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Plant cover of the Western Carpathians (S. Poland)

Zbigniew MIREK and Halina PIĘKOŚ-MIRKOWA

1. INTRODUCTION

The Polish Carpathians belong to the best explored mountains in the world as regards their plant cover. The characterization of the flora and vegetation of the Polish Carpathians, presented in this paper, is based on a rich collection of literature. Of the numerous publications only a small selection could be mentioned here. Extensive literature referring to the plant cover of the Tatra Mts. is quoted in a separate paper (MIREK and PIEKOS-MIRKOWA 1992c). The Carpathians have aroused a great interest among botanists for nearly two hundred years. Investigations have resulted in a great number of floristical papers and local "Floras" (e.g. BIALECKA 1982, GRODZINSKA 1968, 1976, GRODZINSKA and PANCER-KOTEJOWA 1960, GUZIKOWA 1977, JASIEWICZ 1965, KORNAS 1957, KOTONSKA 1991, MIREK and PIEKOS-MIRKOWA 1987, PAWLOWSKI 1956, TOWPASZ 1975, 1987, ZAJAC 1989, ZAPALOWICZ 1880, ZARZYCKI 1981, ZEMANEK 1981). Apart from "Floras", a series of geobotanical monographs referring to the Carpathian ranges in particular is noteworthy (e.g. KORNAS 1955, PAWLOWSKI 1925, SWIES 1982, STUCHLIKOWA and STUCHLIK 1962, TOWPASZ 1974, 1990, ZAJAC 1990). Such monographs show a similar general scheme elaborated by KOTULA (1889-1990) and ZAPALOWICZ (1880) and developed upon by PAWLOWSKI (1925) and KORNAS (1955). A thorough analysis of the altitudinal and horizontal distribution of all plant species appears to be a characteristic feature of Polish geobotanical studies. Parallel to the floristic studies, extensive investigations of plant communities in the Polish Carpathians have been

carried out (e.g. DZWONKO 1977, CELINSKI and WOJTERSKI 1978, GRODZINSKA 1970, KORNAS 1968, KORNAS and MEDWECKA-KORNAS 1967, MEDWECKA-KORNAS et al. 1978, STUCHLIK 1968, WALAS 1933). A synthesis of phytosociological cartography resulted in a series of the vegetation maps comprising especially national parks (e.g. CELINSKI and WOJTERSKI 1961, GRODZINSKA et al. 1982, BARYLA et al. 1985). Based on local "Floras", phytosociological studies and geobotanical monographs, a number of syntheses concerning the Polish Carpathians as a whole have been elaborated on (e.g. DZWONKO 1984, GRODZINSKA and ZARZYCKI 1965, PAWLOWSKI 1972).

ACKNOWLEDGMENTS
The authors are greatly indebted to Lucyna Musial M.Sc. for her technical assistance and to Alicja Sidor M.Sc. and Jacek Wieser M.Sc. for the drawings. Special thanks go to Dr. J.J. Wojcicki for his invaluable help in preparation of the manuscript.

2. SITUATION AND LIMITS

The Carpathians belong to the younger mountains of the Alpine system which rose in the Tertiary Period (Fig. 1). They form an arch 1500 km long, open to

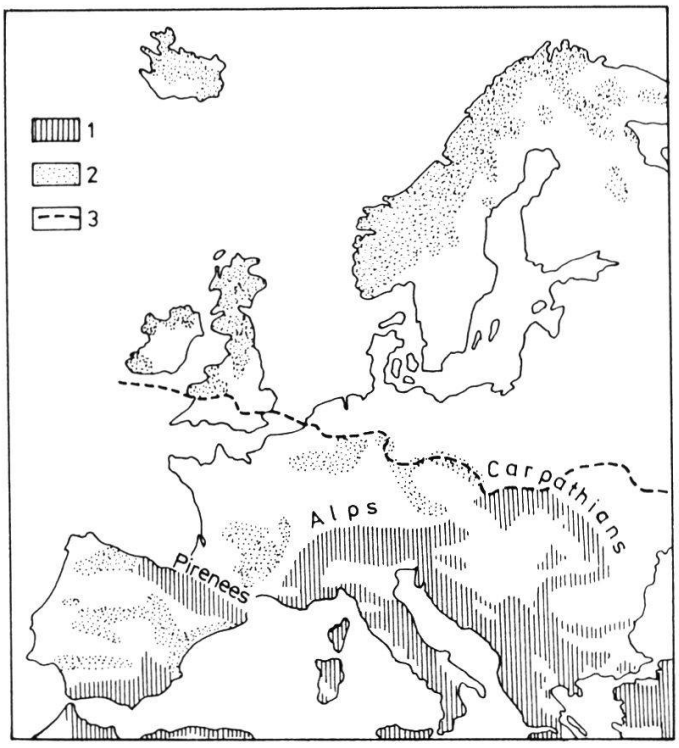

Fig. 1. Location of the Carpathians in relation to other mountains in Europe.
1 - young mountains of the Tertiary Age of the Alpine system, 2 - old Paleozoic mountains, 3 - southernmost limit of the greatest glaciation.

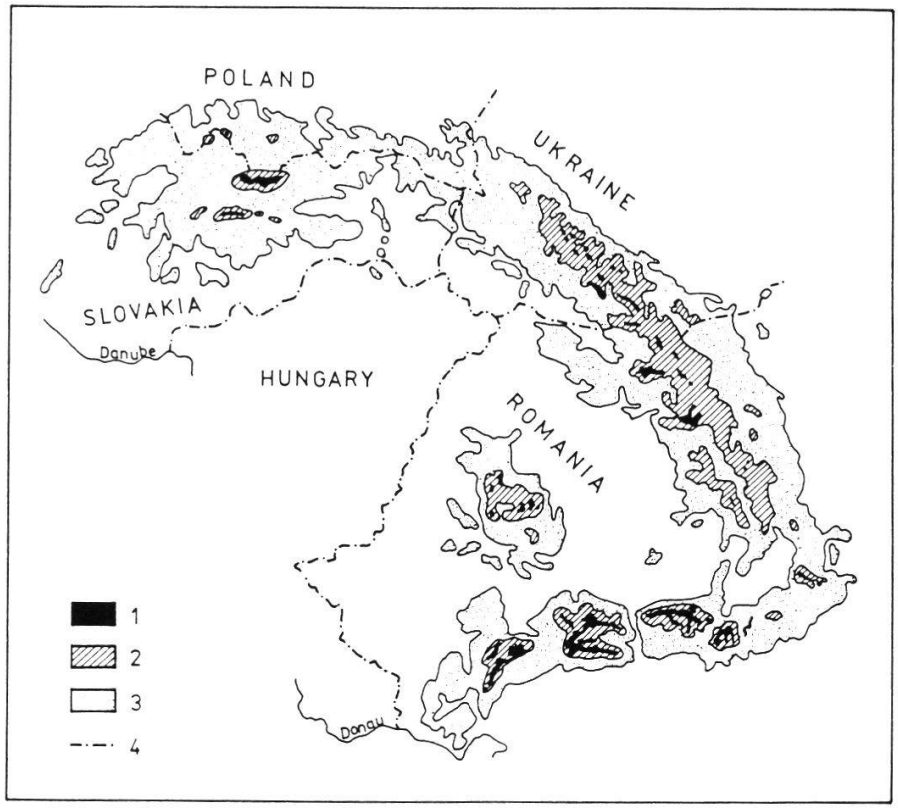

Fig. 2. Vegetation belts in the Carpathians with state boundaries (OZENDA 1983, slightly modified).
1 - subnivale, alpine and subalpine belts, 2 - upper montane belt, 3 - lower montane belt, 4 - state boundaries.

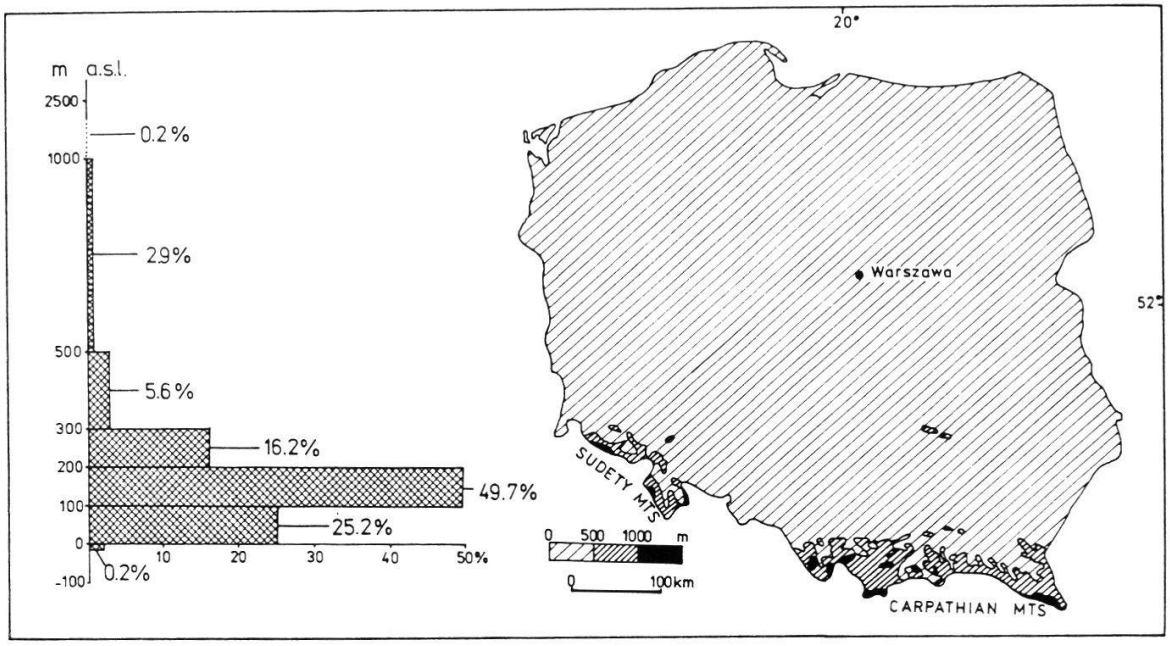

Fig. 3. The Polish Carpathians against the background of hypsometry differentiation in Poland.

the west stretching throughout Poland, Slovakia, Ukraine, Hungary and Romania (Fig. 2). The highest summit (Gerlach) at 2663 m a.s.l. is in Slovakia. The highest point of the Polish Carpathians (Rysy at 2499 m a.s.l.) lies in the Tatras. The Polish Carpathians constitute the most northern part of the whole chain (Fig. 2). They occupy the southern part of the country (Fig. 3) and are about 300 km long and up to 90 km wide. The greater part, from Brama Morawska (the Moravian Gateway) in the west to Lupkowska Pass in the east, belongs to the Western Carpathians, and a much smaller part to the east of this line represents the Eastern Carpathians.
The main elements of the natural environment of the Polish Western Carpathians change along the transect S-N (Fig. 4). This phenomenon manifests itself most evidently in the differences between climatic vegetation belts (Fig. 5).

3. GENERAL FEATURES

The Western Carpathians show a great diversity in respect to geological substratum, relief, elevation and landscape. On this basis three main units within the Polish Carpathians have been distinguished: the Tatras, the Pieniny Mts. and the Beskidy Mts. The Tatras form a small, high-mountain chain, the highest in the whole Carpathians. They display a typical alpine landscape and a rich glacial relief. The Tatras consist of both crystalline rock (granite, gneiss, chlorite schist, etc.) and sedimentary rock (limestone, dolomite, marl). Within the flysch Carpathians, the Pieniny Mts. form a very small, 20 km long, rocky massif consisting of Mesozoic limestone. The highest point reaches 1052 m a.s.l. In contrast to the above mentioned chains, the Beskidy Mts. display a monotonous relief and landscape. They are medium-altitude mountains consisting of flysch deposits of the Cretaceous, Eocene and Oligocene age. Within the Beskidy Mts., several mountain groups and ranges are distinguishable. The highest summit (Babia Gora) attains 1725 m a.s.l.

4. GEOBOTANICAL DIVISION

The Carpathians as a whole form a separate subdivision within the Central European Mountain Province. Within the Carpathians, two geobotanical units are distinguished: the Western and the Eastern Carpathians. Further geobotanical division, referring to the Polish part of the Western Carpathians, is as follows (Fig. 6):

Subdivision: the Western Carpathians
District: the Tatras
Subdistricts: the Western Tatras
the High Tatras
District: the Pieniny Mountains
Subdistricts: the Western Pieniny
the Central Pieniny
the Male Pieniny
the Pas Skalic Spiskich and Nowotarskich
(= the Spiskie and Nowotarskie Cliffs)
District: the Beskidy Mountains
Subdistricts: Slasko-Babiogorski
Sadecki
Bory Nowotarskie
Beskid Niski
District: the Pogorze (the Carpathian Foothills)
Subdistricts: Pogorze Cieszynskie
Pogorze Wielickie
Pogorze Ciezkowickie
Pogorze Strzyzowsko-Dynowskie

In comparison to the adjacent lowlands, the Carpathians are very rich in plant species (Fig. 7) and communities. Moreover, the Carpathians are characterized by a number of endemic species and plant communities (see Chapter 6.4), setting them apart from the lowlands and other European mountains.

