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*Regular research paper*

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## EFFECT OF SHELTERBELTS ON ADJOINING CULTIVATED FIELDS: PATROLLING INTENSITY OF CARABID BEETLES (CARABIDAE) AND SPIDERS (ARANEAE)

**ABSTRACT:** The impact of wooded shelterbelts on the patrolling intensity (number of patrolling individuals per trap, per day (NP) – activity density) of spiders and ground beetles was investigated by using pitfall traps placed in parallel rows in shelterbelt centers, along margins of wood and field, and in open wheat fields at a distance of 10 and 50 m from trees. In the shelterbelt – managed areas the biomass of patrolling (BP) arthropods (ground beetles and spiders) was lower inside the fields ( $F_{10}$ ,  $F_{50}$ ) than at the field margins and in the shelterbelts. The BP and individual weight increased with the age of strips. However, in the control field with no wood in the vicinity, the BP of carabid beetles was as high as inside the shelterbelts. The highest similarity between the shelterbelts and the field (BP, Morisita's similarity index, diversity index  $H'$ , individual weight) was found in the field adjoining the youngest (aged 2 years) shelterbelt. It is concluded that similarity between permanent and cultivated ecosystems is important for successful exchange of individuals between them. In the field adjacent to young shelterbelt and in the field with no woods in the vicinity the aeronautic, agrobiont species prevail. In the fields adjacent to older shelterbelts colonization by large body-size species, characteristic for permanent ecosystems was found.

**KEY WORDS:** patrolling intensity, biomass of patrolling individuals, species diversity, similarity index, aeronautic species

### 1. INTRODUCTION

The idea of introducing permanent, heterogeneous ecosystems representing advanced stages of succession to crop fields to mitigate adverse impact of agriculture on the environment is rather common in the ecological literature. The importance of midfield woods was analyzed by many authors (Ryszkowski 1975, Ryszkowski and Karg 1976, Banaszak *et al.* 1996, Dąbrowska-Prot 1999, Ryszkowski *et al.* 2003). It has been found that they modify climatic conditions, water circulation, and they can function as barriers to eutrophication (Ryszkowski and Kędziora 1987, Życzyńska-Bałoniak *et al.* 1996, Bartoszewicz 2000, Kędziora and Olejnik 1996, Prusinkiewicz *et al.* 1996). One of the ways in which shelterbelts may influence crop fields goes through modifying diversity and abundance of the fauna by the exchange of individuals between those ecosystems.

It has been found that the size of particural fields is an important factor determining invertebrate diversity in farmland, especially where crop fields are surrounded with permanent ecosystems that can be sources of the fauna (Froese 1991, Frank and Nentwig 1995, Siepel *et al.* 1996). The more heterogeneous the landscape, that is, the longer the boundaries between ecosystems in relation to surface area, the greater is the faunal diversity. This relationship was confirmed by Barthel and Placher (1996) for foliage-dwelling spiders. Both the number of species and their abundance increased with the margin density per area. The lowest number of species and individuals was recorded from large, uniform crop fields. It has also been found that the abundance of predatory arthropods can be enhanced by introduction of parallel strips seeded with grasses and forbs into extensive fields (Kemp and Barrett 1989, Nentwig 1988, Lys and Nentwig 1991, 1992, Jepson 1994, Harwood and Wratten, 1994, Barthel and Placher 1995, Frank and Nentwig 1995, Imhasly and Nentwig 1995).

The objective of the present paper is an analysis of the impact of shelterbelts on adjoining fields basing on the analysis of the species diversity and patrolling intensity of the soil surface by the two mainly predatory, abundantly represented arthropod groups – spiders and carabid beetles. They are polyphagous predators effectively controlling numbers of herbivorous insects (Nyffeler 1982, Chiverton 1986, Sunderland *et al.* 1986, Riechert and Bishop 1990). They can also control numbers of some saprophages and enhance the content of organic matter in soil (Kajak 1997, Kajak *et al.* 2000). Both these groups are often considered to be reliable indices of the habitat quality (Duffey 1978, Hänggi *et al.* 1995, Malfait *et al.* 1997, Kromp 1999).

The effects of two variables were examined to estimate the impact of shelterbelts on these animal groups in adjacent fields: the distance to the wood boundary and the age of the tree stand. It has been assumed that if the wood affects adjacent fields, its influence will attenuate with the increasing distance from the edge, and the effect will be stronger with time since introduction of midfield woods. The investigations were performed in the three shel-

terbelts that differed in age and in the adjoining cereal fields. The field without wood in the vicinity was treated as a control. The analysis involved the intensity of patrolling the soil surface by spiders and carabid beetles, their body size in different ecosystems, similarity in the species composition, and species diversity of their communities.

## 2. STUDY AREA AND METHODS

The study was carried out in 2000 in the experimental area of the Research Center for Agricultural and Forest Environment of the Polish Academy of Sciences, situated near the village of Turew, the Wielkopolska region, Western Poland. This region has been cultivated since the 13th century, and agriculture continues to be the main people activity up to the present times. The area is a rolling plain. The upper strata of the soil developed under a deciduous forest. Soils of investigated area are Glossboric hapludalfs on loamy sand over light loam and Arenic hapludalfs on slightly loamy sand over light loam. They are poor in organic matter, with low water holding capacity, and slightly acid (pH 5–6) (Marcinek 1996, Ryszkowski *et al.* 2003, Kostro-Chomać 2003).

Samples were taken from three conventionally cultivated cereal fields bordering on shelterbelts, and from a control field (C) under cereals, with no woods in the vicinity. All the woods were planted on arable land with the soil that initially did not differ from that in the adjacent fields. The tree species in shelterbelts were diverse; the oak was basic (appropriate for oak-hornbeam forest habitats, which dominated in the area). Maples, birch, beech, elm, linden, mountain ash, white beam, larch pine and spruce were accompanying species. Shelterbelts in study area differed in age, they were 2 years old (Site 1), 4 years old (Site 2), and 7 years old (Site 3). The wood strips were 12–18 m wide and 350–800 m long.

