The occurrence of invasive alien plant species in selected forest nature reserves in southern Poland as a conservation problem

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Abstract

Forest reserves are the most common type of nature reserves in Poland. As a result of human impact they also underlie adverse changes from the viewpoint of nature conservation. In this paper, the results of phytosociological studies carried out in 14 selected nature reserves situated in the Silesian-Kraków Upland (southern Poland), with woodland communities as the prevailing vegetation type, were presented. Eleven neophytes were encountered in the forest interiors, of which three are very frequent and abundant: *Impatiens parviflora, Quercus rubra* and *Padus serotina* in the comparison with other alien species.

These three species differ significantly from each other in the phytosociological spectrum and habitat preferences but there are no differences between species richness of the forest patches invaded by them. In spite of the presence of alien species treated as a invasive, the forest communities are quite well preserved compared to invaded managed forests, but in the future some efforts should be made to protect native vegetation from the threat of invasive alien species.

Key words

Invasive plants, nature reserves, phytosociological study, forest vegetation, Poland.

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Nature reserves are created to protect remnants of the natural flora and fauna. The measure of the value of a particular reserve is the inclusion of rare, endangered and protected species. Thus, efforts are made to maximize the number of such species per area unit (cf. Pyšek 2002). However, even as a result of human influence, they are responsible for harmful changes in the flora and vegetation. The subject of synanthropization as defined by Faliński (1972) or human impact and disturbance in nature reserves, has caught the attention of phytogeographers, plant ecologists and conservationists for a long time in both Poland (Krawiecowa 1972; Olaczek 1998) and abroad (cf. Pyšek et al. 2002).

One of the threats to natural biodiversity is the increasing role of plants of alien origin including those considered as invasive species. There have been some quantitative attempts to describe the degree of synanthropization of nature reserves flora (Wika 1986). Besides in literature, one can find more proposals for an estimation of the invasion into vegetation at the phytosociological level (Faliński 1966; Olaczek 1974; cf. Łaska 2001). These methods can be useful in a quick evaluation of the range of biological invasion phenomenon in flora and vegetation in protected areas. Olaczek (1974) suggested the term ‘neophytization’, which is defined as the penetration of the neophytes into the community or artificial introduction of geographically foreign species. In the following work, a ‘neophyte’ is defined as an established alien plant species introduced after 1500 (Pyšek et al. 2004). The Polish equivalent term is ‘kenophyte’ whose definition coincides with that of with ‘neophyte’ (Kornaś 1990).

The main objective of the study was to examine role of invasive alien species in the forest vegetation of chosen nature reserves, in the Silesian-Kraków Upland. In detail, the objectives were designed to answer to the following questions; namely: (i) What is phytocoenotic spectrum of invasive plants in forest communities in selected nature reserves? (ii) What are the differences in invasion by neophytes? (iii) What are the differences (if any) between the degree of invasion in different nature reserves? And (iv) finally, can one on the basis of contemporary conditions, predict the future direction of invasions of forest phytocoenoses in the habitats studied.

Study area and methods

The studies were carried out in six nature reserves in the Silesian Upland and in eight nature reserves in the Kraków-Częstochowa Upland (Fig. 1, Table 1). The first region, covering an area of 3929 km^2 is characterized by a diverse relief and geological structure. The mean annual temperature amounts to ca. 8°C and the mean precipitation per annum amounts to between 665 and 859 mm (Kozyreva 2004). The Kraków-Częstochowa Upland covers an area of about 2615 km^2 and is mostly built from Jurassic dolomites. The characteristic elements of the landscape are limestone rocks of different shapes (relic mountains) and various caves as well as numerous castles.

The mean elevation of the area is about 350 m a.s.l. The soils of this area are rather poor, 60% of them are podzolic soils, and more rarely, brown soils occur. The mean annual temperature is ca. 7.5°C and the mean annual precipitation is ca. 700 mm but it increases to the south (Urbisz 2004).

