cent of the present pastures were historically permanent pastures, thus still being traditionally managed (Figure 1).

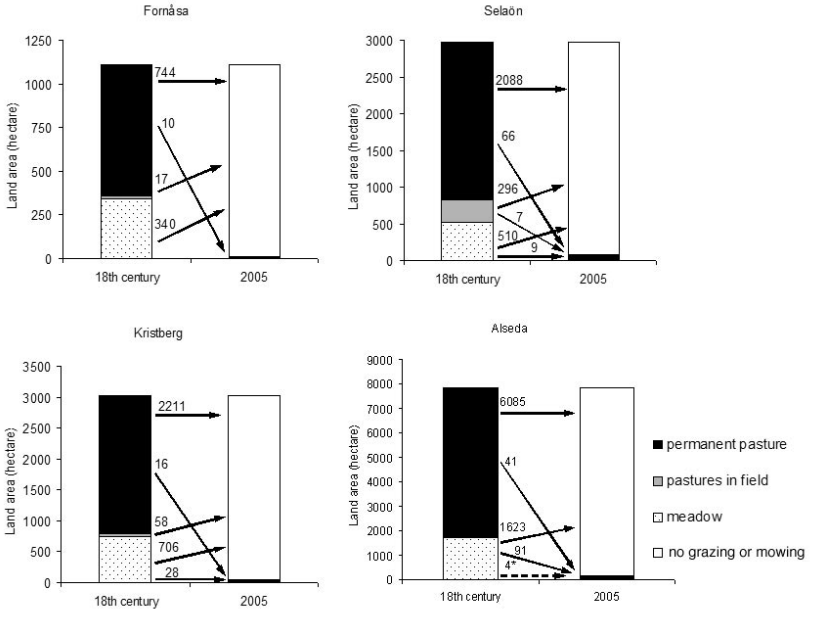

FIGURE 1. Historical and present land use in the four studied landscapes. The arrows show (in hectares) the transition of the historical meadows and pastures into non-grassland (forest or arable fields), pastures or hay meadows. *

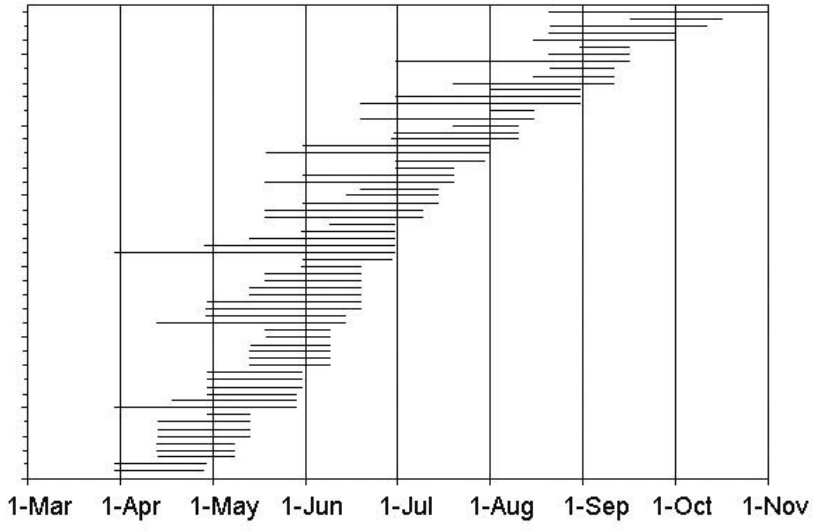

FIGURE 2. Phenology of reproduction of 66 nationally or regionally red-listed grassland butterflies in the Province of Uppland. Each line represents one species, and the line shows the period during which the species is confined to the host plant, either as egg, larva, or pupa.

