20 Five Years of Restoration of Alluvial Meadows: A Case Study from Central Europe

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INTRODUCTION

There are no large natural alluvial grasslands in central Europe (Ellenberg 1988). The present grasslands originated as pastures or meadows and need management to ensure their continued existence.

Central European wet meadows have been subjected to great alterations in the past several decades, reflecting not only changes in their direct management but also changes in the land use of the surrounding landscape. This is especially the case for alluvial meadows in the Czech Republic, where the economics of the communist era did not respect the natural and social conditions connected with river systems. If not ploughed, meadows were damaged through both overexploitation and neglect, resulting in loss of biodiversity and disturbed ecological functions (Rychnovská 1985; Banásová *et al.* 1994; Prach *et al.* 1996).

The meadows in the floodplain of the Lužnice River in the Třeboň Biosphere Reserve are in the southern part of the Czech Republic near the border with Austria (Figure 20.1). They are among 10 of the most valuable complexes of alluvial meadows recently recognized in the Czech Republic (Straškrabová *et al.* 1996). The total extent of the meadows is approximately 10 km^2, extending a further 3 km^2 into the adjoining part of Austria. The meadows along the whole of the Lužnice River were described together with other vegetation types by Prach *et al.* (1990).

In the best preserved part of the Lužnice River floodplain, a long-term ecological project was launched in 1986 within the Unesco Man and Biosphere (MAB) project 'Role of Wetlands in the Temperate Forest Biome'. An important task of the project was the description of rate and directions of vegetation changes. Vegetation pattern was related to three main river-induced environmental gradients: (i) moisture gradient; (ii) nutrient gradient; and (iii) gradient of disturbance intensity (Day *et al.* 1988). Relationships between vegetation and site moisture were described in detail by Prach (1992); the nutrient gradient was evaluated by Prach and Rauch (1992). The gradient of disturbance

See Glossary, p. 305, for explanation of technical terms. Scientific names of vascular plants follow Tutin, T. G. *et al.* (1964–80) *Flora Europaea* Volumes 1–5. Cambridge University Press. See p. 319.

European Wet Grasslands: Biodiversity, Management and Restoration. Edited by Chris B. Joyce and P. Max Wade.

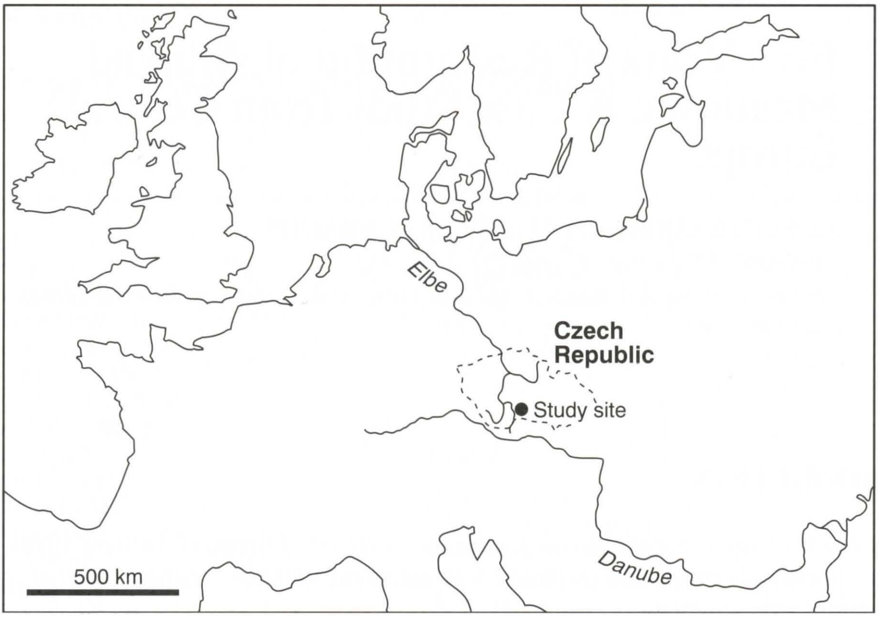

Figure 20.1 Location of the Lužnice River floodplain study area in central Europe

intensity, i.e. frequency and regularity of mowing, has not yet been quantified, but it is possible to compare the vegetation pattern in the floodplain segments unmanaged for 40 years with the pattern in those mown regularly (Figure 20.2). The scheme in Figure 20.2 can serve as a conceptual base for an understanding of vegetation pattern in the floodplain under study (see also Prach *et al.* 1996). It was constructed partly on the basis of quantitative data (see the references cited above) and partly on field experience. A basically similar pattern was observed in other river systems over the Czech Republic (Straškrabová *et al.* 1996).

