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Spatial distribution of different life stages of one Dipteran community along hedgerow and field margin

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Abstract

Flying pattern of Dipteran adults and distribution of larvae in soil and litter were studied using yellow water traps and soil samples, respectively, in four positions near the border of a barley field: in the hedgerow, the grass strip, the field margin (either with perennials or with barley) and the centre of the field. The sampling and trapping covering all seasonal aspects were performed in an agricultural landscape near Venice (Italy).

Higher numbers of flying adults were trapped in the field margin and the field; values in the hedgerow and the grass strip were lower. In contrast, the lowest values of larval abundance were found in the field, while values in the extended field margin, the grass strip and the hedgerow were higher. Comparison of extensively used (uncultivated) part of the field margin with intensively used part of the field margin and centre of the field indicated that the increase in larval abundance in the uncultivated margin is caused by reduced cultivation and not by marginal position.

According to the spatial distributions of adults and larvae, several groups can be distinguished. The first Dipteran group develops in various habitats and prefers the field as adults, e.g. for hunting (Dolichopodidae). The second group develops in the field (particularly, some pest Chloropidae and Agromyzidae) and occurs there as adults too. Grass strip and hedgerow affect the flight activity of these groups negatively. The third Dipteran group prefers the hedgerow, the grass strip and the field margin as adults. Some of these develop in an extensive strip (Scatopsidae) near the hedgerow and some outside the studied plot (Culicidae). Finally, there are Diptera which develop in the extensive part of the field margin (Chironomidae) and disperse around all investigated habitats.

Keywords: Ecotone; Migration; Breeding sites

1. Introduction

Hedgerows are important refuge, migration corridors or barriers for animals (Trnka et al., 1990; Fry and Robson, 1994; Jepson, 1994). They are open structures and exchange of individuals among hedgerows and surrounding landscape plays an important role in the maintenance of community structure (Zwolfer and Stechmann, 1989) and affects the surrounding biotopes as well (Nazzi et al., 1989; Paoletti et al., 1997).

In the majority of studies, the effect of hedgerows on only one life stage was examined. There are few

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data about the pattern of animal–hedgerow interactions during different stages of their life cycle. Diptera display very apparent differences in the utilisation of habitats in particular stages of the life cycle. They go from larvae, which are almost sessile, to adults which can fly and are very mobile. The larvae of terrestrial Diptera can live freely in the soil or use specific microhabitats such as excrement, carrion, fungi, plant tissues etc. (Brauns, 1954; Smith, 1989). Adults can disperse from emergence habitat and select a different habitat for specific behaviour such as mating, feeding or oviposition (Morvan et al., 1994).

There is little information on the effect of hedgerows or extensively cultivated marginal strips on Diptera larvae. Concerning the adults, actively and passively moving insects can be distinguished. Insects moving passively by the wind as 'aeroplankton' have been studied extensively by Levis (1969, 1970). Little quantitative data are available about the effect of hedgerow on the flying pattern of actively flying Diptera. Some data from forest border indicated that tall and dense vegetation can be an important migration barrier (Delettre et al., 1992). The focus on Diptera flying actively for a short distance in the ground layer is important from the quantitative point of view also because they form majority of the whole community; only a small part of the community migrates passively through a large distance at higher levels (Dabrowska-Prot and Karg, 1976). The main questions of this study are: What is the effect of hedgerow and uncultivated field margin on spatial distribution soil dwelling larvae and actively flying adults? How do the spatial distributions of different life stages (adults and larvae) correspond with each other in one Dipteran community?

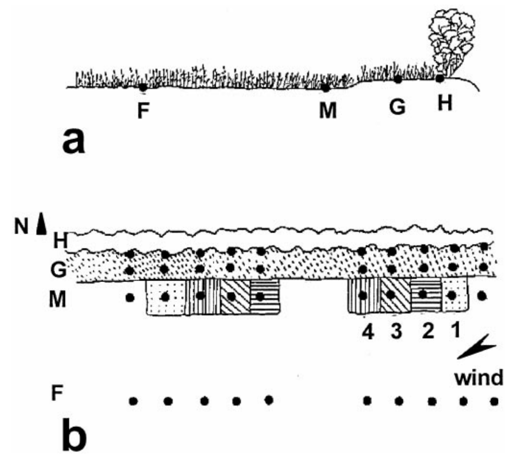

Fig. 1. Scheme of study plot, (a) horizontal view, (b) vertical view; sampling points are marked by black dots; H: hedgerow, G: grass, M: field margin, F: barley field; numbers represent various treatments of extensive strip, 1: first year of spontaneous succession, 2: second year of spontaneous succession, 3: Dactylis, 4: Lolium, 5: margin of barley field; orientation and direction of prevailing wind are given by arrows.

