POLISH JOURNAL OF ECOLOGY (Pol. J. Ecol.)	52	4	421–431	2004

Regular research paper

Jerzy KARG

Research Center for Agricultural and Forest Environment of the Polish Academy of Sciences, Field Station Turew, Szkolna 4, 64-000 Kościan, Poland, e-mail: turew@poczta.onet.pl

IMPORTANCE OF MIDFIELD SHELTERBELTS FOR OVER-WINTERING ENTOMOFAUNA (TUREW AREA, WEST POLAND)

ABSTRACT: The studies on the role of recently established shelterbelts as refuges available for wintering insects were carried out in the years 1994–2002. Soil and litter samples were taken (the material being sorted manually) from five young (up to 7 years old) and two older midfield shelterbelts, from the ecotone zones and from the adjacent croplands.

A high numbers (250–400 ind. m^{-2}) of insects, which biomass varied between 950 and 2300 mg dry wt. m^{-2}, were found to overwinter in young (4–7 years old) shelterbelts. The insects formed communities (dominated by Coleoptera) represented by over 50 families.

Effects of the shelterbelt's age, the presence or absence of litter, specific composition of trees and the location of sampling plots within the shelterbelt on wintering insects are discussed.

KEY WORDS: wintering insects, shelterbelts, agricultural landscape, ecotone

1. INTRODUCTION

Long-term studies carried out near Turew area (West Poland) in diversified agricultural landscape demonstrated the importance of refuges (mainly midfield shelterbelts of various type) for increasing the diversity and abundance of fauna (Banaszak 1983, Karg 1985, 1996, Karg *et al.* 1985, Ryszkowski and Karg 1991, Karg and Ryszkowski 1996, Ryszkowski *et al.* 2002). Studies from other regions of Europe and from other continents confirmed the positive role of shelterbelts for biodiversity and abundance of entomofauna in agricultural landscape (Baudry 1988, Paoletti and Lorenzoni 1989, Malschi and Mustea 1995, Paoletti 2002) as places favourable for overwintering and survival of often beneficial species (Dix *et al.* 1988, Gange and Llewellyn 1989, Thomas *et al.* 1994, Wratten 1998) and as barriers obstructing the penetration of croplands by harmful species (Prevost and West 1990).

Few studies pertaining to the role of shelterbelts as wintering places for insects were restricted to the assessment of selected groups or species or had a preliminary character (Karg 1998, Ryszkowski *et al.* 2002). To fulfil this gap, the long-term studies were undertaken to evaluate the composition and abundance of insect communities wintering in litter and soil of shelterbelts of different age and of adjacent croplands.

2. STUDY AREA, MATERIAL AND METHODS

Studies were carried out in recently introduced and in old shelterbelts situated near Turew (West Poland) in the years 1994–2001.

In the first half of the XIX century an agricultural landscape was formed there. The landscape was largely mosaic due to a dense network of midfield shelterbelts of various type (based on British pattern) planted by General D. Chłapowski, who then managed these areas (Konieczna 1991, Ryszkowski 1996).

