Original Research

Sites of Leachate Inflows on Coalmine Heaps as Refuges of Rare Mountainous Species

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Abstract

In the Silesian Upland (southern Poland), stands of rare mountainous plant species, i.e. *Doronicum austriacum*, *Equisetum telmateia*, and *Veratrum lobelianum,* were recorded close to the River Jamna and the coal mine waste tip Halemba. The species grew in two sites: semi-natural and anthropogenic ones. Soils in the anthropogenic site are more acid, with higher contents of Mg, K, Ca, and Na, but soils of the semi-natural site are richer in P. Vegetation varied in composition of accompanying species between two sites, and the distance to water differentiates the abundance of the focal species. The results demonstrate that artifical springs may creates favorable conditions for rare species.

Keywords: hydrography, montane species, wastelands, leachate

Introduction

Montane species are those for which their optimum occurrence is in mountains. Pawłowski [1] was the first who introduced this term in Polish literature. Some of these species also have scattered stands on lowlands [2, 3]. Zając [3] gave a list of 118 montane species that encroach into lowlands. Many of these lowland stands are located in areas adjacent to mountains, including Silesian Upland [4, 5]. These species in lowlands mostly occur in deciduous forests of the *Carpinion betuli* alliance or in riparian forests, i.e. the *Alno-Ulmion* alliance [3]. However, montane species can also be found in various types of wastelands such as post-coal mine heaps or other anthropogenic habitats, e.g. railways. Such an example is *Chamaenerion palustre* growing in wastelands associated with coal exploitation [6], or in sedimentation pools [7], gravel heaps, or abandoned quarries [8]. In 2005 a new stand of *Doronicum austriacum* in the Silesian Upland in the vicinity of the post coal mine heap Halemba was found [9]. In the present study the ecological conditions of occurrence of the three montane species under legal protection [10] in this location was introduced: *Veratrum lobelianum*, *Doronicum austriacum*, and *Equisetum telamateia*.

The detailed objectives of our paper was to:
1) describe and compare conditions of the occurrence of a community with the presence of montane species in an anthropogenic site close to post coal mine waste-tip and in natural site
2) verify the hypothesis that abiotic conditions, especially water courses, determine penetration and abundance of montane species into anthropogenic habitat

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Experimental Procedures

Study Site

The study area, with two analyzed plant communities dominated by mountainous species, is situated in Katowice in the Silesian Upland (southern Poland). It is located in the northern part of the the Jamna catchment area (Fig. 1A). In the 1950s, the right part of Jamna catchment area saw the exploitation of sand deposits by means of the opencast method. Both underground and precipitation waters inflowing to the exploitation hollow were drained gravitationally to the Jamna River through a system of ditches and dewatering channels (Fig. 1B). After finishing sand exploitation the hollow was destined to a coal mine dumping site from hard coal mines. The deposition started in 1970 but total leveling was in 1994. The deposition of mining wastes continued, and this is how a waste-tip, reaching up to 13 m above the primary surface, was created. Nowadays, the area of the waste-tip covers 148.3 ha and the mass of mining wastes amounts to 1.25 million m^3. The material gathered on the waste-tip is a mixture of various Carboniferous rocks such as cleaving shales, sandstones, and mudstones. After reaching the bottom (the floor of the old sandpit), precipitation waters infiltrating toward the inside of the waste-tip clod are captured by the old draining net and are drained beyond the waste-tip. The outflow of these waters takes place where old dewatering channels cross the topographical surface of the waste-tip. These effluents are not concentrated and they are equivalents of natural bog-springs. Their surface area is several square meters.

Two analyzed vegetation patches with *D. austriacum* are species-poor communities dominated by *D. austriacum*. The first one (site I) grows on stony soil of an anthropogenic origin, the steeper slope (40º SW) close to dripping water from the waste-tip bottom. The water depth is 40 cm. There are about 600 specimens of *D. austriacum*. This patch of community is treated as anthropogenic. The second (site II) natural community, growing on the steep slope 20º SW, is in an ecotone zone between post coal mine waste-tip and ash-alder forest (*Fraxino-Alnetum* W.Mat. 1952) at the river bank. This population of *D. austriacum* amounts to ca. 1,000 specimens. There are also other mountain species, including *Veratrum lobelianum* and *Equisetum telmateia*.

