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Distribution and habitats of Lloydia serotina (Liliaceae) in the Tatra Mts

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ABSTRACT: The distribution of *Lloydia serotina* (L.) Reichenb. in the Polish Tatra Mts is reviewed and mapped. The altitudinal range, orographic and edaphic factors as well as phytocoenoses of the species are characterized and presented in ecodiagrams. Information on the size of populations and the threat to them is provided.

KEY WORDS: *Lloydia serotina*, distribution, habitats, Tatra National Park, southern Poland

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INTRODUCTION

Lloydia serotina (L.) Reichenb., a circumboreal arctic-alpine species, is the most widespread representative of 12 species of this genus. In Poland this species occurs exclusively in the Tatra Mts.

Jones (1997) and Jones and Gliddon (1999) made a comprehensive study of the habitats, population structure and reproductive biology of *L. serotina* in Wales and in the Rocky Mountains of North America, and also collected some data and comparative material on a few sites of *L. serotina* in the Alps and in the Polish Tatra Mts. The aim of this paper is to supplement those studies with a presentation of the distribution of *Lloydia serotina* in the Tatra National Park as well as more detailed information on its habitats and phytocoenoses.

MATERIAL AND METHODS

A distribution map and diagrams showing the altitudinal range, aspect, slope and plant communities for *Lloydia serotina* were elaborated on the basis of our own records and the literature, supported by herbarium material from the Institute of Botany of the Polish Academy of Sciences in Cracow (KRAM) and the Institute of Botany of the Jagiellonian University (KRA). Herbarium materials are rather scarce. They were collected between 1856 and 1961, and the majority of them do not provide information on the precise location of stands.

Soil studies were based on original material we collected from 43 sites in the Tatra National Park. Soils and parent rocks were determined for each vegetation patch. In the rhizosphere layer horizons of the soils the actual moisture was determined by drying at 105^{o}C. After drying the soil samples were sieved through a 1 mm mesh sieve and the following properties were determined: active (pH H_2O) and exchangeable (pH KCl) acidity, potentiometrically; organic carbon content after Tiurin's method; total nitrogen after Kjeldahl's method; the sum of basic cations, by determining the respective cations (Ca^{+2}, Mg^{+2}, K^{+}, Na^{+}) extracted by 0.5 mol · dm^{-3} NH_4Cl solution; hydrolytic acidity after Kappen's method; available nutrients after Egner-Rhiem's method; and MgO after Schachtschabel's method. The number of soil samples in which the respective properties were determined is shown in Table 1. Humus content was calculated by multiplying % org. C by the Waksman's coefficient (1.724).

Our results are presented in the form of ecodiagrams (Zarzycki 1976 a–b; Piękoś-Mirkowa *et al.* 1996). They show the frequency of occurrence of *L. serotina* in various altitudinal belts, with different slopes, aspects and soil properties. Microsoft Excel 7.0 was used to make the graphs. The species names in Table 2 follow Mirek *et al.* (1995).

Distribution of *Lloydia serotina*

General distribution

Lloydia serotina is an arctic-alpine species with a wide circumpolar distribution in the northern hemisphere (Meusel *et al.* 1965). In Europe it occurs in the Alps, the Carpathians, and a few isolated sites on Mt. Snowdon (Wales). It is also found in the Caucasus, Himalayas, Siberia, and mountains in northern China, as well as Alaska, Canada and New Mexico.

Distribution in the Tatra Mts (Fig. 1)

Lloydia serotina occurs throughout the whole of the Polish and Slovakian Tatra Mts at higher elevations, but not in great numbers. The highest localities are on Mt. Malý Ladový štit at 2605 m a.s.l. (sterile plants) in the Slovakian Tatras (Paclová 1979) and on Rysy Mt. at 2470 m in the Polish Tatras (Pawłowski 1972). We found the lowest occurrence in Kobylarz gully, 1540 m. Most frequently, it is to be found between the altitudes of 1800 and 2200 m.

List of localities. **western tatras**. Mt. Wołowiec 2000 m, Mt. Jarząbczy Wierch 1850 m and 2030–2050 m, Mt. Starorobociański Wierch 2110 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Mt. Błyszcz (Sagorski & Schneider 1891), 26 June 1957, *leg. J. Staszkiewicz* (KRAM); Pyszniańska Przełęcz pass 1700 m, 26 June 1937, *leg. B. Pawłowski* (KRAM); Mt. Kamienista 2080 m (Piękoś-Mirkowa & Miechówka 1998), 2045–2060 m (Balcerkiewicz *et al.*, unpubl.); Mt. Smreczyński Wierch 2050 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Stoły above Dolina Tomanowa valley, 6 July 1952, *leg. J. Nowak* (KRAM), 1870 – 1955 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Mt. Kominy Tylkowe (= Kominiarski Wierch) 1700 m, 23 June 1935, *leg. B. Pawłowski* (KRAM), 1829 m, 23 June 1935, *leg. M. Łańcucka & A. Środoń* (KRAM); Twardy Upłaz ca 1800 m (Pawłowski & Stecki 1927); between Twardy Upłaz and Mt. Ciemniak, 4 Aug. 1961, *leg. W. Wojewoda* (KRA); Mt. Ciemniak ca 2000–2050, pass between Mt. Ciemniak and Mt. Krzesanica 2050–2080 m (Pawłowski & Stecki 1927); Mt. Krzesanica, *leg. W. Kulczyński* 1879 (KRAM), 2080 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.), 2112 m (Kotula 1889–1890), 2128 m (Sagorski & Schneider 1891); Dolina Mułowa valley 1770 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.), ca 1800 m (Pawłowski & Stecki 1927); Kozi Grzbiet 1830 m and 1880 m, Dolina Litworowa valley (Kotula 1889–1890), 1600 m and 1820 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); pass between Mt. Krzesanica and Mt. Małołączniak 1980 m, (Šmarda, Unar & Unarova 1966); Mt. Małołączniak 1960 (Mirek, Piękoś-Mirkowa