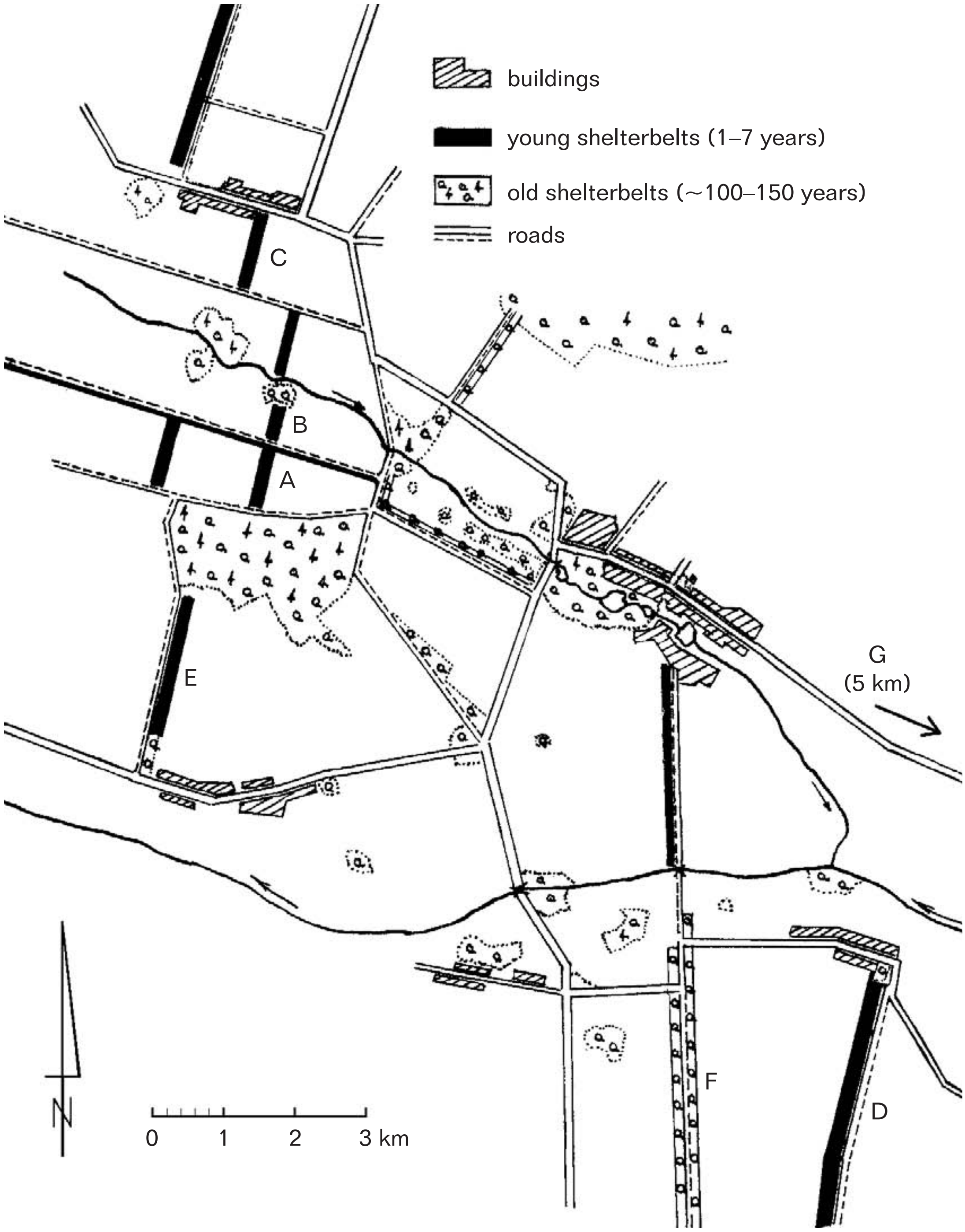

Fig. 1. Study area (see also Ryszkowski *et al.* 2003); A–G – studied shelterbelts.

Starting from 1993 the old network of shelterbelts has been successively supplemented by introducing new shelterbelts having now over 30 km of length. From among several young shelterbelts five were selected for studies: A (“Wyskoć”), B (“Wyskoć B”), C (“Gołębin”), D (“Rogaczewo”) and E (“Wyskoć C”) (Ryszkowski *et al.* 2003) (Fig. 1). All shelterbelts are formed in stripes (from 7 to 11 rows of trees) (see Fig. 2), their width varies from 10 to 20 m and their length – from 230 m (B) to 1650 m (D). All shelterbelts have a diversified tree species composition (9–21 species, mainly deciduous) forming patches (10–15 trees) replicated along the whole shelterbelt’s length. They were meridian oriented (for their role as barriers against erosion caused by mostly westerly winds) and all joined already existing permanent landscape fragments like small woods, clumps of trees and meadows (for their role as ecological corridors). The studies began in winter 1994/1995 in the shelterbelt A planted in autumn 1993. Every subsequent winter next shelterbelts (B, C, D and E) were included. So, the oldest shelterbelt was studied during seven winters (1994/1995 – 2000/2001) while the youngest – during three (1998/1999–2000/2001) (Table 1).

Insects (larvae, pupae and imagines) wintering in soil (in a soil sample – size of 9.5 × 9.5 × 9.5 cm) and in litter (taken with a 30 × 30 cm frame) were evaluated. Two series of samples were taken every winter (December and February) in all shelterbelts (10 soil samples and 20 litter samples per series) from areas situated within the shelterbelt and in the middle of its length. Additionally, samples were collected in the ecotone zones on the western side of the shelterbelt and in adjacent fields 10, 50 and 100 m from the edge. Identical analyses were performed in two old (100–150 years old) shelterbelts: F (“locust tree shelterbelt” – *Robinia pseudacacia*) (6 subsequent winters) and G (“hawthorn shelterbelt” – *Crategus monogyna*) (3 subsequent years) (Table 1, Fig. 1).

Adjacent fields were almost exclusively cropped with cereals – rye, triticale (X *Triticosecale rimpaui* Wittm.), barley, maize and only sporadically by other plants (sugar beet, rape, alfalfa).

Table 1. Description of studied shelterbelts (see Fig.1).

Shelterbelt	Year of planting	Study time (winters)	Length (m)	Width (m)	Herb layer	Bush layer
Young shelterbelts*						
A	1993	1994/95 – 2000/01	390	16	grass, herbs	no bushes
B	1995	1995/96 – 2000/01	230	20	grass, herbs	no bushes
C	1996	1996/97 – 2000/01	380	11	grass, herbs	no bushes
D	1996	1997/98 – 2000/01	1600	7–14	grass, herbs	rich (*Ribes sp., Chaenomeles japonica, Sambucus nigra, Cornus alba*)
E	1998	1998/99 – 2000/01	900	12	grass	*Rosa rugosa*
Old shelterbelts						
F	~ 1850	1994/95, 1996/97 – 2000/01	1800	36	scarce grasses	scarce *Sambucus nigra*
G	~ 1850	1998/99 – 2000/01	700	20	no herbs	no bushes

* local name: A – “Wyskoć”, B – “Wyskoć B”, C – “Gołębin”, D – “Rogaczewo”, E – “Wyskoć C”, F – “locust”, G – “hawthorn”

Table 2. Mean air temperature (°C) and monthly sum (mm) of precipitation in the study area.

Winter period	November		December		January		February		March	
	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm
1994/95	5.1	38.4	2.4	64.7	–0.1	35.4	4.3	47.0	3.7	35.4
1995/96	1.5	29.5	–3.7	18.9	–5.1	6.9	–4.0	21.8	0.3	12.9
1996/97	5.7	19.4	–4.0	8.4	–3.8	4.7	2.9	43.5	4.0	14.1
1997/98	2.6	20.1	1.4	35.8	1.5	48.0	4.1	32.9	3.0	45.4
1998/99	–0.5	32.3	–0.6	17.0	0.5	29.9	–1.3	36.3	4.6	82.6
1999/00	2.6	13.1	1.2	30.7	–0.3	24.0	3.4	21.7	4.5	45.3
2000/01	6.1	60.9	2.2	31.2	0.1	11.1	0.8	12.4	2.5	35.5

