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Invasion of synanthropic plants into the forest vegetation of the Cedynia Landscape Park (NW Poland)

Edyta Stępień

Department of Plant Taxonomy and Phytogeography, University of Szczecin, Wąska 13, 71-415 Szczecin, Poland; e-mail: ditta@univ.szczecin.pl

Abstract. The distribution of synanthropic plants was studied in the Cedynia Landscape Park (Cedyński Park Krajobrazowy), with particular reference to alien species and their capability to penetrate into forest ecosystems. The research was conducted by the cartogram method in the ATPOL system (1-km grid squares). The Park is situated within the Western Pomeranian Province and includes two large woodland complexes: the Piasek Forest (Puszcza Piaskowa) and the Mieszkowice Forest (Lasy Mieszkowickie). The forest vegetation is exposed to various forms of human pressure. Results of this study show that the vascular flora of forests of the Park is composed of 609 species: 506 native taxa (277 non-synanthropic spontaneophytes and 229 apophytes) and 107 anthropophytes (49 archaeophytes, 48 kenophytes, and 9 diaphytes). Most synanthropic plants in the studied forests occur near roads, cottages, and river banks. Contributions of various historical-geographic groups to the total number of species varied between forest types, but apophyte species were usually most numerous. In contrast to some earlier reports, not only alien but also native species were found to be more diverse near forest roads than in the forest interior. Spontaneophytes are equally diverse, while apophytes are much more diverse near roads.

Keywords: synanthropization, Cedynia Landscape Park, human pressure, forest complex, forest roads

1. Introduction

Nowadays the natural environment is very strongly affected by human activity. One of its side-effects is the penetration of natural ecosystems by synanthropic species. The problem of synanthropization of the flora and vegetation has become an important subject of geobotanical research (Faliński 1966, Kowarik 1988, Jackowiak 1990, Chmiel 1993, Pyšek *et al.* 1998).

Forest ecosystems of the Cedynia Landscape Park (Cedyński Park Krajobrazowy) in northwestern Poland have also been greatly influenced by human economy. Its two large forest complexes – Piasek Forest and Mieszkowice Forest – are surrounded by arable fields and grasslands. The forests lie in the immediate neighbourhood of villages, and are crossed by a dense network of roads and paths, so they are directly exposed to penetration by synanthropic species.

The aim of the work was to study the distribution of synanthropic plants in the Cedynia Landscape Park, with particular reference to alien species, and their capability to penetrate into forest ecosystems.

2. Study area

The Cedynia Landscape Park (Cedyński Park Krajobrazowy) lies within the West Pomeranian Province. It includes a part of the ravine valley of the river Odra with its edge zone and two forest complexes: the Mieszkowice Forest (Bory Mieszkowickie) and the Piasek Primeval Forest (Puszcza Piaskowa), in short Piasek Forest. The total area of the Park is 308.5 km^2 (Fig. 1).

According to the physical-geographical division of Poland, the Park lies within the limits of four mesoregions. Its northern part lies in the Myślibórz Lakeland mesoregion (within the West Pomeranian Lakeland macroregion), which presents a complex of glacial formations connected with the Pomeranian phase of the last glaciation (Vistulian). Near the river Odra,

