POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	56	2	343–350	2008

Short research contribution

Katarzyna BARAŃSKA[1], Michał ŻMIHORSKI[2*]

[1] Department of Plant Ecology and Environment Conservation, Warsaw University, Aleje Ujazdowskie 4, 00-478 Warsaw, Poland.
[2] Museum and Institute of Zoology, Polish Academy of Sciences, Wilcza 64, 00-679 Warsaw, Poland, [*] e-mail: zmihorski@miiz.waw.pl (*author for correspondence*)

OCCURRENCE OF RARE AND PROTECTED PLANT SPECIES RELATED TO SPECIES RICHNESS IN CALCAREOUS XEROTHERMIC GRASSLAND

ABSTRACT: Occurrence of rare and protected plant species is regarded as a strong argument for creating a protected area. It is therefore especially important to know whether rare and protected species are reliable indicators of abundance of other, more common, unprotected species. We analysed co-occurrence of protected and rare species with other xerothermic plant species in calcareous xeric grassland in Western Poland. In the years 2005–2006, on 62 plots (25 m^2 each) we identified vascular plants on a 60 km^2 area in the Odra R. Valley and its smaller tributaries valleys. Legally protected species appeared not to be better indicators of xerothermic species richness than non-protected species. The rarest species (*Anthericum liliago* L., *Carex supina* Willd. ex Wahlenb. and *Stipa borysthenica* Klokov ex Prok.) were significantly less useful indicators of xerothermic species richness than other rare and common species. These results let us conclude that designing a network of protected areas on the basis of rare and protected species may result that some common species, biodiversity hotspots or well developed phytocenoses will be ignored.

KEY WORDS: Conservation planning, xerothermic grassland, protection, biodiversity, nature reserves.

There are many criteria of choosing areas for biodiversity conservation. Site selection algorithms (SSA), devised to optimise nature conservation, include a variety of ecological, economical and social factors (Moffet and Sarkar 2006). Factors that are considered in selection of sites for protection include: total number of plant species (biodiversity hotspots); spatial distribution of the sites, expected life span of populations, occurrence of endemic species, habitat features, etc. (e.g. Kingsland 2002, Ovaskainen 2002, Nicholson *et al.* 2006, Zhou and Wang 2006). In practice, however, substantial part of areas for conservation are selected on the basis of rare or protected species occurrence. As underlined by Bonn *et al.* (2002), most of SSA "*have focused particular attention on the patterns of occurrence of threatened and endemic species*" (see also Prendergast *et al.* 1993). This is partially the case with selection of potential NATURA 2000 network areas (e.g. Special Protection Areas), guided by presence of the bird species listed in Annex I: "...*The species mentioned in Annex I shall be the subject of special conservation measures concerning their habitat in order to ensure their survival...*" (Council Directive of 2 April 1979 on the conservation of wild birds). In many

European countries, small protection areas are established around nests of rare birds. In Poland, some of the reserves have been created to protect rare plant and animal species. Moreover, occurrence of species protected by law can be an important argument to control landscape and habitat transformations. As a result, patches containing protected species are better preserved and probably will exist longer.

The following question is important to evaluate the criteria based on rare and protected species distribution: is occurrence of rare species correlated with that of other, more common species? If this is so, protection of rare species will ensure protection of more common species. If not, i.e. when rare species occurrence does not correspond with abundance of more common species, areas selected for protection may be insufficient to protect all species in a given habitat. In this case establishing additional protection areas may be necessary to preserve species diversity in full.

The aim of our study was to verify whether rare and legally protected xerothermic grassland plant species are good indicators of species richness in xerothermic plant communities.

The research was conducted in North-Western Poland, in the Cedyński Landscape Park (CLP) (52°48'N; 14°16'E). The study area was located along the Odra Valley. Its area was ca 60 km^2 and it was 20 km long. The region is characterised by a relatively mild, predominantly oceanic climate, with mean annual January temperature of approximately –1.2°C and mean July temperature of 18.2°C. The total annual precipitation is 550 mm and the vegetation period lasts 220 days (Kondracki 2002, Matuszkiewicz 2002, Stopa-Boryczka and Boryczka 2005). The mild climate, together with favourable relief promote growth of xerothermic plant species (Barańska and Żmihorski 2005, 2007). The study was carried out on patches of calcareous xerothermic grassland belonging to the *Festuco- Stipion* alliance (class *Festuco-Brometea*) and termophilous, calcareous psammophilous grassland communities from the *Koelerion glaucae* alliance (class *Koelerio-Corynephoretea*) (syntaxon names after Matuszkiewicz 2001). These habitats are located mainly on the southern slope of the Odra Valley and the river's smaller tributaries valleys.