Fig. 4 (p. 121). Differentiation of various elements of the natural environment in the Polish Carpathians.
A - vegetation belts: 1 - submontane, 2 - lower montane, 3 - upper montane, 4 - subalpine, alpine and subnival. B - simplified geclogical map of the Polish Carpathians. Outer Carpathians: 1 - Inoceramus, Dukla, Silesian series: sandstone and Krosno shale, menilit shale with chert and sandstone, shale and hieroglyphic sandstone, Ciezkowice sandstone and Inoceramus sandstone; 2 - Silesian and Subsilesian series: shale, conglomerate and Istebna and Czarnorzec sandstone, sandstone and Godula, Lgock, Wierzow and Cieszyn shale, radiolite layer, gaize layer, partially variegated Godula shale, marl and Weglowiec sandstone; 3 - Magura series: sandstone and Magura, Submagura, Belowa, hieroglyphic and Inoceramus shale, conglomerate and variegated shale; 4 - Cieszyn limestone, lower Cieszyn shale. Inner Carpathians: 5 - Pieniny Cliffs zone: sandstone, conglomerate, grey and red marl, chert limestone, marl, and sandstone of the Pieniny series, nodular and crynoidal limestone, marl and black clay of the Czorsztyn series, andesite; 6 - Podhale flysch: Ostrysz sandstone, sandstone, shale and Chocholow conglomerate, shale and Zakopane sandstone, nummulitic limestone, sandstone and conglomerate of the Upper and Middle Eocene; 7 - Subtatra series: marl, limestone with radiolarite, crynoidal limestone, chart, spotty and sandy marl shale with Gresten quartzite; 8 - High Tatra and crystalline core series: marl glauconitic, Urgonian, white and red encrinite limestone, Pisana sandstone, Tomanowa shale, sandstone and Keuper shale, dolomite, quartzite, granite, gneiss, schist and migmatite; 9 - loess, loamy weathered cover, alluvial cover, and loess cover; 10 - gravel sand and clay of upper river terraces. C - duration of vegetation period in days: 1 - 230-220, 2 - 220-210, 3 - 210-200, 4 - 200-190, 5 - 190-180, 6 - 180-170.

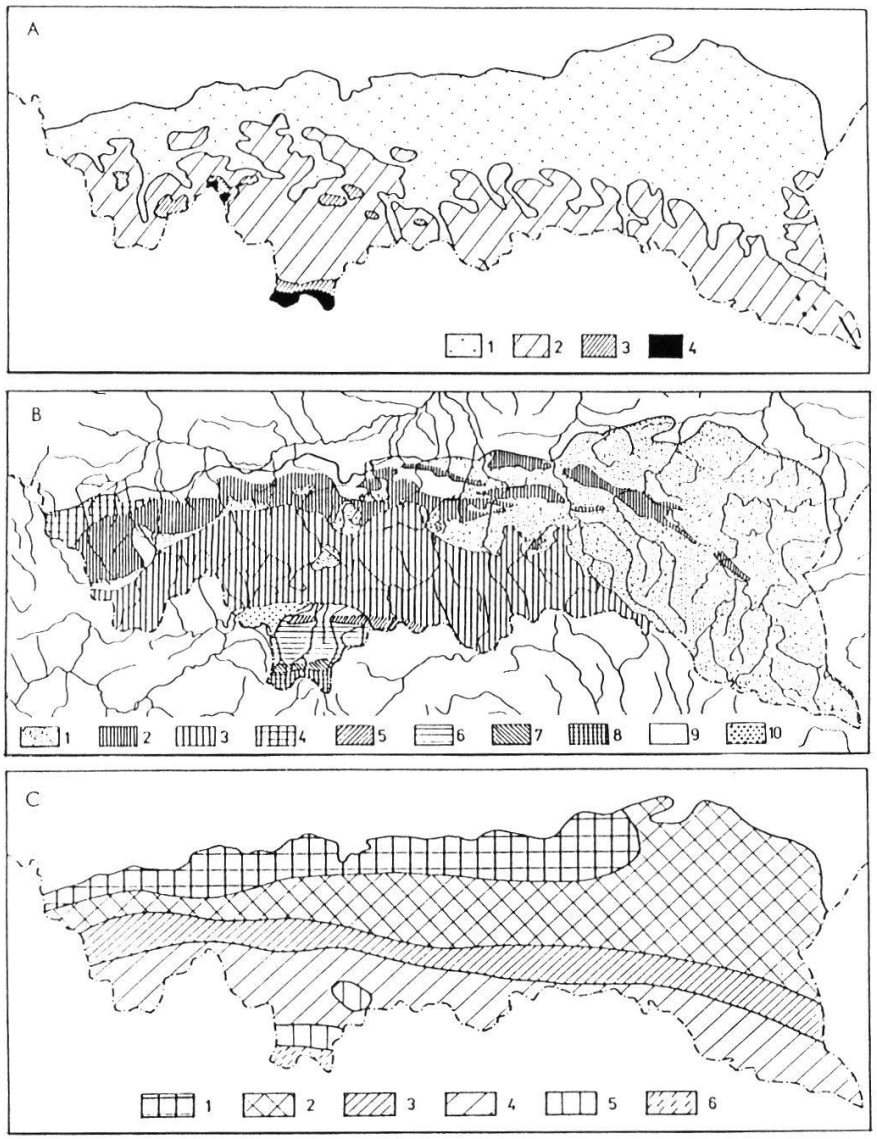

Fig. 4

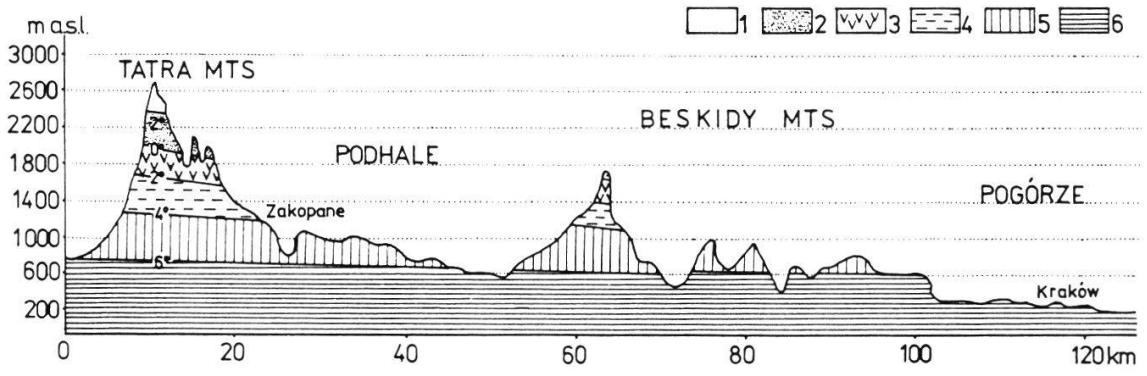

Fig. 5. Climate belts in the Polish Western Carpathians along the N-S transect between Krakow and the Tatras (HESS 1965, slightly modified).
1 - cold belt, 2 - moderately cold, 3 - very cool, 4 - cool, 5 - moderately cool, 6 - moderately warm.

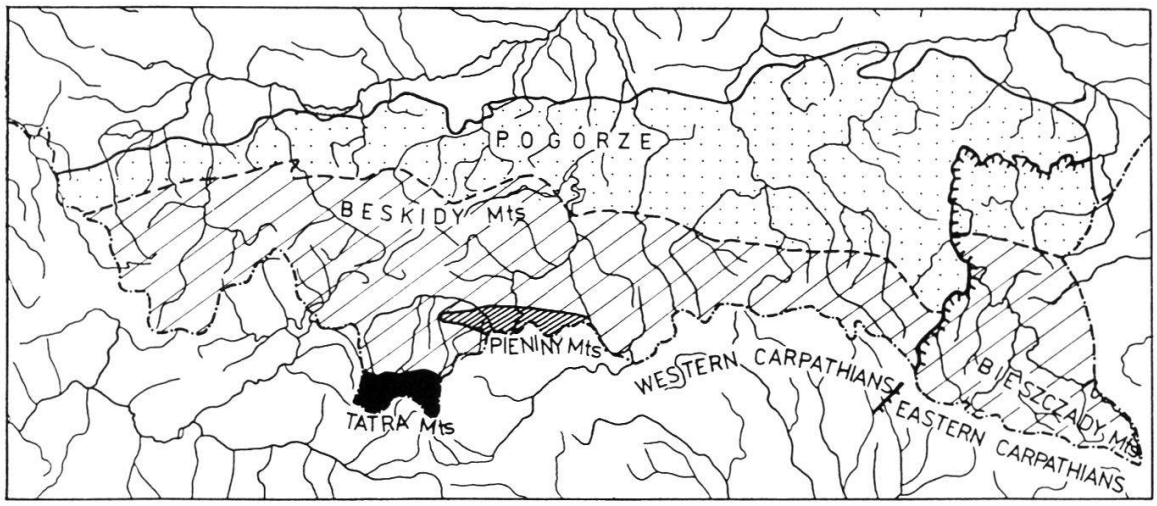

Fig. 6. Geobotanical division of the Polish Carpathians.

The occurrence of both West- and East-Carpathian endemics and non-endemic plants restricted to one part of the Carpathians (Figs. 8-10) is a basis for further division of these mountains into two geobotanical units, the Western and Eastern Carpathians. Further geobotanical division into districts is founded on differences in richness of the flora (in particular of the mountain

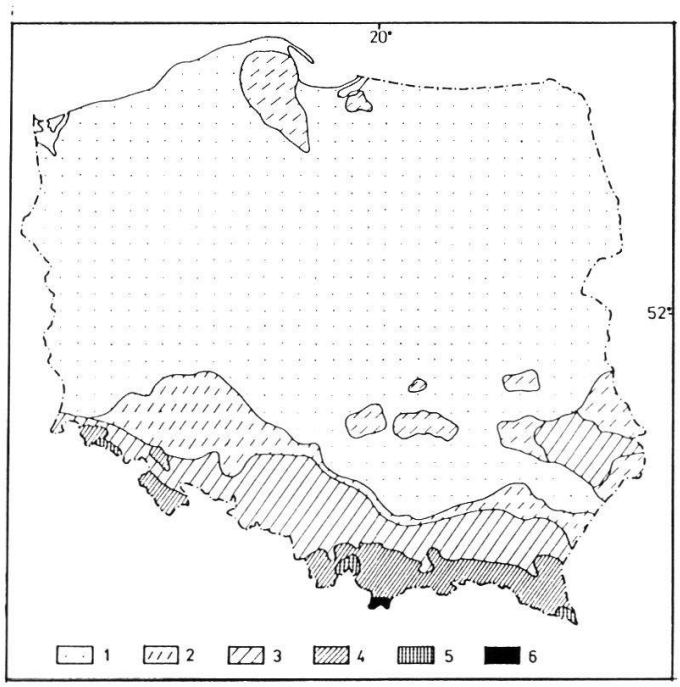

Fig. 7. Mountain vascular plant species in Poland (compiled from various sources).
1 - 1-15, 2 - 16-30, 3 - 31-60, 4 - 61-120, 5 - 121-240, 6 - over 240 species.

plants), on distribution of species and occurrence of endemics. Of the four geobotanical districts distinguished within the Polish Carpathians, the Tatra district is characterized by the greatest number of mountain (especially high-mountain) species (Fig. 13) and by five vegetation belts comprising the subnival belt (Fig. 11). In the Tatras there are about 200 mountain species of which many are relic species (MIREK and PIEKOS-MIRKOWA 1992a) and occur nowhere else in Poland. Moreover, the Tatras appear to be the main centre of

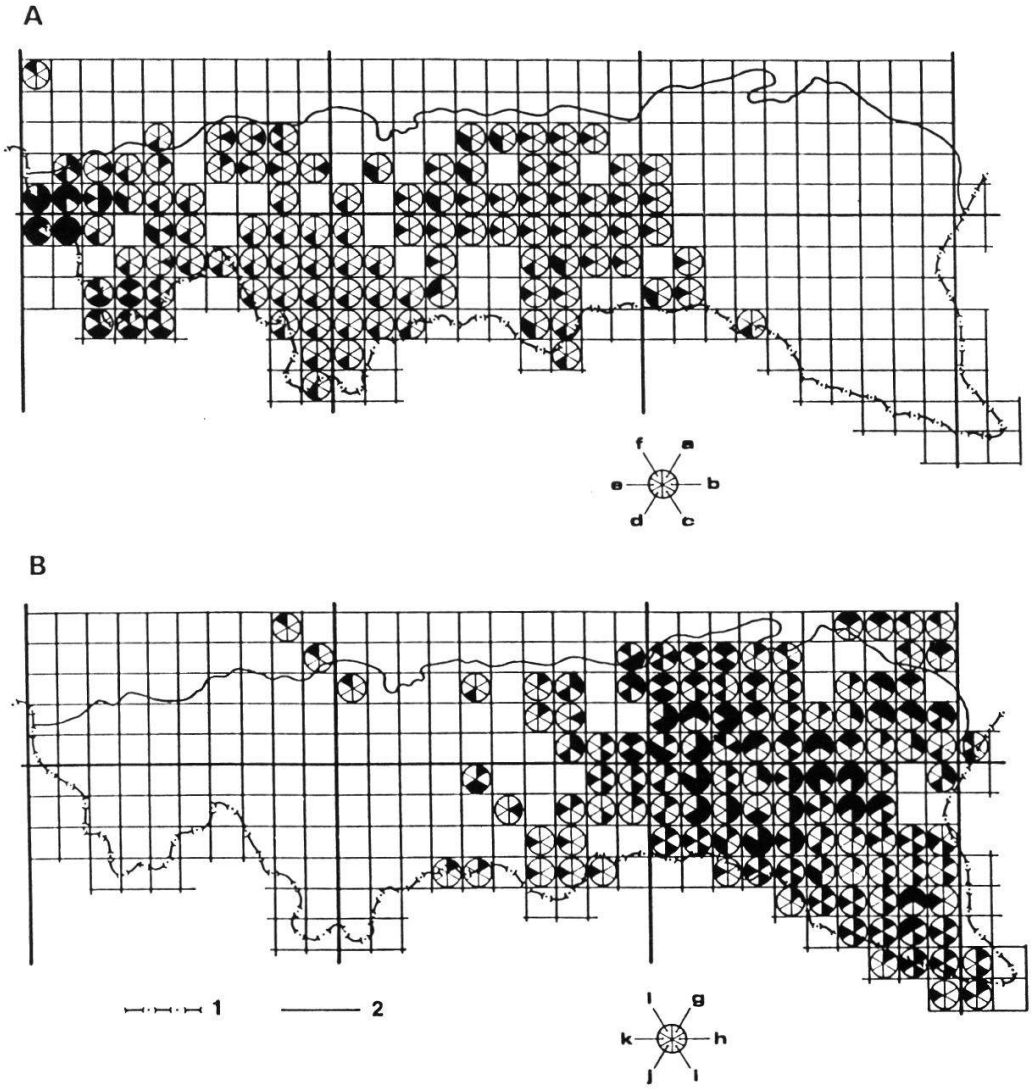

Fig. 8. Comparison of the occurrence of single species (in 10x10 km squares) distinguishing:
A - the Western Carpathians: a - *Potentilla verna*, b - *Hacquetia epipactis*, c - *Centaurea pseudophrygia*, d - *Centaurea oxylepis*, e - *Euphorbia dulcis*, f - *Dentaria enneaphyllos*; B - the Eastern Carpathians: g - *Aposeris foetida*, h - *Cerastium sylvaticum*, i - *Scilla bifolia*, j - *Staphyllea pinnata*, k - *Festuca drymeja*, l - *Evonymus verrucosa*.
1 - state boundary, 2 - the northern limits of the Carpathians (TOWPASZ 1990).

