Plant species diversity in an old, traditionally managed hay meadow compared to abandoned hay meadows in southwest Norway

Mary H. Losvik

Losvik, M. H. 1999. Plant species diversity in an old, traditionally managed hay meadow compared to abandoned hay meadows. - Nord. J. Bot. 19: 473-487. Copenhagen. ISSN 0107-055X.

A chronosequence, representing a successional series, was used for the comparison of a hay meadow site managed in an old traditional way for at least a hundred years, and hay meadow sites abandoned for about 10, 20 and 30 years, respectively. Old traditional management included grazing early and late in the growing season, mowing in August and light or no fertilizing. The tree cover was the most important factor deciding the composition of vegetation. Time since abandonment was not completely correlated to tree cover, as some plots had a dense canopy and others were situated in the open. The total species number decreased with number of years since abandonment in plots > 0.001 m² and < 100 m². The highest species number in 1 m² plots was recorded in the managed site, with 38 species of phanerogams. Fourtyeight % of the indicators of traditional management present in the managed site was recorded in the site which had been abandoned for 30 years. Frequency - log area curves made it possible to group species according to persistence in the sward. As a result, a group of functional indicators of rare hay meadows in the region was distinguished.

M. H. Losvik, Botanical Institute, University of Bergen, Allegt. 42, N-5007 Bergen, Norway.

Introduction

At small scales, temperate grasslands are the most species-rich plant communities in the world (Peet et al. 1983; Walker & Peet 1983; Shmida & Ellner 1984). Grasslands were once widespread in western Europe, but are now greatly reduced in extent as a result from changes in agricultural land-use practices (Keymer & Leach 1990; Willems 1990). The grasslands may have high species numbers, up to well above 60 per m² (Willems 1978, 1982; Kull & Zobel 1991). Old, traditionally managed hay meadows are rare in western Norway at present (Ovstedal 1985; Lundekvam & Gauslaa 1986; Losvik 1988a, 1988b, 1993a; Rosef 1996). Earlier they were common elements of the agricultural landscape, but most of them are now either cultivated in a modern way or abandoned (Losvik 1996a). The few old, traditionally managed hay meadows which are left, are mostly situated on phyllitic soils and have high species diversity. No investigation in the region has so far studied what happen to the species diversity and species composition when such meadows are abandoned.

In this study the species have been grouped into indicators of traditional management, common (hay meadow) species and additional species, the latter includes forest species. The species group indicators of traditional management was preliminary defined in Losvik (1993b), and later (Losvik 1996b) was shown to comprise species occurring in less than 60 % of 548 plots (1-16 m²) of hay meadow vegetation analysed in
western Norway by 6 different authors 1972-1991. These species are often low-satured, creeping, slender and/or with rosettes, and mostly stressstotolerators (Grime 1974, 1979) and hemicryptophytes, annuals or biennials (Raunkiaer 1934). The number of the indicators is usually low in abandoned sites (see data in Losvik 1981; Persson 1984; Austad & Skogen 1990; Borgegaard & Persson 1990). Modern management, including medium or heavy fertilizing, also reduces species number in general (see e.g. During & Willems 1984; Willems et al. 1993), and especially the indicators of traditional management (Losvik 1988b, 1993a, 1996b). As a consequence, indicators of traditional management are becoming increasingly more rare in the region. Common species are defined as being more frequent than indicators of traditional management in the agricultural landscape, tolerating medium quantities of fertilizer. These groups of species is considered to be more useful in choosing areas for hay meadow conservation, than the plain use of total number of species, as it reveals direct information on the number of target species, namely the indicators of traditional management in the sites.

The changes in plant species richness during succession have been studied e.g. by Nicholson & Monk (1974), Bazzaz (1975), Prach (1985) and Symonides (1985). Both increase and decrease in total plant species diversity have been found in these studies, and the situation may be further complicated by environmental gradients (Peet 1978; Prach 1986). As the species diversity depends on the spatial scale considered (e.g. Kwiatkowska & Symonides 1986; van der Maarel 1988a) it may be better described by the species-area relationship than by single species numbers.

