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Biodiversity and species composition of xerothermic grassland patches following removal of shrubs and trees from the ecotone zone within the Polana Polichno reserve

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Abstract: The studies were conducted on species densities and ecological structure of grassland patches which had developed following removal of the shrubs and trees. The observations were made in the forest clearing reserve – the refugium of xerothermic grassland vegetation situated in the Ponidzie region (Poland). The researches were carried out on plots, which were established in the ecotone zone between forest and xerothermic grasslands as well as in the central part of the clearing. The analyses of species cover in recently revealed gaps in the ecotone zone showed a tendency for decline in species richness and strong dominance of the group of forest species. The analogous comparison of the species richness and composition of the gaps in the central part of the reserve indicated that the patches were being overgrown mainly by grassland species predominantly frequent in the surrounding area. Nevertheless, the characteristic feature of both cases was the diminishing density of species from the grassland group in gap areas. Summing up, we can conclude that in both cases, the gap areas, no matter if in the central part or in the ecotone zone, have been colonized predominantly by species transgressed from neighbouring sites – in the ecotone zone these were forest species, in grassland gaps the major group of colonisers constituted the grassland species.

Key words: biodiversity, species structure, xerothermic grassland, gaps, ecotone zone, active protection, Poland

1. Introduction

Changes in the species structure of the xerothermic grasslands are a common phenomena in the whole of Europe and in the majority of cases are due to the cessation of the traditional agriculture use of the areas, which is connected with eutrophication of the environment (Bąba 2003, 2004; Huber 1994; Gibson & Brown 1991; Ward 1990).

The decrease in species diversity is connected with colonisation of grasslands by bushes and trees and some grasses, especially *Brachypodium pinnatum*. The effect of these processes is first of all the disappearance of rare dicotyledonous grassland species, which is commonly explained by their low tolerance for shade (Dzwonko & Loster 1998; Willems 1983; Willems *et al*. 1993).

On the Ponidzie area, the processes of secondary succession on xerothermic grasslands, especially those surrounded by the forest, have proceeded very quickly (Bróż 1985). The ecotone zone at the border of grassland and forest in a very short time is being overgrown by bushes and trees, which causes rapid reduction of the xerothermic area. At the same time, there can be observed the colonisation of trees and bushes in the central parts of grasslands. To prevent secondary succession, many reserves of grassland communities have undergone active protection, which involves cutting bush and tree saplings in the ecotone as well as in central parts of grasslands.

The work presented shows comparison of the biodiversity as well as changes in species structure of gaps, which were created after cutting and removing trees and shrubs from grassland. The gap is defined here as a patch of the grassland community that was previously totally shaded by tree canopy or bushes and was revealed as a result of removing them. The aim of the study was to show: (*i*) which species colonized the gaps situated in the ecotone zone and in the central part of the grassland, (*ii*) what is the difference in percentage and densities of species from different ecological groups in gaps and in their surrounding area.

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2. Material and methods

2.1. Study area

The studies were conducted in one of the most interesting, from a floristic point of view, xerothermic grassland reserves: Polana Polichno. The reserve is situated in the Garb Wodzisławski mesoregion, in the Ponidzie Region about 7 km SSE from Pińczów. The remnant xerothermic grassland clearing, surrounded by *Tilio-Carpinetum* forest contains about 370 species of vascular plants, mainly typical of xerothermic grasslands and forest edges communities (Bróż 1985). Originally, all the area was covered by deciduous forest, which is documented on old 19th century maps. The clearing was formed as a result of cutting trees, after which the area was used as a field and then pasture. The documents show that in last half of the last century, the clearing was forested but such management totally failed because deciduous tree seedlings died due to lack of water.

After establishing the reserve, the whole area of the clearing was excluded from any agricultural use. The effect of such strict protection was the colonisation of the clearing by bushes, mainly by *Juniperus communis* and *Cornus sanguinea*. For several years, the bushes have been cut and removed from the interior of the reserve as well as from the ecotone zone between the grassland and the surrounding forest.

2.2. Methods

Studies on the colonisation of the gap areas were conducted in the ecotone zone between forest and grassland as well as in the interior of the grassland reserve. In the ecotone zone three plots (each 2 x 25 m^2 marked as E1, E2 and E3), divided into 3 x 50 x 1 m^2 subplots were established. Plot E1 represented places recently revealed by bush clearance, mainly *Cornus sanguinea, Prunus spinosa* and *Frangula alnus*. In the ecotone fragments where untouched grassland reached the border of forest, the plot E3 was established. Plot E2 was situated in a transitional belt between the gap areas and the grassland in the ecotone zone.