endemism within the Western Carpathians (see Chapter 6.4). The Pieniny district is distinguished by its own endemic taxa and non-endemic ones restricted in Poland to this range (e.g. *Dendranthema zawadzkii, Juniperus sa-*

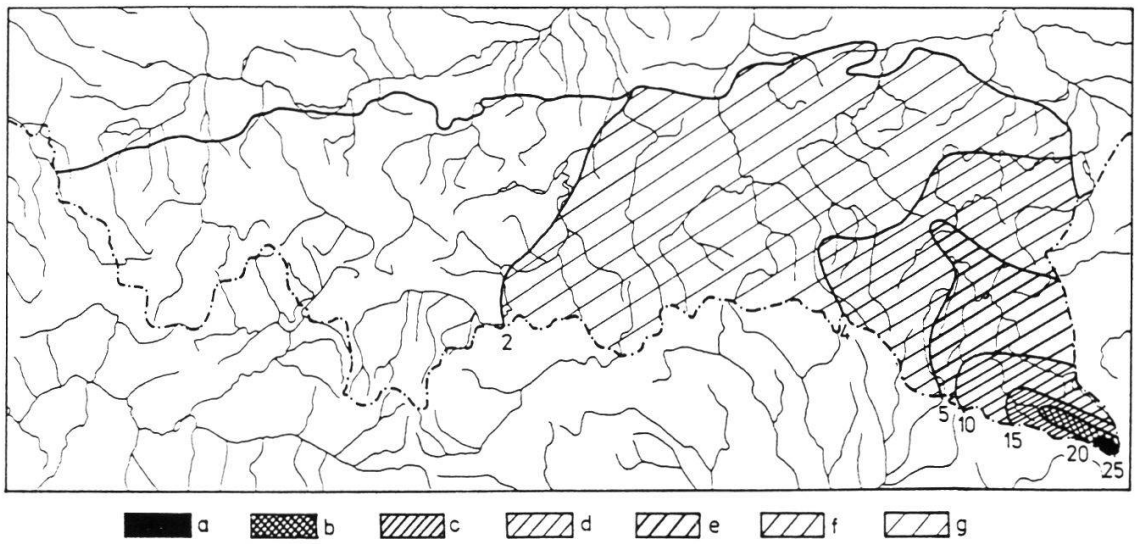

Fig. 9. Number of East-Carpathian species in the Polish Carpathians (ZEMANEK 1991, slightly modified).
a - 25, b - 20, c - 15, d - 10, e - 5, f - 4, g - 1 species.

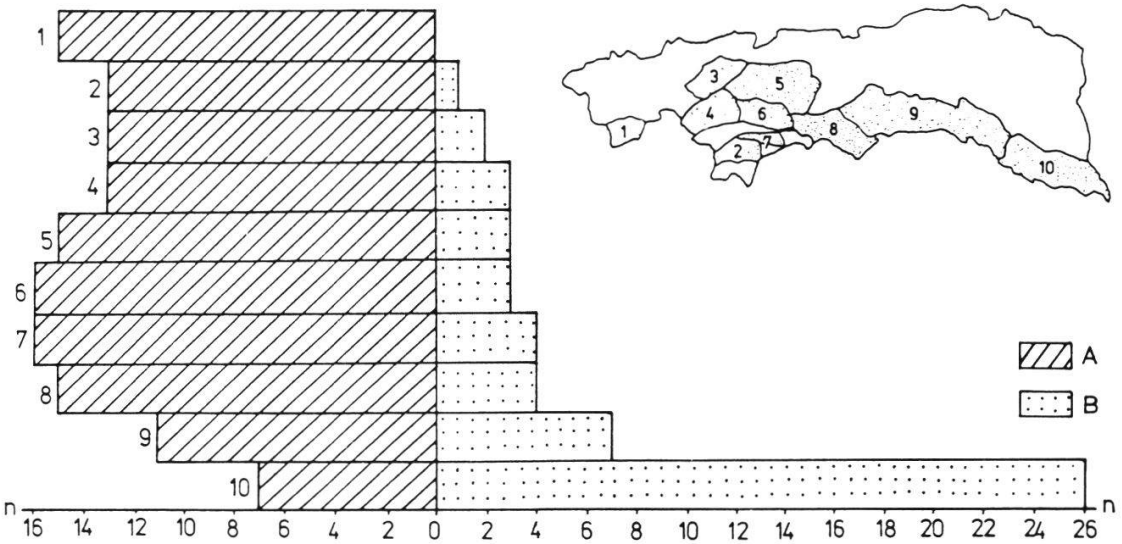

Fig. 10. Numbers of West-Carpathian (A) and East-Carpathian species (B) in single ranges of the Polish Carpathians.
Mountain ranges and their location on the map: 1 - Wielka Racza, 2 - Wzniesienie Gubalowskie, 3 - Polica, 4 - Dzialy Orawskie, 5 - Beskid Wyspowy, 6 - Gorce, 7 - Pas Skalicowy, 8 - Beskid Sadecki, 9 - Beskid Niski, 10 - Bieszczady.

bina). Moreover, in the Pieniny Mts. numerous thermophilous plants occur which are very rare or lacking completely in the Tatras and Beskidy Mts. (e.g. *Teucrium montanum*). In contrast to the Tatra and Pieniny Mts., the distinctiveness of the Beskidy district is considerably less pronounced. There are only a few rare species which, in the Carpathians occur exclusively in the Beskidy Mts. Of particular interest are: *Botrychium lanceolatum*, found in the Gorce range; *Cerastium alpinum* and *Laserpitium archangelica* confined only to the Babia Gora massif.

5. DIFFERENTIATION AND ALTITUDINAL ARRANGEMENT OF VEGETATION

Changes in climatic conditions on an altitudinal gradient (Fig. 5) and parallel changes both in the distribution of species (Table 1) and vegetation units (Table 2) resulted in the distinction of six vegetation belts in the Western Carpathians. With some exceptions, they show the same pattern over the whole Carpathians (Fig. 11). Altitudinal boundaries between vegetation belts usually differ slightly from one Carpathian range to another, depending on their massiveness, elevation and geographical location. On moving southward, these boundaries run at higher altitudes.

The upper limit of the submontane belt, being a transition belt between the lowlands and the mountains, varies from (400)450-550(650) m a.s.l. in the Polish Western Carpathians. The natural plant cover of the submontane belt has been strongly altered or destroyed under man's influence. Originally this area was covered by forest communities, mainly oak-hornbeam forest (*Tilio-Carpinetum*) in damp, fertile habitats and mixed oak-pine forests (*Pino-Quercetum*) in dry, acid habitats. Moreover, in flooded habitats, carrs (of *Alno-Padion* and *Salicion* alliances) and alder forest (*Carici elongatae-Alnetum*) occurred. Anthropogenic communities prevail in the landscape. Natural woodlands have been replaced by meadows and cultivated fields or artificial pine monocultures. In fertile, damp habitats, the oat-grass meadow (*Arrhenatheretum elatioris*) dominates. On wet soils the two most common meadow associations appear to be *Cirsietum rivularis* and *Cirsio-Polygonetum*; in some places *Molinietum medioeuropaeum* has developed.

The lower montane belt reaches to 1150(1180) m a.s.l. in the Beskidy Mts. and to 1200(1250) m a.s.l. in the Tatras. In damp, fertile habitats, beech-fir woods (*Dentario glandulosae-Fagetum*) prevail and fir forests (*Galio-Abietetum*) are also present. In poor habitats, the proportion of acidophilous fir-

Table 1. Altitudinal ranges of tree, shrub and shrublet species in the Polish Western Carpathians.

Species	Vegetation belts					
	sub montane	lower montane	upper montane	sub alpine	alpine	subnival
Evonymus verrucosa						
Quercus sessilis						
Evonymus europaea						
Quercus robur						
Rhamnus catharticus						
Salix alba						
Populus nigra						
Carpinus betulus						
Cornus sanguinea						
Hedera helix						
Prunus spinosa						
Tilia cordata						
Tilia platyphyllos						
Padus avium						
Rubus caesius						
Sambucus nigra						
Rubus plicatus						
Lonicera xylosteum						
Berberis vulgaris						
Salix cinerea						
Myricaria germanica						
Acer platanoides						
Rosa canina						
Cotoneaster nebrodensis						
Cotoneaster niger						
Salix pentandra						
Ulmus glabra						
Arctostaphylos uva-ursi						
Oxycoccus quadripetalus						
Andromeda polifolia						
Taxus baccata						
Ledum palustre						
Ribes uva-crispa						
Populus tremula						
Betula pendula						
Pinus silvestris						
Salix purpurea						
Sorbus aria						
Rubus hirtus						
Salix aurita						
Salix caprea						
Juniperus communis						
Sorbus aucuparia var. *aucuparia*						

Table 1 (continued)

Species	sub montane	lower montane	upper montane	sub alpine	alpine	subnival
Salix elaeagnos						
Alnus incana						
Fagus silvatica						
Acer pseudoplatanus						
Abies alba						
Larix decidua						
Sambucus racemosa						
Vaccinium uliginosum						
Empetrum nigrum						
Ribes alpinum						
Ribes petraeum var. *carpaticum*						
Oxycoccus microcarpus						
Lonicera nigra						
Cotoneaster integerrima						
Rosa pendulina						
Clematis alpina						
Sorbus chamaemespilus						
Rubus saxatilis						
Betula pubescens ssp. *carpatica*						
Picea abies						
Salix silesiaca						
Dryas octopetala						
Salix jacquini						
Sorbus aucuparia var. *glabrata*						
Pinus cembra						
Juniperus nana						
Pinus mugo						
Daphne mezereum						
Rubus idaeus						
Padus avium ssp. *petraea*						
Salix bicolor						
Salix hastata						
Salix helvetica						
Helianthemum chamaecistus ssp. *glabrum*						
Calluna vulgaris						
Empetrum hermaphroditum						
Helianthemum chamaecistus ssp. *grandiflorum*						
Salix reticulata						
Vaccinium myrtillus						
Vaccinium vitis-idaea						
Vaccinium gaultherioides						
Salix kitaibeliana						
Salix herbacea						

Table 2. Scheme of the vegetation belts and the main plant communities in the Polish Western Carpathians.