Data Collection

Twelve (in each site 6) phytosociological relevés, using the Braun-Blanquet method were taken, in two sites occupied by *D. austriacum*. Because *D. austriacum* forms dense patches and the community with its participation is not homogenous in biotopic and phytosociological aspects, we performed detailed analyses to study differences between communities with this species and the habitat requirements of its occurrence. Within these sites we established four study plots. In site I, study plot No. 1, 10 m

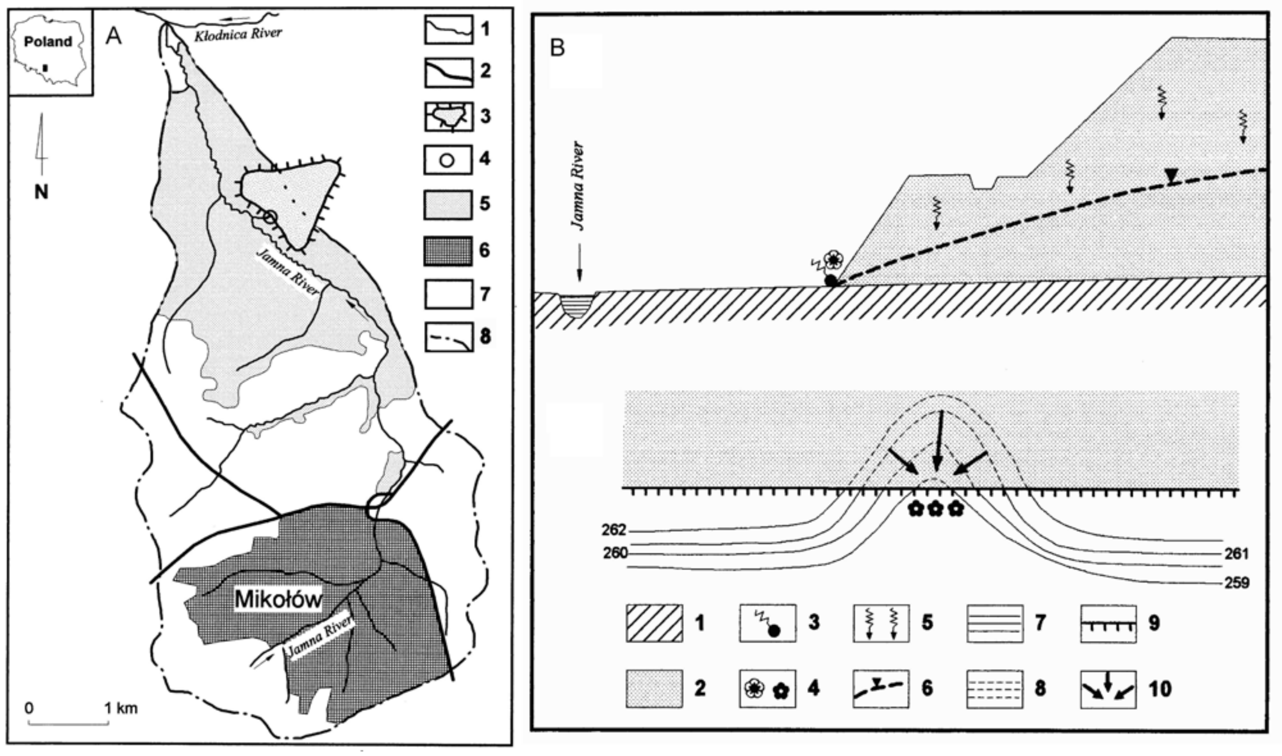

Fig. 1. The study area. A. 1 – streams, 2 – main roads, 3 – coal mine dumping site, 4 – anthropogenic stand of *Doronicum austracum* (on the waste-tip in the valley), 5 – forests, 6 – urban-industrial build-up, 7 – fields, meadows, and wasteland, 8 – watershed .
B. The scheme of anthropogenic bog-spring creation. 1 – substratum (clays), 2 – waste-tip, 3 – outflows of effluent waters, 4 – anthropogenic stand of *Doronicum austracum*, 5 – precipitation water infiltration, 6 – underground water table, 7 – isohypses, 8 – the previous pattern of isohypses, 9 – waste-tip edge, 10 – directions of water inflow.