One of the questions that emerged early in the Unesco MAB project related to the length of time taken for degraded meadows left unmanaged to return to a stage acceptable to both ecologists and agriculturalists. An experiment was established in 1989 to explore this question, and the results from the following five years are presented here.

SITE DESCRIPTION AND METHODS USED

The Lužnice River originates in Austria at 990 m above sea level. After flowing for about 40 km in the solid bedrock of an upland landscape, the river enters a flat sedimentary area of the Třeboň basin in the Czech Republic. Here it meanders for nearly 100 km, between an altitude of 500 and 403 m above sea level, before flowing for about 60 km in a canyon-like valley and finally emptying into the Vltava River at 350 m above sea level. The floodplain section that forms the subject of this chapter is located at 135.5 stream km measured from the mouth, at 455 m altitude. The average discharge near the study site is $5 m^3 s^{-1}$.

The part of the floodplain between the river and the nearest terrace, where the

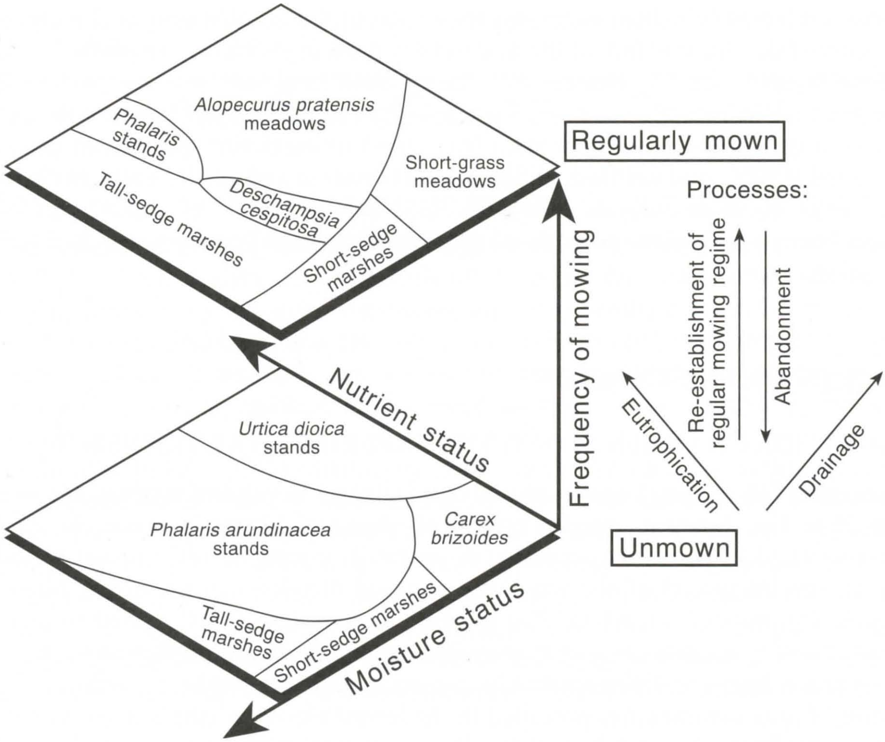

Figure 20.2 Vegetation pattern in regularly mown, and long-abandoned parts of the Lužnice River floodplain, related to the main environmental gradients. Adapted from Prach (1992)

experiment was established, had been left unmown for approximately 20 years. *Phalaris arundinacea* dominated over most of the area, together with *Urtica dioica* in the elevated parts.

In 1989 a transect with a length of 150 m was laid between the river bank and the top of the terrace. The whole transect was surveyed by a level-meter to measure its elevation. Phytosociological records were made in each 1 m^2 along the transect in the beginning of June, comprising a visual estimate of the percentage cover of each species present in the plots. This procedure was repeated in the following five years (until 1994). Vegetation was cut along the transect in a strip 150 m long and 5 m wide. This was done three times a year in the early part of the experiment (1989, 1990, 1991), and twice a year thereafter because of the insufficient increase in biomass later in the 1992 and 1993 seasons.