The patrolling intensity of the soil surface by arthropods was recorded by using pitfall traps (7 cm in diameter, 10 cm deep) containing ethylene glycol and detergent. Traps were placed in rows consisting of 10 traps every 2 m. They were exposed for one week three times a season (May, June, September). The pitfall traps were located in

4–5 rows in every shelterbelt-managed site: (1) in the centre of each shelterbelt (S), (2) at the edge of the shelterbelt ( $E_S$ ), at the field margin ( $E_F$ ), and (3) within the field at distances of 10 m (only on site 3) and 50 m from the wood edge (Fig. 1). The distance between the two rows of pitfalls situated in the marginal zone ( $E_S$  and  $E_F$ ) was several centimetres only.

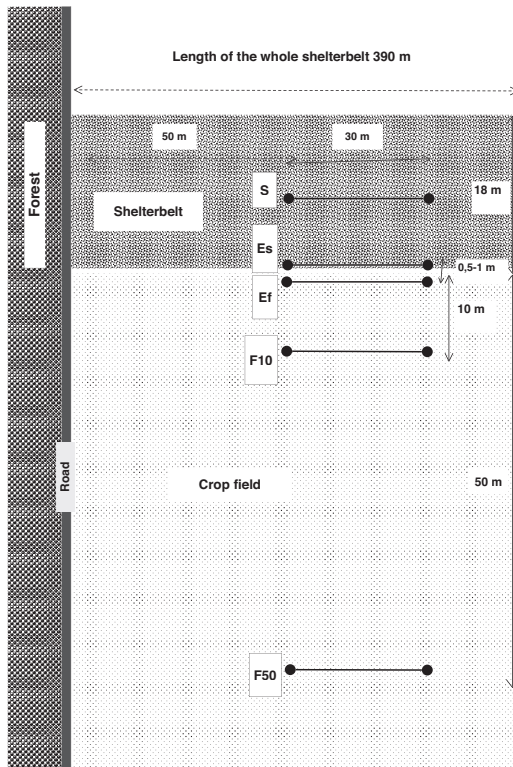


Fig. 1. Schematic overview of the rows of pitfall traps in study sites located in the shelterbelt managed areas S – shelterbelt,  $E_S$  – shelterbelt edge,  $E_F$  – field edge, F10, F50 – field at the distance 10 and 50 m from the edge. (after Wojewoda and Russel 2003).

Based on the pitfall catches, the patrolling intensity (NP – number of patrolling individuals trapped per trap per day – activity density) of ground beetles and spiders was estimated, as well as the biomass of patrolling arthropods (BP – activity biomass). The biomass was determined by weighing adult individuals. Lengths of young specimens have been measured and weight of particular size categories was determined. A total of 2616 individuals (38 species) of carabid beetles and 4049 individuals (110 species) of spiders was caught during the study.

The significance of differences between sites was tested by two ways ANOVA (Statistica) and between plots within sites by Tukey post hoc test or multiple range test.

Morisita's index of similarity between communities (modified by Horn) after Krebs (1989) was applied

$$M = 2 \sum_{i=1}^s x_i y_i / \sum_{i=1}^s x_i^2 + \sum_{i=1}^s y_i^2 \quad (1)$$

where  $x_i$  or  $y_i$  are numbers of individuals in successive species recorded in respective habitats,  $s$  – total number of species.

### 3. RESULTS

In the shelterbelt-managed areas the biomass of patrolling (BP) arthropods (ground beetles and spiders) was lower inside the fields ( $F_{10}$ ,  $F_{50}$ ) than at the field edges and in the woods (Figs 2 and 3, Table 1). Differences in BP values between the fields and the other plots were significant in the fields adjoining older shelterbelts 4 and 7 years old. In the site 1, where the wood was the youngest, (two years old) BP was similar in all the compared plots (Fig. 2 and 3). In the control field, with no woods in the vicinity, biomass (BP) and patrolling intensity of spiders (number of patrolling individuals NP) was similar in values to the fields adjoining shelterbelts. The differences were not significant in most cases (Figs 2 and 4, Tables 1 and 2), but the biomass (BP) and patrolling intensity (NP) of ground beetles was there as high as inside the woods or in the marginal zones; it was significantly higher than in the fields located in the shelterbelt-managed areas (Tables 1 and 2, Figs 3 and 5).

Differences between plots in terms of the number of individuals captured (NP) are less clear. There was no relationship between the shelterbelt age and patrolling intensity of spiders and carabid beetles (Figs 4 and 5). Significant negative relations were found between the distance from the wood and patrolling intensity by spiders and non predatory carabids (spiders –  $F=6.41$ ,  $P=0.0001$ , non predatory carabids –  $F=18.81$ ,  $P=0.0001$ ), but patrolling by predatory carabids was independent on this distance ( $F=1.57$ ,  $P=0.19$ ).

The biomass (BP) of both groups of arthropods was positively correlated with organic matter content in the soil (Table 4).

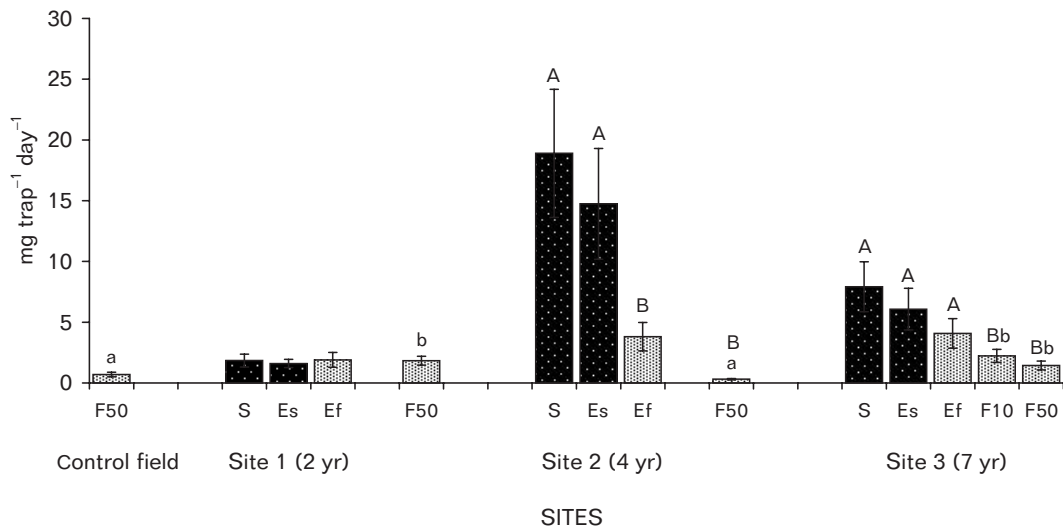


Fig. 2. Mean biomass of spiders patrolling soil surface (BP) ( $\text{mg d.wt.trap}^{-1}\text{day}^{-1}$ ). Different small letters indicate significant differences between fields (two-ways ANOVA followed by Tukey's test), different capital letters indicate significant differences between plots within the same site. Biomass in the shelterbelt-managed area depends on the age of trees ( $F=6.63, P < 0.0003$ ). Black columns – shelterbelts, gray columns – fields. Bars – SE. Abbreviations as in Fig. 1.

