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Effect of woody borders on insect density and diversity in crop fields: a landscape-scale analysis

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Abstract

The relationship between density and richness of herbivorous insects in alfalfa fields, and the amount (total length) of woody field border in the landscapes surrounding the fields was studied. Insects (predominantly herbivorous) were sampled in 35 alfalfa fields in 1995 and 24 fields in 1996, and the total length of woody field borders within the 1 km radius circular landscape surrounding each field was measured. There was no effect of amount of woody border in the landscape on insect density. There was a significant positive effect of amount of woody border in the landscape on overall family richness of insects in the alfalfa fields. The results of this study suggest that woody borders increase diversity but not density of herbivorous insects within crop fields in agro-ecosystems. This suggests that woody borders play a role in maintaining biodiversity in agro-ecosystems, and that this role extends beyond the borders themselves, into the crop fields.

Keywords: Woody borders; Insect density; Insect diversity; Dispersal; Agricultural landscapes; Fencerows; Biodiversity; Canada

1. Introduction

Woody borders around fields are a common element in the agricultural landscape of many areas. Conservation groups have placed great value on woody borders because they provide habitat for many species. However, farmers often view these borders as harbouring weed and insect pests (Marshall and Smith, 1987) and reducing insolation and drying of the soil by wind action. The large-scale effects of woody borders on insect fauna in crop fields are not well known.

Patch boundaries can represent barriers to dispersal for many insects, depending on the structure of the border and the type of insect (Duelli et al., 1990; Frampton et al., 1995). Studies have found that hedgerows can reduce the dispersal of some insects (Lewis, 1969; Bowden and Dean, 1977; Fry, 1994, Mauremooto et al., 1995) and some spiders (Thomas, in Frampton et al., 1995). Forman and Baudry (1984) have called for research on the effects of woody margins on insect movement at a landscape scale.

Fry (1994) states that field borders may affect the habitat searching of insects, possibly making large monoculture crops harder for pest insects to locate. Bach (1988) cited research demonstrating that non-host plants can reduce the ability of herbivorous insects to find habitat patches, and also stated that vegetation height has important effects on insect dispersal. This suggests that the presence of woody borders in a landscape may affect the insect popula-

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tions found within a field. Forman and Baudry (1984) as well suggest that hedgerow networks could reduce dispersal of field species. This would seem to be a benefit to agriculture because herbivorous insects will find it more difficult to locate habitat patches in landscapes with a fine mesh of wooded field edges (Bhar and Fahrig, 1998).[1] Jepson and Thacker (in Jepson, 1994) have stated that field boundaries which reduce dispersal will cause delays in population recovery after patch disturbances. Therefore, woody borders may lead to a reduced number of insects in fields by reducing colonization, and recolonization after disturbance.

In a theoretical study, Weins et al. (1985) found that a relatively impermeable border leads to a localization of activity within the patch. In a simulation exercise, Stamps et al. (1987) also found that edge permeability can be a major factor in animal emigration from a patch. It is possible that woody borders play an important role in such effects because dispersal by flight is the major mode of insect dispersal and recolonization (Johnson, 1969; Duelli et al., 1990), and an insect flying from a field is likely to encounter tall vegetation around the field edge. A field which is several years old (where age is measured as the number of years in the same crop) and has an established insect community could experience population build-ups of the various insect species present if individuals are deterred from emigrating by the woody borders. Such a trapping effect can lead to population increases in some species of leaf beetles and other insects when suitable habitat is surrounded by non-host plants (Bach, 1988). Therefore, woody borders may lead to greater insect densities in older fields (Bhar and Fahrig, 1998). Predictions of the effect of woody borders will therefore be contingent on field age (measured as time since converted to present crop).

Some types of field margins have been found to increase populations of predatory arthropods (Dennis and Fry, 1992; Dennis et al., 1994; Hart et al., 1994). This may lead to lower herbivore densities in woody landscapes because of higher predation rates, a prediction opposite to that above.

Woody borders may also influence insect diversity by offering complementary habitats such as overwintering sites (Dennis and Fry, 1992), summer aestivation sites (Manglitz, 1958), mating sites (Hawkes, 1973) or foraging sites (Hawkes, 1973; Bowden and Dean, 1977). Morris and Webb (1987) stated that field margins can be important to insect conservation for this reason. If so, the most likely result would be an increase in insect diversity with increasing woody border.