The studies concerning the species structure of grassland in the gaps and in the surrounding area were made on seven gaps in the central part of the grassland. Altogether, within the gaps area 40 subplots each 0.25 m^2 were established, which was marked as G1. The places on the border of the gaps and the grassland were categorised as G2 (transitional subplots; 26 x 0.25 m^2 between the gap and the grassland). The G3 plot, containing 35 x 0.25 m^2 subplots, was situated in a belt surrounding the particular gaps on the xerothermic grassland.

For each 3 x 50 x 1 m^2 subplot in the ecotone zone as well as for 101 x 0.25 m^2 subplots in the central part of the grassland, a list of species of vascular plants was made. According to Matuszkiewicz (2001), each species was classified into one of four ecological groups of species in terms of community type for which the species is characteristic: 1 – xerothermic grassland communities (mainly *Festuco-Brometea*), 2 – thermophilous bush communities (mainly *Trifolio-Geranietea*, *Rhamno-Prunetea*), 3 – forest communities (mainly *Querco-Fagetea*, *Vaccinio-Piceetea*), 4 – other species mainly from meadow and synanthropic communities.

The classification of the species into the ecological groups mentioned above was done on the basis of the work of Matuszkiewicz (2001). However, in a few cases, the classification was changed and the species were assigned to the group of communities where they have optimum occurrence especially in the Ponidzie region.

Species diversity for each type of plot was described on the base of the number of species per subplot. For comparison of the mean richness of species/plot, the Student test t was used with the assumption of non equal variance of species number distribution (Łomnicki 2003). The statistics F for comparison of variance between the species number distribution was conducted for the ecotone zone, E1 and E3, and the gaps area in the central part of grassland G1 and G3 (df: m -1, n -1, m=n=49, α=0.05 and df: m -1, n -1 m=40, n=35 α=0.05 for G1 and G3 in the central part of the grassland).

The similarity between the species composition of particular plots was measured by means of the similarity coefficient P of Jaccard-Steinhaus, taking into account qualitative traits of species presence. In the formula P=2c/a+b it was accepted that c was the number of species common for two plots while a and b were the numbers of species noted only in one of the plots compared. The nomenclature of species follows Mirek *et al.* (2002).

3. Results

3.1. Diversity of species richness and composition in ecotone zone

Altogether, on the 150 m^2 area that was divided into one – 1m^2 plots, 99 species of vascular plants were noted. The numbers of species were similar on E1 and E2 patches, 75 and 71 respectively and about one third lower in E1 (Table 1). The mean numbers of species on E3 and E2 oscillated between 14.34-14.76 (SD=2.53 and 2.6 respectively), significantly lower densities were noted on gap-area E1 and this amounted to 11.34 SD=2.54 (Fig. 1).

Forest species. The data from Table 1 shows that forest species turned out to be the most numerous group in all three ecotone plots. However, their percentages were different, on plot E3 they constituted 45% of all the species noted on the plot but on the E1 plot their percentage increased to almost 60%. Notably, the

Table 1. The numbers of species noted on plots situated in ecotone zone between xerothermic grassland and forest in Polana Polichno reserve

Plots	Ecological groups of species				Total
	Xerothermic grassland	Thermophilous bushes	Forest	Meadow and synanthropic communities	
E1	5	8	32	13	58
E2	9	12	37	13	71
E3	20	13	34	8	75
E1+E2+E3	22	15	43	19	99

