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Species trait-environment relationships in semi-dry *Brachypodium pinnatum* grasslands on old waste heaps left by Zn-Pb mining in the western Małopolska region (S Poland)

Brachypodium pinnatum-Halbtrockenrasen auf Zn/Pb-Bergbauhalden in West-Małopolska (Südpolen): Zusammenhänge zwischen Vegetationseigenschaften und Umweltbedingungen

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Abstract

This study describes the vascular flora and community structure of grasslands occurring on heaps of waste rock left by former Zn-Pb mining in relation to the metal content in the soil and other environmental factors. The study was performed on 65 heaps scattered in agricultural land in southern Poland. The sites were described in terms of plant community characteristics, soil physicochemical properties, distance from woodland, altitude and local climate. The number of plant species and proportion of species of the *Festuco-Brometea* class decreased with increasing heavy metal (Cd, Pb, Zn) content in the soil, and increased with Ca content and pH of the soil. There was a negative relationship between the proportion of the later successional species and heavy metal content in the soil and a positive relationship between plants connected with the earlier stages of succession and metals. Floristic composition was also affected by distance from woodland and height above sea level. The investigated heaps were primarily colonised by native species dispersed by wind, characterised as competitive stress-tolerant, ruderal and competitive strategy species. Three types of *Carlino acaulis-Brometum erecti* (*CB*) communities were distinguished: *CB typicum* – dominated by *Brachypodium pinnatum*, with the highest proportion of calcareous grassland species, *CB festucetosum ovinae* subass. nova – loose grassland with abundant facultative metallophytes, and the *CB rubietosum caesi* subass. nova with nutrient-demanding ruderal and woody plants invading from the nearby forest communities. The three subassociations represent different successional stages of *Carlino acaulis-Brometum erecti*, strongly dependent on both the substrate and spatial relations. The proportions of species traits, especially a high occurrence of endangered species and a very low proportion of alien species show that the post-mining habitats studied have a similar degree of 'naturalness' as valuable xerothermic grasslands on non-metalliferous habitats. They thus may be considered as valuable objects for the protection of plant diversity.

Keywords: *Bromion erecti*, heavy metals, historical mining, metallophytes, succession

Erweiterte deutsche Zusammenfassung am Ende des Artikels

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1. Introduction

Relics of former mining and processing of Zn-Pb ores occur widely in western Małopolska (Silesia-Cracow Upland, southern Poland) and are a specific type of anthropogenic habitat. Small heaps of waste rocks scattered in an agricultural landscape, often with a shaft inside, are islands of xerothermic habitat and characterised by a high content of heavy metals in the soil: 5–522 mg Cd kg^{-1}, 0.1–23 g Pb kg^{-1}, 6–51mg Tl kg^{-1}, and 0.4–70 g Zn kg^{-1} (STEFANOWICZ et al. 2014). Skeletal soils forming on the heaps are also rich in Ca and Mg, but the content of N and P is low (STEFANOWICZ et al. 2014, WOCH 2015). Due to these conditions, the heaps are colonised mainly by plants adapted to environmental stress, and succession occurs slowly (ERNST 1974, BAUMBACH 2012). However, the alkaline soil, a relatively humid climate at a low altitude above sea level and presence of some nutrients in the metallicolous Triassic dolomites result in relatively beneficial conditions (in comparison to other European metalliferous areas) for plant encroachment (ERNST 1974, SMITH 1979, GRODZIŃSKA & SZAREK-ŁUKASZEWSKA 2009, WOCH et al. 2016, 2017).

Habitat conditions are largely responsible for the combinations of traits that have been selected in species and for the sorting of species into communities (REINHART 2008). E.g., life strategies are tightly linked to environmental conditions of the habitats. For example, competitiveness was predicted to increase through management characterised by rare disturbance events, e.g., succession, controlled burning and mulching at long intervals. Several studies conformed general trends since competitiveness is related to abandonment (HUHTA & RAUTIO 1998, NOVÁK & PRACH 2003, MOOG et al. 2005). The degree of natural process restoration (closing to naturally occurring vegetation) of the spoil heaps left over following centuries of mining activity and their role in forming local biodiversity is a crucial issue. The degree of land natural process restoration depends on the rate of plant succession and soil formation on the heaps. Pioneer species are poor competitors, while late-successional species are stronger competitors but poor colonisers (OLSSON 1987, GRIME 2001, NOVÁK & PRACH 2003). By analysing the proportion of species representing different strategy types (stress-tolerators, competitors, ruderals as well as mixed strategies) in the heap flora, an estimate can be made of the stage of succession and the plants' response to ecological conditions.

Post-mining areas are often a habitat for endangered species. These species grow in stressful habitats and therefore they are often good stress tolerators but poor competitors (GRIME 1979, WILSON & LEE 2000, FRANZARING et al. 2007). Therefore, in heavily industrialized areas such as those in the Silesia-Cracow Upland, old heaps can become plant diversity hotspots and important areas of valuable grasslands, similar to semi-natural European grassland (MAZARAKI 1981, MARRS 1993, HABEL et al. 2013, TISCHEW et al. 2013). In many places in western Małopolska, Zn-Pb mining ceased at the beginning of the 20th century, while the large mines that are now operating are not the subject of this study. It can therefore be assumed that a significant proportion of the spoil heaps left after former mining activity haven't been disturbed by mining activities since at least one hundred years (GODZIK & WOCH 2015, WOCH 2015). It can thus be presumed that the degree of natural succession of the heaps is large enough to compare plants of those heaps with plants of xerothermic grasslands, screes and rocks. Analysis of the frequency of the common grassland plants in the most polluted habitats can provide an initial list of the most metal-resistant and metal-sensitive species for further verification in the laboratory studies.

In a previous work (WOCH et al. 2016) the vegetation found on the old heaps with high levels of metal contamination (on average 127 mg Cd kg^{-1}, 4 g Pb kg^{-1} and 22 g Zn kg^{-1}) was initially classified as an impoverished *Festuca ovina* variant (*CBF*) of semi-dry calcareous grasslands of the *Carlino acaulis-Brometum erecti* association (*Festuco-Brometea* class, *Bromion erecti* alliance). Two other variants of this association were also identified on the heaps: a typical variant (*CB*) composed of calcareous grassland species occurring at sites with low and moderate concentrations of heavy metals in the soil and localised relatively far from the edge of the forest, and grasslands with woody and ruderal plants classified as *Rubus caesius* variant (*CBR*) occurring in proximity to forests (WOCH et al. 2016). In the current article a phytosociological classification and characterization of these communities is given.

There was also found that plant species composition changed significantly with increasing metal content in the soil (WOCH et al. 2016). Species that are sensitive to metals disappeared, while the number of metal-tolerant species increased. Distance from the heaps to forest and soil thickness had a significant influence on community composition: proximity to forest increased the representation of competitive forest species and ruderals, and calamine grassland formed on shallow soil (WOCH et al. 2016). Other spatial factors such as location above sea level and local climate may also affect the occurrence of plants on heaps and they are tested in this study.

Previous analyses were limited to the variation of vegetation within the 65 designated plots. Whereas, the surface of the calamine grasslands usually were much larger, because it not only was found outside the separated plots but also existed on many neighboring heaps. Therefore, this study focuses on the analysis of the total flora of all the non-forested heaps of the region.

The purpose of this work is to (1) perform an analysis of the total vascular flora of the old heaps, (2) determine the influence of soil features and spatial factors on plant species composition, (3) detect species that are the most sensitive or tolerant to metals, and (4) to describe phytosociologically the communities and define their syntaxonomic position.

2. Material and Methods

2.1 Study area and field survey

The study was conducted in western Małopolska (the Silesia-Cracow Upland, southern Poland) between the towns of Krzeszowice, Libiąż, Jaworzno and Olkusz (ca. 750 km²). The distance between the northernmost and the southernmost heaps was ca. 25 km, and the distance between the easternmost and westernmost heaps was ca. 30 km (Fig. 1). The altitude of the study area ranged from 260 to 460 m a.s.l., the average annual rainfall and temperature was between 705 and 773 mm and 7.1 and 8.3 °C, respectively. The study sites were established on heaps of waste rock which are small (usually not exceeding 20 m in diameter), eroded to some extent, and sometimes hidden under a dense cover of vegetation (Fig. 2). Detailed information about the structure of former mining fields, the geology, the history of Zn-Pb ore mining and the plant cover of the study area is included in previous papers (STEFANOWICZ et al. 2014, GODZIK & WOCH 2015, WOCH 2015, WOCH et al. 2016).

In order to prepare a complete list of plant species, all non-forested old heaps in the area were screened; the total area of these heaps was approximately 20 ha. The plant nomenclature followed MIREK et al. (2002).

In order to analyse the structure of the plant communities, 4 m² circular plots were established in homogenous patches of grassland vegetation on the southern or south-eastern or south-western slopes of 65 heaps (one plot per heap) (Fig. 1). The cover of vascular plant species at each plot was estimated on the basis of a five-degree scale (BRAUN-BLANQUET 1964) during the 2012 and 2013 growing seasons (from April to October). Plant communities were identified according to CHYTRÝ et al. (2007).

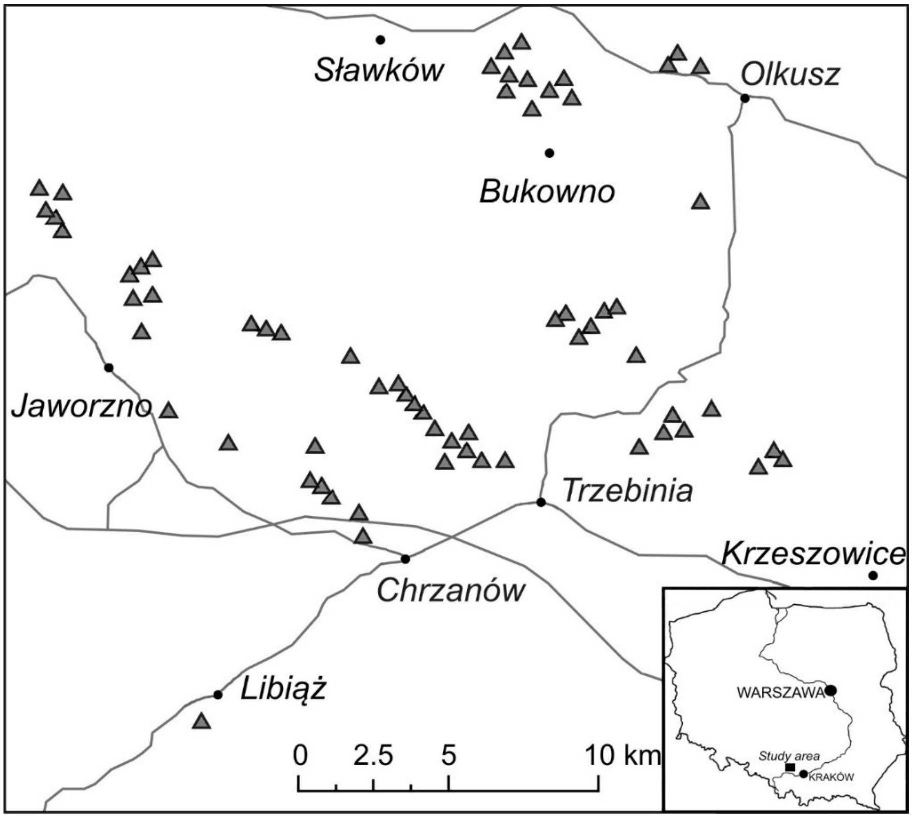

Fig. 1. Location of the study area in Poland and 65 study sites (triangles). Major cities and main roads are indicated.

Abb. 1. Lage des Untersuchungsgebietes in Polen und der 65 untersuchten Standorte (Dreiecke). Größere Städte und Hauptstraßen sind eingezeichnet.

The distance to the nearest forest patch (at least 0.1 ha in size) was measured for each plot directly in the field (with a tape) or by Google Earth (Google Inc.1600 Amphitheatre Parkway Mountain View, CA 94043, USA). Climatic data were obtained from the nearest meteorological station operated by the Institute of Meteorology and Water Management-National Research Institute (IMGW-PIB). Altitudes were derived from 1:50,000 maps.

In July, three topsoil samples were taken from each of the 65 heaps (around the study plot) to a depth of 15 cm (or less if soil depth was less 15 cm) and bulked into one composite sample. The analyses of soil samples included pH, sand, silt, clay and organic carbon content. The concentration of the EDTA-extractable metals were determined and set 'total content' (WOCH et al. 2016).

2.2 Data analyses

In order to analyse the floristic properties, the proportion of alien species (RUTKOWSKI 2008), Grime's CSR strategies (GRIME 1979, 2001), functional groups (graminoids, forbs, legumes, and woody plants) (RUTKOWSKI 2008), life forms (RAUNKIAER 1934), ancient forest and pioneer species (HERMY et al. 1999, SCHMIDT et al. 2014) as well as the seed dispersal types (PODBIELKOWSKI 1995) and vegetation classes (CHYTRÝ et al. 2007, 2009, 2013) were calculated per relevé. Endangered taxa

Fig. 2. An inconspicuous old heap of waste rock left by historical Zn-Pb mining near Trzebinia (S Poland) – an example of a study site (Photo: M.W. Woch, 2015).

Abb. 2. Eine unauffällige alte Bergbauhalde als Hinterlassenschaft historischen Zink-Blei-Bergbaus bei Trzebinia (Süd-Polen) – ein Beispiel einer Untersuchungsfläche (Foto: M.W. Woch, 2015).

(protected and/or rare taxa) were determined on the basis of the Ministry of Environment (REGULATION 2014) and of the Polish red lists (KAŹMIERCZAKOWA & ZARZYCKI 2001, MIREK et al. 2006). I further calculated species' frequency i.e. the percentage of plots in which a species occurred, cover coefficient (where Cc = 100 Σ cover of the species in all plots divided by the number of plots), cover and constancy (the five-scale degree of proportion of the plots containing a taxon within a set of plots), in each of the three community types (BRAUN-BLANQUET 1964, WOCH et al. 2016). Sixty-five heaps were grouped into three categories on the basis of soil Cd (the best heavy metal content representative) pollution level, i.e. 5–10, 10–30 and > 30 mg Cd kg^{-1}, potentially reflecting heavy metal toxicity to the plants (KABATA-PENDIAS 2011); the occurrence of the most frequent species (recorded in at least 20% of sites) in each soil pollution category was calculated. This enabled a rough classification of the species as either metal-sensitive or metal-tolerant to be made.

In order to fulfil normal distribution, variables describing habitat properties were transformed with a logarithmic or exponential function prior to the statistical analyses and expressed on a 0–1 scale. The normal distribution of some plant variables could not be obtained due to the high number of 0 values. Simple regression was used to test the relationship between plant species number and pioneer species number. As significant intercorrelations were found between the soil variables, only a few non-correlated soil parameters were selected as independent variables on the basis of factor analysis (WOCH et al. 2016) to test their influence on vegetation properties. These were EDTA-extractable Cd representing the soil pollution level, total Ca, organic C, silt, clay and pH (WOCH et al. 2016). Spearman's correlations between habitat properties (transformed and standardised variables) and vegetation parameters (original variables) were tested. The statistical analyses employed STATISTICA 9 (StatSoft Inc. Tulsa, OK., USA).

3. Results

3.1 Habitat properties

The sand content in the soil of the heaps ranged from 43% to 82%, silt from 6 to 41%, clay from 6 to 42%, organic C from 1.3 to 13.8%, and total N from 0.10 to 0.80%. The content of total Ca varied from 4869 to 191074 mg kg^{-1}, total Cd from 4.9 to 417 mg kg^{-1}, total Zn from 386 to 81111 mg kg^{-1}, while EDTA-extractable Cd and Zn from 1.3 to 198 mg kg^{-1} and from 39 to 10917 mg kg^{-1}, respectively. The soils on the heaps were alkaline and their pH ranged from 7.07 to 8.71.

3.2 Species traits

The number of vascular plant species per 4 m^2 varied from 4 to 33, and plant cover from 50% to 100%. The total number of plant species correlated positively with the number of pioneer species ($r = 0.85$, $p < 0.001$).

In total, 222 plant species belonging to 49 families were reported on the study heaps. The highest number of species belonged to *Asteraceae*, followed by *Poaceae*, *Fabaceae* and *Rosaceae* (Table 1). It was observed that hemicryptophytes predominated, followed by geophytes. The prevalence of native species was high, with only 6% of the flora represented by alien plants. Anemochory was the main dispersal strategy, followed by zoochory. Competitive stress-tolerant ruderal (CSR) plants predominated, followed by competitors (C). More than a half of all species was classified as pioneer species, and most of them occurred in grasslands on the most polluted sites (Table 1). Despite the prevalence of taxa of xerothermic grasslands (*Festuco-Brometea*), one-fifth of the flora was represented by meadow species (*Molinio-Arrhenatheretea*). On old heaps, nearly three quarters of the species were forbs (Table 1). Among the species noted, eight were strictly protected in Poland (e.g., *Gentiana cruciata*, *Gymnadenia conopsea* subsp. *densiflora* and *Malaxis monophyllos*), four partly protected (*Epipactis atrorubens*, *E. helleborine*, *Ononis spinosa* and *Orobanche lutea*) and nine posted in the Polish red lists (e.g., *Biscutella laevigata*, *Carex praecox* and *Verbascum chaixii* subsp. *austriacum*) (Table 1).