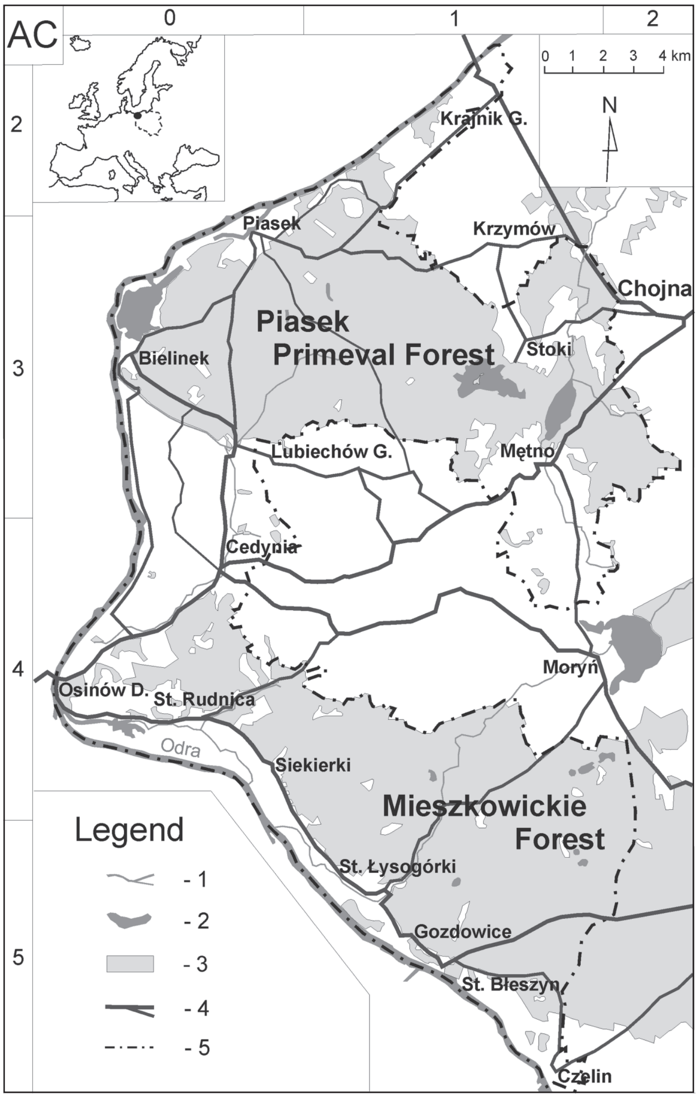

Fig. 1. Map of the Cedynia Landscape Park
Explanations: 1 – rivers, 2 – lakes, 3 – forests, 4 – roads, 5 – border of the Park

moraine hills form a ridge of up to 166 m in height (Czcibor Mountain). To the south lies the Gorzów Plain mesoregion (within the South Pomeranian Lakeland macroregion), constituting a sandur of the Pomeranian phase. A fragment of the Odra valley between Krajnik Dolny and Cedynia belongs to the Lower Odra Valley mesoregion (within the Szczecin Coast macroregion), while the Odra valley between Cedynia and Czelin belongs to the Freienwalde Basin (within the Thorn-Eberswalder Glacial Valley macroregion, also known as the Toruń-Eberswalde Proglacial Valley) (Kondracki 2000).

Forests cover 63% of the Park (19 494 ha). In its northern part the Piasek Forest is located. Mieszkowice Forests are divided from it by a wide woodless belt, and cover the southern part of the Park. In the Park, the most common forest communities are: a degenerated form of fresh coniferous forest *Leucobryo-Pinetum* and oak-pine forest *Querco roboris-Pinetum*. Among the forest communities of the Park, oak forests are particularly important. A patch of acidophilous oak wood *Calamagrostio arundinaceae-Quercetum* aged almost 400 years is found in the Piasek Forest ("Dąbrowa Krzymowska" reserve) (Friedrich 1976). Xerothermic oak forest *Quercetum pubescenti-petraeae* covers southern slopes of the "Bielinek" forest reserve (Celiński & Filipek 1958). Large patches of acidophilic Pomeranian beech wood *Luzulo pilosae-Fagetum*, or more rarely of fertile beech wood *Galio odorati-Fagetum*, are found in the Piasek Forest. Fragments of mixed acidophilous beech and oak woods *Fago-Quercetum petraeae* are located in their neighbourhood (Jasnowski & Markowski 1977).

Oak-hornbeam forests (*Stellario holosteae-Carpinetum*, *Galio sylvatici-Carpinetum*), frequently with distorted structure, grow in stream valleys, accompanying alder-ash riparian forests *Fraxino-Alnetum*. Submontane ash riparian forest *Carici remotae-Fraxinetum* with *Equisetum* *telmateia* is protected in the "Olszyna Źródliskowa pod Lubiechowem Dolnym" nature reserve. Patches of elm riparian forest *Violo odoratae-Ulmetum minoris* develop on the slopes of the Odra valley (Celiński & Filipek 1958). In the whole Park, patches of currant swamp forest *Ribeso nigri-Alnetum* have developed near brooks and water bodies, while moss swamp forest *Sphagno squarrosi-Alnetum* is very rare. Swamp forests are accompanied by osier thickets *Salicetum pentandro-cinereae*. Osier forest *Salicetum triandro-viminalis* is common in the Odra valley while no well-developed patches of riparian willow forest (*Salicetum albo-fragilis*) and white poplar forest (*Populetum albae*) can be observed infrequently.

