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Directional northern element in the flora of vascular plants of Poland

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Abstract: The directional element is a local determinant of spatial diversity of flora of a given country, within widely understood geographical elements. In Poland, a country situated in the middle of Europe, most species belong to the transitional element (with no range limit in our country). Besides the transitional element, the directional northern element (with its southern limit in Poland) is present. It can be divided into two distinct groups: species that have their absolute southern range limit in Poland and those that have both southern and northern limits with a significant disjunction in Central Poland. Although they are two different groups, they will be discussed within the combined study. The first one constitutes 1.9% of the directional element, the second one 1.3%. As far as general ranges are concerned, Circumboreal and Eurosiberian species prevail in the first group, with a significant share of the taxa of geographical connective element. European-temperate taxa are the most numerous in the second group. The two above-mentioned groups will also be distinguished by their species belonging to the higher syntaxonomical units. Such a small share of the northern element in the flora of Poland confirms that our country belongs to the Central European Province, where the North-European element is, to a large extent, a relict of the earlier periods of the Holocene.

Key words: directional northern element, flora of Poland, vascular plants

1. Introduction

Within widely understood geographical elements, the spatial diversity of flora of a given country is locally determined by its directional elements. In the case of Poland, which is a Middle European country, most species represent a transitional element, with no range limits (Kornaś & Medwecka-Kornaś 2002; Pawłowska 1966, 1977). Most directional elements have already been worked out (e.g. Zając M. & Zając A. 2000, 2001, 2006).

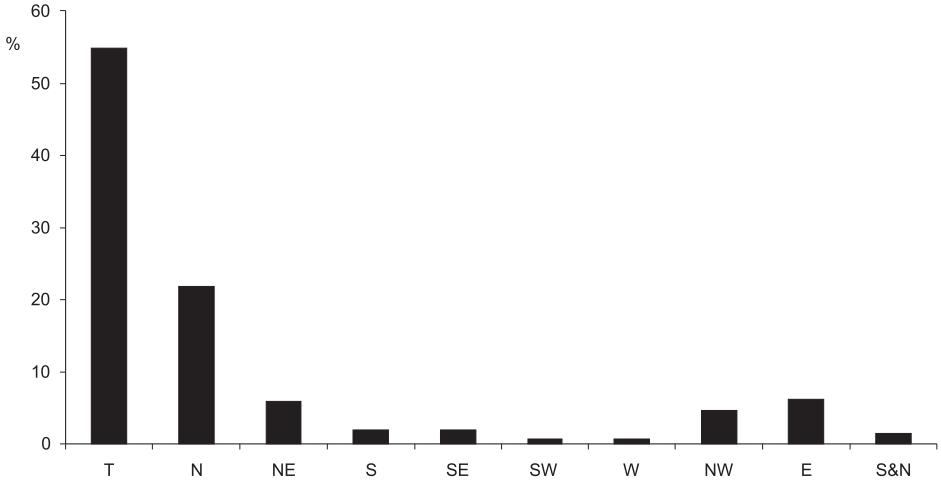

Fig. 1. Proportional contribution of directional elements in the flora of Poland
Explanations: T – transgressive species, N – with a northern limit, NE – with a north-eastern limit, SE – with a south-eastern limit, S – with southern limit, SW – with south-western limit, W – with western limit, NW – with north-western limit, E – with eastern limit, S & N – with southern and northern limit

A directional northern element (with its southern limit in Poland) has remained, while the southern one has its northern limit in Poland (covering most mountain species). The directional northern element can be divided into two explicit groups. The first one covers the species having their absolute southern range limit in Poland, while the second group covers those having both southern and northern limits with a significant disjunction in Central Poland. Although they are two different groups, they will be discussed within the common study. The first one constitutes a small percentage (1.9%) of the directional element, the second one being smaller (1.3%) (Fig. 1).

