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DISPERSAL OF *HARPALUS RUFIPES* (DEGEER)(CARABIDAE) BETWEEN SHELTERBELT AND CEREAL FIELD

ABSTRACT: Former studies usually show a positive effect of landscape heterogeneity on different groups of animals occurring in crop fields but some controversies have been discovered. The aim of this study was to answer the question whether the introduction of mid-field tree belts can help to increase numbers of predatory carabids in crop fields. Distance and the direction of movements of individually marked carabids caught in traps in the shelterbelts and in the adjacent crop fields were measured during one week of July (in 2003 and 2004). Pitfall traps (N=360) were placed 2 meters apart in 30 parallel rows which formed a rectangle of 58 × 22 m divided into 5 strips (5 rows in each one). Strip A was located in the shelterbelt, the others (B-E) were placed in the field. Beetles (exclusively – *Harpalus rufipes* (Degeer, 1774) which predominated in both habitats) after being marked with fast drying paint (non-dissolving in water, not harmful, and using dot code) were released at the same spots where they were caught. Accordingly 1099 and 1683 individuals in both years were marked and the number of recaptured individuals was equal to 259 (24%) and 307 (18%). Proportion of recapture rate for individuals marked in particular strips ranged between 18 and 28%. Mobility of the beetles was similar in both years (15.9 m and 16.5 m; t = 0.59, df = 579, *P* > 0.5). Individuals marked within the shelterbelt (strip A) were in both years caught much further away (25 and 27 m) than the individuals marked in opposite strip E, located in crop field (15 and 17.5 m). Differences between the distance covered daily by insects marked in the field and in the shelterbelt were statistically significant whereas differences between distances covered within the field by insects marked in particular strips – were not significant. Only 8–9% of insects marked in the shelterbelt (strip A) was recaptured in the same strip while recapture rate for individuals marked in other strips was higher –16 to 32%. The proportion of insects marked in the field (strip B, C, D, E) and recaptured in the shelterbelt was very low (2–11%). The comparison of recapture rates between strips A and B also shows that insects move mostly from the shelterbelt to the field. As much as 30–34% of the insects marked in the shelterbelt were caught in the bordering field. Among the insects marked in the next strip B, adjacent to the shelterbelt, only 10–11% individuals were caught in the shelterbelt. Presented results indicate that dominating direction of the dispersal in the mosaic landscape is from the shelterbelt to the field.

KEY WORDS: *Carabidae*, landscape structure, individual marking, movements, farmland

1. INTRODUCTION

In recent years there have been a number of studies on the impact of planted permanent vegetation (hedges, shelterbelts, grass strips) in the crop fields on the diversity and numbers of polyphagous, predatory arthropods. These studies usually show a positive effect of landscape heterogeneity on the fauna in crop fields (Lys and Nentwig 1992, Dennis *et al.* 1994, Hawthorne *et al.* 1998, Thomas and Marshall 1999, Holland and Fahrig 2000, Varchola and Dunn 2001, Imler 2003). It seems that islands of permanent vegetation are most important for animals with long life cycles because such an environment enables them to survive winter and periods of disturbance in the field areas caused by farming practices.

From these studies it can also be expected that a higher density of predators in the diversified landscape can be an important agent of pest control (Sunderland and Vickerman 1980, Kromp 1999). However, despite comprehensive literature on this subject, the role of forest islands for carabid beetles and their indispensability as places for overwintering or as areas from which the colonization of fields can start, is not clear (Kromp 1999). Some of the published results do not match the raised expectations. In particular, a study conducted along a gradient of land use, composed of habitats with an increasing proportion of agricultural land, showed the greatest diversity and numbers of carabid beetles in the most intensively managed agricultural sites (Vanbergen *et al.* 2005).

One of the mechanisms by which islands of permanent vegetation can affect the crop fields, is through the migration of animals between these ecosystems. *Carabidae* is a group of fast efficient runners. They can move several tens meters a day, so they can act as successful links between different habitats. However, some authors show that different strips of permanent vegetation can often be hard to penetrate or slow down the movement of ground beetles (Frampton *et al.* 1995, Mauremooto *et al.* 1995).

