Mowing for biodiversity: grass trimmer and knife mower perform equally well

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Mowing for biodiversity: Grass trimmer and knife mower perform equally well

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Abstract

Mowing of semi-natural grasslands is an important management method to maintain the conservation value and species-richness of this habitat. Mowing using cutting instruments, e.g. sickle bar mowers, is thought to be superior by practitioners compared with other mechanical instruments that tears off the plant material, e.g. grass trimmers. However, almost no studies exist that supports this assumption. We analysed a 12-year field trial in a semi-natural grassland in south-eastern Sweden, with the aim of determining which mowing technique best maintains the conservation value of semi-natural grasslands. Two mowing techniques were compared: mowing using a hand-pushed sickle bar mower (a type of knife mower), or mowing using a grass trimmer at a 5-cm or 0-cm cutting height. The odds that a recorded species belongs to a group of indicator species were calculated for sample plots, and odds ratios were calculated contrasting treatments. Three types of indicator species classification systems were used: (i) indicators of management for species richness, (ii) indicators of excess nitrogen and (iii) indicators of lack of management. The odds ratios were calculated for years 1-5, 7 and 12 of the trial. In addition, Principal Response Curve analysis was performed to analyse the change in vegetation composition over time and ANOVA for plant species richness in plots. The results showed that over time there were no differences in the odds of finding indicators of any of the three types, for any of the mowing techniques. Furthermore, there were no apparent change in vegetation composition and only a small effect on richness. These results suggest that mowing using a sickle bar mower or a grass trimmer had the same effect on the floristic composition of grasslands, and both techniques can be recommended for use in semi-natural grasslands.

Keywords indicators; management; meta-analysis; mowing techniques; odds ratio; semi-natural grassland; Sweden

Abbreviations ln OR = logarithm of odds ratio, PRC = Principal Response Curve

Introduction

Nutrient-poor, semi-natural grasslands are among the most species-rich habitats in northern Europe, with up to 600 plant species in total in the habitat type and 60 plant species per square meter (Kull & Zobel 1991, Hansson & Fogelfors 2000). During the last century, agricultural practices have been modernised and intensified, which has led to the decrease of the area of semi-natural grassland (e.g. Johansson et al. 2008, Dengler et al. 2014). Approximately 90 % of the area of semi-natural grassland in Sweden has been converted into other habitat types (Ihse 1995, Hansson & Fogelfors 2000, Eriksson et al. 2002, Bernes 2011). The loss and subsequent fragmentation of semi-natural grasslands due to changes in management have had negative effects on biological diversity, and many of the species that rely on this type of habitat are now rare and threatened (Gärdenfors 2010). A similar decline in semi-natural grassland habitat has happened in many parts of Europe, and with similar efforts to maintain or restore biodiversity in remaining sites (e.g. Stampfli & Zeiter 1999, Kahmen et al. 2002, Köhler et al. 2005, Poschlod et al. 2005, Valkó et al. 2011, Kelemen et al. 2014). The conservation of the species living in the remaining fragments of semi-natural grasslands is dependent on management that keeps the habitat open and removes the annual production of grasses and herbs (Valkó et al. 2012). The continuing decline in acreage (Nordberg 2013) suggests the need for a refinement of management methods to achieve long-term goals for conservation (Hall Diemer et al. 2013, van Klink et al. 2014).

Today, mowing along with grazing, are the preferred management practices in the remaining semi-natural grasslands. Mowing, by removal of above-ground biomass, means a removal of nutrients (Marrs et al. 1998). Furthermore, mowing helps maintaining the biological diversity and species composition of semi-natural grasslands by reducing competition from tall-growing, nutrient-demanding species (Hansson & Fogelfors 2000, Huhta et al. 2001).

Traditionally, semi-natural grasslands were mown using scythes (Ekstam et al. 1988, Johansson & Hedin 1991, Liira et al. 2009), but during recent decades the use of mechanical tools for mowing has become more common (Humbert et al. 2009), as they are more time- and cost-effective. In fact, mowing with scythes is realistic for only a small proportion of the meadows and we need to consider the conservation benefit of alternative management methods (Carlsson et al. 2014). Mechanical tools can broadly be classified as slicing or clipping implements

(that cut the plant material) or as rotating implements (that tear off the plant material). To be able to actually cut the plant material, a clipping implement must be well maintained. If not, the method would tear rather than cut and hence resemble that of rotating implements. So from the point of view of its potential selective effect on plant species, the distinction between cutting and tearing methods may not always be great.