Table 1. Soil variables of two sites with *D. austriacum* community. For organic carbon, loss on ignition and C:N ratio percentage values are given and for cations – mg/100 g.

Site	pH (H_2O)	pH (KCL)	Organic carbon	Loss on ignition	C:N	N	P	Mg	K	Ca	Na
I	4.5	4.3	12.0	25.1	21.2	0.6	1.7	33.2	15.5	222.2	5.6
II	6.0	5.8	2.4	5.8	14.7	0.2	7.3	12.5	11.2	182.4	3.0

long and 2 m wide, was assigned perpendicularly to the slope in the middle of the patch of the community with the highest abundance of the species. Study plot No. 2, the same in size, was located in paralell to the slope, i.e. from the base of the slope toward the top, also in the middle of the patch of community. In site II the same study plots were placed, numbered 1' and 2', respectively. The distinguished study plots were divided into 20 subplots (1×1 m), in which the percentage cover (1, 2, 5, 10, 20...100%) was estimated. Records were made in June 2008. For 2 and 2' study plots, the distance to water was measured between the margin of water seepages and the middle of subplot (± 1 m).

To analyze geomorphological and hydrological conditions we carried out studies after [11]. Changes in water conditions also were estimated, including depth of filling underground (leachate) waters. Four soil subsamples were collected from 0-10 cm depth and mixed up into one composite sample at each site. Air-dry samples were analyzed for pH (in aqueous solution and in KCL solution)(PN-ISO 103900), exchangeable cations: potassium K, nitrogen N (PN-ISO 11261), calcium Ca, magnesium Mg (PN-R-04020), phosphorus P (PN-R-04023), and sodium Na were detected by spectrophotometry, and organic carbon by the Tiurin method. Nomenclature follows [12, 13].

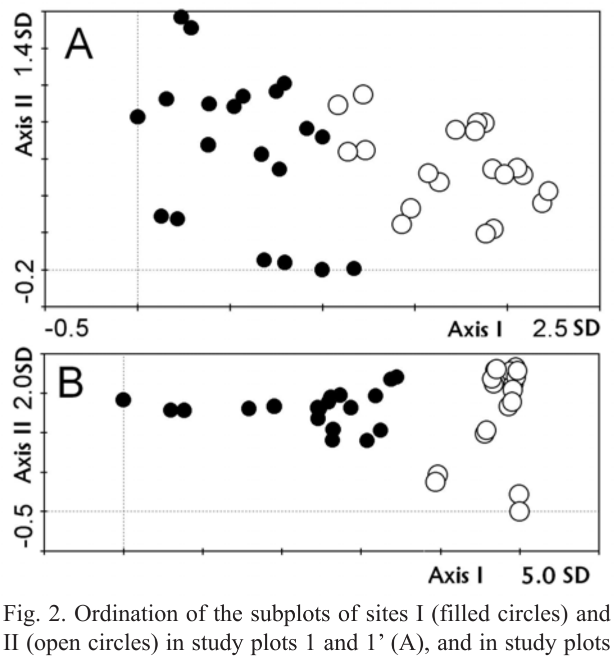

Fig. 2. Ordination of the subplots of sites I (filled circles) and II (open circles) in study plots 1 and 1' (A), and in study plots 2 and 2'(B) along two DCA axes on the basis of species cover.

Data Analysis

Detrended correspondence analysis (DCA) was used to analyze diversity of two studied vegetation patches in the study area. Then data from 1 and 1', as well as from 2 and 2' study plots, were subjected to two analyses. In order to examine some interset relationships between the environmental variable (distance to water seepages) and species richness, Shannon-Wiener index *H'*, total species cover and percentage cover of the species studied, i.e. *D. austriacum*, *E. telmateia*, and *V. lobelianum,* Spearman's rank correlation test was applied for 2 and 2' plots. All statistical analyses were done using R language and environment (www.r-project.org).