3. Methods

The research was conducted in 1998-2003 by the cartogram method in the ATPOL system (1 km grid squares) (Zając 1978). In the squares, all vascular plant species were recorded in the distinguished types of forest and on forest roads. In total, 1086 floristic lists and 104 floristic notes were made (26 802 records). The status of archaeophyte has been given according to Zając E. U. & Zając A. (1975); Zając (1979, 1983, 1987a, 1987b, 1988); Zając A. & Zając M. (2001); and Mirek *et al.* (2002). The status of kenophytes was given according to Zając *et al.* (1998), Zając A. & Zając M. (2001), Mirek *et al.* (2002), Tokarska-Guzik (2005), and on the basis of my earlier records (Stępień 2004). The nomenclature of syntaxa follows Matuszkiewicz (2002), and the nomenclature of taxa follows Mirek *et al.* (2002).

4. Results and discussion

In total, 609 species of vascular plants were recorded in forests of the Cedynia Landscape Park. As many as 503 are native species, while the remaining 106 (17%) are alien species (anthropophytes) (Fig. 2).

Wooded areas of the Park form two large forest complexes surrounded by fields and meadows. Farm buildings in most cases lie on forest edges. Wooded areas lying on the outskirts of forest complexes differ in their species composition and percentage of anthropophytes from the inner parts of forest fragments (Fig. 3). The outer parts of forests are characterized by a more diverse species composition, as much more apophytes and archaeophytes are found here. This confirms that forest communities on outermost sites are exposed to penetration by native non-forest species and anthropophytes.

In general, similar numbers of archaeophytes and kenophytes were recorded in forest communities in the Park. However, the number of alien species is higher in the vicinity of villages, estates, busy roads, and water bodies penetrated by people. By contrast, in central parts of the Piasek Forest and the Mieszkowice Forest, archaeophytes are much less numerous than kenophytes. *Fallopia convolvulus* frequently is the sole representative of archaeophytes or they do not occur there at all (Fig. 4).

The forest stands are cut by a network of roads, where a total number of 494 species of vascular plants were recorded. Compared with the flora of the wooded areas, the flora of forest roads is evidently much poorer in non-synanthropic spontaneophytes, while the number of apophytes and anthropophytes is comparable (Fig. 2). This shows that the anthropophytes appearing on roads penetrate the neighbouring forest patches.

Roads enhance exotic plant invasion by acting as corridors for dispersal, providing suitable habitats, and containing reservoirs of propagules for future episodes of invasion (Parendes & Jones 2000; Trombulak & Frissell 2000). The roadside edge has a less dense canopy, allowing more light to reach understory plants, which often results in a species composition different from that of the forest interior (Parendes & Jones 2000).
In wooded areas lying in the direct vicinity of surfaced roads – asphalt, metalled, and also the more intensely used macadam roads – the species composition is richer.

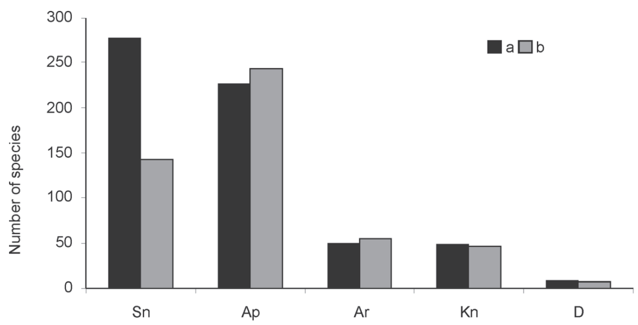

Fig. 2. Numbers of species of various historical-geographical groups in wooded areas (a) and on forest roads (b) in two forest complexes of the Cedynia Landscape Park
Explanations: Sn – non-synanthropic spontaneophytes, Ap – apophytes, Ar – archaeophytes, Kn – kenophytes, D – diaphytes

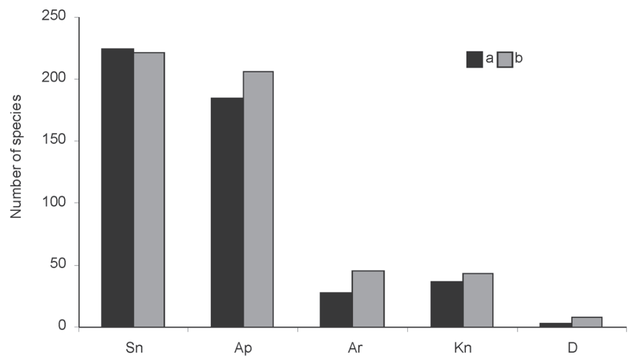

Fig. 3. Numbers of species of various historical-geographical groups in inner (a) and outer (b) parts of two forest complexes of the Cedynia Landscape Park
Explanations: see Fig. 2