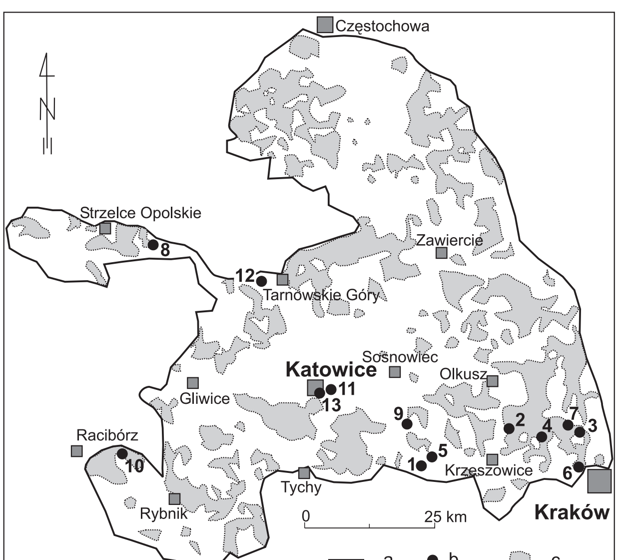

Fig. 1. Situation of the investigated nature reserves in the Silesian-Kraków Upland. a – border of study area, b – nature reserves, c – forests. 1 – Bukowica, 2 – Dolina Eliaszówki, 3 – Dolina Kluczwody, 4 – Dolina Racławki, 5 – Lipowiec, 6 – Ostra Góra, 7 – Skała Kmity, 8 – Wąwóz Bolechowicki, 9 – Hubert, 10 – Dolina Żabnika, 11 – Łężczok, 12 – Ochojec, 13 – Segiet, 14 – Las Murckowski.

In 2004, a total of 121 phytosociological relevés, using the commonly applied Braun-Blanquet method, were taken in forests in plots of 100 m^2. The relevés were collected in the forest interiors, away from forest roads and other sites of disturbance. Previous studies on the forest vegetation of selected nature reserves were used to observe sites occupied by neophytes (Wika, Cabała 1994; Sierka 2001; Bąba 2002; Bąba, Michalik 2002; Chmura 2002). Sites with the occurrence of alien species were mapped and using the random sampling numbers method some of them were selected for phytosociological research. The sites of relevés were included on the map or identified by means of GPS. The criterion for relevé selection was a presence of particular alien species in different forest phytocoenoses, independent of their various cover-abundance. The self collected material was listed in a table using the computer software JUICE 6.3 (Tichy 2002). For statistical purposes, the values of Braun-Blanquet were transformed as follows: r,+=1%; 1=2.5%; 2=15%; 3=38%; 4=63%, 5=88% and in further analysis, using numerical methods (Ward method, city block Manhattan), vegetation units were distinguished. Furthermore, by means of this software, values of the Shannon-Wiener index, average cover, and percentage constancy were calculated. For the purpose of estimation of the naturalization degree of invasive species, based on Aleksandrowicz's degree dominance (1951), the percentage cover of neophytes in relevés was calculated according to the following formula:

$$D_N = \frac{\sum C_N}{\sum C_{ALL}} \times 100\%$$

where: D_N = degree of neophytization, C_{NI} – sum of cover of all neophytes in relevé, C_{ALL} – sum of cover of all species in relevé.

In order to estimate the role of a particular neophyte in the neophytization of a community, its percentage relative cover P_N was computed according to the following formula:

$$P_N = \frac{C_N}{\sum C_N} \times 100\%$$

where: P_N = participation in neophytization, C_N – cover of neophyte in relevé, C_{NI} – the sum of cover of all neophytes in a relevé.

In order to characterize the habitat preferences of invasive species, the average values of Ellenberg (1992)

Table 1. Characteristics of the investigated nature reserves. Abbreviations of the names of forest communities: see Fig 2.

No.	Name	Region	Area (ha)	Forest Communities
1	Bukowica	Krak-Częst.	22.76	DF, LF, FC
2	Dolina Eliaszówki	Krak-Częst.	109.57	QP, FC, DF, TC, FA
3	Dolina Kluczwody	Krak-Częst.	35.22	DF, AU, TC
4	Dolina Racławki	Krak-Częst.	473.9	QP, LF, FC, DF, TC, FA
5	Lipowiec	Krak-Częst.	12.44	QP, DF, LF, FC
6	Ostra Góra	Krak-Częst.	7.22	FC, DF
7	Skała Kmity	Krak-Częst.	19.36	QP, DF, TC
8	Wąwóz Bolechowicki	Krak-Częst.	22.44	QP, TC, DF
9	Hubert	Silesian	13.47	QP, TC
10	Dolina Żabnika	Silesian	42.33	LP, QP, FA
11	Łężczok	Silesian	396.21	FA, TC
12	Ochojec	Silesian	26.77	CP, QP, FA, TC
13	Segiet	Silesian	24.99	FC, DF
14	Las Murckowski	Silesian	100.67	LF

indicators were calculated. During the computations, only binary data (presence/absence of species) were included and the values of invasive species studied were excluded. Syntaxonomical nomenclature were given after Matuszkiewicz (2001) and plant names followed Mirek et al. (2002). For comparisons of differences in D_N, P_N indexes and the values of Ellenberg indicators, the non-parametric ANOVA Kruskal-Wallis test was applied. The probability was called significant for level p<0.05 and lower.