The aim of this study is to verify the direction of migration of one of the commonest runners and answer the question as to whether the introduction of shelterbelts among the fields, can help to increase numbers of predatory carabids in the land under cultivation. Assuming that shelterbelts influence carabid migration across the farmland, a hypothesis can be formulated that the dispersal of these animals in a mosaic of shelterbelts and crop fields is not random.

We tested this hypothesis by analyzing the distance and the direction of movements of individually marked carabids caught in traps in both the shelterbelts and in the adjacent crop fields. If carabid movements were random, their distance and direction should not be related to the place of trapping, i.e. the numbers of movements from arable fields to the shelterbelts and inversely should be balanced.

2. STUDY AREA, MATERIALS AND METHODS

The study was carried out in the third decade of July, two weeks before harvest in years 2003–2004, in the young shelterbelt and in the adjacent field where corn was seeded in the first year and cereals in the next year. The density of growing sprouts was typical for the species. The shelterbelt was 10–11 years old wood, 340 m long and 17.5 m wide, where thirteen tree species were planted (Karg 1999). These were: *Quercus petraea*, *Q. robur*, *Larix decidua*, *Populus nigra*, *Picea abies*, *Fagus silvatica*, *Ulmus* sp., *Betula pendula*, *Sorbus aucuparia*, *S. intermedia*, *Tilia cordata*, *Pinus sylvestris*, *Acer pseudoplatanus*, *Fraxinus excelsior*, *Alnus glutinosa* and *Salix* sp. Tree stand in the studied area consisted mainly of *Picea abies* and *Betula pendula*. In the herb layer grass *Festuca* sp. dominated in the central part and *Calamagrostis* sp. close to the field margin. The plants covered approximately 80% of the ground. During the investigation period no agricultural treatments were done.

Insects were being caught in 360 pitfall traps, PCV cups 8 cm in diameter and 11 cm deep, which were buried vertically in the ground, so that the trap rims were flush with the soil surface. They were emptied every day. Pitfall traps were placed 2 meters apart in 30 parallel rows, with 12 traps in each. The distance between rows amounted to 2 meters. Layout of the traps formed a rectangle of 58 × 22 m. It reached up to 48 m in the field and up to 10 m in the shelterbelt (Fig. 1). This rectangle was divided into 5 strips, each consisted of 5 rows. The strip A was located in

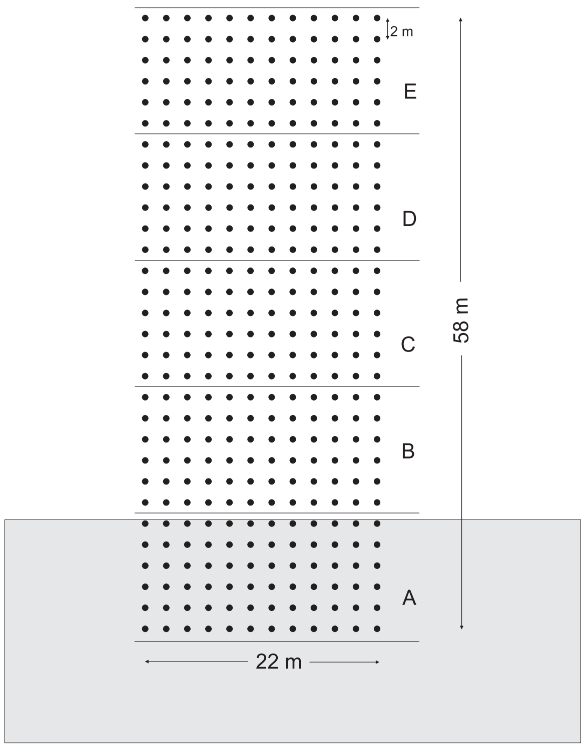

Fig. 1. Distribution of pitfall traps. Gray area – shelterbelt; A, B, C, D, E – defined strips.

the shelterbelt, the others (B-E) were placed in the field (Fig. 1).