Between 2005 and 2006, 62 vegetation plots were mapped (vascular plant species occurrence was recorded) on 33 grassland patches. We controlled all known to us, relatively well developed and little degraded patches of xerothermic vegetation in this part of the CLP. More than one mapping per patch was performed when a patch was large (most often when it was alongside a river valley) and/or had distinctly separated clusters of xerothermic vegetation. Each plot's area was ca 25 m^2. In total, 185 vascular plant species were recorded. On the basis of the following criteria: 1) ecological characteristics of a species, 2) whether a species is characteristic for the syntaxon concerned, 3) species composition of the potential plant communities under study (Filipek 1974, Matuszkiewicz 2001, Zarzycki *et al.* 2002), the recorded species were divided into two groups: xerothermic grassland specialists, i.e. species typical of and desirable in grasslands (n = 71, see Appendix) and other species (including alien and invasive species), or those typical of other communities, mainly forest syntaxon (*Rhamno-Prunetea, Vaccinio-Picetea, Querco-Fagetea*) meadow syntaxon (*Molinio-Arrhenatheretea*) and ruderal or weed syntaxon (*Stellarietea mediae, Epilobietea angustifolii, Artemisietea vulgaris, Agropyretea intermedio-repentis*). Further statistical analyses, results and discussion apply only to the first group (n = 71 species), which is the priority in the protection of xerothermic grasslands.

For each of the recorded species it was tested whether its presence is a reliable indicator of richness of the xerothermic community (i.e. number of species). The following procedure was used: For species A, the mapped plots were divided into those where A was recorded (A1) and those where it was not (A0). Using the Mann-Whitney test, the mean number of all species (except A) in the A0 and A1 groups was compared. This comparison was made for each species individually (A0 *vs.* A1, B0 *vs.* B1, etc.), using a Mann-Whitney statistics "Z" in each case. When the mean species number in A1 was greater than in A0, the statistics Z> 0, whereas if the mean species number in A1

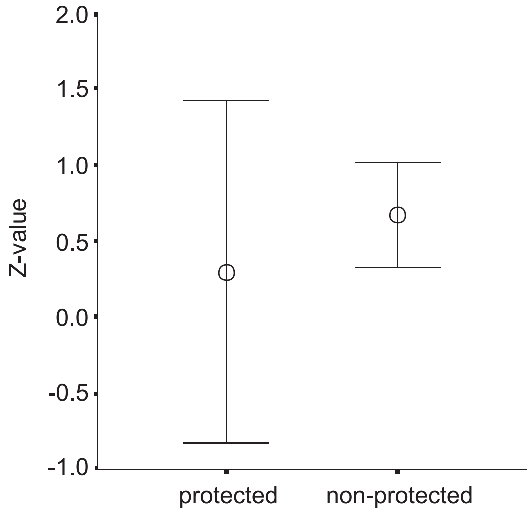

Fig. 1. Mean Z-values and 95% confidence limits for the legally protected in Poland (8 species) and the non-protected (63) xerothermic plant species found in 62 plots (25 m^2 each). Z values determine whether given species is an indicator of high species richness (Z> 0) or low species richness (Z <0). See methods for details.

was lower than in A0 then Z < 0. As a result, for each species it was determined whether its occurrence is an indicator of species richness (Z> 0) or species poverty (Z <0). There was no case when Z = 0.

All species (n = 71) were grouped into two categories, according to the form of protection: species legally protected in Poland (n = 8) and other species. They were also divided according to the degree of rarity: 1) very rare (n = 3), 2) rare (n = 11), and 3) common (n = 57) (see Appendix). The "very rare" group comprised species included in the Polish Red Data Book of Plants (Kaźmierczakowa and Zarzycki 2001) and the "rare group" consisted of species listed in the red list of the endangered and threatened species in the Western Pomerania and Wielkopolska regions in Poland (Żukowski and Jackowiak 1995), but not those found in the Polish Red Data Book of Plants. All the remaining species were classified as "common" (Appendix). The mean Z values were compared between the protected and non-protected species, as well as between the very rare, rare and common species (T-test and one-way ANOVA, respectively). Statistical analyses were carried out using the SPSS 13.0 software.