2. Material and methods

2.1. Study site

The study was carried out in 1996 in a biological farm located at Castelo di Brussa, Lugugnana, Province of Venice (north-east Italy). The rural landscape, mostly used for the cultivation of annual crops, is formed by approximately 70-year old polders. The soil is silt-loam. Observations were made on the margin of a barley field in four parallel strips: hedgerow, grass strip (called grass), field margin (margin) and centre of field (field) (Fig. 1). The hedgerow was formed by a single row of shrubs mainly *Crataegus* sp., *Prunus* sp. and *Pirus* sp. In the field margin, five treatments were settled in spring 1996: (1) spontaneous vegetation in the first year of succession (succession I), (2) spontaneous vegetation in the second year of succession (succession II), (3) temporary grass with *Dactylis glomerata* Linne (Dactylis), (4) temporary grass with *Lolium perenne* Linne (Lolium), and (5) intensively cultivated barley field (intensive). All treatments had two repetitions (Fig. 1). As with the rest of the barley field, these treatments were tilled in July 1996, and in autumnal samples, the whole strip was evaluated as one treatment. Field was represented by cultivated arable land, 1996 by barley (*Hordeum sativum* Linne). Barley was harvested in June and in July the field was cultivated by shallow (5 cm depth) disc cultivation.

Environmental variables in particular strips and treatments were measured twice in May and September 1996 (Table 1). Characteristics of the vegetation cover (amount of litter, height and cover of vegetation) were measured in both terms. Content of soil organic matter (C_{org}) and pH (in H_2O 1:5) were measured in samples taken in May 1996. For all environmental data, three replicates per treatment or strip were taken.

Table 1
Environmental variables in investigated strips or treatments[a]

Strip treatment	pH	C_{org} (%)	Litter (g m^{-2})		Vegetation			
					Cover (%)		Height (cm)	
			Spring	Autumn	Spring	Autumn	Spring	Autumn
Hedgerow	7.98	1.01	294.7	441.3	100	100	300	300
Grass	7.95	1.10	161.7	484.3	100	100	70	50
Margin								
Lolium	7.97	1.00	260.8	253.2	80	70	60	30
Dactylis	7.82	1.19	161.2	253.2	60	70	60	30
Succession 1	7.90	1.11	400.0	253.2	60	70	20	30
Succession 2	7.91	1.02	250.0	253.2	70	70	20	30
Intensive	8.05	0.69	75.2		50	70	60	30
Field	8.04	0.82	95.8	77.1	50	50	60	30

[a] Spring data were collected in May 1996, autumnal data in September 1996. Succession 1 or 2: spontaneous succession 1 or 2 years old.

2.2. Sampling, processing and data analyses

To assess the flight activity of adult Diptera, yellow pan traps were used (Bailliot and Trehen, 1974). Dark brown plastic dishes, 16 cm in diameter, painted yellow on the inside, were used as traps. The traps were exposed at the soil surface. The dishes were filled with a propylenglycol–water mixture (70:30) with a few drops of detergent. The traps were exposed in the field in three 1-week intervals: 3–10 May, 13–20 September and 14–21 October. In all cases, 40 traps were exposed in 10 parallel transects forming a grid of sampling points (Fig. 1). The distance of individual transect was minimally 10 and maximally ca. 150 m. After 1 week of exposure, the adult Diptera were collected from the traps and stored in 80% alcohol. All material was sorted to the family level using McAlpine (1990), while dominant species were determined as species as much as possible. A total of 8895 specimens of adult Diptera were trapped and processed.

To asses the distribution of soil dwelling Diptera larvae, soil samples were taken in a mesh of 40 sampling points (Fig. 1) in three sampling periods 3 May, 13 September and 21 October. At each sampling point, three circular samples (area 79 cm^2, depth 7 cm) were taken during each sampling occasion. Soil samples were extracted in a modified Tullgren heat extraction apparatus described in Paoletti et al. (1991). Extracted larvae were preserved in a propylenglycol–water mixture and stored in 80% alcohol. Larvae were sorted into families using Smith (1989) and Teskey (1990). Cyclorrhapha larvae were sorted only into Acalyptrata and Calyptrata. A total of 360 soil samples were taken and 732 specimens of larvae were extracted and processed.