2. Material and methods

The data on the percentage of particular elements in the flora of indigenous vascular plants were calculated on the basis of the *Distribution Atlas of Vascular Plants in Poland* (Zając A & Zając M. 2001). The cartogram maps presented therein and covering above two thousand indigenous species, made it possible to determine percentages of particular directional elements. It is worth mentioning that these data only slightly differ from the calculations carried out by the authors of the works *Plant Geography* (Kornaś & Medwecka-Kornaś 2002), which were based on the data presented by Szafer *et al*. (1953). The lists of species were based on the above-mentioned atlas. In the first one, species which have their absolute southern limit in Poland were considered (Table 1), while the other one covered species having both their southern and northern limit in Poland separated from each other by a large disjunction (Table 2). No species were taken into consideration in the first list which occur on the very northwestern limit of Poland and tending to extend towards the West, as far as their general range is concerned. They were included in the directional western element and taken into account in a separate work (Zając M. & Zając A. 2006). There are no taxa on the list occurring in the Baltic Division, as they were classified within the eastern element and discussed along with it, whereby the reasons for such a separation were analyzed (Zając M. & Zając A. 2001), and with the comprehensive analysis of the eastern element (Zając M. & Zając A. 2000).

These lists were the basis for the collective maps which were prepared in RAR software (Zając A. & Zając M. 2001). On these maps, the circle diameter shows the species condensation in a given cartogram unit (the square root of the number of species was assumed in the calculation as the one which reflected the real participation of the taxa in the best way).

The species from the lists (Tables 1-2) were estimated in respect of their belonging to the geographical element and wide syntaxonomical units (classes). It was done on the basis of materials contained in the work concerning the geographical elements of the native flora of Poland (Zając M. & Zając A. 2009).

The names of taxa are given after the Mirek *et al*. (2002), but names of classes after Medwecka-Kornaś *et al*. (1966, 1972).

Table 1. Species of northern directional element with the absolute southern limit of distribution in Poland

Name of species	Name of species
Ammophila arenaria (L.) Link	*Littorella uniflora* (L.) Asch.
Angelica archangelica L. subsp. *litoralis* (Fr.) Thell.	*Lobelia dortmanna* L.
Aster tripolium L.	*Luronium natans* (L.) Raf.
Atriplex littoralis L.	*Myrica gale* L.
Atriplex calotheca (Rafn) Fr.	*Myriophyllum alterniflorum* DC.
Blysmus rufus (Huds.) Link	*Najas flexilis* (Willd.) Rost. & W. L. E Schmidt
Cakile maritima Scop.	*Nuphar pumila* (Timm) DC.
Centaurium littorale (Turner) Gilmour	*Petasites spurius* (Retz.) Rchb.
Carex atherodes Spreng.	*Plantago maritima* L. s. str.
Chamaedaphne calyculata (L.) Moench	*Potamogeton filiformis* Pers.
Cladium mariscus (L.) Pohl	*Potamogeton friesii* Rupr.
Dactylorhiza baltica (Klinge) N. I. Orlova	*Potamogeton ×nitens* Weber
Eryngium maritimum L.	*Rosa villosa* L.
Gagea spathacea (Hayne) Salisb.	*Rubus scissus* W. C. R. Watson
Glaux maritima L.	*Ruppia maritima* L.
Groelandia densa (L.) Fourr.	*Salsola kali* L. subsp. *kali*
Hammarbya paludosa (L.) Kuntze	*Samolus valerandi* L. subsp. *valerandi*
Hippophaë rhamnoides L.	*Saxifraga hirculus* L.
Honckenya peploides (L.) Ehrh.	*Schoenoplectus ×kalmusii* (Abrom., Asch. & Graeb.) Palla
Isoëtes echinospora Durieu	*Silene tatarica* (L.) Pers.
Isoëtes lacustris L.	*Sonchus palustris* L.
Juncus balticus Willd.	*Sparganium angustifolium* F. Michx.
Juncus gerardi Loisel.	*Stellaria crassifolia* Ehrh.
Lathyrus japonicus Willd. subsp. *maritimus* (L.) P. W. Ball	*Triglochin maritimum* L.
Linaria odora (M. Bieb.) Fisch.	