Some mowed sites can be managed with tractor-pulled equipment, but the majority of the remaining sites are small or in steep or stony terrain (that once precluded their conversion to arable land), leaving a need for smaller types of cutting implements. In flat terrain, the use of a scythe can be up to two or three times as costly and time-consuming as mowing using a knife mower like a hand-pushed sickle bar mower (Finnish Ministry of Agriculture and Forestry 2003). However, in many cases, even the sickle bar mower is difficult or impossible to use in semi-natural grassland. In these cases, mowing scythes or hand-held grass trimmers (also called string trimmer) are the options for efficient mowing. One problem with scythes is that they require considerable practice for effective use. In contrast, grass trimmers can be used by almost anyone without much practice. However, cutting instruments, i.e., scythes or sickle bar mowers, are the preferred mowing techniques among conservation practitioners as grass trimmers, as well as other tearing methods, are believed to damage the plants and seeds. The tearing of plant stems, in contrast to cutting them, is considered detrimental to the species richness and conservation value of semi-natural grasslands (Ekstam et al. 1988, Johansson & Hedin 1991, Sandberg & Thylén 1999). Furthermore, thoughts have been expressed that the tearing of plant stems into small pieces might lead to litter accumulation (Svensson et al. 2009) and possibly higher nitrogen content in the soil. The current recommendations to avoid grass trimmers restrict management options and flexibility and might involve higher costs. However, we are not aware of any studies that experimentally demonstrate such differences between cutting instruments and grass trimmers or that demonstrate negative effects on grassland flora from grass trimmers. Rather, a long-term study comparing three mowing methods, including both cutting and tearing implements, failed to find any differences in vegetation after 18 years (Parr & Way 1988).

The aim of the present study is to examine which mowing technique best maintains the desired vegetation composition of semi-natural grasslands: hand-pushed sickle bar mower or grass trimmer. We used data from a 12-year old

field trial in south-eastern Sweden. A previous, preliminary and qualitative analysis of data from the first seven years of the trial suggested no or only weak treatment effects (Svensson et al. 2009). In the present study, we evaluate data up to 12 years, with quantitative estimation of effect sizes for the different management practices, as well as a multivariate analysis technique. To examine the effect of the different mowing techniques we identified and focused the analyses on three species groups of indicators that describe the vegetation composition in semi-natural grasslands: (i) indicators of management for species richness, (ii) indicators of excess nitrogen and (iii) indicators of lack of management (Appendix A). The use of a trial, spanning more than a decade, made it possible to understand how the mowing techniques affected the conservation value of the flora in the grassland over an extended time period.

Methods

Study site

The study site is situated in Sättra ängar, a 19-ha nature reserve, located in the county of Östergötland, in south-eastern Sweden (58°16'N, 14°49'E). The site consists of species-rich meadows and pastures with stands of deciduous trees, mainly *Quercus robur*. The bedrock consists of granite, and this is covered by till originating from the last glaciation. The vegetation is of a mesic meadow type (Hansson 1991), with an abundance of *Corylus avellana* and many herbs and grasses considered as indicator species for traditionally managed sites like *Ajuga pyramidalis*, *Bistorta vivipara*, *Briza media*, *Convallaria majalis*, *Crepis praemorsa*, *Lathyrus linifolius*, *Leontodon hispidus*, *Polygala vulgaris*, *Rhinanthus minor* and *Scorzonera humilis*. The altitude of the site is 154 m, the mean annual precipitation is 550 mm, and the mean annual temperature is 6.0°C. The growing period is 180-190 days (Wahlman & Milberg 2002). The site has been mowed at least since the 17th century (Hansson 1991). Between 1938 and the early 1970s, when the nature reserve was formed, the area was used as a pasture (Skogsvårdsstyrelsen 1989). The experimental site was established in 2001 and is situated in a part of the reserve that has been mowed every year since the 1970s in late July, using a scythe or a hand-pushed sickle bar mower (Svensson et al. 2009).