The aim of the study was to compare the vegetation and ecology of 4 sites which formed a chronosequence, representing a successional series from a species-rich, old, traditionally managed hay-meadow to sites which had been abandoned for about 10, 20 and 30 years, respectively. Themes of special interest were: how important are the ecological factors years since abandonment and cover of tree canopy in deciding the composition of the vegetation, what differences in species diversity, as measured by species-area curves, are there between the sites, for how long are species which are characteristic for the agricultural landscape able to persist during overgrowing in such sites, and finally, what forest species and additional species are most important in the sites of this series of abandoned hay-meadows.

Material and methods

Study area

The 4 study sites are located in a hill-side at Gjuvsland, Varaldseøy in The Hardanger fjord, western Norway, generally sloping 25° towards south-east, from about 100 m.a.s.l. down to the shore. The hill-side was formerly common land, used as out-lying hay meadows. They were mown in August and grazed in spring and in autumn by sheep and cattle from 6 farms at Gjuvsland. In 1906 the hill-side was divided between the farms into 6 parts which each was fenced. Four of these parts constituted the study sites.

The bedrock is volcanic supercrustal rocks covered by scree material containing phyllite (Foslie 1955; see also Kolderup 1960; Askvik 1976). The soil is probably enriched with Ca through seepage from limestone bedrock occurring above the hay meadows. The mean precipitation at the nearest meteorological station Rosendal is 1799 mm year⁻¹ (Førland 1993). The mean temperature in January is 0.5° C, in July 15.5° C, and mean yearly temperature is 7.2° C (at the nearest meteorological station measuring temperature, Omastrand, Aune 1993).

Traditional management includes grazing by sheep for about 14 days in May/June and in September/October each year. Until about 50 years ago, mixed grazing by cattle and sheep was common, but later sheep alone were used. Stocking rates are about 300 sheepgrazing days/ha and year (including lambs), less in dry years. After the spring grazing period, dried leftovers of manure and twigs of trees are removed by raking. The grass is mown in August, using a small reaper and different forms of scythes. August may be rainy (Semme 1954), but the farmers usually awaits a period of dry weather to allow drying of the grass on the ground. The grass is turned on the spot twice a day till it is dry, allowing seeds to be spread evenly throughout the grassland. Usually no commercial fertilizers or wintermanure are applied, but some nutrients are recycled through urine and faeces during grazing, particularly when mixed grazing, involving higher grazing intensity than at present, was practised (Brelin 1979). The main features of these management practices were common in western Norwegian out-lying hay meadows till about 1945 (Byrkjeland 1958). As long as the whole hillside was managed, there was a scattered tree-layer of pollards (mostly Fraxinus excelsior) or coppiced trees (Corylus avellana and Alnus incana). These trees and characteristic forest herbs and grasses often grew near outcrops or heaps of rocks, cleared away from the meadows, and functioned as centres of natural afforestation as management ceased. At the study site this has resulted in a mosaic-like pattern of patches with (1) a high, dense
sward of grasses and herbs, lacking a tree layer, (2) a scattered field layer and a more or less closed canopy of trees, and (3) a low dense field layer in areas in the open which are situated close to small outcrops, narrow paths, ant-heaps and springs.

Site A is managed in the old, traditional way (A. A. Gjuvsland, pers. comm.). But since about 1990 the number of sheep has been reduced to about on third. This reduction has, at least partly, been compensated for by longer grazing periods. The low-lying part (about ½) of site A was lightly fertilized (about 100 kg fertilizer/ha.year, type varied) in June from about 1950 till 1990 (in the 60ties at most 200 kg fertilizer/ha.year). The soil is rich in minerals (base saturation: 54-76 %), and poor in organic matter (C: 2.3-3.8 %), nitrogen (0.31-0.47 %) and phosphorus (0.2-0.5 mg/100 g dry matter) with pH 5.1-5.6 (Losvik 1988a). The site has a rather high species diversity (Losvik 1985, 33-38 species of phanerogams/16 m²), compared to other grasslands in south-west Norway (Ovstedal 1985; Lundekvam & Gauslaa 1986; Losvik 1988a, 1988b, 1991, 1993a; Hundt & Vevle 1990). Species such as Cynoglossum cristatum, Briza media, Trifolium dubium and Linum catharticum, which are rare in western Norwegian grasslands at present (Losvik 1996b), are abundant in the site. An assembly of uncommon grassland species separated, each in its subsite. Presence of all rooted phanerogamic species of the field layer were recorded in 1995 or 1996. Shade was estimated as the cover of the tree layer in each 100 m² plot. The number of years since abandonment, in addition to records of former management, was obtained by interviewing each farmer.