Beetles were marked by marker pens with dense, fast drying, harmless paint, non-dissolving in water. The dot code 1–2–4–7 (Fig. 2), which is also used for marking butterflies was applied (Ehrlich and Davidson 1961). This method allowed to use one color of marker pen for marking 1000 individuals.

Each year catching period lasted 7 days but marking was carried out from first to sixth day. Beetles after being marked were released at the same spots where they were caught. Some of them were recaptured more than once. This method allows to determine the distance covered by an individual daily and the direction of movement.

3. RESULTS

Analyses were based on the data concerning the species *H. rufipes* (Degeer, 1774) because only for this species number of captured individuals was high enough to estimate the dispersal activity. They accounted for almost 75% of all captured carabid beetles. *H. rufipes* predominated in both years. In 2003 in successive six days number of marked individuals amounted to 188, 150, 168, 141, 135, 154, 163 (total 1099) and in 2004 – 246, 220, 198, 320, 264, 231 and 204 (total 1683), from which in particular strips 109 to 297 individuals in 2003 and 191 to 461 in 2004 were recaptured (Table 1). The number of recaptured individuals was equal to 259 (24% of the total number marked) in 2003 and to 307 (18%) in 2004. The proportion of recaptured individuals was only slightly different (statistically insignificant) depending on the place of catching. Proportion of recapture rate for individuals marked in particular strips ranged between 18 and 28 (Table 1). The recapture rate was in both years the highest (80–90%) in first two days of the catching period (Fig. 3).

Mobility of the beetles was similar in both years ($t = 0.59$, $df = 579$, $P > 0.5$). The distance between the place of marking to the place of catching again covered by an individual during one day averaged in successive years 15.9 m and 16.5 m (S.D. = 12.4 and 12.9 m) and ca

75% of all recaptures were those of distance up to 25 m (Figs 4, 5). The longest distance covered was 54 and 57 m, respectively.

There was no correlation between the number of days till recapture and the distance from place of marking to the place of recapture. It means that one day only, was enough for an insect to cover whole research area (Fig. 6).

The distance covered by *Harpalus rufipes* differed depending on the place of its first catching and marking (Fig. 7). Individuals marked within the shelterbelt (strip A) were in both years caught much further away than the individuals marked in other strips (B, C, D, E), in the adjoining crop field (Kruskal-Wallis test accordingly in year 2003 H (4, 273) = 18.3; $P = 0.0011$ and in year 2004

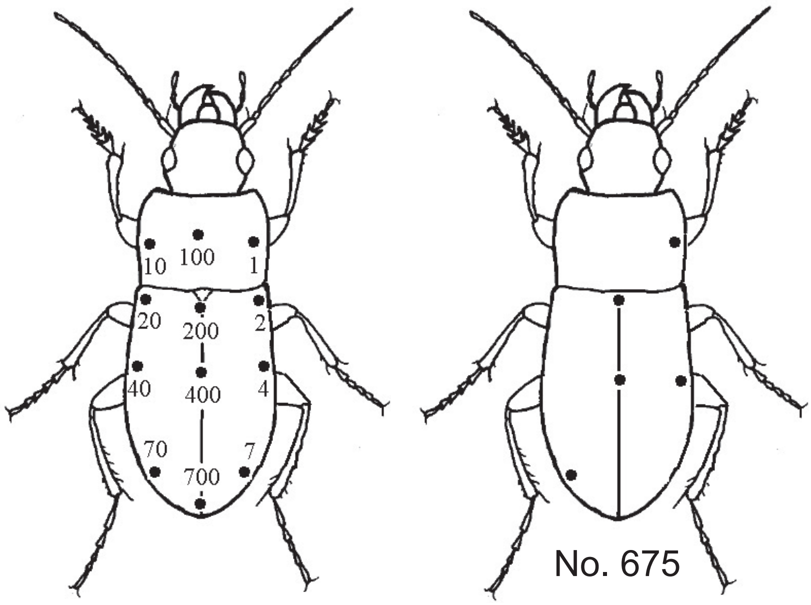

Fig. 2. Configuration of dots used for individual marking of carabid beetles. Each digit in three-digit number can be coded with one or two dots. For example: in number 675, number of hundreds is coded with two dots: "200" and "400" , number of ten's – with dot "70" and the last digit – with dots "1" and "4". This example shows individual no. 675.