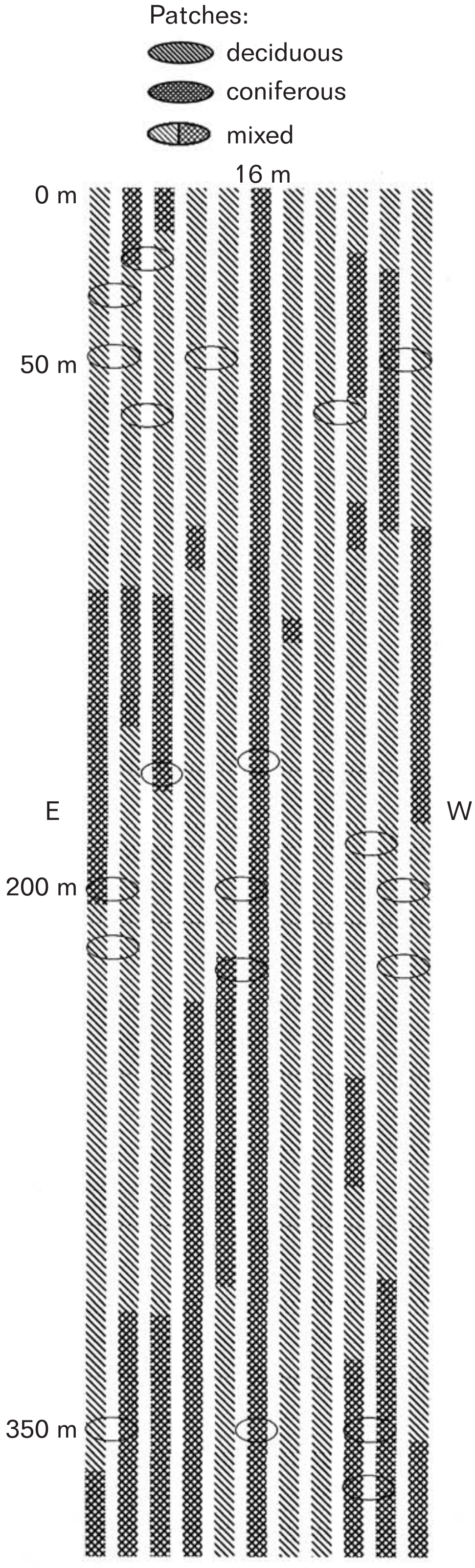

Fig. 2. The "row" structure and localization of study patches of trees in the newly established shelterbelt A (compare Fig. 1, Table 1).

Winters were mild during the whole study period, often devoid of snow with mean temperatures 1.4°C (November – March) (Table 2).

To evaluate the effect of species composition of tree patches on wintering insects, separate studies were performed in three subsequent winters (1999/2000 – 2001/2002) in the 7–8 years old shelterbelt (A). With the methods described above the samples were collected from areas encompassing three main types of patches: those composed entirely of deciduous trees (oak, birch, elm, linden, poplar, rowan), mixed patches (mainly with the admixture of larch and pine) and entirely coniferous (larch, spruce, pine). Areas of 100 m^2 were situated in part of the shelterbelt adjacent to the forest, 50 m apart, in its middle part (200 m from the forest) and 350 m from the forest's edge (Fig. 2). During three subsequent winters samples from soil and litter were collected on 38 areas encompassing, in almost equal proportions, three types of studied patches.

Material from soil and litter samples was handled manually and determined to order or family (for larvae and pupae) and to family or genus in the case of adult insects. Then the results were calculated per unit area (1 m^2). Biomass was calculated upon the determined weighed individual dry mass of particular taxa, dried to constant weight in the temperature 60°C (Karg 1989).

For statistical calculations ANOVA method was used.

3. RESULTS

3.1. Insects wintering in the shelterbelts

Taxonomic diversity expressed in the number of families recorded in insect communities wintering in litter and soil of the shelterbelts increased with time in subsequent winters. In the first year of the shelterbelt existence, when there was little litter or it was absent at all, the number of wintering taxa was low (3–5 on average). With the production of litter (particularly under coniferous trees) the number of wintering insect families increased. In particular 6–7 years old shelterbelts over 50 families were recorded (Table 3). Diversity of insects wintering in litter was generally higher than that of insects in soil. The insect diversity increased

faster in litter in subsequent winters than in soil. In the youngest shelterbelts (1–3 years old) there were 55 families of wintering insects while in the oldest shelterbelts (over 100–150 years old) the number was 71. In all shelterbelts of different age the number of insect families wintering in soil was nearly two times smaller than the respective number in litter (Table 4).

Density (and biomass) of wintering insects in newly established shelterbelts also increased from year to year and was almost two times higher in older shelterbelts (6–7 years old) than in the first winter after planting (Fig. 3). The differences are more distinct (statistically significant) for insects wintering in soil than in litter ($P < 0.001$).

100–150 years old shelterbelts (F, G) had more stabilised structure of wintering insect communities. Both the number of taxa (families) and the density or biomass of insects were similar to those noted in older of the new planted shelterbelts. Mean density and biomass of insects wintering in soil and litter of the F shelterbelt were 237.8 ind. m^{-2} and 716.4 mg dry wt. m^{-2}, respectively and in the G shelterbelt – 464.8 ind. m^{-2} and 1201.6 mg dry wt. m^{-2}, respectively (Fig. 4). In old shelterbelts with well developed and thick litter layer, the contribution of insects wintering in litter was higher than in younger shelterbelts and amounted 35% of the density and 18% of the biomass of all wintering insects while in the young shelterbelts the values were 20% and 12%, respectively (Figs 3 and 4).