Results

Soils in site I are more acid, characterized by higher content of organic matter, more than twofold concentration of magnesium compared to site II. There are also higher contents of potassium, calcium, and sodium. However, soils of natural site II are richer in available phosphorus (Table 1). Due to the vicinity of the river valley, the level of underground water was high and amounted to 0.5-0.2 m down from ground surface in natural site, likewise in anthropogenic site. The species composition of two sites are shown in Table 2. In natural site there is a higher number of species. Mean number of species per subplot for pairs of respective study plots is similar (Table 2). The DCA revealed a great diversity in the vegetation of two communities with *D. austriacum,* both between horizontal study plots 1, 1' (DCA axis 1: λ = 0.41, length of gradient = 2.22; DCA axis 2: λ=0.126 and length of gradient 1.39) in site of the highest abundance of the species, and between parallel to slope study plots 2, 2' with more diverse vegetation (DCA axis 1: λ=0.72, length of gradient = 4.99, DCA axis 2: λ=0.24, length of gradient = 1.82). Especially the second analysis shows that there is a big difference in vegetation between these two communities. Spearman's rank correlation yielded negative rs coefficients between DCA axis 1 and cover of *D. austriacum*, but positive with *Veratrum lobelianum* (Table 3). Distance to water negatively affects percentage cover of *D. austriacum* both in anthropogenic site I (study plot 2) and in natural site II (study plot 2'). Also, there is negative relationship between the abundance of *Equisetum telmateia,* but only in anthropogenic sites. There is no such relationship in the case of *Veratrum lobelianum*. This site cover of remaining species is negatively correlated with distance to water, likewise with their

Table 2. Synoptic table of relevés from sites I and II, and mean percentage cover species in the study plots (1, 1', 2, 2') within two patches of the studied community.

Species	I	II	1	2	1'	2'
Acer pseudoplatanus c	I^{+}	.				
Alnus glutinosa b	.	I^{2}				
Athyrium filix-femina	V^{+2}	I	5		5	
Calamagrostis epigeios	I	.				
Cardaminopsis arenosa	III^{+1}	.			5	
Cardaminopsis halleri	.	III^{+1}				5
Carex brizoides	.	V^{12}		5		19
Cerastium holosteoides	.	III^{+1}				5
Conyza canadensis	I^{+}	.				
Crataegus monogyna c	I^{+}	.				
Deschampsia caespitosa	I^{+}	IV^{r1}				5
Doronicum austriacum	V^{1-4}	V^{2-4}	69	72	34	73
Dryopteris carthusiana	V^{1-2}	I^{+}	6.7		7.5	
Dryopteris filix-mas	I^{+}	.				
Epilobium montanum	I^{+}	.				
Equsetum palustre	.	III^{+1}				5
Equisetum sylvaticum	.	III^{1}				5
Equisetum telmateia	V^{2-5}	V^{1-2}	32	10	40	13
Erigeron acre	I^{+}	.				
Festuca gigantea	III^{+1}	II^{+1}			5	
Ficaria verna	I^{+}	I^{+}				
Frangula alnus b	I^{2}	.				
Galium aparine	III^{2}	V^{1-3}	10	26		18
Hieracium sp.	III^{1-2}	.			7.5	
Holcus mollis	III^{+1}	II^{+1}		5	5	
Humulus lupulus	.	V^{1-2}		4		6
Impatiens noli-tangere	.	V^{2}		20		19
Impatiens parviflora	V^{+-3}	V^{+-2}	15	5	31	18
Juncus effusus	.	III^{+1}				5
Lupinus polyphyllus	III^{2}	.			18	
Lysimachia vulgaris	IV^{1-2}	I^{1}			8.1	
Plantago major	I^{+}	.				
Poa pratensis	I^{1}	.				
Pteridium aquilinum	V^{1-3}	II^{1-2}	26	7.5	16	
Quercus robur c	II^{+1}	I^{+}			5	
Rubus hirtus	III^{+-2}	.	8			
Rubus idaeus	V^{+-2}	V^{+-2}	7.1	20	7.9	8.8
Scirpus sylvaticus	V^{1-2}	.	10		7.5	
Scrophularia nodosa	III^{+1}	.			5	
Senecio ovatus	V^{+-5}	.	10		5	
Solidago gigantea	III^{+-2}	.			20	
Sorbus aucuparia b	.	I^{2}				
Taraxacum officinale	III^{1-4}	.			5	
Trientalis europaea	V^{+1}	.	5		5	
Urtica dioica	V^{1-3}	V^{2-3}	9.5	45	7.5	17
Veratrum lobelianum	I^{1-3}	V^{2-3}	10	17		28
No. of species per study plot/site	36	26	14	12	21	16

number. Also, values of Shannon-Wiener diversity index, likewise species richness, showed negative correlation with distance to water in the natural site (Table 3).