In summary, there are several reasons for predicting effects of woody borders on density and diversity of insects within agricultural fields. As is common in ecological research (Jepson, 1994), most studies of the effects of woody borders on insects have focused on a single species or family, and have been conducted at a small scale. This study was designed to investigate the insect assemblages found in alfalfa (*Medicago sativa* L.) fields of different ages, from landscapes with different amounts of woody border. The relative density and family richness of the total insect assemblage was examined. The relative density and species richness of legume specialist weevils, as well as the relative density of the alfalfa weevil, *Hypera postica*, were also investigated.

2. Methods

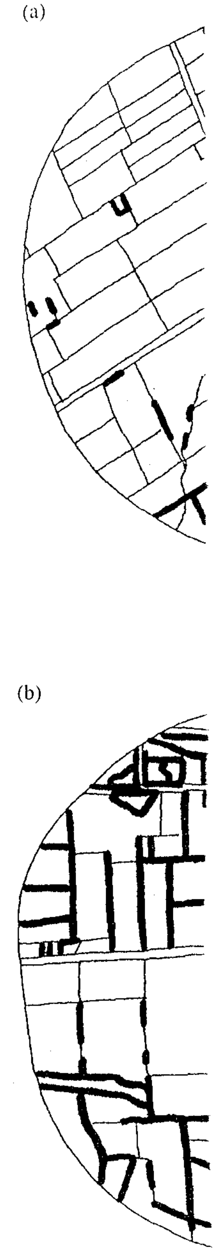
Alfalfa fields in landscapes with varying amounts of wooded borders in the Ottawa area were sampled during the summers of 1995 and 1996 (Fig. 1). Note that the alfalfa grown in the Ottawa region is a perennial crop. 'Landscapes' were arbitrarily defined as the area within 1 km of the field perimeter. Turner (1989) states that a landscape is a heterogeneous area with respect to the ecological process of interest. In the present case the ecological processes are insect movement and habitat use; the landscapes as defined are heterogeneous with respect to these processes.

Fields and landscapes were selected to match, as much as possible, the percent woody border at the local and landscape scales. That is, fields with little woody border were selected in landscapes with little woody border (Fig. 1a), and fields with a large amount of woody border were selected in landscapes with a large amount of woody border (Fig. 1b). Woody borders were defined as any section of a border or woodlot edge that contained adjacent trees or shrubs greater than 2 m in height. Fields were chosen so that landscape overlap was avoided whenever possible.

[1] Available from the Internet. URL: http://www.consecol.org/vol2/iss2/art3

(a)

(b)



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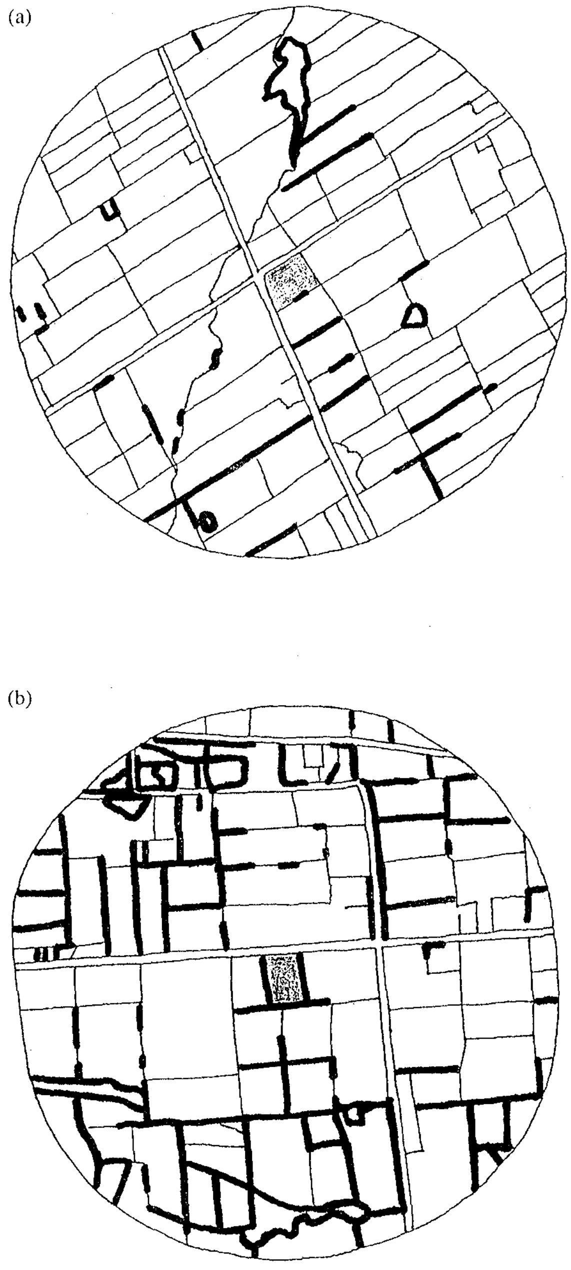