Density of insects wintering in the litter of the youngest shelterbelts (1–3 years old) was three times (and the biomass – two times) lower than respective values for insects wintering in the litter of the oldest, 100–150 years old shelterbelts. In the 4–7 years old shelterbelts the differences became negligible. Density and biomass of insects wintering in soil were comparable among all age classes of the shelterbelts (no statistically significant differences). Biomass of insects wintering in 4–7 years old shelterbelts were even higher than those recorded in old shelterbelts (Table 5). Insects wintering in soil (irrespective of the shelterbelt's age) were larger than those wintering in litter (Table 5).

Regardless of the shelterbelt age, over two times more insects wintered in its inside than in the ecotone zone of adjacent field and over ten times more than in the open field (10 times higher density and 13 times greater biomass, on the average). In some shelterbelts the differences were even larger, over 30–40 times. Similar relationships were noted in some groups of Arthropoda in England, France and the Netherlands (Marshall *et al.* 2002). New planted shelterbelts at the age of 4–7 years hosted the greatest number of wintering insects in their inside as compared with 1–3 years old and over 100–150 years old ones. This was also reflected in the highest density and biomass of insects wintering in the ecotone zones. These differences are of marginal statistical significancy (Table 6). In the

Table. 3. Taxonomic diversity (number of families) of insects wintering in litter and soil of the young shelterbelts (year of planting) in subsequent winter periods since planting (1994/1995 to 2000/2001) (see Fig. 1, Table 1).

Shelterbelt (year of planting)	Subsequent winter periods 1	2	3	4	5	6	7
A (1994)	7	8	14	25	31	55	48
B (1995)	6	13	18	24	22	22	
C (1996)	13	20	21	21	27		
D (1997)	19	28	22	24			
E (1998)	1	23	26				

Table 4. Number of insect families wintering in litter and soil of the shelterbelts of different age (data for 7 shelterbelts) (see Fig. 1, Table 1).

Age (years)	Number of subsequent winters and studied shelterbelts		Layer: litter	soil	litter and soil
1–3	5	A,B,C,D,E	55	33	60
4–7	4	A,B,C,D	61	31	65
~ 100–150	6	F,G	71	36	76

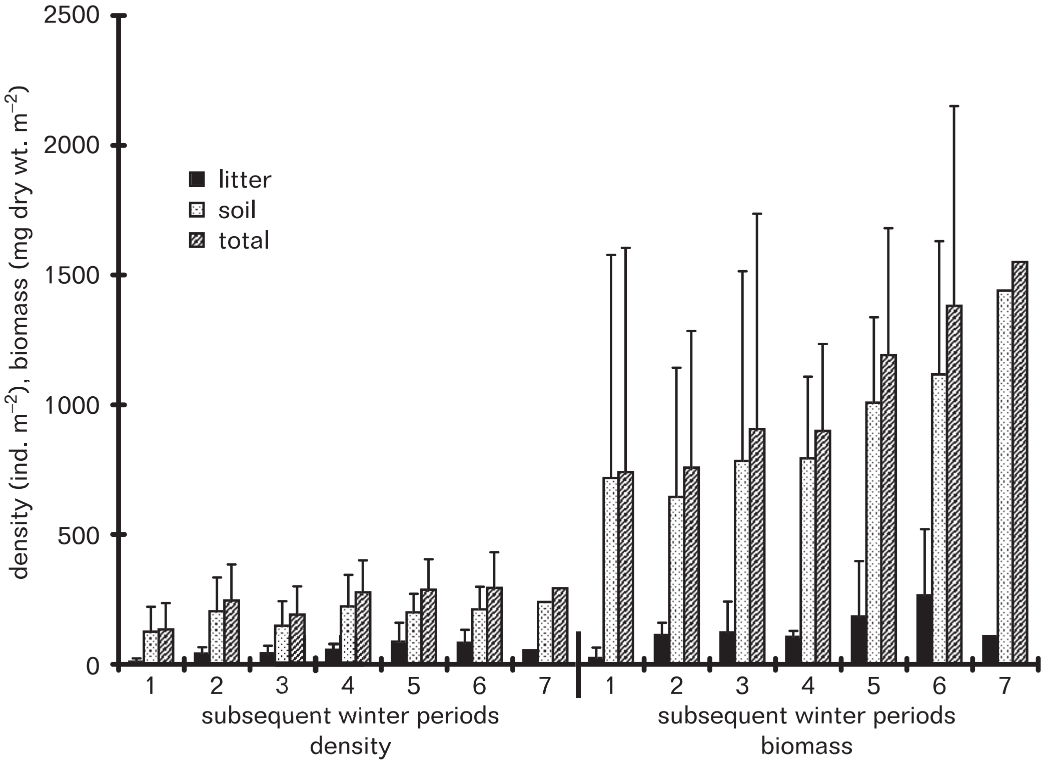

Fig. 3. Mean density and biomass of insects wintering in litter and soil of new young shelterbelts in subsequent years. Mean from 5 shelterbelts for 1 –3 subsequent winters (n = 720), from 4 shelterbelts for 4 subsequent winters (n = 240), from 3 shelterbelts for 5 subsequent winters (n = 180), from 2 shelterbelts for 6 subsequent winters (n = 120) and from 1 shelterbelts for 7 subsequent winters (n = 60). Data for shelterbelts A–E (see also Table 3).