The Kruskal–Wallis test (KW) was used for the comparison of numbers of trapped adults or larval abundance among particular strips or treatments. Spearman rank correlations were used to evaluate correlation between flight activity or soil larval abundance and environmental variables (Sokal and Rohlf, 1981). In the case of vegetation variables, May values were used for comparison with May Diptera data and September values for comparison with autumnal Dipteran data. Contingency tables (2×4) were used for the comparison of distribution of larvae and adults of individual families among the strips. Only families with totals of more than 30 larvae and 30 adults trapped were used for this comparison.

3. Results

3.1. Flight activity of adults

The lowest numbers of flying Diptera were captured in the hedgerow strip, slightly higher in grass, while substantially higher values were found in the field and the field margin (Table 2). The number of flying Diptera trapped correlated negatively with vegetation cover height and amount of litter (Table 4). The

Table 2
Composition of flight activity of adult Diptera in particular strips[a]

Family	Dominant species	Hedgerow	Grass	Margin	Field
Tipulidae			0.1		
Limoniidae		0.4			
Psychodidae	*Logima albipennis* Zetterstedt	0.7			
Culicidae		2.0	0.5	0.5	0.1
Ceratopogonidae		0.6	0.1	0.1	
Chironomidae	*Smittia* cf. *pratorum* (Goetghebuerg)	8.8	1.2	1.6	0.8
Bibionidae		0.2	0.4		
Mycetophylidae		0.8	0.5		
Sciaridae		28.2	16.7	7.7	4.4
Scatopsidae	*Swamerdamella brevicornis* (Meigen)	0.9	1.0		
Cecidomyiidae		1.7	11.8	2.4	1.3
Asilidae			0.3		
Empididae	*Platypalpus* sp.	4.0	1.6	0.2	0.1
Dolichopodidae	*Chrysotus suavis* Loew	3.0	4.8	7.3	10.5
Lonchopteridae		0.8	1.0	0.3	0.6
Phoridae		13.9	15.6	23.4	24.6
Pipunculidae				+	
Syrphidae			0.3	0.2	0.2
Conopidae			0.1		
Tephritidae		0.7	0.1		
Psilidae			+		
Sepsidae		3.7	0.8	0.5	0.3
Drosophilidae	*Scaptomyza palida* (Zetterstedt)	2.8	3.4	2.6	3.1
Ephydridae				0.9	0.2
Agriomyzidae	*Lyriomyza bryonie* (Kaltebach)	1.5	1.0	2.4	1.9
Sphaeroceridae		1.2	1.4	0.2	0.3
Chloropidae	*Melanochata pubescens* (Thalhamner)[b] *Oscinella frit* (Linne)[c]	12.1	26.1	35.8	32.1
Sarcophagidae	*Sarcophaga* sp.	1.8	2.3	2.5	2.6
Caliphoridae		0.9	0.6	0.7	0.5
Anthomyiidae	*Delia platura* (Meigen)	7.4	5.6	9.2	12.9
Muscidae		1.9	2.5	1.7	3.1
Total[d]		100.0	100.0	100.0	100.0
Total[e]		19.2	30.4	159.7	159.0

[a] Proportion of particular families from total catch in percentage (+: families which represent less than 0.1% of total catch).
[b] In grass and hedgerow.
[c] In field.
[d] Total percentage.
[e] Total average amount of individuals per trap week.

distribution pattern of flight activity changed during the season (Fig. 2a). May and September sampling displayed a similar distribution pattern as described above. However, only in September, the differences among the strips were significant (P<0.05, KW) (Fig. 2a). In October, adult data displayed an inverse pattern. The highest numbers of flying Diptera were found in the hedgerow and the lowest in the field. Although this difference was not significant for total Diptera, it was significant for several families (Limoniidae, Culicidae, Ceratopogonidae, Bibionidae, Empididae, Phoridae, Drosophilidae, Agromyzidae, Anthomyidae) (P<0.05, KW) (Figs. 3–5, data are partly not shown).