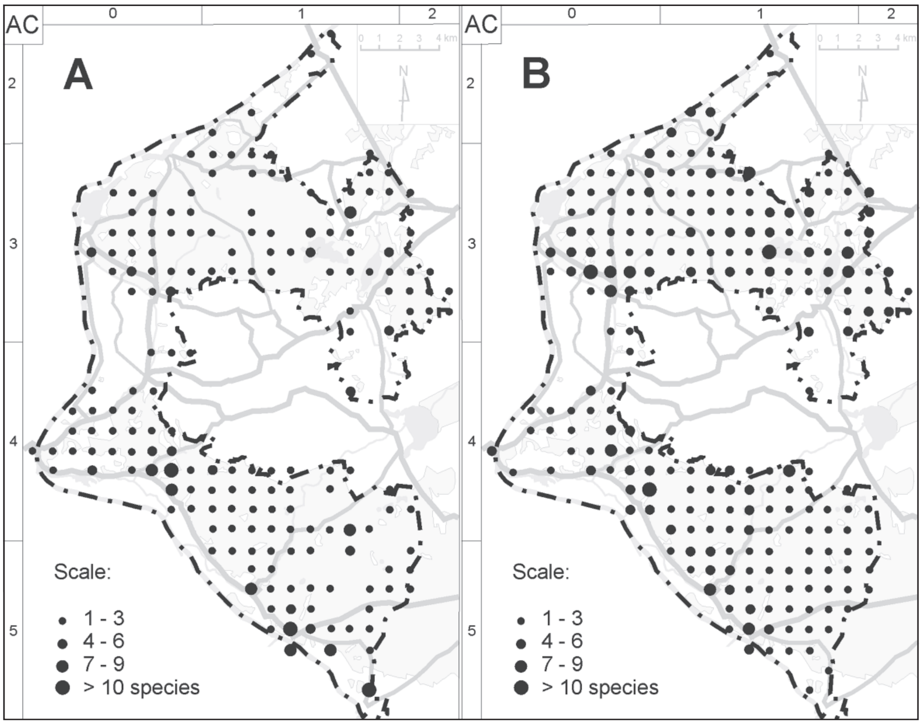

Fig. 4. Concentrations of archaeophytes (A) and kenophytes (B) in the Cedynia Landscape Park

Here the number of anthropophytes, particularly of archaeophytes, is higher and that of apophytes is much higher (Fig. 5), owing to the effect of the phytocoenotic diversity of roads (Paszek & Załuski 2000). It is noteworthy that the number of non-synanthropic spontaneophyte species does not change. Consequently, both native and alien species are more diverse near forest roads. This partly contradicts the findings of Watkins *et al.* (2003), who reported that exotic-species richness increases near roads and native-species richness declines there. However, their study covered a much larger area with a sparse road network.

In the forests and on the roads crossing them, a total of 682 species of vascular plants were found. Among them, 421 species occurred in both types of habitats. This group includes 75 species of anthropophytes (32 kenophytes, 39 archaeophytes, and 4 diaphytes), such as *Conyza canadensis*, *Lamium album*, *Senecio vernalis*, *Symphoricarpos album*, and *Vicia villosa*. Of the plants only found on roads, 31 alien species did not penetrate forest communities (14 kenophytes, 14 archaeophytes, and 3 diaphytes), e.g. *Chamomilla suoveolens*, *Echinochloa crus-galli*, *Galinsoga ciliata*, *Lathyrus tuberosus*. These species usually occur in a few localities and usually belong to the group of plants with high light requirements. It is interesting that the same number of species was only noted in wooded areas and not on forest roads (16 kenophytes, 10 archaeophytes, and 5 diaphytes). Some of these plant species – such as *Cerasus mahaleb*, *Cornus mas*, *Ribes uva-crispa*, and *Scilla sibirica* – could have penetrated forest ecosystems directly from plantations around the present or former human settlements. Other species were noted only at the outskirts of forest complexes, into which they penetrated from neighbouring segetal communities, xerothermic grasslands, and ruderal communities, like *Lithospermum arvense*, *Papaver argemone*, *Veronica triphyllos*, *Sonchus asper*, and *Raphanus raphanistrum*.

