

# Some regularities in the distribution of kenophytes in the Polish Carpathians and their foreland

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**Abstract:** The Polish Carpathians and their northern foreland are a rewarding object for the kenophyte distribution research. The study, using the cartogram method, showed that the number of kenophyte species decreases with increasing altitude. Only few kenophytes were found in the lower forest zone. This regularity concerns also the species that reach higher altitudes in the mountains of their native lands. A number of species migrated into the Carpathians through rivers and streams. River valleys generate many open habitats, which are easily colonized by kenophytes due to the lack of competition. In the Carpathians, towns used to be founded in the mountain valleys and this was also a favouring factor of kenophyte propagation. The arrangement of mountain ranges in the Polish Carpathians, including their foreland, hindered the migration of some species and allowed to discover the possible migration routes into the area covered by research. Tracing these migration routes was possible only for those species that have not occupied the whole available area yet. Additionally, the study indicated the most dangerous invasive species in the Polish Carpathians and their foreland.

**Key words:** kenophytes, alien species, invasive plants, Polish Carpathians, foreland, distribution maps, cartogram method

## 1. Introduction

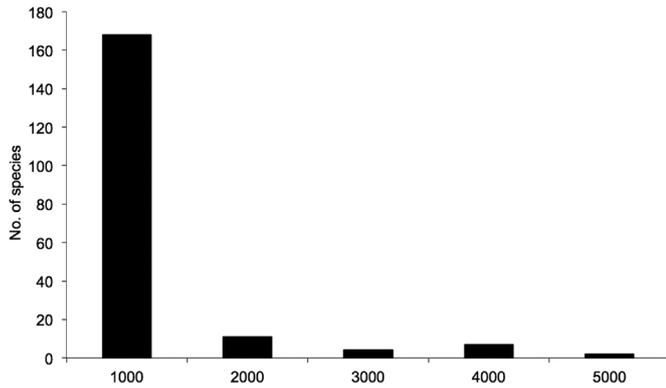
The research on the distribution of species within the geomorphologically and hypsometrically diverse area constitutes one of the main tasks of phytogeography. The area of the Polish Carpathians and their foreland meets these conditions. It was impossible for us to carry out a study of colonization of this area during the Holocene epoch. The modern observations of the colonization by new anthropophytes (kenophytes) may be helpful for the interpretation of a number of paleobotanical data in respect of both directions of arrival of particular species and in the context of assessing the rate of this process.

The research works on the distribution of kenophytes in the Polish Carpathians and in their foreland have been carried out for many years now. Their result is a collective publication which is being prepared under the title: *The Atlas of Kenophyte Distribution in the Polish Carpathians and in their Foreland*. The team of authors: Bartoszek W., Gawroński S., Kostrakiewicz-

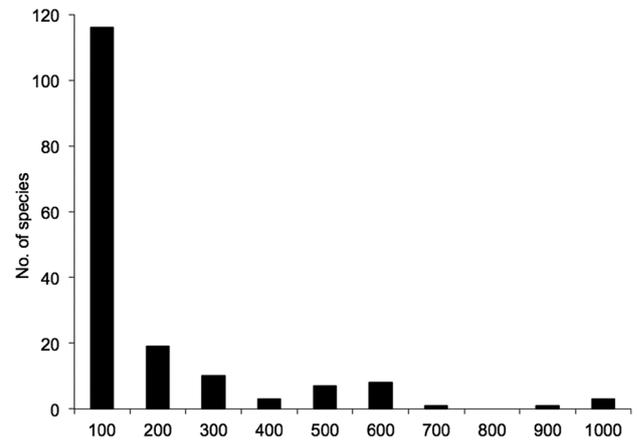
Gierałt K., Kozak M., Mitka J., Oklejewicz K., Nobis A., Nobis M., Stachurska-Swakoń A., Szewczyk M., Tokarska-Guzik B., Towpasz K., Zając A., Zając M., Zemanek B. In total, 195 kenophytes which appear in that area have been reported. The number of kenophytes in Poland, according to Tokarska-Guzik *et al.* (2012), is estimated to amount to 370 species (including those which appear locally). Thus, the kenophytes appearing in the area under discussion constitute approx. 52% of their total number in Poland.

## 2. Material and methods

Distribution maps for the atlas were prepared on the basis of three sources. For the kenophytes, current field research carried out by the team mentioned above as well as field investigations conducted in the course of preparation of several doctor's theses were important. Some of them have already been published and others are being prepared for publication. Other important data derived from literature and from herbarium collections



**Fig. 1.** Number of kenophyte species per 1000 to 5000 cartogram units of 2x2 km in the Polish Carpathians and their foreland



**Fig. 2.** Number of kenophyte species per 100 to 1000 cartogram units of 2x2 km in the Polish Carpathians and their foreland

that were, in most cases, evidence for field research. All the data can be found in the ATPOL Data Base. The entire literature is included in the atlas prepared to be printed.

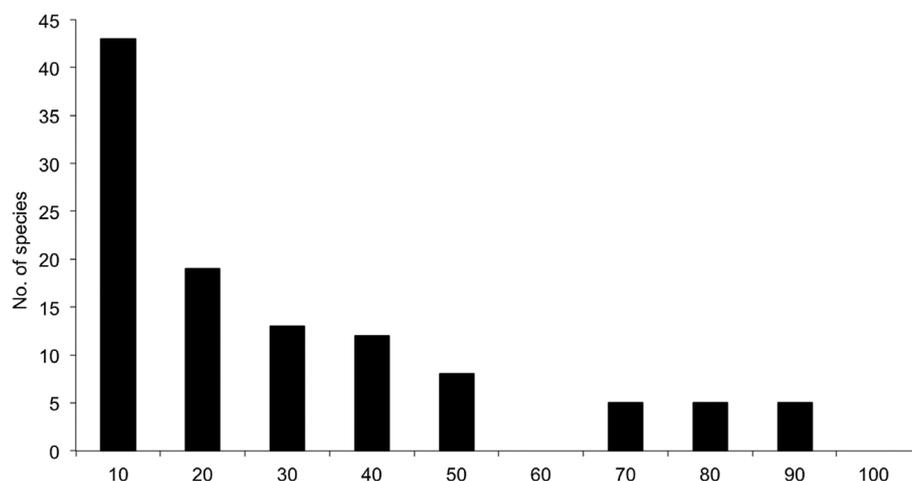
Research methodology is based on the cartogram method used in cartogram units in the *Distribution Atlas of Vascular Plants in Poland* (Zając 1978) similar to other field research carried out in Poland. Kenophyte distribution was investigated using the cartogram scale of 2 x 2 km. It is quite a detailed scale as for the area of over 32.000 km<sup>2</sup> which corresponds to 10% of Polish territory. Their distribution is especially difficult to conduct for taxa whose ranges keep increasing from year to year. On the distribution maps, all data are inserted. For some regions on which detailed field research was carried out ten years ago, the distribution maps could be out of date. Reading the distribution maps of kenophytes, this problem ought to be taken into account. This is a

specific character of this method. The name of taxa in this text are given after Mirek *at al.* (2002).