Composition of adult community varied among treatments as well. Sciaridae were the most important family in flight activity in the hedgerow. The second and third most important families were Phoridae and

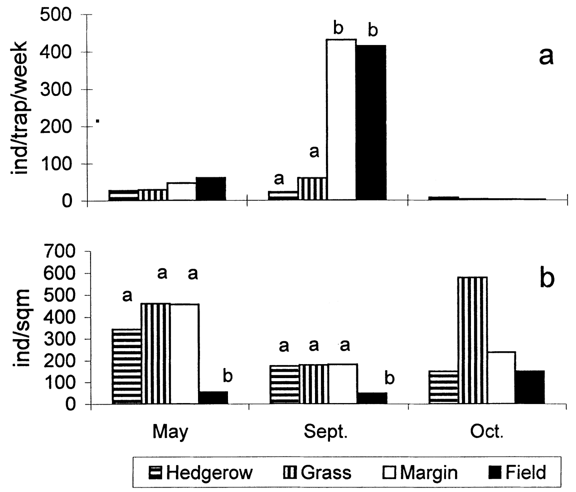

Fig. 2. Average catch of adults (a) and average abundance of larvae (b) in particular strips and sampling terms. Particular strips in particular sampling terms marked by different letters are significantly (P<0.05, Kruskal–Wallis) different. If no letters are given, no significant differences were found.

Chloropidae. Towards the field centre, the relative proportion of Sciaridae decreased and the relative proportion of Chloropidae ad Phoridae increased. In the field, Chloropidae, Phoridae, Anthomyidae and Dolichopodidae were the most numerous families (Table 2).

In most families, significantly higher numbers of adults were trapped in the field than in grass and hedgerow strips, while the field margin displayed intermediate values (Fig. 3a). This kind of distribution was found in May and September for Dolichopodidae, Sarcophagidae, Phoridae, Anthomyidae and in September only for Agromyzidae, Chloropidae and Drosophilidae. Only the Scatopsidae display the highest numbers of trapped adults in the hedgerow in all cases when they are trapped (Fig. 3b). Some families were characterised by higher numbers of trapped adults in the grass and the field margin than in the field centre. Hedgerow affected the flight activity of these families in various ways. Culicidae and Chironomidae (Fig. 3c) which were found in September to be significantly more abundant in the field margin than in other strips can be included in this group. Also, Empididae, which displayed high affinity to the hedgerow in May and to grass and marginal strips in September, may be included here (Fig. 3d). Finally, there are families which display no significant differences among strips, in most cases, with the exception of a shift to the hedgerow in October.

3.2. Larval distribution in soil

The highest abundance of Dipteran larvae in soil was found in the grass strip, slightly lower values were found in the hedgerow and the field margin, and

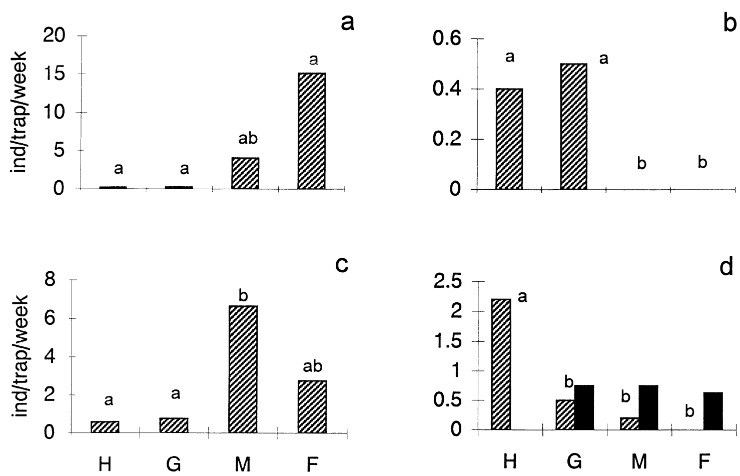

Fig. 3. Distribution of adult flight activity among particular strips; H: hedgerow, G: grass, M: margin, F: field; (a) Dolichopodidae, May; (b) Scatopsidae, September; (c) Chironomidae, September; (d) Empididae, May (shading) and September (black). Columns of the same pattern marked by different letters are significantly different (P<0.05, Kuskal–Wallis).