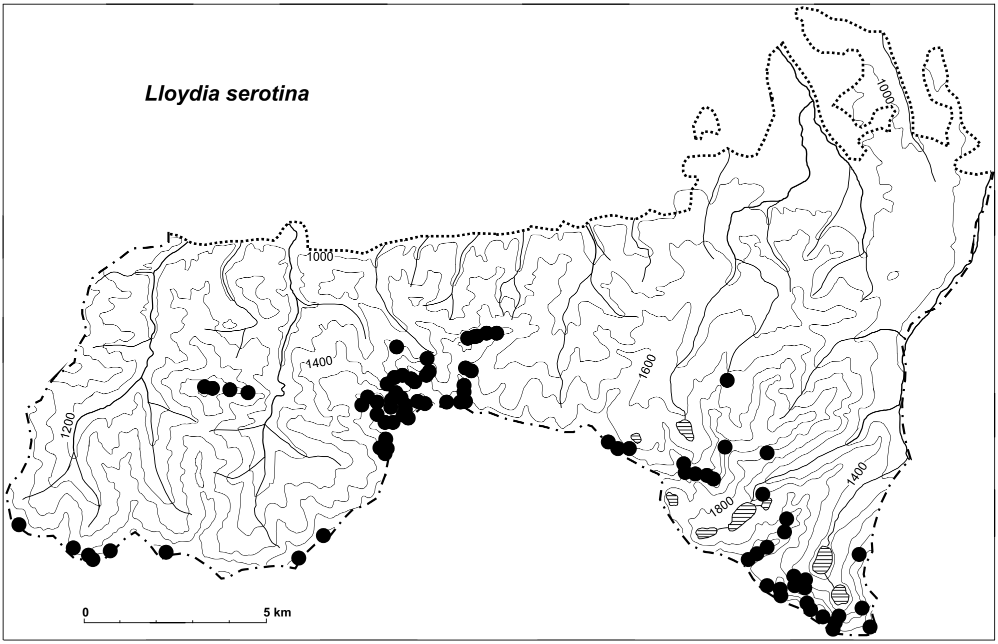

Fig. 1. Distribution of *Lloydia serotina* (L.) Reichenb. in the Polish Tatra Mts.

& Miechówka, unpubl.); Mt. Wielka Turnia 1664 m (Kotula 1889–1890), 1580 m and 1860 m (Pawłowski & Stecki 1927), 1840 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Kobylarz gully 1540 m and 1820 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Mt. Kopa Kondracka (Kotula 1889–1890), 1810 m and 1970 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Żleb Kirkora gully in Giewont, 19 July 1917, *leg. I. Król* (KRAM); Mt. Giewont ca 1890 (Sagorski & Schneider 1891); Mt. Długi Giewont 1650 m and 1770 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Wrótka pass in Giewont, 11 June 1915, *leg. K. Miczyński* (KRAM); Szczerba pass (Kotula 1889–1890), 22 July 1883, *leg. ?* (KRAM); Stare Szałasiska valley 1420 m, Przełęcz Liliowe pass 1953 m, Grzędy below Przełęcz Liliowe pass 1850 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.). HIGH TATRAS. Zawrat pass 21 Aug. 1910, *leg. A. Żmuda* (KRAM), 5 July 1952, *leg. K. Kostrakiewicz* (KRAM), Zawratowy Żleb gully 2050 m and 2080 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Kozia Przełęcz pass 2160 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Mt. Kozi Wierch, 7 Aug. 1902, *leg. I. Król* (KRAM); Granacka Przełęcz pass, 21 July 1914, *leg. I. Król* (KRAM); Dolina Pańszczyca valley ca 1640 m (Piękoś 1962); Dolina Pięciu Stawów Polskich valley – Mt. Krzyżne 1850 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Mt. Opalony Wierch 2110 m, Niżnia Kopa from Roztoka 1665 m, Miedziane – Miedziany Kostur 2190 m, Miedziane – Miedziany Kostur 2200 m, between Szpiglasowa pass and Miedziane 2105 m, under Szpiglasowa pass 2070 m, under Szpiglasowa pass 2080–2085 m, Szpiglasowa pass 2105–2110 m (Balcerkiewicz 1984); Szpiglasowa pass, 1 Aug. 1961, *leg. W. Wojewoda* (KRA), 2105 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.; Mt. Miedziane 2225 m, Mt. Opalony Wierch 2100 m, Wrota Chałubińskiego pass 1965 – 2028 m (Pawłowski, Sokołowski & Wallisch 1928, Piękoś-Mirkowa, Mirek & Miechówka 1999); below Mt. Cubryna ca 1710 m (Pawłowski, Sokołowski & Wallisch 1928); Mt. Cubryna 2340 m (Pawłowski 1972); Mt. Mięguszowiecki Wielki 1590–1650 and 2100 m, Mt. Mięguszowiecki Szczyt Pośredni ca 2060 m (Pawłowski, Sokołowski & Wallisch 1928); Mięguszowiecki near Przełęcz pod Chłopkiem pass 2300 m (Kotula 1889–1890); below Przełęcz pod Chłopkiem pass 2230–2265 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.); Mt. Mięguszowiecki Szczyt Czarny 2140 and 2395 m (Pawłowski, Sokołowski & Wallisch 1928, Pawłowski 1972); Kocioł Czarnostawiański ca 1770 m (Pawłowski, Sokołowski & Wallisch 1928); Mt. Rysy 2200 m (Kotula 1889–1890), 2470 m, Przełęcz pod Rysami pass 2205 (Pawłowski 1972); Mt. Niżnie Rysy 1800–1850 m (Pawłowski, Sokołowski & Wallisch 1928); below Mt. Żabia Czuba 2000 m (Mirek, Piękoś-Mirkowa & Miechówka, unpubl.).