Vegetation belt	Plant community
subnival	*Oreochloetum distichae subnivale* (only on pure crystalline rock)
alpine	*Oreochloo distichae subnivale* (pure crystalline rock); *Festuco versicoloris-Seslerietum tatrae* (calcareous rock)
subalpine (dwarf pine belt)	*Pinetum mughi carpaticum*
upper montane	*Plagiothecio-Piceetum* (pure crystalline rock, flysch); *Polysticho-Piceetum* (calcareous rock)
lower montane	*Dentario glandulosae-Fagetum, Galio-Abietetum, Abieti-Piceetum montanum*
submontane	*Tilio-Carpinetum, Pino-Quercetum*

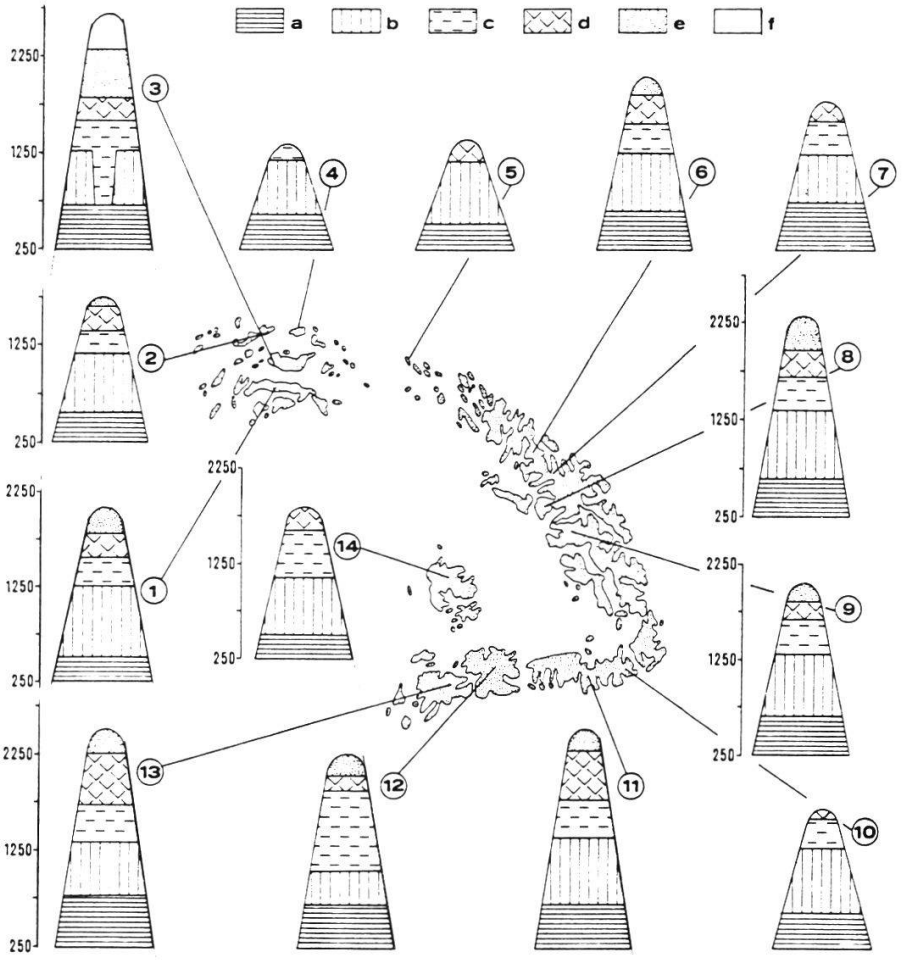

Fig. 11. Altitudinal vegetation belts in single Carpathian ranges (compiled from various sources).
1 - the Nizne (Lower) Tatras, 2 - Babia Gora, 3 - the Tatras, 4 - Gorce, 5 - Bieszczady, 6 - Czarnohora, 7 - Czywczynskie Mts., 8 - Rodnianskie Mts., 9 - Kelimenskie Mts., 10 - Siriu, 11 - Bucegi, 12 - Sebesului, 13 - Retezat, 14 - Vladeasa; vegetation belts: a - submontane, b - lower montane, c - upper montane, d - subalpine, e - alpine, f - subnival.

spruce forests (*Abieti-Piceetum*) is considerable. Beech-fir woods are widespread in the whole Carpathian range, occurring at high altitudes in the Beskidy Mts. The lower sites there are usually occupied by fir woods and artificial spruce forests. In the Tatras, the *Dentario glandulosae-Fagetum* community is attached to the calcareous substratum. In the flooded valley bottoms along the rivers, the grey alder carr (*Alnetum incanae*) thrives and in wet habitats the grey alder bog association (*Caltho-Alnetum*) occurs. Mainly two hay-meadow communities are widespread in the fertile habitats of the lower montane belt in the Western Carpathians: *Gladiolo-Agrostietum* and *Cirsietum rivularis*. In acid habitats, poor grasslands of the *Nardetalia* order develop. Moreover, small patches of mires (*Valeriano-Caricetum flavae*) of the *Scheuchzerio-Caricetea fuscae* class are frequent.

The upper montane belt ranges from 1150(1180)-1390 m a.s.l. in the Beskidy Mts. and from 1200(1250) to 1550 m a.s.l. in the Tatras. The spruce forests of the order *Vaccinio-Piceetalia* dominate in this belt. They display a differentiation related to the geological substratum.

The subalpine belt, with *Pinus mugo* shrubs (*Pinetum mughi carpaticum*) ranges in the Tatras from the upper timberline to 1800 m a.s.l., and in the Beskidy Mts., in the two highest massifs, Babia Gora and Pilsko, from 1390 to 1650 and 1557 m a.s.l., respectively.

The alpine belt ranges from 1800 m to 2300 m a.s.l. in the Tatras and from 1650 m to the summit of the Babia Gora massif. It is dominated by high-mountain grasslands of the order *Seslerietalia variae* on calcareous rock and of the order *Caricetalia curvulae* on siliceous rock.

The subnivale belt developed only in the Tatras from 2300 m to the highest summits. This belt is characterized by the association *Oreochloetum distichae subnivale* (= *Distichetum subnivale*) of the order *Caricetalia curvulae*. The high-mountain communities and their vertical ranges in the Tatra Mts. are described by MIREK and PIEKOS-MIRKOWA (1992c).

6. FLORA

6.1. RICH DIVERSITY

The Carpathian flora differs considerably from that of the surrounding lowlands. The fundamental difference is the great share of mountain species in the spectrum of the Carpathian flora (Fig. 7). Numerous species which used to be common in lowlands have become rare or lacking in the Carpathians.

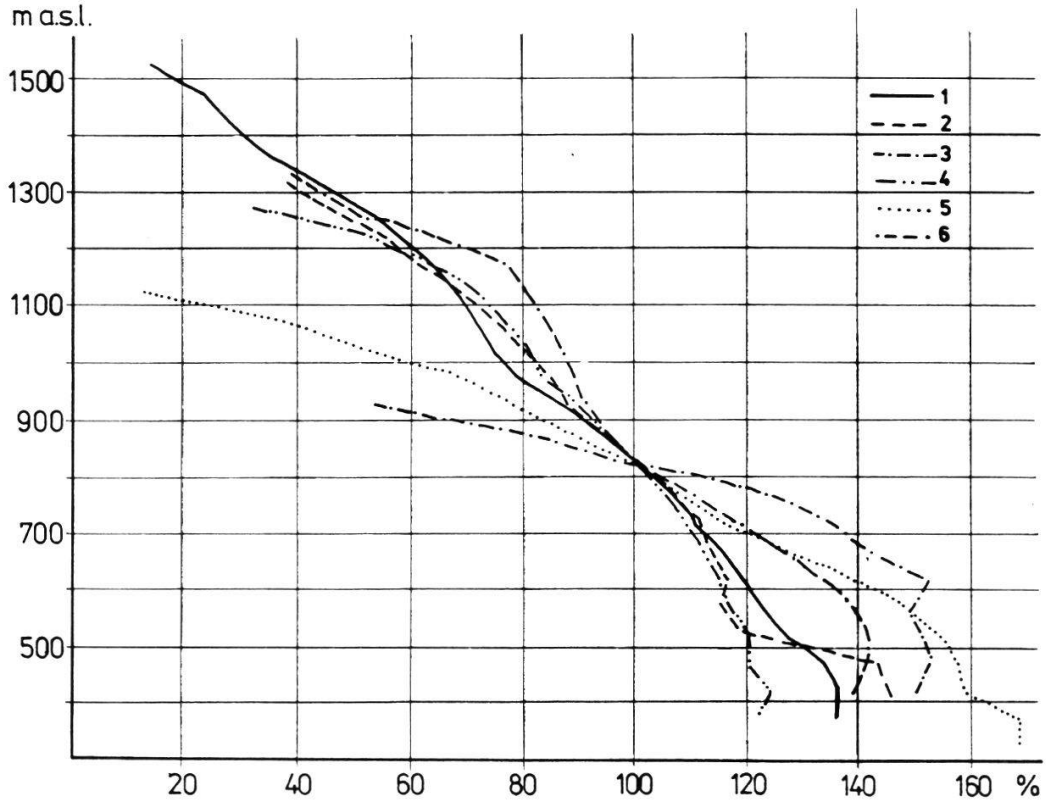

Fig. 12. Decrease of the native vascular species with the rise of altitude above sea level in some ranges of the Polish Carpathians (the number of species occurring between 800 and 850 m a.s.l. has been accepted as 100% (cf. Fig. 15), BIALECKA 1982, slightly modified). 1 - Pilsko, 2 - Polica, 3 - Dzialy Orawskie, 4 - Gorce, 5 - Beskid Wyspowy, 6 - Bieszczady.

The Carpathian flora comprises nearly 1700 vascular plant species, about 75% of the 2300 species occurring in Poland. The number of species in Carpathian ranges varies from 800 to 1000 species, exceeding this number in the mountain groups with great denivelations or with a differentiated geological substratum. In general, the number of vascular plant species decreases gradually (Fig. 12). This phenomenon is illustrated by BIALECKA (1982) for the Beskidy Mts. and by MIREK and PIEKOS-MIRKOWA (1992c) for the Tatras.

6.2. ALTITUDINAL ELEMENTS - MOUNTAIN SPECIES

Plant species can be divided into three main groups according to their altitudinal ranges: lowland species, lowland-mountain species, and mountain species. The latter is the most characteristic element of the Carpathian flora. Further division of montane species, according to their type of altitudinal distribution

is described in detail by MIREK (1990) and MIREK and PIEKOS-MIRKOWA (1992a) with respect to the Tatra Mts. Of the 1700 vascular plant species occurring in the Polish Carpathians, about 450 (26%) represent mountain species. Their number and participation in the local flora depend on the altitude of the particular Carpathian ranges. Forty to fifty mountain species (5% of the total flora), and sometimes more occur in the Carpathian Foothills. There are submontane, montane and multizonal species, whereas the high-mountain species (subalpine, alpine and subnivale) are lacking. In the Beskidy Mts., the number of mountain species varies from 60 to 100 (120), making up 10-15% of the local flora (Fig. 13). In the Beskidy highest ranges, the Babia Gora massif makes an exception with 200 species and the Bieszczady Mts. (the

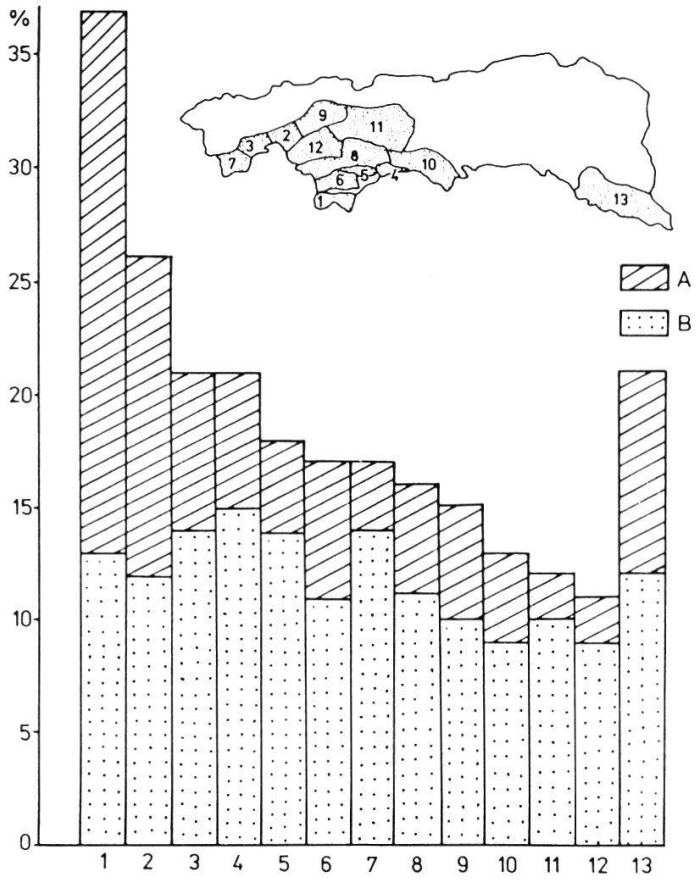

Fig. 13. Percentual participation of the mountain species in the flora of single ranges of the Polish Carpathians.
A - high-mountain species, B - multizonal and mountain species.
Mountain ranges and their location on the map: 1 - the Tatras, 2 - Babia Gora, 3 - Pilsko, 4 - Pieniny, 5 - Pas Skalicowy, 6 - Wzniesienie Gaubalowskie, 7 - Wielka Racza, 8 - Gorce, 9 - Polica, 10 - Beskid Sadecki, 11 - Beskid Wyspowy, 12 - Dzialy Orawskie, 13 - Bieszczady.

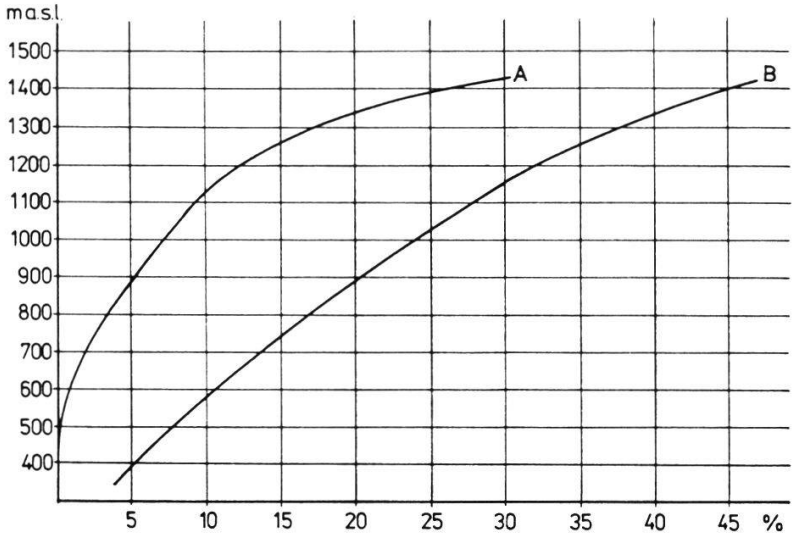

Fig. 14. Average proportion of high-mountain (A) and all mountain (B) species in the native flora at various altitudes in the Polish Western Beskidy Mts.