Table 2. Species of northern directional element with a southern and northern limits of distribution in Poland

Name of species	Name of species
Aconitum variegatum L. subsp. *variegatum*	*Carex pulicaris* L.
Ajuga pyramidalis L.	*Carex supina* Wahlenb.
Adonis vernalis L.	*Centaurea phrygia* L.
Alchemilla baltica Sam. ex Juz.	*Coeloglossum viride* (L.) Hartm.
Alchemilla crinita Buser	*Corallorhiza trifida* Châtel.
Alchemilla cymatophylla Juz.	*Dentaria bulbifera* L.
Alchemilla glaucescens Neygenf	*Empetrum nigrum* L. s. str.
Alchemilla plicata Buser	*Gentiana cruciata* L.
Alchemilla walasii Pawł.	*Hordelymus europaeus* (L.) Jess. ex Harz
Allium ursinum L.	*Listera cordata* (L.) R. Br.
Arnica montana L.	*Lunaria rediviva* L.
Aster amellus L.	*Luzula sylvatica* (Huds.) Gaudin
Baeothryon alpinum (L.) T. V. Egorova	*Malaxis monophyllos* (L.) Sw.
Baeothryon cespitosum (L.) A. Dietr.	*Orchis mascula* (L.) L. subsp. *signifera* (Vest) Soó
Batrachium baudotii (Godr.) Bosch	*Oxytropis pilosa* (L.) DC.
Bupleurum longifolium L.	*Pleurospermum austriacum* (L.) Hoffm.
Campanula sibirica L.	*Polygonatum verticillatum* (L.) All.
Cardamine hirsuta L.	*Rubus chamaemorus* L.
Carex pauciflora Lightf.	*Rubus pedemontanus* Pinkw.

3. Results

The northern geographical element reaching its southern distributional limit in Poland, was composed of various taxa. On the one hand, they included species whose occurrence was related with the Baltic coast or oligotrophic lakes in the Pomerania. As numerous lakelands occur in the northern part of Poland, there were also some species from lakes and eurotrophic waters there, for which the climate of the region was adequate. The time and the route of arrival of these taxa to northern Poland was a very significant factor which, simultaneously, was mostly unknown. Unfortunately no molecular research was carried out in this field. If there were some data available regarding at least several species, then some stronger hypotheses could be presented in the conclusion of this work. 49 species were found reaching their southern limits in Poland that belonged to the directional northern element (Table 1).

Principally, the whole of the northern part of Poland lies in the Baltic Division of the Province of Lowland-Highland Central European area of the Euro-Siberian region. A number of taxa mentioned in Table 1 are characteristic for this Division and constitute its phytogeographical features.

As expected, the species having their southern limits in Poland, showed wide ranges. It was confirmed by the analysis of their membership to the geographical element. Most of them were taxa belonging to Circum-Boreal and Euro-Siberian sub-element and covered approx. 50 per cent of the items on the list (Fig. 2). The share of the European-temperate sub-element was also