3.3 Relations between habitat conditions and species diversity and composition

The presence of a generally late successional plants (stress-tolerant competitors, plants dispersed by animals, phanerophytes, ancient forest species as well as species of the *Quercetea robori-petraeae*, *Carpino-Fagetea* and *Rhamno-Prunetea* classes) (Table 2) were negatively correlated with heavy metal content of the soil, represented by EDTA-extractable Cd. Whereas, there was a positive relationship between the presence of species which predominantly colonise early successional vegetation (chamaephytes, species of the *Asplenietea trichomanis* and *Koelerio glaucae-Corynephoretea canescentis*) and the content of heavy metals. Endangered species declined in frequency with increasing heavy metal content (Table 2).

Proximity to the woodland positively affected the abundance of geophytes, ancient forest species, competitors, lianas, zoochory, alien species, woody plants, as well as taxa of the following classes: *Artemisietea vulgaris*, *Epilobietea angustifolii*, and *Quercetea robori-petraeae*, and negatively affected legumes, endangered species and plants of *Festuco-Brometea* class (Table 2). Higher altitude above sea level, associated with higher rainfall and

Table 1. Characterization of the total flora. Total number of species: 222. The detailed species list is presented in Supplement 1.

Tabelle 1. Charakterisierung der Gesamtflora. Gesamtzahl der Arten: 222. Die detallierte Artenliste findet sich in Anhang E1.

	Number of species	%
Pioneer species	128	58
Endangered species	21	10
Strictly protected	8	4
Partly protected	4	2
Posted in Polish red lists	9	4
Families		
Apiaceae	9	4
Asteraceae	31	14
Brassicaceae	7	3
Campanulaceae	4	2
Caryophyllaceae	7	3
Cyperaceae	7	3
Fabaceae	22	10
Lamiaceae	10	5
Liliaceae	5	2
Orchidaceae	5	2
Poaceae	24	11
Polygonaceae	4	2
Rosaceae	15	7
Rubiaceae	6	3
Scrophulariaceae	10	4
Violaceae	4	2
Other families	53	24
Functional groups		
Graminoids	31	14
Forbs	149	67
Legumes	22	10
Woody plants	21	9
Grime’s strategies		
C (competitive)	71	32
CR (competitive-ruderal)	10	5
CSR (mixed strategy)	98	44
R (ruderal)	5	2
S (stress tolerant)	6	3
SC (stress tolerant-competitive)	27	12
SR (stress tolerant-ruderal)	5	2
Life forms		
Chamaephytes	16	7
Geophytes	35	16

	Number of species	%
Hemicryptophytes	153	69
Liana	1	< 1
Therophytes	17	8
Indigeneity (geographic-historical classification)		
Native	209	94
Alien	13	6
Seed dispersion		
Anemochore	160	72
Anthropochore	8	4
Autochore	23	10
Myrmecochore	32	14
Zoochore	51	23
Plant community classes		
Alnetea glutinosae	3	1
Artemisietea vulgaris	11	5
Calluno-Ulicetea	7	3
Carpino-Fagetea	16	7
Elyno-Seslerietea	1	< 1
Epilobietea angustifolii	4	2
Festuco-Brometea	88	40
Koelerio-Corynephoretea	11	5
Molinio-Arrhenatheretea	42	19
Rhamno-Prunetea	9	4
Quercetea robori-petraeae	6	3
Scheuchzerio palustris-Caricetea nigrae	3	1
Stellarietea mediae	12	5
Vaccinio-Piceetea	7	3
Other classes	2	1
Subassociations		
Carlino acaulis-Brometum erecti typicum	53	24
C-B festucetosum ovinae subass. nova	120	54
C-B rubietosum caesii subass. nova	49	22

lower temperature, favoured the occurrence of graminoids, species of the *Molinio-Arrhenatheretea*, competitors, ancient forest species, geophytes, anthropochory, zoochory, as well as species of the *Epilobietea angustifolii* and *Carpino-Fagetea* classes. Increasing altitude reduced the presence of stress-tolerant competitors, chamaephytes, species of the *Asplenietea trichomanis* and *Koelerio glaucae-Corynephoretea canescentis* (Table 2).

Some taxa, for example *Brachypodium pinnatum*, *Peucedanum oreoselinum* and *Rubus caesius*, were specified as metal-sensitive species as their frequency and/or cover declined considerably with increasing levels of soil pollution (Table 3). An increase in frequency and cover with increasing contamination was observed in the case of *Carex caryophyllea*, *Dianthus carthusianorum*, *Euphorbia cyparissias*, *Festuca ovina* agg., *Galium album*, *Scabiosa*

Table 2. Spearman's correlations between the proportion of species traits (expressed as number of species) and habitat variables. Correlations between the contents of organic C, silt, clay and vegetation parameters are not presented as they were mostly insignificant ($p > 0.05$). Statistically significant correlations are asterisked: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. DFW – distance from woodland, Temp – temperature.

Tabelle 2. Spearman-Korrelationen zwischen dem Anteil von Arteigenschaften (als Artenzahl) und Habitatvariablen. Korrelationen zwischen den Anteilen organischen Kohlenstoffs, Schluff, Ton und Vegetationsparametern sind nicht dargestellt, weil sie überwiegend nicht signifikatn waren ($p > 0,05$). Statistisch signifikante Korrelationen sind mit Sternchen versehen: ***$p < 0,001$; **$p < 0,01$; *$p < 0,05$. DFW – Entfernung vom Wald, Temp – Temperatur.

	DFW	Altitude	Rainfall	$\mathrm{Cd}_{\mathrm{EDTA}}$	Ca	pH
Total cover (%)	n.s.	n.s.	n.s.	n.s.	-0.40***	n.s.
Total species number	n.s.	n.s.	n.s.	-0.25*	0.31*	0.35**
Alien species	-0.27*	n.s.	n.s.	n.s.	n.s.	n.s.
Native species	n.s.	n.s.	n.s.	n.s.	0.30*	0.36**
Endangered species	0.35**	n.s.	n.s.	-0.24*	n.s.	n.s.
Forb	n.s.	n.s.	n.s.	n.s.	0.31*	0.32**
Graminoid	n.s.	0.31*	0.40***	-0.35**	n.s.	n.s.
Legume	0.28*	n.s.	n.s.	n.s.	n.s.	0.41***
Woody	-0.29*	n.s.	n.s.	-0.44***	n.s.	n.s.
Ancient forest species	-0.46***	n.s.	0.32**	-0.44***	n.s.	n.s.
Pioneer species	n.s.	n.s.	n.s.	n.s.	0.42***	0.31*
C (competitor)	-0.42***	0.36**	0.52***	n.s.	n.s.	n.s.
CR (competitive ruderal)	n.s.	n.s.	n.s.	n.s.	n.s.	0.25*
CSR (mixed strategy)	n.s.	n.s.	n.s.	n.s.	0.37**	0.33**
R (ruderal)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
S (stress tolerator)	n.s.	n.s.	n.s.	n.s.	0.40**	n.s.
SC (stress-tolerant competitor)	n.s.	-0.32*	n.s.	-0.36**	n.s.	0.25*
SR (stress-tolerant ruderal)	n.s.	n.s.	n.s.	n.s.	0.33**	n.s.
Hemicryptophyte	n.s.	n.s.	n.s.	-0.25*	0.31*	0.39**
Geophyte	-0.35**	0.29*	n.s.	n.s.	n.s.	n.s.
Therophyte	n.s.	n.s.	n.s.	n.s.	0.26*	n.s.
Chamaephyte	n.s.	n.s.	-0.25*	0.40***	n.s.	n.s.
Liana	-0.25*	n.s.	n.s.	n.s.	n.s.	n.s.
Nanophanerophyte	n.s.	n.s.	n.s.	-0.58***	n.s.	n.s.
Phanerophyte	n.s.	n.s.	n.s.	-0.47***	n.s.	n.s.
Anemochory	n.s.	n.s.	n.s.	n.s.	0.31*	0.33**
Autochory	0.26*	n.s.	n.s.	n.s.	n.s.	0.35**
Anthropochory	n.s.	n.s.	0.25*	n.s.	n.s.	n.s.
Hydrochory	n.s.	n.s.	n.s.	-0.31*	n.s.	n.s.
Myrmecochory	n.s.	n.s.	n.s.	-0.35**	0.30*	0.37**
Zoochory	-0.28*	n.s.	0.37**	-0.58***	n.s.	n.s.
Artemisietea vulgaris	-0.35**	n.s.	n.s.	-0.31*	n.s.	n.s.
Asplenietea trichomanis	n.s.	n.s.	-0.24*	0.46***	0.27*	n.s.
	DFW	Altitude	Rainfall	$\mathrm{Cd}_{\mathrm{EDTA}}$	Ca	pH

Koelerio-Corynephoretea	n.s.	n.s.	-0.25*	0.46***	n.s.	n.s.
Epilobietea angustifolii	-0.35**	0.31*	0.28*	-0.34**	n.s.	n.s.
Festuco-Brometea	0.32**	n.s.	n.s.	-0.27*	n.s.	0.37**
Molinio-Arrhenatheretea	n.s.	0.25*	0.25*	n.s.	0.27*	0.32*
Calluno-Ulicetea	n.s.	n.s.	n.s.	n.s.	0.33**	0.35**
Quercetea robori-petraeae	-0.50***	n.s.	n.s.	-0.30*	n.s.	n.s.
Carpino-Fagetea	n.s.	0.32**	0.28*	-0.40**	n.s.	n.s.
Rhamno-Prunetea	n.s.	n.s.	n.s.	-0.42***	n.s.	n.s.
Vaccinio-Piceetea	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

ochroleuca and *Thymus pulegioides*, thereby indicating that these species are metal-tolerant (Table 3). Some species, for example *Asperula cynanchica*, *Coronilla varia*, *Festuca rubra* and *Medicago falcata*, showed the highest frequencies and/or coverage on sites characterised by medium levels of pollution (Table 3).

The detailed list of vascular plant species is provided in Supplement E1.

3.4 Plant communities

The syntaxonomic positions of the three types of grassland communities distinguished are as follows:

Class: *Festuco-Brometea* Br.-Bl. et Tüxen ex Soó 1947
  Alliance: *Bromion erecti* Koch 1926
    Association: *Carlino acaulis-Brometum erecti* Oberdorfer 1957
      1. *Carlino-Brometum typicum* Oberdorfer 1957
      2. *Carlino-Brometum festucetosum ovinae* subass. nova
      3. *Carlino-Brometum rubietosum caesi* subass. nova

The *Carlino-Brometum typicum* (*CB*) vegetation was strongly dominated by *Brachypodium pinnatum* (Table 4). Other frequent species, though occurring at much lower levels of cover, were *Euphorbia cyparissias* and *Lotus corniculatus*, often accompanied by *Achillea collina* and *Medicago falcata*. Some species diagnostic of the *CB* i.e. *Helianthemum nummularium*, *Galium album*, *Centaurea scabiosa*, occurred with constancy degree II. Numerous calcareous grassland species of the *Bromion erecti* alliance and *Festuco-Brometea* class, e.g., *Anthericum ramosum*, *Carex flacca* and *Ononis spinosa* occurred in the *CB*. It was also characterised by the presence of a relatively large number of endangered taxa, e.g., *Epipactis palustris*, *Gentiana cruciata* or *Gymnadenia conopsea* subsp. *densiflora* (Table 4).

The *Carlino-Brometum festucetosum ovinae* subass. nova (*CBF*) was an open metallophilic vegetation composed of *Carex caryophyllea*, *Festuca ovina* agg. and *Thymus pulegioides* (Table 4). The following were also found at relatively high constancy: *Leontodon hispidus*, *Silene vulgaris* and *Carex hirta*. Moreover, the community was characterised by the abundant occurrence of the facultative metallophytes *Armeria maritima*, *Asperula cynanchica*, *Biscutella laevigata*, *Cardaminopsis halleri* and *Gypsophila fastigiata*. Among the endangered species, a few were found exclusively on the *CBF* plots: *Biscutella laevigata*, *Campanula sibirica*, *Carex praecox*, *Epipactis atrorubens* and *Orobanche lutea* (Table 4).

Table 3. The occurrence of species at sites grouped into three categories of Cd pollution level (mg Cd kg^{-1}), potentially reflecting Cd toxicity to plants (KABATA-PENDIAS 2011). [a] – absolute frequency expressed as percentage of plots of each category of Cd pollution level (*n* = 65), in which the species occurred. Only the most frequent species (recorded in at least 20 % of plots) are given.

Tabelle 3. Vorkommen von Arten an Standorten, gruppiert in drei Kategorien der Cadmium-Belastung (mg Cd kg^{-1}), die potenziell die Cadmium-Toxizität für Pflanzen reflektieren (KABATA-PENDIAS 2011). [a] – absolute Frequenz, ausgedrückt als Prozent der Untersuchungsflächen der jeweiligen Cadmium-Belastungsstufe (*n* = 65), in der die Art vorkam. Nur die häufigsten Arten (Vorkommen in mindestens 20% der Flächen) sind aufgeführt.

Cd pollution level (mg Cd kg^{-1})	5–10	10–30	>30	5–10	10–30	>30
Species		Frequency[a]			Cover (%)	
Achillea collina	8	22	18	3	2	1
Anthyllis vulneraria	6	5	17	3	2	0
Arrhenatherum elatius	2	11	12	1	2	2
Asperula cynanchica	6	18	11	1	2	0
Brachypodium pinnatum	8	20	6	48	32	4
Briza media	6	11	9	4	4	2
Carex caryophyllea	6	18	42	6	6	14
Carex hirta	2	6	25	0	1	3
Centaurea jacea	5	12	5	1	1	1
Centaurea scabiosa	5	14	3	8	1	0
Convolvulus arvensis	2	8	12	1	1	1
Coronilla varia	3	14	12	0	3	0
Daucus carota	6	9	12	1	0	1
Dianthus carthusianorum	3	12	35	1	2	5
Euphorbia cyparissias	8	28	34	7	6	9
Festuca ovina agg.	5	6	40	7	3	29
Festuca rubra	5	22	11	3	12	6
Galium album	2	28	42	1	7	12
Helianthemum nummularium	2	11	18	2	7	11
Hieracium pilosella	5	3	15	2	2	8
Knautia arvensis	5	5	11	1	0	0
Leontodon hispidus	5	8	28	3	1	7
Lotus corniculatus	6	12	29	3	1	2
Medicago falcata	8	25	12	10	12	3
Peucedanum oreoselinum	6	14	11	15	12	4
Phleum phleoides	2	9	11	2	4	1
Pimpinella saxifraga	3	17	28	1	3	2
Plantago lanceolata	5	6	22	1	0	1
Potentilla arenaria	6	15	29	4	5	9
Rubus caesius	6	22	5	20	17	1
Scabiosa ochroleuca	5	17	31	1	1	2
Silene vulgaris	0	9	29	0	0	4
Thymus pulegioides	6	17	32	2	3	11
Veronica chamaedrys	2	12	12	1	0	1
Vicia cracca	2	12	17	1	2	1

Table 4. Occurrence of diagnostic and constant species (bold) of the three subassociations of the *Carlino acaulis-Brometum erecti* (occurring in at least 60% of plots): *CB – C.-B. typicum*, *CBF – C.-B. festucetosum ovinae* subass. nova, *CBR – C.-B. rubietosum caesi* subass. nova. The occurrence coefficients: F – frequency (expressed as percentage of plots, in which the species occurred), Cc – cover coefficient, Mc – mean cover, Cn – constancy (the five-scale degree of proportion of plots containing a certain taxon within a set of plots). The list includes species that were most frequently recorded; the full plots data are presented in Supplements E2, E3 and E4.

Tabelle 4. Vorkommen von diagnostischen und konstanten Arten (Fettdruck) der drei Subassoziationen des *Carlino acaulis-Brometum erecti* (Vorkommen in mindestens 60 % der Vegetationsaufnahmen): *CB – C.-B. typicum*, *CBF – C.-B. festucetosum ovinae* subass. nova, *CBR – C.-B. rubietosum caesi* subass. nova. Indices des Vorkommens: F – Frequenz (prozentualer Anteil der Flächen, in denen die Art vorkam), Cc – Deckungskoeffizient, Mc – mittlere Deckung, Cn – Stetigkeitsklasse (fünfstufig). Die Liste enthält die am häufigsten aufgenommenen Arten; die vollständigen Vegetationsaufnahmen finden sich in den Anhängen E2, E3 und E4.