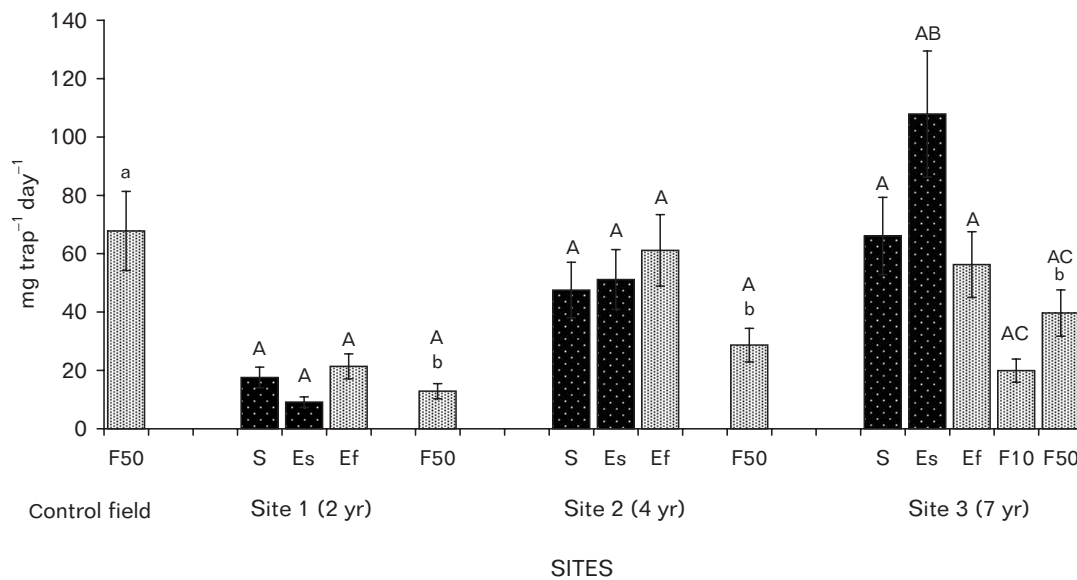


Fig. 3. Mean (May-Sept.) biomass (BP) of carabid beetles patrolling soil surface ( $\text{mg d.wt. trap}^{-1}\text{day}^{-1}$ ). Biomass depends on the age of wood strip ( $F=41.82, P < 0.001$ ) and of distance from the wood ( $F=28.34, P < 0.001$ ). Black – shelterbelts, gray – fields. Explanations in Figs 1 and 2.

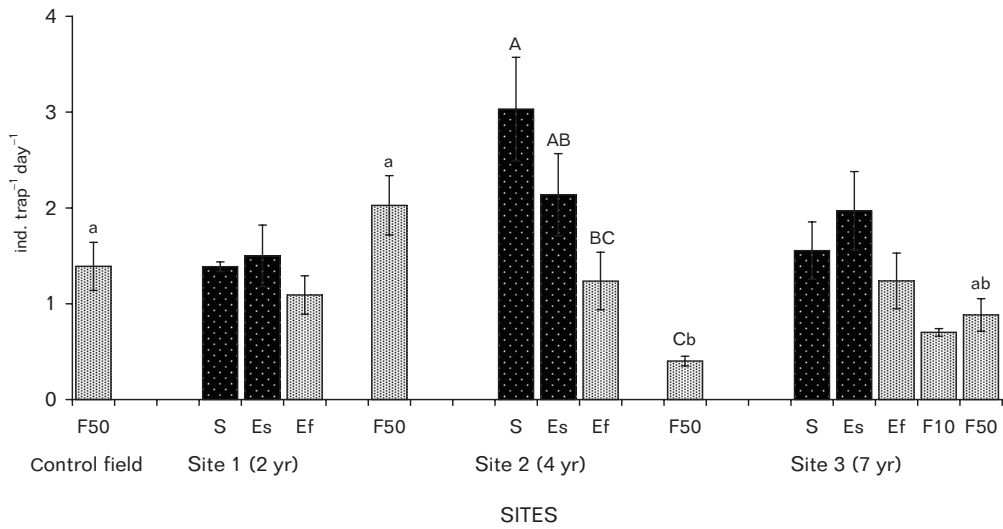


Fig. 4. Mean (May–Sept.) of patrolling intensity of spiders (number ind. trap<sup>-1</sup>day<sup>-1</sup>). Bars – SE. Explanations in Figs 1 and 2.