Results

In the forest patches of the nature reserves, a total 11 neophytes species were observed. The most frequent was *Impatiens parviflora,* and the least represented were *Padus serotina*, and *Quercus rubra.* These three species also occur in the highest number of nature reserves compared to the remaining ones (Table 2).

The nature reserves differ in the number of neophytes. Hubert and Ochojec from the Silesian Upland were the

Table 2. Frequency of neophytes in selected nature reserves.

No. of object	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
Species/no. of relevés	**4**	**13**	**4**	**16**	**5**	**3**	**7**	**18**	**11**	**14**	**7**	**8**	**2**	**9**	**121**
Acer negundo									1			1			**2**
Aesculus hippocastanum		1						1							**2**
Bidens frondosa												1			**1**
Impatiens glandulifera					1										**1**
Impatiens parviflora	4	13	4	16	5		7	18	5	2	4	2	2	5	**87**
Padus serotina				1		3			1	1	3	4	1	3	**17**
Parthenocissus quinquefolia														1	**1**
Quercus rubra							1		8	11		3			**23**
Reynoutria japonica									1			1		2	**4**
Robinia pseudoacacia										2					**2**
Solidago gigantea									1						**1**
Total	**4**	**14**	**4**	**17**	**6**	**3**	**8**	**19**	**17**	**16**	**7**	**12**	**3**	**11**	**141**