### 3. Results and discussion

In the investigated territory of the Polish Carpathians and their foreland, all the established anthropophyte taxa identified as kenophytes were listed according to the classification regarding the time of their arrival (Kornaś & Medwecka-Kornaś 2002).

The number of kenophyte localities constituted an important criterion for the assessment of their influence on the native flora. A site in which a given species covered an area of 4 km<sup>2</sup>, i.e., one cartogram unit, was regarded as a single locality. Because of a significant differentiation in the number of localities, ranging from 1 up to over 4300, the problem was illustrated in several diagrams (Figs. 1-3). The species with up to



**Fig. 3.** Number of kenophyte species per 10 to 100 cartogram units of 2x2 km in the Polish Carpathians and their foreland

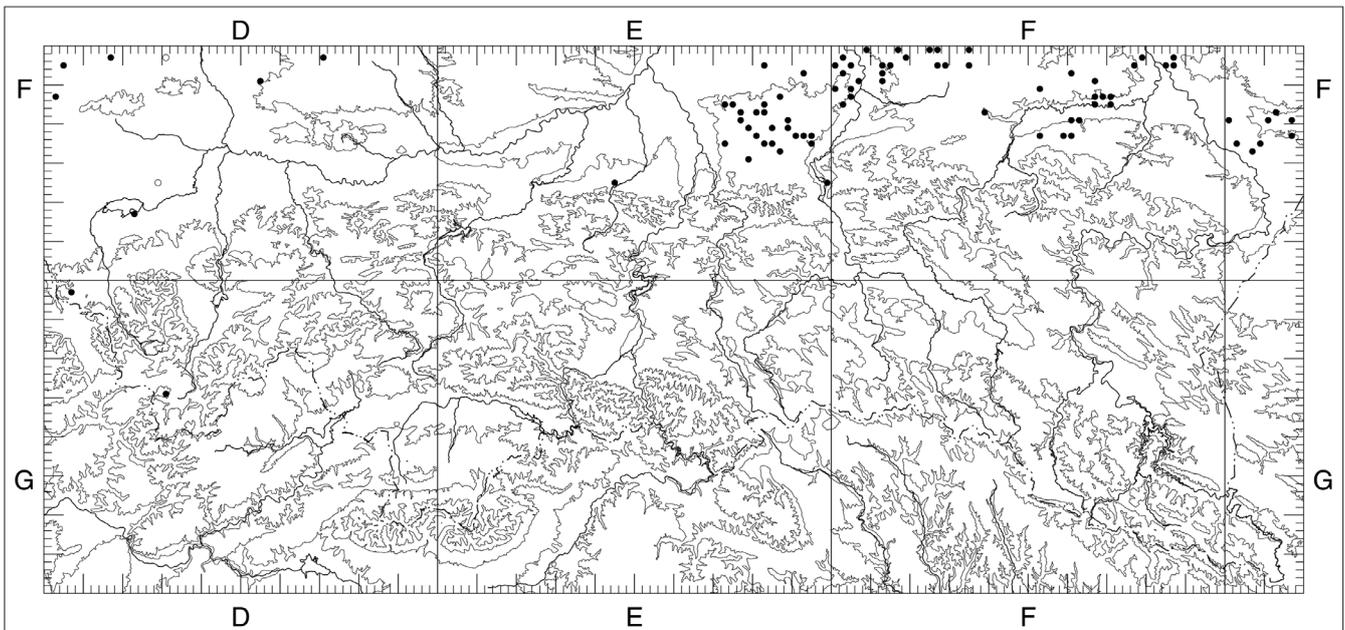


Fig. 4. Distribution of *Anthoxanthum aristatum* Boiss. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

100 localities were the most numerous; their number reached 118. Vast majority of them ranged from 1 up to 1000 localities (167 species). There were only 24 species whose number of localities ranged from 1001 up to 4355. Thus, it can be concluded that the Carpathians and their foreland are not a region where kenophyte species differentiation is significant within the whole territory. A number of species occurred only in a few localities. Most kenophytes appeared in the Carpathians and in their foreland at the same time. Only 23 species (Appendix 1) appeared only in the Carpathian foreland, in Sandomierz Lowland, entering the map of southern borders of South-Poland's uplands. These were species

which either avoided mountain climate even at lower altitudes such as *Anthoxanthum aristatum* (Fig. 4) and *Artemisia annua*, or species which just began to spread within this area such as *Artemisia biennis* reported from several localities in Rzeszów.

The second assessment criterion was the question of the occupied habitats. In this respect, we introduced a division into the following three categories: kenophyte species which occupied the anthropogenic habitats only, the so called epocophytes; those which were established, at least partially, in seminatural or natural habitats – non-invasive agriophytes; and those which showed a significant expansion on the latter ones, i.e. the invasive

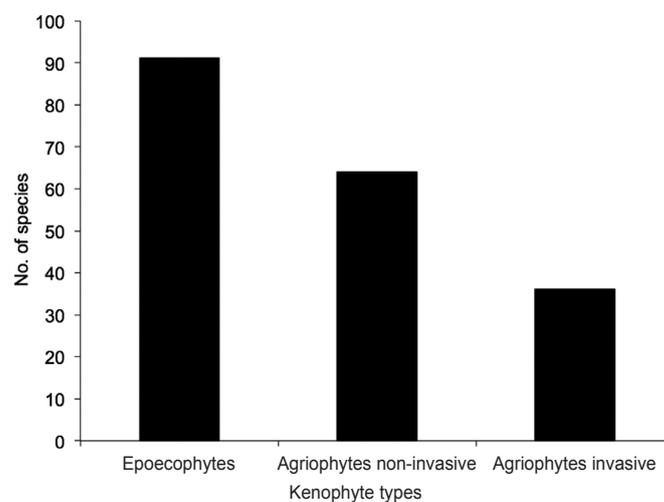


Fig. 5. Kenophytes occurring in the Polish Carpathians and their foreland according to the historical-geographical categories of synanthropic plant classification

agriophytes. The approach to the invasive species was much narrower in comparison with papers of Tokarska-Guzik (2005, 2012; Zając *et al.* 2011), whereby species which were agriophytes were taken into account and those epiphytes which showed an expansive spread within the anthropogenic habitats such as *Chamomilla suaveolens* were omitted. The quantitative distribution of the three above-mentioned groups can be presented as follows: (Fig. 5); the most numerous group was that of epiphytes covering as many as 91 species; non-invasive agriophytes comprising 64 species and the invasive ones covering 36 species. The number of their localities all over the area covered by the study was quite an interesting issue. The most numerous localities were those of the invasive agriophytes covering in total 36.746 cartogram units. The second largest group were epiphytes whose sum of cartogram units amounted to 31.247. Non-invasive agriophytes are the group which covers the fewest cartogram units, i.e. 10.832. Although the invasive agriophytes comprised the lowest number of species, they covered a significant area. It provides evidence that the flora of the Polish Carpathians is endangered by relatively few species covering large areas.