Experimental design

The experiment was set up in 2001 with the aim of detecting differences in the effect of three mowing techniques on the grassland flora: (i) mowing with a

hand-pushed sickle bar mower at a 5-cm height, (ii) mowing with a grass trimmer at a 5-cm height (Grass trimmer normal) (iii) and mowing with a grass trimmer at a 0-cm height (Grass trimmer low), a treatment corresponding to the potentially worst case scenario that can be achieved with a grass trimmer in terms of biodiversity management (Svensson et al. 2009). In the present analyses, the treatment with a sickle bar mower is used as a control treatment as this is the mowing technique used in the reserve where the experimental site is situated and because many seem to think that it best reflects the traditional method using scythe. The treatment plots were 2 m x 4 m, set in a randomised design with five replicates. The mowing of each treatment took place in late July every year from 2001-2012. All cut material was removed after mowing, and the whole area was then grazed by cattle (first five years of trial) or horses (the last seven years) (Svensson et al. 2009).

Sampling

The treatment plots were surveyed in early July, before mowing, in 2001-2005, 2008 and 2012. The presence of rooted vascular plant species was recorded in 40 permanent 10 cm x 10 cm subplots along a transect running along the middle of each treatment plot (Svensson et al. 2009). Occasionally, it was difficult to separate different species within the genera *Carex*, *Hieracium*, *Poa*, *Ranunculus* and *Viola*. In these cases, the plants were noted under their genus. Nomenclature follows Karlsson (1998).

Classification of plants

To allow the application of meta-analysis, and to frame the results within evidence-based conservation (Milberg 2014), we simplified species data using existing indicator systems that had classified grassland species as indicators. There are a number of potential indicator systems, and even if there is often substantial overlap among their species lists (Appendix A), the selection of system might influence the results (Milberg et al. 2014). Therefore, we decided to include several potential systems. As indicator systems work best in their area of geographic origin (e.g. Jansson et al. 2009), and when used for their intended purpose, we selected only systems that were specifically targeting species-rich grasslands in southern Sweden and that were well documented. Species were organised into groups we considered to be ecologically relevant when managing for conservation of semi-natural grasslands. Species were consequently recorded as (i) indicators of management for species richness, (ii) indicators of excess nitrogen, and (iii) indicators of lack of management.

Four different types of indicator systems specific for Sweden were used: three national systems and one regionally developed system for the southwest of Sweden. Bertilsson & Paltto (2003) designed the regional indicator system for the adjacent province of Västergötland for evaluation of the grazing management status in semi-natural grasslands. The classification system of Larsson & Ekstam (1987) was devised to assist in the development of a national inventory of species-rich grasslands. The system we refer to as Swedish EPA is based on the species listed for the defining vegetation types in Natura 2000 by the Swedish Environmental Protection Agency (Naturvårdsverket 2011). This classification system included all of the species typical for one or more grassland types (Codes 6210, 6230, 6270, 6410, 6510, 6530 and 9070, according to the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) (Naturvårdsverket 2011). Ekstam & Forshed (1992) did not provide a simple classification but instead placed species in a nitrogen availability gradient (three classes) and considered the rate at which the species were lost during secondary succession from grassland to forest (four classes). We used Ekstam & Forshed's system to make simple classes (Appendix A). First, we considered indicators of management for species richness to be species lost early in succession (classes A and B) that were growing in sites poor in nitrogen (N1). Second, the indicators of excess nitrogen were species of all successional phases (classes A-D) that were growing in nitrogen-rich sites (N3). Third, the indicators of lack of management were defined as species of late successional phases (class C and D) that were growing in nutrient-poor sites or sites with moderate levels of nitrogen (N1 and N2). A preferred mowing method would either be one that maintained status quo or one where indicators of management for species richness increased and/or indicators of excess nitrogen or indicators of lack of management decreased. The methods compared generated no particular expectation when it comes to selectivity among indicator groups, except for indicators of excess nitrogen where we expected the grass trimmer to leave more cut material and, in the long run, lead to an increase (but see Parr & Way 1988).