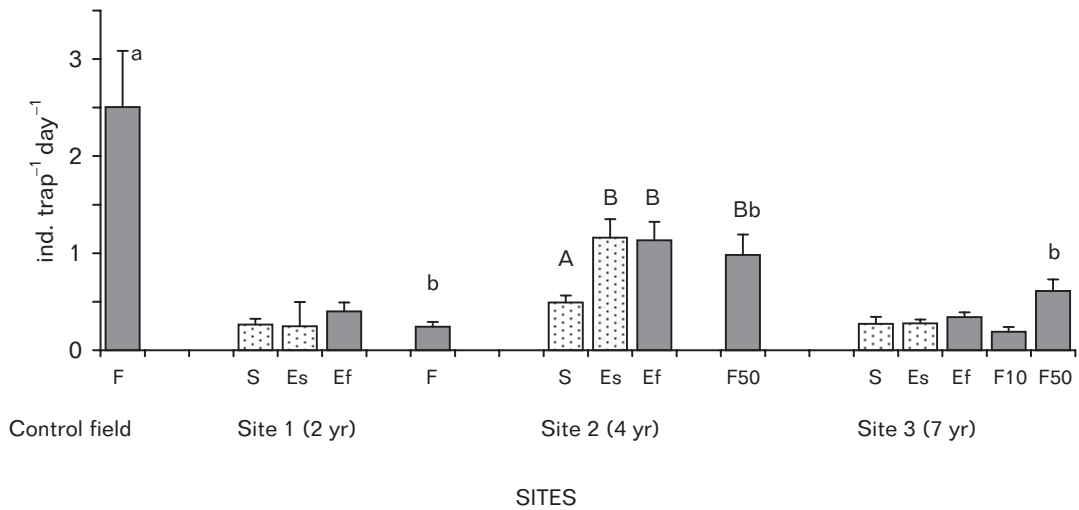


Fig. 5. Mean (May–Sept.) of patrolling intensity of carabid beetles (number of individuals trap<sup>-1</sup>day<sup>-1</sup>). Explanations in Figs 1 and 2.

Table 1. Mean (May–Sept.) patrolling intensity (NP, ind. trap<sup>-1</sup>day<sup>-1</sup>) of arthropods (Carabidae, Araneae) in cereal fields located in control field (C) area with no wood in the vicinity and in fields adjacent to shelterbelts, differentiated by planting time: Site 1 (2 yrs old), Site 2 (4 yrs old), Site 3 (7 yrs old).

Group	Fields adjacent to differently aged shelterbelts			
	Control field	Site 1	Site 2	Site 3
Carabidae				
predatory	17.53a	1.87b	7.1b	3.28b
non predatory	0.73a	0.47ab	0.17b	0.48ab
Araneae	1.39a	2.03a	0.40b	0.88ab

Different letter in the same row means significant difference between values (Tukey test).

Table 2. Mean (May–Sept.) biomass of patrolling arthropods (BP, mg d. wt. trap<sup>-1</sup>day<sup>-1</sup>) in cereal fields adjoining shelterbelts differentiated by planting time: Site 1 (2 yrs old), Site 2 (4 yrs old) and Site 3 (7 yrs old) and in control field (C). Explanations as in Table 1.

Group	Control (C)	Site 1	Site 2	Site 3
Carabidae				
predatory	67.77	12.87	28.67	39.68
Non predatory	37.67a	13.50ab	3.67b	28.75ab
Araneae	0.70a	1.83b	0.31a	1.44b

Different letter in the same row means significant difference between values (Tukey test).

Table 5. Mean (May–Sept.) individual weight (mg d.wt) of Carabidae (A) and Araneae (B) in the shelterbelt-managed sites and in the control site. E<sub>S</sub> – wood edge (ecotone), E<sub>F</sub> – field margin, F<sub>10</sub>, F<sub>50</sub> – field in the distance of 10 and 50 m from the wood edge. Control site – no wood in the vicinity, Site 1 – field bordering on 2 yrs old shelterbelt, Site 2 – on 4 yrs old, Site 3 – on 7 yrs old. Wooded area in bold.

#### A. Carabidae

Site	Plots						F	P
	Shelterbelt	E <sub>S</sub>	E <sub>F</sub>	F <sub>10</sub>	F <sub>50</sub>	F		
Control								
Site 1	<b>65.18</b>	<b>36.48</b>	48.62			53.62a	0.33	0.80
Site 2	<b>101.1</b>	<b>42.28</b>	51.84			27.83ab	3.12	0.03
Site 3	<b>220.3</b>	<b>291.5</b>	152.16	94.90		55.89ac	2.85	0.04

Age effect in shelterbelt managed area: two ways ANOVA F=15.58, p=0.0001. Different letters in the F50 column indicate significant differences between fields (multiple range test).

#### B. Araneae

Site	Plots						F	P
	Shelterbelt	E <sub>S</sub>	E <sub>F</sub>	F <sub>10</sub>	F <sub>50</sub>	F		
Control								
Site 1	<b>1.11</b>	<b>0.97</b>	1.70			0.75a	2.37	0.07
Site 2	<b>3.65</b>	<b>4.13</b>	4.10			0.88a	2.86	0.04
Site 3	<b>6.07</b>	<b>4.82</b>	2.86	2.87		1.67b	6.68	0.0003

Age effect in shelterbelt-managed area: two ways ANOVA F=12.07, P < 0.0001. Different letters in the F50 column indicate significant differences between fields (post hoc Tukey test).

Table 3. Results of analysis of variance (two ways ANOVA) on the effects of shelterbelt age and distance of sampling plots from it on mean biomass of patrolling arthropods.

Effect	df	F	P
Age of shelterbelt:			
Predatory Carabidae	2	23.17	<0.0001
Non predatory Carabidae	2	8.67	<0.0002
Araneae	2	41.82	<0.0001
Distance from wood:			
Predatory Carabidae	3	4.51	<0.004
Non predatory Carabidae	3	11.44	<0.0001
Araneae	3	28.34	<0.0001

Table 4. Correlation coefficients ( $\tau$ ) between soil organic matter content and mean biomass of patrolling arthropods (BP).

Taxa	Correl. coeff. ( $\tau$ )	n	P
Carabidae	0.41	13	0.036
Araneae	0.52	13	0.036

Kendall's  $\tau$  calculated basing on soil organic matter content (Kostro-Chomać 2003) and mean biomass of patrolling individuals recorded in every plot.

In almost all cases an individual weight of spiders and carabid beetles patrolling open fields (F<sub>50</sub>) was smaller than of those patrolling woods or field margins. In both groups an increase in the weight with the

Table 6. Species richness (SR) and Shannon-Wiener diversity index ( $H'$ ) (SD in brackets) of Carabidae (A) and Araneae (B) in shelterbelt managed area and in control site. Explanation of sites in Table 5. Wooded area in bold.