We paid more attention to the species of invasive agriophytes. Their list covering 36 species was interesting (Table 1). The prevailing taxa comprised plants which originate from North America (20 species). Probably, it was caused by the climate similarity between the

area of its origin and its new homeland in Central Europe. Some invasive species penetrating into the Polish Carpathians through rivers were reported several times in the literature. Canadian water-thyme – *Elodea canadensis* occupies habitats in different water reservoirs in river valleys, e.g. in old beds or ponds (Zając *et al.* 2011). It does not enter higher altitudes and its further expansion may be foreseen in the eastern part of the Carpathian foothills. A similar character was shown by the expansion of *Echinocystis lobata*, which entered carr habitats along Carpathian rivers. However, it did not reach the mountain regions situated at higher altitudes and stopped in the lower montane (Fig. 6, see also Zając *et al.* 2011). Among trees, it was *Acer negundo* which was the most dangerous invasive species appearing in carr habitats, like in the area of its origin (Zając *et al.* 2011). Cartogram maps of some kenophytes showed explicitly the direction from which they began their invasion into the area covered by the study. *Veronica filiformis* (Fig. 7), a species originating from the Caucasus, was an example of a species which was spreading from the East. The eastern origin was gradually fading on cartogram maps of some species, as they were spreading to the West. It can be clearly seen on the cartogram map of *Rumex confertus* and *Trifolium patens*. A similar eastern distribution was shown by *Chaerophyllum aureum* (Fig. 8), a species originating from south-eastern Europe, which entered the area of the Polish Carpathians from the South. Its range in

**Table 1.** Invasive species spreading in the Polish Carpathians and their foreland

Species name	No. of cartogram units	Species name	No. of cartogram units
<i>Acer negundo</i> L.	1055	<b><i>Juncus tenuis</i> Willd.</b>	3594
<i>Aster novi-belgii</i> L.	322	<b><i>Lupinus polyphyllus</i> Lindl.</b>	54
<i>Bidens frondosa</i> L.	1373	<i>Onobrychis viciifolia</i> Scop.	228
<b><i>Bromus carinatus</i> Hook. &amp; Arn.</b>	912	<b><i>Padus serotina</i> (Ehrh.) Borkh.</b>	600
<i>Chaerophyllum aureum</i> L.	44	<b><i>Parthenocissus inserta</i> (A. Kern.) Fritsch</b>	826
<i>Digitalis purpurea</i> L.	141	<i>Populus ×canadensis</i> Moench	139
<b><i>Echinocystis lobata</i> (F. Michx.) Torr. &amp; A. Gray</b>	1457	<b><i>Quercus rubra</i> L.</b>	1482
<b><i>Elodea canadensis</i> Michx.</b>	440	<i>Reynoutria ×bohemica</i> Chrtek & Chrtková	75
<b><i>Epilobium ciliatum</i> Raf.</b>	1245	<i>Reynoutria japonica</i> Houtt.	1720
<i>Eragrostis albensis</i> H. Scholz	94	<i>Reynoutria sachalinensis</i> (F. Schmidt) Nakai	167
<b><i>Erechtites hieracifolia</i> (L.) Raf. ex DC.</b>	54	<b><i>Robinia pseudoacacia</i> L.</b>	2884
<b><i>Erigeron annuus</i> (L.) Pers.</b>	2944	<b><i>Rudbeckia laciniata</i> L.</b>	1488
<b><i>Fraxinus pennsylvanica</i> Marshall</b>	283	<i>Rumex confertus</i> Willd.	430
<b><i>Helianthus tuberosus</i> L.</b>	513	<b><i>Solidago canadensis</i> L.</b>	1233
<i>Heracleum mantegazzianum</i> Sommier & Levier	185	<b><i>Solidago gigantea</i> Aiton</b>	3027
<i>Heracleum sosnowski</i> Manden.	133	<i>Trifolium patens</i> Schreb.	173
<i>Impatiens glandulifera</i> Royle	2028	<i>Veronica filiformis</i> Sm.	464
<i>Impatiens parviflora</i> DC.	3643	<i>Vicia grandiflora</i> Scop.	1437

Explanation: bold face denotes species of American origin

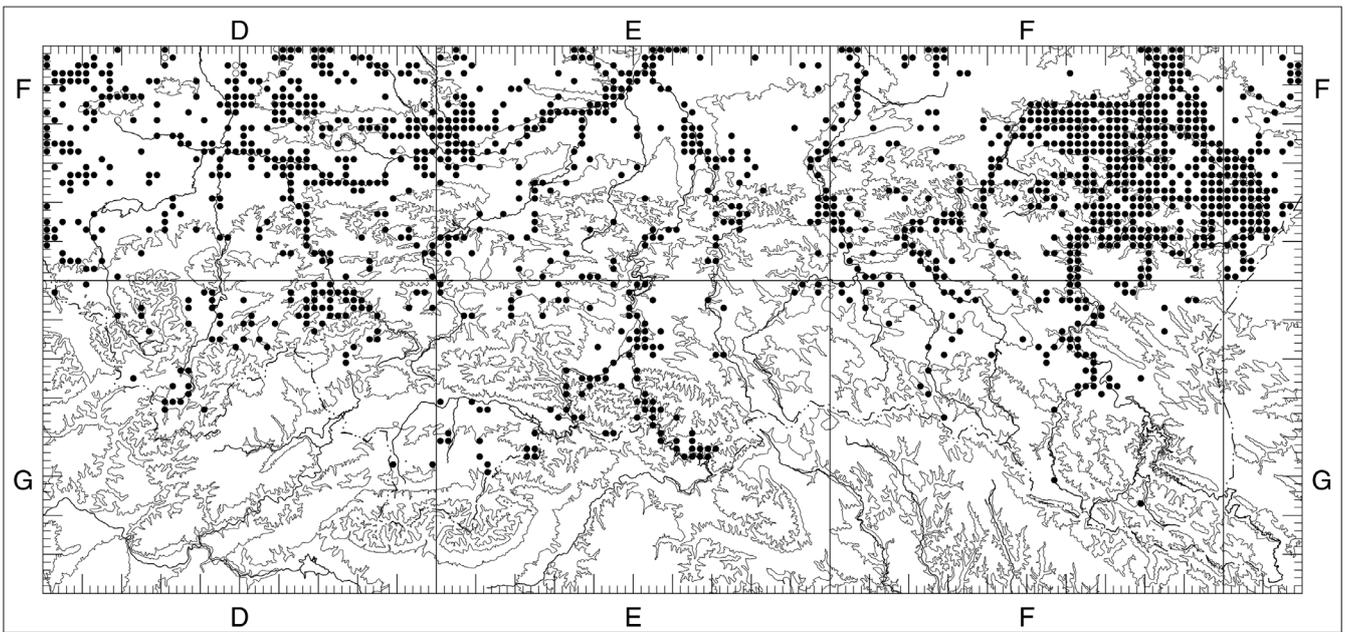


Fig. 6. Distribution of *Echinocystis lobata* (F. Michx.) Torr & A. Gray in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

the Carpathians is „*in statu nascendi*”, like in Poland where it covers large areas e.g. in Małopolska Upland. *Eragrostis albensis* (Fig. 9), another species originating most probably from Central Asia and discovered as new for the World on territory of Germany, was found to have most localities in the East, but it was most probably an artefact, as it can hardly be distinguished by Polish botanists. Some species showed explicitly western origin in the Polish Carpathians. Two invasive agriophytes can be taken as an example, i.e. *Digitalis purpurea* as a

species with a limited range up to the Silesian and Little Beskid and *Solidago canadensis* (Fig. 10), a species with a wider range. The second species of goldenrod, *Solidago gigantea*, showed a much wider distribution (Fig. 11).

