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Plant diversity in three types of hedgerows adjacent to cropfields

CÉLINE BOUTIN[1,*], BENOÎT JOBIN[2], LUC BÉLANGER[2] and LINE CHOINIÈRE[3,4]

*[1]National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada, 100 Gamelin Blvd. Hull, Québec, Canada, K1A 0H3; [2]Canadian Wildlife Service, Environment Canada, 1141 Route de l'Église, C.P. 10100, Sainte-Foy, Québec, Canada, G1V 4H5; [3]Bureau d'Écologie Appliquée Inc., 4950 Boul. de la Rive Sud, Bureau 104, Lévis, Québec, Canada, G6V 4Z6; [4]Present address: Protection de l'habitat, Gestion de l'habitat du poisson, Institut Maurice Lamontagne, 850, Route de la Mer, C.P. 1000, Mont-Joli, Québec, Canada, G5H 3Z4; *Author for correspondence (e-mail: celine.boutin@ec.gc.ca; fax: +1-819-953-6612)*

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Abstract. The farming landscape of eastern Canada is dotted with three main types of hedgerows: (1) natural woody, (2) planted woody and (3) herbaceous. The objective of this study was to compare the value of these habitats as a repository of plant biodiversity in agricultural areas of southern Quebec. The overall plant diversity was higher in natural hedgerows and they contained more plant species of conservation values than other hedgerow types. Plant species richness per quadrat was, however, higher in planted woody hedgerows, and together with the species composition, lead to the conclusion that planted hedgerows in their entirety consisted of an ecotone type of vegetation such as is found in field edges which usually support high plant diversity and productivity but where transient plant species predominate. Consequently, this study indicated that natural hedgerows fare better than planted hedgerows in terms of diversity of plants of conservation interest. In spite of that, planted woody hedgerows contained plant (and bird) species of some interest and should be favoured over more desolate herbaceous hedgerows. In areas where hedgerows were removed and are not re-establishing naturally, a mixture of deciduous trees and conifers should be encouraged in further windbreak planting programs so as to conciliate both the conservation and agronomic objectives. Furthermore, management practices should optimise the growth of establishing plants of conservation values.

Key words: eastern Canada, farmland, field margin, natural woody hedgerow, plant diversity, planted hedgerow, plant species richness, windbreak

Introduction

The Great Lakes – St. Lawrence basin of southeastern Canada, together with the western prairies, are the most intensively managed agricultural regions of Canada. All these areas have undergone a sharp intensification of agriculture since the early 1960s. In eastern Canada, including the study area of southern Quebec, this involves the expansion of cash crops such as cereals, maize (*Zea mays*) and soybean (*Glycine max*) monocultures and a concomitant decrease in the dairy industry. The use of large machinery for the massive application of agrochemicals in increasingly larger fields gradually caused a noticeable reduction of marginal habitats such as hedgerows interspersed within farmland, and an increased woodlot fragmentation (Boutin et al. 1994; Bélanger and Grenier 1998). Currently, less than 30% of the land remains forested in the agricultural plain of southern Quebec (Bélanger and Grenier 1998; Bélanger et al. 1999). Woody hedgerows and small woodlots that are still present in fragmented landscapes constitute important refuges for native flora and fauna (Best 1983; Best et al. 1995; Boutin and Jobin 1998), although scarcely any studies were ever designed for the inventory of plants other than weeds and crops in farming areas of Quebec (Fritz and Merriam 1994; Jobin et al. 1996; Boutin and Jobin 1998). In relation to plants, the attention was mostly devoted to forested ecosystems as part of large forests (Grandtner 1966; Bouchard and Maycock 1978). One exception is the work by Jobin et al. (1996) which demonstrated the crucial importance of habitats associated with farmland for plant conservation where 95 woody species and 283 herbaceous species were recorded, of which three species are considered rare in Quebec (Boutin et al. 1994).

Hedgerows are linear structures which comprise the whole field boundary complex, and this includes the woody and herbaceous flora (hedge-bottom flora) together with adjacent field margins (ecotones between the hedge and the field). In the intensive agricultural landscape of southern Quebec, as in similar areas devoted to agriculture elsewhere in North America, it is possible to observe three different types of hedgerows: (1) natural woody hedgerows, i.e., those remaining from larger forests or left to grow naturally between fields or more likely between adjoining farms, (2) planted woody hedgerows, i.e., those recently established by farmers for the reduction of wind erosion, also called windbreaks or shelterbelts, and (3) herbaceous hedgerows or fencerows, devoid of trees and with a few scattered shrubs, and by far the most common type of habitats abutting cropfields. More than 2500 km of windbreaks were planted since the mid-eighties by farmers in Quebec (Pesant 1994). Both planted and herbaceous hedgerows are regularly maintained for weed suppression, using chemical or mechanical control. Furthermore, most habitats in the vicinity of intensively managed cropfields are recurrently exposed to some extent to pesticide and fertilizer drift which may alter the plant species composition of these habitats (Boutin and Baril 1997).