From the vegetation data, changes in average cover of species were estimated, as well as the number of species along the transect and species density in the 1-m^2 plots. The data were processed by the ordination technique Canonical Correspondence Analysis (CCA) (CANOCO/CANODRAW program; ter Braak and Šmilauer 1993). The cover data were transformed into the ordinal scale 1–8, corresponding to the degrees of the Braun-Blanquet scale (see van der Maarel 1979). The symbol *r* was not distinguished from +. The set of samples was subdivided into two equal subsets according to elevation, corresponding to the wet and dry parts of the transect. Due to the high number of samples, centroids (weighted averages) were used in the graphic output (Figure 20.3), each representing the position of the wet and dry plots in six successive years.

Above-ground biomass samples were taken from randomly selected plots of 0.5 × 0.5 m, five each in both cut and uncut sites. Sampling took place just before cutting of the whole transect. Above-ground biomass was sorted to particular species and dead biomass, dried at 90°C, and weighed. Differences between cut and uncut sites were evaluated using *t*-tests. Biomass analyses were performed only in the elevated (dry) part of the transect because only elevated parts of the floodplain have been recently used for hay production.

RESULTS AND DISCUSSION

VEGETATION CHANGES ALONG THE EXPERIMENTAL TRANSECT

Restoration of the cutting regime induced rapid changes in vegetation cover, as shown in Table 20.1. The dominant species typical of abandoned meadows, namely *Phalaris arundinacea* and *Urtica dioica* decreased dramatically during the observation period. In contrast, species typical of the regularly managed meadows in the area (*Alopecurus pratensis, Deschampsia cespitosa, Poa* sp. div., *Ranunculus repens*) started to increase. Instead of a monotonous cover of *P. arundinacea* over the major portion of the transect, the vegetation began to differentiate with regard to moisture conditions reflected by the elevation. *Carex* communities prevailed in the lowest elevation (the wettest part of the moisture gradient), being followed by *D. cespitosa*-dominated communities and *A. pratensis* communities. In the highest elevation, species appeared that are typical of the driest alluvial meadows in the Lužnice River floodplain, such as *Avenula pubescens, Holcus lanatus* and *Festuca rubra* (Prach 1992; Prach *et al.* 1996). For a complete list of species noted before and additional ones observed during the experiment see the Appendix.

Similarly rapid changes were observed with respect to species diversity (Table 20.2). The number of species per m^2 (species density) almost doubled after one year. The observed maximum in the second year of the experiment can be explained by the fact that, in the period between the decline of the dominants typical of abandoned meadows

Table 20.1 Changes in average cover (%) of principal species along the transect across the Lužnice River floodplain after a regular mowing regime was re-established (in 1989, after a period of approximately 20 years without mowing). After Prach *et al.* (1996)

	Average cover (%)					
Species	1989	1990	1991	1992	1993	1994
Alopecurus pratensis	14.4	20.3	16.3	26.5	26.8	30.4
Deschampsia cespitosa	0.0	0.0	0.4	0.6	1.6	1.7
Phalaris arundinacea	28.0	35.1	12.3	4.4	1.0	0.9
Poa spec. div.	0.0	0.7	1.5	2.5	2.9	4.7
Ranunculus repens	0.0	5.8	10.8	29.2	42.4	43.5
Urtica dioica	18.4	7.8	2.0	0.0	0.0	0.0

Table 20.2 Average number of species per m^2 and the total number of species along the whole transect. After Prach *et al.* (1996)

	1989	1990	1991	1992	1993	1994
No. of species m^{-2}	4.0	7.3	8.9	6.9	8.1	8.2
Total no. of species	28	48	61	71	79	70

and expansion of grasses typical of managed meadows, there was an opportunity available for the establishment of various other species including some ruderals. The average species density in regularly managed meadows nearby reaches 8.6 species m^{-2}. Thus, it can be concluded that the meadows were restored with respect to species diversity in only two years. The increase in the number of species along the whole transect was similarly dramatic, reaching almost three times the number recorded before the experiment started.

Results of ordination (CCA) demonstrate that the quickest changes in floristic composition occurred during the first three years following the re-establishment of mowing in both wet and dry parts of the transect (Figure 20.3). Differences between the last two years seem to be small, especially in the case of plots representing the dry part of the transect. Thus, the results of the ordination support the conclusion that five years was a sufficient period for the restoration of the meadows. If the species composition of the experimental transect is compared with that of the regularly mown meadows nearby (Prach 1992; Prach *et al.* 1996), it is almost the same, especially in the dry parts.