The behaviour of the aggressive invasive species is different in the Polish Carpathians than elsewhere in Poland. For example, *Padus serotina* enters the Carpathians with few localities. The largest number of localities and the occupation of the largest territory

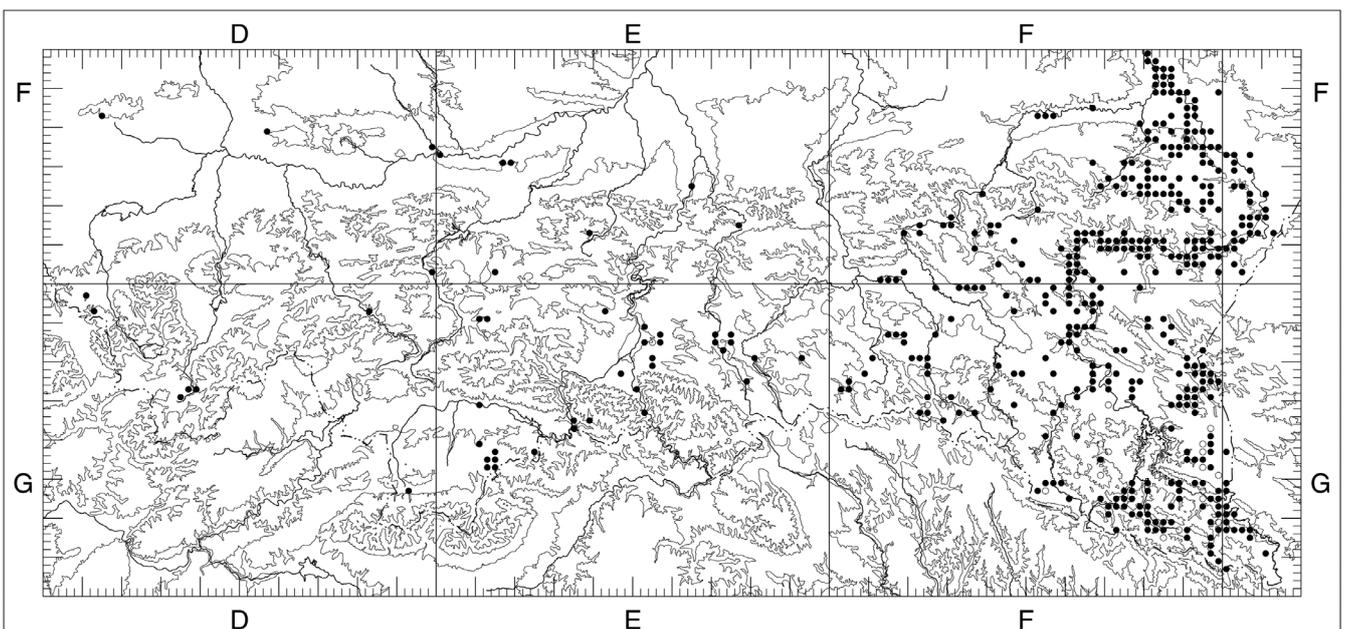


Fig. 7. Distribution of *Veronica filiformis* Sm. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

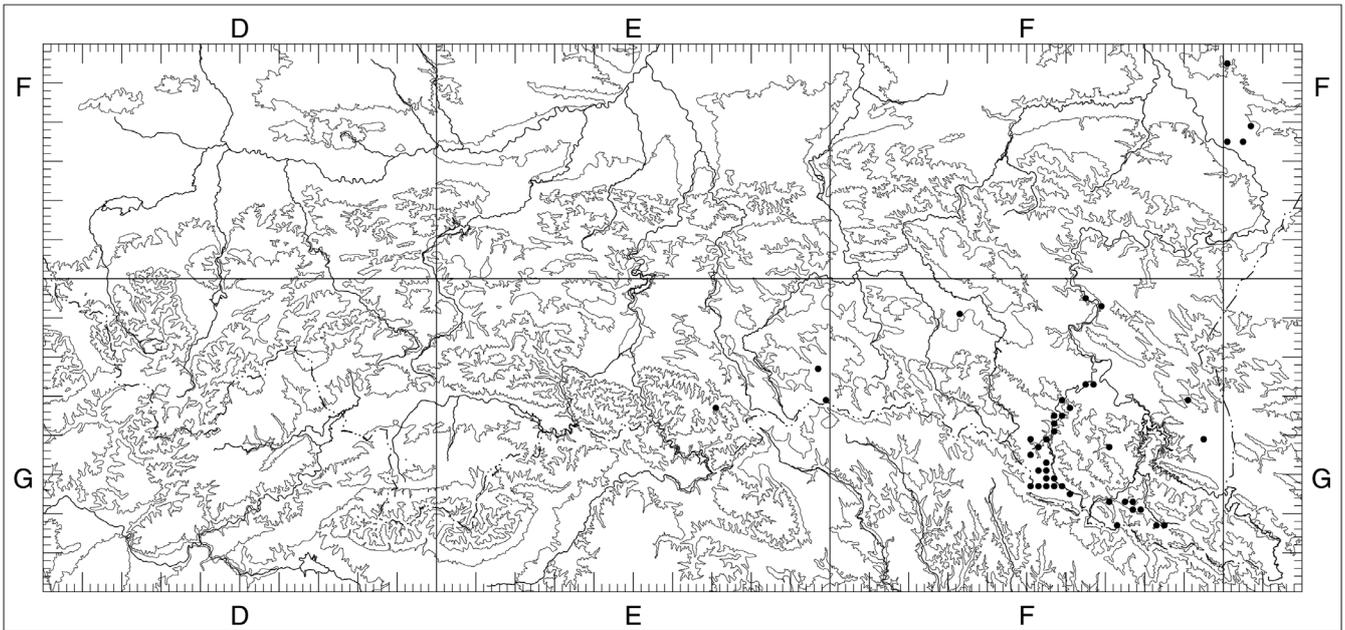


Fig. 8. Distribution of *Chaerophyllum aureum* L. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

is shown by the species of invasive agriophytes which occupies numerous localities almost all over Poland; two species of balsamines; one of them, *Impatiens glandulifera* (Fig. 12, Zając *et al.* 2011) originating from the Himalayas and growing there up to the altitude of 4000 m above sea level, appears in the Carpathians at the altitude of up to 800 m above sea level. The second species *Impatiens parviflora* (Fig. 13), originating from Central Asia, enters deeper into the Carpathians reaching the altitude of up to 1000 m above sea level. Clear differences can be seen between the distribution

of these species; *Impatiens glandulifera* is a cultivation plant and, apart from its migrations within its range, it enriches its populations by escaping from cultivations, especially in the regions where it is popular (e.g. NE edge of the map). *Impatiens parviflora* has never been cultivated outside botanical gardens and all its range is due to its expansion from one or several sources; it shows a regular distribution of localities.