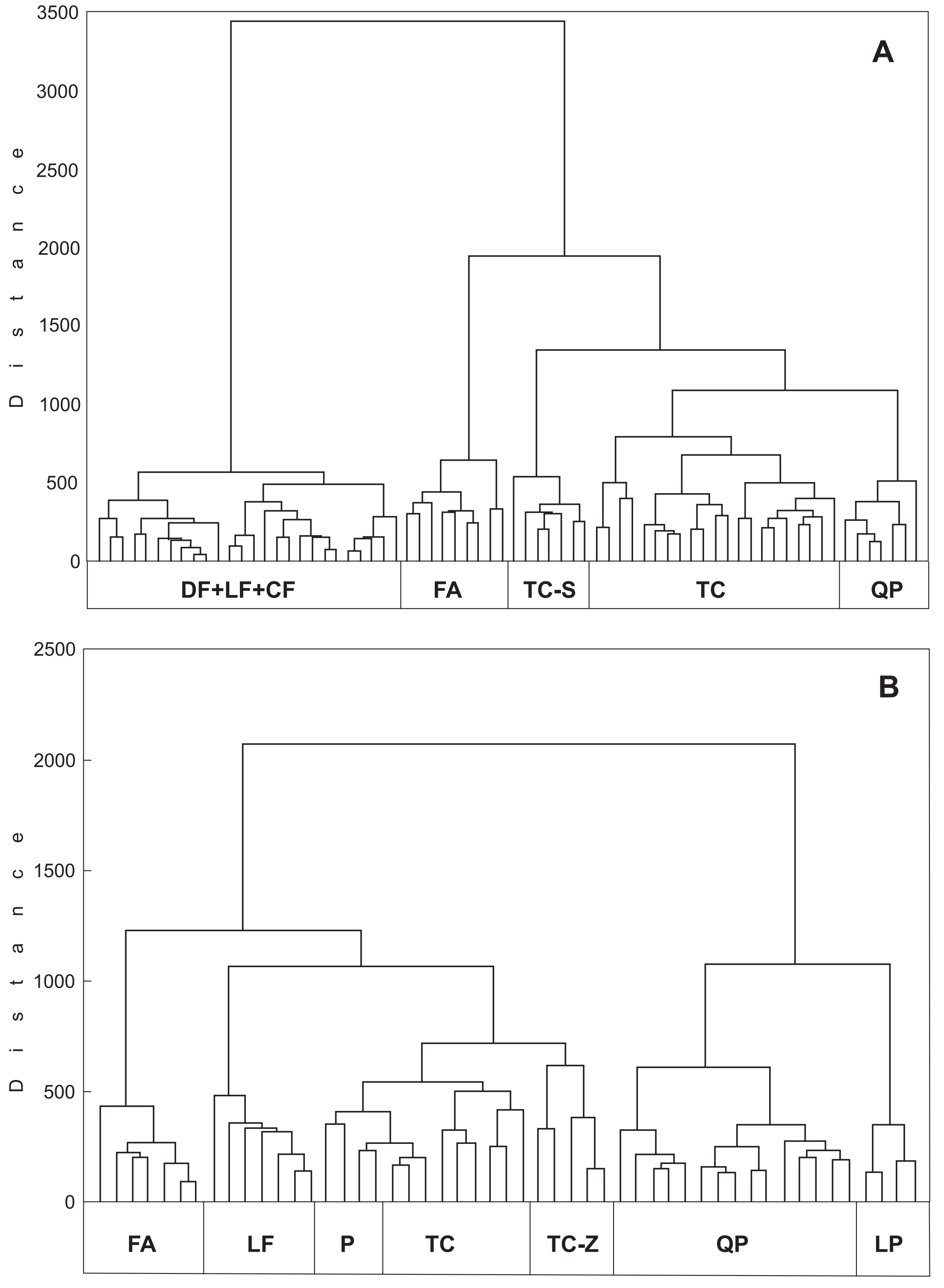

Fig. 2. Dendogram of the similarity of forest communities in the Kraków-Częstochowa Upland (A) and the Silesian Upland (B) using the Manhattan city block distance and Ward method. *Leucobryo-Pinetum* (LP), *Querco roboris-Pinetum* (QP), community *Fagus sylvatica-Cruciata glabra* (FC), *Luzulo pilosae-Fagetum* (LF), *Dentario glandulosae-Fagetum* (DF), *Fraxino-Alnetum* (FA), two subassociations *Tilio-Carpinetum stachyteosum* (TC-S), *Tilio-Carpinetum typicum* (TC-T), disturbed community of *Tilio-Carpinetum* (TC-Z), transitional phase between LF and TC (T) and one community of alliance *Alno-Ulmion* (AU).

most abundant. However, the highest number of records of neophytes was noted in Dolina Eliaszówki, Dolina Racławki, and Wawóz Bolechowicki on the Kraków-Częstochowa Upland, and on the Silesian Upland: Hubert and Dolina Żabnika (Table 2).

Numerical analysis led to 12 syntaxonomical units being distinguished in the forest communities of the Kraków-Częstochowa Upland and the Silesian Upland as follows: from the *Vaccinio-Piceetea* class: *Leucobryo-Pinetum* W. Mat. (1962) 1973, *Querco roboris-Pinetum* W. Mat. (1981) J. Mat 1988; from the *Querco-Fagetea* class: *Fraxino-Alnetum* W. Mat. 1952, two sub-associations of *Tilio cordatae-Carpinetum betuli* Tracz. 1962: *T-C stachyetosum*, *T-C typicum*, disturbed community of *Tilio-Carpinetum*, *Luzulo pilosae-Fagetum* W. Mat. et. A. Mat. 1973, *Dentario glandulosae-Fagetum* Oberd. et Müller, community *Fagus sylvatica-Cruciata glabra*, transitional phase between *Luzulo pilosae-Fagetum* and *Tilio-Carpinetum* and one community of alliance *Alno-Ulmion* Br.-Bl. et R.Tx. 1943 (Fig. 2A, 2B).

Table 3 comprises data on invaded forest communities. In the analysis, the phytocoenoses of oak-hornbeam forests *Tilio-Carpinetum* and its disturbed phases as well as transitional patches between it and the beech forests *Luzulo pilosae-Fagetum,* were treated together. The highest number of aliens was found in *Fraxino-Alnetum*, but in forest communities as *Querco roboris-Pinetum, Tilio-Carpinetum typicum,* and *Luzulo pilosae-Fagetum* – 4 species (Table 3). Of the neophytes observed, *Impatiens parviflora* has the widest phytocoenotic spectrum and it was noted in eight of nine vegetation units. In the relevés with the presence of neophytes, this species has a 100% frequency in *Tilio-Carpinetum stachyetosum*, as well as in alder carrs (*Alno-Ulmion*) and the *Fagus sylvatica-Cruciata glabra* community. In the remaining plant communities, the species also scores high percentage constancy (from 32% to 86%). However, its highest cover-abundance was noted in mixed pine forest *Querco roboris-Pinetum,* oak-hornbeam forest *Tilio-Carpinetum*, and beech forest *Dentario glandulosae-Fagetum*. Other frequent species are: *Padus serotina* (six forest communities), and *Quercus rubra* (four). Of the three, the most common and abundant species *I. parviflora,* contributes significantly more to the neophytization of forest vegetation both in the complete data set (Table 4) and in specific forest communities (Table 5). However, there are no statistical significant differences between *Q. rubra,* and *P. serotina* in relation to neophytization. The forest phytocoenoses differ significantly in degree of neophytization, with the highest percentage cover of neophytes concerning *Tilio-Carpinetum typicum* and beech forests *Luzulo pilosae-Fagetum,* and *Dentario glandulosae-Fagetum* as well as alder forest *Fraxino-Alnetum* (Table 5).