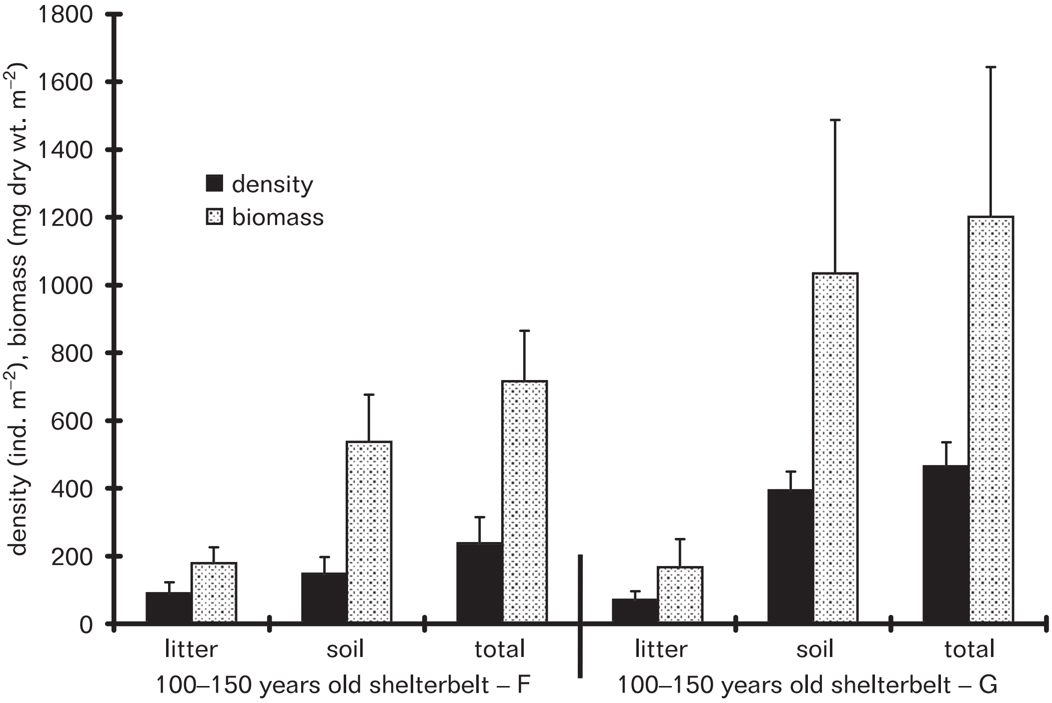

Fig. 4. Mean density and biomass of insects wintering in litter and soil of old shelterbelts. Mean values for 6 subsequent winter seasons (n = 340) for shelterbelt F, and for 3 subsequent winter seasons (n = 180) for shelterbelt G.

open field (50–100 m from the shelterbelt's edge) no statistically significant differences were noted in density or biomass of insects (Table 6).

Table 5. Mean density, biomass and individual biomass of insects wintering in litter and soil of shelterbelts of different age. Different letters denote significant differences between shelterbelts at $P < 0.05$ (Tuckey's test).

	density (ind. m^{-2})	biomass (mg dry wt. m^{-2})	mean individual biomass (mg dry wt. ind.$^{-1}$)
1–3 years old shelterbelts			
Litter	31.4 ^{a}	86.6 ^{a}	2.76
Soil	159.5 ^{a}	715.4 ^{a}	4.48
Total	190.9 ^{a}	802.0 ^{a}	4.20
4–7 years old shelterbelts			
Litter	70.0 ^{b}	161.5 ^{a}	2.31
Soil	215.6 ^{a}	987.1 ^{a}	4.58
Total	285.6 ^{a}	1148.6 ^{a}	4.02
~100–150 years old shelterbelts			
Litter	83.7 ^{b}	175.2 ^{a}	2.09
Soil	229.7 ^{a}	702.8 ^{a}	3.06
Total	313.4 ^{a}	878.0 ^{a}	2.80

3.2. The effect of species composition of the tree patches on insects wintering in soil and litter

Studies were carried out in an 7 years old shelterbelt (A) with typical high growth rate of deciduous and coniferous trees (crown density and production of the litter layer in the latter) and with permanent herb layer dominated by grasses and perennial species.

The insect community wintering in litter and soil (larvae and imagines together) achieved mean density of 250–400 ind. m^{-2} and mean biomass of 950–2300 mg dry wt. m^{-2} (Fig. 5). As in other woodlots of the same age, Coleoptera (mainly Carabidae and Staphylinidae) were the dominating groups; their contribution to the density and biomass of the whole community amounted 90%. The second most numerous group were dipterans. In the years of massive appearance of Bibionidae (*Bibio marci*), their larvae distinctly (over 50%) dominated total biomass of the whole community.

Insect communities wintering in patches composed exclusively of deciduous trees differed distinctly in both density and biomass. The density and biomass of insects were lowest there (Fig. 5). The highest values (400 ind. m^{-2} and 2048 mg. dry wt. m^{-2}) were noted in mixed patches where larch was usually the main coniferous tree. High values of the two parameters were also found in patches composed entirely of coniferous species (mostly of larch). The density values differed significant ($P < 0.05$) between the mixed and deciduous patches and the biomass values – between the deciduous and other patches (Fig. 5).

Marked differences were found (in all type of patches) between the part of insects wintering in litter and that wintering deeper in soil. The difference in density was over threefold and in biomass – over eleven times in favour of the soil. Such differences in biomass resulted from the fact that soil was inhabited in winter by larger insects of greater individual biomass than those inhabiting litter (Table 7).

The community of insects wintering in litter achieved the highest density (57.0––137.9 ind. m^{-2}) in mixed patches composed of deciduous species with the admixture of larch or pine. The density of insects wintering in soil was also highest in mixed patches. Biomass of insects wintering in

Table 6. Density (ind. m^{-2}) and biomass (mg dry wt. m^{-2}) of insects wintering in litter and soil of shelterbelts of different age and on adjacent fields. Different letters denote significant differences between shelterbelts at $P < 0.05$ (Tuckey's test) (see Fig. 1, Table 1 for abbreviations).