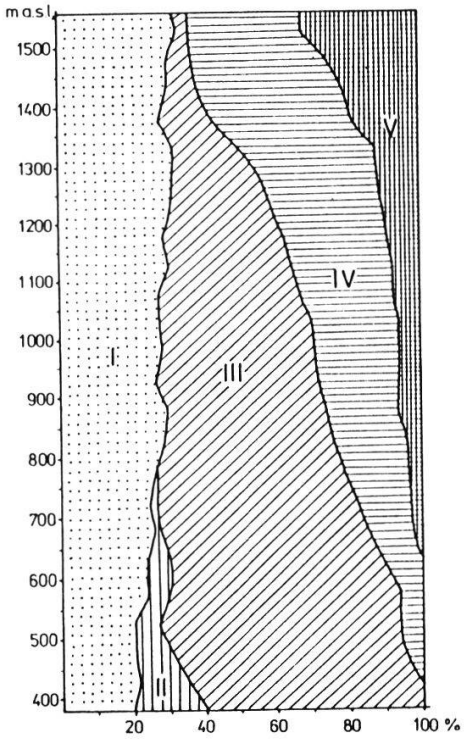

Fig. 15. Structure of the mountain flora of the Pilsko group in relation to altitude above sea level (the respective total number of mountain species in each altitude belt has been accepted as 100%) (BIALECKA 1982).
I - multizonal mountain, II - submontane, III - montane, IV - subalpine, V - alpine species.

Polish Eastern Carpathians) with 174. The Tatras appear to be the richest in mountain species with about 400 species (40% of the total Tatra flora). Altitudinal patterns of mountain species and their various groups are illustrated in Figs. 14 and 15.

6.3. GEOGRAPHICAL ELEMENTS

Most lowland and lowland-mountain species occurring in the Polish Western Carpathians represent one of three geographical elements:

1. the Central-European element (e.g. *Dentaria bulbifera, Digitalis grandiflora*)
2. the Euro-Siberian element (e.g. *Pinus silvestris, Daphne mezereum, Majanthemum bifolium*)
3. the Circum-Boreal element (e.g. *Adoxa moschatellina, Equisetum silvaticum, Pirola minor*)

Other elements (i.e. Sub-Atlantic and Pontic) play a small part with only a few rare plant species.
The mountain species are divided into three main elements:

1. Arctic-Alpine and Boreal-Mountain (Fig. 16)
2. Central-European (Fig. 17)
3. Endemic to the Carpathians (Chapter 6.4)

The Arctic-Alpine element comprises about 50 high-mountain species, most of them confined to the Tatra Mts. (e.g. *Lloydia serotina, Luzula spicata, Juncus triglumis, Silene acaulis*). Only a few are more widely distributed in the Western Carpathians; e.g. *Diphasium alpinum* (Fig. 16) and *Poa alpina* which occur in the Tatras and in the higher ranges of the Carpathians (e.g. Babia Gora massif, Pilsko, Gorce range).
Plants belonging to the Central-European element form the most fundamental component of the Carpathian flora. Numerous montane and high-mountain species represent this element. Typical examples of montane species of the Central-European element are: *Abies alba, Aruncus silvestris* and *Lonicera nigra* (Fig. 17). They are widespread throughout the whole Western Carpathians. Most species occurring above timberline in the Western Carpathians belong to the high-mountain group within the Central-European element. They exhibit various distribution patterns. Numerous species are widely distributed in all Central-European mountains (*Geum montanum, Pinus mugo, Potentilla aurea*). The second big group is made up of species restricted to the Alps (mostly to the eastern part) and the Carpathians (e.g. *Cerastium latifolium,*

Dianthus glacialis, Salix jacquinii [Fig. 17]). A small number of species represent the Carpatho-Balkan distributional type (e.g. *Linum extraaxillare, Senecio carpaticus*).

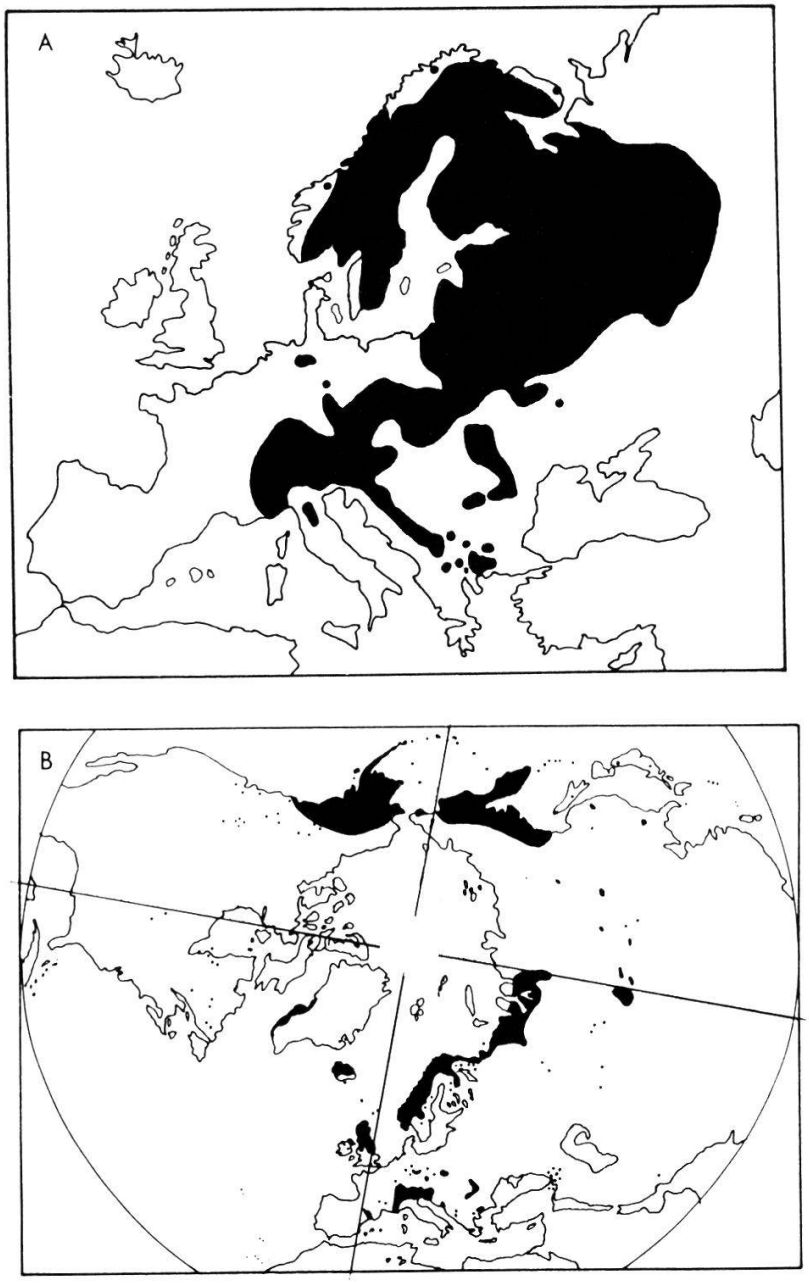

Fig. 16. Distribution patterns of boreal-mountain (A) and arctic-alpine (B) species in the Polish Carpathians.
A - *Picea abies* (BORATYNSKA et al. 1980), B - *Diphasium alpinum* (MEUSEL et al. 1965, slightly modified).

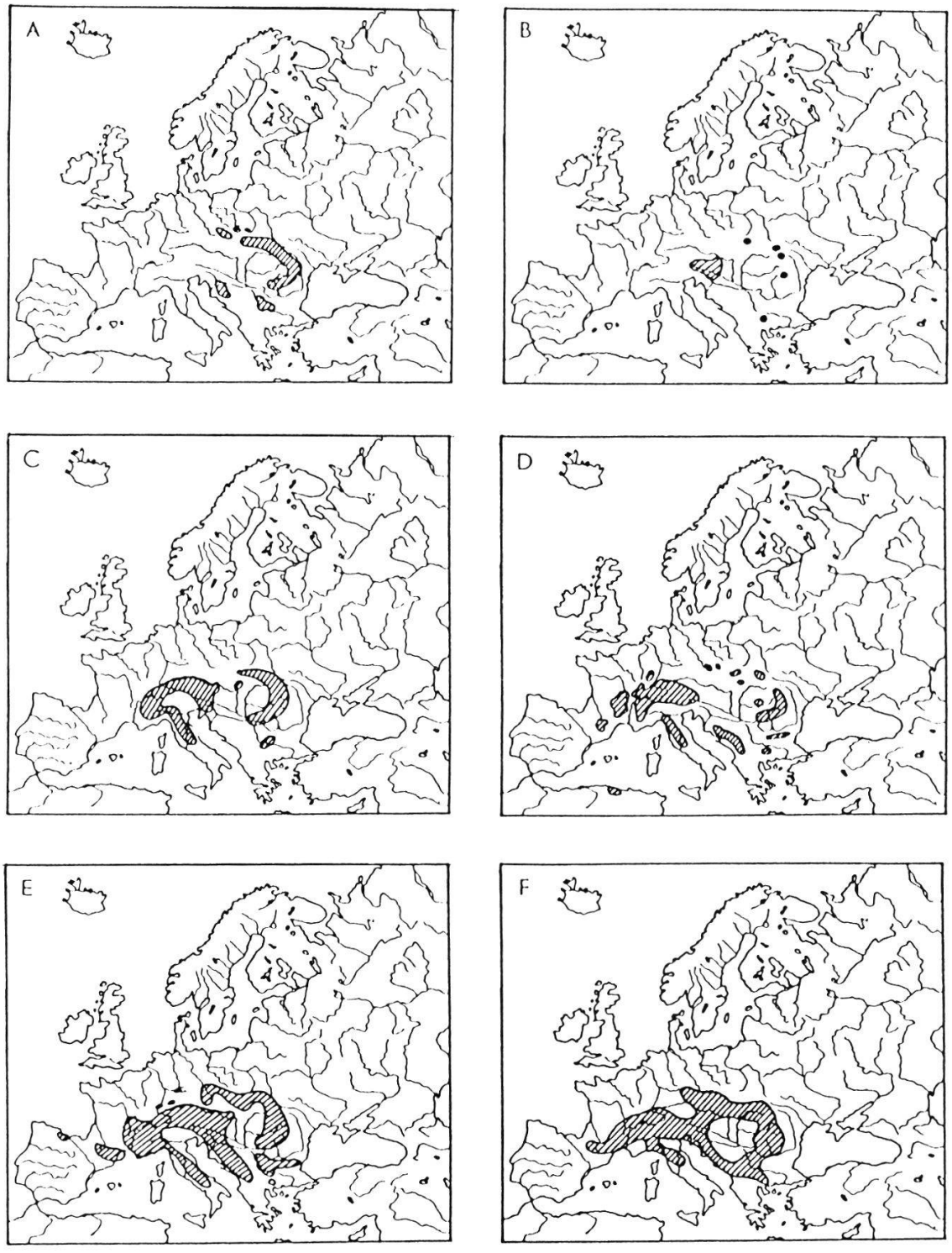

Fig. 17. Distribution patterns of Central-European mountain species in the Carpathians. A - *Salix silesiaca* (ZIELINSKI 1976), B - *Salix jacquinii* (BROWICZ and GOSTYNSKA-JAKUSZEWSKA 1970), C - *Clematis alpina* (BROWICZ and GOSTYNSKA-JAKUSZEWSKA 1966), D - *Ribes petraeum* (BORATYNSKI and BROWICZ 1976), E - *Rosa pendulina* (BROWICZ and GOSTYNSKA-JAKUSZEWSKA 1968), F - *Lonicera nigra* (BROWICZ and GOSTYNSKA-JAKUSZEWSKA 1967).

6.4. ENDEMISM

The degree of endemism in the flora of Europe, in particular considering old endemics of the Tertiary age, is closely related to the maximum extent of the Fenno-Scandinavian ice sheet in the Pleistocene (Fig. 18). This explains the fact that the flora of Poland is poor in endemic species and communities, most of which are found only in the Carpathians (Fig. 19). In contrast to the Alps, the Carpathians as a whole have far fewer endemics (Table 3). This discrepancy arose partially because the Carpathians are lower than the Alps and have much less area above timberline (Fig. 20). Moreover, in the Pleistocene, the Scandinavian ice sheet extended at its maximum quite close to the Carpathians (Figs. 1 and 18), whereas the closest it came to the Alps was 800 km.