Community type	*CB* (*n* = 13)				*CBF* (*n* = 38)				*CBR* (*n* = 14)			
Occurrence coefficients	F (%)	Cc	Mc (%)	Cn	F (%)	Cc	Mc (%)	Cn	F (%)	Cc	Mc (%)	Cn
Carlino acaulis-Brometum erecti festucetosum ovinae												
Carex caryophyllea	**38**	**192.3**	**5**	**II**	**84**	**1494.5**	**18**	**V**	**29**	**37.9**	**1**	**II**
Festuca ovina agg.	**23**	**711.5**	**31**	**I**	**76**	**2585.8**	**34**	**IV**	7	35.7	5	I
Thymus pulegioides	**38**	**116.9**	**3**	**II**	**68**	**1047.1**	**15**	**IV**	**29**	**162.1**	**6**	**II**
Scabiosa ochroleuca	**46**	**117.7**	**3**	**II**	**68**	**227.4**	**3**	**IV**	**14**	**71.4**	**5**	**I**
Potentilla arenaria	**31**	**212.3**	**7**	**II**	**66**	**988.2**	**15**	**IV**	7	125.0	18	I
Dianthus carthusianorum	**38**	**213.1**	**6**	**II**	**66**	**547.4**	**8**	**IV**	**14**	**1.4**	**< 0.1**	**I**
Carlino acaulis-Brometum erecti rubietosum caesi												
Rubus caesius	.	.	.	.	**13**	**118.7**	**9**	**I**	**93**	**3750.0**	**40**	**V**
Festuca rubra	**38**	**384.6**	**10**	**II**	**18**	**447.4**	**24**	**I**	**71**	**1465.0**	**21**	**IV**
Carlino acaulis-Brometum erecti typicum												
Brachypodium pinnatum	**100**	**6480.8**	**65**	**V**	5	46.3	9	I	**50**	**3107.1**	**62**	**III**
Centaurea scabiosa	**38**	**213.1**	**6**	**II**	**18**	**66.3**	**4**	**I**	7	267.9	38	I
Carlina acaulis	**38**	**154.6**	**4**	**II**	8	< 1	< 0.1	I	7	< 1	< 0.1	I
Polygala comosa	**38**	**154.6**	**4**	**II**	**11**	**13.9**	**1**	**I**	**14**	**36.4**	**3**	**I**
Helianthemum nummularium	**31**	**904.6**	**29**	**II**	**34**	**947.4**	**28**	**II**	**14**	**160.7**	**11**	**I**
Knautia arvensis	**31**	**40.8**	**1**	**II**	**16**	**14.5**	**1**	**I**	**21**	**37.1**	**2**	**I**
Coronilla varia	**23**	**115.4**	**5**	**I**	**24**	**73.9**	**3**	**I**	**43**	**322.9**	**8**	**II**
Anthyllis vulneraria	**15**	**326.9**	**21**	**I**	**39**	**88.4**	**2**	**II**	.	.	.	.
Diagnostic for two subassociations												
Euphorbia cyparissias	**85**	**481.5**	**6**	**IV**	**71**	**903.9**	**13**	**IV**	**50**	**501.4**	**10**	**III**
Lotus corniculatus	**77**	**405.4**	**5**	**IV**	**61**	**180.8**	**3**	**III**	.	.	.	.
Galium album	**46**	**501.5**	**11**	**II**	**79**	**975.3**	**12**	**IV**	**71**	**857.1**	**12**	**IV**
Bromion erecti + Festuco-Brometea												
Achillea collina	**69**	**1231.5**	**18**	**III**	**39**	**145.8**	**4**	**II**	**43**	**214.3**	**5**	**II**
Medicago falcata	**54**	**616.2**	**11**	**III**	**32**	**553.2**	**18**	**II**	**50**	**947.1**	**19**	**III**
Phleum phleoides	**46**	**347.7**	**8**	**II**	**21**	**165.3**	**8**	**I**	7	35.7	5	I
Trifolium montanum	**38**	**175.4**	**5**	**II**	3	46.1	18	I	**14**	**160.7**	**11**	**I**

Community type	*CB* (*n* = 13)				*CBF* (*n* = 38)				*CBR* (*n* = 14)			
Occurrence coefficients	F (%)	Cc	Mc (%)	Cn	F (%)	Cc	Mc (%)	Cn	F (%)	Cc	Mc (%)	Cn
Pimpinella saxifraga	**31**	**116.2**	**4**	**II**	**58**	**213.4**	**4**	**III**	**36**	**197.9**	**6**	**II**
Leontodon hispidus	**31**	**308.5**	**10**	**II**	**58**	**730.8**	**13**	**III**	**14**	**1.4**	**< 0.1**	**I**
Peucedanum cervaria	**31**	**346.2**	**11**	**II**	5	13.4	3	I	7	35.7	5	I
Prunella grandiflora	**31**	**78.5**	**3**	**II**	3	46.1	18	I	7	< 1	< 0.1	I
Centaurea stoebe	**23**	**616.2**	**27**	**I**	**16**	**86.1**	**5**	**I**	.	.	.	.
Festuca pallens	**23**	**327.7**	**14**	**I**	8	46.6	6	I	7	< 1	< 0.1	I
Fragaria viridis	**23**	**173.8**	**8**	**I**	5	59.2	11	I	.	.	.	.
Trifolium medium	**23**	**115.4**	**5**	**I**	3	13.2	5	I	7	< 1	< 0.1	I
Centaurea jacea	**23**	**77.7**	**3**	**I**	**13**	**85.8**	**7**	**I**	**21**	**37.1**	**2**	**I**
Asperula cynanchica	**15**	**1.5**	**< 0.1**	**I**	**32**	**106.3**	**3**	**II**	**36**	**108.6**	**3**	**II**
Veronica chamaedrys	**15**	**289.2**	**19**	**I**	**24**	**99.7**	**4**	**I**	**43**	**39.3**	**1**	**II**
Agrimonia eupatoria	**15**	**39.2**	**3**	**I**	2	< 1	< 0.1	I	**29**	**37.9**	**1**	**II**
Anthericum ramosum	**15**	**326.9**	**21**	**I**	5	< 1	< 0.1	I	.	.	.	.
Carex flacca	**15**	**39.2**	**3**	**I**	3	13.2	5	I	.	.	.	.
Ononis spinosa	**15**	**39.2**	**3**	**I**	8	59.5	8	I	.	.	.	.
Salvia pratensis	**15**	**173.1**	**11**	**I**	.	.	.	.	.	.	.	.
Plantago media	**15**	**76.9**	**5**	**I**	.	.	.	.	.	.	.	.
Hieracium pilosella	8	38.5	< 0.1	I	**32**	**888.4**	**28**	**II**	7	< 1	< 0.1	I
Poa compressa	8	< 1	< 0.1	I	**16**	**177.6**	**11**	**I**	14	36.4	3	I
Artemisia campestris	8	< 1	< 0.1	I	**16**	**60.3**	**4**	**I**	.	.	.	.
Euphrasia stricta	8	38.5	< 0.1	I	**16**	**14.5**	**1**	**I**	.	.	.	.
Cerastium arvense	.	.	.	.	**18**	**86.3**	**5**	**I**	**14**	**1.4**	**< 0.1**	**I**
Avenula pubescens	.	.	.	.	**13**	**125.5**	**10**	**I**	.	.	.	.
Anthoxanthum odoratum	.	.	.	.	**13**	**40.0**	**3**	**I**	.	.	.	.
Fragaria vesca	.	.	.	.	5	98.9	19	I	**43**	**109.3**	**3**	**II**
Festuca rupicola	.	.	.	.	3	98.7	38	I	**14**	**303.6**	**21**	**I**
Other species												
Peucedanum oreoselinum	**46**	**1135.4**	**25**	**II**	**24**	**612.1**	**26**	**I**	**29**	**804.3**	**28**	**II**
Agrostis stolonifera	**31**	**212.3**	**7**	**II**	8	39.5	5	I	**14**	**250.0**	**18**	**I**
Aegopodium podagraria	**31**	**750.0**	**24**	**II**	.	.	.	.	7	446.4	63	I
Plantago lanceolata	**31**	**308.5**	**10**	**II**	**50**	**108.2**	**2**	**III**	.	.	.	.
Arrhenatherum elatius	**23**	**173.8**	**8**	**I**	**26**	**198.4**	**8**	**I**	**36**	**232.9**	**7**	**II**
Daucus carota	**23**	**2.3**	**< 0.1**	**I**	**29**	**74.5**	**3**	**II**	**21**	**2.1**	**< 0.1**	**I**
Briza media	**23**	**211.5**	**9**	**I**	**26**	**290.0**	**11**	**I**	**14**	**160.7**	**11**	**I**
Vicia cracca	**15**	**76.9**	**5**	**I**	**32**	**126.3**	**4**	**II**	**43**	**268.6**	**6**	**II**
Achillea millefolium	**15**	**423.1**	**28.0**	**I**	5	13.4	3	I	7	< 1	< 0.1	I
Agrostis capillaris	**15**	**39.2**	**3**	**I**	8	26.6	3	I	7	35.7	5	I
Convolvulus arvensis	**15**	**39.2**	**3**	**I**	**26**	**100.0**	**4**	**I**	**14**	**36.4**	**3**	**I**
Sedum maximum	**15**	**39.2**	**3**	**I**	3	13.2	5	I	7	< 1	< 0.1	I
Rhamnus catharticus	**15**	**1.5**	**< 0.1**	**I**	5	13.4	3	I	7	< 1	< 0.1	I
Crataegus monogyna	**15**	**39.2**	**3**	**I**	**11**	**1.1**	**< 0.1**	**I**	.	.	.	.

Community type	*CB* (*n* = 13)				*CBF* (*n* = 38)				*CBR* (*n* = 14)			
Occurrence coefficients	F (%)	Cc	Mc (%)	Cn	F (%)	Cc	Mc (%)	Cn	F (%)	Cc	Mc (%)	Cn
Carex hirta	8	38.5	< 0.1	I	**47**	**278.2**	**6**	**III**	7	35.7	5	I
Cruciata glabra	8	< 1	< 0.1	I	8	39.5	5	.	**21**	**517.9**	**24**	**I**
Armeria maritima	8	134.6	< 0.1	I	**13**	**60.0**	**5**	**I**	.	.	.	.
Pinus sylvestris	8	< 1	< 0.1	I	**13**	**1.3**	**< 0.1**	**I**	.	.	.	.
Euphorbia esula	8	< 1	< 0.1	I	.	.	.	.	**14**	**36.4**	**3**	**I**
Cirsium arvense	8	< 1	< 0.1	I	.	.	.	.	**14**	**1.4**	**< 0.1**	**I**
Silene vulgaris	.	.	.	.	**55**	**324.7**	**6**	**III**	**14**	**1.4**	**< 0.1**	**I**
Silene nutans	.	.	.	.	**24**	**119.7**	**5**	**I**	7	35.7	5	I
Rumex thyrsiflorus	.	.	.	.	**21**	**15.0**	**1**	**I**	7	< 1	< 0.1	I
Pteridium aquilinum	.	.	.	.	5	< 1	< 0.1	I	**57**	**591.4**	**10**	**III**
Melandrium album	.	.	.	.	5	< 1	< 0.1	I	**36**	**3.6**	**< 0.1**	**II**
Calamagrostis epigeios	.	.	.	.	5	13.4	3	I	**29**	**429.3**	**15**	**II**
Equisetum arvense	.	.	.	.	5	13.4	3	I	**21**	**393.6**	**18**	**I**
Dactylis glomerata	.	.	.	.	5	13.4	3	I	**21**	**339.3**	**16**	**I**
Ranunculus bulbosus	.	.	.	.	**29**	**100.3**	**3**	**II**	.	.	.	.
Rumex acetosa	.	.	.	.	**29**	**15.8**	**1**	**II**	.	.	.	.
Cardaminopsis arenosa	.	.	.	.	**16**	**27.4**	**2**	**I**	.	.	.	.
Centaurea diffusa	.	.	.	.	**11**	**72.6**	**7**	**I**	.	.	.	.
Solidago canadensis	.	.	.	.	.	.	.	.	**43**	**341.4**	**8**	**II**
Elymus repens	.	.	.	.	.	.	.	.	**21**	**393.6**	**18**	**I**
Melica nutans	.	.	.	.	.	.	.	.	**21**	**285.7**	**13**	**I**
Poa pratensis	.	.	.	.	.	.	.	.	**14**	**125.7**	**9**	**I**
Heracleum sphondylium	.	.	.	.	.	.	.	.	**14**	**36.4**	**3**	**I**

The vegetation of the *C.-B. rubietosum caesi* subass. nova (*CBR*) was fully closed and consisted of taller plants including several nutrient-demanding ruderals and as well as woody plants which had probably invaded the heaps from the adjacent forests. The diagnostics of this community are *Rubus caesius*, *Festuca rubra* and *Galium album* (Table 4). Other relative frequent taxa in the stands were *Brachypodium pinnatum*, *Medicago falcata* and *Pteridium aquilinum*. An important role played synanthropic species of the *Artemisietea vulgaris*, *Epilobietea angustifolii* and *Molinio-Arrhenatheretea* classes with wide ecological amplitudes, e.g., *Arrhenatherum elatius*, *Fragaria vesca* and *Solidago canadensis*. The ecotonal character of this community was also shaped by the presence of species connected with forest or forest-steppe interface such as *Agrimonia eupatoria*, *Melica nutans* and *Peucedanum oreoselinum*, including several endangered species such as *Astragalus glycyphyllos*, *Epipactis helleborine* or *Malaxis monophyllos* (Table 4).

More data about the structure of the three plant communities (individual plots presented as phytosociological relevés) are provided in the Supplements E2, E3 and E4.

4. Discussion

4.1 General features of the vascular flora of the heaps

A very low proportion of alien species, represented mainly by archeophytes, and a relatively high proportion of grassland species, including endangered species, are a characteristic feature of the old heaps studied. This means that post-mining habitats show a similar degree of 'naturalness' as non-metalliferous xerothermic grasslands (most of whose genesis is also considered to be semi-natural in the temperate zone of Central Europe) and thus may be considered valuable in terms of plant diversity conservation. In addition, in heap grasslands and non-metalliferous xerothermic grasslands, the proportion of alien species is similar. (CRAWLEY 1987, MCCOLLIN et al. 2000, WOCH & HAWRYLUK 2014).

It was observed that competitive stress-tolerant ruderals and competitors dominated the heaps investigated. A low proportion of *CSR* plants was usually observed on old heaps with advanced succession and not polluted with heavy metals, such as waste heaps from coal mining, and xerothermic grasslands undisturbed for years (ROSTAŃSKI & TRUEMAN 2001, THOMPSON et al. 2001, MOOG et al. 2005). With regard to the heaps that were examined here, competitors were the second plant group of similar size, whereas competitive stress-tolerators constituted the third group. This can be explained by the fact that the heavy metals present in soil are an environmental stress factor while there are no disturbances promoting competitiveness (HODGSON et al. 1999). The results obtained indicate that those species that are adapted to both competition and constant moderate stress generally perform better on old metallicolous grasslands. The proportion of stress tolerators was highest on those heaps that were most polluted with metals (WOCH et al. 2016). The relatively loose plant cover of such places may have additionally increased the xeric features of the habitat. A similar influence of stress intensification on community structure, such as stress from the intensification of grazing, burning or stress of drought and high temperature, is observed on other non-calamine grasslands and meadows (WILSON & LEE 2000, MOOG et al. 2002, WOCH et al. 2016). In the case of *CB* and *CBR* grasslands with more advanced succession on the less polluted heaps, metals are a moderate stress. Moderate stress causes similar changes in community structure as on other non-calamine grasslands, where moderate grazing/cutting promoting *CSR*-strategists constitutes a constant stress factor (GRIME 2001, MOOG et al. 2005). With a low metal content in the soil and rapid progress of succession, typical changes related to the decrease of disturbances after land abandonment, with an increase of competitors, can be observed (GRIME 2001, PRÉVOSTO et al. 2011).

4.2 Influence of habitat on the diversity and properties of vascular flora

This work shows that diversity and species composition of the flora of the heaps largely depend on the content of heavy metals and calcium in the soil. This result is in accordance with the results from many other metalliferous areas (e.g., CLARK & CLARK 1981, BROWN 2001, BECKER & BRÄNDEL 2007, HERNÁNDEZ & PASTOR 2008, HALE & ROBERTSON 2016, WOCH et al. 2017). Heavy metal content was connected with the stage of succession of the heaps. It was observed that vegetation in the intermediate successional stage was most diverse. This can be explained by the common presence of pioneer species and species of later successional stages. A similar effect can be observed in the temporary increase in species diversity on various types of post-industrial sites, where primary succession occurs on the bare substratum (e.g., NOVÁK & PRACH 2003, ŘEHOUNKOVÁ & PRACH 2010, WOCH et al.