Discussion of Results

Encroachment of montane species to the lowlands, especially along river valleys, has been a known phenomenon since the first half of the 20th century [14-16]. The other frequent phenomenon is their expansion range due to human impact, and establishment in artifical habitats referred to as their apophytization and synathropization [17]. These processes are an aftermath of loss of natural habitats occupied by native species, due to expansion of agricultural, urban, and industrial activities [18]. However, secondary succession and regeneration can result in phytocoenoses restoration and assembly of new ones. Both migration to the lowlands and apophytization may lead to an increase of mountain species' resources and enrichment of the local flora, usually built-up by synanthropic vegetation [18-20]. The species-building community – *D. austriacum* – (according to Ellenberg [21]) and the environmental indicator system and ecological indicator values by Zarzycki [22] are of semi-shade tolerance and semi-light demands. This species grows in the studied sites on steep, stony slopes under medium cover of shrubs. Within its native range, the species prefers low temperatures typical of montane zones, but slopes are of SW aspect, which make conditions quite warm. Within its native range and natural montane habitats, the species prefers similar abiotic conditions, i.e. stony slopes and close small water courses [3, 23]. Values of pH obtained in this study (4.5-6, mean: 5.2) do not differ much from a montane region where range of soil reaction ranged from 4.6 to 7.1 (mean 5.6) [23]. After the pH indicator values scale applied by [24], *D. austriacum* can be treated as an acid-tolerant species, likewise after division by [25], who treat species with pH<5.5 as acidophytic. High abundance of *D. austriacum* and other montane species can result from low species richness, and the absence of plants that have similar ecological requirements, e.g. other tall forbs such as *Aruncus dioicus*, *Senecio nemorensis*, *Valeriana sambucifolia*, and *Aconitum variegatum* [23] that accompany the studied species in montane plant communities. Only with increasing percentage cover of *D. austriacum* do species richness and the Shannon-Wiener diversity index decrease in semi-natural site II (Table 4). Similar results were obtained by [26] for nitrophilous fringal communities, also located in the valleys of water courses on slopes, with herb perennial species such as *Petasites hybridus* and *Parietaria officinalis*. However, instead of coverage, aboveground phytomass was taken into calculation of *H'*. The analyzed stand of *D. austriacum*, especially the population on the waste-tip, is probably only one of purely anthropogenic origin among the known locations of this species in the Silesian Upland. The remaining stands of *D. austriacum* are located in river valleys in forest or shrub communities built by alder *Alnus glutinosa* (*Alno-Ulmion* alliance) or in pine forest, i.e. in "Żabnik"

Table 3. Some intercorrelations (Spearman rank coefficients) between characteristics of patches with mountain species for study plots 2 and 2'.

Variable (separately for 2,2' plots)	DCA Axis 1		Cover of *D. austriacum*		Cover of *V. lobelianum*		Cover of *E. telmateia*		Cover of remaining species		No. of species		*H'*	
	2	2'	2	2'	2	2'	2	2'	2	2'	2	2'	2	2'
DCA Axis 1	-	-												
Cover of *D. austriacum*	-0.79***	-0.72***	-	-										
Cover of *V. lobelianum*	0.55**	NS	NS	NS	-	-								
Cover of *E. telmateia*	NS	NS	0.53*	NS	NS	0.44*	-	-						
Cover of remaining species	-0.48**	NS	NS	-0.59**	NS	NS	NS	-0.62**	-	-				
No. of species	NS	-0.43**	NS	- 0.64***	NS	NS	NS	NS	NS	0.61**	-	-		
H'	NS	-0.62***	NS	-0.75 ***	NS	NS	NS	NS	NS	0.82***	0.91***	0.68***	-	-
Distance to water	NS	0.37*	-0.7***	-0.53*	NS	NS	-0.45*	NS	NS	-0.84***	NS	-0.57**	NS	-0.79***