PAWLOWSKI (1970), who has dealt with endemism of the vascular flora of the Alps and Carpathians, compiled a list comprising 452 species endemic and subendemic to the Alps and 146 to the Carpathians. Based on investigations carried out by HENDRYCH (1982) the number of species endemic and subendemic to the Carpathians has been supplemented and increased from 146 to

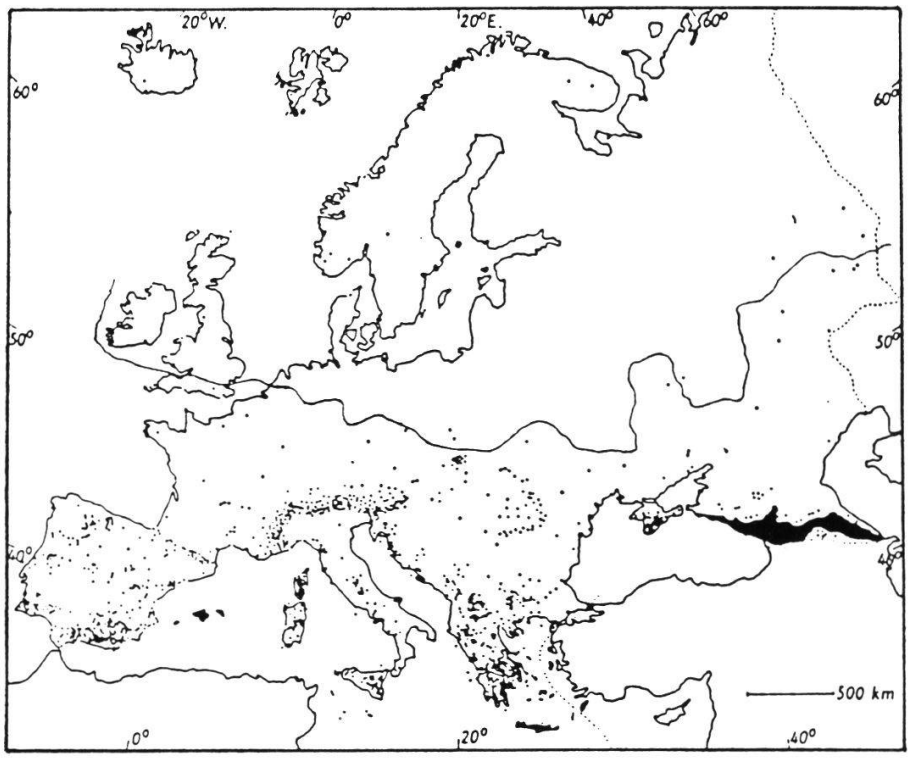

Fig. 18. Synoptical cartogram of the dislocation of highly stenochoric to monotopic endemic species in Europe. The southern limit of the greatest glaciation is marked with a solid line (HENDRYCH 1982).

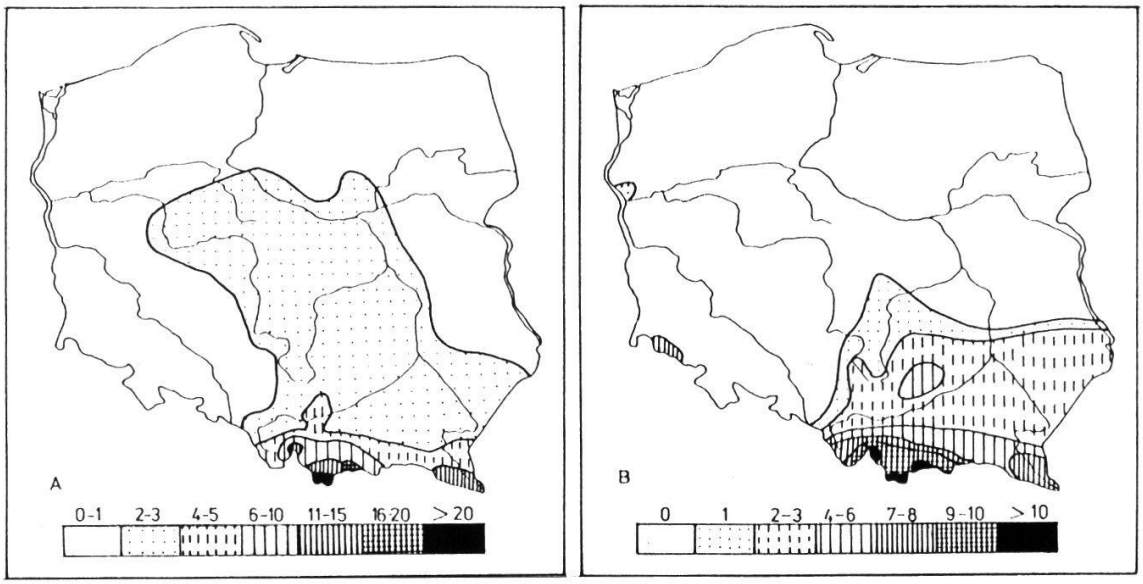

Fig. 19. Endemic vascular plant species (A, original) and endemic communities (B, MATUSZKIEWICZ 1991) in Poland.

Table 3. Comparison of endemism in the flora of the Alps and the Carpathians.

	Alps	Carpathian Mts.
Endemic species	333	117
Subendemic species	119	32
Total	452	149
Endemic genera and sections	33	11

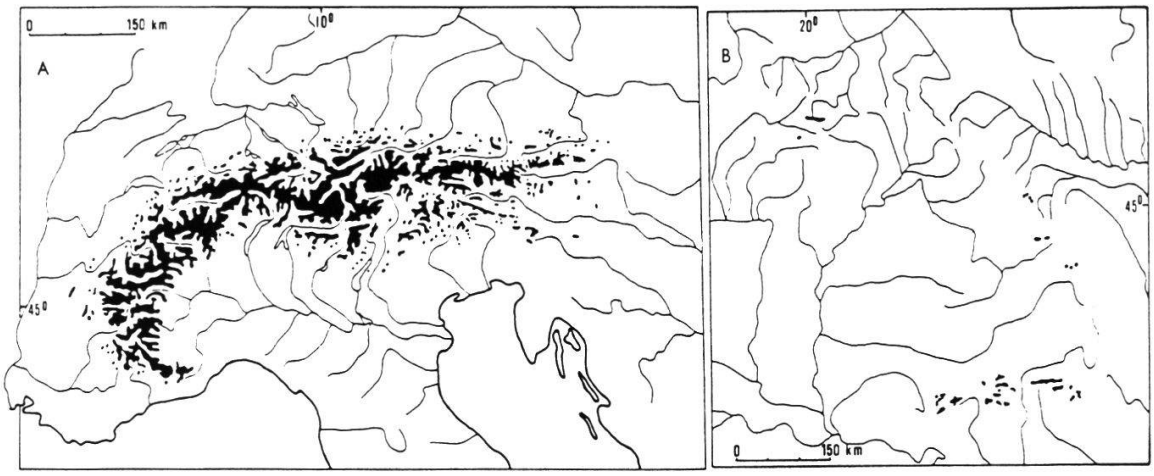

Fig. 20. Comparison of the Alps (A) and the Carpathians (B).
Areas elevated above 2000 m a.s.l. are marked black (PAWLOWSKI 1970).

149. Besides Linnean species there are numerous endemic microspecies of the genera: *Alchemilla, Hieracium, Rubus, Taraxacum* etc., and taxa below the rank of a species (subspecies, varietas) which have not been taken into account.

In the Polish Carpathians 45 endemic and subendemic species have been recorded. They represent 2.6% of the whole vascular flora of the Polish Carpathians. Among them are ten of the twelve Pan-Carpathian endemic species: *Cardaminopsis neglecta* (Schult.) Hay., *Erigeron nanus* Schur (Fig. 21), *Erysimum wittmannii* Zaw., *Festuca carpatica* Dietr. (Fig. 21), *Leontodon pseudotaraxaci* Schur, *Oxytropis carpatica* Uechtr., *Poa granitica* Br.-Bl., *Salix kitaibeliana* Willd., *Thymus pulcherrimus* Schur and *Trisetum fuscum* Kit. Besides endemics, 13 of the 15 Pan-Carpathian subendemic species are found in the Polish Carpathians: *Aconitum moldavicum* Hacq., *Campanula polymorpha* Witasek, *Campanula serrata* (Kit.) Hendrych, *Centaurea mollis* W. et K., *Dentaria glandulosa* W. et K., *Erigeron macrophyllus* Herb., *Euphrasia tatrae* Wettst., *Festuca varia* Haenke (Fig. 21), *Leucanthemum waldsteinii* (Schultz Bip.) Pouzar, *Melampyrum herbichii* Wol., *Petasites kablikianus* Tausch, *Saxifraga carpatica* Rchb., and *Symphytum cordatum* W. et K. (Fig. 22). In comparison to the 99 species endemic and subendemic to the Eastern Carpathians, the Western Carpathians' 23 species is strikingly low. The Western Carpathians form the most northerly situated part of the whole Carpathian chain. It is probable that their plant cover was strongly damaged during quaternary glaciation, resulting in comparatively few old and young endemic species.

The following three Western Carpathian endemics are usually considered to be from the Tertiary age: *Saxifraga wahlenbergii* Ball (Fig. 21), *Delphinium oxysepalum* Borb. et Pax (Fig. 21), *Dianthus nitidus* W. et K.; a few others (e.g. *Soldanella carpatica* Vierh. [Fig. 21], *Dianthus praecox* W. et K.) probably developed directly from the Carpathian taxa living there in the Tertiary age. Moreover, five other West Carpathian endemics (e.g. *Carduus lobulatus* Borb., *Cerastium tatrae* Borb., *Festuca tatrae* Borb., *Pulsatilla slavica* G.Reuss, *Sesleria tatrae* [Czako] Degen) and three subendemic species (*Knautia kitaibelii* [Schult.] Borb., *Ranunculus pseudomontanus* Schur, *Thymus carpaticus* Cel.) are encountered within the Polish boundaries. Of the numerous East Carpathian species, only two endemics (*Euphorbia carpatica* Wol., *Melampyrum saxosum* Bmg.) and two subendemics (*Aconitum lasiocarpum* Rchb., *Senecio papposus* [Rchb.] Less.) from Poland have been recorded. Some endemic species are confined to one Carpathian range only.

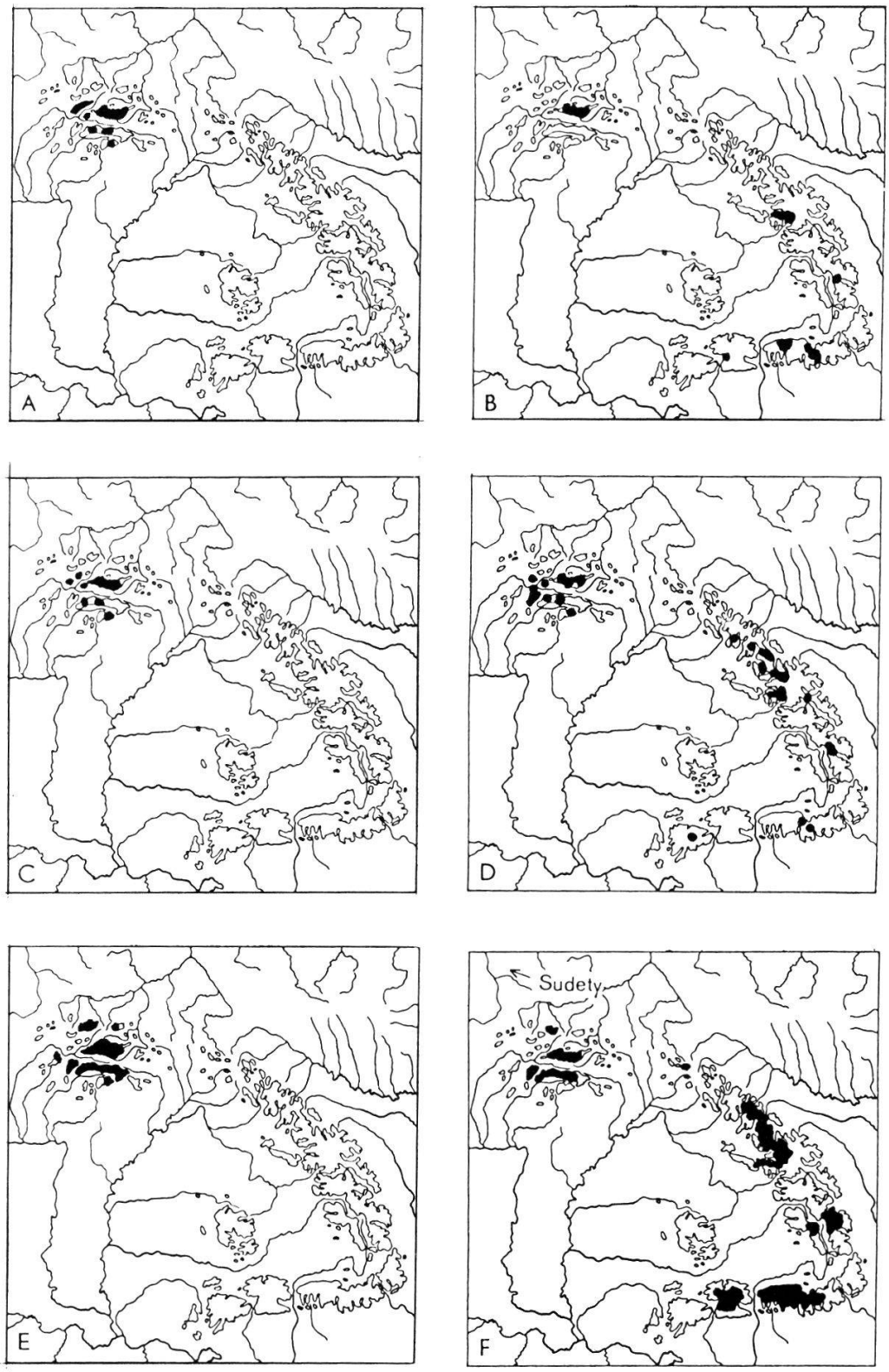

Fig. 21. West-Carpathian (A, C, E) and Pan-Carpathian endemic (B, D) and subendemic (F) species.
A - *Saxifraga wahlenbergii*, B - *Erigeron nanus*, C - *Delphiniun oxysepalum*, D - *Festuca carpatica*, E - *Soldanella carpatica*, F - *Festuca varia*.