2013). This is also the case on abandoned grasslands and meadows, where secondary succession proceeds (OLSSON 1987, KULL & ZOBEL 1991, HUHTA & RAUTIO 1998, PRÉVOSTO et al. 2011, BARABASZ-KRASNY 2016).

Soil enriched in nutrients from mineralisation of accumulating litter has a beneficial influence on species number, however, this development only runs to a certain level above which nitrogen-demanding competitors becomes dominate and number of species decreases (OOMES 1990, FACELLI & FACELLI 1993, GRIME 2001, FRANZARING et al. 2007, PRÉVOSTO et al. 2011, WOCH et al. 2017). *CB* grasslands, in a more advanced successional stage, were dominated by the competitive and eutrophilous grass *Brachypodium pinnatum* that is a species producing large amounts of organic matter and forming dense mats (BOBBINK et al. 1989, BORNKAMM 2006, WOCH et al. 2016). In the case of heaps located in the vicinity of forest (*CBR*), soil enriched in organic matter from litterfall was beneficial for eutrophilous tall herbs and grasses (PRÉVOSTO et al. 2011, LOYDI et al. 2013, WOCH et al. 2016). The number of species was lower in *CB* and *CBR* grasslands and higher in *CBF* grasslands.

Heavy metals were negatively correlated with stress-tolerant competitors, hemicryptophytes, phanerophytes, plants dispersed by animals, graminoids, ruderals, shrub and forest types, and positively correlated with chamaephytes and pioneer species. This can be explained by the fact that strong environmental stress by heavy metals reduces many late-successional species and facilitates early-successional species (WILSON & LEE 2000, GRIME 2001, ŘEHOUNKOVÁ & PRACH 2010). However, pioneer species are often weak competitors while late-successional species are stronger competitors but poor colonisers (OLSSON 1987, GRIME 2001, NOVÁK & PRACH 2003). Therefore, late successional traits predominated on heaps with the lowest concentration of heavy metals, which proves that at these sites succession was most advanced. Toxicants, such as SO_2, ozone or herbicides, have a similar influence on community structure – they first eliminate fast-growing, productive species (LAVOREL et al. 1999, FRANZARING et al. 2007). Other authors indicated that community responses to disturbance or degradation manifest less in changes in local species richness and more in changes in the structure, the fine-scale spatial complexity, of the community (STANDOVÁR et al. 2006, VIRÁGH et al. 2008).

Species of extreme habitats are often rare (FRANZARING et al. 2007, BAKER et al. 2010). Despite the fact that these studies found a negative relationship between heavy metals and endangered species, several natural stress tolerators were found on the heaps, such as *Alyssum montanum*, *Festuca pallens*, *Gypsophila fastigiata*, *Thymus marschalianus* and *Verbascum chaixii* subsp. *austriacum*. Generally, the greatest number of such species was observed in *CBF* plots. Also over half of the species occurring on the heaps were connected with this community.

Spatial relations, such as proximity of other plant types as well as altitude above sea level, had a significant influence on the composition of the grasslands examined. Proximity of forest and scrub communities positively influenced the occurrence of competitive and other plants connected with woodlands, as well as the participation of nutrient-demanding and synanthropic plants. At the same time, it negatively affected grassland species. Such changes are similar to the processes occurring on the different types of European meadows and grasslands that, due to lack of grazing or cutting, are invaded by eutrophic communities (THOMPSON et al. 2001, MYSTER & PICKETT 1993, PRÉVOSTO et al. 2011, HABEL et al. 2013, BARABASZ-KRASNY 2016). Succession is probably accelerated by seed rain and the deposition of litter by forest species (MCDONNELL & STILES 1983, MYSTER & PICKETT 1993, LOYDI et al. 2013, WOCH et al. 2016, 2017). Location at a higher altitude above sea level and the related increase in mean annual rainfall positively affected the occurrence of more mesophilic, late successional species – both of meadow and woodland types. Lower altitude and higher annual temperatures were beneficial for the occurrence of grassland species with pioneer features such as stress-tolerant ones and xerophytic ones. The effect of local climate on plant composition and the course of succession has been pointed out by several authors (NOVÁK & PRACH 2003, OTTO et al. 2006, PRACH & ŘEHOUNKOVÁ 2006, PRACH et al. 2014).

4.3 Syntaxonomic problems in the communities studied

It is justifiable to assign the studied heap grasslands to the *Carlino-Brometum* for the following reasons: 1) All the heaps investigated were dominated by species characteristic for the *Carlino-Brometum*; 2) the *CB* association developed on some metalliferous sites (although with lower metal contamination than the *CBF*); and 3) there was a clear continuity in species composition observed between *CBF* and *CB* as well as *CBR* grasslands, as revealed by DCA (WOCH et al. 2016).

The *CB* was characterized by a dominance of *Brachypodium pinnatum* and abundant species typical for the *Bromion erecti*. The lack of *Cirsium acaule*, as well as several continental character species of the *Cirsio-Brachypodion* (e.g., *Aster amellus*, *Inula ensifolia* or *Linosyris vulgaris*) and the high cover of subatlantic species such as *Anthyllis vulneraria*, *Carlina acaulis* and *Helianthemum nummularium*, as well as other species characteristic of *Carlino acaulis-Brometum erecti*, such as *Briza media*, *Leontodon hispidus* and *Ranunculus bulbosus,* were the considerations that prevailed in determining it as *CB*. The *CB* vegetation is, in many respects, similar to the *Brachypodium*-dominated suboceanic grassland of Central Germany and the middle altitudes of the Czech Republic and Slovakia (= *Bromion erecti*) (ILLYÉS et al. 2007). On the other hand, the grasslands on the old heaps lacked some subatlantic species that are diagnostic of the *Bromion erecti* alliance, such as *Bromus erectus* and *Koeleria pyramidata*. Rare stands of those species on the Silesian-Cracow Upland are located at the north-eastern edge of its range (ZAJĄC & ZAJĄC 2001). The transitional location of the area studied between the western and eastern ranges suggests rather an intermediate character of the grasslands between *Bromion erecti* and *Cirsio-Brachypodion pinnati*. The *CB* vegetation corresponds to some stands of *Adonido-Brachypodietum arrhenatheretosum* Krausch 1961 or the *Adonido-Brachypodietum anthericetosum* in this region (BABCZYŃSKA-SENDEK 2005).

Carlino acaulis-Brometum erecti occurs in cooler and wetter areas, and on calcareous soils developed on limestone, dolomite or various calcareous sediments (CHYTRÝ 2007). The old mine waste heaps, with their shallow rendzina-like soil, resemble such habitats; thereby they seem to be suitable sites for this community. Additionally, the area where study was performed is locally characterised by a moister and colder climate (LORENC 2005). There is need for a modern syntaxonomic revision of the semi-dry grasslands in southern Poland based on a comprehensive vegetation-plot database of the neighbouring territories in Poland, the Czech Republic, Slovakia and Germany, followed by a statistical elaboration of the diagnostic species. Similar communities may also be typical for less calciferous substrates, especially in cooler and more humid regions such as the Silesia-Cracow and Małopolska Uplands.

The composition of the *CB* found on the old heaps may be distorted due to its specific, anthropogenic character; therefore, the use of the term ‘typical’ is rather a descriptive one. Moreover, the heavy metal concentration was high even on the least polluted heaps, and this should be taken into account. The concentration of total Cd in the *CB* soil varied from 6 to

57 mg kg^{-1} (WOCH et al. 2016). It could be the factor which made both the growth of some metal-sensitive taxa impossible and which disturbed the populations of others. It seems that an encroachment of *Carlino -Brometum* on the dolomite waste is a typical phenomenon under the observed climatic conditions. This study has shown that this is indeed true at low or moderate Cd-Pb-Zn contamination, whereas the community changes into the *CBF* at high and very high concentrations of heavy metals in the soil (WOCH et al. 2016).

CBF, which is a predominant subassociation on the old heaps, is similar to the vegetation of a large century-old heap of metal-rich dolomite located in Bolesław (near Olkusz). GRODZIŃSKA & SZAREK-ŁUKASZEWSKA (2009) described this vegetation as loosely related to the *achilletosum millefoliae* subassociation of the *Armerietum halleri* Libb. 1930 (*Violetea calaminariae* Br. -Bl. et R. Tx. 1943 class) from metalliferous areas in Germany (e.g., SCHUBERT 1954, ERNST 1974, BECKER & DIERSCHKE 2008), but have not decided about its precise syntaxonomic position due to the incomparability and rarity of the phytosociological materials. The community described developed on soil containing 3.2–16.6 g Pb kg^{-1} and 33–104 g Zn kg^{-1} (GRODZIŃSKA & SZAREK-ŁUKASZEWSKA 2009). These values correspond to the highest metal concentrations found in this study. The results suggest that the dissimilarity of the heavy metal grassland from the typical limestone grassland is a consequence of a decrease in the number of metal-sensitive species, and an increase in the number of species with wider ecological amplitude (including those from classes other than *Festuco-Brometea*) but apparently of lower competitiveness.

The *CBR* that developed in proximity to woodland is similar to the subatlantic *Brachypodium* grassland invaded by shrubs to a certain degree (ILLYÉS et al. 2007) in terms of the occurrence of *Agrimonia eupatoria*, *Arrhenatherum elatius*, *Galium album* and shrubs such as *Prunus spinosa*, *Rosa canina* and *Rubus caesius*. *Brachypodium pinnatum* plays an important role during the transition of grassland to scrub vegetation (BORNKAMM 2006). The abundance of synanthropic species of wide ecological amplitude, and some species from the forest communities, e.g., *Melica nutans*, *Pteridium aquilinum* and *Solidago canadensis*, was characteristic of *CBR*. This mix of species from different communities is typical for the ecotonal habitat. In this regard, *CBR* corresponds to later successional communities – the warm forest margin vegetation of *Geranio-Peucedanietum cervariae* (Kuhn 1937) Th. Müll. 1961 or the impoverished *Adonido-Brachypodietum pinnati* (Libb. 1933) Krausch 1961 (BABCZYŃSKA-SENDEK 2005, WOCH 2011).

5. Conclusions

In this study, numerous old heaps scattered over a relatively large area were used for investigating vegetation-environment-relationships in metallicolous vegetation, as well as processes of natural succession in these habitats.

The old heaps were scattered islands of grasslands in the agricultural landscape and represent refuges for endangered plants. The heaps are also of great importance as starting points for colonisation of neighbouring wastelands by xerothermic plants. Therefore, the heaps should be protected in order to maintain endangered species and to preserve the heritage of a industrial region.

Erweiterte deutsche Zusammenfassung

Einleitung – In der Małopolska-Region im Südpolen (schlesisch-krakauischen Hochland) finden sich vielerorts Reste des einstigen Zink/Blei-Bergbaus. In der Agrarlandschaft existieren zerstreut kleine Abraumhalden mit hohen Schwermetallgehalten im Boden: 5–522 mg Cadmium (Cd) kg^{-1}, 0,1–23 g Blei (Pb) kg^{-1}, 6–51 mg Talkum (Tl) kg^{-1} und 0,4–70 g Zink (Zn) kg^{-1} (STEFANOWICZ et al. 2014). In einer früheren Studie (WOCH et al. 2016) waren die auf den Halden wachsenden Kalk-Halbtrockenrasen als verarmte *Festuca ovina*-Variante des *Carlino acaulis-Brometum erecti* (im Folgenden *CBF*) beschrieben worden. Zudem existieren relativ weit von Wäldern entfernt eine typische Ausbildung der Assoziation (*CB*) mit zahlreichen Arten der Kalkmagerrasen auf Böden mit niedrigen bis moderaten Schwermetallkonzentrationen und in der Nähe von Wäldern eine *Rubus caesius*-Ausbildung (*CBR*) mit Holz- und Ruderal-Pflanzenarten (WOCH et al. 2016). Ziele der vorliegenden Studie waren (1) die Analyse der Flora der alten Halden, (2) die Einschätzung des Einflusses von Bodeneigenschaften und der Entfernung der Halden vom nächsten Wald sowie der Meereshöhe auf die Vegetation, (3) die Identifikation besonders schwermetalltoleranter und -intoleranter Pflanzenarten, und (4) die pflanzensoziologische Einordnung der Rasen auf den Zn/Pb-Bergbauhalden in West-Małopolska.

Material und Methoden – Die Studie wurde in einem 750 km² großen Gebiet, das zwischen den Städten Krzeszowice, Libiąż, Jaworzno und Olkusz liegt, durchgeführt (Abb. 1). Die Untersuchungsorte umfassten teilweise erodierte Abraumhalden mit einem Durchmesser von oftmals nicht mehr als 20 m; manche Halden waren unter einer dichten Vegetationsdecke verborgen (Abb. 2). In den Vegetationsperioden 2012 und 2013 wurde die Vegetation am Süd-, Südwest- und Südost-Hang von insgesamt 65 Halden aufgenommen (Nomenklatur der Arten nach MIREK et al. 2002). In homogenen Beständen wurden runde Aufnahmeflächen mit 4 m² Größe angelegt. Die Deckung der Gefäßpflanzen wurde mit Hilfe der fünfteiligen Braun-Blanquet-Skala (BRAUN-BLANQUET-1964) geschätzt. Für alle unbewaldeten Halden im Untersuchungsgebiet wurde zudem eine vollständige Pflanzenartenliste erstellt; die kumulative Gesamtfläche dieser Halden betrug etwa 20 ha. Für jede Halde wurde die Entfernung zum nächsten Waldgebiet mit mindestens 1 ha Größe entweder im Gelände oder mit Hilfe von Luftbildern bestimmt. Die verwendeten Klimadaten stammten von der nächsten Messstation des Institutes für Meteorologie und Wasserwirtschaft (IMGW-PIB). Die Meereshöhe der Halden wurde topographischen Karten entnommen. Im Juli wurden in jeder Aufnahmefläche drei Oberbodenproben genommen und jeweils zu einer Mischprobe vereinigt. Zur Analyse der Vegetation wurden die Anteile der geographischen und historischen Artengruppen nach RUTKOWSKI (2008) und SUDNIK-WÓJCIKOWSKA (2011), der CSR-Strategietypen nach GRIME (1979, 2001), der funktionellen Gruppen nach RUTKOWSKI (2008), der Lebensformen nach RAUNKIAER (1934), der Arten alter Wälder sowie Pionier-Arten nach HERMY et al. (1999) und SCHMIDT et al. (2014), der Ausbreitungstypen der Arten nach PODBIELKOWSKI (1995) und der Vegetationsklassen nach CHYTRÝ et al. (2007, 2009, 2013) bestimmt. In Polen geschützte und gefährdete Arten wurden nach KAŹMIERCZAKOWA & ZARZYCKI (2001) und MIREK et al. (2006) determiniert. Die Pflanzengesellschaften wurden nach CHYTRÝ et al. (2007) bestimmt. 65 Halden wurden nach der Cadmiumkonzentration des Bodens in drei Kategorien eingeteilt: Halden mit 5–10, 10–30 und > 30 mg Cd kg^{-1} Boden (KABATA-PENDIAS 2011). Die statistischen Analysen wurden mithilfe des Programms STATISTICA 9 (StatSoft Inc. Tulsa, OK., USA) durchgeführt.

Ergebnisse – Insgesamt wurden 222 Pflanzenarten aus 49 Familien nachgewiesen (Tab. 1). Die Artenzahl der Gefäßpflanzen der 4 m²-Flächen reichte von 4–33 und die Deckung der Gefäßpflanzen von 50–100 %. Pionierarten trugen erheblich zum Pflanzenartenreichtum bei. Der Artenreichtum und Anteil der *Festuco-Brometea*-Arten nahmen mit dem Schwermetallgehalt des Bodens ab und mit dem Kalkgehalt zu. Mit zunehmender Schwermetallkonzentration nahm der Anteil an Arten früher Sukzessionsstadien zu und der Anteil an Arten später Sukzessionsstadien ab. Weitere wichtige erklärende Variable waren die Distanz zum Waldland und die Meereshöhe. Waldnähe beeinflusste die Häufigkeit von Holz- und Ruderalarten positiv. Meereshöhe stand dagegen in einem positiven Zusammenhang zum Vorkommen von Wiesen- und Wald- sowie synanthropen Pflanzenarten, und in einem negativen Zusammenhang zum Vorkommen von xerothermen Pflanzenarten. Sowohl auf waldnahgelegenen als auch auf Halden in höherer Höhenlage lagen die Anteile an Arten später Sukzessionsstadien höher, wohingegen der Anteil der Pionierarten mit Meereshöhe und Jahresmitteltemperatur negativ korreliert waren. Insgesamt waren die Halden vor allem von windausgebreiteten Ruderalarten mit hoher Stresstoleranz sowie von konkurrenzstarken Arten besiedelt. Bodenbedingungen hatten vielfältige Einflüsse auf die Vegetation der Halden (Tab. 2): Schwermetalle hatten einen positiven Einfluss auf die Anwesenheit von Arten früher Sukzessionsstadien und einen negativen Einfluss auf die Anwesenheit von Arten später Sukzessionsstadien. Verschiedene Pflanzenarten wie z. B. *Brachypodium pinnatum*, deren Stetigkeit und Deckung mit dem Schwermetallgehalt des Bodens abnahm, wurden als metallsensitiv eingeschätzt. Nur wenige Pflanzenarten, z. B. *Carex caryophyllea*, nahmen mit dem Schwermetallgehalt des Bodens zu. Die Vegetation des *Carlino-Brometum typicum* (*CB*) war von *Brachypodium pinnatum* stark dominiert. In dieser Gesellschaft wurde auch der höchste Anteil an typischen Kalkmagerrasenarten festgestellt. Die Struktur des *Carlino-Brometum festucetosum ovinae* subass. nova (*CBF*) war dagegen eher offen; in dieser Gesellschaft wuchsen auch besonders viele Metallophyten. Die Rasen des *Carlino-Brometum rubietosum caesi* subass. nova (*CBR*) waren dagegen geschlossen und hochwüchsiger, und enthielten zahlreiche nährstoffliebende und holzige Pflanzenarten, die teilweise offenbar aus den angrenzenden Wäldern stammten (Tab. 4).