## A. Carabidae

Site	Parameter	S	$E_s$	$E_f$	$F_{10}$	$F_{50}$
Control area	SR					15
	$H'$					2.93 (0.19)
Site 1						
2 yr old	SR	<b>19</b>	<b>16</b>	22		15
shelterbelt and adjacent field	$H'$	<b>2.85</b> (0.11)	<b>3.34</b> (0.29)	3.58 (0.28)		3.16 (0.16)
Site 2						
4 yr old	SR	<b>16</b>	<b>23</b>	23		16
shelterbelt and adjacent field	$H'$	<b>2.71</b> (0.17)	<b>3.56</b> (0.26)	3.50 (0.28)		3.19 (0.24)
Site 3						
7 yr old	SR	<b>15</b>	<b>20</b>	17	12	16
shelterbelt and adjacent field	$H'$	<b>3.00</b> (0.04)	<b>3.55</b> (0.13)	3.52 (0.10)	3.24 (0.10)	2.70 (0.13)

## B. Araneae

Site	Parameter	S	$E_s$	$E_f$	$F_{10}$	$F_{50}$
Control site	SR					22
	$H'$					2.59 (0.31)
Site 1						
2 yr old	SR	<b>34</b>	<b>28</b>	31		26
shelterbelt and adjacent field	$H'$	<b>3.67</b> (0.10)	<b>3.26</b> (0.11)	3.66 (0.10)		3.04 (0.25)
Site 2						
4 yr old	SR	<b>24</b>	<b>27</b>	27		15
shelterbelt and adjacent field	$H'$	<b>2.62</b> (0.27)	<b>2.81</b> (0.11)	3.68 (0.12)		2.62 (0.06)
Site 3						
7 yr old	SR	<b>45</b>	<b>37</b>	41	27	26
shelterbelt and adjacent field	$H'$	<b>3.98</b> (0.10)	<b>3.90</b> (0.26)	4.42 (0.03)	3.76 (0.12)	3.46 (0.14)

Differences between plots tested by t – test, all not significant.

age of wood was also noted, not only inside the woods, but also in the adjoining fields (Table 5). The individual weight was smaller in the control field, than in the fields located in the shelterbelt managed areas. Some exceptions to this picture were noted in the site 2 (Table 5).

Species diversity of spiders was in most cases higher in the shelterbelts and field margins than in the open field ( $F_{50}$ ). The highest values were noted at the site 3, in the oldest shelterbelt and in the adjoining field. The lowest diversity was found in the control field, with no wood in the vi-

city (Table 6B). The carabid beetle community responded differently to the management. In the most cases the diversity was higher in marginal zones ( $E_s$  and  $E_f$ ) than inside the shelterbelts. Species diversity in the fields was not lower than in the shelterbelts. The diversity in the control field was as high as in the field bordering on the oldest shelterbelt (Table 6A). Differences in diversity among particular plots in both communities (spiders and carabid beetles) were not significant.

In the shelterbelt managed areas a high similarity was found between the wood cen-

tres and the wood margins, in both the spider and the carabid beetle communities. The Morisita's similarity index (equation 1) values ranged from 0.75 to 0.95 in spider communities, and from 0.51 to 0.77 in carabid beetles (Table 7). The similarity index was still high in most cases between the shelterbelt centre and the field edge, but was much lower between the shelterbelts and more distant parts of the adjoining fields ( $F_{10}$ ,  $F_{50}$ ) (spiders: 0.005–0.70, carabids: 0.07–0.44). In spider communities, the highest similarity was noted between the youngest shelterbelt and the adjoining field (Table 7). The community of carabids did not show this regularity. It is possible however that the number of individuals of this group captured in the field at the site 1 was too small (70 individuals) to conclude about the index value. Similarity between the two edges – the shelterbelt and the field edge, were the highest in the youngest shelterbelt and adjoining field in both communities (Table 7).

Table 7. Morisita's index of similarity between communities in differently aged shelterbelts and successive plots in adjacent fields. Explanations as in Table 6. Wooded area in bold.

#### A. Carabidae

Sites	Similarity values			
	S→E <sub>s</sub>	S→E <sub>F</sub>	S→F <sub>50</sub>	E <sub>s</sub> →E <sub>F</sub>
1	<b>0.68</b>	0.81	0.18	0.90
2	<b>0.51</b>	0.52	0.39	0.84
3	<b>0.77</b>	0.71	0.07	0.70

#### B. Araneae

Sites	Similarity values			
	S→E <sub>s</sub>	S→E <sub>F</sub>	S→F <sub>50</sub>	E <sub>s</sub> →E <sub>F</sub>
1	<b>0.79</b>	0.96	0.70	0.78
2	<b>0.95</b>	0.19	0.005	0.26
3	<b>0.70</b>	0.74	0.24	0.68

Table 8. Morisita's index of similarity between communities in the field located in control area (C) and in strip managed areas (Site 1, 2, 3). Explanations as in Table 5.

Taxa	Sites		
	Site 1	Site 2	Site 3
	C→F <sub>50</sub>	C→F <sub>50</sub>	C→F <sub>50</sub>
Carabidae	0.085	0.40	0.02
Araneae	0.90	0.40	0.51

The community of the control field markedly differed from those of the other fields. These differences were especially high among carabid communities (Table 8).

In the study area eleven dominant carabid taxa were distinguished: *Pterostichus virens*, *P. cupreus*, *Bembidion* sp. *Calathus melanocephalus*, *C. ambiguus*, *C. fuscipes*, *Carabus hortensis*, *Agonum dorsale*, *Trechus* sp. *Harpalus* sp. and *Amara* sp. (App. 1). They account in particular plots for 30–94% of the total number of captured individuals. Two taxa (*C. ambiguus* and *P. virens*) were numerous in the field plots of all compared sites. All other dominant species change from site to site. The proportion of *P. cupreus* was higher in the shelterbelts and marginal zones than in the fields in the older sites only (2 and 3). At the site 1 three *Harpalus* species (*H. psitaceus*, *H. affinis* and *H. froelichii*) and *Amara* sp. were important in these plots. *Bembidion* sp., *C. ambiguus* and *fuscus*, *Agonum dorsale* and *Trechus* sp. were numerous in site 2 in marginal zone (Es, Ef) and in the adjacent field as well as in the control field. *C. melanocephalus*, dominating in the control field (35%) was scarce in other sites. So it can be concluded that the carabid beetle community structure was very variable from site to site.