Within the Polish Carpathians, *Erysimum pieninicum* (Zap.) Pawl. and *Taraxacum pieninicum* Pawl. are endemic to the Pieniny Mts., whereas *Poa nobilis* Skalinska is endemic to the Tatra Mts. and two other species (*Cochlearia tatrae* Borb. and *Papaver tatricum* [Nyarady] Ehrend.) are subendemics. The numbers of endemic and subendemic species which occur in the Carpathian ranges are given in Fig. 23.

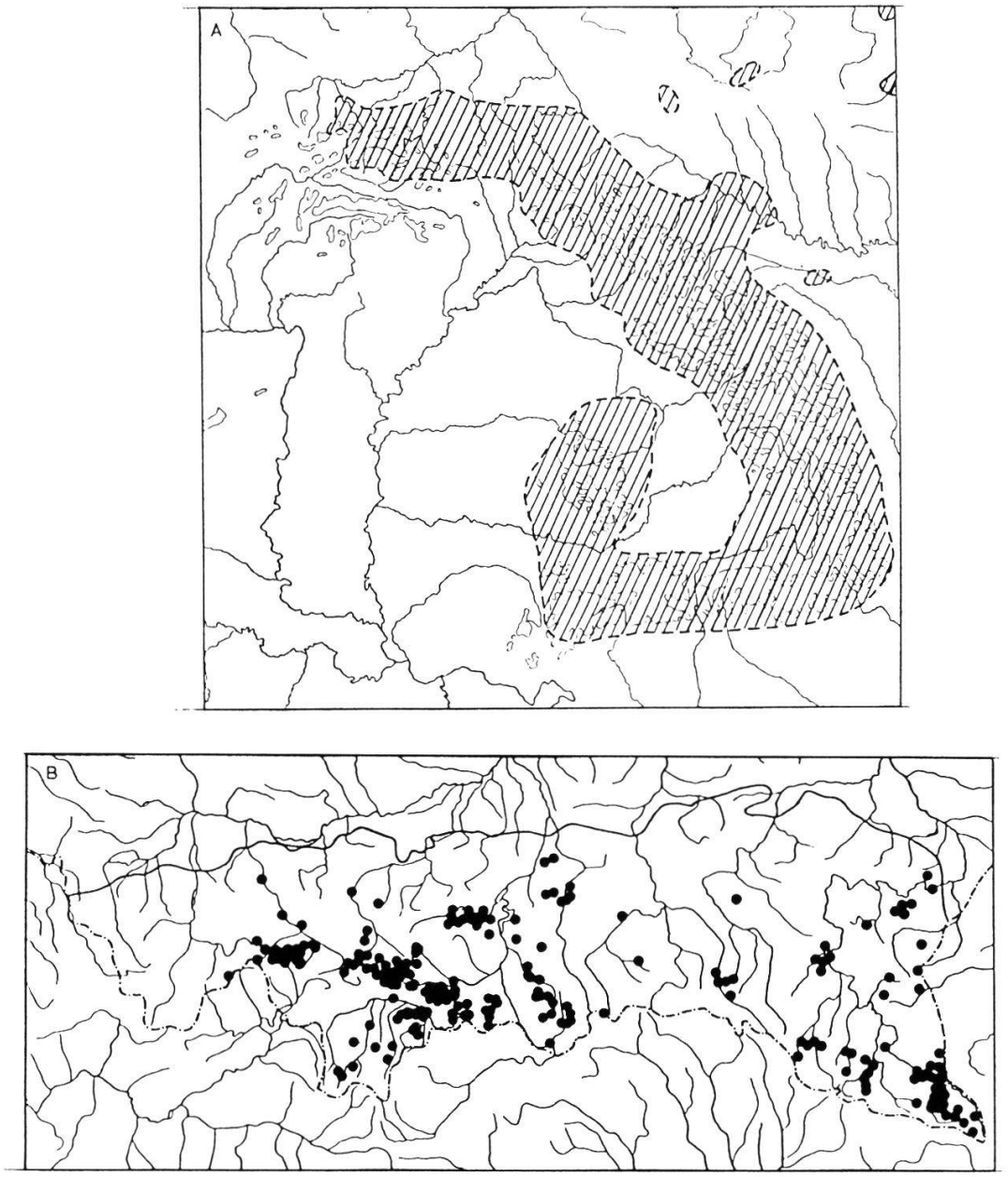

Fig. 22. Distribution maps of the Pan-Carpathian subendemic species *Symphytum cordatum*.
A - general distribution (PAWLOWSKI 1970, slightly modified), B - local distribution in the Polish Carpathians (KORNAS 1966, supplemented).

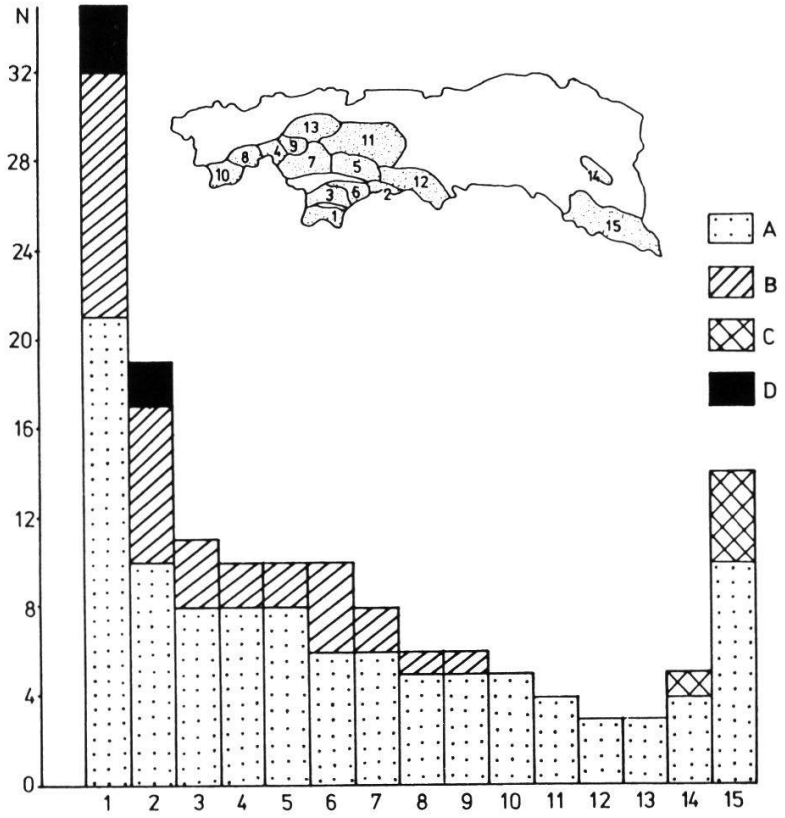

Fig. 23. Endemic and subendemic species in single Carpathian ranges.
A - Pan-Carpathian endemics, B - West-Carpathian endemics, C - East-Carpathian endemics, D - species endemic to the Tatras or Pieniny Mts.
Mountain ranges and their location on the map: 1 - the Tatras, 2 - the Pieniny Mts., 3 - Wzniesienie Gubalowskie, 4 - Babia Gora, 5 - Gorce, 6 - Pas Skalicowy, 7 - Dzialy Orawskie, 8 - Pilsko, 9 - Polica, 10 - Wielka Racza, 11 - Beskid Wyspowy, 12 - Beskid Sadecki, 13 - Beskid Maly, 14 - Slonne Mts., 15 - Bieszczady.

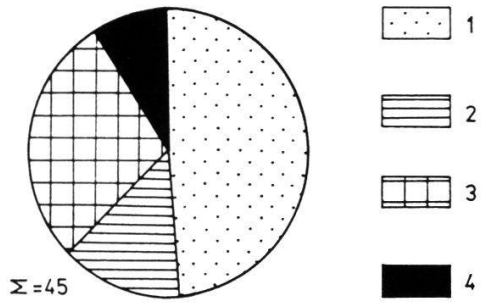

Fig. 24. Grouping of the Carpathian endemics and subendemics according to the altitudinal elements.
1 - alpine species, 2 - subalpine species, 3 - montane species, 4 - multizonal mountain species.

The Tatra Mts., as the highest Carpathian chain, constitute a prominent centre of endemism within the Western Carpathians, having the largest number of endemic and subendemic species. Nine West Carpathian and seven Pan-Carpathian endemics or subendemics are restricted in Poland to the Tatra Mts. The Pieniny Mts., a small calcareous chain, appear to be a centre for the second largest concentration of endemic species. In contrast to the Tatra and Pieniny Mts., the Beskidy Mts. are much poorer in endemics. Endemic species occur in all vegetation belts. Of the 45 endemics and subendemics found in the Polish Carpathians, 28 are high-mountain species (22 alpine and six subalpine), 13 are montane species and four multizonal species (Fig. 24). Most of the endemics are associated with rock and scree vegetation, alpine grasslands, snow patch vegetation, tall-herb and tall-grass communities. Only three species are connected with forest communities.

6.5. SPECIES OF PARTICULAR INTEREST

The presence of numerous endemic taxa points to the distinctiveness of the Carpathian flora. Apart from the endemics, some other species are of particular interest. Of these species the most interesting is *Dendranthema zawadzkii* (Herb.) Tzvel., in Europe only represented by one isolated relic site in the Pie-

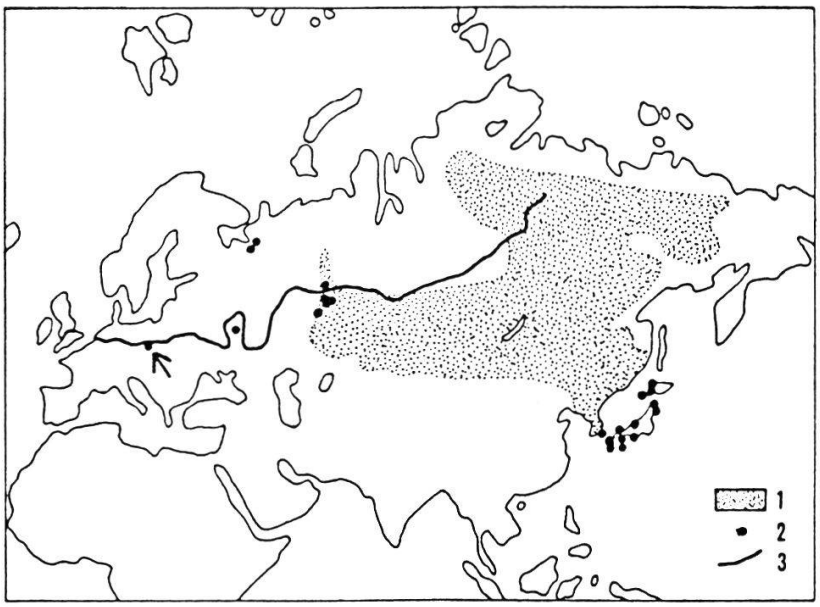

Fig. 25. Distribution of *Dendranthema zawadzkii* (Herb.) Tzvel. (ZARZYCKI 1976).
1 - sites according to "Flora of the U.S.R.R.", 2 - precisely located sites on the margin of distribution area, 3 - southern limit of the greatest glaciation. The arrow denotes the locality in the Pieniny Mts.

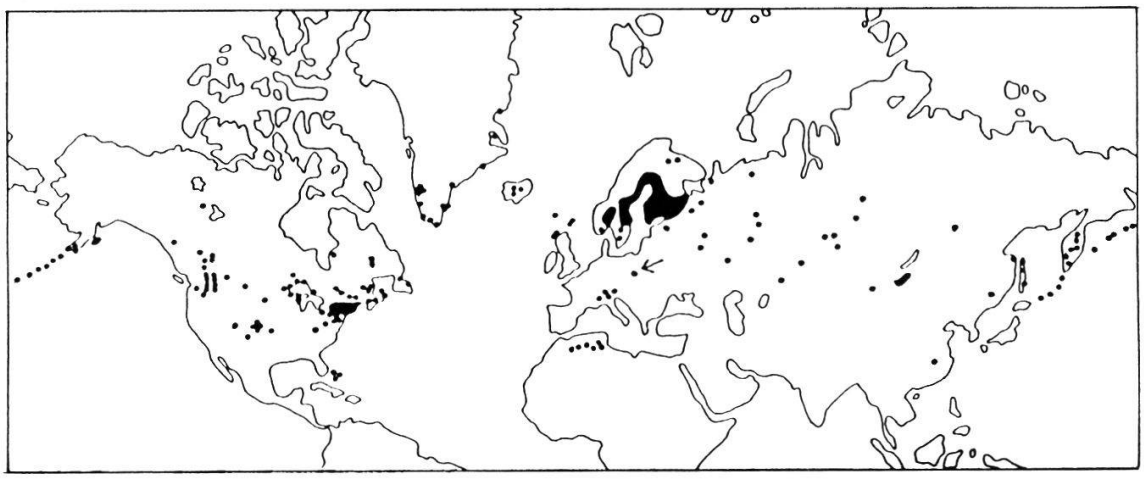

Fig. 26. Geographical distribution of *Botrychium lanceolatum* (Gmel.) Angstroem (MEUSEL et al. 1965, slightly modified). The arrow denotes the locality in the Carpathians.

niny Mts. (ZARZYCKI 1976). The next closest site is in the Central Russian Highlands near Kursk (Fig. 25). Three other extremely rare species found in the Carpathians, *Dryopteris villarsii* (Bellardi) Woynar ex Schinz et Thell., *Sibbaldia procumbens* L. and *Sparganium affine* L., have been recorded only in the Tatras. The next known sites are in the Alps.
Moreover, two species which recently died out in their only sites in the Carpathians should be mentioned. They are *Botrychium lanceolatum* (Gmel.) Angstroem (Fig. 26), recorded in the Gorce range (the Beskidy Mts.) and *Saxifraga hirculus* L., was restricted to the Sub-Tatra region. A third very rare species, *Ligularia sibirica* (L.) Cass., has disappeared from its only site in the Western Carpathians, in the Sub-Tatra region.