Diskussion – Die Artenzusammensetzung des Graslands der von uns untersuchten Halden war mit verschiedenen raumabhängigen Variablen, wie z. B. der Waldnähe oder der Meereshöhe, korreliert. Die zugrundeliegenden Prozesse, die in anderen Graslandgesellschaften Europas z. B. durch Brache bedingt ablaufen, führen in den Schwermetallrasen dazu, dass die mageren Schwermetallrasen mit der Zeit durch nährstoffliebende Gesellschaften ersetzt werden (THOMPSON et al. 2001, MYSTER & PICKETT 1993, PRÉVOSTO et al. 2011, HABEL et al. 2013, BARABASZ-KRASNY 2016). Die drei untersuchten Subassoziationen der Schwermetallrasen repräsentieren v. a. verschiedene Sukzessionsstadien des *Carlino-Brometum*, welche wiederum durch verschiedene Umweltbedingungen charakterisiert sind: Das *CB* ähnelte in vielerlei Hinsicht den von *Brachypodium* dominierten subozeanischen Graslandbeständen des *Bromion erecti* Deutschlands sowie den Beständen mittlerer Höhenlagen Tschechiens und der Slowakei (ILLYÉS et al. 2007). Die Übergangsposition des Untersuchungsgebiets zwischen eher westlich und östlich verbreiteten Gesellschaften und Arten deutet auf seine intermediäre Stellung zwischen *Bromion erecti* und *Cirsio-Brachypodion pinnati* hin. Das *CBF*, das die vorherrschende Subassoziation der alten Halden darstellte, ähnelte der Vegetation der jahrhundertealten Halden aus metallhaltigen Dolomitgestein in Bolesław (Umgebung von Olkusz). GRODZIŃSKA & SZAREK-ŁUKASZEWSKA (2009) wiesen hingegen auf die Ähnlichkeit unserer Bestände mit der *Achillea millefolium*-Subassoziation des *Armerietum halleri* Libb. 1930 hin, welche auf Schwermetallstandorten in Deutschland wächst (z. B. SCHUBERT 1954, ERNST 1974, BECKER & DIERSCHKE 2008). Das *CBR*, das in der Nähe zu Wäldern entwickelt war, ähnelte subatlantischen *Brachypodium*-Graslandbeständen (ILLYÉS et al. 2007).

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Supplements

Additional supporting information may be found in the online version of this article.

Zusätzliche unterstützende Information ist in der Online-Version dieses Artikels zu finden.

Supplement E1. List of vascular plant species occurring on the studied heaps.

Anhang E1. Liste der auf den untersuchten Halden vorkommenden Arten.

Supplement E2. Vegetation table of the *Carlino acaulis-Brometum erecti typicum*.

Anhang E2. Vegetationstabelle des *Carlino acaulis-Brometum erecti typicum*.

Supplement E3. Vegetation table of the *Carlino acaulis-Brometum erecti festucetosum ovinae*.

Anhang E3. Vegetationstabelle des *Carlino acaulis-Brometum erecti festucetosum ovinae*.

Supplement E4. Vegetation table of the *Carlino acaulis-Brometum erecti rubietosum caesi*.

Anhang E4. Vegetationstabelle des *Carlino acaulis-Brometum erecti rubietosum caesi.*

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Supplement E1. List of vascular plant species occurring on the studied heaps.

Anhang E1. Liste der auf den untersuchten Halden vorkommenden Arten.