A considerable amount of work on species living in hedgerows has been done in Europe where farmland covers large areas and where hedgerows constitute critical habitats for the maintenance of woodland, grassland or old field plant species that would not otherwise subsists in agricultural landscapes (Pollard et al. 1974; Baudry 1988; Bunce and Hallam 1993). Collectively these and other studies ascertained that plant species composition was influenced by an array of distinct factors such as hedgerow structures and physical characteristics, especially width (Burel and Baudry 1990), soil characteristics and microclimate (Barr and Gillespie 2000; McCollin et al. 2000). At the landscape level, connectivity, distance from sources (e.g., woodland) as well as neighbouring land use appear to influence the colonisation pattern for several species (Burel and Baudry 1990; Barr and Gillespie 2000; Baudry et al. 2000). Furthermore, some inherent characteristics of species such as mode of dispersion was found important (Burel and Baudry 1990), although this is disputed (McCollin et al. 2000). The historical background, i.e., whether or not hedgerows were remnant of forested areas, or were growing spontaneously or had been planted could be a primordial factor for the presence of a number a species (McCollin et al. 2000; Boutin unpublished). On the other hand, intensity and management regime of hedgerows and adjacent land may determined the presence of weeds and opportunistic species in field boundaries (Marshall and Smith 1987; Marshall 1989; Boutin and Jobin 1998).

The contribution of woody natural (spontaneous), woody planted and herbaceous hedgerows to the plant biodiversity in rural areas has never been investigated in south-western Quebec and elsewhere. Therefore, the objective of this study was to compare the value of the different types of hedgerows as repository of plant biodiversity in intensive farmland. To achieve this goal, hedgerow structures, some characteristics of the landscape and plant species richness and abundance were studied in hedgerows situated within intensive farming regions of southern Quebec.

Study area

Sixty-one hedgerows were located in the Richelieu/Saint-Hyacinthe regions, south-east of Montreal in the Quebec province in eastern Canada (45°40′ N, 72°40′ W); the area is part of the lowland clay soil type of the St. Lawrence watershed. The study area is situated where two vegetation associations or physiographic zones meet (Grandtner 1966), both with sugar maple (*Acer saccharum*) as the dominant species (sugar maple/hickory (*Carya cordiformis*) and sugar maple/basswood (*Tilia americana*)/yellow birch (*Betula lutea*)). These two types of associations are characterized by a high species richness with plants thriving in rich soil and mild climatic conditions. Because it is situated within the 2500 thermal unit zone and because of important soil drainage works before the sixties and later, the climatic and edaphic conditions are, or became, suitable for industrial type of agriculture dominated by rowcrops of cereals, maize and soybean.

Methods

Selected hedgerows were situated between intensively cropped fields, including maize, soybean, dry beans (*Phaseolus vulgaris*), peas (*Pisum sativum*), other vegetables, small fruits or potatoes (*Solanum tuberosum*). Hedges adjacent to pastures, hay or forage crops were not surveyed because of the known differences in the management of adjacent fields, e.g., tilling, pesticide and fertilizer use, and ensuing effects on plants in adjacent habitats (Jobin et al. 1997). Information on pesticide and fertilizer use in fields adjacent to the selected hedgerows was obtained directly from farmers and farm workers, and by consulting the local representative of the Quebec Agriculture Ministry (MAPAQ). In forage corn, soybean and cereals, herbicides were used once or twice a year, and seeds were usually coated with a fungicide and an insecticide. Chemical fertilizers were frequently applied, coupled with manure. In other crops bordering the selected hedgerows (peas, other vegetables, small fruits or potatoes), several herbicide applications were performed annually, supplemented with insecticide, aphicide and fungicide applications several times a year, often aerially. Chemical fertilizers and manure were also abundantly used.