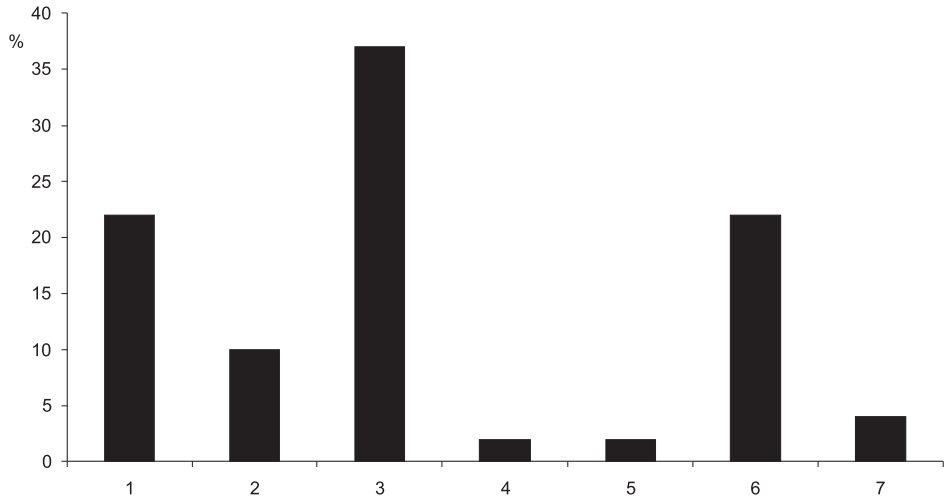

Fig. 2. Proportional contribution of species of northern directional element with absolute southern limit in geographical elements
Explanations: 1 – species of European-temperate-sub-element, 2 – species of Euro-Siberian sub-element, 3 – species of Circum-Boreal sub-element, 4 – species of Altaic-Alpic sub-element, 5 – species of Amphi-Atlantic sub-element, 6 – species of connective sub-element, 7 – cosmopolitan species

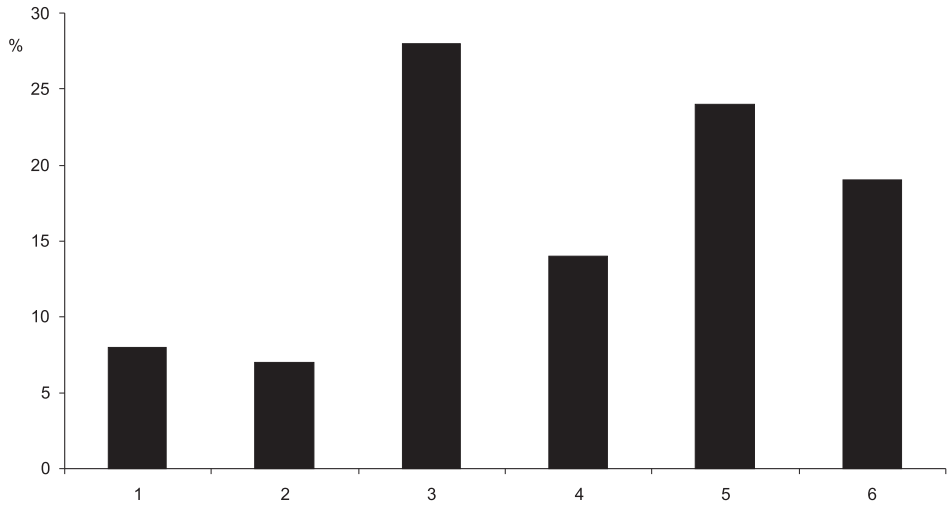

Fig. 3. Proportional contribution of species of northern directional element with absolute northern limit to various habitats
Explanations: 1 – species of costal dunes, 2 – swamp species, 3 – halophytic species, 4 – species of raised and transition bogs, 5 – aquatic species, 6 – species of others habitats

significant. It was interesting to find out what species they belonged to. A significant part of them were taxa whose range was related to the Atlantic part of Europe and had their eastern range extensions on the Baltic Sea coast. They comprised such taxa as e.g. *Ammophila arenaria*, *Myriophyllum alterniflorum*, *Luronium natans* and others. A number of the species belonging to the Connective Element had the Atlantic region in their range diagnostics. The ranges of several species belonging to this sub-element were confined to the northern part of Europe. They included such taxa as *Atriplex calotheca*, *Juncus balticus* and others.