Lloydia serotina has also been recorded from several localities without precise locations given. They could be not marked on the map. These are as follows:

Dolina Chochołowska valley (Kotula 1889–1890); north-facing slope of Mt. Wołowiec, 31 July 1922, *leg. B. Pawłowski* (KRAM); below Mt. Hruby Wierch in Dolina Chochołowska valley, 15 Aug. 1883, *leg. ?* (KRAM); Dolina Kościeliska valley (Kotula 1889–1890); Pyszna (Knapp 1872, Sagorski & Schneider 1891), 31 July 1875, *leg. W. Kulczyński* (KRAM), 31 July ?, *leg. Bobek* (KRAM); Mt. Ornak (Sagorski & Schneider 1891); Mt. Tomanowa, Babie Nogi valley (Knapp 1872, Sagorski & Schneider 1891), 29 July 1875, *leg. W. Kulczyński* (KRAM); Mt. Giewont, 2 May 1856, *leg. F. Berdau* (KRAM), *leg. B. Gustawicz* (KRAM); Mt. Mały Giewont (Knapp 1872, Berdau 1890), 10 July 1914, *leg. I. Król* (KRAM); below Mt. Kozi Wierch, 26 July 1879, *leg. W. Kulczyński* (KRAM); Mt. Granaty, ?. June 1952, *leg. J. Błaszczyk* (KRA); Kocioł Mięguszowiecki, ?. July 1911, *leg. M. Raciborski* (KRA); below Mt. Rysy, ?. June 1929, *leg. J. Błaszczyk* (KRA).

Characteristics of habitats

Lloydia serotina is a high mountain (alpine) species. It occurs from the subalpine belt up to the subnival belt, having its main center of occurrence in the alpine belt (75% of localities). This species grows on rock ledges and steep rocky slopes with inclination reaching 90^{o}. It tends to prefer a northern aspect.

Lloydia serotina occurs mainly on soils belonging, according to the FAO-ISRIC and ISSS (1998) classification, to *Lithic Leptosols* (61% out of investigated samples) and *Folic Histosols* (24%). **??** The species occurs less frequently on soils belonging to the other soil units (Fig. 2). *Lithic Leptosols* are very shallow soils (to 10 cm in depth) derived from lithic rocks. They exhibit humic or organic horizons containing fragments of parent rocks. More than a half of the *Lithic Leptosols* (64%) with *L. serotina* are

Table 1. Some properties of soils with *Lloydia serotina* (L.) Reichenb. in the Tatra Mts. *N* – number of soil samples.

Soil properties	*N*	Minimum	Maximum	Arithmetic mean	Standard deviation
pH H_2O	42	4.2	7.3	5.7	0.9
pH KCl	42	3.5	6.9	5.0	1.1
carbonate CO_2 (%)	20	0.00	2.17	0.54	0.25
actual moisture (%)	36	16.70	70.00	44.81	15.35
organic C (%)	41	1.70	31.76	13.67	8.09
total N (%)	41	0.15	2.35	1.10	0.63
C/N	41	6.6	19.6	12.29	2.77
Available nutrients [mg $100g^{-1}$]					
P_2O_5	35	0.40	40.00	6.74	7.62
K_2O	35	1.00	165.80	18.82	27.24
MgO	35	0.10	111.10	17.60	21.79
Exchange cations [cmol(+) kg^{-1}]					
Ca^{+2}	21	1.41	45.89	15.16	14.64
Mg^{+2}	21	0.81	27.33	5.41	7.18
Na^{+}	21	0.03	0.33	0.11	0.08
K^{+}	21	0.08	0.61	0.26	0.13
Sum of basic cations	21	2.80	67.93	20.94	18.34
Hydrolytic acidity	16	1.80	25.54	12.50	7.27
Cation exchange capacity	16	9.59	60.80	28.22	11.68
% base saturation	16	9.88	93.37	52.37	26.64

derived from noncarbonate rocks (mainly mylonites and also chlorite and serpentinite slates). The other soils belonging to this unit (36%) are derived from carbonate rocks (dolomites and limestones). *Folic Histosols* are deeper than 10 cm and characterized by *folic* diagnostic horizons which consist of well-aerated organic material. *Folic* horizons contain more than 20% organic carbon. *Folic Histosols* occupied by *L. serotina* are derived from carbonate rocks (limestones and dolomites).

The basic chemical properties of the rhizosphere layer are shown in Table 1 and Figure 2. The soil reaction ranges from strongly acid to alkaline (pH 4.2–7.5), reflecting the variability of the underlying geological substratum. However, 65% of the samples showed an acid or strongly acid reaction. This is more than would be expected from the rock types at *Lloydia serotina* sites and may be the result of the large amount of acidic organic matter in the upper horizons, connected with climatic factors (high rainfall and low temperature). In the Tatras a majority of the soils supporting *L. serotina* are characterized by a high cation exchange capacity. In the soils derived from carbonate rocks and some soils derived from mylonites the sorption complex is more than half-saturated by basic cations, among which calcium prevails.

Lloydia serotina grows on soils rich in organic matter, which in their upper horizons ranges from (2.45) 5.59% to 54.75% (22.83% on average). Almost half of the samples