Finally, we used the rarefaction method to predict consequences of protection of plots with very rare plant species. We divided all the analysed plots into two groups: plots with very rare plant species (n = 16 plots) and other plots (n = 46). Next, we computed the expected cumulative number of common plant species for the 16 plots containing very rare plant species and for 16 plots randomly chosen out of the 46 plots without very rare species. The division into "Common species" and "very rare species" was explained above. We used EstimateS 751 software (Colwell 2005).

We found that usefulness values of the protected and other species as indicators of xerothermic species richness were comparable (Fig. 1). The average Z value did not differ significantly between the protected (Z = 0.29) and the non-protected species (Z = 0.67) (Independent-Samples T test: t = 0.73, df = 69, P = 0.470).

Mean Z-value was the lowest in the group of very rare species (average Z = -1.19). The Z values of the rare and common species group were comparable (0.87 and 0.68, respectively) (Fig. 2). The ANOVA revealed that the differences in the Z-value between the three groups were marginally insignifi-

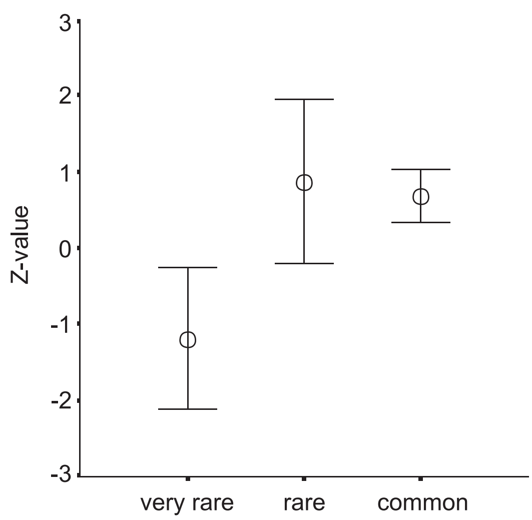

Fig. 2. Mean Z-values and 95% confidence limits for the very rare (3 species), rare (11) and common (57) xerothermic plant species found in 62 plots (25 m^2 each). Z values determine whether given species is an indicator of high species richness (Z> 0) or low species richness (Z <0). See methods for details.

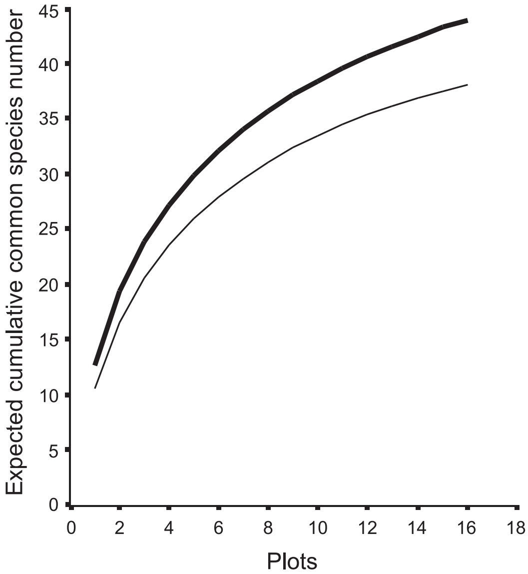

Fig.3. Expected cumulative common plant species number plotted against number of 25 m^2 plots of xerothermic grasslands containing species defined as very rare (thin, lower line) and without very rare species (thick, upper line). See methods for details.

cant (ANOVA df = 2; F = 2.97; *P* = 0.058). Indeed, the contrast test showed that there was a significant difference between the group of very rare species and the other groups (t = 2.44, df = 68, *P* = 0.017).

The expected cumulative number of common plant species for the 16 grassland plots containing very rare species was 38 species, being lower than the expected cumulative number of common plant species for the 16 randomly chosen plots without very rare species, which was 43.87 species (Fig. 3).

Our research concerned vegetation distribution pattern on relatively small plots (25m^2). For this reason the obtained results should be treated with caution. They need to be confirmed on a larger sample and on a larger spatial scale to propose an effective method of creating xeric vegetation reserves. However, as an effect of long term habitat transformations, the majority of real xerothermic calcareous grassland patches in the study area have greatly restricted size. Our sample plot size (25 m^2) is therefore not so small in relation to the average area of a grassland patch. In addition, on 16 different plots we recorded tree species classified as "very rare", which always occurred separately. This indicates that the observed pattern is not affected by clustered distribution of very rare species among analysed plots, which increases the reliability of our results.