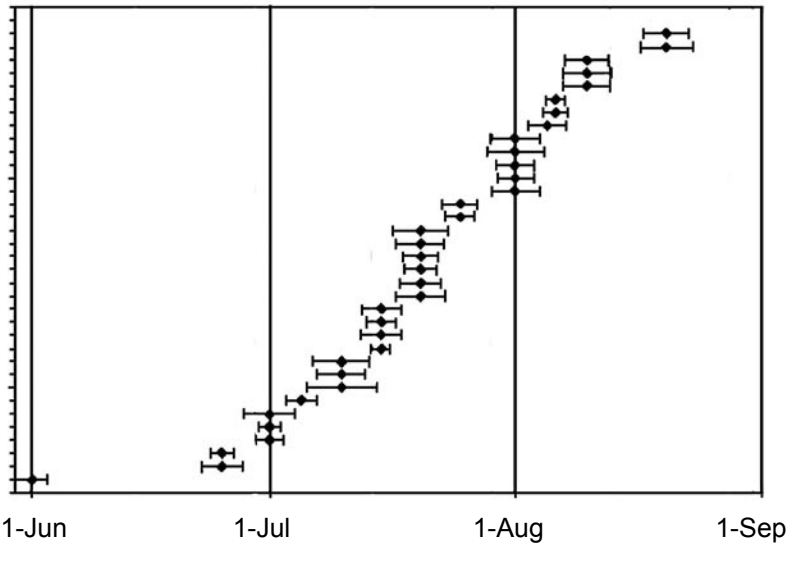

FIGURE 3. Mean date of fruit maturation of 35 grassland plant species in a semi-natural grassland. Maturation date is defined as the date at which 50 per cent of the fruits are mature. Error bars show standard deviation of 15–20 plots, see text for explanation.

Grasslands historically subject to late management, every year or every second year, were mostly unmanaged in 2005. Only 0, 2, 3.5 and 5.2 per cent of the historical hay meadows and pastures fenced with fields were grazed in 2005, but with early grazing. The four hectares of hay meadow in Alseda represents 0.2 per cent of the historical hay meadow area in that landscape (Figure 1).

Ecological significance of timing of management

Between 55 and 67 per cent of the red-listed butterfly species had finished their development on the host plant (Figure 2), and 20–40 per cent of the plant species had produced mature fruits (Figure 3) during the time interval for the normal onset of the mowing period, 1–20 July. When the latest hay meadows were mown historically, in mid-August (Table 2), 78 per cent of the butterflies had left their host plants, and 95 per cent of the plant species had matured (Figures 2 and 3). In grasslands managed as late as in early September, such as those which were grazed and fenced with arable fields, about 90 per cent of the butterfly species and all plant species would have finished their reproductive development at the time of disturbance (Figures 2 and 3).

DISCUSSION

This study shows that the studied landscapes have experienced a substantial loss of area of semi-natural grasslands during the last 150 years, through abandonment and cultivation.[30] Furthermore, it shows that the loss of historical management practices is even larger. Historically, semi-natural grassland of different types covered between 67 and 95 per cent of the studied landscapes, compared to 0.6–2.2 per cent today. The loss of historical management practices implies that different types of late season management and between-year variation in management today are nearly absent from the studied landscapes, whereas historically 20–45 per cent of the grasslands were managed late. In addition, a considerable proportion of the presently grazed grassland used to be late managed, and have thus experienced a management shift from mowing or late grazing to all-season grazing.

To our knowledge, this is the first study to quantify change in management timing and its potential implications for the reproduction of grassland species. Other studies have shown that many species are negatively affected by early management.[31] The delayed onset of grazing (until c. 25 July) increased the seed production of most grassland plants considerably, leading in turn to increased densities of seedlings the following spring, and to a higher density of individual plants in the sward after seven years. The benefits of increased seed production must be weighed against disadvantages of increased light competition in the early summer, especially for small species.[32] The total effect on plant populations

can be estimated using population models, and Lennartsson and Oostermeijer (2001)[33] showed that the traditional timing of mowing combined with aftermath grazing was most beneficial for the endangered grassland plant field gentian (*Gentianella campestris*). In fact, it has been suggested that some plant species adapt to certain management timing by evolving particular flowering phenologies.[34] The timing of management is also crucial for butterflies.[35]

The results suggest that reduced use of late management is a considerable cause of the observed decline of these organisms,[36] and that non-traditional early management thus leads to a deterioration in grassland habitats. Other environmental changes, for example, climate change, also affect grassland biodiversity, but such effects are usually small in comparison with the strong influence of management changes and habitat loss.[37]