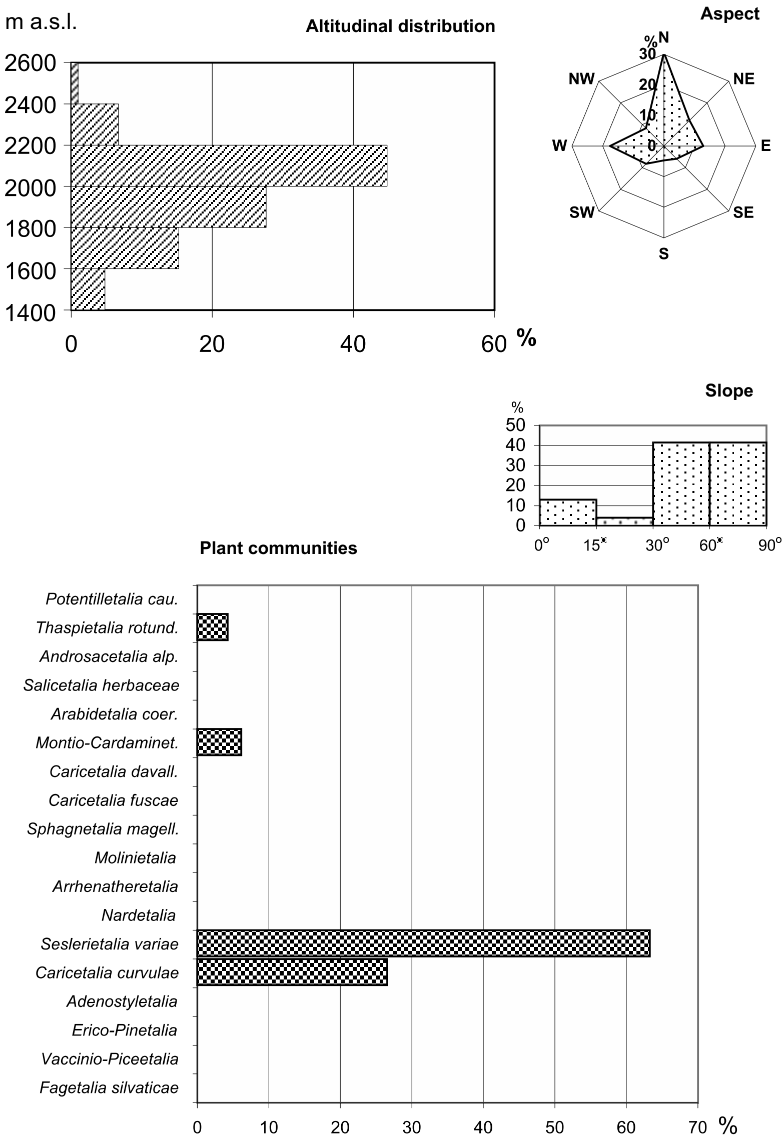

Fig. 2. Ecodiagrams for *Lloydia serotina* (L.) Reichenb. in the Polish Tatra Mts. In the diagram presenting species occurrence in plant communities, the following abbreviations of order names were used: *Potentilletalia cau. – Potentilletalia caulescentis, Thlaspietalia rotund. – Thlaspietalia rotundifolii, Androsacetalia alp. – Androsacetalia alpinae, Arabidetalia coer. – Arabidetalia coeruleae, Montio-Cardaminet. – Montio-Cardaminetalia, Caricetalia davall. – Caricetalia davallianae, Sphagnetalia magell. – Sphagnetalia magellanici.*

(49%) contain more than 20% organic matter. The relatively low values of the carbon to nitrogen ratio, for high mountain conditions, found in the examined samples, indicates a high degree of humification. In 63% of the investigated soils the C/N values range from 10 to 15, and in 23% are lower than 10. The high content of amorphic organic matter in

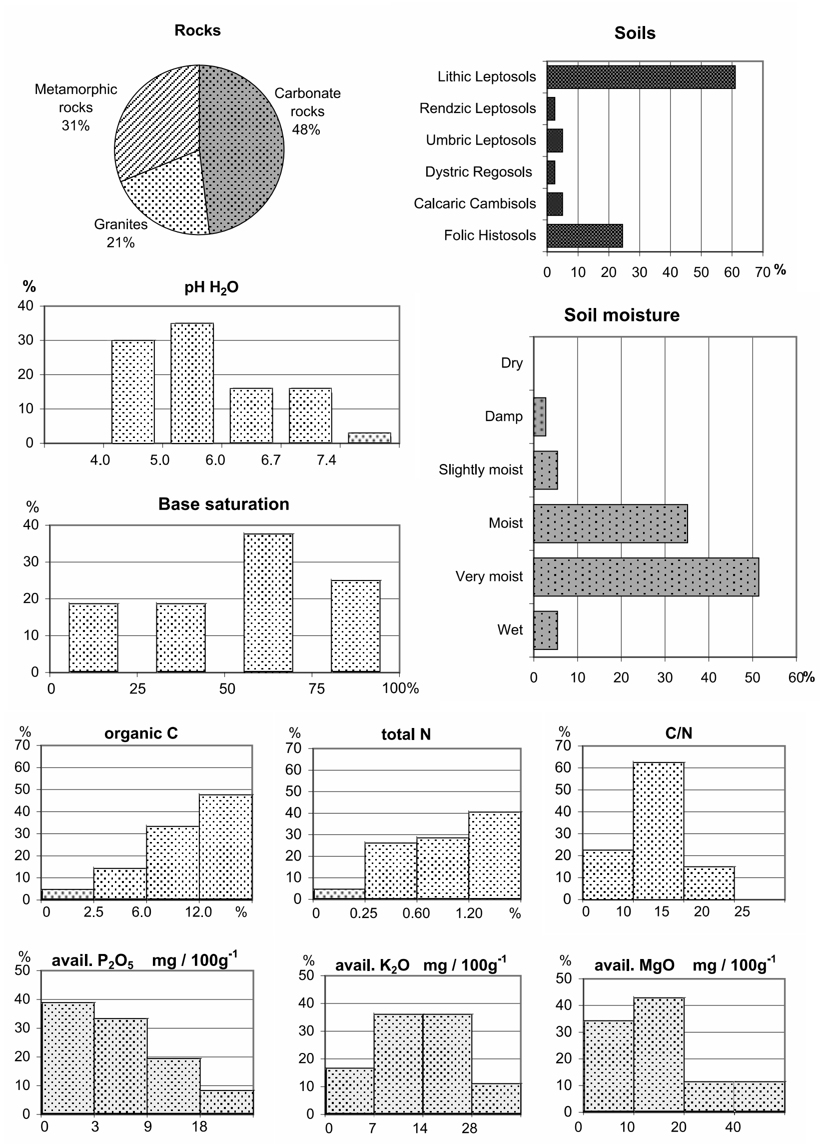

Fig. 2. Continued.

the soils increases their water capacity and explains their high moisture (44.81% on average) (Table 1). Organoleptic examination showed that more than half of the soils were very humid (Fig. 1).

The content of available nutrients ranges within wide limits (Table 1) but more than half of the samples are of medium or rich abundance in available phosphorus, potassium and magnesium (Fig. 2). These levels of available potassium and magnesium are typical for Tatra soils, while in the case of phosphorus it is rather rare, as Tatra soils are usually poor in this nutrient.

According to Slovakian authors (e.g., Šmarda 1975) the occurrence of *Lloydia serotina* is connected with mylonite bedrock. Studies in other mountain areas indicate that this species grows on different parent rocks (granites, gneisses, basalts, marbles, pyroclastic rocks), and available nutrient content may not be limiting to the successful growth of *L. serotina* (Jones 1997).