Significance: * – $p < 0.05$, ** – $p < 0.01$, *** – $p < 0.001$, NS – nonsignificant.

reserve. Thus, populations of this species are situated mainly in (semi-)natural habitats. In one stand, in the *Fraxino-Alnetum* forest in the Ślepiotka River valley, growth of Austrian leopard's bane populations was observed for almost 30 years [27]. The cause of this situation was similar to that introduced in the present study. According to them, the increase in humidity of soil due to water seepage after regulation of the water course led to an increase in numbers of specimens of *D. austriacum*. However, [28] they believe that in lowlands special cold microhabitats explain the persistence of populations of *D. austriacum*. They present thermal characteristics of areas where other stands of *D. austriacum* occur in the Silesian Upland for support of this hypothesis. Nevertheless they claim, based on observations, that one of two populations in Błędów Desert will probably exist and even develop due to the high level of underground water caused by the vicinity of a pond exploited by anglers. But the second population decreased in abundance because of desiccation and thinning of the tree stand, as well as expansion of grasses, shrubs, and tree saplings. Thus, humidity seems to play the most important role in the occurrence and sustainability of lowland stands of *D. austriacum,* including those of anthropogenic origin. In the present study we observed that distance to water seepage from the bottom of the waste-tip negatively affected the abundance of *D. austriacum* and positive cover of *Equisetum telmateia* in a semi-natural site. In the former site population grew on stony, dry soil with a thin layer of litter, but in the latter site specimens of both species grow on less steep, stony, and more humid soil with a thicker litter layer. Based on results of phytosociological studies by [29], one can believe that in the river valley of Jamna ash-alder forest *Carici remotae-Fraxinetum,* Koch 1926 ex Faber 1936 occurred, what can be indicated by the presence, among others, of mountain species *Veratrum lobelianum* – one of the local dominant species of this association. During the course of time changes in species composition and structure of this community and its habitat, due to the human-induced environmental, transformation and disturbance took place. As a result, the current populations of *D. austriacum* and *Veratrum lobelianum*, as well as *Equisetum telmateia,* are located in the ecotone of degenerated alder forest and the waste-tip, as well as on the bottom of the latter. The studied species themselves formed communities in which they are dominant components instead of former ash-alder forest patches in which they played a minor role.