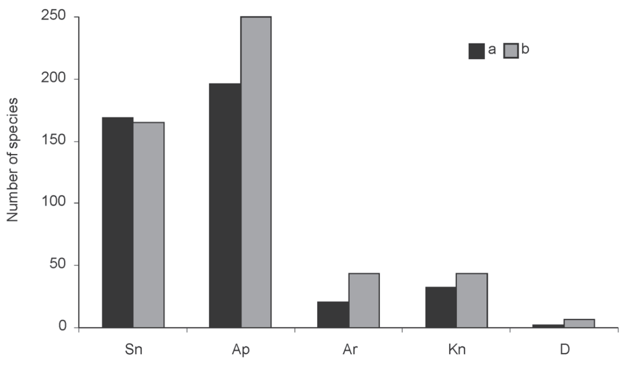

Fig. 5. Numbers of species of various historical-geographical groups in forests more than 150 m away from forest roads (a) and near forest roads (b) in two forest complexes of the Cedynia Landscape Park
Explanations: see Fig. 2

Probably some species were brought into the interior of forest complexes through the network of roads, although they were not found on forest roadsides (e.g. *Teucrium scorodonia* and *Solanum nigrum*). Some anthropophytes, like *Vicia narborensis* and *Bidens connata,* invaded the wooded areas through river valleys, chiefly the Odra valley. The latter species appears on widely scattered sites within the limits of the Piasek Forest, and hence it seems that animals must have strongly

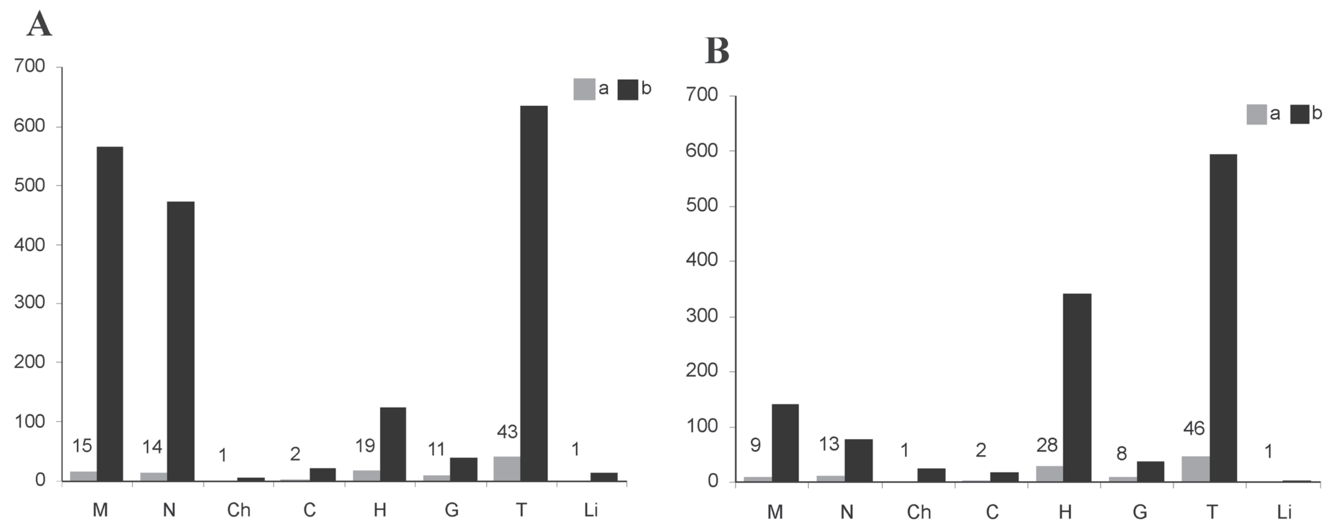

Fig. 6. Numbers of species (a) and records (b) of Raunkiaer's life-forms in the alien flora of wooded areas (A) and forest roads (B) in the the Cedynia Landscape Park

Explanations: M – megaphanerophyte, N – nanophanerophyte, Ch – chamaephyte, H – hemicryptophyte, T – therophyte, G – geophyte, Li – liana

contributed to its expansion. Alien species recorded on forest roadsides and in the surrounding stands, used many different ways to penetrate forest ecosystems. In spite of the fairly dense network of roads, the highest numbers of alien species and the highest numbers of their records were found on the outermost parts of the Piasek Forest and Mieszkowice Forests, so in this respect their interior was distinctly poorer.