Shelterbelt age (years)	Inside shelterbelt	Ecotone zone (0.5–10 m)	Open field (50–100 m)	Number of subsequent winters and studied shelterbelts
Density				
1–3	190.9 ^{a}	63.5 ^{a}	32.4 ^{a}	5 (A,B,C,D,E)
4–7	285.6 ^{a}	162.8 ^{a}	27.9 ^{a}	4 (A,B,C,D)
~ 100–150	313.4 ^{a}	113.3 ^{a}	21.5 ^{a}	6 (F,G)
Biomass				
1–3	802.0 ^{a}	274.8 ^{a}	59.9 ^{a}	5 (A,B,C,D,E)
4–7	1148.6 ^{a}	618.2 ^{a}	110.2 ^{a}	4 (A,B,C,D)
~ 100–150	878.0 ^{a}	397.0 ^{a}	61.6 ^{a}	6 (F,G)

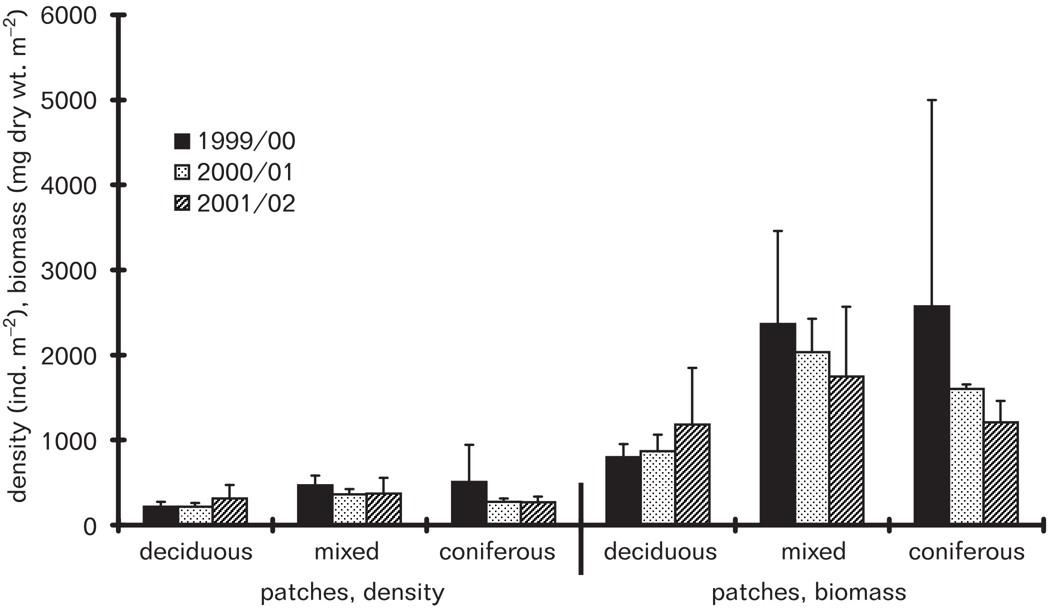

Fig. 5. Mean density and biomass of insects wintering in litter and soil of patches differing in tree species composition during subsequent winter periods in 7 years old shelterbelt (A).

Table 7. Mean density, biomass and individual biomass of insects wintering in the 7 years old shelterbelt (A) (n = 1760) (see Fig. 1, Table 1).

Place	Denisty (ind. m^{-2})	Biomass (mg dry wt. m^{-2})	Individual biomass (mg dry wt. $ind.^{-1}$)
Litter	86.2 *	132.5 *	1.54
Soil	264.4	1496.2	5.66
Total	350.6	1628.7	4.64

*$P<$ 0.0001 n – total number of samples

litter achieved the highest values in deciduous or mixed patches and the lowest in coniferous patches while biomass of insects wintering in soil was the lowest in deciduous patches and the highest in mixed and coniferous patches (Table 8).

Distinguished patches of trees did not influence on the density or biomass values of insects wintering in the adjacent fragments of croplands (no statistically significant differences). Slightly higher values (by 40% in the case of density and 20% in the case of biomass) were noted, however, in the ecotone zones neighbouring coniferous patches. This was probably a shielding

Table 8. Mean density, biomass and individual biomass of insects wintering in litter and soil in patches of different tree species composition (shelterbelt A). Different letters denote significant differences between shelterbelts at $P<$ 0.05 (Tuckey's test) (see Fig. 1, Table 1).

Layer	Patch	Density (ind. m^{-2}) subsequent winter periods				Biomass (mg dry wt. m^{-2}) subsequent winter periods				Mean individual biomass
		1999/00	2000/01	2001/02	Average	1999/00	2000/01	20001/02	Average	(mg dry wt. $ind.^{-1}$)
Litter	deciduous	50.1	54.6	85.7	63.5 [a]	153.8	120.2	122.5	132.2 [a]	2.08
	mixed	80.8	57.0	137.9	92.9 [a]	160.9	99.5	176.9	145.8 [a]	1.59
	coniferous	49.3	47.9	96.7	64.6 [a]	100.5	112.0	93.7	102.1 [a]	1.58
Soil	deciduous	167.6	162.7	227.6	186,0 [a]	645.4	747.2	1061.4	818.0 [a]	4.40
	mixed	387.1	303.5	232.9	307.8 [a]	2203.2	1935.7	1568.6	1902.5 [b]	6.18
	coniferous	456.3	227.3	170.5	284.7 [a]	2469.8	1491.5	1117.3	1692.9 [ab]	5.95
Total	deciduous	217.8	217.2	313.4	249.5 [a]	799.2	867.4	1184.0	950.2 [a]	3.81
	mixed	467.8	360.5	370.8	399.7 [a]	2364.2	2035.1	1745.5	2048.3 [b]	5.12
	coniferous	505.6	275.2	267.2	349.3 [a]	2570.3	1603.5	1210.9	1794.9 [ab]	5.14
	n =	270	180	180	–	270	180	180	–	–

n – total number of samples

Table 9. Mean density and biomass of insects wintering in different parts of the 7 years old shelterbelt (A) (n = 1260). No significant differences. (see Fig. 1, Table 1).