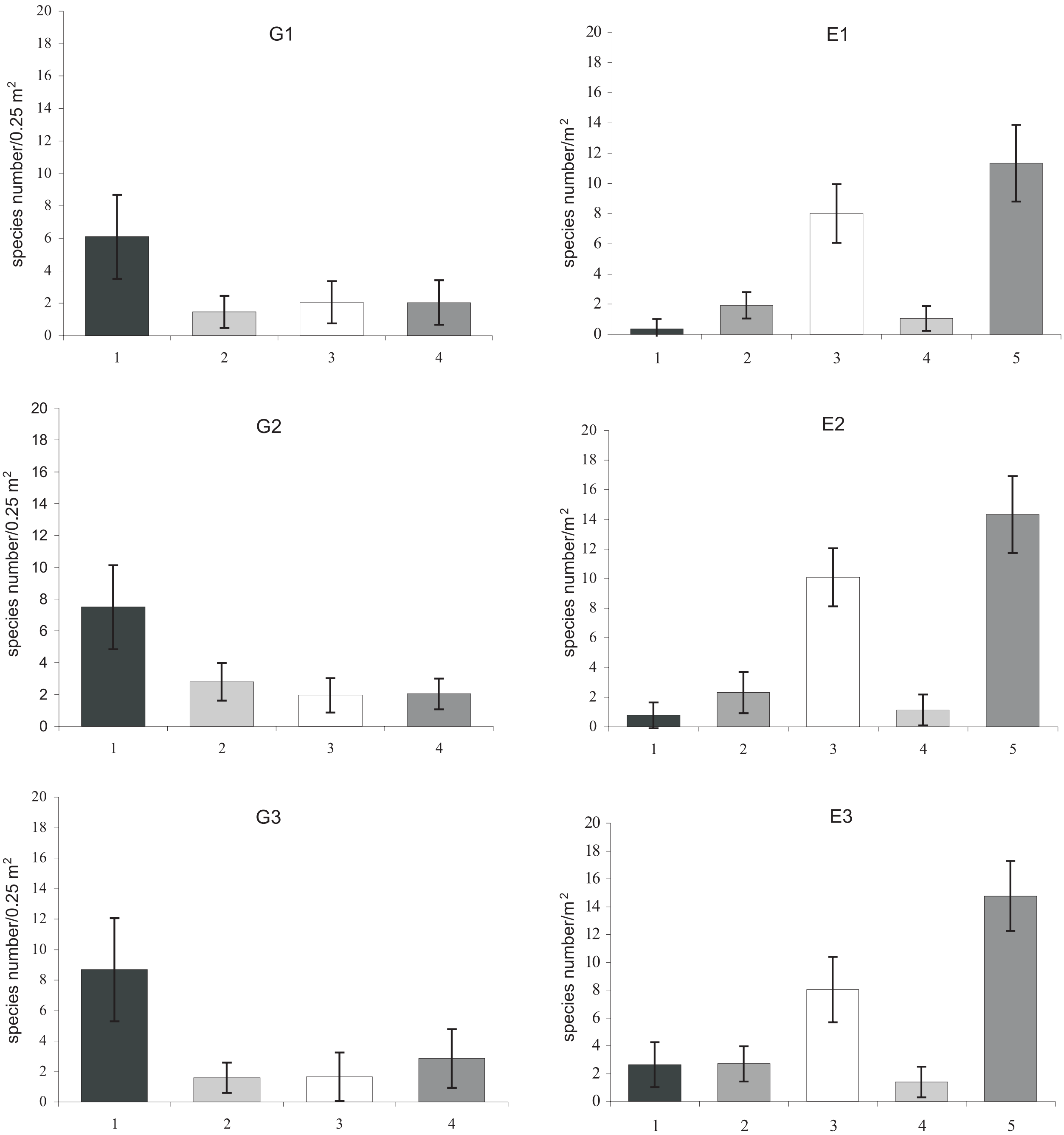

Fig. 1. The mean densities of the species from the different ecological group noted on plots which were situated in the central part of the grassland reserve (G) and in the ecotone zone respectively (E)
Explanations: 1 – xerothermic grassland communities, 2 – thermophilous bushes and forest edges communities, 3- forest communities, 4 – meadow and synanthropic communities, 5– all species