It should be stressed, however, that the most frequented asphalt roads chiefly go along the outskirts of the forest, while distinctly higher numbers of anthropophytes are gathered along this type of roads if they cross the inside of the forest. In the internal fragments of stands, far from the frequented forest roads, a total of 55 alien species were noted. Only a few of them had a high number of records. The most numerously noted were *Padus serotina* (an underplanted species, currently strongly invasive), *Fallopia convolvulus*, *Impatiens parviflora*, and *Robinia pseudoacacia*. Also *Conyza canadensis*, *Lamium purpureum*, *Ribes rubrum*, and *Ribes uva-crispa* are relatively frequent. However, the presence of alien species in the interior of forest complexes manifests some disturbance. Alien species are most frequent within 15 m of the roads, with highest abundance within 5 m of the roads. Light availability and soil disturbance was high in that zone. This suggests that before alien species can move from the roads and colonize the forest interior, disturbances may be required (Watkins *et al*. 2003).

It was also interesting to compare the participation of Raunkiaer's life-forms in the alien flora of wooded areas and forest roads. Therophytes, which prevail among anthropophytes, are represented by the highest number of species and records (Fig. 6). In forest phytocenoses, *Fallopia convolvulus* (250 records) and *Impatiens parviflora* (138 records), *Lamium purpureum* (38 records) are most abundant (Fig. 7). These species were not only recorded in disturbed habitats but also very frequently in undisturbed forests. The first two species were often recorded in undisturbed plant communities in different parts of Poland (Jakubowska-Gabara & Zielińska 2003; Ratyńska 2003). On forest roads, C*onyza canadensis* (82 records), *Fallopia convolvulus* (52 records), and *Melandrium album* (51 records) are most frequent.

The participation of hemicryptophytes and phanerophytes in the alien flora of wooded areas and forest roads is also very high (Fig. 6). These results approximate the Raunkiaer spectrum of alien species in the flora of Poland (Tokarska-Guzik 2005). Compared with forest roads, a higher number of phanerophyte species and records was observed in the wooded areas. The frequency of numerous phanerophytes to a great degree is due to afforestation (frequently including whole forest subcompartments), from where their diaspores penetrate the neighbouring parts of forest ecosystems. The most common species are *Padus serotina* (474 records), *Picea abies* (218 records), *Robinia pseudoacacia* (173 records), *Pseudotsuga menziesii* (59 records), while less frequent are *Acer negundo*, *Aesculus hippocastanum*, *Alnus incana*, *Quercus rubra*, *Ribes uva-crispa*, and *Ribes rubrum*. Some of these species belong to the most expansive ones in Polish forests (Żukowski *et al*. 1995; Jakubowska-Gabara & Zielińska 2003; Tokarska Guzik 2005).

On forest roads, hemicryptophytes are very diverse (Fig. 6B) and frequent, e.g. *Capsella bursa-pastoris* (87 records), *Berteroa incana* (37 records), *Anchusa officinalis* (36 records). Similar trends were observed in the flora of the eastern part of the Gniezno Lakeland, where