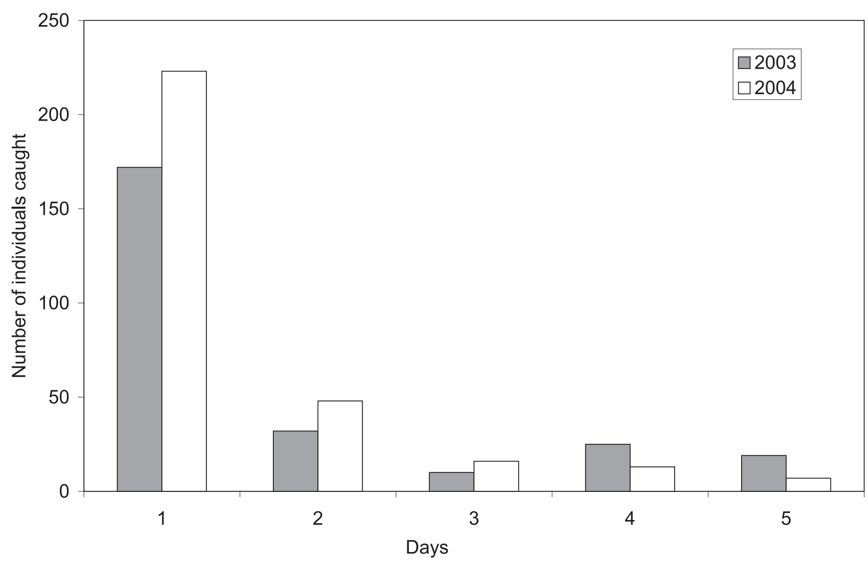

Fig. 3. Relationship between number of days after marking and number of recaptures – totals for all strips A–E (Fig. 1).

Table 1. Numbers of individuals of *H. rufipes* marked and recaptured during 7 days in the third decade of July (2003–2004) in particular strips (A-E) (see Fig. 1).

	2003			2004			% in 2003-04 (on average)
	Marked	Recaptured	%	Marked	Recaptured	%	
A	109	37	34	191	44	23	28
B	233	63	27	407	80	20	23
C	297	61	20	297	55	18	20
D	220	48	22	461	61	13	18
E	240	50	21	327	67	20	21
Total	1099	259	24	1683	307	18	21

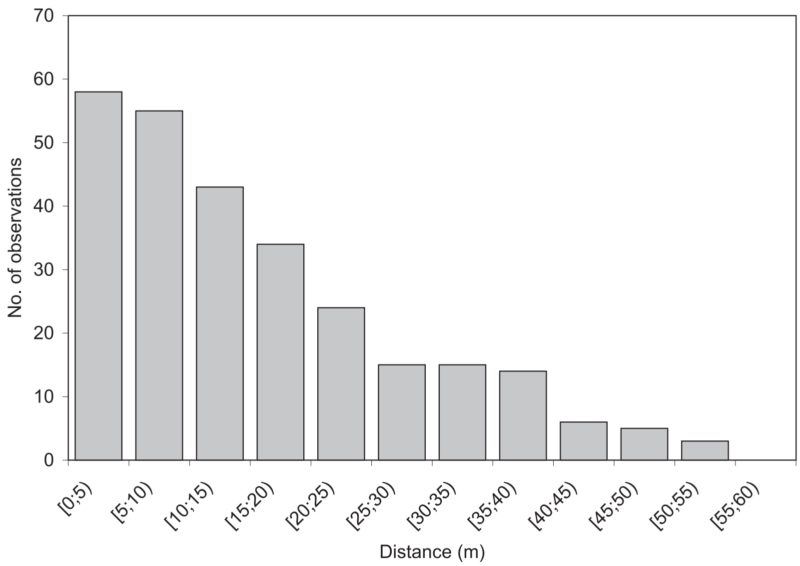

Fig 4. Frequencies of distance covered by beetles between place of marking and recapture. Data for 7 days of study in July, 2003.