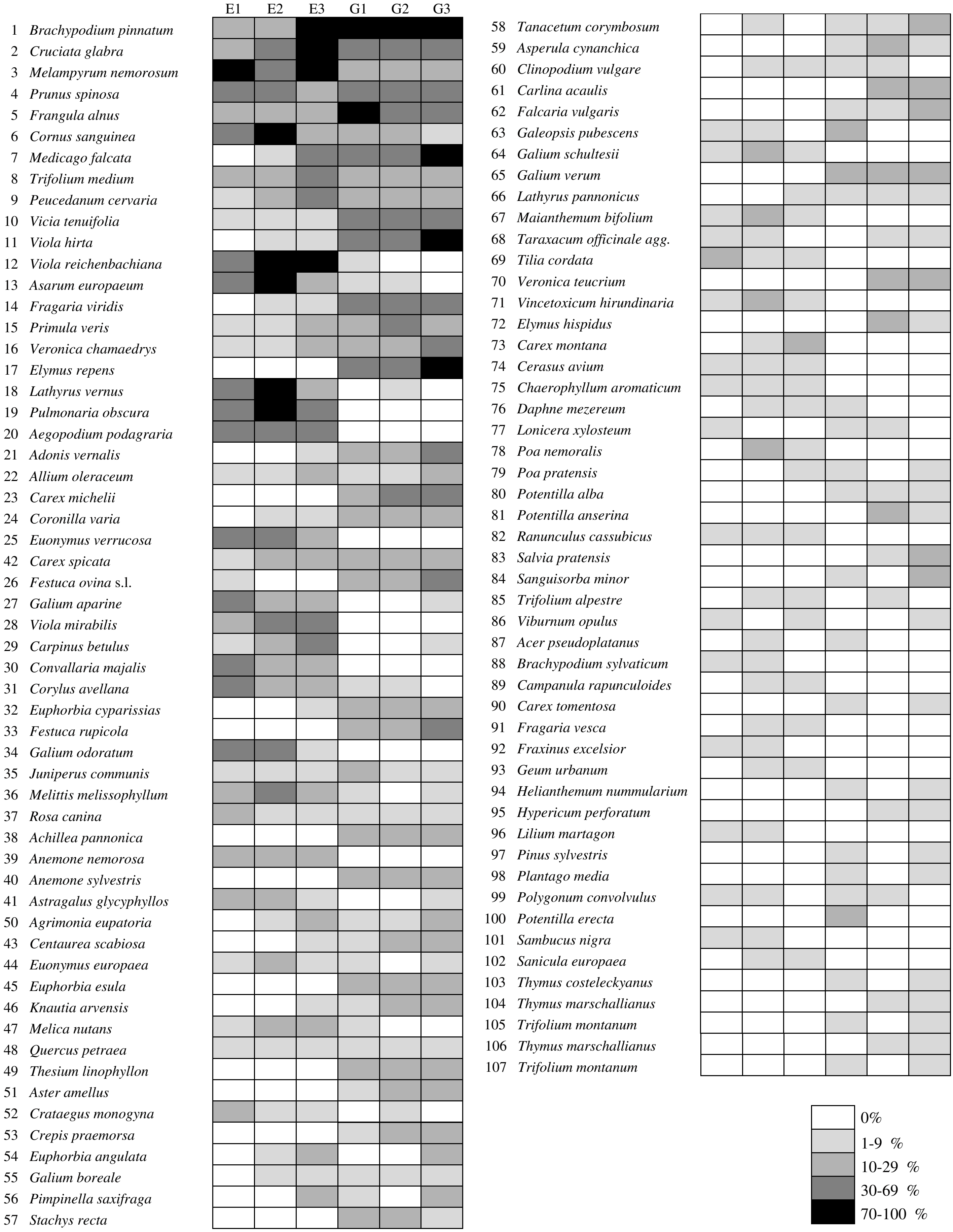

Fig. 2. The frequencies of species growing on plots situated in the ecotone zone between xerothermic grassland and forest (E) and in the central part of Polana Polichno reserve (G). Only species found on at least two plots, or on one but with frequency over 10%

highest density of forest species was observed on E2, i.e. on the border of the gap subplots /E3/ and undisturbed ecotone grassland /E1/ (Fig. 1).

To the most abundant forest herbs, which were present on E1 and E3 as well, belonged: *Pulmonaria obscura, Viola reichenbachiana, Cruciata glabra, Aegopodium podagraria* and among trees and bushes *Carpinus betulus, Euonymus verrucosa, Corylus avellana, Tilia cordata, Euonymus europaea, Quercus petraea, Q. robur, Cerasus avium*. The coefficient of similarity between E1/E3 amounted to 3.0.

Thermophilous bush and forest edge species. In the ecotone zone, the mean density of species from this group was 2-3 times lower than forest species. Altogether, fifteen species were observed, from which half were noted in each plot. The most frequent were: *Trifolium medium, Cornus sanguinea, Prunus spinosa, Peucedanum cervaria, Astragalus glycyphyllos, Crataegus monogyna* and *Rosa canina*.