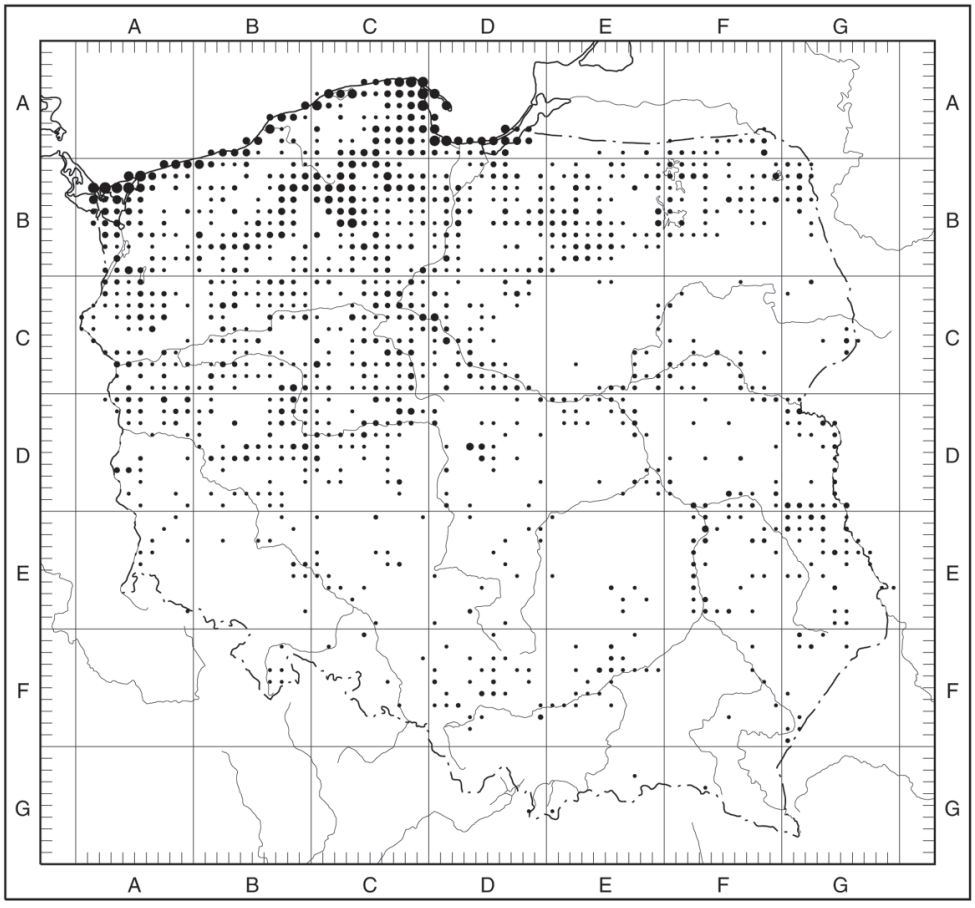

Fig. 4. Collective map of species of northern directional element with the absolute southern limit in Poland

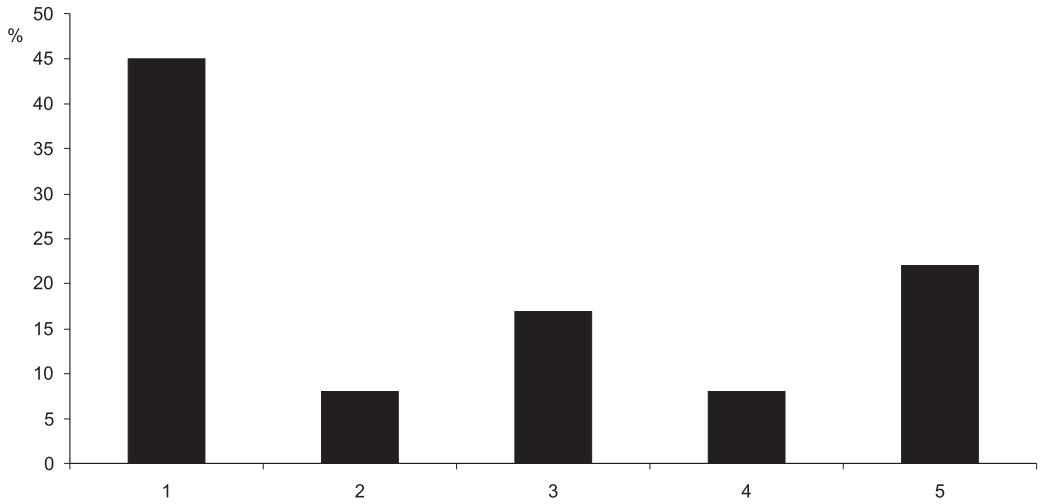

Fig. 5. Proportional contribution of species of northern directional element with southern and northern limit in geographical elements
Explanations: 1 – species of European-temperate-sub-element, 2 – species of Euro-Siberian sub-element, 3 – species of Circum-Boreal sub-element, 4 – species of Arctic-Alpine sub-element, 5 – species of connective element

Summarizing; the species of the northern element showed wide ranges covering Holarctis or the Euro-Siberian area and, if they belonged to the European-temperate sub-element, they were linked to the Atlantic part of Europe or even to the Baltic Sea basin with respect to their general range.