Hedgerows were surveyed from 5 to 19 July 1995. A hedgerow usually started at the corner of a cropfield, often near and perpendicular to a road, and extended up to 800 m between cropfields. Physical and biological structures were recorded as well as the plant species composition. Length was measured by staking at 100 m intervals and width, defined as the mean width of the herbaceous stratum, was measured every 200 m, or every 100 m if necessary to provide a minimum of three measurements for each hedgerow under 400 m in length. Area was computed by multiplying hedgerow length by its mean width. Woody species composition (presence–absence) of the shrub and tree strata was determined by walking and searching for every species growing in each hedgerow. The shrub stratum included all woody species <5 m; the tree stratum thus corresponded to all woody species >5 m in height. Mean height of the shrub and tree strata were calculated by visually estimating the height of every 100-m section. Cover of woody species in the tree and shrub strata was estimated for every 100-m section, and averaged to an overall percentage. Woody hedgerows lacking a tree stratum were categorized as woody hedgerows with shrubs, other hedgerows showing a well-developed tree stratum were classified as woody hedgerows with trees. From the 27 natural hedgerows surveyed, 12 contained trees and 15 had only shrubs as woody vegetation whereas we inventoried six planted hedgerows with trees and 11 planted hedgerows with shrubs. The number of dead trees in the tree stratum was counted and the percentage of gaps, i.e., the portion of the hedgerow without any trees or shrubs exceeding 2 m, was estimated. Seventeen herbaceous hedgerows were inventoried (total hedgerows = 61). For each hedgerow, distance to the nearest farm building, woodlot, hedgerow and road was also estimated visually or calculated on 1:50 000 topographic maps.

Herbaceous vegetation of every hedgerow was sampled in 1 m^2 quadrats distributed along three or four transects perpendicular to the field edge and positioned every 200 m. Along each transect, one quadrat was placed in the centre of the hedgerow and one on each side at the immediate edge of the field. Only two quadrats per transect were deployed in hedgerows <3 m wide. Presence and cover of all species with a cover $\geq 5\%$ were recorded within each quadrat. Mean height of the herbaceous layer and total cover percentages of the herbaceous vegetation and bare ground were determined. A total of 730 quadrats was sampled (342 in natural hedgerows, 178 in planted hedgerows, 210 in herbaceous hedgerows).

For each quadrat, the total number of herbaceous species inventoried was calculated, and each plant species was characterized according to specific attributes: lifespan (annual, biennial, perennial), status (native, introduced) and weediness. The latter is presented in Boutin et al. (in press). Furthermore, plants from the herbaceous layer were classified in four categories according to their frequency of presence and their average percent cover in quadrats: A: low cover ($<$10%) and low frequency of presence ($<$10%), B: low cover and high frequency ($\geq$10%), C: high cover ($\geq$10%) and low frequency, D: high cover and high frequency of presence.

Statistical analyses

Species accumulation curves were constructed for each hedgerow type to evaluate sampling efficiency among hedgerow types, using PC-ORD software (McCune and Mefford 1995). The program subsamples the dataset a maximum of 500 times and calculates the average number of species as a function of sample size. First-order jackknife estimators of species richness were calculated and sampling efficiency (%) was derived from the observed number of species divided by the estimator of species richness.

Biophysical characteristics were compared among the five different types of hedgerows using Kruskal–Wallis and multiple comparison tests. Non-parametric tests were preferred since residuals of the analyses did not follow a normal distribution according to the Wilk test and normal probability plots (SAS Institute Inc. 1988).

Two discriminant analyses were performed in order to determine which of the descriptive variables best differentiated hedgerow types. We first conducted a stepwise discriminant analysis to select the best discriminating variables (*P*-value for entry and stay = 0.15) followed by a canonical discriminant analysis completed with these variables to position hedgerows along a two-dimensional space. The importance of the selected variables to differentiate hedgerow types was assessed via the structure coefficients (total canonical structure) which are Pearson correlations calculated between the original variables and canonical variables of the first two axes. Two sets of analyses were conducted: (1) all 61 hedgerows were included in the analysis to discriminate among the five types of hedgerows (12 natural with trees, 15 natural with shrubs, six planted with trees, 11 planted with shrubs, 17 herbaceous) and (2) only hedgerows with trees (12 natural and six planted) to discriminate between tall woody hedgerows. Descriptive variables included in the analyses are listed in Table 1. In the first discriminant analysis, 15 variables, excluding those associated with the tree layer, were used. In the second analysis, all 20 variables listed in Table 1 were included.

A two-factor analysis of variance (SAS Institute Inc. 1988; General Linear Model procedure) was used to test for differences in attributes of the herbaceous vegetation recorded among the three types of hedgerows and positioning of quadrats within

Table 1. Biophysical characteristics (mean per hedgerow and standard error) of woody natural and planted hedgerows, with shrubs only or with shrubs and trees (with trees) as the woody vegetation, and herbaceous hedgerows in southern Quebec, Canada (Kruskal–Wallis tests and multiple comparisons were performed).