There are two species of invasive agriophytes which began their expansion within the Carpathian forests, although they appeared in the area covered by the study

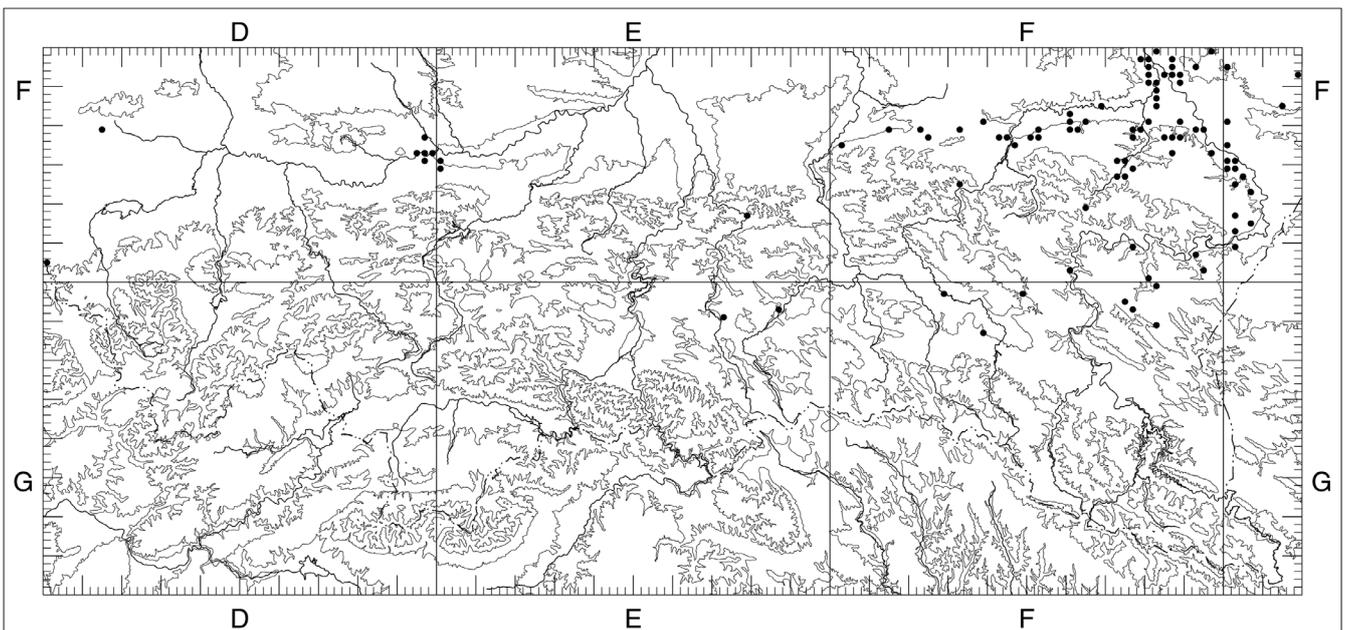


Fig. 9. Distribution of *Eragrostis albensis* H. Scholtz in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

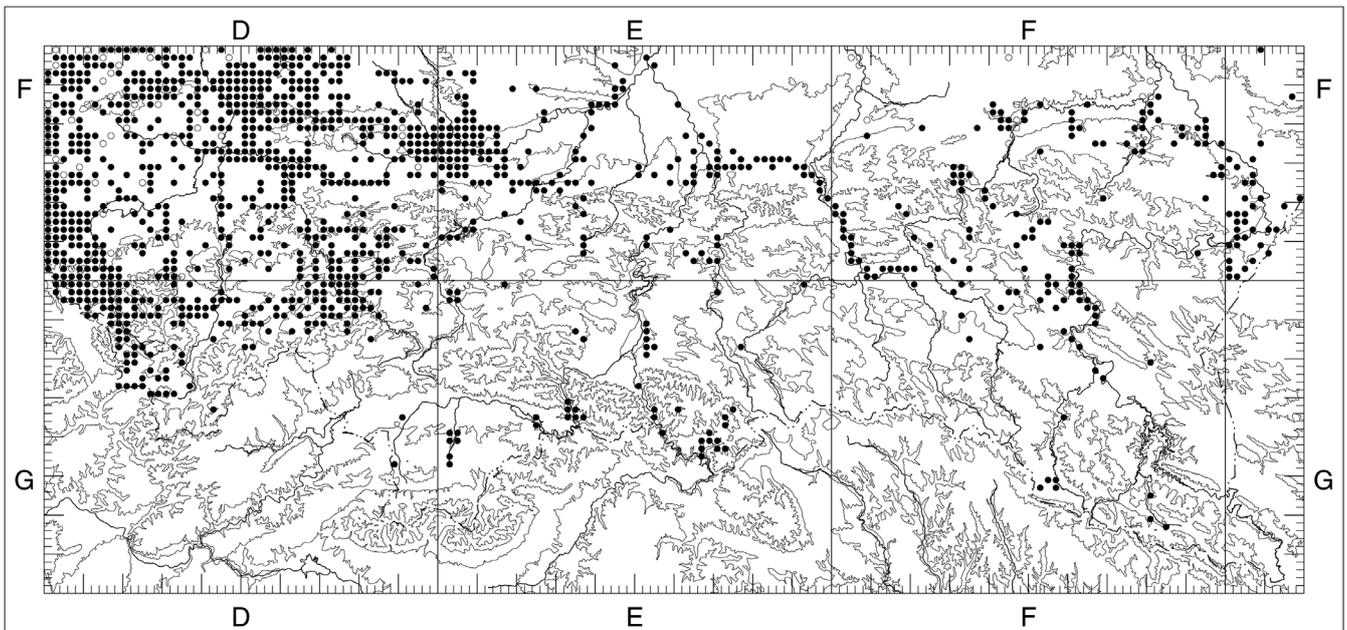


Fig. 10. Distribution of *Solidago canadensis* L. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

for a long time. The first one, *Erechtites hieracifolia* (Fig. 14) originates from North America and spreads mainly along forest paths; the second one, *Telekia speciosa* (Fig. 15), originating from the Eastern Carpathians, used to be cultivated in gardens of the region of Bieszczady and it can presently be found in different regions whereby the number of its localities is growing.

*Galinsoga ciliata* (Fig. 16) and *Conyza canadensis* are the most popular epiphytes appearing in the Polish Carpathians and in their foreland. Their wide distribution is due to a wide environmental scale which

allows them to occupy different ruderal and segetal habitats. Thus, in mountain area they reach the cultivation borders with quite numerous localities. *Sisymbrium loeselii*, a species originating from stony semi deserts and steppes of Central Asia, is an example of an epiphyte which enters the Carpathians sporadically.