Historical land use differed considerably between landscapes, mainly according to topography. For example, hay meadows fenced with arable fields were found mostly in the parish of Alseda and pastures fenced with arable fields occurred mainly in Selaön. Selaön contains large areas with mosaics of clayey sediment and low hills of till, resulting in irregularly shaped arable fields interspersed with numerous drier pastures. In general, in all landscapes, the permanent pastures were situated on larger areas with till, whereas the arable fields were fenced to protect them from grazing before the harvest.[38] In order to keep fencing efforts at a reasonable level, and to create large enough grazing entities, it was necessary to include some smaller patches of till in the fenced areas. For every hectare of arable field about 0.4 hectares of pasture were included in the fence in Selaön. Depending on the crop rotation system, these pastures were subject to grazing after harvesting the fields every year, every second or third year.[39]

These topographic characteristics are to be found in large parts of central Sweden and Finland, especially in the fissure valley landscape of eastern Sweden, and also along the coasts and archipelagos of the Baltic Sea.[40] We can thus expect that semi-natural grasslands fenced with arable fields have been common in some parts of Scandinavia and other regions where topography and geology have formed irregularly shaped arable fields. Late management in terms of mowing of hay meadows was not dependent on topography, but a characteristic component of the 'mixed farming' agricultural system that was practised across northern Europe until the late nineteenth century.[41]

The two groups of organisms included in this study, vascular plants and butterflies, indicate that the timing of management has a great influence on the completion of reproductive development of many species. The timing of traditional mowing, from early July to mid-August, allowed 50–80 per cent of the butterflies, and 20–95 per cent of the plant species to complete their reproduction before vegetation disturbance. The higher figures correspond with later mowing dates. An even later onset of management, such as takes place in pastures fenced with arable fields and the late mowing of meadows and road

verges, enabled the reproduction of almost all of the studied species of grassland plants and butterflies.

Loss of hay meadows has been highlighted as a major cause of decline in plant and insect species dependent upon grasslands that are undisturbed in the early summer. Such grasslands provide pollen- and nectar resources, and undamaged host plants for insects, as well as favourable conditions for early-reproducing plants. Interestingly, this study shows that traditional mowing may in many cases have been too early for the reproduction of a considerable proportion of the grassland plants and butterflies. Instead, late-reproducing species may have occurred mainly in pastures fenced with arable fields, in which management was initiated late enough. Examples from the studied plant species are *Campanula rotundifolia* (Harebell), *Centaurea jacea* (French hardhead), and *Potentilla erecta* (Tormentil). Among the studied butterflies, many late-reproducing species feed on hay meadow plants, such as the moth *Ethmia pyrausta* and *Perizoma sagittata* (Marsh carpet), both on *Thalictrum flavum* (Common meadow-rue), the leaf-tie *Aganopterix pallorella* on *Serratula tinctoria* (Sawworth), and *Catarhoe rubidata* (Ruddy carpet) on *Galium album* (White bedstraw). Similar studies of other groups of insects feeding on plant tissue, pollen or nectar, would no doubt prove that late management is essential for large numbers of grassland species in several taxonomic groups. Many such species are found among, for example, beetles (Coleoptera, in particular the families Chrysomelidae and Curculionidae) and wasps (Hymenoptera, suborder Symphyta[42]).

In addition to late management, grassland species can be assumed to have also been favoured by spatial and temporal variations in management. Old cadastral maps are useful tools for reconstructing historical land uses.[43] The maps have, however, been shown to underestimate deviations from the major land use[44] and variations in management intensity, for example changes in grazing pressure.[45] In this study, grasslands subject to late season management were determined on the basis of the location of permanent fences. We can, however, expect the organisation of grazing to have been more flexible as a result of the use of temporary fences and livestock herding.[46] Accordingly, in years with scarce grazing resources, grazing in pastures fenced with arable fields could also have been possible before crops were harvested, but not in pastures surrounded by arable fields. On the other hand, late grazing also occurred within the permanent pastures, since herding was used to direct the livestock to different parts of the pasture on different occasions throughout the grazing season, thus leaving some plots for late grazing.[47]