Fig. 1. Example landscapes, traced from 1 : 15,000 air photographs. The sampled alfalfa field is in the centre of the landscape. Woody borders are denoted by the thicker lines. Alfalfa fields and landscapes were chosen such that the proportion of the alfalfa field's border that was woody was approximately equal to the proportion of all borders in the landscape that were woody. (a) example landscape with small amount of woody border; (b) example landscape with large amount of woody border.

Thirty-five fields were sampled in 1995 and 24 were sampled in 1996.

A sweepnet with a 31 cm diameter hoop was used to take samples along a 40-pace north–south transect in the centre of each field. Because of time constraints 20-pace transects were used for the final two sample sets in 1995. Thirty-pace transects were used throughout 1996. Fields were swept at a rate of one sweep per pace, with half of the sweepnet hoop passing through the vegetation. Sampling was carried out over two consecutive days every two weeks. Fields were sampled at different times of the day to avoid sampling different temporal assemblages in different fields. During each sampling period the percent ground cover of different plant types (alfalfa, other legumes, other dicots and grasses) and bare ground within 1 m^2 quadrats that were randomly placed near each end of the transects were estimated. In 1996 the number of plant species within the quadrats was also recorded.

In 1995 all adult insects except Diptera and Hymenoptera were counted and identified to the family level using keys in Borror et al. (1989). In 1996, all adult insects including Diptera and Hymenoptera were identified to family. Weevils (Coleoptera: Curculionidae) were identified to species using keys in Titus (1911), Arnett (1968), Clark (1971), Bright (1994), and by consulting a professional taxonomist at Agriculture Canada (D. Bright, pers. comm.). All weevil species were placed in one of two groups: legume specialist species, or non-legume specialist species.

Landscape maps were created by tracing air photographs (1 : 15,000) onto transparencies. The total length of woody border within each landscape (Fig. 1), and the perimeter of each field sampled, was measured on these landscape maps using a Hoco map measurer. The average of three readings was converted to linear amount of woody border, or field perimeter, in metres. The landscape maps were taken into the field to fill in land use information by ground survey and to confirm field edge classifications.

Field age and amount of woody border in the landscape were the main predictor variables in the statistical analyses. However, other variables were included to control for their effects. The percent cover alfalfa was averaged over the season for each field and included in the analysis to account for variation among fields in local habitat quality. This variation was important to consider because it can have significant

Table 1
Data summarized by field/landscape[a]