Main ecological gradients in the data set and length of the gradients were assessed by Detrended Correspondence Analysis, DCA (Hill 1979; Hill & Gauch 1980) applied to presence-absence data for 137 species (species occurring in < 5 plots were omitted) in 40 quadrates of 100 m² each, using CANOCO version 3.12 (ter Braak 1987a, 1990). Canonical Correspondence Analysis, CCA (ter Braak 1986, 1987b) was used to evaluate the importance of the environmental factors: years since abandonment and cover of trees. Standard options were used. Monte Carlo test (ter Braak 1990) with 99 permutations was used to assess the significance of first canonical axis and overall significance. Species - log area curves, frequencies - log area curves, and the significance of differences in species richness (t-test) were constructed or calculated using EXCEL version 4.0 (Microsoft Corporation 1992). Each point on the curves represented mean values of 40 plots of the smallest size and 10 plots of each of the other plot sizes. Species - log area curves were used to demonstrate the differences in species richness between sites and according to plot sizes. The species - log area method used made it possible to demonstrate differences in presence of single species in the sites by frequency - log area curves. The species were grouped according to per-
Results

DCA indicated a gradient of shade along the first axis (eigenvalue 0.37, 2.8 SD) and of nutrients along the second axis (eigenvalue 0.15, 2.2 SD). The indicators of traditional management and the common species as expected were situated in the light part of the first axis gradient, while the additional species, comprising forest species and species common along edges and roadsides, were mainly in the opposite direction (Fig. 1a). When the plots were classified according to tree cover, the gradient of shade along the first axis was clearly demonstrated (Fig. 1b). Grouping of the plots according to sites showed small variations along the gradients in sites A, B and C compared to site D (Fig. 1c). The plots within each site were more similar to each other than to any plot outside the site along axis 1 and 2. CCA demonstrated that tree cover (Cover) as expected was positively correlated with the first axis (Fig. 2, eigenvalue 0.28). Years since abandonment (Abandon) was positively correlated to both the first and the second axis. Axis 1 accounted for 21.9% of the species data, axis 2 accounted for only 4%. Significance (p) of the first axis was 0.01, and an overall test also gave significant results.

Of the 154 species recorded in sites A-D, 35% were absent in the plots of site D, 40% were absent in site A (Appendix 1, 2). Seven% of the species was only recorded in A, 12% only in D. The species - area curves of site A for the total number of species, indicators of traditional management and common species were nearly linear, but the B-D curves increased exponentially with log area. Construction of log species - log area curves made the total species number curve of site D close to linear, but the other curves then turned into power function curves. None of the curves showed any tendency to flatten out at the investigated size ranges.

The mean total species number for plot sizes >0.001 m² and <100 m² was higher in the traditionally managed site A than in the abandoned sites (Fig. 3a, p < 0.001). Sites B and C had intermediate mean species numbers, while site D had a lower number of species than sites A-C in these plot sizes (p < 0.01). The highest species number in 1 m² plots was recorded in site A with 38 species (mean 32, SD 3) and in the 100 m² plots in site C with 60 species (mean 50, SD 7), followed by site A with 56 species (mean 49, SD 5). When all species in the 10 plots of each site were added ('plot' size 0.1 ha) however, site B had the highest species number (Appendix 1, 2). The number of indicators of traditional...
management was higher in site A than in sites B-D for the whole range of investigated plot sizes (Fig. 3b, p < 0.002). Only 48% of the indicators of traditional management in site A was recorded in site D (Appendix 1, 2). Site A had the highest and site D the lowest mean number of common species in plot sizes from 0.01 m² to 100 m² (Fig. 3c). The differences in mean number of additional species between sites were negligible for plot sizes up to 1 m² (Fig. 3d), but for larger plot sizes the mean number was lower in site A than in sites C-D (p < 0.01) and for the largest plots it was also lower in site A than in site B (p < 0.01).