As already mentioned, *Lloydia serotina* occurs in the Polish Tatras mainly on soils derived from carbonate rocks, alkaline metamorphic slates (mylonites, serpentinite and chlorite slates) and granitoids (Fig. 2). These soils appear to show a wide range of pH in H_2O, from 4.2 to 7.5. Investigations at 14 sites of this species in Wales, Colorado (U.S.A.) and the Alps showed a smaller range of pH values (5.0–7.4) (Jones 1997). However, over all *L. serotina* sites in Europe and America the average pH values were similar, ranging from 5.6 to 6.0. A majority of the *L. serotina* sites found in the Tatra Mts are on soils containing a large amount of well-decomposed organic matter. A similar mean percentage of organic matter was determined in soils supporting *L. serotina* in Wales, although the range of organic matter content was smaller (Jones 1997).

Phytocoenoses

Lloydia serotina is regarded as a characteristic species of the high mountain grasslands representing the *Festuco versicoloris–Agrostietum alpinae* Pawł., Sokoł. & Wall. 1928 (= *Versicolori-Agrostietum*) association of the order *Seslerietalia variae* (Pawłowski *et al.* 1928; Matuszkiewicz 1982; Balcerkiewicz 1984). This association occupies rather small patches in the alpine and subalpine belts. It is characterized by a mosaic of intermixed calciphilous and calcifuge species (Table 2). The species is also to be found in some phytocoenoses of the *Oreochloetum distichae subnivale* Pawł. 1926 (= *Distichetum subnivale*) association in the subnival belt. These phytocoenoses of the order *Caricetalia curvulae* showed a resemblance to the *Festuco versicoloris-Agrostietum alpinae* association (Table 2). Sporadically it could be found in scree vegetation in the *Oxyrio-Saxifragetum carpaticae* Pawł., Sokoł. & Wall. 1928 association of the order *Androsacetalia alpinae*, and exceptionally in the flush community of *Swertia perennis* and *Saxifraga aizoides* of the order *Montio-Cardaminetalia* (Balcerkiewicz 1984).

Population size and threat

The population size of *Lloydia serotina* in the Tatra Mts varies between sites, usually from several dozen individuals to hundreds of plants. Sterile plants prevail in the populations. Seeds capsule production as a percentage of plants in five investigated Tatra populations varied from 0 to 20% (Jones 1997). In the subnival belt, mostly sterile plants have been found (Paclova 1979).

Generally the *L. serotina* sites in the Tatra National Park are not threatened. The species often grows on rock ledges or very steep slopes difficult for tourists to access. The most threatened site appears to be the Liliowe pass. The large population of *L. serotina* there has been fragmented, and is impacted by the thousands of tourists visiting this popular and easily accessible trail every year.

Table 2. Floristic composition of phytocoenoses with *Lloydia serotina* (L.) Reichenb.

Number of relevé	*Festuco versicoloris-Agrostietum alpinae*													*Caricetum firmae*				*Oreochloetum distichae subnivale*					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
I. Ch. Festuco versicoloris – Agrostietum alpinae																							
Lloydia serotina	+	+	+	+	+	1	1	1	+	2	1	1	+	2	1	+	+	+	1	+	2	2	+
Pachypleurum simplex	+	+	+	+	+	1	1	1	1	+	+	+	r	.	.	.	.	+	(+)	+	1	.	.
Antennaria carpatica	+	+	+	+	+	.	+	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex fuliginosa	+	.	+	+	+	.	.	.	.	.	1	.	.	.	.	.	.	.	(+)	.	1	.	.
Callianthemum coriandrifolium	.	+	+	+	+	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Agrostis alpina	+	1	1–2	1–2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Alchemilla flabellata	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
II. Elyno – Seslerietea																							
Pedicularis oederi	+	+	+	+	+	+	+	+	+	1	+	+	.	1	1	+	+	+	.	.	.	.	.
Festuca versicolor	3	3	3	2	3	+	3	3	3	+	2	1	.	3	3	2–3	2–3	.	.	.	.	.	.
Saxifraga paniculata	.	1	1–2	+-1	+	+	2	1	1	1	2	+	1	1	1	+	.	.	.	.	.	.	.
Salix reticulata	.	+	+	+	(+)	2	2	2	+	.	2	+	r	1	2	1	+	.	.	.	.	.	.
Pedicularis verticillata	+	+	+	.	.	+	+	+	+	1	+	.	r	.	.	+	.	.	.	+	+	+	.
Ranunculus alpestris	.	+	+	.	+	+	+	+	r	2	1	.	.	+	.	1	+	.	.	.	.	1	.
Minuartia verna subsp. *gerardi*	.	.	+	.	.	+	1	+	+	+	1	.	.	.	+	.	.	.	.	.	.	1	+
Silene acaulis subsp. *pannonica*	.	.	.	.	.	.	.	1	2	3	2	.	1	2	1	1–2	2	.	.	.	.	.	.
Selaginella selaginoides	+	.	+	1	+	.	+	.	.	.	.	+	.	.	.	1	+	.	.	.	.	.	.
Leontodon pseudotaraxaci	1–2	.	+-1	1	+	.	+	.	.	.	.	+	.	.	.	r	r	.	.	.	.	.	.
Bartsia alpina	+	+	+	+	+	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Galium anisophyllon	.	+	+	.	+	.	.	.	.	.	.	+	.	.	.	+	+	.	.	.	.	.	.
Dryas octopetala	.	.	.	.	.	.	.	.	.	.	1	1	.	2	3	2	.	.	.	.	.	.	.
Carex sempervirens subsp. *tatrorum*	.	.	.	3	2–3	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.
Bellidiastrum michelii	.	+	.	2	1	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
Hedysarum hedysaroides	.	.	.	+	.	.	.	.	.	.	.	+	.	2	.	.	+	.	.	.	.	.	.
Phyteuma orbiculare	.	+	1	.	+-1	.	.	.	.	.	.	.	r	.	.	.	.	.	.	.	.	.	.
Ranunculus oreophilus	.	+	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.

(cont.)

Table 2. Continued.