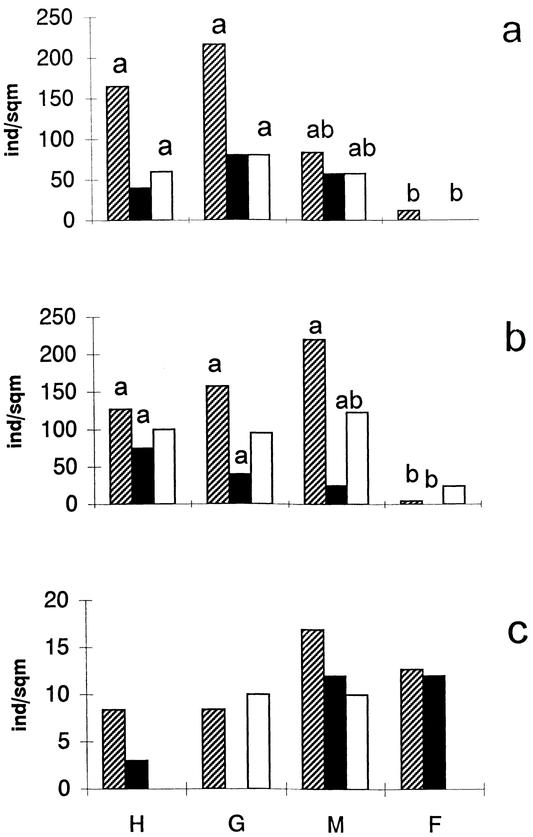

Fig. 4. Distribution of larval abundance among particular strips and terms, H: hedgerow, G: grass, M: margin, F: field; May: shaded, September black and October white; (a) Stratiomyidae, (b) Chironomidae, (c) Empididae; values for particular strips in particular time and family marked by different letters are significantly different ($P<0.05$, Kruskal–Wallis).

substantially lower values were found in the centre of the field (Table 3). This pattern was stable during the whole study period (Fig. 2b). Content of soil organic matter, amount of litter, plant cover and vegetation height correlated positively with larval abundance, whereas pH correlated negatively (Table 4). In the field, Ceratopogonidae, Chironomidae, Scatopsidae and Empididae were the most abundant families. In other strips, Chironomidae, Stratiomyidae and Scatopsidae belonged to the most abundant ones. Proportions of these families vary among particular strips; Stratiomyidae were the most important in the hedgerow, Scatopsidae in the grass strip and Chironomidae in the field margin (Table 3). Larvae of Chironomidae were highly dominated by *Smittia* sp., and Stratiomyidae by *Chloromyia formosa* Scopoli.

Table 3
Composition and abundance of Diptera larvae in particular strips[a]

	Hedgerow	Grass	Margin	Field
Tipulidae	0.0	0.4	0.6	0.0
Limoniidae	0.0	0.0	0.0	9.2
Chironomidae	31.5	23.3	43.4	15.6
Ceratopogonidae	0.8	1.7	4.3	16.1
Scatopsidae	10.0	30.9	8.2	11.9
Cecidomyidae	7.6	10.6	14.4	9.6
Sciaridae	4.0	0.7	0.5	2.3
Stratiomyidae	39.3	27.8	19.7	5.5
Empididae	1.9	1.5	3.2	11.0
Dolichopodidae	0.6	0.9	1.7	6.0
Rhagionidae	3.5	1.0	1.9	8.3
Acalyptrata	0.0	0.7	1.1	0.0
Calyptrata	0.8	0.4	1.1	4.6
Total[b]	100.0	100.0	100.0	100.0
Total[c]	222.2	413.8	290.4	77.0

[a] Proportion of particular families from total catch as a percentage.
[b] Total percentage.
[c] Total average abundance of Diptera larvae (ind. m^{-2}).

Table 4
Spearman rank correlation coefficients of catch of adult Diptera and abundance of Dipteran larvae with environmental variables

Life stage; sampling term	pH	C_{org}	Litter	Cower	Height	No. of samples
Adult May	0.104	−0.218	−0.192	−0.296	−0.2366	33
Adult September	−0.103	−0.067	−0.692*	−0.804*	−0.887*	32
Adult October	−0.007	−0.035	0.068	0.210	0.292	32
Larvae May	−0.478*	0.462*	0.326*	0.415*	0.202**	120
Larvae September	−0.145	0.147	0.183**	0.238*	0.214**	120
Larvae October	−0.182	0.237**	0.186**	0.107	−0.162	120

* Significant for $P<0.01$.
** Significant for $P<0.05$.