The species were grouped according to presence/frequency of each species in all plot sizes in sites A-D (Appendix 1, 2). Group 1 mostly comprised indicators of traditional management and common species, species which are more or less dependent on high light availability. The frequency of species of group 1a tended to be much lower in sites B-D for all plot sizes than in site A, if they were present there at all (Fig. 4a). Species of group 1b (Fig. 4b) persisted rather well as long as there were openings in the tree canopy. Other agricultural landscape species were rather shade tolerant (group 1c, Fig. 4c), and some species even increased in frequency after abandonment (group 1d, Fig. 4d). Group 2a comprised border species which benefit from the lack of management in addition to the high light availability in the early successional phases (Fig. 5a), and group 2b comprised forest species (Fig. 5b). The rest of the species occurred too scattered in the sites to be grouped.

Discussion

The ordination results confirmed that low tree cover was important for the indicators of traditional management and the common species, while the additional species may tolerate well both abandonment and a high tree cover, even if the species may be present also in the traditionally managed hay meadows. With the assumption that the vegetation in sites B-D was about the same as in site A when they were managed, DCA indicated that open abandoned areas gradually became poorer in nutrients with time while areas with a closed tree canopy became richer (see Figs 1b and 1c, plots B1, D7, D9-10). Austad & Skogen (1990) recorded both rather poor Betula pendula forest and rich forest types with e.g. Ulmus glabra in abandoned meadows in a hillside in Sogn. In Losvik (1981) it is concluded that successional trends in abandoned hay meadows take different courses according to nutrient content in the soil. A similar investigation in Sweden showed higher soil nitrogen in woodland than in open mown areas (Borgegård & Persson 1990), but as the open areas of sites B-D are not
Fig. 3. Species - log area curves for the mean total number of phanerogamic species (a), the number of indicators of traditional management (b), the number of common grassland species (c) and the number of additional species (d) in sites A - D.

mown, soil analysis will be necessary to prove that the differences in vegetation resulted from differences in soil nutrients. A theory would be that litter of trees, here mainly ash (*Fraxinus excelsior*), decomposes more rapidly than the grass sward of the open areas, releasing more nutrients to the soil in the studied time span of abandonment. Bearing these statements in mind, an interesting interpretation of the CCA result may be that tree cover, according to the distribution of species in the diagram, seemed to be positively correlated to nutrients, while abandonment in general seemed to be negatively correlated to nutrients. In an abandoned area, tree cover, and with it the area which is in shade will increase with time. But the increase is not evenly distributed in space, as some areas are open for a considerable time span, and as such may be poorer in nutrients than areas with a tree canopy. This implies that the composition of the vegetation in an abandoned area is dependent not only on time since abandonment, but also on the local extent of the tree cover. The occurrence of seedlings of ash (*Fraxinus excelsior*) in at least 7 out of 10 plots of 0.1 m² in sites B - D (Fig. 5b) indicate that the open areas of
Fig. 4. Examples of frequency - log area curves for group 1a (*Linum catharticum*), group 1b (*Danthonia decumbens*), group 1c (*Conopodium majus*) and group 1d (*Lotus corniculatus*). Frequency is number of 100 m² plots in which the species occur.

these sites is really in a transitional phase, during which the content of nutrients in the soil may be lower than in areas with a closed canopy.