The above mentioned species i.e. *I. parviflora, Q. rubra,* and *P. serotina* differ in their habitat preferences, mostly with respect to light tolerance (L index). The small

Table 3. Percentage constancy and median cover of neophytes in forest communities

Species/syntaxon	**LP[5]**	**QP[25]**	**TC-S[7]**	**TC-T[30]**	**FC[2]**	**LF[13]**	**DF[21]**	**AU[9]**	**FA[9]**
Acer negundo									22(3)
Aesculus hippocastanum				3(2)				11(3)	
Bidens frondosa									11(3)
Impatiens glandulifera							1(3)		
Impatiens parviflora		32(17)	100(2)	90(18)	100(8)	69(8)	86(18)	100(5)	78(7)
Padus serotina b		16(14)				8(3)			
Padus serotina c				13(2)	50(2)	15(20)	14(5)		11(13)
Parthenocissus quinquefolia						8(2)			
Quercus rubra a		24(3)							
Quercus rubra b	60(13)	32(10)							
Quercus rubra c		16(3)		3(2)					11(2)
Reynoutria japonica		4(2)				15(13)			11(3)
Robinia pseudoacacia a	40(2)								
Solidago gigantea									11(2)
Total	**2**	**4**	**1**	**4**	**2**	**5**	**3**	**2**	**7**

Tab. 4. Comparison of habitat preferences, expressed by Ellenberg indicator values, and values of the Shannon diversity *H'* and average participation in neophytization P_N of three of the most common species. Values with different letters differ at a level of $p < 0.05$. L-light, T-temperature, F-moisture, R-soil reaction, N-nitrogen.

Species/indicator value	L	T	F	R	N	H'	P_N
I. parviflora	4.6^a	5.2^a	5.6^a	5.7^a	5.6^a	2.15	67.7^a
Q. rubra	5.6^b	5.3^b	5.7^b	4.4^b	4.5^b	2.13	13.6^b
P. serotina	5.7^c	5.3^b	7.3^b	6.1^a	6.0^a	2.14	10.8^b

Tab. 5. Comparison of the participation in "neophytization" of the three most common species and degree of neophytization", expressed by the percentage of neophytes D_N of particular forest communities. Values with different letters differ at a level of $p < 0.05$

Species/syntaxon	LP	QP	TC-S	TC-T	FC	LF	DF	AU	FA
I. parviflora	0	32^a	100	90^a	75	59.4	83.3	89	64.3^a
Q. rubra	60	53.7^a	0	0.07^b	0	0	0	0	0.2^b
P. serotina	0	10.3^b	0	9.4^c	25	19.2	14.2	0	11.1^b
D_N	4.56	6.93	0.93	9.05	4.36	7.3	7.65	2.58	6.74

balsam *I. parviflora,* prefers sites more shaded, whereas *P. serotina* prefers sites with the highest light availability. Both species occur in habitats less acid and with higher content of nitrogen compared to red oak *Q. rubra*. There are no statistical differences in the Shannon-Wiener index concerning relevés with the occurrence of these three species, although particular forest communities differ in relation to the value of *H'* (χ^2= 25, df=8, p<0.01).

