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Recreating semi-natural grasslands: A comparison of four methods

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ABSTRACT

Semi-natural grasslands and their species and populations are declining rapidly throughout Europe, bringing about a need for successful vegetation recreation methods. To maintain biodiversity and ecological services of semi-natural grasslands, we need more knowledge on the relative performance of different recreation methods. In a replicated experiment in western Norway, we evaluated two hay transfer methods (hard or light raking of local hay), sowing of local seeds and natural regeneration for recreating semi-natural grassland in a road verge. We compared treated trial plots with their respective donor plots (where hay and seeds were harvested) for three successive years by evaluating vegetation cover, species richness and species transfer rates, and vegetation dynamics analysed by Bray–Curtis compositional dissimilarity (BC) and GNMDS (Global Non-Metric Multidimensional Scaling) ordination. Vegetation cover at the trial site exceeded that of donor sites in three years. Transfer rates of common species were high for seed sowing and both hay transfer procedures. Species composition in trial plots for all three treatments became significantly more similar to donor plots, but was still relatively dissimilar after three years. Natural regeneration showed a different temporal pattern and also had a higher successional rate. The species composition of the other treatments followed the same trajectory toward the donor sites as revealed by GNMDS. We found relatively small differences between the two hay transfer methods and seed sowing. Transfer of local hay therefore appears to be a successful method of establishing local species when recreating semi-natural grasslands, and is generally cheaper than using commercial local seed mixtures.

1. Introduction

Landscape changes have brought about decline or even extinction of many species and populations during the last 50–100 years across Europe (cf. Wells, 1991; Poschlod and WallisDeVries, 2002; Hamre et al., 2007). Plant species associated with low-intensity semi-natural grasslands are at particularly high risk, since agricultural intensification, agricultural abandonment and landscape fragmentation have dramatically reduced the number of suitable habitats for these species (Ehrlén et al., 2005). Awareness of these trends and the fact that species richness is usually high in semi-natural grasslands (Kull and Zobel, 1991) have led to great interest in ways of maintaining semi-natural grasslands. Grassland recreation and restoration are proposed conservation strategies alongside conservation of the few remaining intact sites (Stevenson et al., 1995).

There are, however, several challenges that have to be solved in order to successfully recreate or restore semi-natural grasslands. Both the elevated soil nutrient concentrations of most ex-arable land and the general scarcity of seed sources for native (target) species put constraints on restoration. The target species may be absent both aboveground and in the soil seed bank (Bekker et al., 1997). A common strategy in such cases is to remove the topsoil and transfer species, using either a seed mixture of local provenance (Vander Mijnsbrugge et al., 2010) or local hay containing seeds (Patzelt et al., 2001; Hölzel and Otte, 2003; Kiehl et al., 2006). Another way of increasing the area of valuable semi-natural grassland is to create new habitats. Road verges provide particularly suitable areas, since they have to be kept open for traffic safety reasons.

Roads may serve as dispersal corridors for grassland plant species (Tikka et al., 2001). However, in the absence of their most important dispersal vector, livestock, many of these species are restricted to short-range seed dispersal (Poschlod et al., 1998; Poschlod and WallisDeVries, 2002). There has been some discussion of whether road verges can serve as substitute habitats for native grassland plant species (Tikka et al., 2001; Auestad et al.,

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2008), but they are undoubtedly important for restoring and maintaining overall landscape diversity (Damschen et al., 2006).

Hydroseeding with commercial species-poor seed mixtures is the conventional method of establishing vegetation cover on new road verges (cf. Skrindo and Pedersen, 2004; Tormo et al., 2006). This method effectively and rapidly establishes vegetation cover and also reduces the probability of soil erosion. However, the resulting species-poor vegetation of homogenous road verges may actually lower the local botanical diversity. To maintain diversity, road verges need to be actively used as substitute habitats for semi-natural grasslands. Rapid and effective methods of establishing vegetation cover that use seeds from local seed mixtures and/or the transfer of seed-containing hay are therefore needed (Wells, 1991; Stevenson et al., 1995; Walker et al., 2004). Hay transfer is a technique that provides safe sites for germination and establishment of diaspores (Jones et al., 1995; Patzelt et al., 2001; Hölzel and Otte, 2003; Kiehl et al., 2006; Edwards et al., 2007; Woodcock et al., 2008). The methods used for harvesting the hay may influence recreation success. Hay transfer by manual cutting and raking – in particular hard raking that collects considerable amounts of ground debris and bryophytes – probably transfers more seeds than mechanised harvesting. Manual cutting and raking also make it possible to record the species composition of the hay accurately, thus enabling examination of the finer details in species transfer success and vegetation development.

Restoration studies seek to identify optimal methods for restoration or recreation of habitats. However, it is inherently difficult to evaluate the success of such methods (Ruiz-Jaén and Aide, 2005a) and particularly to compare the outcomes of different studies. Vegetation structure in terms of species composition (commonly used for evaluating restoration success; Ruiz-Jaén and Aide, 2005b) may for example be measured and analysed in many different ways. The sampling scheme and inherent properties of the methods employed will consequently influence the outcome of the analyses.