Statistical analysis

Odds ratio

The odds of finding indicators from the different groups in plots mowed using a hand-pushed sickle bar mower or grass trimmer was calculated. The best mowing technique for preserving biodiversity is the technique with high odds of

finding indicator species of management for species richness and/or low odds of finding indicator species of excess nitrogen and lack of management (Milberg et al. 2014). Analysis of the odds ratios was then performed, with meta-analysis tools, to determine the effect of the different mowing techniques on the grassland flora. The total number of indicator and non-indicator species recorded per subplot was calculated per year and indicator classification system. Thereafter, the number of records of indicators and non-indicators per subplot was summed for each treatment plot and year, and this measure represents the frequency of indicator and non-indicator species per treatment plot and year.

The meta-analyses were performed with the software Comprehensive Meta-analysis version 2 (Biostat, Inc. 2006, Comprehensive Meta-analysis version 2. www.meta-analysis.com). We consistently performed random effects meta-analysis, and effect sizes were the natural logarithm of odds ratio (ln OR): $\ln OR = \ln [(a*d) / (b*c)]$, where a is the frequency of indicators in the sickle bar mower treatment; b is the frequency of non-indicators in the sickle bar mower treatment; c is the frequency of indicators in the grass trimmer normal or grass trimmer low treatment; d is the frequency of non-indicators in the grass trimmer normal or grass trimmer low treatment. All ln ORs were calculated for each replicate and then used in the meta-analysis.

Meta-regression of the random effects ln OR was performed to determine any temporal trend in ln OR, using the number of years since the onset of the trial as a covariate.

Principal Response Curve

To compare the differences in the plant community composition and to determine the extent and direction of the development of the grassland vegetation over the years between the treatments, a Principal Response Curve (PRC, van den Brink & ter Braak 1999) analysis was conducted with the software CANOCO 5 (Ter Braak & Šmilauer 2012). Species occurrence was used as the response variable, time (year)*mowing technique used as explanatory variable and the number of mowing occasions used as covariate. A Monte Carlo permutation test with a hierarchical design and 499 permutations was used.

Richness

The number of species recorded per plot was subjected to a repeated measures ANOVA (with block design).

Results

A total number of 112 species was recorded throughout the experimental run. On average, 25 % of the observed species were either indicators of management for species richness or lack of management, whereas approximately 10 % belonged to the excess nitrogen indicator group (Table 1). The full lists of plant species recorded in 2012 can be found in Appendix A.

#Table 1 approximately here#

Odds ratios and meta-regression

The odds of finding indicators of management for species richness did not differ between the grass trimmer treatments and the sickle bar mower treatment (Figure 1a-d, Table 2). However, the Bertilsson & Paltto indicator system suggested a weak positive trend in the grass trimmer normal treatment, but no such trend was observed with the grass trimmer low treatment (Table 2).

The odds of finding indicators for lack of management displayed a negative trend in the grass trimmer normal treatment for one of the two indicator systems (Bertilsson & Paltto) but not for the grass trimmer low treatment (Table 2). Furthermore, the odds of finding indicators of excess nitrogen did not change over time. However, the odds of finding indicators of excess nitrogen and lack of management differed between treatments at the onset of the trial (Figure 1 e-h, significant intercepts in Table 2).

#Figure 1 approximately here#

Principal Response Curve

The PRC analysis confirmed the general lack of trends over time ($F=4.3$, $p=0.702$). Hence, the vegetation composition did not differentiate over time.

Richness

There was a significant interaction time*treatment effect ($F_{(12, 48)}=2.21$; $p=0.0262$) on the number of species recorded per plot. This was due to grass trimmer normal having somewhat lower richness in the last two recordings, but the effect sizes were small compared with the confidence intervals (Figure 2). No corresponding trend was seen in grass trimmer low, the expected worst scenario (Figure 2).