AGE	WOOD	PERIM	HARV	%ALF	SWEEPS	ALLIND	WEEVIND	HPOST	FAMRICH	WEEVRICH
(a) 1995 Data										
3	18645	1125	2	39.3	240	1949	1	0	18	1
1	7215	1755	2	54.6	240	2041	1	0	13	1
2	20145	720	2	35.9	240	1602	11	5	20	3
6	38250	2085	1	30.6	240	1315	9	0	20	3
4	22050	1035	1	28.4	240	1447	3	0	21	2
4	13560	675	2	36.4	240	1575	2	0	14	2
1	9930	900	1	77.3	240	2057	2	0	19	1
3	21030	1710	2	43.8	240	2500	1	0	17	1
5	22455	1095	2	44.3	240	2128	1	0	25	1
4	13740	1275	2	16.4	220	1266	3	1	17	2
2	19710	825	1	63.3	240	2521	2	0	21	1
7	12465	1140	1	49.6	240	1575	6	0	20	4
10	29055	1035	1	11.7	240	1254	6	1	14	3
2	16125	600	2	46.9	240	3391	5	0	19	2
3	23295	660	1	54.3	240	2180	17	11	19	4
4	16740	900	2	32.0	240	1490	16	3	21	5
2	8085	1785	2	50.4	240	2880	4	1	18	3
3	6075	675	2	51.1	240	3116	1	1	20	1
6	20550	1125	2	37.8	240	2258	10	1	20	4
5	23100	735	2	25.4	240	1134	8	3	17	3
1	10245	1005	3	32.1	200	3136	12	1	20	2
6	14310	1575	2	42.9	240	2834	3	0	21	2
12	21900	465	2	39.3	240	1717	12	2	22	4
8	21390	1935	3	31.4	240	1229	3	0	18	2
3	18255	1725	2	37.6	240	2407	2	1	21	2
10	18660	885	2	34.4	240	2792	12	5	23	3
4	12555	435	1	16.6	180	770	3	0	15	2
4	13650	780	1	65.8	240	1239	12	2	19	5
2	18450	1665	2	43.2	240	1008	1	0	14	1
2	17385	1680	3	44.3	240	1424	3	0	18	2
1	16995	795	2	53.2	240	2031	8	1	19	2
3	6225	630	2	50.2	240	2888	10	0	17	2
2	13950	915	2	45.1	240	2927	3	3	23	1
1	8550	1095	2	55.3	240	1232	1	0	18	1
2	11595	945	2	60.1	240	3606	7	4	23	2
(b) 1996 Data										
4	18645	1125	2	3.7	240	335	4	0	33	1
3	20145	720	2	7.1	240	423	2	0	35	1
7	38250	2085	1	1.4	240	855	1	1	36	1
5	22050	1035	1	5.8	240	751	4	0	34	1
6	22455	1095	1	17.6	240	616	2	0	25	2
8	12465	1140	1	17.9	240	663	1	0	39	1
11	29055	1035	1	3.2	240	655	0	0	32	0
3	16125	600	2	23.9	240	3136	4	0	37	2
7	20550	1125	1	12.2	240	554	4	2	41	2
6	23100	735	1	16.1	240	958	7	1	40	3
7	14310	1575	1	4.2	240	2494	50	0	32	3
9	21390	1935	2	27.4	240	601	2	0	31	1
11	18660	885	1	26.8	240	1135	9	5	42	4
3	17385	1680	2	44.9	240	1220	3	1	31	2
2	16995	795	2	17.8	240	1146	8	0	39	3
3	6225	630	2	1.7	240	341	2	0	25	2

Table 1 (*Continued*)

AGE	WOOD
2	8550
4	11595
3	8430
1	6855
1	23220
1	14265
1	15735
1	9750

[a] Predictor variabl
landscape in meters; F
season; %ALF, averag
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species of alfalfa-speci

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was included to

Table 2
Multiple regression an

Source
1995: $R^2=0.3$
PERIM
HARV
%ALF
SWEEPS
AGE
WOOD
AGE × WOOD
Corrected total
1996: Model $R^2=0.45$
PERIM
HARV
%ALF
SWEEPS
AGE
WOOD
AGE*WOOD
Corrected Total

[a] Predictor variables
landscape in meters; PE
season; %ALF, average
summer. Significance te
variation due to all othe

Table 1 (*Continued*)

AGE	WOOD	PERIM	HARV	%ALF	SWEEPS	ALLIND	WEEVIND	HPOST	FAMRICH	WEEVRICH
2	8550	1095	2	57.9	240	1908	1	0	29	1
4	11595	945	2	45.9	240	995	6	3	30	3
3	8430	1575	1	23.3	180	292	2	0	26	1
1	6855	795	2	14.5	240	487	3	1	32	2
1	23220	315	1	1.3	240	582	4	0	37	2
1	14265	1425	2	53.1	240	950	5	0	32	4
1	15735	1320	2	21.7	240	773	8	3	32	3
1	9750	900	2	13.9	240	751	10	0	29	2

[a] Predictor variables were: AGE, number of years since the field was converted to alfalfa; WOOD, length of woody border in the landscape in meters; PERIM, length of alfalfa field perimeter in meters; HARV: number of times the alfalfa was cut during the sampling season; %ALF, average percent cover of alfalfa in the field and SWEEPS, number of sweeps of the insect net over the field during the summer. Response variables were: ALLIND, total number of insects collected; WEEVIND, number of alfalfa-specialist weevil individuals; HPOST, number of *Hypera postica* (alfalfa weevil) individuals; FAMRICH, total number of insect families and WEEVRICH, number of species of alfalfa-specialist weevils.