The community structure of spiders was more consistent. The number of dominant species recorded was similar to that of carabids: *Erigone atra*, *E. dentipalpis*, *Oedothorax apicatus*, *Pachygnatha degeeri*, *Alopecosa pulverulenta*, *Pardosa palustris*, *P. lugubris*, *Trochosa terricola*, *Drassylus pusillus*, *Xysticus cristatus* and *X. kochi* were most important (App. 2). They constituted 70–91% of the total number of captured individuals. Three groups of dominant species can be distinguished (Table 9): 1. Agrobionts – the small size, aeronautic spiders, most numerous in open areas and in the youngest shelterbelt – (*E. atra* and *O. apicatus* comprised a high proportion), 2. Species numerous in the older shelterbelts and in marginal zones – (mainly *A. pulverulenta*), 3. Eurytopic species, represented in all plots, numerous in the fields, shelterbelts and field margins as well – (mainly *P. palustris* and *P. degeeri*) (Table 9). Two species common in forests, even in ancient forests – *T. terricola* and *P. lugubris*, dominated only in the oldest shelterbelt (site 3).

Table 9. Total numbers of dominant spider species captured in pitfall traps in control field (C) located in landscape without woods in vicinity and in landscape with differently aged shelterbelts: Site 1–2 yrs old, Site 2–4 yrs old, Site 3–7 yrs old. Abbreviations as in Fig. 1. Wooded areas in bold.

Numbers of individuals captured																		
Species	C					Site 1				Site 2				Site 3				
	F50	S	Es	Ef	F50	S	Es	Ef	F50	S	Es	Ef	F10	F50				
<i>Group 1: Agrobionts</i>																		
<i>Erigone atra</i>	102	<b>83</b>	<b>66</b>	49	111	<b>6</b>	<b>8</b>	6	5	<b>5</b>	<b>8</b>	5	23	5				
<i>Erigone dentipalpis</i>	16	<b>35</b>	<b>9</b>	33	55							2	2	2				
<i>Oedothorax apicatus</i>	117	<b>35</b>	<b>94</b>	50	114		<b>11</b>	38	43	<b>1</b>		2	19	48				
<i>Oedothorax retusus</i>	2	<b>16</b>	<b>32</b>	8					7				18					
Total	237	<b>169</b>	<b>201</b>	140	280	<b>6</b>	<b>19</b>	44	55	<b>6</b>	<b>8</b>	9	62	55				
<i>Group 2: Inhabitants of permanent ecosystems</i>																		
<i>Alopecosa pulverulenta</i>		<b>4</b>	<b>1</b>	6	2	<b>275</b>	<b>210</b>	25		<b>55</b>	<b>87</b>	44	6	3				
<i>Drassyllus pusillus</i>		<b>1</b>	<b>1</b>	2		<b>5</b>	<b>5</b>	3		<b>36</b>	<b>36</b>	28	3	1				
<i>Pardosa prativaga</i>		<b>4</b>	<b>9</b>			<b>43</b>	<b>16</b>	5		<b>1</b>	<b>4</b>	3	2	1				
<i>Trochosa terricola</i>		<b>2</b>	<b>1</b>	4	3	<b>3</b>				<b>49</b>	<b>15</b>	9	1	2				
<i>Pardosa lugubris</i>		<b>1</b>		1	1			1		<b>33</b>	<b>14</b>	6	11	5				
<i>Xysticus cristatus</i>			<b>5</b>	3		<b>28</b>	<b>23</b>	2		<b>31</b>	<b>13</b>	9	4					
Total		<b>12</b>	<b>17</b>	16	6	<b>354</b>	<b>254</b>	36	0	<b>205</b>	<b>169</b>	99	27	12				
<i>Group 3: Eurytopic species</i>																		
<i>Pachygnatha degeeri</i>	7	<b>34</b>	<b>12</b>	29	63	<b>22</b>	<b>10</b>	7	1	<b>1</b>	<b>8</b>	9	12	8				
<i>Pardosa palustris</i>	45	<b>19</b>	<b>11</b>	11	16	<b>58</b>	<b>43</b>	14	2	<b>27</b>	<b>31</b>	13	35	35				
<i>Xysticus kochi</i>	1	<b>15</b>	<b>11</b>	10	15	<b>3</b>	<b>4</b>	3		<b>12</b>	<b>28</b>	18	7	13				
Total	53	<b>68</b>	<b>34</b>	50	94	<b>83</b>	<b>57</b>	24	3	<b>40</b>	<b>67</b>	40	54	56				
Total number of dominant species	328	<b>301</b>	<b>289</b>	249	434	<b>533</b>	<b>399</b>	175	83	<b>319</b>	<b>394</b>	220	163	162				
Dominant species (%)	88	<b>83</b>	<b>87</b>	83	88	<b>83</b>	<b>83</b>	59	70	<b>79</b>	<b>62</b>	91	89	76				

The analysis of similarity indices and composition of dominant species suggests, that many species occurred in both the shelterbelts and the adjoining fields, so the exchange of individuals between these plots is quite possible.

#### 4. DISCUSSION

We tried to answer a question whether the enrichment of farmland with shelterbelts intensified the patrolling of the whole area by large, mainly predatory arthropods. The biomass of patrolling (BP) spiders was significantly higher in the two fields under study located near shelterbelts than in the control field without nearby woods. Also the marginal zone was more frequently penetrated than more distant field areas. Biomass (BP) of carabids followed a different pattern. It was also the highest in the marginal zone, but very high in

the control field with no woods in the vicinity. Differences in favor of the control field were particularly high in autumn. The average weight of individual in both arthropod communities increased with the age of shelterbelts. In spider community significant increase concerned not only wooded areas but also the adjoining fields.

It can be concluded that the introduction of habitat islands to farmland is of importance to fauna primarily when the exchange of individuals is possible between the bordering ecosystems, that is when they are inhabited by fauna, with at least partly similar species composition. In our study, the biomass of the patrolling spiders and ground beetles, increased with years after the introduction of the shelterbelts. These corresponded with increasing contrasts between the woods and the adjacent fields in terms of the species composition, individual body weight, and total biomass of the patrolling fauna. Differences in all

the variables measured, between the youngest, 2 years old shelterbelt, and the adjoining field were not significant. It is likely that, the exchange of individuals was most intense there.