#### 4. Conclusions

This short review of new anthropophytes (kenophytes) appearing in the Polish Carpathians and in

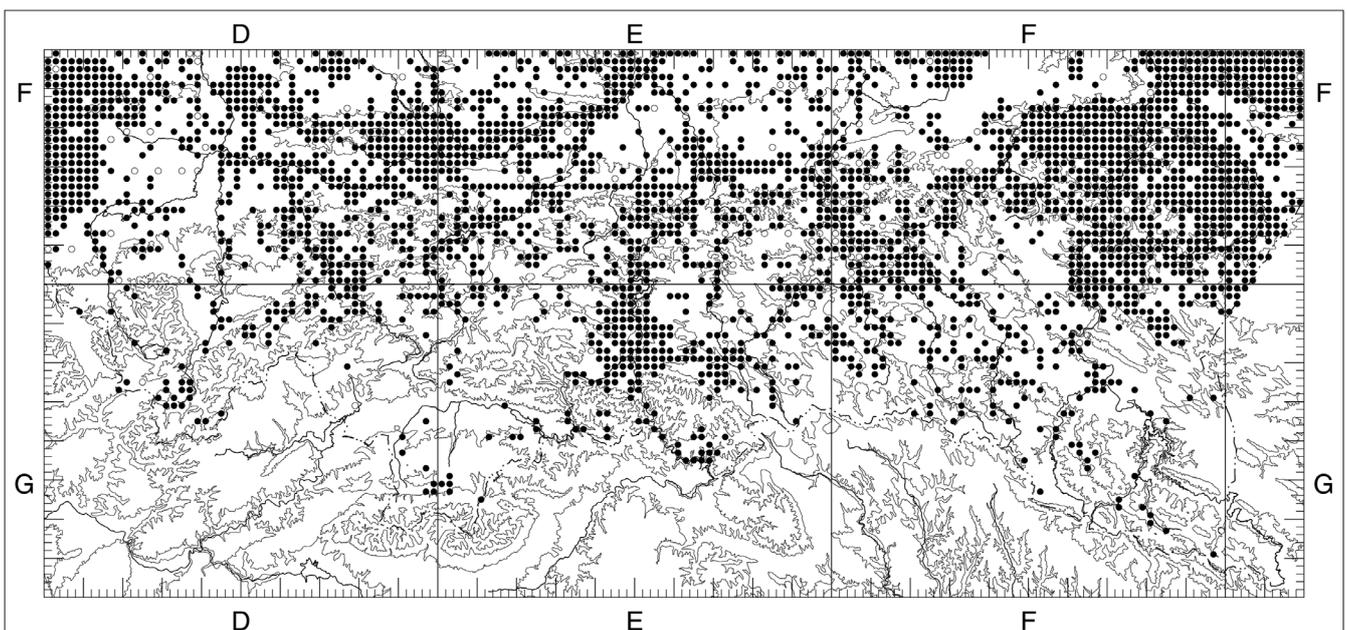


Fig. 11. Distribution of *Solidago gigantea* Aiton in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

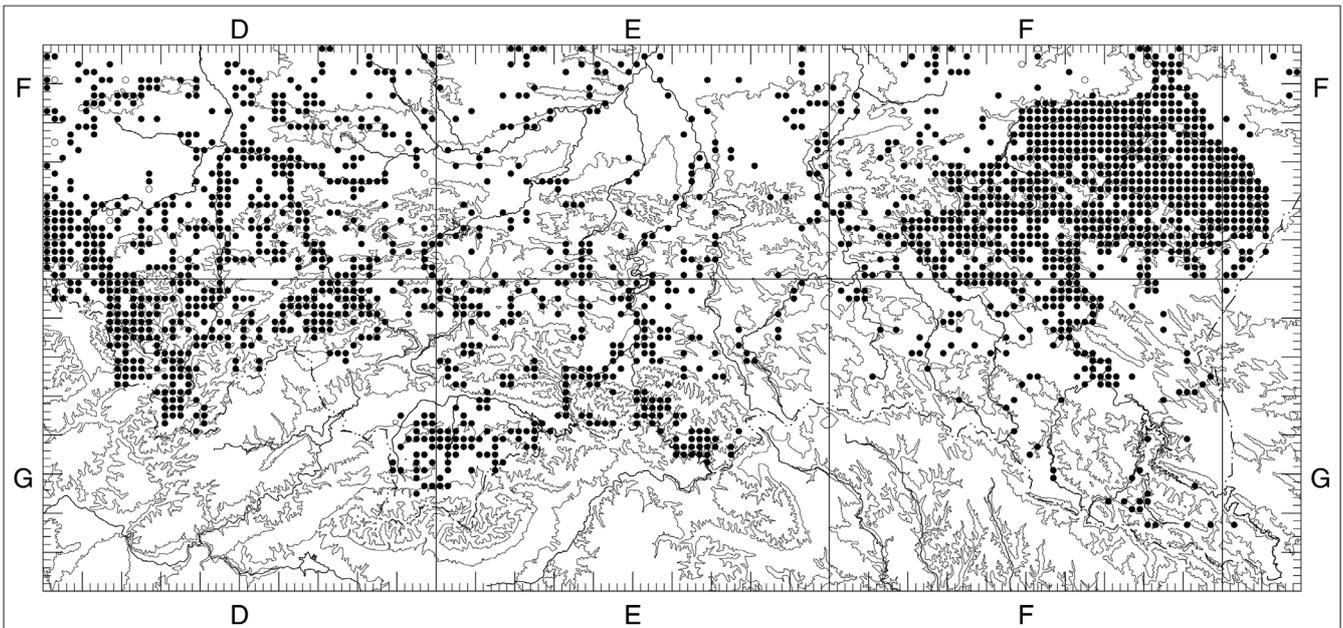


Fig. 12. Distribution of *Impatiens glandulifera* Royle in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

their foreland does not exhaust problems related to their distribution. Collection list of the localities of all kenophytes shows the regions of their density on the collective map (Fig. 17). However, the cartogram map requires to be interpreted. The data related to the area covered by the study was gathered intensely for almost half a century. The areas, for which their local floras were investigated before the cartogram grid for Poland was proposed, appear on cartogram maps as

“gaps”. In the case of rapidly spreading kenophytes,, which distribution changes considerably over a 10-year period, the problem becomes especially difficult. The idea of an atlas of distribution of all plants occurring in the Carpathians was first proposed by Kornaś in 1960s. The Atlas of Kenophytes is the first step towards the publication of the complete work. Research aimed at the common species at least to be fully covered on the maps is still under way in some regions.