Parameter	Location		
	windward side (western)	leeward side (eastern)	centre of the shelterbelt
Density (ind. m^{-2})	263.4	358.5	350.0
Biomass (mg dry wt. m^{-2})	1218.7	1803.4	1697.5

effect of a compact tree clump, which produced better microclimatic conditions in the closest vicinity (0.5–10 m from the shelterbelt) (Table 9).

Since studied patches were distributed more or less uniformly within the whole width of the shelterbelt and in three zones situated at different distances from adjacent forest, it was possible to analyse the effect of the patch location on density and biomass of wintering insects both within the shelterbelt (side *versus* inner zone) and adjacent forest (50, 200 and 350 m from the forest edge). Both density and biomass of insects wintering in litter and soil were higher in the leeward (eastern) zone than in the inner and windward (western) zones (Table 9). Insect density was similar along the whole shelterbelt's length while biomass decreased with the increasing distance from the forest. Larger insect species wintered closer to the forest, probably penetrating the shelterbelt from there. Mean individual biomass of insects wintering 50 m from the forest edge was 5.5. mg dry wt. while that at a distance of 200 m was 4.6 mg dry wt. However, all those differences are not statistically significant.

4. DISCUSSION

Studies carried out in newly introduced shelterbelts since their planting allowed to find the attractiveness for insects of such a new stable ecosystem among croplands. Insects use shelterbelts as refuges already in the first winter after planting. The attractiveness of a shelterbelt as a wintering place is in its initial phase of succession (1–3 years) and is determined probably by the exclusion of a fragment of cropland from agrotechnical pressure and by abundantly growing herb vegetation. Too young trees in that phase are probably of negligible importance; they do not form any barrier mitigating climatic conditions and they do not produce litter. Great numbers of wintering insects (including beneficial predatory beetles) immigrating there from adjacent croplands were also found (Thomas *et al.* 1991) in planted strips of grassy vegetation analogous to the youngest shelterbelts.

The abundance, biomass and diversity of wintering insects increases with age of the shelterbelt to reach in 4–7 years old shelterbelts the values comparable or even higher than those typical for 100–150 years old shelterbelts. In several years old shelterbelts wintering insect communities encompass over 50 families and produce biomass exceeding 1 g dry wt. m^{-2}. Density and biomass of insects wintering in shelterbelts of that age class are on the average ten times higher than the respective values for insects wintering in open fields. Similar relationships were noted in studies carried out in England (Marshall *et al.* 2002).

Developing herb layer vegetation and, first of all, fast growing trees of the shelterbelts improve conditions for wintering through formation of the isolation litter layer (particularly in fragments planted with coniferous trees) and through mitigation of microclimate (decrease of wind velocity, formation of thick snow cover on the leeward side).

In spite of the formation of litter in older shelterbelts, the litter is inhabited by relatively few insects, mainly small species and mostly imagines. Larger species and insect larvae prefer soil as a habitat for wintering. More of them were found in places with litter, which probably functions as an isolation layer. Hence, more insects wintered in the fragments of shelterbelts overgrown by mixed patches with coniferous species (mostly larch), which provided thermal isolation through the layer of fallen needles, than in patches formed exclusively by deciduous species with no litter. Fallen leaves of most species decomposed more rapidly than fallen needles. No effect was, however, found of the dead remains of herb plants on the number of wintering in-

sects with the exception of a few insects wintering inside dried stems or shoots.

Two times less insects wintered in the ecotone zone of the adjacent field, particularly in its belt directly neighbouring the woodlot (0.5–10 m), than in the woodlot itself. The numbers in the open field were over ten times smaller. All this was similar to proportions reported by Marshall *et al.* (2002).

5. CONCLUSIONS

– Shelterbelts newly introduced to agricultural landscape are very soon (already in the first winter after planting) used as refuges available for insects wintering.
– Rich communities comprising representatives of over 50 insect families wintered in young 4–7 years old shelterbelts; total biomass of insects there was comparable with biomass found in old (over 100–150 years old) shelterbelts.
– Species composition of the shelterbelt affects the numbers of wintering insects; this should be taken into account when designing the shelterbelts.
– Patches (area of several m^2) inside the shelterbelts planted with mixed composition of birch, rowan, elm and linden with the admixtures of coniferous larch and pine are preferred by wintering insects.
– The ratio of insects wintering in the shelterbelt to those wintering in the ecotone and open field is 10:2:1 on the average.

6. REFERENCES

Banaszak J. 1983 – Ecology of bees (*Apoidea*) of agricultural landscape – Pol. ecol. Stud. 9: 421–505.

Baudry J. 1988 – Hedgerows and Hedgerow networks as wildlife habitat in agricultural landscapes. (In: Environmental Management in Agriculture. European Perspectives, Ed. J. R. Park) – Belhaven Press, London, 111–124.

Dix M . E., Leatherman D., Brandle J. R., Hintz D. L. 1988 – Insect management in windbreaks Proceedings of a symposium on windbreak technology, Lincoln, Nebraska, 23–27 June, 1986. – Agriculture, Ecosystems and Environment, 22–23: 513–537.

Gange A. C., Llewellyn M. 1989 – Factors affecting orchard colonisation by the black-kneed capsid (*Blepharidopterus angulatus* (Hemiptera: Miridae) from alder windbreaks) – Ann. Appl. Biol. 2: 221–230.