6.6. LOCAL PATTERNS OF DISTRIBUTION

Numerous species, (e.g.*Vaccinium myrtillus, Deschampsia flexuosa*) able to grow in various habitats from the foothills to the highest summits, are very common and widely distributed over the whole Polish Carpathians. Contrary to them, many species having a more or less narrow ecological amplitude, exhibit limited distribution closely related to the occurrence of suitable habitats. The species representing the *Oxycocco-Sphagnetea* class show almost the same distribution pattern (Fig. 27) and indicate the regions where the raised bogs are to be found in the Polish Carpathians.
A specific distribution pattern is represented by thermophilous species. Their

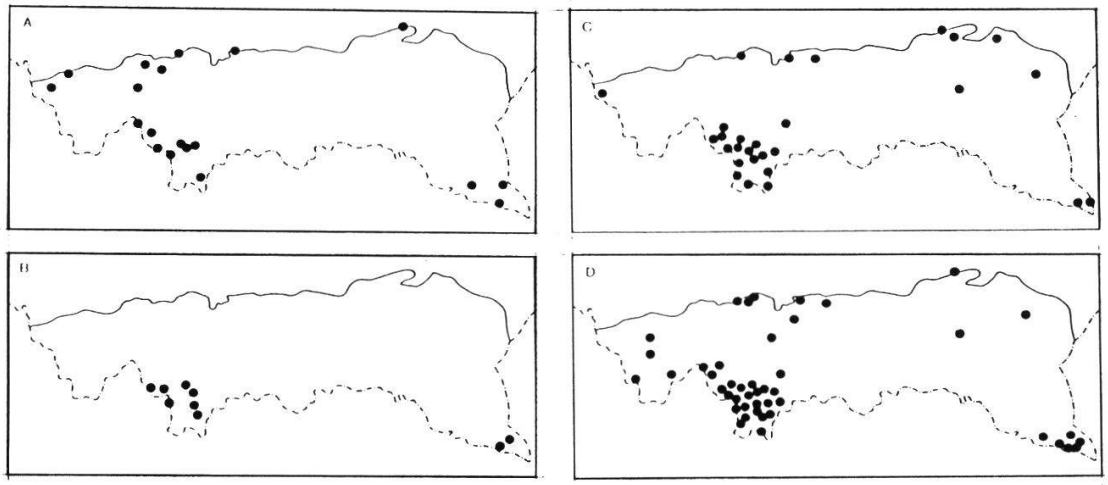

Fig. 27. Distribution of the raised peat bog species in the Polish Carpathians.
A - *Andromeda polifolia* (BROWICZ and GOSTYNSKA-JAKUSZEWSKA 1974), B - *Oxycoccus microcarpus* (GOSTYNSKA-JAKUSZEWSKA and HANTZ 1980), C - *Ledum palustre* (BORATYNSKI and BROWICZ 1976), D - *Oxycoccus quadripetalus* (GOSTYNSKA-JAKUSZEWSKA and HANTZ 1980).

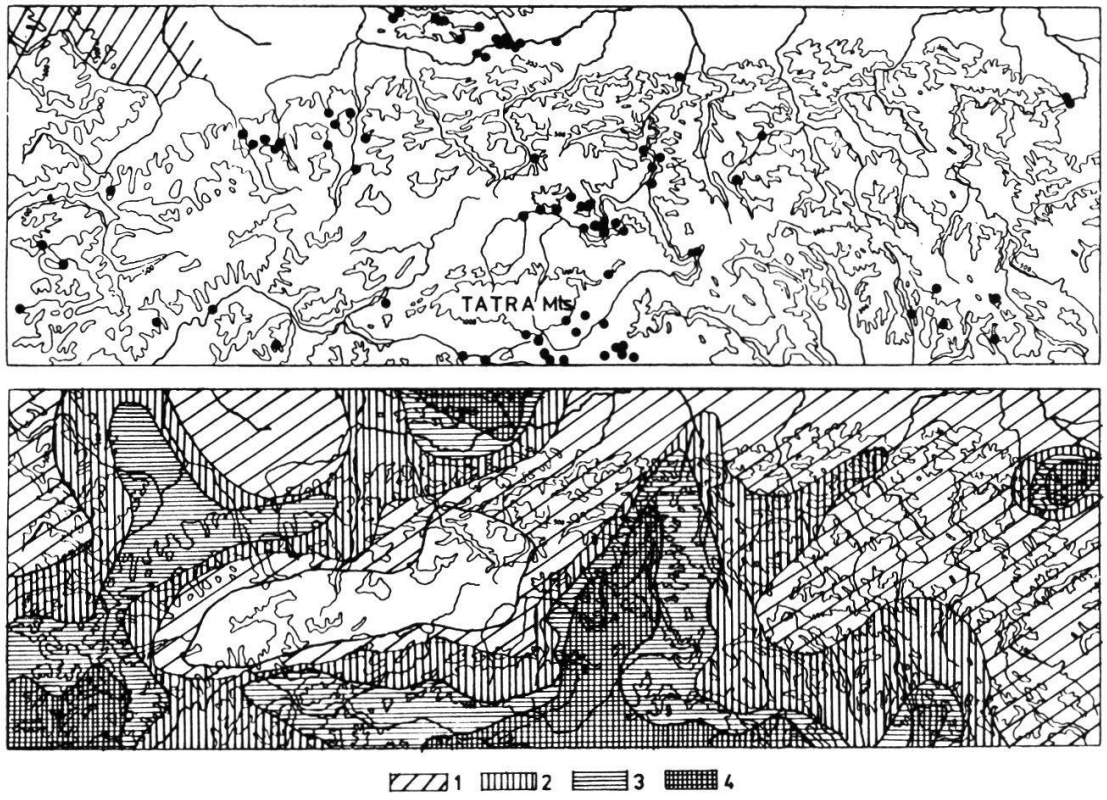

Fig. 28. Distribution of thermophilous species *Polygala comosa* (top) and density of localities of other 13 xerothermophilous plants (bottom) (*Ajuga genevensis, Allium montanum, Anthemis tinctoria, Anthericum ramosum, Brachypodium pinnatum, Bupleurum falcatum, Centaurea scabiosa, Coronilla varia, Inula conyza, Inula salicina, Iris graminea, Lathyrus niger,* and *Lathyrus tuberosus*) in the Polish Carpathians.
1 =1-3, 2 = 4-6, 3 = 7-9, 4 = 10-13 species.

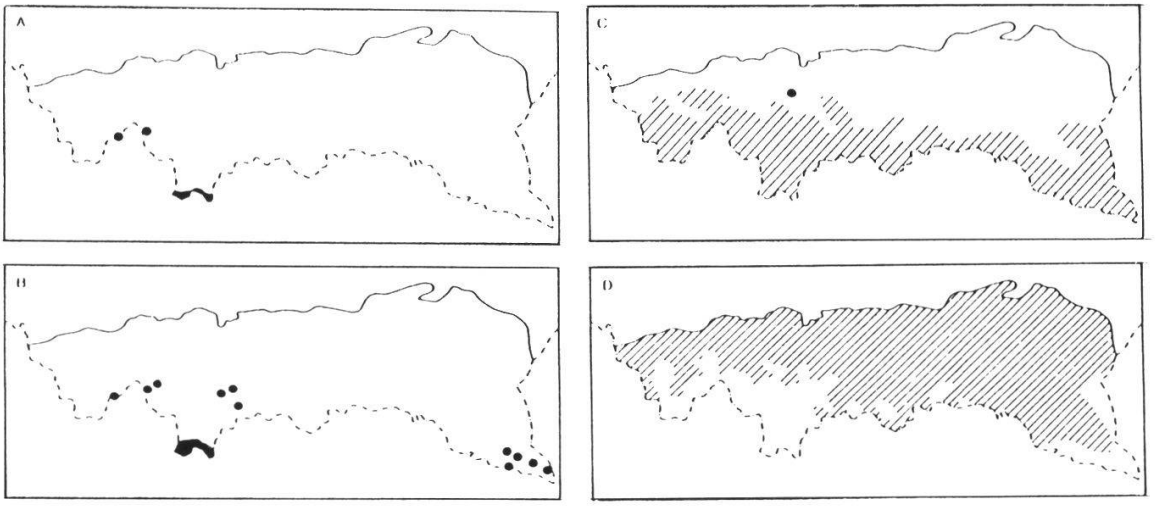

Fig. 29. Distribution of species characteristic to various vegetation belts in the Polish Carpathians.
A - alpine *Salix herbacea*, B - subalpine *Ribes petraeum* (BORATYNSKI and BROWICZ 1976), C - montane *Lonicera nigra* (BROWICZ and GOSTYNSKA-JAKUSZEWSKA 1976), D - lowland and submontane *Carpinus betulus* (GOSTYNSKA-JAKUSZEWSKA 1976).

occurrence (Fig. 28) concentrates in the warmest regions and indicates the main routes of their migration from the south-west (the Moravian Gate) and from the south (gorges of the Dunajec and Poprad river valleys, as well as in the greatest 'depression' between the Western and Eastern Carpathians).
Other distribution patterns (Fig. 29) are demonstrated by the species limited to the particular vegetation belts (see also Fig. 4A).

7. CONSERVATION OF THE PLANT COVER

The differentiation of the plant cover in the Polish Carpathians resulted in a network of established and proposed national parks, reserves and landscape parks (Fig. 30). They preserve the most valuable elements of flora and plant communities, characteristic of the Carpathians. At present the national parks and reserves cover not more than 2% of the Polish Carpathian territory. There are four national parks situated in the Western Carpathians and one in the Eastern Carpathians. Besides national parks, 83 reserves have been hitherto established in the Polish Carpathians to preserve endemic, relic, rare and threatened plant species as well as alpine vegetation, fragments of primeval or natural forest communities and peat bogs. Moreover, 978 valuable or unique nature objects throughout the Carpathian chain in Poland are protected as nature monuments (ALEXANDROWICZ 1989). Of about 1700 vascular plant spe-

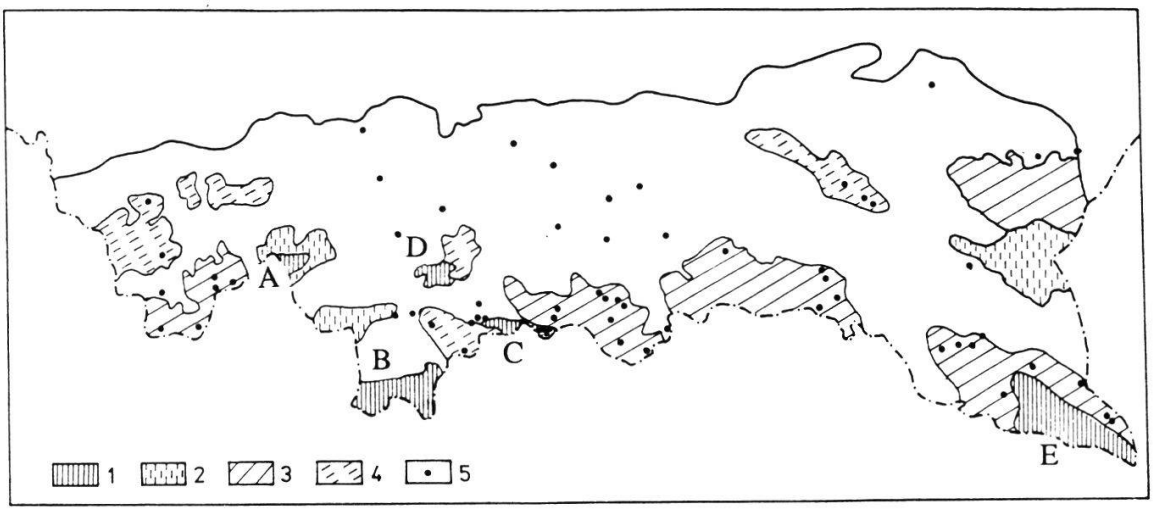

Fig. 30. Protected areas in the Polish Carpathians.
1 - national parks, 2 - projected national parks, 3 - landscape parks, 4 - projected landscape parks, 5 - nature reserves (outside of the national parks).
A - Babia Gora National Park, B - Tatra National Park, C - Pieniny National Park, D - Gorce National Park, E - Bieszczady National Park (compiled from ALEKSANDROWICZ 1989 and other sources).

cies recorded from the Polish Carpathians, 146 species are legally protected, i.e. 65% of the total number of plant species under legal protection in Poland.

SUMMARY

The results of scientific research on the plant cover of the Polish Western Carpathians is summarized. The main features and differentiation of the flora and vegetation are characterized and illustrated with the use of numerous figures and maps. The presence of the Carpathian endemics and numerous mountain species points to the distinctiveness of the Carpathians, as compared with the adjacent lowlands.

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