The only species exclusively found in ecotone gaps was *Rhamnus cathartica*. The mean density of the species in places that had not been shaded by bushes and trees (E1 and E2) amounted to 2.3 and 2.7/m^2 (SD=1.6 and 1.39 respectively) while in gaps (E3) the mean density decreased to 1.92±0.87. The similarity coefficients between the ecotone patches in respect of the species amounted to: E1/E3 P=2.33.

Grassland species. In this group of species, a noticeable difference in their densities in gap areas (E1) and on the undisturbed part of the ecotone (E3), can be easily observed (Fig. 1). The gaps which were created after cutting bushes and trees were very slowly colonised by grassland species. As we can see on figure 1, the mean densities of the species decreased from 2.64/m^2 on E3 plot to 0.36 and 0.78 on E1 and E2 plots. Among all the species growing in the ecotone, only *Brachypodium pinnatum* occurred frequently. The frequencies of the rest of the species did not exceed the level of a few percent. All five grassland species, which were noted on E1, were also present on the E3 patch. Besides the *Vincetoxicum hirundinaria* all the species diminished their frequency in E1 with comparison to E3 (Fig. 2). The similarity coefficients between E1 and E3 for the species are lower than those analogous for bushes or forest species. E1/E3 P=0.57.

Other species mainly from meadow and synanthropic communities. Altogether, in the ecotone zone, 18 species of this group were found. It is worth stressing that on gap-patch (E1) they made up about 22% of all species, whereas on the lightly shaded part of the ecotone – E3, it was half as much, about 11%. However, the difference in mean densities of the species per 1 m^2 turned out not to be significant. The most frequent in the group of species were: *Galium aparine, Veronica chamaedrys, Fragaria vesca, Chaerophyllum aromaticum*. The coefficient of similarities between patches E1/E3: P=0.91

3.2. Diversity of species richness and composition in the central part of the grasslands

The observation concerned 7 gaps and their surrounding areas in the central part of the xerothermic grassland. Altogether on 101 subplots (each 0.25 m^2) 106 species of vascular plants: 47 grassland species, 13 thermophilous bushes and forest edges species, 26 forest species and 20 meadow and synanthropic species were found (Table 2). The mean number of species per 0.25 m^2 was the lowest in gap areas G3 and amounted to 11.7±3.16 (13.58±2.21; 14.80±3.47 on G1 and G2 respectively). Comparison of the frequency of particular species categorized by the above-mentioned group as well as changes of the number of species, were analysed as follows:

Grassland species. This group of species turned out to be the most numerous. The species made up 44% of all those noted. The most noteworthy for the authors is that grassland species dominated not only on surrounding areas G2 and G3 but also within the gaps area G1. However, the mean densities of the species in G3 an G2 amounted to 7.50 and 8.69 respectively and were significantly higher than on G1 (Fig. 1).

As many as 21 species were common for all the plots, the most frequent among them were: *Brachypodium*

Table 2. The numbers of species noted: within 7 gaps areas (G1) situated in central part of grassland; in transitional belts between gaps interior and xerothermic grassland (G2); in xerothermic grassland area surrounding the gaps (G3)

Plots	Ecological groups of species				Total
	Grassland	Thermophilous bushes	Forest	Meadow and synanthropic communities	
G1	34	9	21	14	78
G2	30	11	12	11	64
G3	42	8	15	15	80
G1+G2+G3	47	13	26	20	106

pinnatum, Medicago falcata, Viola hirta, Vicia tenuifolia, Carex michellii, Fragaria viridis, Primula veris, Festuca rupicola, Adonis vernalis. Only three species, which were found with frequency >10% on G2 and G3 were absent from the gaps area G1 (Fig. 2).

Forest species. When we consider the species number as well as their percentage on plots G1, G2, G3, the forest species were the most abundant in gap area (G1), where they made up 27% of all colonising species. However, the mean densities of the species were not considerably higher in gaps than in the neighbouring area (G1=2.08±1.31; G2=1.96±1.08; G3=1.66±1.64). Among 26 species noted in the gaps only two were found with distinctly higher frequencies. They were: *Cruciata glabra* and *Frangula alnus*. The majority of forest species were very rare or only noted once or twice on all subplots.