Karg J. 1985 – Impact of crop rotation on soil insect larvae. (In: Soil ecology and management. Ed. J. Cooley) – Athens, Ga., Intecol Bulletin. 12: 95–101.

Karg J. 1989 – Zróżnicowanie liczebności i biomasy owadów latających krajobrazu rolniczego zachodniej Wielkopolski [Differentiation in the density and biomass of flying insects in the agricultural landscape of the Western Wielkopolska] – Roczniki Akademii Rolniczej w Poznaniu [Agricultural University Annals Poznań], 188: 1–78. (in Polish, English summary)

Karg J. 1996 – Wstępna ocena roli krajobrazu w kształtowaniu struktury troficznej zespołów owadów w agroekosystemach [Introductory estimation of lanscape role in forming of trophic structure of insects in agroecosystems] (In: Ekologiczne procesy na obszarach intensywnego rolnictwa [In: Ecological processes on the areas of intensive agriculture] Eds: L. Ryszkowski, S. Bałazy) – Research Center for Agricultural and Forest Environment PAS, Poznań 33–41. (in Polish, English summary)

Karg J. 1998 – Wpływ nowo wprowadzonych zadrzewień śródpolnych na wzbogacenie zespołów owadów krajobrazu rolniczego [Influence of newly planted midfield shelterbelts on agricultural landscpe insects communities enrichment] (In: Dobre praktyki w produkcji rolniczej, mat. konferencji naukowej. Puławy, 3–4 czerwca 1998 [Good practices in agriculture, Mat. of scientific conference]) – IUNG Puławy. 1: 211–217. (in Polish)

Karg J., Margarit G., Hondru N., Gogoasa C. 1985 – Preliminary data regarding the influence of landscape types on the epigeic insect from wheat and alfalfa crops – Probleme de Prot. Plant., 13: 268–302.

Karg J., Ryszkowski L. 1996 – Wpływ struktury krajobrazu rolniczego na bioróżnorodność i procesy regulacji biocenotycznej [Influence of agricultural landscpe structure on biodiversity and biocenotic regulation processes] (In: Ekologiczne procesy na obszarach intensywnego rolnictwa [Ecological processes on the intensive agriculture areas] Eds: L. Ryszkowski, S. Bałazy) – Research Center for Agricultural and Forest Environment PAS, Poznań: 21–31. (in Polish, English summary)

Konieczna E. 1991 – The influence of the British pattern on the agricultural work of Dezydery Chłapowski. (In: Polish-Anglosaxon Studies, Ed. W. Lipoński) – UAM. Poznań, 2: 69–78.

Malschi D., Mustea D. 1995 – Protection and use of entomophagous arthropod fauna in cereals – Romanian Agricultural Research. 1995, 4: 93–99.

Marshall J., Baudry J., Burel F., Joenje W., Gerowitt B., Paoletti M., Thomas G., Kleijn D., Le Coeur D., Moonen C. 2002 – Field boundary habitats for wildlife, crop, and environmental protection (In: Landscape ecology in agroecosystems management, Ed. L. Ryszkowski) – CRC Press, Boca Raton, New York, Washington D.C.: 219–247.

Paoletti M. G. 2002 – Biodiversity in agroecosystems and bioindicators of environmental health (In: Structure and Function in Agroecosystems Desing and Management – Advances in Agroecology, Eds: M. Shiyomi and H. Koizumi) – CRC Press, Boca Raton, Fl.: 11–44.

Paoletti M. G., Lorenzoni G. G. 1989 – Agroecology patterns in northeastern Italy – Agric. Ecosys. Environ., 27: 139–154.

Prevost Y. H., West R. J. 1990 – Environmental architecture – preventing loss of seed production to insects in black and withe spruce seed orchards. – Proceedings – Cone and seed pest workshop, 4 October 1989, St. John's, Newfoundland, Canada. Information Report of Newfoundland and Labrador Region Forestry, Canada. 1990: 100–117.

Ryszkowski L. 1996 – The agricultural landscape near Turew (In: Dynamics of an agricultural landscape, Eds: L. Ryszkowski, N. French, A. Kędziora) – PWRiL, Poznań: 13–18.

Ryszkowski L., Karg J. 1991 – The effect of the structure of agricultural landscape on biomass of insect of the above-ground fauna – Ekol. pol., 39, 2: 171–179.

Ryszkowski L., Karg J., Kujawa K., Gołdyn H., Arczyńska-Chudy E. 2002 – Influence of landscape mosaic structure on diversity of wild plant and animal communities in agricultural landscape of Poland (In: Landscape ecology in agroecosystems management, Ed. L. Ryszkowski) – CRC Press, Boca Raton, New York, Washington D.C.: 185–217.

Ryszkowski L., Karg J., Bernacki Z. 2003 – Biocenotic function of the midfield woodlots in west Poland: Study area and research assumptions – Pol. J. Ecol. 51: 269–281.

Thomas M., Wratten S., Sotherton N. 1991 – Creation of "island" habitats in farmland to manipulate populations of beneficial arthropods: predator densities and emigration – J. Appl. Ecol. 28: 906–917.

Thomas C. F .G., Cooke H., Bauly J., Marshall E. J. P. 1994 – Invertebrate colonization of overwintering sites in different field boundary habitats (In: Arable Farming under CAP Reform – Aspects of Applied Biology No. 40, Eds: J. Clarke, A. Lane, A. Mitchell, M. Ramans and P. Ryan) – Association of Applied Biologists, Wellesbourne, U.K.: 229–232.

Wratten S. D. 1998 – The role of field boundaries as reservoirs of beneficial insects (In: Environmental Management in Agriculture: European Perspectives, Ed. J. R. Park) – 144–150. Belhaven Press, London.

(Received after revising May 2004)