	Natural woody hedgerows				Planted woody hedgerows				Herbaceous		Kruskal–Wallis	
	With trees ($n = 12$)		With shrubs ($n = 15$)		With trees ($n = 6$)		With shrubs ($n = 11$)[d]		hedgerows ($n = 17$)[e]			
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	H	*P* value
Length (m)	717.9 a	86.9	520.7 a	45.9	466.7 a	52.7	613.2 a	46.1	596.3 a	82.5	5.00	0.2872
Width (m)	7.3 a	0.4	4.8 b	0.5	9.1 a	0.8	4.3 b	0.4	4.8 b	0.5	28.29	0.0001
Area (ha)	0.5 ac	0.1	0.3 b	0.0	0.4 bc	0.0	0.3 bc	0.0	0.3 bc	0.0	14.51	0.0058
Distance from nearest woodlot (m)	299.2 a	95.5	301.3 a	81.2	753.3 ac	438.5	1332.7 bc	281.0	545.3 ac	146.4	11.63	0.0203
Distance from nearest hedgerow (m)	134.2 ab	19.6	89.3 a	24.6	221.7 b	96.2	187.3 ab	65.5	107.1 ab	41.9	14.15	0.0068
Distance from nearest road (m)	386.7 a	114.9	185.0 a	69.6	93.3 a	18.6	230.0 a	84.5	229.4 a	79.3	4.23	0.3756
Distance from nearest building (m)	305.8 a	82.8	360.0 a	86.1	206.7 a	139.0	488.2 a	131.9	360.3 a	92.6	3.72	0.4451
Variables associated with the tree layer												
% Cover	59.1 a	5.9	16.7 ac	2.4	88.8 a	4.8	4.0 bc	2.2	0.4 b	0.3	52.37	0.0001
No. woody spp.	10.3 a	0.9	6.3 a	0.6	3.0 ac	0.9	0.9 bc	0.3	0.3 bc	0.2	50.32	0.0001
Mean height (m)	8.0 a	0.3	5.7 bc	0.2	8.3 a	0.5	7.4 ac	1.4	8.6[f]	2.5	18.82	0.0003
Percent hedgerow with gaps	25.8 ac	5.1	57.4 ad	2.9	11.2 c	4.8	54.0 cd	8.4	99.6 b	0.3	47.78	0.0001
No. dead trees	13.3 a	3.4	2.9 ac	0.8	0.2 bc	0.2	0.3 bc	0.2	0.0 b	0.0	40.88	0.0001
Variables associated with the shrub layer												
% Cover	81.0 a	3.6	69.1 ac	4.1	40.0 bc	12.0	55.0 acd	5.3	24.4 bd	6.9	29.12	0.0001
No. woody spp.	24.8 a	2.1	14.9 a	0.6	13.7 ac	2.4	7.2 bc	0.8	7.4 bc	1.1	39.06	0.0001
Mean height (m)	2.3 a	0.3	2.1 a	0.1	2.3 a	0.4	2.6 a	0.2	1.0 b	0.1	34.07	0.0001
Variables associated with the herb layer												
% Cover	52.7 a	4.3	62.6 a	2.1	57.7 a	8.1	65.1 a	5.6	61.6 a	3.4	5.53	0.2375
No. herb spp.	20.7 a	1.4	16.5 a	0.9	18.5 a	1.4	17.2 a	1.8	18.9 a	1.2	5.57	0.2338
Max height (cm)	37.4 a	2.5	41.3 a	2.2	33.9 a	3.2	35.9 a	1.9	36.6 a	1.5	5.28	0.2594
Mean height (cm)	22.5 a	1.9	25.5 a	2.0	22.2 a	2.4	22.3 a	1.7	23.3 a	1.5	1.87	0.7597
% Bare ground	21.0 a	3.7	16.3 a	2.2	18.2 a	5.0	13.8 a	4.5	21.8 a	4.0	4.39	0.3553

Different letters following means in the same row indicate significant differences.
[d] $n = 7$ for mean height of the tree strata.
[e] $n = 2$ for mean height of the tree strata.
[f] Herbaceous hedgerows not included in this analysis because of low sample size ($n = 2$).

hedgerows (centre vs. sides). Interactions among hedgerow types and quadrat positioning were tested for significance at the 0.05 level. When interactions occurred the ANOVA testing the difference between quadrats was repeated separately for each hedgerow type and for each quadrat positioning. Tukey's multiple comparisons, testing differences among means, were performed when the ANOVA showed that mean values were significantly different. Percent data were arcsin transformed. Residuals from the ANOVA showed normality and homogeneity of variance in all cases.

Two detrended correspondence analyses (DCA) were performed, using the downweighting option for less common species (McCune and Mefford 1995) in order to group hedgerows with respect to their vegetation composition. Presence–absence data were used with the hedgerow being the sample unit. The first analyses incorporated all 210 woody and herbaceous species while the second analysis only included the 131 herbaceous species recorded. In order to identify plant species responsible for the positioning of the different hedges along axes, Pearson correlations between species presence and species scores on the first two axes were calculated.