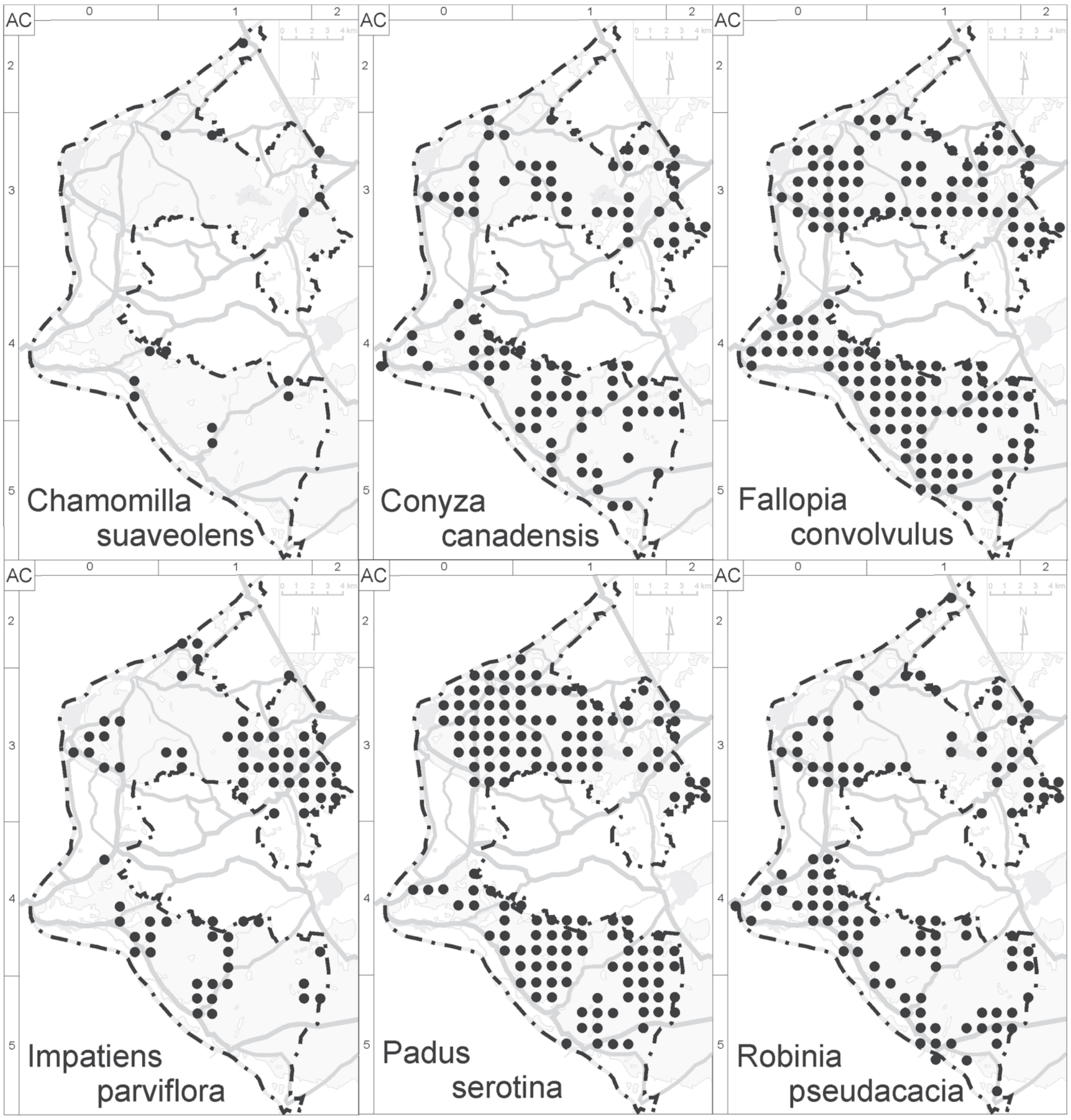

Fig. 7. Distribution map of selected anthropophytes in two forest complexes in the Cedynia Landscape Park

in deforested areas hemicryptophytes constituted a dominant group of plants. However, they play a less significant role in forest communities (Chmiel 1993), which is confirmed by results of the present study (Fig. 6A).

Contributions of historical-geographical groups to the total number of species varied between forest types, but apophyte species were usually most numerous (Fig. 8). The highest number of alien species was found in alluvial forests (alliance *Salicion albae*, *Alnenion glutinoso-incanae*), and riparian mixed forests along the major rivers (alliance *Ulmenion minoris*). The most numerously noted were *Impatiens parviflora*, *Fallopia convolvulus*, *Acer campestre*, *Lamium purpureum*, and *Viola odorata*. Phytocoenoses surrounded by rivers are penetrated by anthropophytes. Pine monocultures, which dominate in the Park, also are habitats of numerous alien species (like young plantations of *Pinus sylvestris*). The most numerously noted were *Padus serotina*, *Fallopia convolvulus*, *Picea abies*, *Conyza canadensis*, *Impatiens parviflora*. They are slightly less numerous in oak-hornbeam forests (*Impatiens parviflora*, *Fallopia convolvulus*, *Picea abies*, *Robinia pseudoacacia*, *Padus serotina*) and in mixed coniferous forests (*Fallopia convolvulus*, *Padus serotina*, *Picea abies*). Such trends are also observed in other regions of Poland (Chmiel 2000; Załuski & Paszek 2003).