The type and timing of management can be considered to be key elements of the ecological processes that form different grassland habitats. Cessation of grazing or mowing rapidly changes the environment for grassland species, and considerable changes can also be expected due to a change in the timing of management, from late to early management. While the cessation of management is acknowledged as a major threat to grassland biodiversity, the lack of

historical management practices is rarely discussed.[48] This study suggests that non-traditional management methods may have been overlooked as a cause of decline in grassland biodiversity. We therefore advise an increased focus on historical management practices, and in particular greater attention should be paid to the timing of management, and an increased use of late mowing or grazing, specifically of grasslands where late management was historically dominant. Farmers are often advised that semi-natural grasslands should be grazed in spring and early summer, and arable fields later, after the harvesting of hay.[49] Considering the current EU attempts to decrease production intensity on arable land, it should be possible to challenge this recommendation, i.e. to use some marginal arable fields for early grazing, thereby enabling late grazing of semi-natural grassland. The manipulation of the timing of management may increase costs for fencing and the moving of livestock between different grasslands, but might also be cost-efficient if the conservation benefit of this strategy is included. In general, historical management practices can be assumed to be essential for biodiversity in most anthropogenic habitats, and we, therefore, welcome similar studies which address other ecosystems, and which consider other management components.

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NOTES

[1] e.g. Statistiska Centralbyrån 1990, Nature Conservancy Council 1984.

[2] http://www.iucnredlist.org/ (accessed 30 July 2007).

[3] Gärdenfors 2005.

[4] http://www.cbd.int/2010-target/default.shtml (accessed 30 July 2007).

[5] http://www.iucnredlist.org/ (accessed 30 July 2007).

[6] Duffey 1974; Wolkinger and Plank 1981; Fuller 1987; Tucker 1991; Garcia 1992; Stanners and Bordeau 1995.

[7] e.g. Karlsson 1984; Fuller 1987.

[8] Fry 1991.

[9] e.g. Morris 1991; Zobel 1992; Linusson et al 1998,; Jacquemyn et al., 2003; Coulson et al. 2001.

[10] e.g. Poschlod and Bonn 1998; Söderström et al. 2001; Eriksson et al. 2002.

[11] Lennartsson and Oostermeijer 2001.

[12] Beaufoy et al. 1995.

[13] Lennartsson and Svensson 1996.

[14] García 1992; Bernes 1994; Beaufoy et al. 1995.

[15] Dahlström 2006a.

[16] Wissman 2006.

[17] Karlsson 1984; Lennartsson and Svensson, 1996; Zopfi 1998.

[18] Lennartsson and Oostermeijer 2001.

[19] Linusson et al. 1998; Lennartsson & Oostermeijer 2001; Mitlacher et al. 2002; Matejkova et al. 2003.

[20] Veenendaal et al. 1996.

[21] Hansson & Fogelfors 2000; Stammel et al. 2003; Kotiluoto 1998; Krahulec et al. 2001; Klimes and Klimesova 2001; Tamm 1956; Jensen and Meyer 2001.

[22] Westrich 1996.

[23] Westrich 1996; Kruess and Tscharntke 2002.

[24] Björklund 2005; Bergman 2006.

[25] Kain and Bagient 1992, Tollin 1996.

[26] eg Lilja 1996; Flygare 1999; Israelsson 2005.

[27] Swedish Board of Agriculture 2004.

[28] Gärdenfors 2005.

[29] Svensson 1993.

[30] cf. Gadd 2000, Morell 2001.

[31] Linusson et al. 1998; Lennartsson and Oostermeijer 2001; Mitlacher et al. 2002; Matejkova et al. 2003, Veenendaal et al. 1996; Wissman 2006.

[32] Jutila 2003; Jutila and Grace 2002.

[33] Lennartsson and Oostermeier 2001.

[34] Wettstein 1895; Warwick and Briggs 1979, Karlsson 1984; Zopfi 1993; Lennartsson 1997.

[35] E.g. Johst et al 2006; Valtonen and Saarinen 2005.

[36] Gärdenfors 2005.

[37] Lennartsson and Simonsson in press; Nordic Council of Ministers 2005; Reid et al. 2004.

[38] Dahlström 2006a.

[39] Gadd 2000.

[40] Nordic Council of Ministers 1984.

[41] Grigg 1974.

[42] Borror et al 1989.

[43] Tollin 1996, Kain and Baigent 1992, Cousins 2001.

[44] Vestbö-Franzén 2005.

[45] Dahlström 2006b.

[46] Kardell 2007, Kardell 2004.

[47] Kardell 2007.

[48] E.g. Fry 1991.

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