Discussion and conclusions

Results of the studies carried out confirm that the most invasive species in the scale of the country (*Impatiens parviflora, Padus serotina, Quercus rubra*) (Tokarska-Guzik 2003b), are also very invasive in terms of the scale of the region including protected areas, i.e. in habitats which are relatively well preserved. These species are troublesome, from an environmental and conservation point of view, as they can compete and even exclude native woodland species (Pyšek et al. 1998; Vor 2004; Godefroid et al. 2005). It is a known fact that species which occur more frequently in a specific area, can usually easily spread in natural habitats as well (Kühn, Klotz 2004; Urbisz, Chmura 2005). Therefore, one can expect that species common in country flora are also more frequent in natural habitats. Another predictor of invasiveness and ability to enter natural communities, but of less importance, is the number of habitats occupied by a given species. The species found in forest interiors in the reserves studied are usually to be found in many types of habitats (Tokarska-Guzik 2003a) e.g. *Acer negundo, Impatiens parviflora, Quercus rubra, Reynoutria japonica,* and *Solidago* sp. Some of them i.e. *R. japonica* and *Solidago gigantea* are frequent but restricted to a smaller number of biotopes in terms of the country and *Impatiens glandulifera* are of less importance in forest vegetation. *Parthenocissus quinquefolia* is a casual alien, not established in the Polish flora (Mirek et al. 2002). Some species were encountered only on forest paths, roads and in the vicinity of nature reserves as archaeophytes: *Capsella bursa-pastoris, Malva neglecta, Senecio vulgaris, Lamium album* but they occur scarcely and not abundantly. Of the neophytes, the species to be found only in ruderal habitats are: *Oxalis fontana, Chamomilla suaveolens,* and *Juncus tenuis*. Also some species were found in forest interiors, more frequently they were encountered in semi-natural and ruderal habitats (forest paths). The forest stands with the occurrence of aliens do not differ significantly from those deprived of them; they also are characterized by a high species richness index (Table 4). This is due to the fact that invasive alien plant species in the reserves studied occur in quite well preserved phytocoenoses and their abundance is lower than in managed forests. There is considerable body of literature data indicating that logging, soil disturbance, the thinning of tree stands and above all the system of forest roads, promote invasions into forest interiors (Medwecka-Kornaś 1994; cf. Noss 2001; Watkins et al. 2001). In nature reserves forest management activities are limited or have completely ceased, dependent on conservation plans. Therefore, in the forest reserves studied, the number and abundance of neophytes is lower than in the managed forests of this region, especially for the Silesian Upland (Chmura 2004; Chmura, Sierka 2005). As the other studies show, the earlier establishment of nature reserves lead to smaller proportions of aliens in flora (Pyšek et al. 2003). Native resident vegetation also plays a role in the naturalization of non-native species. Pyšek et al. (2002) in the studies on the invasion in the reserves reported, that in lowland flora the proportions of aliens are biggest in beech and hornbeam forests compared to pine and oak forests. This is consistent with our data in spite of very small group of samples. The exception is pine-oak forest, phytosociologically *Querco roboris-Pinetum*, which in the objects studied is very abundant in aliens. This forest community is of an anthropogenic origin and is a degenerative phase of deciduous forests that was suggested by Bąba (2002), in the Dolina Eliaszówki and by Cabała (1990) for forest vegetation in the Silesian Upland.

Olaczek (1998) in his review work of floristic and phytosociological studies on 50 nature reserves mentions 13 of the most aggressively invasive and common neophytes, including: *Acer negundo, Padus serotina, Aesculus hippocastanum, Quercus rubra, Reynoutria japonica, Impatiens parviflora* and *I. glandulifera, Solidago* sp. and *Juncus tenuis*. The presence of all of them were confirmed in the forest reserves of the study area.

In our preliminary study we focused on the phytosociological approach and we omitted the relationships between invasions and both abiotic characteristics of nature reserves i.e. area, shape, vicinity, land use and biotic: the number and percentage of particular habitats and plant communities.

It is possible and reasonable for a larger pool of samples as in the review work by Pyšek et al. (2002, 2003), who analyzed data from 302 nature reserves. To assess the degree of invasion and its impact on indigenous plants, one should map localities and the range of the occurrence of invasive alien species and further analyze the obtained data. There is a debate as to whether native species richness and diversity hampers (Tilman 1999) or enhances invasions (Meiners et al. 2004). At present there are no literature data for forest communities, only for grasslands and abandoned fields in relation to invasion resistance. Preliminary studies on the permanent plots devoted to the relationships between native species richness and abundance of aliens, showed that some species e.g. *Impatiens parviflora* occur in sites characterized by higher numbers of native species, but it affects the cover of resident species (Chmura, Sierka 2005). At the phytosociological level, it is possible to determine negative or positive correlation between cover-abundance of alien and native species (Godefroid et al. 2005; Chmura, Sierka 2005; Chmura 2005). In the comparison with the other phytosociological results (Cabała 1990; Sierka, Chmura 2004), one can say that invaded forest communities occurring in nature reserves are better preserved than those which are exploited by forest management. They are also easier to classify phytosociologically in spite of the higher abundance of aliens in some relevés. One can predict that the vegetation of nature reserves without any control can be changed similarly as managed forests. Some species such as *Acer negundo, Padus serotina, Quercus rubra, Reynoutria japonica, Impatiens parviflora* and *I. glandulifera,* and *Solidago* sp. are considered as species which are still expanding their range and abundance (Zarzycki et al. 2002) and pose a serious threat to biological diversity, landscape and protected areas (Tokarska-Guzik 2005). Therefore some efforts should be made to prevent the remnants of native vegetation and flora from the threat of invasive species.

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REFERENCES

Aleksandrowicz B.W. 1951. Roślinność dna lasu (Vegetation of the forest floor). PWRiL (in Polish).

Bąba W. 2002. Zbiorowiska roślinne rezerwatu krajobrazowego „Dolina Eliaszówki" (Plant communities of the Eliaszówka Valley landscape reserve). Prądnik. Prace Muzeum Szafera 13: 115-120 (in Polish with an English summary).