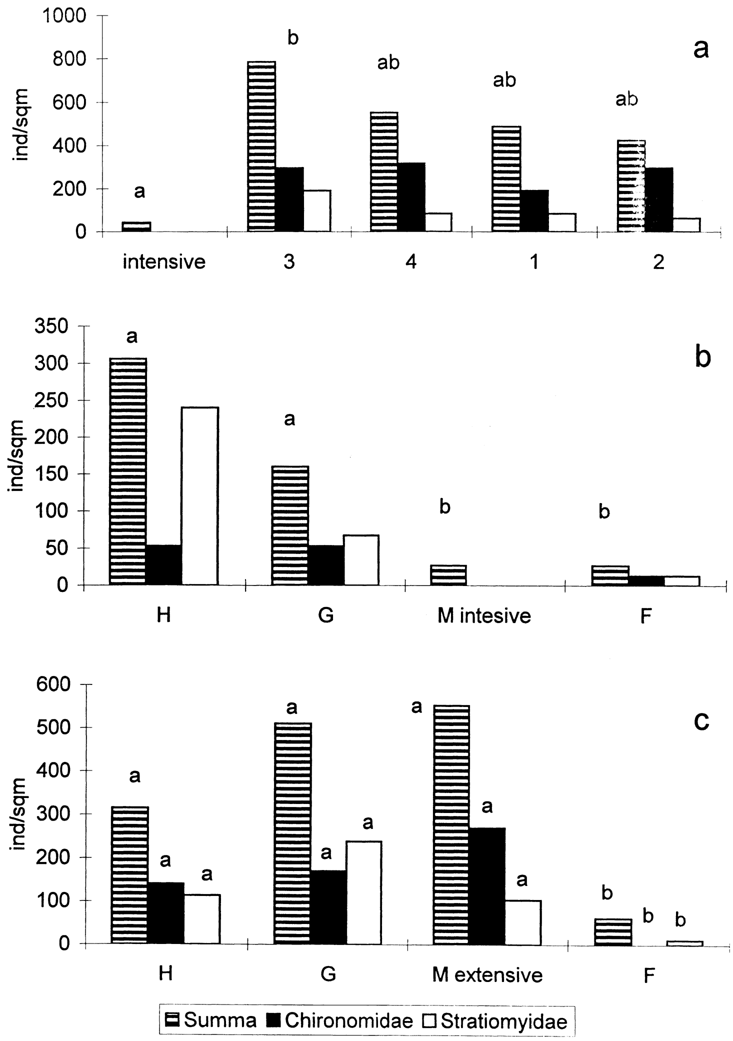

Fig. 5. Distribution of total larval abundance and abundance of families Stratiomyidae and Chironomidae in particular patches of the marginal strip (a) and in the rows of sampling plots from hedgerow to field centre (H: hedgerow, G: grass, M: margin, F: field) which cross the intensively cultivated margin of barley field (treatment 5) (b) and in rows which cross extensive marginal treatments (1–4) (c) in May 1996, treatments marked by different letters are significantly different ($P<0.05$, Kruskal–Wallis).

The majority of families displayed a distribution similar to the distribution of total abundance described above. However, only in Stratiomyidae and Chironomidae, differences among strips were significant ($P<0.05$, KW) (Fig. 4a and b). Only Empididae in the September sampling term displayed higher abundance in the field than in the hedgerow and the grass strip, but the differences were not significant.

The effect of particular treatments in the field margin on larval distribution was evaluated in the spring sampling term only (Fig. 5). In the marginal strip, the lowest value of total abundance was found in intensively cultivated marginal treatment; nevertheless, the differences were significant only between Dactylis and intensive treatment (Fig. 5a). No significant differences between intensively cultivated field margin and centre of field were found, but both of them differ significantly from grass and hedgerow treatment adjacent to intensive field margin (Fig. 5b). Extensive treatments differ significantly from the field centre and not from the grass strip and the hedgerow (Fig. 5c).

Scatopsidae, Dolichopodidae, Empididae, Sciaridae and Chironomidae were used for comparison of larval and adult distribution among the strips using the contingency tables. In all these families, composition of species or morfospecies (in larvae) among the strips was roughly homogeneous. Significant differences in relative larval and adult distribution were found only for Chironomidae ($P<0.01$); in the remaining families, proportional distribution of larvae and adults among the treatments does not differ.