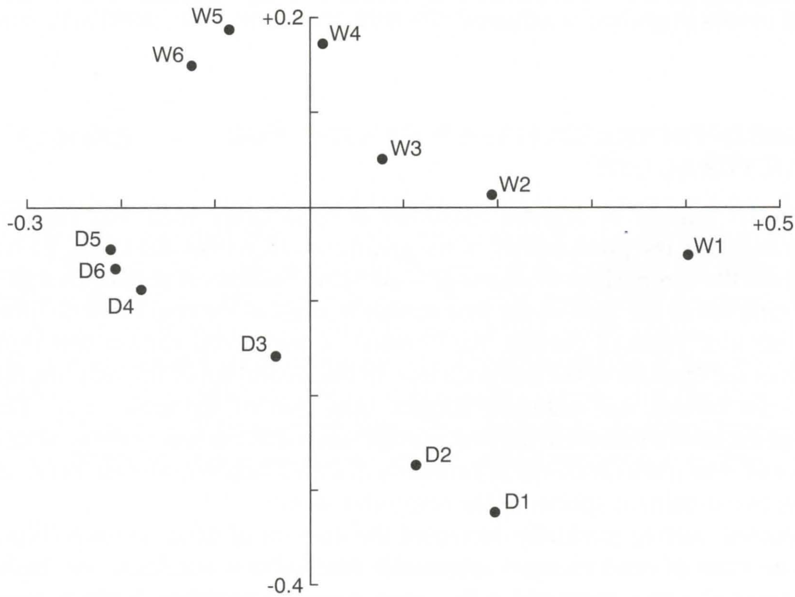

Figure 20.3 Results of ordination Canonical Correspondence Analysis (CCA). The positions of centroids are indicated, representing samples in the dry (D) and wet (W) parts of the experimental transect in the successive years 1–6 (from 1989, just before the experiment started, to 1994). The longer the distance between two successive years, the greater the change in species composition. From Prach *et al.* (1996), reproduced with permission from SPB Academic Publishing, Amsterdam

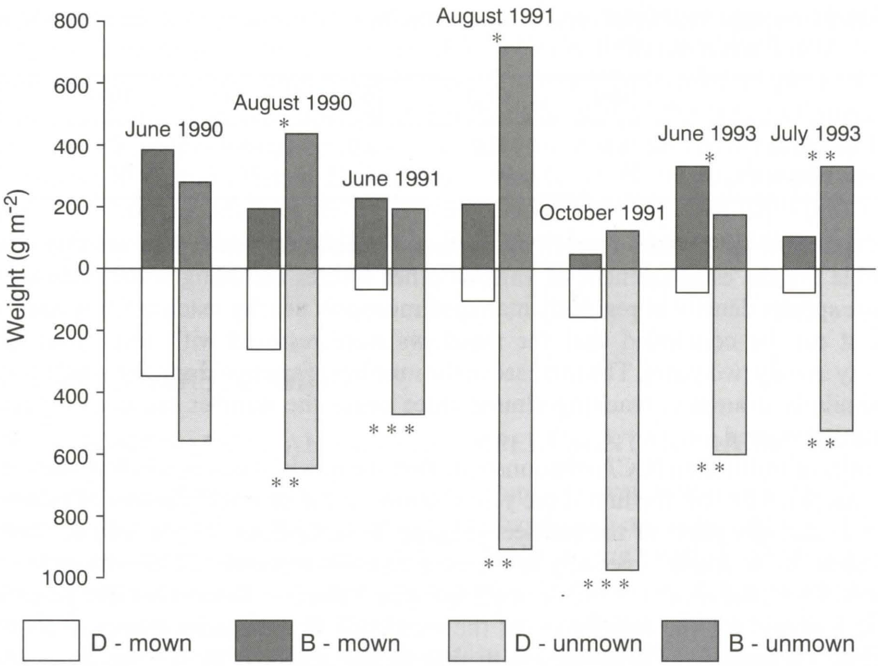

Figure 20.4 Changes in living (B) and dead (D) biomass of mown and unmown stands in three of the years during which the experiment was conducted. Significant differences (*t*-test) between mown and unmown variants are indicated: $*P<0.05$; $**P<0.01$; $***P<0.001$

CHANGES IN PRODUCTIVITY: A POTENTIAL FOR AGRICULTURAL USE

The potential harvest of alluvial meadows is remarkably high and regular cutting generally supports the productivity of the grasslands (Rychnovská 1985). This is recognizable from the comparison of above-ground living biomass of the mown and unmown variants sampled at the time of the first annual harvest at the beginning of June (Figure 20.4). After four years of cutting, the biomass of the mown variant was significantly greater than the biomass of the unmown one. In the second cut of the year, the biomass of the unmown variant was naturally greater than that of the mown one. The higher biomass of the mown variant in the first harvest was partly caused by the growth earlier in the season of *Alopecurus pratensis* in comparison with *Phalaris arundinacea* (Rychnovská 1985), the two dominant species of the respective stands.