Bąba W., Michalik S. 2002. Zbiorowiska roślinne rezerwatu „Wąwóz Bolechowicki" na Wyżynie Krakowskiej (Plant communities of the „Wąwóz Bolechowicki" landscape reserve in Kraków Upland). Prądnik. Prace Muzeum Szafera. 13: 121-129 (in Polish with English abstract).

Cabała S. 1990. Zróżnicowanie i rozmieszczenie zbiorowisk leśnych na Wyżynie Śląskiej (Differentiation and distribution of forest communities in the Silesian Upland). Uniwersytet Śląski, Katowice (in Polish with an English summary).

Chmura D. 2002. Występowanie kenofitów w zbiorowiskach leśnych na Wyżynie Śląskiej (The occurrence of kenophytes in forest communities of the Silesian Upland). UŚ, Katowice (mscr) (in Polish).

Chmura D. 2005. Invasion of woodland communities in the light of phytosociological studies. In: 8th International

Conference Ecology and Management of Alien Plant Invasions. University of Silesia, Katowice. Abstracts book. 50.

Chmura D., Sierka E. 2005. Effects of forest management on alien plant invasions of woodlands. Thaiszia – J. Botany 13 (15, Suppl. 1: 289-300).

Ellenberg H., Weber H.E., Düll R., Wirth V., Werner W., Paulissen D. 1992. Zeigwerte von Pflanzen in Mitteleuropa. Scripta Geobot. 18. Erich Goltze, Göttingen.

Faliński J. B. 1966. Próba określenia zniekształceń fitocenozy. System faz degeneracyjnych zbiorowisk roślinnych (An attempt of determination of degenerations changes in. of. System of degenerative phases of plant communities). Ekologia Polska 12: 31-42 (in Polish with a French summary)

Faliński J. B. 1972. Synantropizacja szaty roślinnej – próba określenia istoty procesu i głównych kierunków badań (Synanthropization of the plant cover – an attempt to define the nature of the process and of the main fields of investigations). Phytocoenosis 1, 3: 157-170 (in Polish with an English summary).

Godefroid S., Phartyal S.S., Weyembergh G., Koedam N. 2005. Ecological factors controlling the abundance of non-native invasive black cherry (*Prunus serotina*) in deciduous forest understory in Belgium. Biol. Conserv. 210: 91-105.

Kornaś J. 1990. Plant invasions in Central Europe: historical and ecological aspects. In: Di Castri F., Hansen A.J., Debussche M. (eds.). Biological invasions in Europe and Mediterranean Basin: 19-36. Kluwer Academic Publishers, Dordrecht/Boston/London.

Kozyreva E.A., Mazareva O., Molenda T., Rzętała M.A., Rzętała M., Trzhtsinky Y.B. 2004. Geomorphological processes in conditions of human impact. University of Silesia, Sosnowiec, pp. 1-88.

Kühn I., Klotz S. 2004. Why do alien plant species that reproduce in natural habitats occur more frequently? Diversity Distrib. 10: 417-425.

Krawiecowa A. 1972. Synantropizacja rezerwatów leśnych Opolszczyzny (Synanthropization of forest reservation of the Opole District). Phytocoenosis 1, 4: 257-266 (in Polish with an English summary).

Łaska G. 2001. The disturbance and vegetation dynamics: a review and an alternative framework. Plant Ecol. 157: 77-99.

Matuszkiewicz J.M. 2001. Przewodnik do oznaczania zbiorowisk roślinnych Polski (A guide for identification of plant communities in Poland). PWN, Warszawa, p. 537.

Medwecka-Kornaś A. 1994. Ochrona flory i roślinności na obszarach leśnych: stan i zadania (Conservation of forest flora and vegetation: actual state and tasks). Ochrona Przyrody 51: 3-21 (in Polish with an English summary).

Meiners S.J., Cadenasso M.L., Pickett S.T.A. 2004. Beyond biodiversity: individualistic controls of invasion in a self-assembled community. Ecol. Lett. 7: 121-126.

Michalik S., Michalik R., Michalik A. 1995. Szata roślinna rezerwatu krajobrazowego „Skała Kmity" i zagadnienia jej ochrony (The vegetation cover of the Skała Kmity landscape reserve (Cracow Upland) and its conservation). Ochrona Przyrody 52: 111-122 (in Polish with an English summary).

Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M. 2002. Flowering plants and pteridophytes of Poland: a checklist. W. Szafer Institute of Botany, PAS.

Noss R.F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conserv. Biol. 15 (3): 578-590.

Olaczek R. 1974. Kierunki degeneracji fitocenoz leśnych i metody ich badania (Trends of forest phytocoenoses degeneration and methods of their investigation). Phytocoenosis 3, 3/4: 179-190 (in Polish with an English summary).