In the present study we assessed the effects of two methods of hay transfer (hard or light raking after cutting), seed sowing and natural regeneration on vegetation development in the first three years after the establishment of a new road verge. We compared species composition at the trial site (new road verge) and the donor sites. We asked three questions: (1) How rapidly does the vegetation cover of vascular plants and bryophytes and lichens become established at the trial site? (2) Does the species composition at the trial site follow a successional trajectory towards that of the donor sites? (3) Does the success of the four methods differ?

2. Materials and methods

2.1. Study sites

In 2004, we established a trial site for hay transfer, seed sowing and natural regeneration on a newly constructed road verge (total area about 0.5 ha) at Borgund (61°3′N, 7°49′E), altitude 420 m, in Lærdal, Sogn og Fjordane county, W Norway. We collected hay and seeds from three donor sites (Molde, Nese and Stuvane), each of which included two habitats (pasture and road verge). The three sites are 16, 9, and 3 km from Borgund and situated at altitudes between 35 and 420 m. The trial site and the donor sites are all situated within a slightly continental section of the southern boreal region (Moen, 1999), with a mean annual precipitation of ca. 500 mm (Førland, 1993), and mean annual temperature of ca. 5.9° C (Aune, 1993). The bedrock in the area consists mainly of Precambrian gneisses, but one site (Nese) is situated on gabbro covered by a layer of terraced glacifluvial deposits (Klakegg et al., 1989).

2.2. Experimental design and sampling

At each of the three donor sites, we established five blocks of 15–16 m^2 (cf. Auestad et al., 2008), in each of the two habitats (pasture and road verge). In each block we marked out two randomly sited plots of 0.5 m × 0.5 m with buffer zone of 0.25 m at all sides, giving a total of 60 plots. We divided each plot into 16 equally sized subplots and in June–July 2004 we recorded the abundance of vascular plants in each plot as frequency out of 16 subplots. We also recorded the species richness, number of vascular plant species per plot. In August 2004, we used a sickle and shears to cut the hay in all plots and buffer zones and gathered the cuttings by light or hard raking (the latter gathers most of the bryophyte layer), plots and buffer zones separately. The hay from the 30 light-raked and 30 hard-raked plots and their respective buffer zones were dried indoors, separately in paper bags hanging on a horizontal stick above the floor, and stored for ca. one month in anticipation of finishing of the road. We harvested ripe seeds for the seed sowing treatment at each of the three donor sites (without differentiating between the two habitats and wherever within each site) during late summer and early autumn 2004. Seeds were harvested from 17 species (see Appendix A for further details), eight of which were found at all donor sites, while nine were site-specific. The seeds were cleaned, examined and counted in the laboratory and 5 × 3 seed mixture bags (three different seed mixtures differing between the sites), each with 11 species, were made (125 seeds of each grass species and 25 seeds of each herb species).

In September 2004 a top layer of local soil (80% local gravel and sand and 20% local arable soil, thereby containing parts of an arable soil seed bank) was added at the trial site. Five blocks (8 m× 8 m) 1 m apart were positioned in the centre of the road verge. Sixteen plots of 0.5 m × 0.5 m, divided into 16 subplots of 12.5 cm × 12.5 cm, with 0.25 m buffer zone at all sides were positioned at random within each block. Plots with their buffer zones were not allowed to share sides, giving a minimum between-plot distance of 0.7 m. The 16 plots in each block were randomly selected for the following four treatments: hay transfer by light (Light) or hard raking (Hard) from each of the three donor pastures, hay transfer by light (Light) or hard raking (Hard) from each of the three donor road verges, seed sowing using seeds from each of the three donor sites (Seed). The last plot was used for natural regeneration (Natural).

Hay transfer and seed sowing were carried out in late September. Each donor plot was randomly assigned to a plot at the trial site. The seed mixtures were hand sown. The hay from the donor plot was placed in the trial plot, while the hay from the buffer zone of the donor plot was placed in the buffer zone of the trial plot, thereby functioning as a small guard row. The rest of each block at the trial site was left untreated.

In the three following years (2005–2007) we recorded species abundance as subplot frequency out of 16 subplots, total cover of bryophytes and lichens (mainly bryophytes), total cover of vascular plants and species richness in the 80 trial plots in late July to early August. The management of the trial site from 2006 onwards included annual mowing and subsequent removal of hay in July or August.

In early September 2007 we took soil samples from every trial plot, from the upper 5 cm of the soil just outside the buffer zone. The soil was dried at 40 °C for two days before sifting (2.5 mm mesh width). Loss on ignition (%), total nitrogen (%) determined by the Kjeldahl method, and pH were measured in aqueous solution by a professional laboratory (Analycen).

Species nomenclature follows Lid and Lid (1994) except for *Betula pubescens* agg. (which includes *B. pubescens* and *B. verrucosa)*