The rate of increase in species number with increase in plot size is an appropriate measure of richness, instead of using number of species in one plot size (Kilburn 1966; van der Maarel 1988a; Leps & Stursa 1989). But this rate ought to be constant along the curve, and as the species-area curves differed too much in shape in this study, only differences in species numbers between sites at the different plot sizes were compared. Singh et al. (1996) stated that neither the exponential function \( s = a + b \log A \) nor the power function \( S = c A^x \) fitted their data equally well in all situations and the same may be said for the present study. In the dynamically stable state of site A the species - log area
Fig. 5. Examples of frequency - log area curves for group 2a (Holcus mollis) and group 2b (Fraxinus excelsior juv.). Frequency is number of 100 m² plots in which the species occur.

curves were close to linear, while in sites B-D, with a large turnover of species, the curves were exponential. The form of the curves is dependent on density of individuals and plant unit areas. In the traditionally managed hay meadow the species were mostly small with individuals of the species quite evenly distributed. The much smaller variance in plots of site A compared to site D (Fig. 1c) demonstrated that in site A the vegetation was more homogenous (van der Maarel & Sykes 1993). Wherever the analysis would have started, comparatively many species would have been added by increasing the area (Fig. 3a). In the abandoned meadows, the plant unit area was probably larger and there was a tendency for a few species to dominate in the plots. Both invaders and persistent agricultural landscape species had a contemporary scattered presence in the plots. Thus the linear log area curves may indicate homogenous stands, while exponential species - log area curves may indicate succession or disturbance. Continuous increase of the curve at and even above the investigated plot sizes is recorded e. g. by Hopkins (1955) and Barkman (1989).

Both tree cover and management was important in deciding the species richness in the investigated chronosequence. In a wooded meadow in Estonia Kull & Zobel (1991) also found the highest species richness where tree canopy cover was lowest (see also Pausas 1994), and highest species richness in sites with the most regular long-term mowing as compared to cases of cessation of mowing. For semi-natural grasslands van der Maarel (1988a) argued that grazing animals and mowing imply disturbance and to some extent stress, which enable more species to coexist than on a similar area without grazing or mowing. The reasons for the high mean species richness in site A compared to the other sites may be complex (see e. g. Giller 1984), but the management itself undoubtedly plays a major role in providing light and gaps for all the species at the right time and place throughout the growing season. In the abandoned sites less light penetrated into the lowest part of the field layer and this resulted in exclusion of low-growing species (Kull & Zobel 1991). The species may either disappear after a gradual reduction in population size, or there may be a collapse in the occurrence of the species. Some of the species in this study (Appendix 1, group 1a) may have experienced such rapid (in less than 10 years) disappearance. The species diversity decline in sites B-D in 10-20 years was 21% - 57 % in plots of 0.01 m² - 10 m² (Table 1). However, when the whole investigated area in each site was considered, the total number of species increased in all the abandoned sites (Appendix 1, 2). This clearly demonstrated that use of total species number is very dependent on plot size and that it may be rather useless in choosing hay meadows for conservation. High species turn-over rates during the first 50-60 years of a sere was reported e. g. by Houssard et al. (1980). Much more rapid decline in species diversity, 70% in 10-15 years, was reported from chalk grassland by Willems (1990). In time sites B-D will turn into deciduous woodland with a closed canopy and the indicators of traditional management and common grassland species will even-
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Common grassland species are quite frequent in the studied abandoned sites. They thrive when biomass is no longer removed, resulting in increased nitrogen levels in the soil. The additional species occur very scattered in the whole chronosequence, and are thus generally infrequent in small plots. In larger plots the difference, mainly between site A and site D become visible. In site D more forest species have established than in the other sites. As site C had been abandoned for a longer time than site B, more forest species had established there, and at the same time more light demanding species persisted (Appendix 1, 2) probably a result from the period with grazing after cessation of mowing, and thus species richness was higher there than in site B. Similar species overlap, occurring when competitive exclusion has not yet had time to drive subordinate species to extinction is advocated also by Palmer (1994). Higher species richness in grazed areas as compared to non-grazed areas generally occur in western Norway at present. In abandoned hay meadows they are often recorded close to or at refuges like outcrops or heaps of stones on dry or shallow ground in the open, where the field layer is low and scattered. Some of them are annuals which are dependent on gaps in the sward for germination of their seeds. For example Pimpinella saxifraga is known to be very sensitive to increased density of the sward (Grubb 1990). These species will presumably not be able to survive the closing up of the canopy where they grow at present, and thus they face extinction at their sites in the near future. At sites in western Norway where these species have been recorded during the last 20 years, they probably will experience a collapse extinction as indicated by the differences in the frequency - area curves. Hay meadows which have been abandoned less than 20 years ago are getting increasingly rarer, and so are the rare species within these groups. Other species in these groups are as vulnerable to abandonment as the rare species, but are generally more common because they tolerate the low or medium quantities of fertilizers used in the western Norwegian small scale and part time farming system. Thus a smaller group of species, tolerating neither fertilizing nor abandonment may be delimited and used as indicators in choosing hay meadows for conservation (Appendix 1, 2: *). These species occur in less than 23% of analysed hay meadow plots in western Norway published 1972-1991 (Losvik 1996b), while indicators of traditional management occurred in less than 58% of the plots. Several rare hay meadow species, not recorded in the plots of this study, such as Botrychium lunaria, Dianthus deltoides, Galium verum, Gymnadenia conopsea and Lychnis viscaria, will have to be added to complete this list of indicators of rare hay meadows.