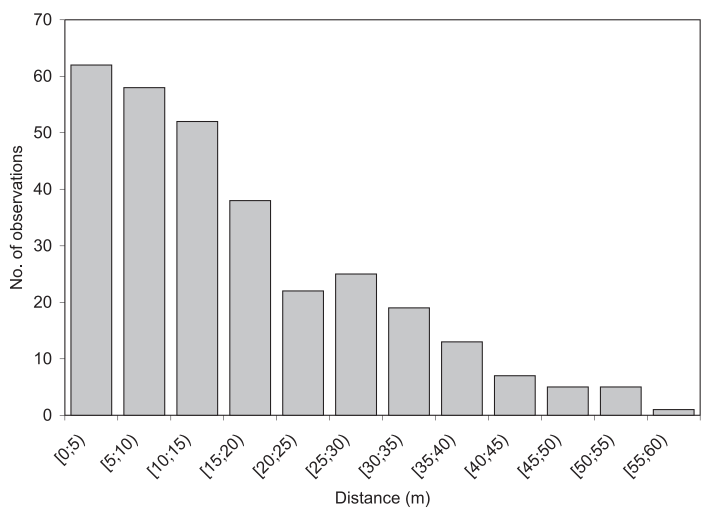

Fig 5. Frequencies of distance covered by beetles between place of marking and recapture. Data for 7 days of study in July, 2004.

Table 2. Recapture rate (%) values of *H. rufipes* in particular strips (A–E, Fig. 1) in relation to the place of marking and the period of capture-recapture monitoring (7 days in third decade of July). In bold – individuals marked and recaptured in the same strip.

Recapture place	Place of marking									
	A		B		C		D		E	
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
A	**8**	**9**	10	11	5	2	8	5	8	4
B	32	30	**41**	**40**	23	16	12	18	8	18
C	16	16	21	18	**36**	**38**	21	16	10	13
D	24	23	10	15	21	27	**33**	**41**	22	24
E	19	23	19	16	15	16	25	20	**52**	**40**

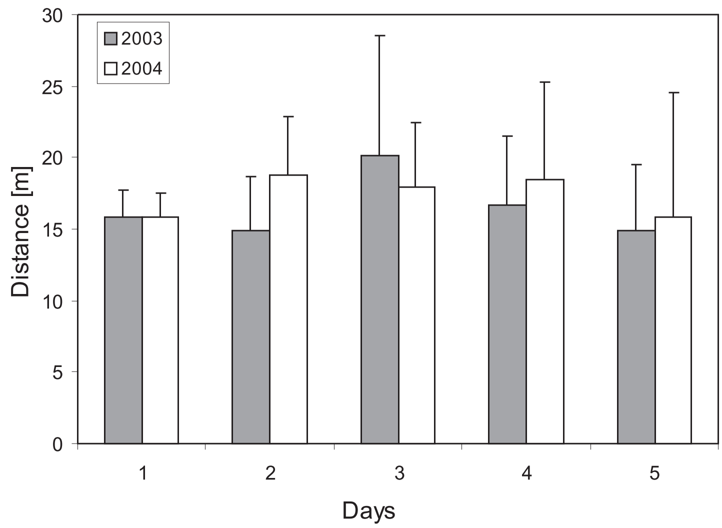

Fig. 6. Relationship between number of days after marking and distance covered (mean and confidence interval for $P = 0.05$). Data for 7 days of study in July.