Number of relevé	Festuco versicoloris-Agrostietum alpinae													Caricetum firmae				Oreochloetum distichae subnivale					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Carex firma	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	4	2–3	.	.	.	.	.	.
Sesleria tatrae	.	.	.	.	.	.	.	.	.	.	.	2	.	.	+	1	1	.	.	.	.	.	.
Androsace chamaejasme	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	1–2	+	.	.	.	.	.	.
Potentilla crantzii	.	+	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Salix alpina	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	+	+	.	.	.	.	.	.
III. Caricetea curvulae																							
Festuca airoides	3	2–3	3	.	1	2	1	+	1	+	1	.	1	.	.	.	.	3	3	3	3	2	+
Primula minima	+-1	+	+	+	+	2	+	2	r	+	.	.	.	.	.	+	.	2	+	+	+	1	1
Minuartia sedoides	.	+	.	.	.	.	.	r	+	1	+	+	1	.	.	1	1–2	2	2	+	2	2	+
Silene acaulis subsp. *norica*	1	+	+	+	+	+	1	+	.	.	o	.	.	.	.	.	.	(+)	(+)	(+)	3	2	3
Gentiana frigida	+	+	+	.	.	.	.	+	r	+	+	.	+	.	.	.	.	2	1	2	1	2	1
Oreochloa disticha	1–2	+	+	.	.	.	.	+	+	+	.	.	.	.	.	.	.	2	3	3	2	1	1
Campanula alpina	2	+	+	.	.	.	+	1	1	+	.	.	.	.	.	+	.	+	2	2	1	.	.
Juncus trifidus	+	+-1	+	.	.	1	+	r	.	.	+	.	.	.	.	.	.	.	.	(+)	.	+	.
Luzula spicata	.	+	+	.	.	.	.	.	.	.	r	.	r	.	.	.	.	1	.	+	+	1	.
Salix kitaibeliana	+	+	+	(+)	+	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio carniolicus	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.
Agrostis rupestris	3	.	+	.	1–2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.
Avenula versicolor	+	+	1–2	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pulsatilla alba	+	+	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hieracium alpinum subsp. *alpinum*	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
IV. Others																							
Polygonum viviparum	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+	1	+	.	.	.	.	.	+
Soldanella carpatica	+	.	+	+	+	.	+	+	+	.	.	+	.	.	+	+	+-1	.	.	.	.	.	+
Swertia perennis subsp. *alpestris*	+	+	.	1	+	.	.	+	1	.	+	.	.	+	+	+	+	.	.	.	.	.	.
Luzula alpino-pilosa	+	.	$+^{r}$	.	.	+	+	r	r	.	+	.	.	.	.	.	.	+	.	1	2	.	+
Tanacetum alpinum	1	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	+	+	+

Saxifraga retusa subsp. *retusa*	+	.	+	.	.	1	.	1	.	1	1	.	.	.	.	.	.	.	.	.	+	1	.
S. bryoides	+	.	+	.	.	.	.	.	+	+	.	.	r	.	.	.	.	+r	.	.	.	+	+
Campanula polymorpha	+	+	+	+	+	.	.	.	+	.	.	1	.	+	.	.	.	.	.	.	.	.	.
Anemone narcissifolia	+	+-1	+	+	+	.	.	r	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Carex sempervirens	+	2	+	.	.	.	+	+	+	.	r	.	.	.	.	.	.	.	.	.	.	.	.
Doronicum clusii	+	+	+	.	.	.	.	.	.	.	.	.	r	.	.	.	.	.	.	1	1	.	+
Vaccinium vitis-idaea	+	+	2	+	1	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.
Dianthus glacialis	.	+	+	.	.	+	+	r	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga moschata	.	.	+	.	.	.	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	+	.
S. oppositifolia	+	.	+	.	.	.	.	.	.	r	+	.	+	.	.	.	.	.	.	.	.	+	.
Huperzia selago	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cerastium tatrae	.	+	+	.	+	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.
Ranunculus pseudomontanus	+	1	+	1–2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Rhodiola rosea	.	+	+	.	.	.	.	.	.	.	.	+	r	+	.	.	.	.	.	.	.	.	.
Polygonum bistorta	.	+	.	+	+	.	.	+	r	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga wahlenbergii	.	+	.	.	.	.	.	.	.	.	+	.	r	.	.	.	+	.	.	.	.	+	.
Vaccinium myrtillus	+	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Viola biflora	+	1	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Parnassia palustris	.	+	.	+	+-1	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
Mutellina purpurea	.	.	.	+-1	+-1	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Oxyria digyna	+	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+
Saxifraga aizoides	.	.	+	.	+	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
Thymus alpestris	.	1	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Homogyne alpina	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Luzula luzuloides	.	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Solidago alpestris	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erigeron uniflorus	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga hieracifolia	.	+	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.
Alchemilla pyrenaica	.	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Carex atrata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	.	.
Poa laxa	+r	.	+r	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
Pinguicula alpina	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.

(cont.)

Table 2. Continued.