Species	Fam	No	Comm	Fg	Gs	Lf	St	Disp	Veg	Remarks
Achillea collina	*As*	38	*CB*	Forb	SC	H	N	An	*Fest-Brom*	ps
Achillea millefolium	*As*	5	*CB*	Forb	C	H	N	An/Zooch/Myr	*Mol-Arr*	ps
Aegopodium podagraria	*Ap*	2	*CB*	Forb	C	G/H	N	An	*Car-Fag*	
Agrimonia eupatoria	*Ro*	9	*CBR*	Forb	C	H	N	Zooch	*Fest-Brom*	
Agrostis capillaris	*Po*	6	*CB, CBR*	Graminoid	CSR	H	N	An	*Mol-Arr*	ps
Agrostis stolonifera	*Po*	7	*CB*	Graminoid	CSR	H	N	An	*Mol-Arr*	ps
Ajuga reptans	*La*	1	*CBR*	Forb	CSR	H	N	Myr	*Car-Fag*	
Ajuga genevensis	*La*	4	*CBF*	Forb	CSR	H	N	Myr	*Fest-Brom*	
Allium oleraceum	*Li*	5	*CBR*	Forb	CSR	G	N	An	*Fest-Brom*	
Allium vineale	*Li*	1	*CBF*	Forb	C	G	N	An	*Fest-Brom*	
Alyssum montanum	*Br*	3	*CBF*	Forb	CSR	Ch	N	An	*Fest-Brom*	ps
Angelica sylvestris	*Ap*	1	*CBR*	Forb	C	H	N	An	*Aln glu*	
Anthericum ramosum	*Li*	11	*CB*	Forb	CSR	G	N	An	*Fest-Brom*	
Anthoxanthum odoratum	*Po*	7	*CBF*	Graminoid	CSR	H	N	An	*Mol-Arr*	ps
Anthyllis vulneraria	*Fa*	22	*CBF*	Legume	CSR	H	N	An	*Fest-Brom*	ps
Arabis glabra	*Br*	1	*CBR*	Forb	CSR	H	N	An	*Rha-Prun*	ps
Arabis hirsuta	*Br*	8	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Arenaria serpyllifolia	*Ca*	1	*CBF*	Forb	R	T	N	An	*Fest-Brom*	ps
Armeria maritima	*Pl*	11	*CBF, CB*	Forb	CSR	H	N	An	*Koe-Cor*	ps
Arrhenatherum elatius	*Po*	17	*CBF, CBR*	Graminoid	C	H	N	An	*Mol-Arr*	ps
Artemisia campestris	*As*	7	*CBF*	Forb	SC	Ch	N	An/Zooch	*Fest-Brom*	ps
Artemisia vulgaris	*As*	1	*CBR*	Forb	C	Ch	N	An/Zooch	*Artem*	ps
Asperula cynanchica	*Ru*	25	*CBF, CBR*	Forb	CSR	H	N	Myr	*Fest-Brom*	ps
Astragalus cicer	*Fa*	1	*CB*	Legume	C	H	N	Au	*Fest-Brom*	
Astragalus glycyphyllos	*Fa*	1	*CBR*	Legume	C	H	N	Au	*Fest-Brom*	
Avenula pubescens	*Po*	7	*CBF*	Graminoid	C	H	N	Au/An	*Mol-Arr*	ps
Betula pendula	*Be*	2	*CBF*	Woody	C	M	N	An/Zooch	*Vac-Pic*	ps
Biscutella laevigata	*Br*	3	*CBF*	Forb	CSR	H	N	An	*Ely-Ses*	ps, RL
Brachypodium pinnatum	*Po*	24	*CB*	Graminoid	SC	H	N	An	*Fest-Brom*	
Brachypodium sylvaticum	*Po*	1	*CBF*	Graminoid	SC	H	N	An	*Car-Fag*	
Briza media	*Po*	21	*CBF*	Graminoid	CSR	H	N	An	*Mol-Arr*	ps
Calamagrostis epigeios	*Po*	9	*CBR*	Graminoid	C	G/H	N	An	*Epilob*	ps
Campanula glomerata	*Cm*	1	*CB*	Forb	CSR	H	N	An	*Fest-Brom*	
Campanula patula	*Cm*	3	*CBF*	Forb	CSR	H	N	An	*Mol-Arr*	ps
Campanula rotundifolia	*Cm*	1	*CBR*	Forb	CSR	H	N	An	*Koe-Cor*	
Campanula sibirica	*Cm*	1	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	SP
Cardaminopsis arenosa	*Br*	9	*CBF*	Forb	CSR	H	N	An	*Mol-Arr*	ps
Cardaminopsis halleri	*Br*	6	*CBF*	Forb	CSR	H	N	An	*Mol-Arr*	ps
Carduus acanthoides	*As*	1	*CBF*	Forb	CR	H	A	An/Zooch	*Artem*	ps
Carex caryophyllea	*Cy*	43	*CBF*	Graminoid	CSR	G/H	N	An	*Fest-Brom*	ps
Carex ericetorum	*Cy*	3	*CBF*	Graminoid	CSR	G	N	An	*Fest-Brom*	ps
Carex flacca	*Cy*	4	*CB*	Graminoid	CSR	G	N	An	*Cal-Ulic*	
Carex hirta	*Cy*	24	*CBF*	Graminoid	C	G	N	An	*Mol-Arr*	ps
Carex digitata	*Cy*	4	*CBR*	Graminoid	CSR	H	N	An	*Fest-Brom*	
Carex pairae	*Cy*	2	*CBF*	Graminoid	SC	H	N	An	*Epilob*	ps
Carex praecox	*Cy*	1	*CBF*	Graminoid	CSR	G/H	N	An	*Fest-Brom*	ps, RL
Carlina acaulis	*As*	11	*CB*	Forb	CSR	H	N	An/Zooch	*Fest-Brom*	
Carlina intermedia	*As*	1	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Carlina longifolia	*As*	2	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Carlina vulgaris	*As*	2	*CBF*	Forb	CSR	H/T	N	An	*Fest-Brom*	ps
Centaurea diffusa	*As*	2	*CBF*	Forb	CSR	T/H	K	An	*Stel med*	ps
Centaurea jacea	*As*	15	*CBF, CB*	Forb	C	H	N	An	*Mol-Arr*	
Centaurea scabiosa	*As*	14	*CB*	Forb	C	H	N	An/Myr	*Fest-Brom*	ps
Centaurea stoebe	*As*	8	*CB*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Cerastium arvense	*Ca*	11	*CBF*	Forb	CR	Ch	N	Myr	*Koe-Cor*	ps
Chamaecytisus ratisbonensis	*Fa*	1	*CB*	Legume	SC	Ch	N	Au/Myr	*Fest-Brom*	
Cirsium arvense	*As*	4	*CBR*	Forb	C	G	N	An/Zooch/Antr	*Stel med*	ps
Convolvulus arvensis	*Co*	17	*CBF*	Forb	CR	G/H	N	Antr	*Fest-Brom*	ps
Cornus sanguinea subsp. *sanguinea*	*Cr*	1	*CB*	Woody	C	N	N	Zooch	*Rha-Prun*	
Cornus sanguinea subsp. *australis*	*Cr*	1	*CB*	Woody	C	N	N	Zooch	*Rha-Prun*	
Coronilla varia	*Fa*	22	*CBR*	Legume	C	H	N	Au	*Fest-Brom*	ps
Corydalis cava	*Fu*	1	*CB*	Forb	CSR	G	N	An	*Car-Fag*	
Corylus avellana	*Cl*	2	*CBR*	Woody	C	N	N	Zooch	*Car-Fag*	
Crataegus monogyna	*Ro*	7	*CB*	Woody	C	N/M	N	Zooch	*Rha-Prun*	
Cruciata glabra	*Ru*	8	*CBR*	Forb	CSR	H	N	An	*Mol-Arr*	
Cuscuta epithymum	*Co*	1	*CBR*	Forb	CR	T	N	An/Antr	*Cal-Ulic*	
Cytisus scoparius	*Fa*	1	*CBF*	Legume	C	N	N	Au/Myr	*Cal-Ulic*	ps
Dactylis glomerata	*Po*	8	*CBR*	Graminoid	C	H	N	An	*Mol-Arr*	
Daucus carota	*Ap*	19	*CBF*	Forb	CR	H	N	An/Antr	*Mol-Arr*	ps
Dianthus carthusianorum	*Ca*	37	*CBF*	Forb	CSR	Ch	N	An	*Fest-Brom*	ps
Echinops sphaerocephalus	*As*	1	*CBR*	Forb	C	H	K	Zooch	*Artem*	
Elymus repens	*Po*	5	*CBR*	Graminoid	C	G	N	An	*Stel med*	ps
Epipactis atrorubens	*Or*	2	*CBF*	Forb	CSR	G	N	An	*Car-Fag*	PP
Epipactis helleborine	*Or*	6	*CBR*	Forb	CSR	G	N	An	*Car-Fag*	PP
Epipactis palustris	*Or*	2	*CB*	Forb	CSR	G	N	An	*Sch-Car*	SP, RL
Erysimum hieraciifolium	*Br*	2	*CBF*	Forb	CSR	H	N	An	*Rha-Prun*	ps
Equisetum arvense	*Eq*	4	*CBR*	Forb	CR	G	N	An/Antr	*Stel med*	ps
Euphorbia cyparissias	*Eu*	48	*CBF*	Forb	CSR	G/H	N	Au/Myr	*Fest-Brom*	ps
Euphorbia esula	*Eu*	2	*CBR*	Forb	CSR	H	N	Au/Myr	*Car-Fag*	ps
Euphorbia serrulata	*Eu*	2	*CBF*	Forb	CSR	H	N	Au/Myr	*Fest-Brom*	ps
Euphrasia stricta	*Sc*	8	*CB*	Forb	SR	T	N	An	*Fest-Brom*	ps
Fagus sylvatica	*Fg*	1	*CBF*	Woody	C	M	N	Zooch	*Car-Fag*	
Fallopia convolvulus	*Pg*	2	*CBF, CB*	Forb	CR	T	A	An/Myr	*Stel med*	ps
Festuca ovina agg.	*Po*	35	*CBF*	Graminoid	CSR	H	N	An	*Koe-Cor*	ps
Festuca pallens	*Po*	4	*CB*	Graminoid	SC	H	N	An	*Fest-Brom*	ps, SP, RL
Festuca rubra	*Po*	25	*CBR*	Graminoid	CSR	H	N	An	*Mol-Arr*	
Festuca rupicola	*Po*	3	*CBR*	Graminoid	SC	H	N	An	*Fest-Brom*	ps
Fragaria vesca	*Ro*	8	*CBR*	Forb	CSR	H	N	Zooch	*Epilob*	
Fragaria viridis	*Ro*	4	*CB*	Forb	CSR	H	N	Zooch	*Fest-Brom*	
Galium album	*Ru*	48	*CBF, CBR*	Forb	C	H	N	An	*Fest-Brom*	ps
Galium mollugo	*Ru*	3	*CBF, CB*	Forb	C	H	N	An	*Mol-Arr*	
Galium odoratum	*Ru*	2	*CBF*	Forb	S	H	N	Zooch	*Car-Fag*	
Galium verum	*Ru*	1	*CBF, CB*	Forb	CSR	H	N	An	*Fest-Brom*	
Gentiana cruciata	*Ge*	1	*CB*	Forb	CSR	H	N	An	*Fest-Brom*	SP
Geranium pratense	*Gr*	1	*CB*	Forb	C	H	N	Au	*Mol-Arr*	
Geranium sanguineum	*Gr*	6	*CB*	Forb	CSR	H	N	Au	*Fest-Brom*	
Gymnadenia conopsea subsp. *densiflora*	*Or*	1	*CB*	Forb	CSR	G	N	An	*Fest-Brom*	SP
Gypsophila fastigiata	*Ca*	2	*CBF*	Forb	S	Ch	N	An	*Koe-Cor*	ps
Helianthemum nummularium	*Ci*	21	*CBF*	Forb	SC	Ch	N	An	*Fest-Brom*	ps
Heracleum sphondylium	*Ap*	2	*CBR*	Forb	C	H	N	An	*Mol-Arr*	
Hieracium pilosella	*As*	16	*CBF*	Forb	CSR	H	N	An	*Cal-Ulic*	ps
Hieracium umbellatum	*As*	1	*CB*	Forb	SC	H	N	An	*Que rob*	
Holcus mollis	*Po*	1	*CBF*	Graminoid	CSR	G/H	N	An	*Que rob*	ps
Humulus lupulus	*Cn*	2	*CBR*	Forb	C	H/Li	N	An	*Aln glu*	
Hypericum perforatum	*Cs*	5	*CBR*	Forb	C	H	N	An	*Fest-Brom*	
Hypochoeris maculata	*As*	1	*CBF, CB*	Forb	CSR	H	N	An	*Fest-Brom*	
Jovibarba sobolifera	*Cra*	1	*CBF*	Forb	CSR	Ch	N	An	*Asplen*	ps, SP
Juniperus communis	*Cp*	2	*CBF*	Woody	C	N	N	Zooch	*Koe-Cor*	
Knautia arvensis	*Di*	18	*CB*	Forb	C	H	N	Myr	*Fest-Brom*	
Laserpitium latifolium	*Ap*	1	*CB, CBR*	Forb	C	H	N	An	*Fest-Brom*	
Leontodon autumnalis	*As*	1	*CBF*	Forb	CSR	H	N	An	*Mol-Arr*	ps
Leontodon hispidus	*As*	28	*CBF*	Forb	CSR	H	N	An	*Mol-Arr*	ps
Leucanthemum vulgare	*As*	1	*CBR*	Forb	C	H	N	An	*Mol-Arr*	
Linum catharticum	*Ln*	6	*CBF*	Forb	SR	T	N	Au/Zooch	*Mol-Arr*	ps
Lotus corniculatus	*Fa*	32	*CB*	Legume	CSR	H	N	Au	*Mol-Arr*	ps
Lysimachia vulgaris	*Pr*	2	*CBR*	Forb	SC	H	N	An	*Aln glu*	
Malaxis monophyllos	*Or*	2	*CBR*	Forb	CSR	G	N	An	*Car-Fag*	SP, RB, RL
Medicago falcata	*Fa*	31	*CBR*	Legume	SC	H	N	An/Zooch	*Fest-Brom*	ps
Medicago lupulina	*Fa*	1	*CBF*	Legume	CSR	H/T	N	An/Zooch	*Stel med*	ps
Medicago sativa	*Fa*	1	*CBF*	Legume	C	H	K	An/Zooch	*Mol-Arr*	ps
Melampyrum arvense	*Sc*	6	*CB*	Forb	SR	T	N	Myr	*Fest-Brom*	
Melampyrum pratense	*Sc*	1	*CBF*	Forb	SR	T	N	Myr	*Vac-Pic*	
Melandrium album	*Ca*	8	*CBR*	Forb	C	T	N	An	*Artem*	ps
Melica nutans	*Po*	4	*CBR*	Graminoid	CSR	G/H	N	An/Antr	*Car-Fag*	
Molinia caerulea	*Po*	3	*CBF*	Graminoid	SC	H	N	An	*Que rob*	ps
Monotropa hypopitys	*Py*	1	*CBF*	Forb	CSR	G	N	An	*Vac-Pic*	
Nardus stricta	*Po*	1	*CBF*	Graminoid	SC	H	N	An	*Cal-Ulic*	ps
Oenothera biennis	*On*	1	*CBF*	Forb	CR	H	N	An	*Artem*	ps
Ononis arvensis	*Fa*	2	*CB*	Legume	SC	H/N	N	Au	*Fest-Brom*	
Ononis spinosa	*Fa*	12	*CBF*	Legume	SC	H/N	N	Au	*Fest-Brom*	PP
Origanum vulgare	*La*	1	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	
Ornithogalum umbellatum	*Li*	2	*CB*	Forb	CSR	G	N	An/Myr	*Fest-Brom*	RB, RL
Orobanche lutea	*Ob*	8	*CBF*	Forb	CSR	G	N	An	*Fest-Brom*	PP
Peucedanum cervaria	*Ap*	9	*CB*	Forb	SC	H	N	An	*Fest-Brom*	
Peucedanum oreoselinum	*Ap*	22	*CB*	Forb	SC	H	N	An	*Fest-Brom*	
Phleum phleoides	*Po*	16	*CB*	Graminoid	CSR	H	N	An	*Fest-Brom*	
Phleum pratense	*Po*	1	*CB*	Graminoid	C	H	N	An	*Mol-Arr*	
Picris hieracioides	*As*	1	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Pimpinella saxifraga	*Ap*	33	*CBF*	Forb	SC	H	N	An	*Fest-Brom*	ps
Pinus nigra	*Pi*	1	*CBF*	Woody	C	M	K	An/Zooch	*Vac-Pic*	ps
Pinus sylvestris	*Pi*	9	*CBF, CB*	Woody	C	M	N	An/Zooch	*Vac-Pic*	ps
Plantago lanceolata	*Pa*	24	*CBF*	Forb	CSR	H	N	Zooch	*Mol-Arr*	ps
Plantago major	*Pa*	1	*CBF*	Forb	CSR	H	N	Zooch	*Mol-Arr*	ps
Plantago media	*Pa*	1	*CB*	Forb	CSR	H	N	Zooch	*Fest-Brom*	
Poa annua	*Po*	1	*CBF*	Graminoid	R	H/T	N	An	*Stel med*	ps
Poa compressa	*Po*	8	*CBF*	Graminoid	CSR	H	N	An	*Fest-Brom*	ps
Poa pratensis	*Po*	2	*CBR*	Graminoid	C	H	N	An	*Mol-Arr*	ps
Polygala comosa	*Pol*	14	*CB*	Forb	CSR	H	N	An/Myr	*Fest-Brom*	
Polygala oxyptera	*Pol*	1	*CBF*	Forb	CSR	H	N	An/Myr	*Cal-Ulic*	
Polygonatum multiflorum	*Cv*	1	*CBF*	Forb	CSR	G	N	Zooch	*Car-Fag*	
Potentilla arenaria	*Ro*	39	*CBF*	Forb	S	H	N	An	*Fest-Brom*	ps
Potentilla neumanniana	*Ro*	8	*CBF*	Forb	S	H	N	An	*Fest-Brom*	ps
Potentilla reptans	*Ro*	1	*CB*	Forb	CSR	H	N	An/Myr/Zooch	*Mol-Arr*	ps
Primula veris	*Pr*	3	*CB*	Forb	CSR	H	N	An/Myr	*Fest-Brom*	
Prunella vulgaris	*La*	1	*CBF*	Forb	CSR	H	N	Zooch	*Fest-Brom*	ps
Prunella grandiflora	*La*	5	*CBF*	Forb	CSR	H	N	Hy/Zooch	*Mol-Arr*	ps
Prunus padus	*Ro*	2	*CBR*	Woody	C	M	N	Zooch	*Car-Fag*	
Prunus serotina	*Ro*	1	*CBR*	Woody	C	N/M	K	Zooch	*Car-Fag*	
Prunus spinosa	*Ro*	3	*CB, CBR*	Woody	C	N	N	Zooch	*Rha-Prun*	
Pteridium aquilinum	*Hy*	11	*CBR*	Forb	C	G	N	An	*Que rob*	
Pyrus pyraster	*Ro*	1	*CBR*	Woody	C	M	K	Zooch	*Rha-Prun*	
Quercus robur	*Fg*	2	*CBF*	Woody	C	M	N	Zooch	*Que rob*	
Ranunculus acris	*Ra*	4	*CBF*	Forb	C	H	N	An/Zooch	*Mol-Arr*	
Ranunculus bulbosus	*Ra*	13	*CBF*	Forb	CSR	G/H	N	An	*Fest-Brom*	ps
Ranunculus repens	*Ra*	1	*CBF, CB*	Forb	CSR	H	N	An	*Stel med*	ps
Reseda lutea	*Re*	1	*CBF*	Forb	CSR	H	N	An/Zooch/Myr	*Artem*	ps
Rhamnus catharticus	*Rh*	4	*CBF*	Woody	C	N	N	Zooch	*Rha-Prun*	
Rosa canina	*Ro*	2	*CB, CBR*	Woody	C	N	N	Zooch	*Rha-Prun*	
Rubus caesius	*Ro*	22	*CBR*	Woody	C	N	N	Zooch	*Artem*	ps
Rubus plicatus	*Ro*	1	*CBF*	Woody	C	N	N	Zooch	*Que rob*	
Rumex acetosa	*Pg*	14	*CBF*	Forb	C	H	N	An	*Mol-Arr*	ps
Rumex acetosella	*Pg*	1	*CB*	Forb	CSR	G/H/T	N	An/Antr	*Koe-Cor*	ps
Rumex thyrsiflorus	*Pg*	10	*CBF*	Forb	C	H	N	An	*Mol-Arr*	ps
Salix capraea	*Sa*	1	*CBR*	Woody	C	N/M	N	An	*Epilob*	ps
Salvia nemorosa	*La*	1	*CBR*	Forb	CSR	H	N	An/Zooch	*Fest-Brom*	
Salvia pratensis	*La*	3	*CB*	Forb	CSR	H	N	An/Zooch	*Fest-Brom*	
Scabiosa columbaria	*Di*	1	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Scabiosa ochroleuca	*Di*	39	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Sedum acre	*Cra*	4	*CBF, CBR*	Forb	S	Ch	N	Hy/Myr	*Koe-Cor*	ps
Sedum maximum	*Cra*	5	*CB*	Forb	SC	G/H	N	Hy/Myr	*Fest-Brom*	
Senecio jacobaea	*As*	3	*CBR*	Forb	C	H	N	An	*Fest-Brom*	ps
Seseli annuum	*Ap*	2	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Silene nutans	*Ca*	13	*CBF*	Forb	CSR	H	N	An	*Fest-Brom*	ps
Silene otites	*Ca*	1	*CBF*	Forb	S	H	N	An	*Koe-Cor*	ps
Silene vulgaris	*Ca*	30	*CBF*	Forb	CSR	Ch/H	N	An	*Asplen*	ps
Solidago canadensis	*As*	11	*CBR*	Forb	C	G/H	K	An	*Artem*	ps
Solidago virgaurea	*As*	2	*CBF, CB*	Forb	C	H	N	An	*Vac-Pic*	ps
Sonchus arvensis	*As*	1	*CBF*	Forb	CR	G/H	N	An/Antr	*Stel med*	ps
Sorbus aucuparia	*Ro*	1	*CBF*	Woody	C	M/N	N	Zooch	*Vac-Pic*	
Taraxacum officinale	*As*	4	*CBF, CBR*	Forb	CSR	H	N	An/Myr	*Mol-Arr*	ps
Thymus glabrescens	*La*	1	*CBF*	Forb	SC	Ch	N	Myr	*Fest-Brom*	ps
Thymus marschalianus	*La*	1	*CBF*	Forb	SC	Ch	N	Myr	*Fest-Brom*	ps, RL
Thymus pulegioides	*La*	38	*CBF*	Forb	SC	Ch	N	Myr	*Fest-Brom*	ps
Tilia cordata	*Ti*	2	*CBF*	Woody	C	M	N	An	*Car-Fag*	
Tofieldia calyculata	*Li*	1	*CB*	Forb	SC	H	N	An	*Sch-Car*	SP, RL
Tragopogon orientalis	*As*	1	*CBF*	Forb	CSR	H	K	An	*Mol-Arr*	ps
Tragopogon pratensis	*As*	2	*CBR*	Forb	CSR	H	N	An	*Mol-Arr*	ps
Trifolium arvense	*Fa*	1	*CB*	Legume	SR	H	N	An/Zooch	*Koe-Cor*	ps
Trifolium medium	*Fa*	4	*CB*	Legume	C	H	N	An/Zooch	*Fest-Brom*	ps
Trifolium montanum	*Fa*	14	*CB*	Legume	CSR	H	N	An/Zooch	*Fest-Brom*	
Trifolium pratense	*Fa*	1	*CB*	Legume	C	H	N	An/Zooch	*Mol-Arr*	
Trifolium repens	*Fa*	3	*CBF*	Legume	CSR	H	N	An/Zooch	*Mol-Arr*	ps
Trifolium rubens	*Fa*	1	*CBF*	Legume	C	H	N	An/Zooch	*Fest-Brom*	ps
Tussilago farfara	*As*	2	*CBF*	Forb	CSR	G	N	An	*Artem*	ps
Valeriana angustifolia	*Va*	1	*CBF*	Forb	SC	H	N	An	*Fest-Brom*	
Valeriana officinalis	*Va*	1	*CBR*	Forb	C	H	N	An	*Mol-Arr*	
Valeriana simplicifolia	*Va*	2	*CBF, CBR*	Forb	C	H	N	An	*Sch-Car*	
Verbascum chaixii subsp. *austriacum*	*Sc*	3	*CBF, CB*	Forb	SC	H	N	An	*Fest-Brom*	ps, RB
Verbascum densiflorum	*Sc*	1	*CBF*	Forb	C	H	N	An	*Artem*	ps
Verbascum lychnitis	*Sc*	5	*CBF*	Forb	SC	H	N	An	*Fest-Brom*	ps
Verbascum phlomoides	*Sc*	1	*CBF*	Forb	C	H	N	An	*Artem*	ps
Verbascum thapsus	*Sc*	1	*CBF*	Forb	C	H	N	An	*Cal-Ulic*	ps
Veronica chamaedrys	*Sc*	20	*CBR*	Forb	CSR	Ch	N	An/Myr	*Mol-Arr*	ps
Veronica spicata	*Sc*	8	*CB*	Forb	CSR	H/Ch	N	An	*Fest-Brom*	
Vicia angustifolia	*Fa*	1	*CB, CBR*	Legume	R	T	A	Au	*Stel med*	ps
Vicia cracca	*Fa*	21	*CBR*	Legume	C	H	N	Au	*Mol-Arr*	ps
Vicia hirsuta	*Fa*	1	*CBR*	Legume	CR	T	A	Au	*Stel med*	ps
Vicia tenuifolia	*Fa*	1	*CBR*	Legume	C	G/H	N	Au	*Fest-Brom*	ps
Viola arvensis	*Vi*	1	*CBF*	Forb	R	T	A	Au/Myr	*Stel med*	ps
Viola collina	*Vi*	1	*CBF*	Forb	CSR	H	N	Au/Myr	*Fest-Brom*	ps
Viola hirta	*Vi*	9	*CBF*	Forb	CSR	H	N	Au/Myr	*Fest-Brom*	ps
Viola tricolor	*Vi*	2	*CBF, CB*	Forb	R	T	N	Au/Myr	*Koe-Cor*	ps

Fam – families: *Ap* – *Apiaceae*, *As* – *Asteraceae*, *Be* – *Betulaceae*, *Br* – *Brassicaceae*, *Ca* – *Caryophyllaceae*, *Ci* – *Cistaceae*, *Cl* – *Corylaceae*, *Cm* – *Campanulaceae*, *Cn* – *Cannnabaceae*, *Co* – *Convolvulaceae*, *Cp* – *Cupressaceae*, *Cr* – *Cornaceae*, *Cra* – *Crassulaceae*, *Cs* – *Clusiaceae*, *Cv* – *Convallariaceae*, *Cy* – *Cyperaceae*, *Di* – *Dipsacaceae*, *Eq* – *Equisetaceae*, *Eu* – *Euphorbiaceae*, *Fa* – *Fabaceae*, *Fg* – *Fagaceae*, *Fu* – *Fumariaceae*, *Ge* – *Gentianaceae*, *Gr* – *Geraniaceae*, *Hy* – *Hypolepidaceae*, *La* – *Lamiaceae*, *Li* – *Liliaceae*, *Ln* – *Linaceae*, *Ob* – *Orobanchaceae*, *On* – *Onagraceae*, *Or* – *Orchidaceae*, *Pa* – *Plantaginaceae*, *Pg* – *Polygonaceae*, *Pi* – *Pinaceae*, *Pl* – *Plumbaginaceae*, *Po* – *Poaceae*, *Pol* – *Polygalaceae*, *Pr* – *Primulaceae*, *Py* – *Pyrolaceae*, *Ra* – *Ranunculaceae*, *Re* – *Rosedaceae*, *Rh* – *Rhamnaceae*, *Ro* – *Rosaceae*, *Ru* – *Rubiaceae*, *Sa* – *Salicaceae*, *Sc* – *Scrophulariaceae*, *Ti* – *Tiliaceae*, *Va* – *Valerianaceae*, *Vi* – *Violaceae*; No – number of records (total heap area, including 4m^2 plots); Comm – a community variant, in which a given species was the most common: *CB* – *Carlino acaulis-Brometum erecti typicum*, *CBF* – *Carlino acaulis-Brometum erecti festucetosum ovinae* subass. nova, *CBR* – *Carlino acaulis-Brometum erecti rubietosum caesii* subass. nova; Fg – functional groups: Forb, Graminoid, Legume, Woody plant; Gs – the Grime's C-S-R strategies: primary strategies (C – competitor, R – ruderal, S – stress-tolerator); secondary strategies (CR – competitive-ruderal, SC – stress-tolerant competitor, SR – stress-tolerant ruderal, CSR – competitive stress-tolerant ruderal); Lf – the Raunkiaer life forms: Ch – chamaephyte, G – geophyte, H - hemicryptophyte, Li – liana, M – megaphanerophyte (phanerophyte), N – nanophanerophyte (phanerophyte), T – therophyte; St – geographical/historical status of a given species in the flora of Poland: A – archaeophyte, K – kenophyte, N – native; Disp – seed dispersion types: An – anemochory, Antr – anthropochory, Au – autochory, Hy – hydrochory, Myr – myrmecochory, Zooch – other zoochory (epizoochory or endozoochory); Veg – the species optimum in terms of the type of vegetation class: *Aln glu* – *Alnetea glutinosae*, *Artem* – *Artemisietea vulgaris*, *Asplen* – *Asplenietea trichomanis*, *Cal-Ulic* – *Calluno-Ulicetea*, *Ely-Ses* – *Elyno-Seslerietea*, *Epilob* – *Epilobietea angustifolii*, *Fest-Brom* – *Festuco-Brometea*, *Koe-Cor* – *Koelerio glaucae-Corynephoretea canescentis*, *Mol-Arr* – *Molinio-Arrhenatheretea*, *Que rob* – *Quercetea robori-petraeae*, *Car-Fag* – *Carpino-Fagetea, Rha-Prun* – *Rhamno-Prunetea, Sch-Car* – *Scheuchzerio palustris-Caricetea nigrae, Stel med* – *Stellarietea mediae, Vac-Pic* – *Vaccinio-Piceetea. Remarks: ps – pioneer species; forms of protection and posted in red lists: SP – strictly protected, PP – partly protected, RB – Polish Red Book of Vascular Plants, RL – the Red List of Plants and Fungi in Poland.*

Supplement E2. Vegetation table of the *Carlino acaulis-Brometum erecti typicum* . S – number of species per relevé, Cn – constancy, F – frequency (expressed as a percentage of relevés, in which the species occurred).