4. Discussion and conclusion

4.1. Flight activity of adults

Reduction of flying Diptera trapped in yellow traps was observed in grass and hedgerow strips. We expect that these strips can be an important migration barrier for flying Diptera. Similar negative effect of tall and dense vegetation on flight activity was observed for chironomids (Delettre et al., 1992; Frouz and Olejníček, 1999). Adverse effects of tall hedges for migration of flying insects was also shown by other methods such as direct observation of butterflies (Fry and Robson, 1994). Dolichopodidae, Anthomyidae, Sarcophagidae, Chloropidae and Agromyzidae were trapped more frequently in the open field than near the hedgerow using motor nets (Dabrowska-Prot and Karg, 1976). The interpretation of data obtained by yellow pan traps only must be made with care because the attractiveness of traps may vary according to actual behaviour, e.g. for Empididae, the traps are attractive during hunting but not during mating (Bailliot and Trehen, 1974). Even if difficulties in interpretation exist, we think that yellow traps can indicate the density of actively flying Diptera, particularly smaller species, which prefer to fly near the soil surface. This is a reason why the general pattern observed in this study differs from that observed by Levis (1969, 1970), in wind-transported insect community. Based on the comparison of literature data and our results, we speculate that the hedgerow affects actively and passively flying insects in different ways. Insects transported passively by wind accumulate near the hedgerow due to the concentration of individuals passing from airborne community in the shelter formed by the hedgerow (Levis, 1969, 1970). On the other hand, our results indicated that hedgerow and grass strips could be an important barrier for actively flying insects moving through a short distance in the ground layer. The mechanisms of this barrier effect seem to be connected more with an effect on insect behaviour rather than with the creation of a real physical barrier. For example, specific microclimatic conditions or vegetation structure can prevent the Diptera from flying into these strips. Also, Fry and Robson (1994) suppose similar mechanisms for the effect of hedgerows on butterfly migration. This effect can moreover be influenced by actual weather as indicated also by change in the adult flight activity in the October sampling period. The decrease in catch near the hedgerow also allows a possible alternative explanation to the change in flight direction, and thus, that the catch is reduced due to increase in the flying level as the Diptera try to overfly the hedgerow. Nevertheless, these alternative hypotheses are in contradiction to the literature data. Decrease in catch, in families forming the bulk of Dipteran community in the field, was observed near the hedgerow also using a motor net operating 1 m above surface (Dabrowska-Prot and Karg, 1976). Using yellow traps exposed at various heights indicated the highest catch in soil surface exposed trap; when the catch decreased in higher vegetation, the catch in upper levels also decreased (Pollet and Grootaert, 1991). This literature evidence, combined with our observations, indicated that the decrease in catch in soil surface exposed yellow traps in hedgerow and grass strips is more likely caused by change in flight direction (i.e. that some environmental cues prevent Diptera from flying into these strips) than by the height of flying level.

Only Scatopsidae display high affinity to the hedgerow. This corresponds with the results of Dabrowska-Prot and Karg (1976) who found higher amounts of Scatopsidae near a hedgerow than in the centre of a field. We speculate that, similarly as in above-mentioned Diptera which avoid the hedgerow and the grass strip, the reason for the preference for the hedgerow by Scatopsidae comprises some environmental cues which affect adult behaviour.

Some families, even if they were not strongly attracted by the hedgerow, were more frequent in strips near the hedgerow (grass and field margin).

This indicates the importance of the hedgerow field ecotone for the flight activity of Diptera. This acuteness can be important migration corridors in directions along the hedgerow. Similar role of acuteness for insect migration was found for Diptera (Trnka et al., 1990) or for butterflies (Gatehouse, 1994). Hedgerow–field ecotone can also be important for hunting or swarming (Morvan et al., 1994; Smith and Gadawski, 1994).

4.2. Larval distribution in soil

The lowest larval abundance was found in the field; the abundance in other, extensively used strips was higher. This finding is in agreement with the distribution of Dipteran larvae in agricultural fields under various crops (perennials or annual) and in different stages of secondary succession (Carter et al., 1985; Frouz, 1997a). In particular, the abundance of micro- and macro-saprophagous Dipteran larvae such as Chironomidae, Scatopsidae and Stratiomyidae increased in the hedgerow, the grass strip and the uncultivated field margin. As the area covered by seminatural biotopes and permanent grassland is low in the investigated landscape, the hedgerow and particularly other uncultivated strip on the field margin can be a refuge for saprophagous Diptera larvae. A higher population of Diptera larvae can also be a reservoir for some insect parasites such as mermithid nematodes (Paoletti and Poinar, 1985). Decrease in amount of litter on the soil surface seems to be the most important factor that causes low abundance of Dipteran larvae in the field. Populations of soil dwelling Dipteran larvae depend directly or indirectly on the input of litter, which is a primary food source. They reflect very sensitively experimental litter manipulation (Hövemeyer, 1992). Low amounts of litter were assumed to be the reason for low Dipteran abundance in arable land by other authors (Nielsen et al., 1994). Soil cultivation can cause damage to populations of Dipteran larvae (Nielsen et al., 1994) and can be another reason for low larval abundance in the field. The abundance reached in the field is very low even in comparison with data from other arable fields (Carter et al., 1985; Nielsen et al., 1994; Frouz, 1997a). Lower abundance in comparison with other studies can be caused by the absence of winter samples which usually display higher abundance (Altmüler, 1979; Frouz, 1997a). Higher larval abundance in the field margin was observed even in autumn after disc cultivation of an extensive marginal strip, probably due to better litter supply and more suitable soil conditions (Table 1).