They belonged to different syntaxonomical classes. Using high units at the level of classes, none of them could be distinguished where most species could be grouped together. As shown in Fig. 3, there were only some preferences to be shown 28 per cent of them occurred with the seashore communities and with the habitats showing a higher sodium chloride content. They comprised communities from *Asteretea tripoli* and *Cakiletea maritime* classes. 7 per cent of the species occurred in communities from *Ammophiletea arenariae* class. A significant percentage of the species (24%) was linked to water macrophyte communities from *Potametea* and *Litorelletea* classes or to the communities depending on the level of water, such as swamp communities and peat-bogs (14% of the species) from *Phragmitetea australis* or *Scheuchzerio-Caricetea nigrae* and *Oxycocco-Shagnetea* classes. Some single species occurred in communities of other classes. In principle, the syntaxonomical analysis showed specificity and unity of the group.

The collective map drawn up for the species from Table 1 showed (Fig. 4) the largest condensation of the species from directional northern element to occur on the Baltic Sea coast. Then, after a slight discontinuity, a smaller condensation could be noticed in the belt of moraines in Pomerania. An explicit border appeared running diagonally through Poland from north-west (from the southern limits of Wielkopolska up to the

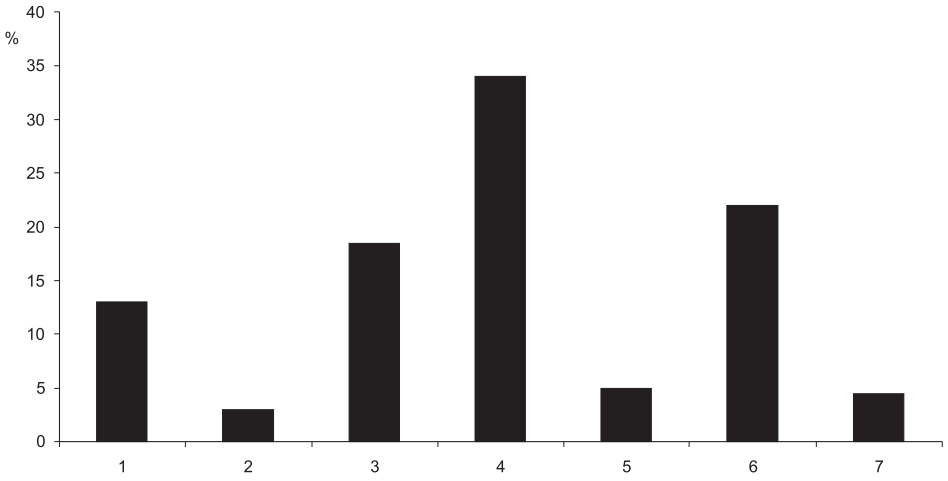

Fig. 6. Proportional contribution of species of northern directional element with southern and northern limit to various habitats
Explanations: 1 – species of raised and transition bogs, 2 – aquatic species, 3 – meadow species, 4 – thermophytic species of open habitats, 5 – tall herb species, 6 – woodland species, 7 – species of others habitats

western limits of the Baltic Division). Some scattered locations of the species reached the foreland of the Carpathians and Sudetes. It was related, inter alia, with the fact that a number of species, e.g. the halophytic ones, reached the southern limits of Małopolska Upland.