The abundance of spiders and ground beetles were assessed in the same area several ten years earlier within a mature shelterbelt, comprising mainly *Robinia pseudo-acacia*, and in surrounding fields (Górny 1968a and b, Bońkowska 1970, Bońkowska and Ryszkowski 1975, Łuczak 1975, 1979, 1980). Górny (1968a), who analysed Carabidae, recorded an intensive exchange of individuals between adjacent habitats. He found a high penetration of fields at long distances from the shelterbelt by the species that reproduced in wood. Moreover, he found that this old wood was dominated by the species associated with open areas. Likewise, Bońkowska (1970) found that many most abundant species occurred in both the wood and the adjoining field. Bońkowska and Ryszkowski (1975) gave evidence of high ability to migrate in carabid populations in crop fields. However, the exchange of individuals between shelterbelts and crop fields is not a rule. Kromp (1999), who reviewed the literature on the response of Carabidae to the way of management of the agricultural landscape, quotes data of various authors who found that shelterbelts not always functioned as dispersal sources to fields, or as wintering sites. Using marked individuals, it was found that their dispersal from various wood islands beyond the ecotone zone was weak.

It has even been found that increased densities of spiders at the edge of fields have not resulted in increases in the field interior, especially in large habitats (Samu *et al.* 1999). On the other hand however, decline in the carabid and spider density was recorded, after extending the area of crop fields (e.g. the removal of hedges) (Kromp 1999).

More consistent are the results of manipulations designed to diversify crop fields by introducing strips of multispecies grassy vegetation. It has been found that they contribute to an increase in the density, diversity and area patrolling by predatory arthropods (Kemp and Barret 1989, Nentwig 1988, Froese 1991, Lys and Nentwig 1991, 1992, Thomas *et al.* 1991 and 1992, Jepson 1994, Harwood and Wratten 1992, Hawthorne and Has-

sall 1994, Lys 1994, Barthel and Plachter 1995, Frank and Nentwig 1995, Imhasly and Nentwig 1995, Wolak 2001). It has been found in addition that the smaller the distance between strips of permanent vegetation, the higher was activity density in interspaced fields.

These findings imply that the introduction into the crop fields, of permanent ecosystems inhabited by invertebrate communities partly similar to those occurring in field areas, increases their possibility to colonize surrounding crops.

In this study we found that the intensity of the patrolling of soil surface by carabid beetles and spiders was positively related to the content of organic matter in the soil. The same relationship concerning the effect of predatory macroarthropods on organic matter accumulation was found in field experiments conducted on meadows (Kajak 1997, Kajak *et al.* 2000). Kaczmarek (1978) however, found that during succession in forest ecosystems – the abundance of saprophages increased with the increasing content of organic matter in the soil, whereas the intensity of area patrolling by predators decreased. In deeper soil layers only, where carbon content was very low, this author found positive correlation between activity of predators and organic matter content.

A characteristic feature, observed by many authors and also confirmed in this study, is the occurrence of larger individuals in communities of predatory arthropods in woods or in marginal zone than in cultivated fields (Łuczak 1975, 1979, Kajak and Łukasiewicz 1994, Szujecki *et al.* 1983, Skłodowski 1995). The body size of carabids is treated as one of the indices of the conditions of the habitats (Szujecki *et al.* 1983, Szujecki 1990, Szyszko 1993, Blake *et al.* 1994). Our study shows, in addition, that the individual body weight of spiders increased not only within shelterbelts, but also in the adjacent cereal fields.

Most of the dominant species found in this study can be classified as occurring in the open habitats (Turin *et al.* 1991, Hänggi *et al.* 1995, Platen 1996, Samu and Szinetár 2002). In the communities of carabid beetles it was difficult to distinguish between species associated with shelterbelts and those associated with fields. The analysis of changes in carabid communities with secondary succession of pine forests grown on old fields showed that the

species typical of forests appeared as late as after 11 years (Szujecki *et al.* 1983, Skłodowski 1995). In the communities of carabid beetles in ancient forests totally different species composition in relation to field communities was found (Kabacik-Wasylik 1970). In spider communities, however, such a distinction was clear also between fields and young woods.

In the both studied communities a high proportion of the dominant species associated with fields consisted of colonizers, that is species able for aerial dispersal, such as *Erigone sp.*, *Oedothorax sp.* and *P. palustris* among spiders (Łuczak 1975, Thomas and Jepson 1999, Ratschter and Roth 2000) or *Bembidion sp.*, *Amara sp.*, and *Harpalus sp.* among carabids (Van Huizen 1980). It is likely that arable fields are colonized by these species from open areas, as far as they are more numerous in the field with no woods in the vicinity than in the fields located in shelterbelt-managed areas. The above-mentioned species of spiders typically appear as first colonizers in damaged or reclaimed areas (Snazell and Clarke 2000, Samu and Szinetár 2002). In the fields adjacent to the older shelterbelts higher number of species originated from permanent ecosystems (Group 2) was recorded. It is likely, that they colonize fields from the area of shelterbelts.

Later with the succession open fields are colonized also from shelterbelts by the species of larger body size, characteristic for permanent ecosystems – forests and meadows (Group 2 of spider community). The bigger mean individual weight of spiders found in these fields are the consequences of this event. The highest abundance of representatives of this group originated from permanent ecosystems was recorded in the field adjoining the oldest – 8 years old shelterbelt. These species were absent in the control field, without woods in the vicinity. Only in the oldest shelterbelt, species common in ancient forests (*T. terricola*, *P. lugubris*) were found (Biström and Väisänen 1988).

## 5. CONCLUSIONS

1. In the cultivated fields the dominant spider species comprised agrobiont and eurytopic species, mainly small in size, dispersing by air, originated from open habitats, mainly fields. In the shelter-

belt-managed areas spiders larger in size, inhabiting forest and meadow ecosystems, absent in the uniform, agricultural landscape, colonize fields also.