In robinia woods, which are characteristic elements of plant cover in the Cedynia Landscape Park, anthropophytes occur in strikingly high numbers. Disturbances of the structure of plant communities and of the soil structure intensify the penetration by alien species (Faliński 1998; Orczewska 2000). The particularly high number of archaeophytes is also connected with their frequent contact with xerothermic swards and field phytocenoses, e.g. *Valerianella locusta*, *Vicia tetrasperma*, *Papaver dubium*, *Bromus sterilis*, *Anthriscus caucalis*,

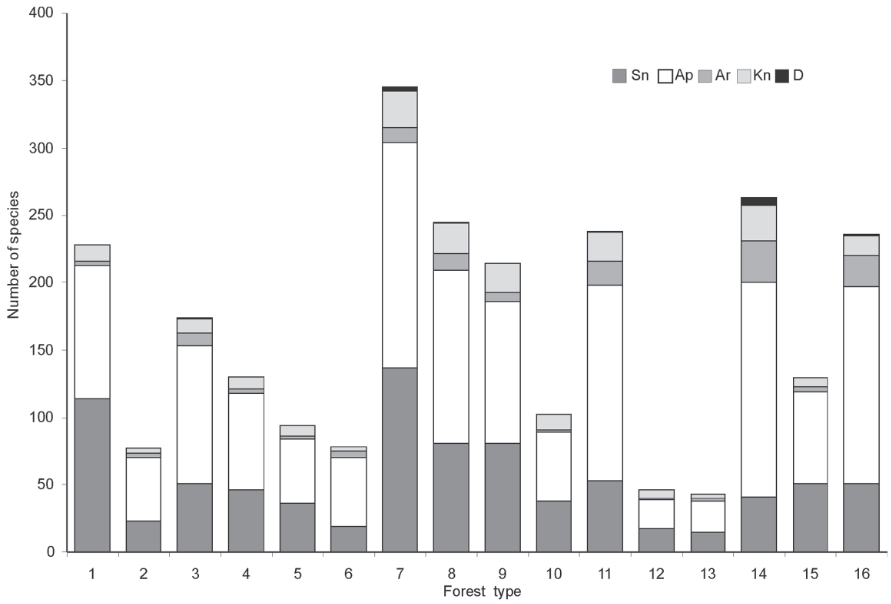

Fig. 8. Contributions of various historical-geographical groups to the flora of major forest types in the Cedynia Landscape Park
Explanations: 1 – alder swamp woods (*Alnion glutinosae*), 2 – fresh coniferous forest (*Leucobryo-Pinetum*), 3 – mixed coniferous forest (*Querco roboris-Pinetum*), 4 – mixed acidophilous beech and oak woods (*Fago-Quercetum petraeae*), 5 – acidophilous oak woods (*Calamagrostio arundinaceae-Quercetum*), 6 – Euro-Siberian steppe oak woods (*Quercetalia pubescenti-petraeae*), 7 – alluvial forests (*Salicion albae*, *Alnenion glutinoso-incanae*), 8 – riparian mixed forests along major rivers (*Ulmenion minoris*), 9 – oak-hornbeam forests (*Carpinion betuli*), 10 – beech forests (*Luzulo pilosae-Fagetum*, *Galio odorati-Fagetum*), 11 – monocultures of *Pinus sylvestris*, 12 – monocultures of *Picea abies*, 13 – monocultures of *Pseudotsuga menziesii*, 14 – monocultures of *Robinia pseudoacacia*, 15 – young plantations of *Alnus glutinosa*, 16 – young plantations of *Pinus sylvestris*; others: see Fig. 2

and *Consolida regalis*. A very low number of anthropophytes was found in the shaded understory of Douglas fir and spruce monocultures, whose species composition is poor.

5. Final reamarks

Phytocoenoses of large forest complexes are exposed to the penetration of synantropic plants to a various degree. Their outer parts are characterized by a higher number of apophytes and alien species which penetrate from neighbouring segetal and ruderal communities, meadows and xerothermic grasslands. Nevertheless, the number of non-synanthropic spontaneophytes is similar in the outer and inner parts of forest complexes.

Synanthropic species migrate into the internal parts of forest complexes from a network of roads, village areas, plantations surrounding the present or former human settlements and from rivers. The frequency of occurrence of many phanerophytes depends to a great degree on afforestation. New forest communities provide diaspores that penetrat neighbouring ecosystems. The highest number of alien species was found in alluvial forests and riparian mixed forests along the rivers. Phytocoenoses surrounded by rivers are penetrated by anthropophytes. Pine monocultures, which dominate in the Park, are also habitats of numerous alien species such as robinia woods. Disturbed habitats are more susceptible to invasion by alien plant species.

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