Sporadic species: **I.** *Hieracium alpicola* subsp. *ulepitschii* 3(+), 5(+); *Pulsatilla vernalis* 3(+), 5(+); **II.** *Biscutella laevigata* 14(+), 16(+); *Cerastium lanatum* 3(+); *Gentiana clusii* 16(+); *Gentiana verna* 11(+); *Gymnadenia odoratissima* 16(+); *Hieracium caesium* 5(+); *Saussurea alpina* subsp. *macrophylla* 4(+), 5(+); *Ranunculus thora* v. *carpaticus* 5(+); *Crepis jacquinii* 14(1), 16(+); *Helianthemum grandiflorum* 14(1); *Thymus carpaticus* 16(+); *Scabiosa lucida* 16(+); *Viola alpina* 16(1), 17(1); **IV.** *Alchemilla glabra* 2(+); *Anthoxanthum alpinum* 2(+), 5(+); *Arabis alpina* 2(+), 3(+); *Artemisia eriantha* 5(+^{r}), 13(1); *Asplenium viride* 5(+); *Calamagrostis villosa* 4(+), 5(+); *Campanula cochleariifolia* 16(+); *Cardaminopsis neglecta* 7(r); *Leucanthemum vulgare* v. *saxicola* 5(+); *Clematis alpina* 4(+), 5(+); *Coeloglossum viride* 2(+), 5(+); *Cystopteris fragilis* 2(+); *Draba aizoides* 17(+); *Empetrum hermaphroditum* 5(+); *Euphrasia tatrae* 5(+); *Festuca picta* 2(1), 5(+); *Gentiana punctata* 1(+); *Geum reptans* 3(+), 13(r); *Gymnadenia conopsea* 4(+), 5(+); *Hieracium valdepilosum* subsp. *grabowskianum* 5(+); *Hypochoeris uniflora* 5(+-1); *Juniperus communis* subsp. *alpina* 4(+^{r}), 5(+^{r}); *Leontodon hispidus* v. *opimus* 4(+), 5(+); *Leucorchis albida* 2(+); *Linum extraaxillare* 4(2), 5(2); *Myosotis alpestris* 3(+), 10(r); *Poa alpina* 3(+), 17(+); *Polygonatum verticillatum* 4(+); *Potentilla aurea* 4(+), 5(+); *Primula auricula* 16(+), 17(+); *Rhinanthus alpinus* 5(+); *Salix herbacea* 1(+), 3(+); *Saxifraga androsacea* 11(+), 23(+); *S. caesia* 16(+); *S. moschata* subsp. *kotulae* 21(+); *Sedum alpestre* 3(+^{r}); *Taraxacum alpinum* 23(+); *Tofieldia calyculata* 4(+), 5(+); *Vaccinium gaultherioides* 2(+), 3(+); *Veratrum lobelianum* 4(+^{r}), 5(+^{r}); *Veronica aphylla* 3(+), 16(+).

Localities and source of relevés: **1.** Czarnostawiański Kocioł, 1770 m, E, 60^{o}, surface: 300 m^2, date: 11.09.1926 (Pawłowski, Sokołowski & Wallisch 1928). **2.** Niżnie Rysy, 1850 m, SW, 60^{o}, date: 25.08.1926 (Pawłowski, Sokołowski & Wallisch 1928). **3.** Mięguszowiecki Pośredni, 2060 m, NE, 50^{o}, surface: 200 m^2, date: 10.09.1926 (Pawłowski, Sokołowski & Wallisch 1928). **4.** Mięguszowiecki Wielki, 1590 m, NEN, 70^{o}, surface: 50 m^2, date: 14.08.1928 (Pawłowski, Sokołowski & Wallisch 1928). **5.** Below Cubryna, 1710 m, E-ENE, 70^{o} , surface: 200 m^2, date: 24.08.1927 (Pawłowski, Sokołowski & Wallisch 1928). **6.** Szpiglasowa Przełęcz, 2105 m, NNW, 35^{o}, surface: 6 m^2, plant cover: 30%, date: 25.08.1976 (Balcerkiewicz 1984). **7.** Szpiglasowa Przełęcz, 2110 m, W, 45^{o}, surface: 5 m^2, plant cover: 60%, date: 25.08.1976 (Balcerkiewicz 1984). **8.** Pod Szpiglasową Przełęczą, 2070 m, SSW, 55^{o}, surface: 20 m^2, plant cover: 70%, date: 25.08.1976 (Balcerkiewicz 1984). **9.** Pod Szpiglasową Przełęczą, 2070 m, W, 50^{o}, surface: 5 m^2, plant cover: 80%, date: 25.08.1976 (Balcerkiewicz 1984). **10.** Szpiglasowa Przełęcz, 2110 m, W, 55^{o}, surface: 3 m^2, plant cover: 50%, date: 25.08.1976 (Balcerkiewicz 1984). **11.** Pomiędzy Szpiglasową Przełęczą a Miedzianem, 2105 m, N, 60^{o}, surface: 25 m^2, plant cover: 75%,date: 31.08.1976 (Balcerkiewicz 1984). **12.** Kozi Grzbiet, 1880 m, N, 10^{o}, surface: 3 m^2, plant cover: 70%, date: 27.09.1996 (Piękoś-Mirkowa & Miechówka, unpublished). **13.** Mt Kamienista, 2080 m, NE, 80^{o}, surface: 40 m^2, plant cover: 60%, date: 31.07.1990 (Piękoś-Mirkowa & Miechówka 1998). **14.** Stoły Dolina Tomanowa valley, 1870 m, SW, 5^{o}, surface: 5 m^2, plant cover: 75 %, date: 2.09.1994 (Piękoś-Mirkowa & Miechówka, unpublished). **15.** Stoły Dolina Tomanowa valley, 1955 m, SW, 30^{o}, surface: 5 m^2, plant cover: 75 %, date: 2.09.1994 (Piękoś-Mirkowa & Miechówka, unpublished). **16.** Twardy Upłaz, 1800 m, W, date: 12.07.1923 (Pawłowski & Stecki 1927). **17.** Ciemniak, 2000–2050 m, N, date: 12.07.1923 (Pawłowski & Stecki 1927). **18.** Below Rysy-Niżnie Rysy pass, 2205 m, W, 30^{o}, surface: 4 m^2, plant cover: 75%, date: 23.07.1937 (Pawłowski 1972). **19.** Rysy, 2470 m, E, 50^{o}, surface: 4 (15) m^2, plant cover: 65%, date: 20.08.1931 (Pawłowski 1972). **20.** Mięguszowiecki Szczyt Czarny, 2395 m, S, 35^{o}, surface: 4 (8) m^2, plant cover: 70%, date: 28.08.1931 (Pawłowski 1972). **21.** Cubryna, 2340 m, ESE, 35^{o}, surface: 40 m^2, plant cover: 75%, date: 31.08.1954 (Pawłowski, Sokołowski & Wallisch 1928). **22.** Miedziane – Miedziany Kostur, 2200 m, NNW, 52^{o}, surface: 12 m^2, plant cover: 70%, date: 24.08.1976 (Balcerkiewicz 1984). **23.** Miedziane – Miedziany Kostur, 2190 m, N, 20^{o}, surface: 3 m^2, plant cover: 50%, date: 24.08.1976 (Balcerkiewicz 1984).