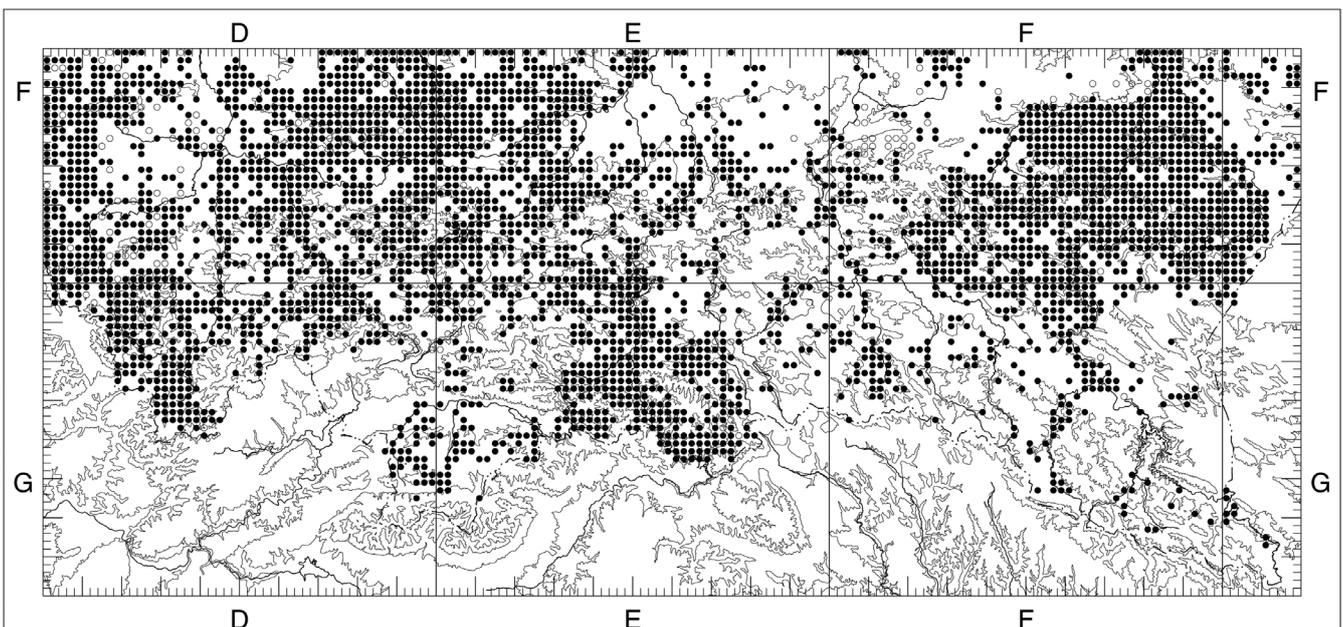


Fig. 13. Distribution of *Impatiens parviflora* DC. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

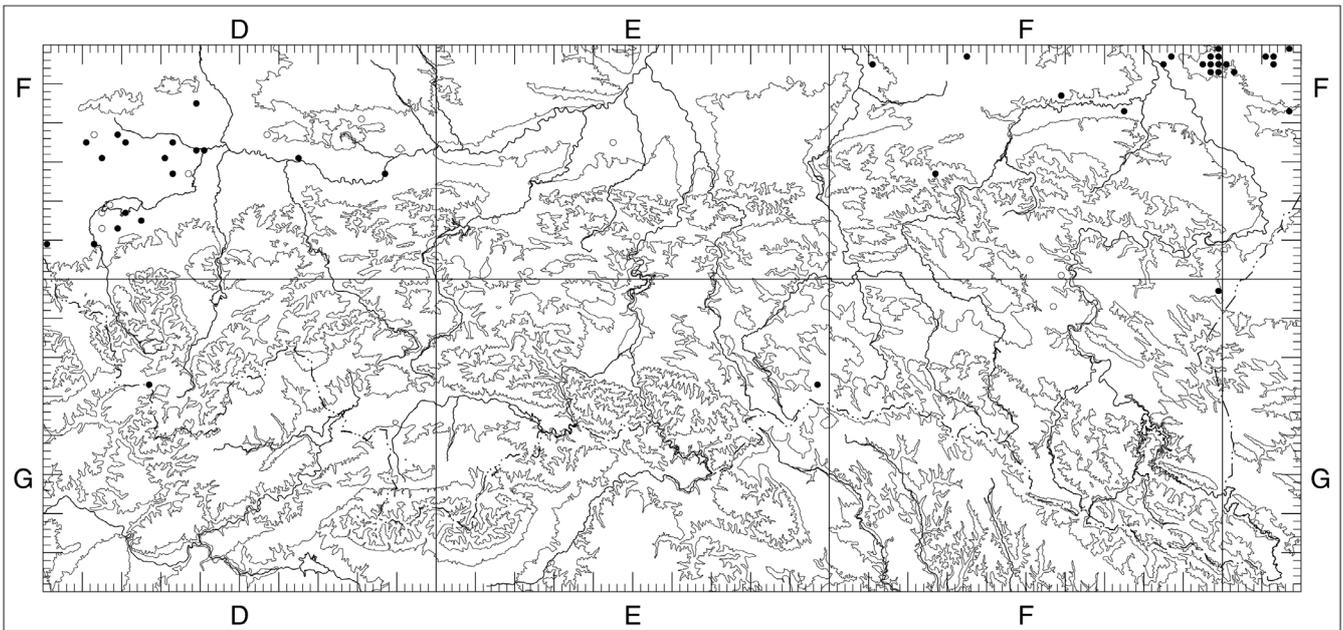


Fig. 14. Distribution of *Erechites hieracifolia* (L.) Raf. ex DC. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

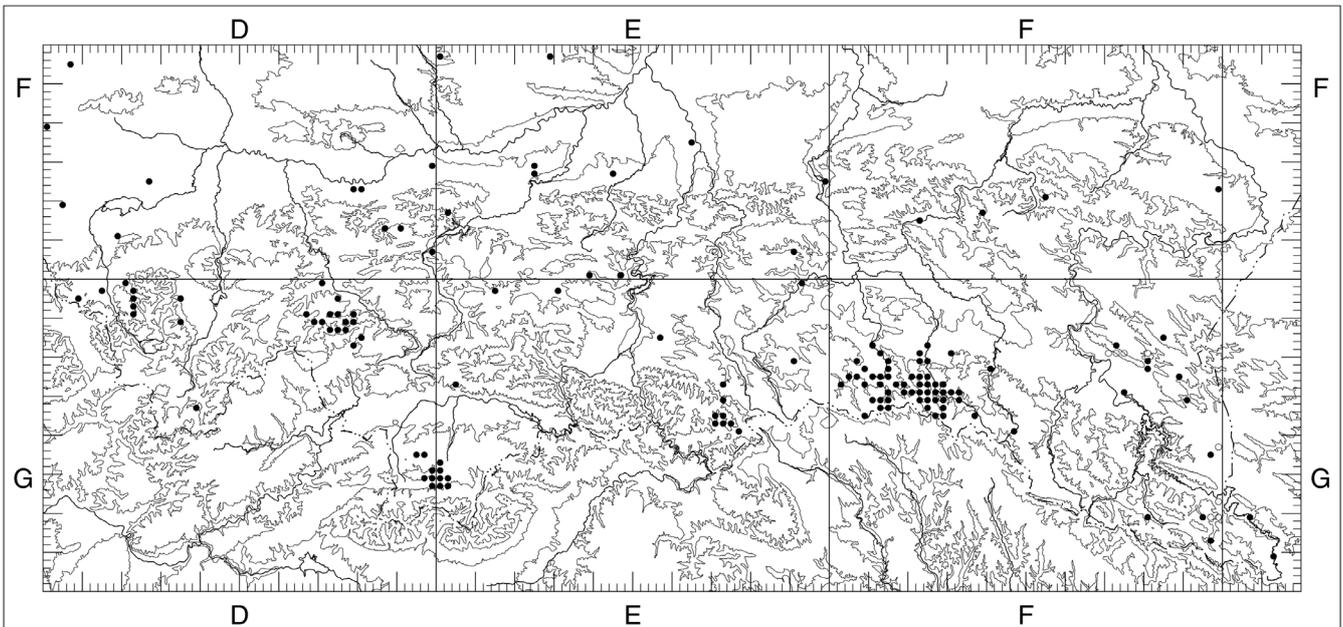


Fig. 15. Distribution of *Telekia speciosa* (Schreb.) Baumg. in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