The species from the other list (Table 2) belong to the taxa reaching their southern limit in the northern part of Poland and, at the same time, to those reaching their northern limit in the southern part of our country. An explicit disjunction could be seen in the belt of lowlands of Central Poland. Certainly, this directional element did not belong to the northern one, but it formed a separate group showing decisively different properties. This group included 38 species. Their membership in the geographical element, as shown in Fig. 5, can be presented in the following way. Approximately half of the species belong to the European-temperate sub-element (45%), while the remaining ones have wider ranges, i.e. 17% belong to circumboreal sub-element and 8% to the Euro-Siberian sub-element. The species of Arctic-Alpine range showed a similar percentage. The share of connective species (22%) was also significant and covered, apart from Central Europe, also the regions of northern Mediterranean Sea coast and the Pontic-Pannonian Province. In can be noticed in Fig. 6 that their habitats were more diversified. They occurred in different open, thermophytic habitats i.e. sand communities of inland dunes from class *Sedo-Scleranthetea* (7%), xerothermic grasslands from class *Festuco-Brometea* (19%) and communities of low grasslands on infertile soils from class *Nardo-Callunetea* (8%), but also and in various meadows communities from class *Molinio-Arrhenathretea* (18,5%). Among the open communities, they had a significant share in peatbogs from class *Scheuchzerio-Caricetea nigrae* and *Oxycocco-Shagnetea* (13%). They also occurred in tall herbs communities from class *Betulo-Adenostyletea* (5%) and in various types of forests from deciduous up to coniferous ones from class *Querco-Fagetea* and *Vaccinio-Piceetea* (22%).

The difference between the discussed group and the species of the directional northern element, with respect to their habitats (Fig. 6), remained characteristic. There were no aquatic and some other types of plants among the species having two limits in Poland and linked to seashore communities (pioneer communities of coastal sand-dunes and halophytic communities). However, there were forest species. Moreover, there was one essential difference within the group of taxa with two limits; numerous mountain species occurred. They