As expected, cutting gradually decreased the amount of dead biomass (Figure 20.4). The low amount of dead biomass apparently enabled new species to establish, mainly heliophytes of shorter stature and with a lower competitive ability. Some of these species would probably not be able to germinate in soil covered with several centimetres of litter and a closed cover of tall grasses such as *Phalaris arundinacea* (see Grime *et al.* 1988).

Approximate estimates of productivity can be obtained by summing the biomass figures obtained at the time of each harvest in the mown variant, and using the maximum biomass of the unmown variant, respectively. These are summarized in Table 20.3 for

Table 20.3 Approximate annual production of above-ground biomass estimated for the mown and unmown variant in the elevated part of the floodplain section

	Above-ground biomass (g dry mass m^{-2})	
Year	Mown	Unmown
1990	593	436
1991	495	701
1993	444	344

each year and variant. It is evident that except for the wet year of 1991 the productivity of the mown variant was higher than that of the unmown one. Although the measurement of biomass was repeated only two to three times a season, so the estimates of production are very approximate, it was found that the productivity of the restored meadow in the elevated part of the transect was comparable with that of regularly mown meadows nearby (Šmilauer *et al.* 1996).

The change from *Phalaris arundinacea* stands to *Alopecurus pratensis* meadow is desirable from the point of view of potential agricultural exploitation. *A. pratensis* is more palatable to animals than *P. arundinacea* and is the most productive species in the area (Tetter *et al.* 1988).

CONCLUSIONS

It was demonstrated that restoration of alluvial meadows in the Lužnice River floodplain was relatively easy and rapid even when the meadows had been left without cutting for two decades. Similar trends, albeit perhaps slower, can be expected for those meadows abandoned for the longest time in the floodplain under study (over 40 years). Unfortunately, at present, there are no economic incentives that would persuade local agriculturalists to re-establish regular mowing over the whole floodplain. If they were to do so, they could have, relatively quickly, the most productive meadows in the area, which are also of value from an ecological perspective. The conclusions described here seem to be applicable to the majority of alluvial meadows of similar species composition in central Europe.

ACKNOWLEDGEMENTS

We thank Marek Bastl for computation of CCA, Petr Šmilauer for consultancy, Chris Joyce for English revision and two anonymous reviewers for their helpful comments. The research was supported by the grant of the Czech Academy of Sciences no. 60520 and partly by the grant of the Grant Agency of the Czech Republic no. 204/94/0395.

SUMMARY

An experiment was conducted to assess the feasibility of restoring a complex of alluvial meadows in the Lužnice River floodplain, in the Třeboň Biosphere Reserve, Czech Republic. The meadows had been abandoned for approximately 20 years. A regular cutting regime was re-established along a transect from the river to the nearest terrace. Rapid changes in species composition were observed during the next five years, from monotonous, species-poor stands to diverse meadows comparable with those subjected to uninterrupted management. The total number of species along the transect increased nearly threefold. Species density (the number of species m^{-2}) more than doubled. Biomass and production were comparable with those of regularly cut meadows by the third year of the experiment. Thus, a potential agricultural use could easily be restored to abandoned parts of the floodplain.

Keywords: Alluvial meadows, Biomass, Production, Restoration, Vegetation.

REFERENCES

Banásová, V., Otahelová, H., Jarolímek, I., Zaliberová, M. and Husák, Š. (1994) Morava River floodplain vegetation in relation to limiting ecological factors. *Ekológia (Bratislava)*, **13**, 247–262.

Day, R.T., Keddy, P.A. and McNeill, J. (1988) Fertility and disturbance gradients: a summary model for riverine marsh vegetation. *Ecology*, **69**, 1044–1054.

Ellenberg, H. (1988) *Vegetation ecology of central Europe*. Cambridge University Press, Cambridge.

Grime, J.P., Hodgson, J.G. and Hunt, R. (1988) *Comparative plant ecology. A functional approach to common British species*. Unwin Hyman, London.