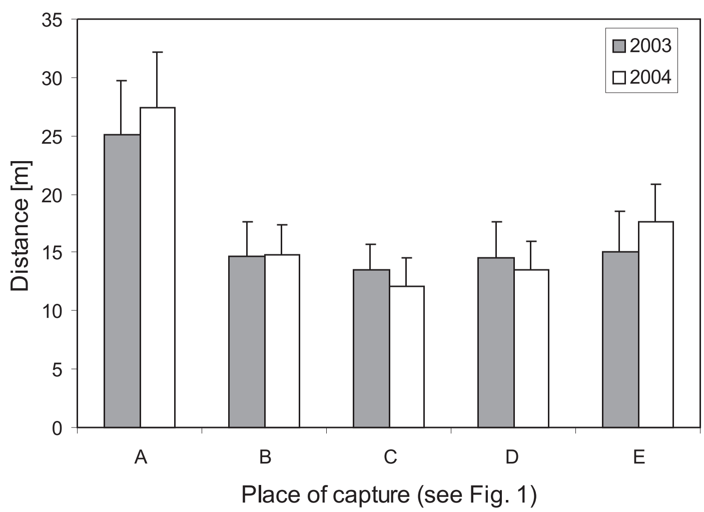

Fig. 7. Relationship between the place of first capture (marking) and mean distance covered daily by an individual (mean and confidence interval for $P = 0.05$). Data for 7 days of study in July.

– H(4, 307) = 29.5; P <0.0001). The results were not dependent on the kind of crops in the field, since the differences were very similar in both years. Insects marked in the shelterbelt covered averagely 25 and 27 m. This distance was significantly longer than the average distance covered by individuals marked in the strip E, which measured from 15 and 17.5 m (only this strip can be used for comparison with the shelterbelt strip since maximal potential distances were shorter in strips B, C and D).

Differences between the way covered daily by insects marked in the field and in the shelterbelt were statistically significant whereas differences between distances covered within the field by insects marked in particular strips were not significant. Based on the data it can be concluded, that insects caught and marked in the shelterbelt covered longer distances while moving from the shelterbelt to the fields.

This tendency is even clearer if check the distribution of places of recapture in relation to the places where the beetles were marked and released. (Table 2). Among insects marked in the strip A, in the shelterbelt, only 8–9% were recaptured in the same strip, while recapture rate for individuals marked in other strips was higher –16 to 32%.

However, the recapture rate was distributed differently for the insects caught in other strips. In those cases most recaptures occurred in the same strip, where the insects were marked (34 to 52%) (Table 2). The proportion of insects marked in the field (strip B, C, D, E) and recaptured in the shelterbelt was very low, only 2 to 11%. The comparison of recapture rates between strips A and B shows also that insects move mostly from the shelterbelt to the field. As much as 30–34% of the insects marked in the shelterbelt, were caught in the bordering field while of the insects caught in the next strip B, bordering the shelterbelt, only 10–11% individuals were caught in the shelterbelt with twice as much caught on the other side, in the strip C (Table 2).

Presented results indicate that dominating direction of the dispersal in the mosaic landscape is from the shelterbelt to the field. This can be supported by the following observations:

- Beetles caught in the shelterbelt covered much longer distances than those caught in the crop fields.
- Beetles marked in the shelterbelt moved more often to the field, while the opposite direction was rather exceptional.

4. DISCUSSION

Harpalus rufipes is an eurytopic species (Turin *et al.* 1991) preferring open areas – mostly meadows, ruderal areas, crop fields, reed lands, heaths and plantations of pine forests (Turin *et al.* 1991, Kromp 1999, Holland and Fahrig 2000, Molnár *et al.* 2001, Collins *et al.* 2003, Imler 2003, Magura 2002). While comparing various forest areas it was found that the highest locomotive activity of this species was found in forest plantations established on old woodland after clear cutting, which was higher than in analogous young forests planted in abandoned arable fields (Skłodowski 1995). This species was also found in primeval forest (Günther and Assmann 2004) or in forests without management (du Bus de Warnaffe and Lebrun 2004) as well as on afforested mine waste dumps (Topp *et al.* 2001). High numbers of *Harpalus rufipes* were also recorded in young hedgerows (Sotherton 1985). In the investigations carried out by us a few years ago in the same area as the current study, the highest locomotive activity of the species was found in the shelterbelt margin. This species however, was not dominant at that time (Kajak and Oleszczuk 2004). Thomas *et al.* (1991) observed relatively stable, i.e. repeated over several successive catches, aggregates of this species in the field/hedgerow boundary. The authors claim that dominant species of carabid beetles divide up the territory between themselves; that aggregates of different populations do not overlap.