Generally the species which gradually decreased in

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frequency with time since abandonment or increased in early successional stages (Groups 1c and 1d) were plants of some height and thus good light competitors in this situation. The groups comprised indicators of traditional management which are more common than species of groups 1a and 1b, as a result from their tolerance of shade and/or light fertilization. Unusual long stalks, bringing them up towards the top of the field layer were observed in individuals of *Potentilla erecta* and *Lotus corniculatus* in the studied abandoned sites.

Many border and forest species do in fact occur even in the traditionally managed hay meadow site. These species are usually growing close to stone heaps and below trees. They constitute a species pool and are able to expand as soon as the hay meadow is abandoned. The existence of a forest and border line species pool in managed hay meadows must be an old feature, as the whole of these landscapes were used very intensively in the traditionally managed hay meadow site. These species are usually growing close to stone heaps and becoming extinct in the site. Therefore it is very important to try to retain the management in areas with traditional landscape diversity and typical population structure.

**Acknowledgements** — The project was supported by O. Grolle Olsen Foundation. I am grateful to Shanthakumari Kishorekumar for the assistance with the input of data, and to three unknown referees for comments on the manuscript.

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Appendix 1

Frequency of species in 10 plots of 100 m² each in the investigated sites. Species occurring in < 4 plots: see Appendix 2. T: indicator of traditional management, * indicator of rare hay meadows. C: common grassland species, F: forest species. A: additional species, Abb.: Abbreviations of species names.

| Site | A | B | C | D |
|------|---|---|---|---|
| Years since abandonment | 0 | 10 | 20 | 30 |
| Mean tree canopy % | 3.5 | 27 | 25.5 | 74.5 |
| SD tree canopy | 4.1 | 23.4 | 20.9 | 29.4 |
| Number of species | 88 | 103 | 89 | 94 |
| Indicators of traditional management | 35 | 28 | 31 | 18 |
| Indicators of old hay meadows | 18 | 12 | 15 | 6 |

Group 1. Light demanding species

1a. Low frequency species in B-D

| Species | Abbreviation |
|---------|--------------|
| T Rhinanthus minor* | Rhin min |
| T Euphrasia stricta* | Euph str |
| T Carum carvi* | Caru car |
| T Trifolium dubium* | Trif dub |
| A Anthyllis vulneraria | Anth vul |
| T Hieracium pilosella* | Hier pil |
| T Linum catharticum* | Linu cat |
| T Leucanthemum vulgare* | Leuc vul |
| T Polygala vulgaris* | Pol vul |
| T Luzula campestris | Luzu cam |
| T Hypochoeris radicata | Hypo rad |
| C Trifolium repens | Trif rep |
| C Cerastium fontanum | Cera fon |
| T Cynosurus cristatus* | Cyno cri |
| T Leontodon autumnalis | Leon aut |
| T Prunella vulgaris* | Prun vul |
| T Pimpinella saxifraga* | Pimp sax |