In many European countries, xerothermic vegetation is rare and has been strongly degenerated, chiefly due to change in land use and resulting secondary succession (Poschlod and WallisDeVries 2002, WallisDeVries *et al.* 2002). In Poland, problems stem also from active afforestation of grassland areas falling within the boundaries of the private- and state-owned forests (personal data). Presence of legally protected species may be a strong argument for ceasing afforestation practices and may facilitate fund-raising for active protection of xeric grasslands. However, as our study has shown, legally protected species are not reliable indicators of species richness of xeric grasslands.

We have shown that rare species are less reliable indicators of species richness than the common ones. The majority of studies focusing on indicators of species richness report that rare species are good predictors of species richness. In Europe, two very rare species are good indicators of beetle species richness: the hermit beetle *Osmoderma eremita* (Coleoptera: Cetonidae; Ranius 2002) and the white-backed woodpecker *Dendrocopos leucotos* (Aves: Piciformes; Martikainen *et al.* 1998). In Central Europe, woodpeckers (10 species) which mainly comprise rare species are good indicators of avian species richness (Mikusiński *et al.* 2001). Also, Spyreas and Matthews (2006) found that rare plant species indicated species-rich forests in Illinois, USA and Pearman and Weber (2007) found a similar pattern for butterflies community (but not for plants and birds). Our results lead us to conclude that in some ecosystems the reverse pattern may be observed: the rarest species are indicators of low species number i.e. species poverty.

Our observations are in accordance with other, large-scaled research indicating that total species richness pattern is a function of common species distribution and not of rare species distribution (e.g. Lennon *et al.* 2004, Pearman and Weber 2007). There are no clear explanations for this. We hypothesize that very rare species growing in poor xerothermic calcareous grasslands are more specialised, have narrower habitat tolerance and occur in more extreme habitats than do common species. This habitat-related distribution of particular plant species may explain the observed pattern. First, plant species that require extreme habitat features are rare, since a considerable proportion of grassland patches is affected by habitat transformation (fertilising, shading, increase in soil moisture and many others) and only small patches of truly extreme conditions survived till now. Second, the other (more common) xerothermic plant species may avoid patches characterised by extreme habitat conditions, which in turn leads to the observed inverse relationship between occurrence of very rare species and of common species.

Our results indicate that habitats in which rare species occur are not necessarily abundant in more common species, even if both are similar in terms of ecology and habitat requirements. This means that selecting areas for protection on the basis of the rarest or protected xerothermic grassland species cannot allow for full protection of all species common for these sites. For example, the 16 randomly chosen grassland patches without very rare species contained on average about 6 common xerothermic species more than the 16 patches containing very rare species. On the basis of our results it can be concluded that reserves with very rare species can be less effective in common species protection than those without very rare plants. It should be emphasised that our data do not deny need for rare species protection. On the basis of our results and former research we suggest that a network of reserves set out for rare species conservation should be supplemented with protection of species-rich patches. It should be underlined that our results concern the distribution of xerothermic plant species only (both rare and common). This issue is discussed by Bonn *et al.* (2002), who emphasises that protection of endangered and endemic bird species is not sufficient for conservation of all bird species. This observation holds also in cases when species subsets occurring on consecutive patches exhibit a significantly nested pattern (Fisher and Lindenmayer 2005). On the other hand, on the basis of our results, it can be supposed that grassland patches of the highest species richness may not include the rarest species. This is consistent with the pattern noted by Prendergast *et al.* (1993) and partly also by Lennon *et al.* (2004). Therefore, it is very plausible that protection of rare species and protection of species-rich patches will select different areas (patches) for conservation. We recommend to consider the results of our study when creating a strategy of conservation of xerothermic species or habitats.

ACKNOWLEDGEMENTS: We are deeply grateful to Dr Przemysław Chylarecki, Prof. Anna Hillbricht-Ilkowska and an anonymous reviewer for valuable comments on the manuscript.

REFERENCES

Barańska K., Żmihorski M. 2005 – Ostnica włosowata *Stipa capillata* L. w Cedyńskim Parku Krajobrazowym [*Stipa capillata* in the Cedyński Landscape Park (Western Poland)] – Chrońmy Przyr. ojcz. 61, 6: 81–86. (in Polish, English summary)

Barańska K., Żmihorski M. 2007 – Stanowiska rzadkich gatunków roślin muraw kserotermicznych w Cedyńskim Parku Krajobrazowym (NW Polska) [Rare plant sites in the xeric calcareous grasslands of the Cedynia Landscape Park (NW Poland)] – Bad. Fizjograf. Pol. Zach. ser. B. 56: 163–172. (in Polish, English summary)

Bonn A., Rodrigues A.S.L., Gaston K.J. 2002 – Threatened and endemic species: are they good indicators of patterns of biodiversity on a national scale? – Ecol. Lett. 5: 733–741.