Prach, K. (1992) Vegetation, microtopography and water table in the Lužnice River floodplain, South Bohemia, Czechoslovakia. *Preslia, Praha*, **64**, 357–367.

Prach, K. and Rauch, O. (1992) On filter effects of ecotones. *Ekológia, Bratislava*, **11**, 293–298.

Prach, K., Kučera, S. and Klimešová, J. (1990) Vegetation and land use in the Lužnice River floodplain and valley in Austria and Czechoslovakia. In: Whigham, D.F., Good, R.E. and Květ, J. (Ed.), *Wetland ecology and management: case studies*, pp. 117–125. Kluwer, Dordrecht.

Prach, K., Jeník, J. and Large, A.R.G. (eds) (1996) *Floodplain ecology and management. The Lužnice River in the Třeboň Biosphere Reserve, central Europe*. SPB Academic, Amsterdam.

Rychnovská, M. (ed.) (1985) *Ecology of grasslands*. Academia, Praha [in Czech].

Šmilauer, P., Prach, K. and Rauch, O. (1996) Biomass and nutrient allocation in the main vegetation types. In: Prach, K., Jeník, J. and Large, A.R.G. (eds), *Floodplain ecology and management. The Lužnice River in the Třeboň Biosphere Reserve, central Europe*, pp. 181–190. SPB Academic, Amsterdam.

Straškrabová, J., Prach, K., Joyce, C. and Wade, M. (eds) (1996) Floodplain meadows in the Czech Republic – ecological functioning, contemporary state and possibilities for restoration. *Příroda, Praha*, **4**, 1–176.

ter Braak, C.J.F. and Šmilauer, P. (1993) *CANOCO 3.1/CANODRAW 3.0*. Šmilauer, České Budějovice.

Tetter, M., Květ, J., Suchý, K. and Dvořáková, H. (1988) Productivity of grassland communities in the Upper Lužnice River floodplain. *Sborník VŠ Z České Budějovice*, **5**, 119–129 [in Czech].

van der Maarel, E. (1979) Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Vegetatio*, **38**, 85–96.

APPENDIX

Species present along the transect before the experiment started: *Alisma plantago-aquatica, Alopecurus pratensis, Angelica sylvestris, Barbarea stricta, Cardamine pratensis, Carex acuta, Carex vesicaria, Carex vulpina, Cerastium fontanum* subsp. *vulgare, Deschampsia cespitosa, Galeopsis tetrahit, Galium aparine, Galium palustre, Glechoma hederacea. Glyceria fluitans, Iris pseudacorus, Lysimachia vulgaris, Myosotis scorpioides, Oenanthe aquatica, Phalaris arundinacea, Poa palustris, Poa trivialis, Ranunculus repens, Rorippa amphibia, Rumex crispus, Rumex obtusifolius, Symphytum officinale, Urtica dioica.*

Species that appeared during the experiment: *Achillea millefolium, Achillea ptarmica, Aegopodium podagraria, Agrostis capillaris, Anemone nemorosa, Arrhenatherum elatius, Artemisia vulgaris, Avenula pubescens, Betula pendula* juv., *Capsella bursa-pastoris, Cardaminopsis halleri, Carex ovalis, Centaurea jacea, Cirsium arvense, Cirsium palustre, Cuscuta europaea, Dactylis glomerata, Dianthus deltoides, Elymus repens, Epilobium roseum, Festuca rubra, Filipendula ulmaria, Galium album, Galium uliginosum, Heracleum sphondylium, Hieracium pilosella, Holcus lanatus, Hypericum humifusum, Hypericum perforatum, Knautia arvensis, Leontodon autumnalis, Lotus corniculatus, Lotus uliginosus, Lychnis flos-cuculi, Lycopus europaeus, Lysimachia nummularia, Lythrum salicaria, Matricaria perforata, Mentha arvensis, Myosoton aquaticum, Pimpinella major, Plantago lanceolata, Poa pratensis, Prunella vulgaris, Ranunculus auricomus, Ranunculus flammula, Rumex acetosa, Salix cinerea* juv., *Sanguisorba officinalis, Scutellaria galericulata, Stellaria graminea, Stellaria media, Taraxacum officinale, Trifolium hybridum, Trifolium pratense, Trifolium repens, Verbascum* sp. juv., *Veronica arvensis, Veronica chamaedrys, Veronica scutellata, Veronica serpyllifolia.*