Thermophilous bush and forest edge species. In the studies, 13 thermophilous bushes and forest edges species were noted. The mean frequency oscillated here between 1.48±0.99 in gaps areas G1 and 2.08±1.20 on G2 (Fig.1). The most noteworthy fact is that this group turned out to be the most abundant in the zone between the gap and the grassland. The most frequent were: *Prunus spinosa, Coronilla varia, Peucedanum cervaria, Trifolium medium, Galium verum, Cornus sanquinea, Rosa canina.*

Other species mainly from meadow and synanthropic communities. The mean number of the species was similar on each of three plots. The total percentage number of the species amounted to 18% for G1, 17% for G2 and 19% for G3 respectively. The most abundant species were: *Elymus repens, Euphorbia esula, Festuca ovina s.l., Veronica chamaedrys.*

4. Discussion

The species – rich grassland communities are spread throughout Europe in different environments, but the common condition of stability of such ecosystems is maintained by the periodical removal of grasses by mowing, grazing or burning (Kotańska *et al.* 2000; Bakker & Berendse 1999). Mechanisms concerning the maintenance of species richness i.e. the number of species per unit, has been the subject of many plant ecological studies during recent decades (Bąba 2005; Hillier 1990; Huber 1994; Ward 1990; Willems 1983; Willems *et al.* 1993; Dzwonko & Loster 1992).

It is commonly believed, as seen in the works of Dzwonko & Loster (1998), Ward (1990), Bąba (2003) and others that species turnover was highest in the two years after shrubs and trees were cut. Generally, on managed plots the species richness was higher than in non-managed ones. Our results do not entirely support this point of view.

In the ecotone zone, the mean number of species was significantly lower than in the central part of grassland (Jankowska-Błaszczuk & Przemyski, unpub. data). Within the ecotone zone all observed patches were characterised by dominance of the forest species (Table 1). However, ecotone-gap areas were poorer in species and the percentage of forest species was higher than on the rest of the ecotone plots. The recently cleared areas (called here ecotone-gaps) were mainly colonised by forest species growing also on adjacent ecotone areas i.e.: *Melampyrum nemorosum, Cornus sanquinea, Viola reichenbachiana, Asarum europaeum, Lathyrus vernus, Pulmonaria obscura*. Some bush and forest species were even more frequent in the gaps than in the surrounding area: *Euonymus verrucosa, Galium odoratum, Crataegus monogyna, Corylus avellana, Tilia cordata, Convallaria majalis*. A significantly lower number of species in ecotone gaps, with a simultaneously higher percentage of tree and bush species, allows us to presume that on these places we would not be able to restore the original species structure of the xerothermic grassland.

Comparing the relationships between species richness as well as percentages of particular groups of species in the ecotone zone and in the interior of the grassland reserve, shows us some similarities and differences as well. In both cases, the mean densities of species declined in gap area (G1 and E1) and the percentage of the forest species was considerably higher in the recently cleared areas than that in the adjacent areas. In the case of the grassland gaps, the total number of species noted was not significantly lower than in the surrounding grassland. Nevertheless, on particular subplots, lower mean numbers of species were observed. The characteristic feature for both cases is the diminishing density of species from the grassland group in gap areas.

In the central part of the reserve two groups of species predominated in respect of their frequencies inside and outside the gap. The first group represented the species which were frequent in all plots (G1, G2 and G3 as well) e.g. *Brachypodium pinnatum, Cruciata glabra, Prunus spinosa, Vicia tenuifolia, Viola hirta, Fragaria viridis, Euphorbia esula,* and the second consisted of species whose frequencies were higher in gaps then in adjacent areas. They were: *Frangula alnus, Viola reichenbachiana, Asarum europaeum, Potentilla erecta, Galeopsis pubescens, Stachys recta, Juniperus communis*. It is worth noting that in spite of the decline in mean density of grassland species in grassland gaps, generally the species from the group dominated in G1, G2 and G3.

Summing up, we can conclude that in both cases, the gap areas, no matter if in the central part or in the ecotone zone, have been colonized predominantly by species from neighbourhood – in the ecotone zone it was forest species, in grassland gaps the major group of colonisers was the grassland species. As we know from literature, the persistent soil seed bank does not play an important role in recovering the grassland community (Bekker *et al.* 1997). In our studies, very few species appeared in the gap areas and at the same time were absent from adjacent plots.

Many authors emphasize that restoration of species-rich calcareous grasslands without additional management such as mowing and grazing would not be effective. (Dzwonko & Loster 1998; Kiefer & Paschlod 1996). The results showed clearly that cutting shrubs or trees from calcareous grassland causes changes in the species structure and does not stop impoverishment of species richness. Moreover, the gaps formed after cutting shrubs are very quickly overgrown by suckers of woody species.

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