1b. Low frequency species in D

| Species | Abbreviation |
|---------|--------------|
| C Trifolium pratense | Trif pra |
| T Veronica officinalis | Vero off |
| T Briza media* | Briz med |
| T Carex pilulifera* | Care pil |
| T Achillea millefolium | Achi mil |
| T Plantago lanceolata | Plan lan |
| C Alchemilla glabra | Alch gla |
| T Centaurea jacea* | Cent jac |
| A Carex panicea | Care pan |
| C Anthoxanthum odoratum | Anth odo |
| T Danthonia decumbens* | Dant dec |
| T Holcus lanatus | Holc lan |
1c. Shade tolerant species

| Species                           | Frequency |
|-----------------------------------|-----------|
| Ranunculus acris                  | 10        |
| Taraxacum vulgaris                | 10        |
| Carex pallescens                  | 10        |
| Campanula rotundifolia            | 10        |
| Cirsium palustre                  | 9         |
| Festuca rubra                     | 10        |
| Agrostis capillaris               | 10        |
| Conopodium majus                  | 10        |
| Hypericum maculatum               | 8         |

1d. Highest frequency in early succession:

| Species                           | Frequency |
|-----------------------------------|-----------|
| Gali saxatil                      | 8         |
| Luzula multiflora                 | 10        |
| Potentilla erecta                 | 10        |
| Rumex acetosa                     | 7         |
| Festuca pratensis                 | 1         |
| Lotus corniculatus                | 9         |
| Dactylis glomerata                | 4         |
| Deschampsia cespitosa             | 4         |
| Carex pulicaris                   | 3         |
| Festuca vivipara                  | 2         |
| Vicia sepium                      | 2         |

1e. Highest frequency in early succession:

| Species                           | Frequency |
|-----------------------------------|-----------|
| Angelica sylvestris               | 1         |
| Holcus mollis                     | 2         |
| Rubus nemoralis                   | 3         |
| Rosa sp.                          | -         |
| Juniperus communis                | -         |
| Pteridium aquilinum               | -         |
| Geum rivale                       | -         |
| Veronica chamaedrys               | -         |

2a. Early successional species

| Species                           | Frequency |
|-----------------------------------|-----------|
| Fraxinus excelsior, juv.          | 10        |
| Primula vulgaris                  | 8         |
| Viola riviniana                   | 4         |
| Carex sylvatica                   | 4         |
| Geum urbanum                      | 3         |
| Athyrium filix-femina             | 3         |
| Fragaria vesca                    | 2         |
| Filipendula ulmaria               | 2         |
| Alnus incana                      | 1         |
| Oxalis acetosella                 | 1         |
| Taxus baccata juv.                | 1         |
| Corylus avellana                  | -         |
| Rubus idaeus                      | -         |
| Brachypodium sylvaticum           | -         |
| Poa nemoralis                     | -         |
| Ilex aquifolium                   | -         |
| Prunus padus                      | -         |
| Geranium robertianum              | -         |

2b. Forest species

| Species                           | Frequency |
|-----------------------------------|-----------|
| Fraxinus excelsior, juv.          | 10        |
| Primula vulgaris                  | 8         |
| Viola riviniana                   | 4         |
| Carex sylvatica                   | 4         |
| Geum urbanum                      | 3         |
| Athyrium filix-femina             | 3         |
| Fragaria vesca                    | 2         |
| Filipendula ulmaria               | 2         |
| Alnus incana                      | 1         |
| Oxalis acetosella                 | 1         |
| Taxus baccata juv.                | 1         |
| Corylus avellana                  | -         |
| Rubus idaeus                      | -         |
| Brachypodium sylvaticum           | -         |
| Poa nemoralis                     | -         |
| Ilex aquifolium                   | -         |
| Prunus padus                      | -         |
| Geranium robertianum              | -         |
Appendix 2