Colwell R.K. 2005 – EstimateS: Statistical estimation of species richness and shared species from samples. Version 7.5.1 – User's Guide and application published at: http://purl.oclc.org/estimates.

Council Directive of 2 April 1979 on the conservation of wild birds; Office for Official Publications of the European Community published at: http://eur-lex.europa.eu/en/index.htm.

Filipek M. 1974 – Murawy kserotermiczne regionu Dolnej Odry i Warty. [Xerothermic swards in lower Odra and Warta region] – Prace Kom. Biol. PTPN 38: 1–110. (in Polish, English summary)

Fisher J., Lindenmayer D.B. 2005 – Perfectly nested or significantly nested – an im-

portant difference for conservation management – Oikos 109: 485–494.
Kaźmierczakowa R., Zarzycki K. 2001 – Polish Red Data Book of Plants – W. Szafer Institute of Botany, PAN, Kraków, 664 pp. (in Polish, English summary)
Kingsland S.E. 2002 – Creating a science of nature reserve design: Perspectives from history – Environ Model Assess 7: 61–69.
Kondracki J. 2002 – Geografia regionalna Polski [Regional geography of Poland] – Polish Scientific Publishers, Warszawa, 441 pp. (in Polish)
Lennon J.J., Koleff P., Greenwood J.J.D., Gaston K.J. 2004 – Contribution of rarity and commonness to patterns of species richness – Ecol. Lett. 7: 81–87.
Matuszkiewicz W., 2001 – Przewodnik do oznaczania zbiorowisk roślinnych Polski – Polish Scientific Publishers, Warszawa, 537 pp. (in Polish)
Matuszkiewicz J.M. 2002 – Zespoły leśne Polski – Polish Scientific Publishers, Warszawa, 358 pp. (in Polish)
Mikusiński G., Gromadzki M., Chylarecki P. 2001 – Woodpeckers as Indicators of Forest Bird Diversity – Conserv. Bio.l 15: 208–217.
Martikainen P., Kaila L., Haila Y. 1998 – Threatened beetles in white-backed woodpecker habitats – Conserv. Biol. 12: 293–301.
Moffett A., Sarkar S. 2006 – Incorporating multiple criteria into the design of conservation area networks: a minireview with recommendations – Diversity Distrib. 12, 125–137.
Nicholson E., Westphal M.I., Frank K., Rochester W.A., Pressey R.L., Lindenmayer D.B., Possingham H.P 2006 – A new method for conservation for the persistence of multiple species – Ecol. Lett. 9: 1049–1060.
Ovaskainen O. 2002 – Long-Term Persistence of Species and the SLOSS Problem – J. Theor. Biol. 218: 419–433.
Pearman P.B., Weber D. 2007 – Common species determine richness patterns in biodiversity indicator taxa – Biol. Conserv. 138: 109–119.
Poschlod P., WallisDeVries M.F. 2002 – The historical and socioeconomic perspective of calcareous grasslands – lessons from the distant and recent past. – Biol. Conserv. 104: 361–376.
Prendergast J.R., Quinn R.M., Lawton J.H., Eversham B.C., Gibbons D.W 1993 – Rare species, the coincidence of diversity hotspots and conservation strategies – Nature 365: 335–337.
Ranius T. 2002 – *Osmoderma eremita* as an indicator of species richness of beetles in three hollows – Biodiv. Conserv. 11: 931–941.
Spyreas G., Matthews J.W. 2006 – Floristic conservation value, nested understory floras, and the development of second-growth forest – Ecol. Appl. 16: 1351–1366.
Stopa-Boryczka M., Boryczka J. 2005 – Klimat [Climate] (In: Geografia fizyczna Polski [Physical geography of Poland] Eds: Richling A., Ostaszewska K.) – Polish Scientific Publishers, Warsaw, 84–126 pp. (in Polish).
WallisDeVries M.F., Poschlod P., Willems J.H. 2002 – Challenges for the conservation of calcareous grasslands in northwestern Europe: integrating the requirements of flora and fauna. – Biol. Conserv. 104: 265–273.
Zarzycki K., Trzcińska-Tacik H., Różański W., Szeląg Z., Wołek J., Korzeniak U. 2002 – Ecological indicator values of vascular plants of Poland – W. Szafer Institute of Botany, PAN, Kraków, 183 pp.
Zhou S.R., Wang G. 2006 – One large, several medium, or many small? – Ecol. Model. 191: 513–520.
Żukowski W., Jackowiak B. 1995 – Ginące i zagrożone rośliny naczyniowe Pomorza Zachodniego i Wielkopolski [Endangered and threatened vascular plants of Western Pomerania and Wielkopolska] – Prace Zakładu Taksonomii Roślin UAM nr 3: 1–141 (in Polish, English summary)