Olaczek R. 1998. The synanthropization of plant cover in the protected areas as scientific and conservation problem. Phytocoenosis N.S. 10: Suppl. Cart. Geobot. 9: 275-279.

Pyšek P., Jarošík V., Kučera T. 2002. Patterns of invasion in temperate nature reserves. Biol. Conserv. 104: 13-24.

Pyšek P., Jarošík V., Kučera T. 2003. Inclusion of native and alien species in temperate nature reserves: a historical study from Central Europe. Conserv. Biology 17(5): 1414-1424.

Pyšek P., Prach K., Mandák B. 1998. Invasions of alien plants into habitats of Central European landscape: a historical pattern. In: U. Starfinger, I. Kowarik, M. Williamson (eds). Plant invasions: Ecological mechanisms and human responses. Backhuys Publishers, Leiden. The Netherlands: 23-32.

Pyšek P. Richardson D.M., Rejmánek M. Grady L. Webster G.L., Williamson M., Kirschner J. 2004. Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon 53 (1): 131-143.

Sierka E. 2001. Ekologiczne uwarunkowania występowania *Carex brizoides* na Wyżynie Śląskiej (Ecological background of the occurrence of *Carex brizoides* in the Silesian Upland). Ph.D. Thesis, University of Silesia, Katowice.

Sierka E., Chmura D. 2004. Changes in mixed pine forest (*Querco roboris-Pinetum*) as a result of forest economy in the Silesian Upland. Uniwersytet Zielonogórski, Inżynieria Środowiska, Zesz. Nauk. 131: 327-334.

Tichy L. 2002. JUICE, software for vegetation classification. J. Veget. Sci. 13: 451-453.

Tilman D., 1999. The ecological consequences of changes in biodiversity: a search for general principles. Ecology 80, 1455-1474.

Tokarska-Guzik B. 2003a. Habitat preferences of some alien plants (kenophytes) occurring in Poland. In: A. Zając, M. Zając, B. Zemanek (eds). Phytogeographical problems of synanthropic plants, p. 75-83. Institute of Botany, Jagiellonian University, Cracow.

Tokarska-Guzik B. 2003b. The expansion of some alien plant species (neophytes) in Poland. In: L.E. Child, J.H. Brock, G. Brundu, K. Prach, P. Pysek, P.M. Wade, M. Wiliamson (eds.). Plant invasions: Ecological treats and management solutions, Backhuys Publishers, Leiden, The Netherlands, p. 147-167.

Tokarska-Guzik B. 2005. Invasive ability of kenophytes occurring in Poland: a tentative assesment. In: W. Nentwig et al. (eds.). Biological Invasions – from ecology to control. NEOBIOTA 6: 47-65.

Urbisz A. 2004. Konspekt flory roślin naczyniowych (Synopsis of the vascular plant flora of the Kraków-Częstochowa Upland). University of Silesia, Katowice (in Polish with an English summary).

Urbisz A., Chmura D. 2005. Structure, characteristics and status of alien flora in the Kraków-Częstochowa Upland (southern Poland). 8th International Conference Ecology and Management of Alien Plant Invasions. University of Silesia, Katowice. Abstracts book, p. 89.

Vor T. 2004. Competitiveness of Northern Red Oak (*Quercus rubra* L.) regeneration in Germany. In: Abstract booklet. 3rd International Conference on Biological Invasions NEOBIOTA: from Ecology to Control 30. September – 1. October 2004. Zoological Institute, University of Bern, Switzerland, p. 28.

Watkins R.Z, Chen J., Pickens J., Brosofske K.D. 2001. Effects of forest roads on understory plants in a managed hardwood landscape. Conserv. Biol. 17(2): 411-419.

Wika S. 1986. Zagadnienienia geobotaniczne środkowej części Wyżyny Krakowsko-Częstochowskiej (Geobotanical problems of middle part of Kraków-Częstochowa Upland). Katowice, Uniwersytet Śląski (in Polish).

Wika S., Cabała S. 1994. Waloryzacja przyrodnicza rezerwatu „Las Murckowski" w Katowicach. Roślinność rezerwatu (Environmental valorization of the „Las Murckowski" in Katowice. Vegetation of the reserve). Kształtowanie środowiska geograficznego i ochrona przyrody na obszarach uprzemysłowionych i zurbanizowanych. WBIOŚ, WNOZ, UŚ, Katowice-Sosnowiec 15: 23-32.

Zarzycki K., Trzcińska-Tacik H., Różański W., Szeląg Z., Wołek J., Korzeniak U. 2002. Ecological indicator values of vascular plant of Poland. W. Szafer Institute of Botany, PAS.