Results

Estimating sampling efficiency

In order to assess the sampling efficiency, and because sample size was unequal among hedgerow types, species accumulation curves with herbaceous species were calculated. Curves were constructed in two ways: using hedgerows or quadrats as the sampling unit (Table 2). The number of observed species in a subsample will typically be smaller than the true number of species. The jackknife estimator of species richness calculated that the true number of species would be 122, 99 and 129 in natural woody, planted woody and herbaceous hedgerows respectively, which was between 71.3 and 77.0% of the species observed. Probably because more natural hedgerows were sampled, species richness was slightly better estimated. Table 2a shows that only eight planted hedgerows were required to inventory 75% of the estimated species richness while 12 were necessary for natural hedgerows. When using quadrats as the sample unit, sampling efficiency varied between 72% for planted hedgerows with shrubs to 78.3% for natural woody with trees (Table 2b). Only 27 quadrats were needed to adequately sample planted hedgerows with trees whereas in the case of herbaceous hedgerows, 86 quadrats were required. In conclusion, sampling different number of hedgerow types resulted in relatively similar sampling efficiencies.

Biophysical characteristics of hedgerows

Hedgerows measured on average 594 m in length and were 6 m wide. Both natural and planted hedgerows with trees were wider and covered a larger area than shrubby

Table 2. Result of sampling efficiency: cumulative number of herbaceous species using (a) hedgerows, and (b) 1-m^2 quadrats as sampling units. Sampling efficiency is estimated using a first-order jackknife estimate. Number of units necessary to observe 75% of the species is then calculated.

Hedgerow type	Number of units	Number of spp. observed	Estimate (jackknife) of spp. richness		No. units for 75% of spp. observed (% of total units)
			Number	% Obs.	
a) Hedgerows as sampling unit					
Natural woody	27	94	122	77.0	12 (44.4)
Planted woody	17	76	99	76.8	8 (47.1)
Herbaceous	17	92	129	71.3	10 (58.8)
b) Quadrats as sampling unit					
Natural woody	342	94	118	79.7	144 (42.1)
With trees	171	72	92	78.3	74 (43.3)
With shrubs	171	64	84	76.2	75 (43.9)
Planted woody	178	76	96	79.2	76 (42.7)
With trees	58	49	64	76.6	27 (46.6)
With shrubs	120	59	82	72.0	58 (48.3)
Herbaceous	210	92	118	78.0	86 (41.0)

or herbaceous hedgerows (Table 1). The shrub layer was well established in all but herbaceous hedgerows, even though no shrub species was part of the establishment program for planted hedgerows. However, natural hedgerows exhibited a higher cover of the shrub layer and had more dead trees than planted hedgerows. The herb layer was similar among the five types of hedgerows whereas their distances to other farmland features varied, e.g., natural woody hedgerows were situated nearer to woodlots.

Fifteen descriptive variables (excluding those associated with the tree layer in Table 1) were included in the discriminant analysis performed with all 61 hedgerows and eight variables were retained in the stepwise analysis to select the best discriminating variables (hedgerow width and area, number of woody species in the shrub layer, mean height of the shrub layer, percent cover of the shrub layer, percent cover of the herb layer, distance from the nearest woodlot and road). Among those, two variables best separated hedgerows along axis one, number of shrub species ($r = 0.92$) and cover of the shrub layer ($r = 0.70$), and two additional variables were significant for axis two, mean height of the shrub layer ($r = 0.69$) and distance from the nearest woodlot ($r = 0.48$) (Figure 1A). It is noteworthy that while most hedgerow types are clustered adjacent to each other, those planted with trees are scattered along both axes.

Twenty variables (Table 1) were included in the second discriminant analysis performed with planted and natural hedgerows with trees and only three variables were selected for the canonical discriminant analysis (hedgerow length, number of woody species in the tree layer, percent cover of the tree layer). Planted and natural woody hedgerows formed two distinct groups along the first axis, primarily on the basis of the number of tree species ($r = 0.85$) and the percent tree cover ($r = 0.67$) (Figure 1B). No other variables were significant with the second axis.