Anhang E2. Vegetationstabelle des *Carlino acaulis-Brometum erecti typicum* . S – Zahl der Arten je Vegetationsaufnahme, Cn – Stetgikeitsklasse, F – Frequenz (ausgedrückt als Prozent der Aufnahmen, in dem die Art vorkam).

Site	1	2	3	4	5	6	7	8	9	10	11	12	13		
	9	17a	17b	21b	25a	29c	30	32a	32c	41	54	57	60		
Cover (%)	100	100	100	100	95	100	95	100	90	80	100	100	100		
S	18	20	14	11	25	16	23	26	22	9	23	26	23		
Height above sea level (m)	340	340	335	450	330	270	280	315	325	300	330	430	335		
Exposition	SW	E	SW	SW	S	S	S	S	S	S	S	SW	SSE		
Inclination (°)	5	20	10	5	15	5	30	15	10	15	5	5	5		
Geographical coordinates (WGS-84)	E19.398387,N50.193612	E19.374028,N50.162505	E19.37203,N50.162754	E19.516635,N50.202549	E19.285336,N50.210288	E19.241538,N50.251357	E19.242559,N50.246819	E19.340399,N50.211999	E19.348149,N50.210187	E19.312764,N50.093543	E19.29635,N50.186947	E19.547386,N50.248508	E19.383061,N50.202921		
Carlino acaulis-Brometum erecti typicum														**Cn**	F
Brachypodium pinnatum	2	3	5	5	4	4	4	5	4	5	4	5	3	V	100
Carlina acaulis	1	.	.	.	1	.	1	+	.	.	.	1	.	II	38
Centaurea scabiosa	.	.	+	.	.	.	.	2	1	.	+	.	1	II	38
Helianthemum nummularium	4	3	.	.		.		.	2	.	+			II	31
Knautia arvensis	.	+	.	.	.	.	+	.	.	.	+	1	.	II	31
Polygala comosa	.	1	.	.	.	.	1	+	1	.	.	1	.	II	38
Thymus pulegioides	1	.	.	.	1	.	+	1	+	.	.	.	.	II	38
Coronilla varia	.	.	1	.		1		.	.	.	1			I	23
Anthyllis vulneraria	.	.	.	.	.	.	.	1	3	.	.	.	.	I	15
Bromion erecti + Festuco-Brometea															
Euphorbia cyparissias	+	1	1	1	1	1	1	.	1	.	2	1	1	IV	85
Lotus corniculatus	.	1	+	.	1	.	1	1	1	2	1	1	+	IV	77
Achillea collina	+	+	.	1	.	1	4	1	1	.	1	.	1	III	69
Medicago falcata	2	1	1	+	.	2	.	.	.	2	2	.	.	III	54
Galium album	.	3	2	+	+	.	.	.	.	.	1	1	.	II	46
Phleum phleoides	2	+	.	.	2	.	+	.	.	.	1	.	1	II	46
Scabiosa ochroleuca	+	.	.	.	1	+	.	1	1	.	.	+	.	II	46
Dianthus carthusianorum	1	1	+	.	2	.	.	.	.	.	+	.	.	II	38
Trifolium montanum	+	.	.	.	1	.	+	+	2	.	.	.	.	II	38
Leontodon hispidus	+	.	.	.	.	.	2	1	.	.	.	.	2	II	31
Peucedanum cervaria	.	.	.	.	.	2	.	.	2	1	1	.	.	II	31
Pimpinella saxifraga	.	.	1	1	.	.	.	.	.	1	.	+	.	II	31
Plantago lanceolata	+	.	.	.	.	.	2	.	.	.	.	1	2	II	31
Potentilla arenaria	1	2	.	.	.	.	.	+	1	.	.	.	.	II	31
Prunella grandiflora	.	1	.	.	.	.	.	1	.	.	+	+	.	II	31
Centaurea jacea	.	.	+	.	.	.	.	1	.	.	.	.	1	I	23
Centaurea stoebe	.	.	.	.	4	.	.	.	+	.	.	2	.	I	23
Festuca ovina agg.	3	3	.	.	.	.	.	2	.	.	.	.	.	I	23
Festuca pallens	.	.	.	.	3	.	.	.	.	.	.	1	+	I	23
Fragaria viridis	.	.	.	.	.	.	.	.	.	.	2	+	1	I	23
Trifolium medium	.	1	.	.	.	.	1	.	.	.	.	1	.	I	23
Achillea millefolium	.	.	.	.	.	.	3	.	.	.	.	.	2	I	15
Alyssum montanum	.	.	.	.	+	.	.	.	.	.	.	+	.	I	15
Anthericum ramosum	.	.	.	.	.	1	.	3	.	.	.	.	.	I	15
Asperula cynanchica	.	.	.	.	.	.	.	+	+	.	.	.	.	I	15
Ononis spinosa	.	.	.	.	.	.	.	1	+	.	.	.	.	I	15
Plantago media	.	.	.	.	.	.	.	.	.	.	.	1	1	I	15
Salvia pratensis	.	.	.	.	.	.	.	.	.	2	.	1	.	I	15
Veronica chamaedrys	.	.	.	.	.	.	.	.	.	.	+	.	3	I	15
Agrimonia eupatoria	.	.	.	.	.	.	.	.	.	1	.	.	.	I	8
Armeria maritima	.	.	.	.	.	.	2	.	.	.	.	.	.	I	8
Artemisia campestris	.	.	.	.	.	.	.	+	.	.	.	.	.	I	8
Carex flacca	.	.	.	.	.	.	.	.	.	.	.	.	+	I	8
Carlina vulgaris	.	.	.	.	.	.	.	+	.	.	.	.	.	I	8
Euphrasia stricta	.	.	.	.	.	.	.	.	.	.	.	1	.	I	8
Galium mollugo	.	.	.	.	.	.	.	.	.	.	.	.	+	I	8
Galium verum	.	.	.	.	+	.	.	.	.	.	.	.	.	I	8
Geranium sanguineum	.	.	.	.	.	4	.	.	.	.	.	.	.	I	8
Hieracium pilosella	.	1	.	.	.	.	.	.	.	.	.	.	.	I	8
Hypochoeris maculata	.	.	.	.	.	.	+	.	.	.	.	.	.	I	8
Laserpitium latifolium	.	.	.	.	+	.	.	.	.	.	.	.	.	I	8
Linum catharticum	.	.	.	.	.	.	.	.	.	.	.	.	+	I	8
Poa compressa	.	.	.	.	.	.	.	+	.	.	.	.	.	I	8
Poa pratensis	.	.	.	.	.	.	.	.	.	.	.	1	.	I	8
Rumex acetosa	.	.	.	.	.	+	.	.	.	.	.	.	.	I	8
Rumex acetosella	.	.	.	.	.	.	+	.	.	.	.	.	.	I	8
Verbascum chaixii ssp. austriacum	.	.	.	+	.	.	.	.	.	.	.	.	.	I	8
Veronica spicata	.	.	.	.	.	.	.	.	.	.	+	.	.	I	8
Viola hirta	.	.	.	.	.	.	.	.	.	1	.	.	.	I	8
Other															
Peucedanum oreoselinum	.	1	.	.	.	.	1	3	3	.	4	.	+	II	46
Carex caryophyllea	1	1	.	.	.	.	.	1	1	.	1	.	.	II	38
Festuca rubra	.	.	2	2	.	1	.	.	1	.	1	.	.	II	38
Aegopodium podagraria	.	.	.	3	2	.	3	.	.	.	.	.	1	II	31
Agrostis stolonifera	.	.	.	.	1	.	+	.	.	.	.	2	1	II	31
Arrhenatherum elatius	.	.	.	2	1	.	.	.	.	.	.	+	.	I	23
Briza media	1	.	1	.		.		2	.	.	.			I	23
Daucus carota	.	+	+	.	.	.	.	+	.	.	.	.	.	I	23
Agrostis capillaris	.	.	.	.	.	1	.	.	.	.	.	+	.	I	15
Carex ericetorum	+	.	.	.	.	.	.	.	1	.	.	.	.	I	15
Convolvulus arvensis	.	.	+	.	.	.	.	.	.	1	.	.	.	I	15
Crataegus monogyna	.	.	.	.	1	.	.	.	.	.	+	.	.	I	15
Rhamnus catharticus	.	.	.	.	.	+	.	.	.	.	.	+	.	I	15
Sedum maximum	.	.	.	.	1	+		.	.	.	.			I	15
Vicia cracca	.	.	.	1	.	.	1	.	.	.	.	.	.	I	15
Carex hirta	.	.	.	.	.	1	.	.	.	.	.	.	.	I	8
Centaurea diffusa	.	.	.	.	1	.	.	.	.	.	.	.	.	I	8
Cirsium arvense	.	.	.	.	.	.	+	.	.	.	.	.	.	I	8
Cruciata glabra	.	.	.	.	.	.	.	.	.	.	.	.	+	I	8
Euphorbia esula	.	.	.	.	.	.	.	.	.	.	.	+	.	I	8
Fallopia convolvulus	.	.	.	.	.	+	.	.	.	.	.	.	.	I	8
Humulus lupulus	.	.	.	.	.	.	.	.	.	.	.	.	1	I	8
Leontodon autumnalis	.	.	.	.	+	.	.	.	.	.	.	.	.	I	8
Melampyrum arvense	.	.	.	.	.	.	.	.	.	.	+	.	.	I	8
Pinus sylvestris	.	.	.	.	.	.	.	+	.	.	.	.	.	I	8
Potentilla reptans	.	.	.	.	.	.	.	.	.	.	1	.	.	I	8
Prunus spinosa	.	.	.	.	.	.	.	.	+	.	.	.	.	I	8
Ranunculus repens	.	.	.	.	.	.	.	.	.	.	.	+	.	I	8
Rosa canina	.	.	.	.	.	.	.	.	.	.	.	.	+	I	8
Solidago virgaurea	.	+	.	.	.	.	.	.	.	.	.	.	.	I	8
Vicia angustifolia	.	.	.	.	1	.	.	.	.	.	.	.	.	I	8
Viola tricolor	.	.	.	.	+	.	.	.	.	.	.	.	.	I	8

Supplement E3. Vegetationstabelle des *Carlino acaulis-Brometum erecti festucetosum ovinae* . S – number of species per relevé, Cn – constancy, F – frequency (expressed as a percentage of relevés, in which the species occurred).

Anhang E3. Vegetationstabelle des *Carlino acaulis-Brometum erecti festucetosum ovinae* . S – Zahl der Arten je Vegetationsaufnahme, Cn – Stetgikeitsklasse, F – Frequenz (ausgedrückt als Prozent der Aufnahmen, in dem die Art vorkam).