2. The introduction of shelterbelts to agricultural landscape has little effect on the total patrolling intensity of adjacent crop fields by carabids and spiders. The biomass of patrolling communities was high in the marginal zone, whereas spiders patrol internal parts of the crop field with the intensity similar to that in the area without shelterbelts. The patrolling intensity by carabid beetles was the highest in the field with no wood in the vicinity.
3. The distinct differences between the field located in the area without woods and in the shelterbelt-managed areas are in the species composition and mean body weight of individuals.
4. Spider and beetle communities occurring in the youngest, 2-years-old shelterbelt, were most similar to those occurring in adjoining fields in terms of species composition, size of individuals, and diversity. Thus, the highest rate of faunal exchange between these habitats may be expected.

## 6. SUMMARY

The purpose of the paper was to analyze differences in the intensity of area patrolling by predatory arthropods between shelterbelts and the adjoining winter wheat fields, and also differences between shelterbelt-managed areas and the control field without woods in the vicinity. Young shelterbelts that differed in age (2, 4, and 7 years since establishment) were under study. The patrolling intensity was examined by using traps inserted into soil, arranged in parallel rows containing 10 traps each at 2-m distances. The rows of traps were placed in the center of each shelterbelt, on the boundary line of the shelterbelt, on the boundary line of adjoining crop fields, and at a distance of 50 m from the tree line (Fig. 1). An additional trap row was established at a distance of 10 m in the field bordering on the oldest shelterbelt. The presence of shelterbelts did not increase the patrolling intensity of the adjacent cereals. Both the patrolling intensity in terms of numbers (NP) and of the biomass (PB) were significantly higher in the control field located in the woodless area, as compared with those in the fields interspaced with woods. The patrolling intensity of this area by spiders was similar to that of the crop fields adjoining the shelterbelts (Tables 1 and 2, Figs 2, 3, 4, and 5).

The total PB of spider and carabid communities was lower in the fields adjoining shelterbelts (aged 4 and 7 years) than within these strips or in the marginal zone (Figs 2 and 3, Table 3). Their biomass increased with the age of woods (Figs 2 and 3). Individual body size was also smaller in the fields than in the woods (Table 5). The species diversity of the two groups under study was lower in the fields, but differences between the fields and the woods were not significant (Table 6).

The biomass of faunal communities patrolling these areas was positively correlated with the content of organic matter in soil (Table 4).

Faunal similarity between the woods and the fields (biomass, body size, species composition) was highest for the area adjoining the youngest shelterbelt (Figs 2 and 3, Tables 5, 6, 7, and 8). It may thus be concluded that the exchange of individuals between the adjoining ecosystems was most intense in this habitat. Dominants in the crop fields were agrobiont and eurytopic species, mainly small in size colonizers that can disperse by air. Based on the comparison of the spider community composition in the fields located in shelterbelt-managed landscape and in the uniform landscape without permanent ecosystems, it can be concluded, that fields are colonized by these species from other crops, mainly by air. The fields adjacent to woods are colonized also by spiders larger in size, which originate from the shelterbelts (Table 9).

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Appendix 2. Species composition and number of individuals of Araneae collected by pitfall traps in shelterbelts differentiated by age and in adjacent cereal fields. (Explanations as in App. 1).

Species	Control	Site 1				Site 2				Site 3				
	field	S	E <sub>S</sub>	E <sub>F</sub>	F <sub>50</sub>	S	E <sub>S</sub>	E <sub>F</sub>	F <sub>50</sub>	S	E <sub>S</sub>	E <sub>F</sub>	F <sub>10</sub>	F <sub>50</sub>
<i>Agroeca brunnea</i> (Blackwall)										5		2		
<i>Agroeca</i> sp.				1						2				
<i>Alopecosa cuneata</i> (Clerck)			1								4	2		
<i>Alopecosa pulverulenta</i> (Clerck)		4	1	6	2	275	210	25		55	87	44	6	3
<i>Alopecosa</i> sp.	1					14	5	1	2		1	1		
<i>Antistea elegans</i> (Blackwall)		1								1				
<i>Araeoncus humilis</i> (Blackwall)	8	4	5	2	9				1			4	1	2
<i>Araneus diadaematus</i> (Clerck)								1						
<i>Araneus quadratus</i> (Clerck)						8	2	1						
<i>Araniella cucurbitina</i> (Clerck)	1													
<i>Araniella</i> sp.								1						
<i>Arctosa leopardus</i> (Sundevall)												1		
<i>Ballus chalybaeus</i> (Walckenaer)										1			2	
<i>Baryphyma pratense</i> (Blackwall)		1												
<i>Bathypantes parvulus</i> . (Westring)													1	
<i>Centromerita bicolor</i> (Blackwall)				1						1	2			
<i>Centromerus sylvaticus</i> (Blackwall)			1											
<i>Clubiona</i> sp.						1								
<i>Diplostyla concolor</i> (Wider)	1			1			3	1						
, <i>Drassodes</i> sp.											3	1		
<i>Drassodes signifer</i> (C.L. Koch)				1										
<i>Drassyllus lutetianus</i> (L. Koch)		1				1		2			1			
<i>Drassyllus pusillus</i> (C.L.Koch,)		1	1	2		5	5	3		36	36	28	3	1
<i>Enoplognatha oelandica</i> (Thorell)													1	
<i>Enoplognatha thoracica</i> (Hahn)		2								2	3	1		
<i>Episinus angulatus</i> (Blackwall)										1				
<i>Erigone atra</i> (Blackwall)	102	83	66	49	111	6	8	6	5	5	8	5	23	5
<i>Erigone dentipalpis</i> (Wider)	16	35	9	33	55							2	2	2
<i>Erigone longipalpis</i> (Sundevall)				1					1					1
<i>Ero furcata</i> (Villers)										1				
<i>Euophrys aequipipes</i> (O.P.-Cambridge)													2	
<i>Euophrys monticola</i> (Kulczynski)				1							1			
<i>Evarcha arcuata</i> (White)						1								
<i>Gnaphosidae</i>										1	1	3		
<i>Gnathonarium dentatum</i> (Wider)			1							1				1
<i>Gongylidiellum murcidum</i> Simon								1	1					
<i>Lepthyphantes</i> sp.					1					1				