The presence of *Harpalus rufipes* in the cultivated areas is often treated as an indicator of less intensive agriculture (Döring and Kromp 2003) as it prefers small crop fields (Kromp 1999, Imler 2003) and reduced tillage plots (Andersen 1999). Numerous populations have been found in field margins overgrown with weeds (de Snoo 1999).

This species is included in the group of large size carabid beetles (10–17 mm), with a life cycle lasting two years, autumnal breeders, nocturnal, good dispersers that can move not only on the ground but also by flying (Purtauf *et al.* 2004). Their larvae hatch from September to March and the highest numbers are recorded in October (Traugott 1999). The greatest locomotory activity of the adults occurs in July and August. Larvae live in upper soil layers and feed on the seeds of weeds (Hartke *et al.*1998). Adult beetles are euryphagic and plant as well as animal matter is found in their alimentary tracts. It was found that about 35% of their food consisted of aphids. *H. rufipes* can indeed decrease aphid populations (Loughridge and Luff 1983, Kromp 1999). It was also found that it can be an effective predator of Colorado beetle *Leptinotarsa decemlineata* (Sorokin 1981 after Kromp 1999) as well as other beetles. For example, it can feed on *Elateridae* (Click Beetles) living in the soil. It is believed that many species of *Carabidae* use islands of permanent ecosystems in the fields as refuges for overwintering in the adult form, and that this is the main role of these environments for them (Sotherton 1985, Thomas and Marshall 1999). However both the larvae and adult *Harpalus rufipes* spend winter time buried deep in the soil in the field area (Desender 1982).

There are few papers concerning the dispersal of *H. rufipes* and the presented results are not always consistent with each other. For example data about an influence of hunger on mobility of beetles diverges considerably (Frampton *et al.* 1995, Mauremooto *et al.* 1995). All authors agree however that the physical features of an environment can have a major influence on beetles mobility – they move faster on the crop fields, or over bare ground than through forest undergrowth or meadow (Lys and Nentwig 1992, Frampton *et al.* 1995, Mauremooto *et al.* 1995). Results of our investigations support these findings. Activity density was lower in the shelterbelt, than in the field strips. They also give evidence of exchange of individuals between the shelterbelt and the crop field and indicate the prevailing tendency to disperse from the shelterbelt to the field area. Those migrations, recorded in July, cannot be considered as the leaving of habitat where the beetles spent the winter. Dispersal may be connected with an abundance of potential prey in the field. For example during the first year of study there were high numbers of *Agrostis segetum* larvae. Dispersal into the fields in the period of the highest mobility of adult beetles is probably also caused by the mating behavior, occurring at that time.

Thomas *et al.* (2001) show that in the period of highest occurrence of *H. rufipes* (second and third decade of July) the frequency of beetle capture was decreasing with the increasing distance from the forest and, that there were very few or almost no catches at more than 20 m from it. Our investigations show that the exchange of individuals between the shelterbelt and the adjoining fields reaches further, up to 50 m at least. There was however no difference in the average distances covered in different crops, either in fields of rye or corn.

The results of Lys and Nentwig (1992) showed that the direction of migration can be dependent on the agro-technical procedures used in the fields. For instance *Harpalus rufipes,* clearly migrated after harvest from the fields to meadow strips – the number of recaptured individuals was much higher in those strips than within the field.

Results of our study support the suggestions of some authors that crop fields are preferred by this species during the growing season (Wallin 1986) and show that a network of wooded shelterbelts can strengthen those environmental preferences, creating places from which the beetles disperse to the crop fields, at least in some periods of the growing season and that crop fields are their main area for hunting and mating.

The results of our study presented here show that shelterbelts can be an important habitat for increasing insect species diversity and numbers in crop fields. They show that the movement of individuals between wood and field ecosystems occurs more often from the woods to the field then from the field to the woods. They also show that the distance covered daily by *Harpalus rufipes* is relatively long (several tens of meters).

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