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38		
Cover (%)	100	100	90	100	70	80	90	100	70	80	95	90	100	95	95	100	100	70	95	90	90	80	100	90	90	95	80	100	95	80	50	85	100	95	100	100	100	100		
S	23	19	18	19	17	22	26	23	20	22	18	20	21	31	25	22	26	23	26	26	22	33	15	21	26	17	16	19	13	20	4	12	19	6	24	25	22	10		
Height above sea level (m)	350	350	345	365	360	350	360	370	355	415	415	300	330	350	310	325	260	270	290	320	390	405	360	440	320	440	325	340	330	340	330	320	320	320	320	350	450	320		
Exposition	SSW	S	W	S	S	S	S	S	S	S	S	S	S	S	E	S	S	S	S	SW	S	S	S	S	S	S	S	S	S	W	W	S	S	S	SW	SW	S	S		
Inclination (°)	20	40	15	20	20	35	40	5	5	20	35	15	5	5	20	10	15	5	10	10	45	10	40	5	5	40	10	15	10	5	5	5	5	5	10	5	5	15		
Geographical coordinates (WGS-84)	E 19.454365,N50.171395	E19.444197,N50.17161	E19.43714,N50.174726	E19.434525,N50.177485	E19.430809,N50.177711	E19.421978,N50.182259	E19.418369,N50.186212	E19.411306,N50.18876	E19.4054,N50.193695	E19.533474,N50.180325	E19.530726,N50.180678	E19.387992,N50.147523	E19.386299,N50.153115	E19.366096,N50.164575	E19.283735,N50.226832	E19.42677,N50.170963	E19.245776,N50.252831	E19.243587,N50.249597	E19.24599,N50.244673	E19.344508,N50.210656	E19.493892,N50.211902	E19.517546,N50.174619	E19.54662,N50.288054	E19.535207,N50.290347	E19.478662,N50.280456	E19.53368,N50.289194	E19.462459,N50.294772	E19.459283,N50.290728	E19.453097,N50.288855	E19.466406,N50.285087	E 19.458235,N50.283144	E19.468248,N50.276706	E19.476628,N50.282285	E19.481102,N50.284538	E19.366564,N50.175841	E19.408876,N50.19058	E19.574166,N50.169226	E19.457536,N50.287121		
Carlino acaulis-Brometum erecti festucetosum avinae																																							Cn	F
Carex caryophyllea	1	.	2	4	1	2	1	2	1	.	3	3	4	1	+	.	1	1	2	+	2	1	4	2	1	.	+	2	.	2	.	1	2	1	3	+	3	2	V	84
Galium album	1	.	+	2	3	1	.	1	+	2	1	1	1	1	2	+	1	+	+	.	.	.	1	2	1	3	2	1	2	+	.	1	2	.	3	.	3	3	IV	79
Euphorbia cyparissias	+	+	+	2	3	1	3	.	+	+	+	2	1	2	3	.	3	+	3	1	1	3	2	.	1	.	.	2	.	+	.	.	.	.	+	1	.	+	IV	71
Dianthus carthusianorum	.	2	2	1	1	2	1	.	.	.	3	1	1	+	1	.	+	1	.	+	.	.	1	+	1	2	.	1	2	2	.	1	1	+	1	.	.	.	IV	66
Scabiosa ochroleuca	1	.	.	+	.	+	2	1	+	+	.	1	+	.	.	1	+	+	+	1	+	+	+	1	.	.	+	1	.	1	.	+	+	.	1	2	1	.	IV	68
Thymus pulegioides	1	+	2	1	1	2	2	4	1	+	.	1	2	.	.	.	.	1	1	+	.	1	.	3	1	4	2	+	.	.	.	1	1	.	2	3	3	.	IV	68
Festuca ovina agg.	2	.	4	4	3	3	1	2	3	.	.	+	.	2	1	.	1	4	.	1	2	2	2	2	3	4	2	2	5	4	3	4	4	5	.	1	.	.	IV	76
Potentilla arenaria	+	.	.	.	2	2	3	+	1	2	1	.	.	.	2	+	.	3	3	1	+	2	+	2	2	1	1	3	.	3	.	1	2	.	.	2	.	.	IV	66
Lotus corniculatus	.	.	1	+	+	+	1	+	1	.	.	.	.	1	1	.	+	+	1	1	.	+	.	1	1	+	+	2	+	+	.	.	.	.	1	.	+	.	III	60
Anthyllis vulneraria	+	+	.	.	.	+	+	.	1	.	.	.	.	1	.	+	1	+	.	.	+	2	.	.	+	.	.	.	.	.	.	+	.	.	.	+	+	.	II	39
Helianthemum nummularium	3	.	.	.	.	1	.	4	.	.	.	4	3	.	1	.	.	.	2	2	.	.	.	3	.	.	.	.	.	.	.	.	2	.	2	3	1	.	II	34
Coronilla varia	.	.	.	+	+	.	.	.	.	.	.	+	+	+	.	2	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	I	24
Centaurea scabiosa	.	.	.	.	.	+	.	.	.	1	.	.	+	1	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	18
Knautia arvensis	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	+	.	.	1	.	.	I	16
Polygala comosa	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	11
Carlina acaulis	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Brachypodium pinnatum	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Bromion erecti + Festuco-Brometea																																								
Leontodon hispidus	+	.	1	.	1	1	1	1	2	.	.	.	.	.	.	1	.	1	.	1	2	1	.	2	4	1	2	2	1	1	.	.	+	.	1	.	4	.	III	58
Pimpinella saxifraga	1	.	2	1	+	+	.	1	1	.	.	+	+	1	+	2	+	1	+	.	.	+	.	1	+	.	.	.	+	+	.	.	1	.	1	.	.	.	III	57
Achillea collina	.	.	.	.	.	.	1	1	.	.	.	1	+	.	1	.	+	.	1	+	1	1	1	.	.	1	.	+	.	.	.	.	.	.	1	.	1	.	II	39
Asperula cynanchica	.	.	.	.	.	.	1	.	+	1	1	.	.	1	1	.	+	.	+	1	.	1	.	.	.	.	.	1	.	.	.	.	.	.	.	+	.	.	II	32
Hieracium pilosella	+	2	3	3	2	2	4	.	.	.	.	.	.	2	.	3	.	.	.	.	.	2	.	3	.	.	.	3	.	.	.	.	.	.	.	.	.	.	II	32
Medicago falcata	+	2	.	.	.	.	.	.	.	2	3	.	.	+	.	.	.	.	1	.	1	2	.	.	.	.	.	1	.	.	.	.	.	.	4	3	.	1	II	32
Phleum phleoides	.	1	.	.	.	.	.	.	.	.	.	2	+	2	.	.	1	.	2	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	I	21
Artemisia campestris	.	.	.	.	.	.	.	.	.	.	2	+	.	+	.	.	.	.	+	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	16
Centaurea stoebe	.	.	.	.	+	.	.	.	.	.	+	.	.	.	2	.	.	.	.	1	.	1	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	I	16
Euphrasia stricta	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	I	16
Armeria maritima	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2	.	+	.	.	.	.	.	.	.	+	1	.	.	.	.	I	13
Centaurea jacea	.	1	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	2	.	.	I	13
Alyssum montanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	1	.	.	.	.	.	.	.	.	I	8
Arabis hirsuta	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Festuca pallens	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.	I	8
Hypericum perforatum	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	I	8
Ononis spinosa	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Verbascum lychnitis	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Viola hirta	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	+	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Anthericum ramosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Fragaria viridis	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Galium mollugo	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Geranium sanguineum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	I	5
Linum catharticum	.	.	+	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Peucedanum cervaria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Seseli annuum	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I	5
Agrimonia eupatoria	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Arenaria serpyllifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	3
Campanula patula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I	3
Carex flacca	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Carlina vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Chamaecytisus ratisbonensis																																						1	I	3
Festuca rupicola	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Hypochoeris maculata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Galium verum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	3
Jovibarba sobolifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Prunella grandiflora	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Thymus marschalianus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Tragopogon orientalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	I	3
Trifolium medium	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Trifolium montanum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Trifolium rubens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Verbascum chaixii ssp. austriacum	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Other																																								
Silene vulgaris	.	.	+	1	1	1	2	+	1	.	.	+	.	.	.	+	+	1	+	.	.	.	.	.	+	.	2	.	+	2	1	2	1	2	.	.	+	.	III	55
Plantago lanceolata	+	.	+	1	.	.	+	+	.	+	1	.	.	+	.	.	.	.	.	.	1	+	+	1	1	1	.	.	+	+	.	.	1	.	.	+	1	.	III	50
Carex hirta	1	2	+	2	.	1	.	+	+	.	1	.	+	.	.	.	1	.	.	.	+	.	2	+	1	.	.	.	1	+	.	.	.	1	.	.	.	2	III	47
Vicia cracca	1	.	.	1	.	+	.	+	.	+	+	.	+	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	1	1	II	32
Daucus carota	.	+	.	.	.	.	+	.	.	.	+	1	.	+	.	+	.	2	+	.	.	+	.	.	.	.	.	.	.	1	.	.	.	.	+	.	.	.	II	29
Ranunculus bulbosus	+	.	2	.	.	1	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	1	.	.	.	.	.	+	+	1	.	II	29
Rumex acetosa	.	.	+	.	.	.	.	1	.	.	+	.	+	.	.	.	.	.	.	+	.	.	.	+	.	+	.	.	+	+	.	.	+	.	.	.	+	.	II	29
Arrhenatherum elatius	.	3	.	.	.	.	.	.	.	2	.	.	.	+	1	1	1	+	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	I	26
Briza media	.	.	.	.	.	.	1	.	.	+	.	1	.	2	.	3	+	.	.	.	1	1	.	.	.	.	.	2	.	.	.	.	.	.	.	.	2	.	I	26
Convolvulus arvensis	.	.	.	.	.	1	1	.	.	+	2	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	1	+	.	I	26
Peucedanum oreoselinum	.	.	.	.	.	.	.	.	.	.	.	2	+	.	4	3	.	.	.	4	3	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	.	.	I	24
Silene nutans	+	2	.	.	.	.	.	.	1	.	.	2	+	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	1	.	I	24
Veronica chamaedrys	.	+	.	+	.	1	+	.	.	1	.	.	.	.	.	+	2	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	I	24
Rumex thyrsiflorus	+			+						+								+					1		+							+				+		.	I	21
Cerastium arvense	+	.	.	.	+	.	.	.	.	1	.	.	.	.	2	.	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	I	18
Festuca rubra	.	.	.	.	.	.	.	2	.	2	.	.	.	.	2	.	3	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	3	3	.	.	I	18
Cardaminopsis arenosa	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	1	.	+	.	.	.	1	.	I	16
Poa compressa	.	.	.	.	.	.	2	.	.	1	.	.	.	.	.	2	.	.	1	.	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	16
Anthoxanthum odoratum	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.	I	13
Avenula pubescens	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	1	.	3	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	I	13
Pinus sylvestris	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	I	13
Rubus caesius	.	.	.	.	.	.	.	.	.	.	.	.	.	1	2	.	.	.	1	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I	13
Centaurea diffusa	.	.	.	.	.	.	.	.	.	.	.	.	.	2	1	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	I	11
Crataegus monogyna	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	11
Cruciata glabra	.	.	.	.	.	.	.	.	1	.	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Agrostis capillaris	.	1	.	.	.	.	.	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Agrostis stolonifera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	I	8
Cardaminopsis halleri	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1	.	.	.	.	.	.	I	8
Achillea millefolium	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Calamagrostis epigeios	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	5
Carex ericetorum	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Dactylis glomerata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	5
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Euphorbia serrulata	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Fragaria vesca	.	.	.	.	.	.	.	.	.	+	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Galium odoratum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I	5
Gypsophila fastigiata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	1	.	.	.	.	.	.	.	.	I	5
Juniperus communis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	I	5
Melandrium album	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I	5
Pteridium aquilinum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	5
Ranunculus acris	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I	5
Rhamnus catharticus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	5
Ajuga genevensis	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Betula pendula	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Brachypodium sylvaticum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Fallopia convolvulus	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Holcus mollis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Leontodon autumnalis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	I	3
Lysimachia vulgaris	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Nardus stricta	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Ononis arvensis																																						3	I	3
Orobanche lutea	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Picris hieracioides	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Polygala oxyptera	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Ranunculus repens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Rubus plicatus	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Sarothamnus scoparius	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Sedum acre	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Sedum maximum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Solidago virgaurea	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Sonchus arvensis	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Taraxacum officinale	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I	3
Valeriana simplicifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Verbascum phlomoides	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I	3
Viola tricolor	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I	3

Supplement E3. Vegetationstabelle des *Carlino acaulis-Brometum erecti rubietosum caesi* . S – number of species per relevé, Cn – constancy, F – frequency (expressed as a percentage of relevés, in which the species occurred).

Anhang E3. Vegetationstabelle des *Carlino acaulis-Brometum erecti rubietosum caesi*. S – Zahl der Arten je Vegetationsaufnahme, Cn – Stetgikeitsklasse, F – Frequenz (ausgedrückt als Prozent der Aufnahmen, in dem die Art vorkam).

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14		
Cover herb layer (%)	100	100	100	100	100	80	95	100	100	100	100	100	100	100		
S	23	10	16	16	10	18	27	18	15	17	22	17	12	15		
Height above sea level (m)	405	310	310	305	330	385	390	380	380	385	460	305	450	450		
Exposition	S	SE	S	S	S	S	S	S	S	S	SW	S	S	SW		
Inclination (°)	20	5	5	20	5	15	10	30	35	15	15	10	20	10		
Geographical coordinates (WGS-84)	E19.531485,N50.179785	E19.285118,N50.228024	E19.288617,N50.228258	E19.281672,N50.22109	E19.283014,N50.210901	E19.500394,N50.214416	E19.498698,N50.213937	E19.489949,N50.210109	E19.484967,N50.2141	E19.483848,N50.214006	E19.55154,N50.187003	E19.325761,N50.177467	E19.580023,N50.174361	E19.579188,N50.172692		
Carlino acaulis-Brometum erecti rubietosum caesi															Cn	F
Rubus caesius	.	1	1	3	4	4	1	4	4	4	3	2	5	2	V	93
Festuca rubra	4	.	.	1	1	1	3	2	3	2	+	2	.	.	IV	71
Galium album	3	1	.	1	.	.	1	2	1	1	2	1	2	.	IV	71
Brachypodium pinnatum	.	5	2	5	5	.	.	1	.	.	.	5	.	4	III	50
Coronilla varia	1	.	.	.	+	+	1	.	.	2	.	.	2	.	II	43
Thymus pulegioides	.	.	.	.	.	.	2	+	.	.	1	+	.	.	II	29
Knautia arvensis	+	.	.	.	.	+	.	.	.	.	.	1	.	.	I	21
Helianthemum nummularium	.	.	1	.	.	.	.	.	.	.	.	2	.	.	I	14
Polygala comosa	.	.	.	.	.	.	1	+	.	.	.	.	.	.	I	14
Carlina acaulis	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	7
Centaurea scabiosa	.	.	.	.	.	.	.	.	.	.	.	3	.	.	I	7
Bromion erecti + Festuco-Brometea																
Euphorbia cyparissias	3	.	.	+	.	+	1	1	.	2	.	1	.	.	III	50
Medicago falcata	3	+	.	1	.	.	2	.	2	2	.	3	.	.	III	50
Achillea collina	.	.	.	.	1	1	1	.	.	1	1	.	.	1	II	43
Asperula cynanchica	+	.	.	1	.	.	+	1	.	.	.	1	.	.	II	36
Pimpinella saxifraga	.	+	.	+	.	.	1	2	1	.	.	.	.	.	II	36
Agrimonia eupatoria	1	.	.	.	.	+	.	+	.	.	.	.	+	.	II	29
Centaurea jacea	.	+	.	.	.	+	.	.	1	.	.	.	.	.	I	21
Briza media	1	.	.	.	.	.	2	.	.	.	.	.	.	.	I	14
Dianthus carthusianorum	.	.	+	.	.	.	.	.	.	.	.	+	.	.	I	14
Festuca rupicola	1	.	3	.	.	.	.	.	.	.	.	.	.	.	I	14
Leontodon hispidus	+	.	.	.	.	.	+	.	.	.	.	.	.	.	I	14
Poa pratensis	.	.	.	.	+	.	.	.	.	.	.	.	2	.	I	14
Scabiosa ochroleuca	.	.	1	.	.	.	1	.	.	.	.	.	.	.	I	14
Trifolium montanum	.	.	.	.	.	.	.	.	.	.	.	1	.	2	I	14
Arabis glabra	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I	7
Festuca pallens	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	7
Geranium sanguineum	.	.	.	.	.	.	.	.	.	.	.	.	.	1	I	7
Hieracium pilosella	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I	7
Laserpitium latifolium	.	.	.	.	.	.	.	.	.	.	.	.	.	2	I	7
Peucedanum cervaria	.	.	.	.	.	1	.	.	.	.	.	.	.	.	I	7
Prunella grandiflora	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	7
Salvia nemorosa	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I	7
Trifolium medium	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I	7
Viola hirta	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	7
Other																
Pteridium aquilinum	3	1	+	2	.	.	2	+	1	+	.	.	.	.	III	57
Fragaria vesca	1	.	.	.	.	+	1	+	1	.	.	+	.	.	II	43
Solidago canadensis	.	.	.	+	.	1	+	.	3	.	+	.	.	1	II	43
Veronica chamaedrys	+	.	.	+	.	.	.	.	+	+	+	1	.	.	II	43
Vicia cracca	+	1	.	1	1	.	.	.	.	.	1	.	2	.	II	43
Arrhenatherum elatius	1	.	.	.	.	.	.	.	1	.	1	.	+	2	II	36
Calamagrostis epigeios	.	.	.	.	1	.	.	.	.	3	+	.	2	.	II	29
Carex caryophyllea	+	.	.	.	.	.	1	+	.	.	+	.	.	.	II	29
Melandrium album	.	.	.	+	.	+	+	.	+	+	.	.	.	.	II	36
Peucedanum oreoselinum	.	+	3	3	.	.	.	.	.	.	.	3	.	.	II	29
Cruciata glabra	.	2	3	.	.	.	.	2	.	.	.	.	.	.	I	21
Dactylis glomerata	.	.	.	.	.	1	.	.	.	.	.	.	3	1	I	21
Daucus carota	+	.	+	.	+	.	.	.	.	.	.	.	.	.	I	21
Elymus repens	.	.	.	.	.	+	.	.	2	3	.	.	.	.	I	21
Melica nutans	2	.	.	.	.	1	.	2	.	.	.	.	.	.	I	21
Agrostis stolonifera	.	.	.	.	.	.	.	2	2	.	.	.	.	.	I	14
Cirsium arvense	.	.	.	.	.	.	.	.	.	+	.	.	+	.	I	14
Convolvulus arvensis	+	.	.	.	.	.	.	.	.	.	1	.	.	.	I	14
Equisetum arvense	.	.	.	.	.	.	.	.	.	.	.	.	1	+	I	14
Euphorbia esula	.	.	.	1	.	.	.	.	.	.	+	.	.	.	I	14
Heracleum sphondylium	+	.	.	.	.	.	.	.	.	.	.	.	1	.	I	14
Silene vulgaris	.	.	.	.	.	.	.	.	+	.	+	.	.	.	I	14
Achillea millefolium	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I	7
Aegopodium podagraria	.	.	.	.	.	.	.	.	.	.	.	.	.	4	I	7
Agrostis capillaris	1	.	.	.	.	.	.	.	.	.	.	.	.	.	I	7
Allium oleraceum	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I	7
Artemisia vulgaris	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	7
Astragalus glycyphyllos	.	.	.	.	.	.	.	.	.	.	.	.	.	2	I	7
Carex digitata	.	.	.	.	.	.	.	.	.	.	2	.	.	.	I	7
Carex hirta	.	.	.	.	.	.	.	.	.	1	.	.	.	.	I	7
Echinops sphaerocephalus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	7
Festuca ovina agg.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	I	7
Humulus lupulus	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I	7
Hypericum perforatum	.	.	.	.	.	.	.	2	.	.	.	.	.	.	I	7
Leucanthemum vulgare	.	.	.	.	.	.	.	.	.	.	1	.	.	.	I	7
Lysimachia vulgaris	.	.	.	.	.	.	.	.	.	.	1	.	.	.	I	7
Malaxis monophyllos	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I	7
Ononis arvensis	.	.	2	.	.	.	.	.	.	.	.	.	.	.	I	7
Poa compressa	.	.	.	.	.	.	.	.	.	.	2	.	.	.	I	7
Potentilla areniria	.	.	.	.	.	.	2	.	.	.	.	.	.	.	I	7
Phleum phleoides	.	.	.	1	.	.	.	.	.	.	.	.	.	.	I	7
Prunus padus	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	7
Prunus spinosa	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	7
Rhamnus catharticus	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I	7
Rosa canina	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	7
Rumex thyrsiflorus							+								I	7
Sedum acre	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	7
Sedum maximum	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I	7
Salix capraea	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I	7
Senecio jacobaea	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	7
Silene nutans	1	.	.	.	.	.	.	.	.	.	.	.	.	.	I	7
Taraxacum officinale	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I	7
Valeriana simplicifolia	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I	7
Vicia angustifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	1	I	7
Vicia hirsuta	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I	7