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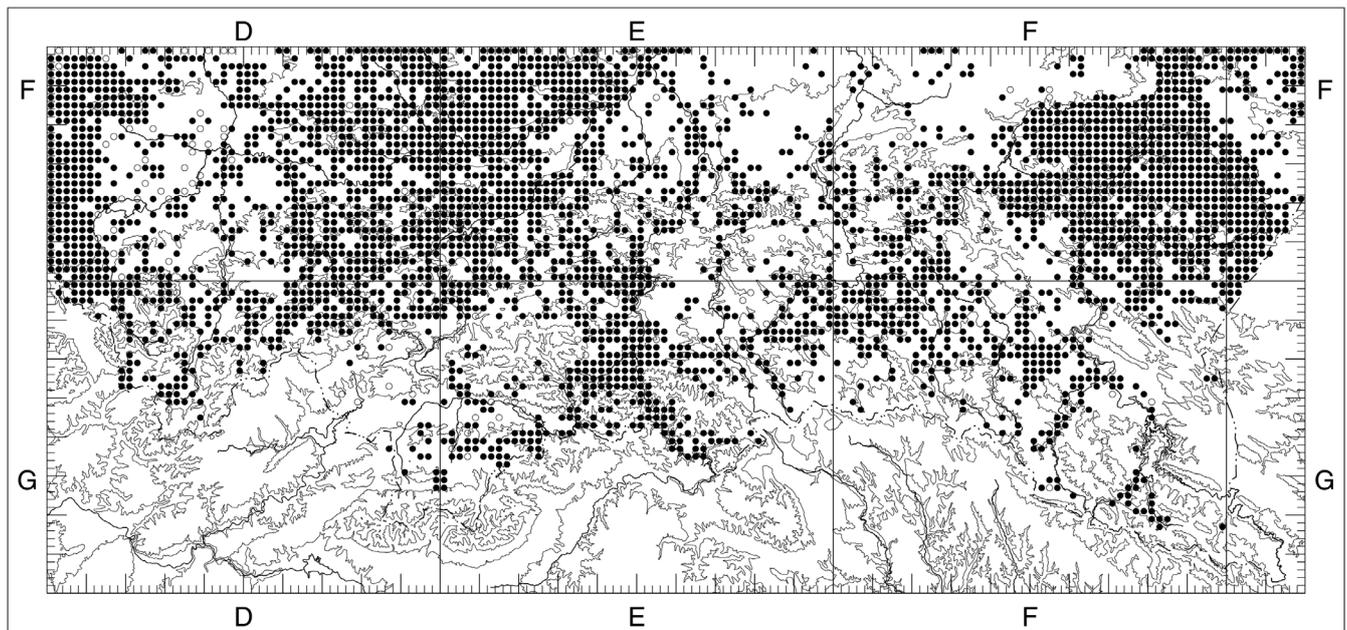


Fig. 16. Distribution of *Galinsoga ciliata* (Raf.) S. F. Blake in the Polish Carpathians and their foreland within 2 x 2 km cartogram units

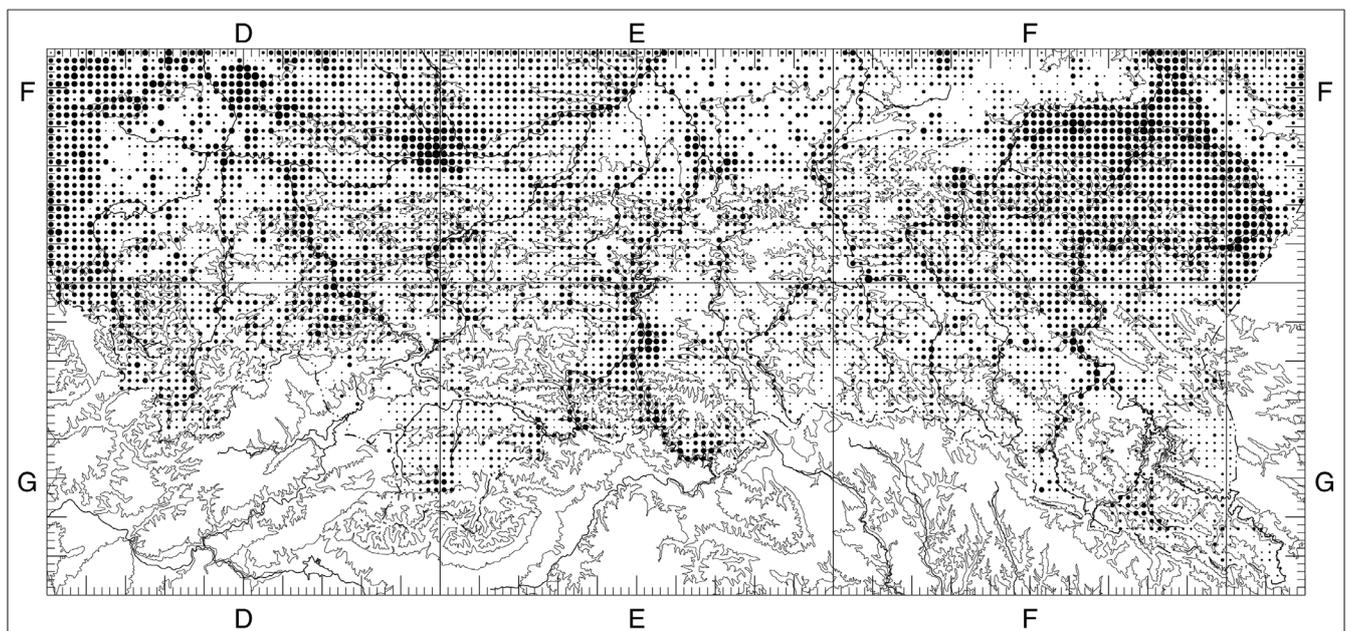


Fig. 17. The collective map of kenophytes occurring in the Polish Carpathians and their foreland. The diameter of a circle on the map fits in twice the square root of the species numbers in the cartogram unit

### Appendix 1. List of kenophytes occurring only in the Polish Carpathian Foreland

*Anthoxanthum aristatum* Boiss., *Artemisia annua* L., *A. biennis* Willd., *Atriplex hortensis* L., *A. tatarica* L., *Chenopodium botrys* L., *Diploaxis tenuifolia* (L.) DC., *Eragrostis multicaulis* Steud., *Lathyrus aphaca* L., *Linaria genistifolia* (L.) Mill., *Oenothera acerviphila* Rostański, *Oe. canovirens* E. S. Steelle, *Oe. fallax* Renner emend. Rostański, *Oe. pseudochicagiensis* Rostański, *Oe. subterminalis* R. R. Gates, *Oe. victorini* R. R. Gates & Catches. in R. R. Gates, *Oe. wienii* Renner ex Rostański, *Oxalis dillenii* Jacq., *Potentilla intermedia* L. non Wahlenb., *Salsola kali* L. subsp. *ruthenica* (Iljin) Soó, *Senecio inequidens* DC., *Sorbaria sorbifolia* (L.) A. Braun, *Thladiantha dubia* Bunge