#Figure 2 approximately here#

Discussion

A recommended mowing technique in semi-natural grasslands should preserve the high species diversity of flora and fauna as well as the rare and threatened species that depend on this habitat (Wahlman & Milberg 2002, Gärdenfors 2010, Milberg et al. 2014). The conservation value of this type of habitat must also be preserved over a relatively long time period and the management practice should, at the same time, prevent the occurrence of less desirable species. In our trial, we found little evidence for any differences in the effect of the different mowing techniques over the twelve years (Figure 1a-h, Table 2, PRC analysis, Figure 2). Mowing using the grass trimmer used at the low cutting height (0 cm) did not cause any discernible trend in the data, whereas the normal cutting height (5 cm) was associated with an undesirable trend in one of the indicator systems used (Bertilsson & Paltto) and in richness. For some indicator systems, the odds of finding indicators differed at the beginning of the trial (Table 2) but then remained unchanged over time. Therefore, the differences most likely had to do with the initial variability of the grassland. Analysis of partly the same data, but for fewer years, performed by Svensson et al. (2009) reached similar conclusions based on changes in species richness and an unspecified multivariate analysis. It is of course still possible that the methods are selective among species (e.g. that chamaephytes and cryptophytes are differently affected), but our focus here was on the conservation value of the resulting vegetation, which seemed unaffected.

Studies have indicated the importance of light availability (Einarsson & Milberg 1999), cutting height (Wadi et al. 2004, Wijitphan et al. 2009) and timing of mowing (Hellström et al. 2006) on the flora in grasslands. However, few long-term studies have experimentally compared different mowing techniques on the flora of semi-natural grasslands (Parr & Way 1988) and, to our knowledge, no other studies have experimentally compared the grass trimmer with a cutting implement (with the exception of the previous interim report of data from the present trial by Svensson et al. 2009). Therefore, the felt misgivings towards grass trimmers among conservation managers (e.g., Ekstam et al. 1988, Johansson & Hedin 1991, Sandberg & Thylén 1999) are not supported by the present study. Despite using several different indicators, a twelve-year follow up period that should allow manifestation of relevant treatment effects, and a powerful multivariate method, only weak trends of a more negative effect of mowing using the grass trimmer compared to the sickle

bar mower could be found. The treatment expected to be worse – trimming at 0 cm – only revealed small, non-significant negative effects on the flora. In a recent study, Milberg et al. (2014) used the same indicators in data from other grassland trials and could then document substantial trends in data; hence, the analysis approach has been shown to have decent power to detect a trend in similar vegetation and over similar time spans. To conclude, if there is a detrimental effect of grass trimmer, it is a weak one that takes much more than a decade to become discernable.

Apart from the actual cutting, a crucial side-effect of mowing is the removal of the cut material. In fact, it is possible that the perceived negative effect of mowing using grass trimmers emerged from the many cases where grass was cut but not removed, a practice known to have a negative effect (e.g., Parr & Way 1988, Schreiber et al. 2009, Ruprecht et al. 2010, Loydi et al. 2013). A potential negative aspect of mowing using the grass trimmer, when conducted in a non-experimental setting, might be the collection of the cut material that might be more disintegrated compared to what is left after mowing using a sickle bar mower. The effect of remnant litter, however, tends to be negative only at relatively high densities (Loydi et al. 2013, Kelemen et al. 2014), so whether small amounts of mowing residues left is a concern in conservation management remains to be evaluated. Another reason for the perceived negative effect of mowing using grass trimmers could be that, in contrast to a scythe or sickle bar mower, it can be used efficiently many times during a growth season, i.e., even on relatively short grass.

It is important to note that the present experiment was performed in a semi-natural grassland that had been mowed for a long period and which therefore had the desired vegetation composition of meadows. The results may differ when restoring a grassland that has been abandoned for some period or when shifting from grazing to mowing. Still, in the absence of strong evidence, there is little support for avoiding grass trimmers in conservation work. On the contrary, it supports the use of grass trimmers in meadows if the alternative would be abandonment or a change in management to e.g. grazing.

Implications for conservation

Grassland vegetation was not observed to differ over time in a field trial comparing mowing using a hand-pushed sickle bar mower and grass trimmer. Therefore, both mowing techniques can be recommended for conservation

management in semi-natural grasslands. Furthermore, mowing height (0 vs. 5 cm) did not appear to cause differences, a finding that also simplifies management.