Frequency of species which were present in < 4 out of 10 plots of 100 m² each in the investigated sites. T: indicator of traditional management, * indicator of rare hay meadows. C: common grassland species, F: forest species. A: additional species, Abb.: Abbreviations of species names.

| Site                                      | A | B | C | D | Abb.    |
|-------------------------------------------|---|---|---|---|---------|
| C Aegopodium podagraria                   | 3 |   |   |   | Aego pod|
| A Anemone nemorosa                       | 1 | 1 | - | - | Anem nem|
| A Carex echinata                         | 1 | 1 | - | - | Care ech|
| T Carex hostiana*                        | 2 | - | 1 | - | Care hos|
| A Carex serotina ssp. serotina           | 2 | - | - | - | Care ses|
| A Carex ovalis                           | 1 | - | - | 1 | Care ova|
| A Digitalis purpurea                     | 1 | 1 | - | - | Digi pur|
| A Elymus repens                          | 1 | - | - | - | Elym rep|
| A Geranium columbinum*                   | 1 | - | 1 | - | Gera col|
| A Geum sp.                               | 2 | - | - | - | Geum sp.|
| A Juncus arcticulatus                    | 2 | - | - | 1 | Junc arc|
| A Juncus effusus                         | 2 | - | - | - | Junc eff|
| A Juncus filiformis                      | 1 | 1 | - | - | Junc fil|
| A Myosotis arvensis                      | 1 | - | - | - | Myos arv|
| C Poa trivialis                          | 1 | 1 | - | - | Poa tri |
| A Sagina procumbens                      | 2 | - | - | - | Sagi pro|
| A Sedum maximum                          | 2 | - | - | 1 | Sedu max|
| A Asplenium adianthum-nigrum             | 1 | 1 | - | - | Aspl adi|
| F Betula pendula                         | - | 1 | 1 | - | Betu pen|
| A Calluna vulgaris                       | - | 1 | - | - | Call vul|
| C Cardamine pratensis                    | - | 1 | - | - | Card pra|
| A Carex sp.                              | - | 1 | - | - | Care sp.|
| A Crepis paludosa                        | - | 1 | - | - | Crep pal|
| A Gallium uliginosum                     | - | 1 | - | 1 | Gali uli|

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A Hypericum pulchrum - 1 - - Hype pul
A Juncus conglomeratus - 2 - - Junc con
A Luzula sudetica - 2 - - Plant maj
A Poa annua - 1 - - Poa ann
F Ranunculus ficaria - 1 - - Ranu fic
A Ranunculus flammula - 1 - 1 Ranu fla
C Ranunculus repens - 1 - 1 Ranu rep
A Sedum anglicum - 1 - - Sedu ang
A Senecio jacobaea - 1 - - Sene jac
C Veronica serpyllifolia - 1 - 1 Vero ser
A Viola palustris - 1 - - Viol pal
A Agrostis canina - - 1 - Agro can
A Hedera helix - - 1 1 Hede hel
T Knautia arvensis - - 3 - Knau arv
A Listera ovata - - 1 - List ova
A Luzula sp. - - 1 - Luzu sp.
F Pinus sylvestris - - 1 - Pinu syl
A Rumex acetosella - - 1 - Rume ac
A Sedum acre - - 1 - Sedu ac
A Silene rupestris - - 1 - Sile rupe
C Stellaria graminea - - 1 1 Stel gra
A Silene dioica - - - 1 Sile dio
F Orchis mascula - - - 1 Orch mas
F Polystichum aculeatum - - - 1 Poly acu
F Ranunculus auricomus - - - 1 Ranu aur
F Roegneria canina - - - 1 Roeg can
F Dryopteris pseudomas - - - 1 Dryo pse
F Alnus glutinosa - - - 1 Alnu glu
A Carex demissa - - - 1 Care dem
F Viburnum opulus - - - 2 Vibu opu
F Circaea alpina - - - 2 Circ alp
F Blechnum spicant - - - 3 Blec spi
F Cystopteris fragilis - - - 3 Cyst fra
F Lysimachia nemorum - - - 3 Lysi nem

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