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References

1. PAWŁOWSKI B. Geobotanical relations of Sądecczyznaa region. Prace Monograficzne Komisji Fizjograficznej Polskiej Akademii Umiejętności, Kraków, **1**, 1-336, **1925**.
2. CIACIURA M. Characteristics of distribution of montane species in the Silesia Part 1-2 Akademia Medyczna, Wrocław, **1988**.
3. ZAJĄC M. Mountain Vascular Plants in the Polish Lowlands. Polish Bot. Stud. **11**, 1-92, **1996**.
4. SENDEK A. Vascular plants of Upper Silesian Industrial Region. Wydz. III Nauk Przyr. pp. 1-138, **1984**.
5. URBISZ A.L. Montane species in vascular flora of southern-western part of Katowice Upland. Acta Biol. Siles. **35**, (52), 108, **2000**.
6. WOŹNIAK G., ROSTAŃSKI A. *Chamaenerion palustre* Scop. as a frequent apophyte in plant communities of post-industrial waste sites. Natura Silesiae Superioris: pp. 55-66, **2001**.
7. WOŹNIAK G. Vascular plants flora of the coal mine underground water sedimentation pools – post industrial wastelands in the Upper Silesia. Centrum Dziedzictwa Przyrody Górnego Śląska, Materiały i Opracowania **6**, 1-48, **2001**
8. BRÓŻ E., PODGÓRSKA J. Expansion of *Chamaenerion palustre* (Onagraceae) in the Małopolska Upland. Fragm. Flor. Geob. Pol. **25**, (1), 21, **2008**.
9. CHMURA D., MOLENDA T. A new stand of Austrian leopard's-bane *Doronicum austriacum* Jacq. in the Upper Silesia (Poland). Chroń. Przyr. Ojczystą **63**, (1), 20, **2007**.
10. THE ORDINANCE OF THE MINISTER OF ENVIRONMENT of 9st of July 2004 concerning the plant species, occurring in wildlife, under legal protection. J. L. No. 168, Item. 1764.
11. JONES A., DUCK R., REED R., WEYERS J. Practical skills in Environmental Science, Prentice Hall, **2000**.
12. MATUSZKIEWICZ W. Guidebook for identification of plant communities in Poland. PWN, Warszawa, pp. 537, **2007**.
13. MIREK Z., PIĘKOŚ-MIRKOWA H., ZAJĄC A., ZAJĄC M. (Ed.) Flowering plants and pteridophytes of Poland. A checklist. Biodiversity of Poland 1., W. Szafer Institite of Botany. Polish Academy of Sciences, Kraków, pp. 442, **2002**
14. WALAS J. Spread of plants along Tatra Mts rivers. Spraw. Kom. Fizjogr. PAU 72, 1-131, **1938**.
15. PACYNA A., PIĘKOŚ H., RAJCHEL-KAŹMIERCZAKOWA R. Distribution of spread of montane plant species in Tatra Mts rivers. Fragm. Flor. Geobot. **12**, (4), 423, **1966**.
16. KOCZUR A. Influence of hydrotechnical engineering of Czarny Dunajec river of Dynamics of montane species. **56**, 35, **1999**.
17. JEHLIK V. Apophytization of two montane species and their plant communities in Jezirskie Mts. Zpravy Ces Bot Spolec., Praha, **39**, 299, **2004**.
18. COHN E.V.J., ROSTAŃSKI A., TOKARSKA-GUZIK B., TRUEMAN I.C., WOŹNIAK G. The flora and vegetation o fan old solvay process tip in Jaworzno town (Upper Silesia, Poland). Acta Soc. Bot. Polon. **70**, (1), 47, **2001**.
19. BZDĘGA K., PASIERBIŃSKI A., CHMURA D. The role of post-coal mine heaps in the maintenance of regional floristic diversity in the Upper Silesia.) Chroń. Przyr. Ojczystą. **60**, (2), 17, **2004**.
20. CHMURA D. Impact of woodland islands on species richness in Jaworzno town and problem of their conservation. Arch. Ochr. Środ. **30**, 121, **2004**.
21. ELLENBERG H., WEBER H.E., DÜLL R., WIRTH V., WERNER W., PAULIßEN D. Ecological indicator values of plants in Central Europe. Scripta Geobot. 18. Erich Goltze, Göttingen, **1992**.

22. ZARZYCKI K., TRZCIŃSKA-TACIK H., RÓŻAŃSKI W., SZELĄG Z., WOŁEK J., KORZENIAK U. Ecological indicator values of vascular plant of Poland. W. Szafer Institute of Botany, PAN, **2002**.
23. KORNAŚ J. Vascular plants in Gorce Mts. Monographiae Botanicae **5**, 1-260, **1957**
24. CLAUDE G.J., KRIZOVA E. Comparison of indicator values of forest understory plant species in Western Carpathians (Slovakia) and Vosges Mountains (France). Forest Ecol. Manag. **182**, 1, **2003**.
25. GOUGH L., SHAVER G.R., CARROLL J., ROYER D.L. LAUNDRE J.A. Vascular plant species richness in Alaskan arctic tundra: the importance of soil pH. J. Ecol. **88**, 54, **2000**.
26. UHERCIKOVA E., ELIÁŠ P. Standing crop, dominance, and species diversity of tall-herb communities in the Male Karpaty Mts., Western Slovakia. Ekologia Bratislava **6**, (2), 147, **1987**.
27. CZYLOK A., STANEK J. The stand of of *Doronicum austriacum* Jacq. in Katowice. Nat. Siles. Super. **4**, 5, **2000**.
28. BUCHALIK M., DROBNIK J. History and perspectives of preservation of (*Doronicum austriacum*) in site of ecological interest "Błędów Desert" Nat. Siles. Super. **9**, 21, **2005**.
29. CABAŁA S. Differentiation and distribution of forest communities in the Silesian Upland. Prace naukowe UŚ w Katowicach No. **1068**, 142, **1990**.