According to the Finnish Ministry of Agriculture and Forestry (2003), mowing using a hand-pushed sickle bar mower is more cost- and time-effective than mowing using either a scythe or grass trimmer. For grassland that are large and with a relatively level surface, the use of the sickle bar mower might therefore be superior. Nevertheless, there are situations when a grass trimmer might still be better, e.g., management of small patches, and steep or stony ground. Furthermore, most farmers own a grass trimmer used for other purposes, e.g., cutting grass beneath electrical fences, and therefore do not need to invest in new equipment if the grass trimmer is used for mowing. Hence, our findings suggest a greater management flexibility.

When recommending the use of a mowing technique in semi-natural grasslands, more factors than the effect on the floristic composition need to be considered. Current and previous management practices, as well as the cost and time-consumption, the practical aspects of the mowing technique and the effect on the conservation of a large range of species. Although not considered in our study, it is important to remember the invertebrate fauna of semi-natural grassland (van Klink et al. 2014, Littlewood et al. 2012). The stress caused by mechanical mowing techniques and the changes in the micro-climate caused by management can have negative effects on the fauna (Humbert et al. 2009). Intensive mowing has been shown to have a negative effect on butterflies (Johst et al. 2006), ground beetles, orthopterans and spiders (Cizek et al. 2012) and grasshoppers (Gardiner & Hassall 2009), among others (Humbert et al. 2009). Consequently, Cizek et al. (2012) recommend less intensive mowing and sequential mowing of land units to minimise the negative effects of mowing. However, the question at stake in our study was whether the actual technique for mowing mattered. Unfortunately, few studies have investigated the effect of different mowing techniques on the fauna (but see Humbert et al. 2010) and fewer specifically have investigated the effect of using a grass trimmer compared with a sickle bar mower.

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Figure legends

Figure 1. Ln OR for different types of indicators and indicator systems comparing mowing techniques. Sickle bar mowers or grass trimmers at different cutting heights were used, and each treatment was replicated five times. Error bars represent 95 % CI.

Figure 2. Richness per plot ($CI_{95\%}$) over time in the three mowing treatments.

1 Table 1. Overview of indicator system used and the percentage of species belonging
 2 to each. The total number of species found throughout the trial was 112.

Indicator system	
Management for species richness	
Bertilsson & Paltto	24.1 %
Ekstam & Forshed	25.9 %
Larsson & Ekstam	25.9 %
Swedish EPA	27.7 %
Excess Nitrogen	
Bertilsson & Paltto	9.8 %
Ekstam & Forshed	11.6 %
Lack of Management	
Bertilsson & Paltto	4.5 %
Ekstam & Forshed	25.9 %

3

Table 2. Meta-regression results comparing the effect of the sickle bar mower and grass trimmer at normal or low, testing if the ln OR of indicator species frequencies change from 2001 to 2012. If the slope is positive, evidence suggests the sickle bar mower has more indicators than grass trimmer, and vice versa if slope is negative. When the intercept deviates from zero, the odds of finding indicators differed at the beginning of the trial. Stars indicate estimates that were significantly different from zero.

Treatment	Indicator system		Estimate	CI	p-Value
Grass trimmer normal	Management for species richness				
	Bertilsson & Paltto Management for species richness	Slope	0.020	± 0.022	0.082
		Intercept	-0.182	± 0.136	0.009 **
	Ekstam & Forshed Management for species richness	Slope	0.011	± 0.023	0.352
		Intercept	-0.160	± 0.139	0.024 *
	Larsson & Ekstam Management for species richness	Slope	0.010	± 0.018	0.292
		Intercept	-0.236	± 0.105	0.000 ***
	Swedish EPA Management for species richness	Slope	0.006	± 0.023	0.636
		Intercept	-0.144	± 0.106	0.008 **
	Excess nitrogen				
	Bertilsson & Paltto Excess Nitrogen	Slope	0.010	± 0.018	0.292
		Intercept	-0.236	± 0.105	0.000 ***
	Ekstam & Forshed Excess Nitrogen	Slope	0.050	± 0.072	0.173
		Intercept	0.032	± 0.399	0.877
	Lack of Management				
	Bertilsson & Paltto Lack of Management	Slope	-0.030	± 0.019	0.002 **
		Intercept	0.311	± 0.126	0.000 ***
	Ekstam & Forshed Lack of Management	Slope	-0.006	± 0.018	0.515
		Intercept	0.021	± 0.128	0.749
Grass trimmer low	Management for species richness				
	Bertilsson & Paltto Management for species richness	Slope	0.000	± 0.025	1.000
		Intercept	-0.083	± 0.186	0.384
	Ekstam & Forshed Management for species richness	Slope	0.004	± 0.026	0.771
		Intercept	-0.041	± 0.159	0.611
	Larsson & Ekstam Management for species richness	Slope	-0.002	± 0.029	0.875
		Intercept	-0.144	± 0.207	0.170
	Swedish EPA Management for species richness	Slope	-0.001	± 0.035	0.940
		Intercept	-0.093	± 0.223	0.415
	Excess Nitrogen				
	Bertilsson & Paltto Excess Nitrogen	Slope	-0.016	± 0.046	0.489
		Intercept	-0.086	± 0.303	0.576
	Ekstam & Forshed Excess Nitrogen	Slope	-0.007	± 0.074	0.855
		Intercept	-0.404	± 0.517	0.125