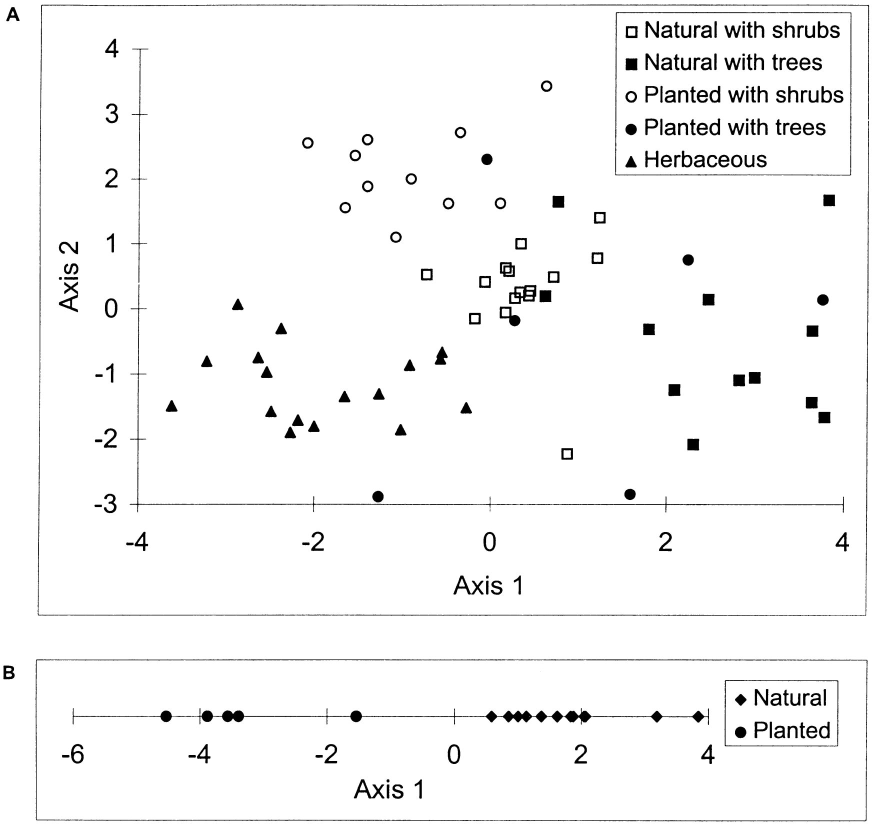

Figure 1. First plan of ordination of the discriminant analysis performed with (A) the 61 hedgerows to discriminate among the five study types (12 natural with trees, 15 natural with shrubs, six planted with trees, 11 planted with shrubs, 17 herbaceous) and (B) only 17 hedgerows with trees (12 natural and six planted) to discriminate between tall woody hedgerows. Descriptive variables included in the analyses are listed in the text.

Comparing species composition among hedgerow types

In total 79 woody species were identified, 78 of which were in the shrub layer and 35 in the tree layer. Among those, 66 were found in natural hedgerows, 47 in planted hedgerows and as many as 31 different species in herbaceous hedgerows (Appendix 1). The tree layer of natural hedgerows was mostly colonised by grey birch (*Betula populifolia*), aspen (*Populus tremuloides*), cottonwood (*P. deltoides*), balsam poplar (*P. balsamifera*), pin cherry (*Prunus pensylvanica*), two willow species (*Salix rigida* and *S. bebbiana*) and red elm (*Ulmus rubra*) whereas conifer tree species were commonly observed in planted hedgerows (Appendix 1). In the shrub layer of natural hedgerows, the most common species were grey birch, red osier dogwood (*Cornus stolonifera*), aspen, raspberry (*Rubus idaeus*), willows (*Salix bebbiana*, *S. discolor*, *S. petiolaris* and *S. rigida*) and meadowsweat (*Spiraea latifolia*). In planted hedgerows, the most common shrubs were choke cherry (*Prunus virginiana*) and various conifer species. The introduced conifer Scotch pine (*Pinus sylvestris*) was found in the shrub layer of planted hedgerows. In herbaceous hedgerows, a few isolated tree specimens of grey birch and poplar trees (*Populus* spp.) as well as several shrub species were encountered.

A total of 131 species were inventoried in the herbaceous layer, 94 in natural hedgerows, 76 in planted and 92 in herbaceous hedgerows (Appendix 2). Seventy percent of the species recorded were perennials. Approximately 38% of the species were widespread across the three types of hedgerows while many others (35%) were confined to one type, among them *Aralia nudicaulis*, *Athyrum filix-femina*, *Cornus canadensis*, and *Dryopteris spinulosa* only found in natural hedgerows (Appendix 2). Species with low frequency of presence (types A and C) dominated regardless of hedgerow types. Only 12% (11/94), 14% (11/76) and 10% (9/92) of herb species were recorded in more than 10% of quadrats (types B and D) in natural, planted and herbaceous hedgerows, respectively (Appendix 2). A few of the latter species were well established in all hedgerow types, e.g., *Asclepias syriaca*, *Elytrigia repens*, *Equisetum arvense*, *Poa pratensis* and *Vicia cracca*.