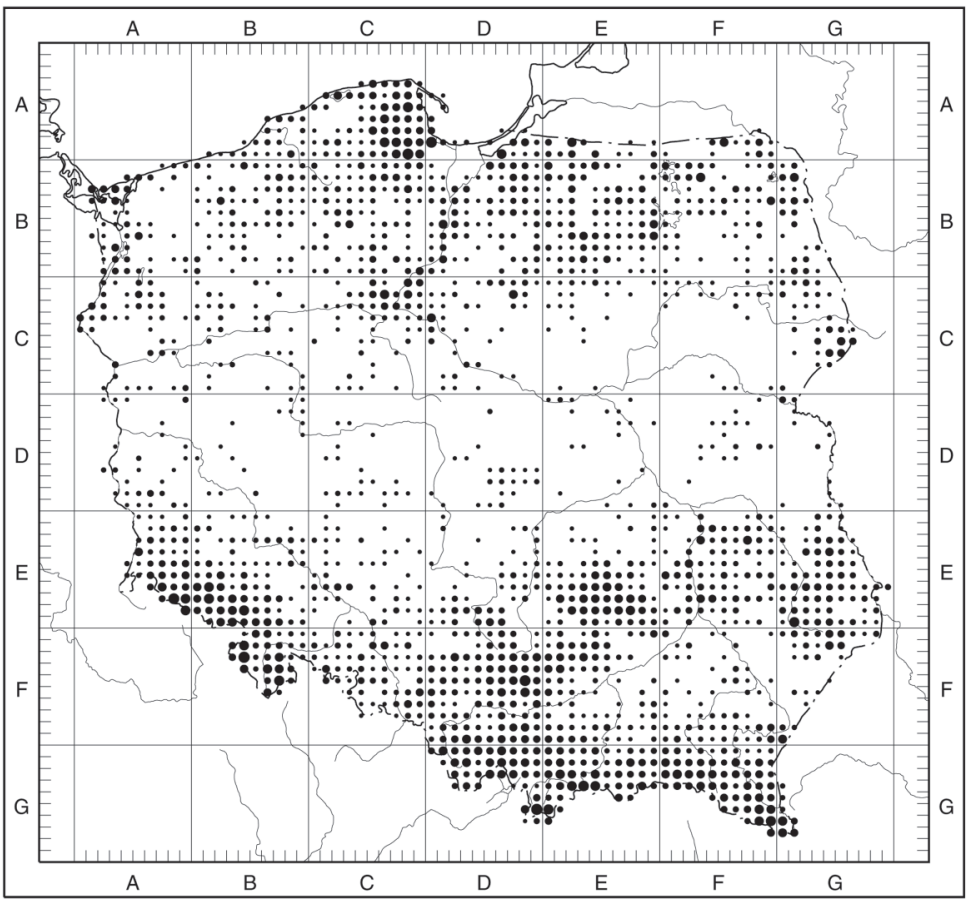

Fig. 7. Collective map of species of northern directional element with southern and northern limit in Poland

constituted approximately 40 per cent of the discussed group. As far as the altitudinal element was concerned, there were 6 multizonal mountain species and 9 montane species. We already know the problem of occurrence of mountain species in lowland (Zając 1996). It is specific for the lowland in Poland whereby this phenomenon was only marginally reported westwards and eastwards from Poland.

Collective distribution of the species reaching their southern and northern limits is presented in Fig. 7. An explicit northern belt with condensation in Gdańsk Pomerania and in Lower Vistula Valley appeared. On the other hand, the southern range covered the Sudeten and Carpathians, on the foreland of Carpathians, after a discontinuity in Sandomierz Valley, the uplands of Southern Poland beginning from the Silesian Upland in the west up to the Lublin Upland in the east. In the lowland of Central Poland, an explicit range discontinuity appeared, a disjunction 100 up to 150 km wide.

4. Discussion

The material presented above, taking the volume of the directional northern element and its poor share into consideration, confirmed Poland to belong to Central European Province on one hand, and indicated some historical aspects of this phenomenon, on the other. The species linked to the Atlantic Province of Europe could have come from north-west to the area covered by research. It was the case for such species as *Ammophila arenaria*, *Cakile maritima* or *Eryngium maritimum*. The species showing wide circumboreal ranges could have arrived after withdrawal of continental glacier from both east and west; both routes are probable. Certainly, the correct direction of their arrival in Northern Poland could be defined by means of molecular research to be planned in an appropriate way. However, it could turn out, which is very probable, that there are mixed populations within Poland, as it was the case for Southern Poland, where trees had been migrating into our country from both Balkan and West-European refugia.

There are two more or less contemporary works in the literature discussing the time of arrival of several of them (Zając 1996; Popiela 2004) and giving some suggestions about the time of their arrival in the Polish territory. However, they differ for some species in details which may be attributed to the fact that the first of them discusses the range period for whole Poland, while the other is restricted to the region of Pomerania. However, it pertains to the group of mountain species in lowland and, in the case of Pomerania, to the forest species. When comparing the data, it can be found that Popiela (2004) assumes *Empetrum nigrum* as the only species from the considered list of plants to have arrived in the late glacial period. Among the mountain species Zając (1996) reported *Pleurospermum austriacum* only. According to Popiela (2004), *Listera cordata* was the only item from the lists presented in Tables 1 and 2 which arrived in pre-boreal period, while, according to Zając (1996), it arrived in Poland later, i.e. in the boreal period. I think, there may be no contradiction here, as the northern and the southern range of this species seem to be the result of migration from two different areas. Zając (1996) mentions some more taxa of open habitats whose pre-boreal age is probable; they are species of *Alchemilla* genera (*A. crinita*, *A. glaucescens*, *A. walasii*) and *Bupleurum longifolium* and *Carex pauciflora*. Successively, some more items mentioned in the above works arrived in later periods, i.e. the boreal and the Atlantic ones. Two routes are probable for the species of the western provenience, i.e. the northern and the southern ones, in respect of the northern and the southern ranges, and even the different time of arrival. Suggestions presented in both works were based on indirect evidence, i.e. on the largeness of the northern area outside Poland associated with minimum temperatures occurring there in winter, and on the types of habitats. The use of the molecular clock for some selected species will allow us to approximate the real time of their migration.

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