No differences were found between intensively cultivated margin and field centre, indicating that the higher abundance observed in the extensive part of field margin was caused by extensive use and not by marginal position. This is in agreement with the results of Nielsen et al. (1994) who observed no differences in the abundance of Dipteran larvae between the central and marginal parts of the field.

4.3. Relationships between larval and adult distribution

Only in soil dwelling, the Diptera larval and adult distribution among the strips can be compared statistically. For majority of soil dwelling Diptera, the distribution of larvae and adults correspond well, the only exception being Chironomidae. The higher catch in the places of larval occurrence can be caused by the fact that adults emerge here and also search here for oviposition places; moreover, it is possible that adults prefer to fly in habitats where suitable larval breeding sites occur. In Diptera developing in habitats other than soil, the discussion about the larval distribution can be based only on the occurrence of sources suitable for larvae.

Considering their whole life cycles, recorded Diptera can be ranked in several groups according to the utilisation of habitats at the hedgerow–field interface. The first group is formed by the families Anthomyidae and Phoridae, developing in various habitats mostly outside fields (such as carrion, mushrooms, faeces, dead plants, or in other invertebrates as parasitoids, etc.), but the field is the preferred habitat for adults. Dolichopodidae can be assumed to be some interstep between this group and next group specialised in the field during the whole life cycle. Larvae of Dolichopodidae occur both in the field and outside the field, but adults display an apparent affinity to the field (Fig. 3). The reason for this distribution may be that the open field is more suitable, e.g. for hunting in Dolichopodidae. Agromyzidae and Chloropidae form another group. These Diptera with phytophagous larvae develop most probably in the field and this emergence and oviposition habitat is also where adult flies most frequently occur. Tall and dense vegetation of the hedgerow and the grass strip seems to be an important migration barrier for both of the above-mentioned groups of Diptera in the direction perpendicular to the hedgerow. For other Diptera, the hedgerow or strips closely adjacent to the hedgerow can be an important migration corridor namely in the longitudinal direction along the hedgerow. The reasons for the preference for the hedgerow and related strip for adult Diptera can vary among families. In Scatopsidae, which develop in this habitat, dispersion and search for ovipositon places is the most probable reason for the preference for this habitat. In families, which develop in another habitats or at least do not prefer these strips for development, such as Culicidae or Empididae, utilisation of this habitat for hunting, swarming or as a migration corridor can be expected. Finally, there are Diptera which develop mostly in an extensive strip as larvae, but disperse into the surrounding field as adults such as Chironomidae. Abundance of chironomid larvae in soil is negatively affected by tillage (Delettre and Lagerlöf, 1992; Frouz, 1994). During succession, their abundance increases rapidly in the initial stages of succession such as early-abandoned field (Strüve-Kusenberg, 1981; Frouz, 1994), but in more advanced succession stages, their abundance decreased (Frouz, 1994). In the observed plots, chironomids dominated in the extensive marginal strip. Persistence in a stable habitat such as a grass strip and dispersion along surrounding habitats is important for the persistence of these species at the landscape level. Grass strip and extensive patches in the field margin can thus be a sink and source habitat (see Pulliam and Danielson (1991)) for terrestrial chironomids. Similar kinds of interaction were observed in chironomids utilising the temporary initial stages of succession (Frouz, 1997b).

4.4. Conclusion

Effects of the hedgerow on air borne insect community and actively flying insects are different; hedgerow can accumulate insects passing from airborne community but can also be a barrier for actively flying insects in the direction perpendicular to the hedgerow. This is particularly important in some pest species developing in the field (Agromyzidae, Chloropidae). This barrier effect lay more likely in some environmental cues, which prevents adults from flying into this habitat, rather than in the formation of a real physical barrier. Strips near the hedgerow may serve as a migration corridor in the longitudinal direction along the hedgerow. Larval habitats are an important factor affecting the migration behaviour of actively flying Dipteran adults because of the occurrence of adults in emergence and oviposition places and perhaps also because of the preference for habitats suitable for larval development for active adult migration. Nevertheless, in some situations, adults search for other habitats particularly when suitable for hunting swarming or dispersion.

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