The average number of herbaceous species per quadrat (total richness) was significantly higher in planted hedgerows (Table 3), although the total number of species inventoried overall was higher in natural woody hedgerows (Appendix 1). More species were observed at the field margin than in the centre of hedgerows. In general, significantly more perennial species were inventoried in quadrats located in the centre of planted hedgerows than in other types of hedgerows, and 46 and 53% of the species recorded at the centre and edge of planted hedgerows, respectively, were introduced. Overall however, only a few introduced species were unique to planted hedgerows (e.g., *Avena sativa*, *Capsella bursa-pastoris*, *Euphorbia helioscopia*, *Melilotus alba*, *Pastinaca sativa*, *Setaria viridis*, *Sinapis arvensis*, *Sonchus arvensis* and *Tragopogon pratensis*) (Appendix 2).

The DCA performed with the whole suite of plant species (210), well separated natural and planted hedgerows on the first axis (eigenvalue = 0.27) based on the types of woody plants encountered, i.e., with deciduous species in natural hedgerows vs. mostly coniferous species in planted hedgerows (Figure 2, Table 4). On the second axis (eigenvalue = 0.14), planted hedgerows with trees were isolated due to the presence of herbaceous species, generally dominated by species of invasive propensity (*Convolvulus sepium*, *Cyperus esculentus*, *Setaria glauca*). The DCA including only the 131 herbaceous species found in the 61 hedgerows, also clearly discriminated between the various hedgerow types (Figure 3). Both axes one (eigenvalue = 0.23) and two (eigenvalue = 0.17) of the DCA separated natural from planted hedgerows with herbaceous hedgerows standing midway between them. Pearson correlations showed that many native perennial species, several of which usually found in wet habitats, e.g., *Typha latifolia*, *Onoclea sensibilis*, *Eupatorium maculatum*, and *Carex* sp., were found in natural hedgerows (Table 5). In contrast, more short-lived, introduced spe-

Table 3. Average number (SE) of herbaceous species per quadrat for total richness and different categories: Lifespan (short-lived and perennial species) and status (introduced, native species). *P* values from two-factor ANOVA.

Hedgerow type	Quadrat positioning		*P* among positions
	Centre	Side	
Total richness			
Natural	2.7 (0.1)	4.0 (0.1)	<0.0001
Herbaceous	3.4 (0.2)	4.2 (0.1)	0.0012
Planted	3.9 (0.2)	4.5 (0.1)	0.0073
P among hedgerow types	0.0721	0.0468	0.0235*
Short-lived species			
Natural	0.2 (0.0)	0.3 (0.0)	0.0083
Herbaceous	0.4 (0.1)	0.5 (0.1)	0.7470
Planted	0.2 (0.1)	0.7 (0.1)	0.0020
P among hedgerow types	0.0180	0.0284	0.0053*
Perennial species			
Natural	2.2 (0.1)	3.3 (0,1)	<0.0001
Herbaceous	2.2 (0.2)	3.3 (0.1)	<0.0001
Planted	3.4 (0.2)	3.5 (0.1)	0.4619
P among hedgerow types	0.0032	0.6842	0.0009*
Introduced species			
Natural	0.7 (0.1)	1.8 (0.1)	
Herbaceous	1.2 (0.2)	2.3 (0.1)	<0.0001
Planted	1.8 (0.2)	2.4 (0.1)	
P among hedgerow types	0.0603		0.0805*
Native species			
Natural	1.7 (0.1)	1.9 (0.1)	
Herbaceous	1.6 (0.1)	1.5 (0.1)	0.7161
Planted	1.9 (0.1)	1.9 (0.1)	
P among hedgerow types	0.5425		0.3385*

**P* associated with interaction term: hedgerow type × positioning.

cies were associated with planted hedgerows, e.g., *Chenopodium album*, *Medicago lupulina*, *Arctium lappa*, *Setaria glauca*.

Discussion

The three types of hedgerows studied were quite different in their structure, plant diversity and abundance. With a total inventory of 79 woody and 131 herbaceous species, we contend that hedgerows are likely to contribute significantly to the plant diversity in farming areas but that the three types are not equal contributors.

The woody vegetation was well developed but very dissimilar among the different hedgerows, i.e., while trees in natural woody hedgerows consisted almost exclusively of deciduous native species (only two hedgerows harboured small cedar (*Thuja*