Lack of Management

Bertilsson & Paltto	Slope	0.005	± 0.045	0.810
Lack of Management	Intercept	0.398	± 0.321	0.015 *
Ekstam & Forshed	Slope	0.011	± 0.019	0.254
Lack of Management	Intercept	-0.001	± 0.146	0.985

1 Appendix A. Species recorded in the trial in the year 2012, and whether they are
2 indicators/non-indicators according to eight indicator systems for classifying
3 grassland plants

	Indicators of management for species richness				Indicators of excess nitrogen		Indicators of lack of management	
	Bertilsson & Paltto	Ekstam & Forshed	Larsson & Ekstam	Swedish EPA	Bertilsson & Paltto	Ekstam & Forshed	Bertilsson & Paltto	Ekstam & Forshed
<i>Achillea millefolium</i>								x
<i>Agrostis capillaris</i>								x
<i>Ajuga pyramidalis</i>	x	x	x	x				
<i>Alchemilla</i> sp.								
<i>Anemone nemorosa</i>					x			x
<i>Anthoxanthum odoratum</i>	x	x	x					
<i>Betula pubescens</i>								
<i>Bistorta vivipara</i>	x	x	x	x				
<i>Briza media</i>	x	x	x	x				
<i>Campanula persicifolia</i>	x		x	x				x
<i>Campanula rotundifolia</i> ssp. <i>rotundifolia</i>	x	x	x	x				
<i>Carex montana</i>		x		x				x
<i>Carex pilulifera</i>		x		x				
<i>Carex</i> sp.								
<i>Convallaria majalis</i>				x				x
<i>Corylus avellana</i>								
<i>Crepis praemorsa</i>	x	x	x	x				
<i>Cynosurus cristatus</i>								
<i>Dactylis glomerata</i>					x	x		
<i>Dactylorhiza maculata</i>	x	x	x	x				
<i>Danthonia decumbens</i>	x	x	x	x				
<i>Deschampsia cespitosa</i>					x			x
<i>Deschampsia flexuosa</i>								x

[illegible]

<i>Poa pratensis</i>					x	x		
<i>Polygala vulgaris</i>	x	x	x	x				
<i>Potentilla erecta</i>				x				x
<i>Prunella vulgaris</i>						x		
<i>Quercus robur</i>								
<i>Ranunculus acris</i>					x	x		
<i>Ranunculus auricomus</i>								
<i>Rhinanthus minor</i>	x	x	x	x				
<i>Rumex acetosa</i>					x	x		
<i>Scorzonera humilis</i>	x	x	x	x				
<i>Stellaria graminea</i>								x
<i>Taraxacum sect. Ruderalia</i>					x	x		
<i>Trifolium medium</i>							x	x
<i>Trifolium pratense</i>		x						
<i>Trifolium repens</i>					x	x		
<i>Veronica chamaedrys</i>							x	x
<i>Veronica officinalis</i>		x						
<i>Vicia sepium</i>								x
<i>Viola canina</i>								
<i>Viola sp.</i>