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References

BALCERKIEWICZ S. 1984. Roślinność wysokogórska Doliny Pięciu Stawów Polskich w Tatrach i jej antropogeniczne przemiany [High-mountain vegetation of the Five Polish Lakes Valley in the Tatra Mts. and its anthropogenic changes]. – Uniw. A. Mickiewicza w Poznaniu Ser. Biologia **25**: 1–191 (in Polish with English summary).

BERDAU F. 1890. Flora Tatr, Pienin i Beskidu Zachodniego ["Flora of the Tatra Mts, the Pieniny Mts and the West-Beskidy Mts"]. 827 pp. J. Filipowicz, Warszawa (in Polish).

FAO-ISRIC AND ISSS. 1998. World reference base for soil resources. World Soil Resources Reports **84**. FAO-ISRIC and ISSS, Rome.

JONES B. 1997. The Snowdon lily. – Flora Facts & Fables **9**: 18–19.

JONES B. 1997. The ecology, genetics and conservation of *Lloydia serotina*. Ph. D. thesis, University of Wales, Bangor.

JONES B. & GLIDDON C. 1999. Reproductive biology and genetic structure in *Lloydia serotina*. – Pl. Ecol. **141**: 151–161.

KNAPP J. A.1872. Die bisher bekannten Pflanzen Galiziens und der Bukowina. 520 pp. W. Braumüller, Wien.

KOTULA B. 1889–1890. Distributio plantarum vasculosarum in Montibus Tatricis. 512 pp. Wydawnictwo Akademii Umiejętności, Kraków (in Polish).

MATUSZKIEWICZ W. 1982. Przewodnik do oznaczania zbiorowisk roslinnych Polski ["Guidebook to plant communities in Poland"]. 298 pp. Państwowe Wydawnictwo Naukowe, Warszawa (in Polish).

MEUSEL H., JÄGER E. & WEINERT E. 1965. Vergleichende Chorologie der Zentraleuropäischen Flora. **1**. Karten, pp. 258. Gustav Fischer, Jena.

MIREK Z., PIĘKOŚ-MIRKOWA H., ZAJĄC A. & ZAJĄC M. 1995. Vascular plants of Poland: a checklist. – Polish Bot. Stud., Guideb. Ser. **15**: 1–303.

PACLOVÁ L. 1979. The vegetation of the subnival High Tatra Degree. 2nd Part. – Zbornik prác o Tatranskom Národnom Parku **21**: 131–218 (in Slovak with Russian, German and English summaries).

PAWŁOWSKI B. 1972. Szata roślinna gór polskich ["Plant cover of Polish mountains"]. – In: W. SZAFER & K. ZARZYCKI (eds), Szata roślinna Polski ["Vegetation of Poland"] **2**, pp. 189–252. Państwowe Wydawnictwo Naukowe, Warszawa (in Polish).

PAWŁOWSKI B. & STECKI K. 1927. Die Pflanzenassoziationen des Tatra Gebirges. IV Teil. Die Pflanzenassoziationen des Miętusia-Tales und des Hauptmassivs der Czerwone Wierchy. – Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B **1**, Bot., Suppl. **2**: 79–121.

PAWŁOWSKI B., SOKOŁOWSKI M. & WALLISCH K. 1928. Die Pflanzenassoziationen des Tatra-Gebirges. VII Teil. Die Pflanzenassoziationen und die Flora des Morskie Oko Tales. – Bull. Int. Acad. Polon. Sci., Cl. Sci. Math., Sér. B 1, Bot., Suppl. **2**: 205–272.

PIĘKOŚ H. 1962. Flora Doliny Bystrej, Suchej Wody i Pańszczycy w Tatrach ["Flora of the Bystra, Sucha Woda and Pańszczyca valleys in the Tatra Mts"]. Mscr. of M. Sc. thesis, Institute of Botany, Jagiellonian University, Kraków (in Polish).

PIĘKOŚ-MIRKOWA H. & MIECHÓWKA A. 1998. Distribution and habitats of *Artemisia eriantha* (Asteraceae) in the Tatra Mts (Western Carpathians). – Fragm. Flor. Geobot. **43**(2): 215–222.

PIĘKOŚ-MIRKOWA H., MIREK Z. & MIECHÓWKA A. 1996. Endemic vascular plants in the Polish Tatra Mts. – distribution and ecology. – Polish Bot. Stud. **12**: 1–107.

PIĘKOŚ-MIRKOWA H., MIREK Z. & MIECHÓWKA A. 1999. Distribution and habitats of *Pulsatilla vernalis* (L.) Mill. in the Tatra Mountains. – Oecol. Montana **7**: 26–30.

SAGORSKI E. & SCHNEIDER G. 1891. Flora der Centralkarpathen. **1**. 591 pp. E. Kummer, Leipzig.

ŠMARDA J. 1975. Vzťahy rastlín k podložiu [Relation of plants to the substratum]. – Zbornik prác o Tatranskom Národnom Parku **17**: 45–60 (in Slovak with Russian, German and English summaries).

ŠMARDA J., UNAR J. & UNAROVÁ M. 1966. Kvetena Tomanowej doliny a Žl'abu spod Diery v Západných Tatrách. Knižnica Sbornika Prác o Tatranskom Národnom Parku. 101 pp. Brno (in Slovak).

ZARZYCKI K. 1976a. Ecodiagrams of common vascular plants in the Pieniny Mts. (the Polish Western Carpathians). Part I: Ecodiagrams of selected woodland species. – Fragm. Flor. Geobot. **22**(4): 479–797.

ZARZYCKI K. 1976b. Ecodiagrams of common vascular plants in the Pieniny Mts. (the Polish Western Carpathians). Part I: Ecodiagrams of selected grassland species. – Fragm. Flor. Geobot. **22**(4): 499–528.

ZARZYCKI K. & SZELĄG Z. 1992. Czerwona lista roślin naczyniowych zagrożonych w Polsce [Red list of threatened vascular plants in Poland]. – In: K. ZARZYCKI, W. WOJEWODA & Z. HEINRICH (eds), Lista roślin zagrożonych w Polsce [List of threatened plants in Poland]. Ed. 2, pp. 87–98. W. Szafer Institute of Botany, Polish Academy of Sciences, Cracow (in Polish with English summary).