effects on the insect populations within patches (Duelli et al., 1990). The number of harvests taken from each field during the sampling season was included to account for possible disturbance effects on insect populations (Fahrig and Jonsen, 1998). The number of sweeps taken in each field throughout the season was included to correct for variation in sampling effort among fields; one sampling period was missed for each of three fields because of farmer activity, and one was not sampled during the last two sampling periods because of the presence of cows. Field perimeter was also included to account for possible effects of field size and shape on insect relative density or richness. Field size and shape determine the amount

Table 2
Multiple regression analysis results for total family richness[a]

Source	df	Type III SS	*F* falue	Pr>*F*	Coefficient
1995: $R^2=0.3$					
PERIM	1	8.811	1.28	0.268	−0.00129
HARV	1	16.10	2.34	0.138	1.43
%ALF	1	33.92	4.92	0.035	0.115
SWEEPS	1	1.593	0.23	0.635	−0.024
AGE	1	23.28	3.38	0.077	1.11
WOOD	1	34.15	4.96	0.034	0.000341
AGE × WOOD	1	14.90	2.16	0.153	−0.0000429
Corrected total	34	267.0			
1996: Model $R^2=0.45$					
PERIM	1	37.13	1.98	0.178	−0.00374
HARV	1	0.6947	0.04	0.850	−0.570
%ALF	1	5.465	0.29	0.596	0.0360
SWEEPS	1	4.069	0.22	0.647	0.0456
AGE	1	53.82	2.88	0.109	1.76
WOOD	1	76.82	4.10	0.060	0.000639
AGE*WOOD	1	48.43	2.59	0.127	−0.0000778
Corrected Total	23	541.0			

[a] Predictor variables were: AGE, number of years since the field was converted to alfalfa; WOOD, length of woody border in the landscape in meters; PERIM, length of alfalfa field perimeter in meters; HARV: number of times the alfalfa was cut during the sampling season; %ALF, average percent cover of alfalfa in the field and SWEEPS, number of sweeps of the insect net over the field during the summer. Significance tests are based on Type III sums of squares (SAS Institute, 1990), i.e., the variation explained by the term after the variation due to all other terms has been accounted for.

of interface between the field and the agricultural matrix (measured directly as field perimeter), which is related to the probability of insects encountering the field.

The increase i
borders suggests
increasing insect
sibly by offering

The increase in insect family richness with woody borders suggests that woody borders provide a way of increasing insect biodiversity within crop fields, possibly by offering additional complementary habitats. This is in addition to any increase in biodiversity which may occur strictly within the woody borders themselves. In addition, large amounts of woody border may be indicative of landscape diversity, i.e., diversity of habitats within the landscape. Jonsen and Fahrig (1997) found that diversity of generalist insects in the Cicadellidae (Auchennorhyncha) and Curculionidae (Coleoptera) in alfalfa fields increased with increasing landscape diversity.

The marginally significant positive relationship between the number of insect families and field age supports the prediction that insect diversity increases with field age. This could result from different types of insects taking different amounts of time to colonize the fields. A second possible explanation is that the insect diversity simply follows the plant diversity, which increases as the field ages. Many studies have found that host plant and insect herbivore diversities are positively correlated (see Bach, 1980 for many examples), but there was no evidence of this in the present study.

Rapid colonization could explain why there were no significant effects of field age or the woody border-field age interaction on the relative density measures at a time scale of years. However, the marginally significant effect of age on diversity suggests that there may be an initial rapid colonization by very populous species of a few families (e.g., Aphididae), and subsequent slower colonization by members of other, more rare, families. If the populous species colonize fields in large numbers within the first year, subsequent density increases could be comparatively insignificant. Continued colonization over years by rarer species would have little effect on overall density but would result in a gradual increase in family richness over years.

The results of this study show that woody borders can increase insect diversity of herbivorous insects within fields in agro-ecosystems. Woody borders play a general role in the conservation of biodiversity in such systems, and their effects extend beyond the border itself. It is especially important that such conservation may be accomplished without incurring economic losses by increased herbivorous insect densities within crop fields.

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