Received after revising December 2007

APPENDIX

Rarity and protection category of the 71 xerothermic plant species recorded on the study area (xeric grassland). Rarity category: *** – very rare (included in the Polish Red Data Book of Plants), ** – rare (listed in the red list of the endangered and threatened species in the Western Pomerania and Wielkopolska regions in Poland, but not those found in the Polish Red Data Book of Plants), * – common (remaining species); Protection by-low: ** – protected, * – not protected.

Species	Rarity	Protection
Achillea pannonica Scheele	*	*
Acinos arvensis (Lam.) Dandy	*	*
Agrimonia eupatoria L.	*	*
Allium oleraceum L.	*	*
Allium vineale L.	*	*
Anthemis tinctoria L.	*	*
Anthericum liliago L.	***	**
Anthericum ramosum L.	*	*
Anthyllis vulneraria L.	*	*
Arenaria serpylifolia L.	*	*
Artemisia campestris L.	*	*
Asparagus officinalis L.	*	*
Aster linosyris (L.) Bernh.	**	**
Avenula pratensis (L.) Dum.	**	*
Bromus erectus Hudson	*	*
Campanula sibirica L.	**	**
Carex caryophyllea Latourr.	*	*
Carex praecox Schreber	*	*
Carex supina Willd. ex Wahlenb.	***	**
Carlina vulgaris L.	*	*
Centaurea scabiosa L.	*	*
Centaurea stoebe L.	*	*
Cerastium pumilum Curtis	*	*
Chondrilla juncea L.	*	*
Coronilla varia L.	*	*
Dianthus carthusianorum L.	*	*
Echium vulgare L.	*	*
Erigeron acer L.	*	*
Euphorbia cyparissias L.	*	*
Falcaria vulgaris Bernh.	*	*
Festuca psammophila (Hackel ex Čelak) Fritsch	**	*
Festuca trachyphylla (Hackel) Krajina	*	*
Filipendula vulgaris Moench	*	*
Fragaria viridis Duch.	*	*

Species	Rarity	Protection
Galium verum L.	*	*
Gypsophilla fastigiata L.	*	*
Helianthemum nummularium (L.) Miller	*	*
Hieracium echioides Lumn.	**	*
Koeleria glauca (Schrader)DC.	*	*
Koeleria macrantha (Ledeb.) Schultes	*	*
Medicago falcata L.	*	*
Medicago minima (L.) Bartal	*	*
Ononis spinosa L.	*	*
Orobanche caryophyllacea Sm.	**	**
Petrorhagia prolifera (L.) P.W.Ball et Heyw.	*	*
Peucedanum oreoselinum (L.)Moench	*	*
Phleum phleoides (L.)Karsten	*	*
Pimpinella saxifraga L.	*	*
Plantago media L.	*	*
Poa angustifolia L.	*	*
Poa compressa L.	*	*
Polygala comosa Schkuhr	*	*
Potentilla arenaria Borkh.	*	*
Pulsatilla pratensis (L.)Miller	**	**
Salvia pratensis L.	*	*
Sanguisorba minor Scop.	*	*
Scabiosa canescens W. et K.	**	*
Sedum maximum (L.)Hofm.	*	*
Sedum reflexum L.	*	*
Silene chlorantha (Willd.)Ehrh.	*	*
Silene otites (L.)Wibel	*	*
Stachys recta L.	**	*
Stipa borysthenica Klokov ex Prok.	***	**
Stipa capillata L.	**	**
Thesium linophyllon L.	**	*
Thymus pulegioides L.	*	*
Trifolium alpestre L.	*	*
Trifolium montanum L.	*	*
Verbascum lychnitis L.	*	*
Veronica spicata L.	*	*
Viola hirta L.	*	*