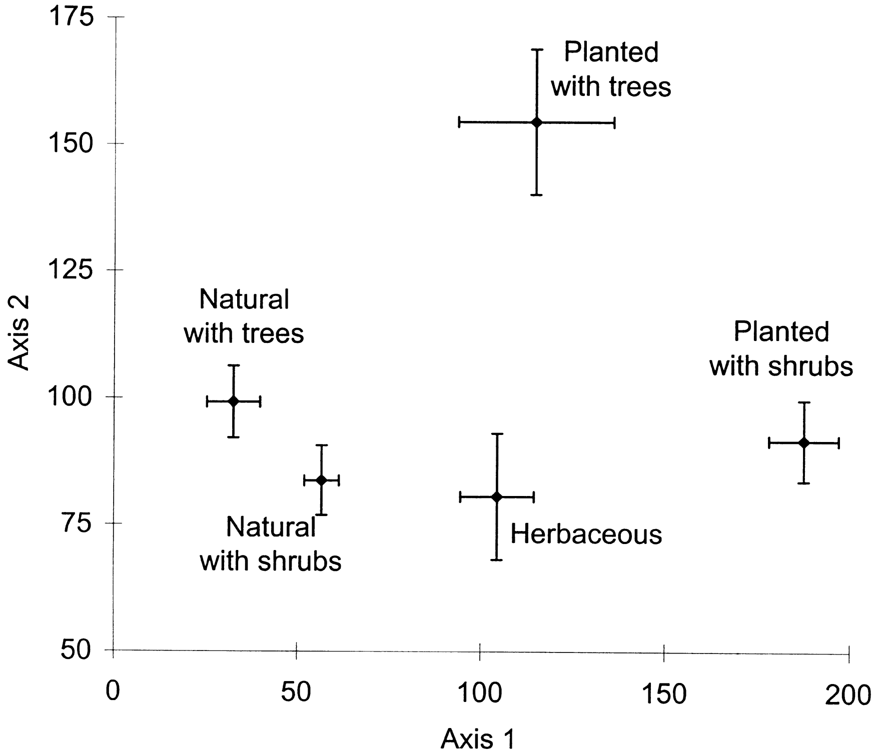

Figure 2. First plan of ordination of the DCA performed with the 210 herbaceous and woody species observed in the 61 hedgerows: 27 natural hedgerows (12 with trees, 15 with shrubs), 17 planted hedgerows (six with trees, 11 with shrubs) and 17 herbaceous hedgerows. Mean site score (±SE) for each hedgerow type is shown. Species are presented in Appendices 1 and 2.

occidentalis) shrubs), in contrast, all planted hedgerows contained a high density of coniferous trees and/or shrubs. Natural woody hedgerows, especially those with trees, consistently sheltered more shrubs as also obvious from their positioning to the right of axis one in Figure 1. In general, an ample variety of deciduous tree and shrub species provides a habitat structure with a large selection of vertical and horizontal nesting and foraging sites for birds (Roth 1976; Schroeder et al. 1992), whereas coniferous species contribute more to winter wind protection and additional nest sites and food resources for birds and mammals. For instance, Yahner (1982a,b, 1983) in Minnesota documented that spruce (*Picea* spp.) and pine (*Pinus* spp.) were important for some bird species such as the robin (*Turdus migratorius*), ring-necked pheasant (*Phasianus colchicus*), flycatchers (*Empidonax* spp.), ruby-crowned kinglet (*Regulus calendula*), etc. Apart from being essential as cover, many of the trees and shrubs produce fruits, mast, seeds, foliage, shoots and buds used by birds and mammals in their diet (Martin et al. 1951). In addition, trees and shrubs harbour large

Table 4. Pearson correlation coefficients between all species (herb + woody) scores on the first two axes of a DCA and species presence in the 61 hedgerows. Only significant correlations at $P < 0.001$ are presented.

Axis 1 (eigenvalue = 0.27)			Axis 2 (eigenvalue = 0.14)		
Species	Type	Correlation	Species	Type	Correlation
Salix bebbiana	woody	−0.82	*Taraxacum officinale*	herb	−0.72
Betula populifolia	woody	−0.81	*Poa pratensis*	herb	−0.55
Populus tremuloides	woody	−0.80	*Phleum pratense*	herb	−0.54
Spiraea latifolia	woody	−0.77	*Trifolium hybridum*	herb	−0.50
Salix discolor	woody	−0.69	*Panicum* sp.	herb	−0.41
Salix rigida	woody	−0.66	*Triticum aestivum*	herb	0.41
Salix petiolaris	woody	−0.66	*Sonchus asper*	herb	0.44
Cornus stolonifera	woody	−0.63	*Setaria glauca*	herb	0.47
Populus balsamifera	woody	−0.63	*Rhamnus alnifolius*	woody	0.47
Agrostis sp.	herb	−0.58	*Impatiens capensis*	herb	0.49
Prunus pensylvanica	woody	−0.57	*Cyperus esculentus*	herb	0.57
Solidago rugosa	herb	−0.53	*Convolvulus sepium*	herb	0.66
Rubus idaeus	woody	−0.52			
Salix lucida	woody	−0.51			
Acer rubrum	woody	−0.50			
Amelanchier laevis	woody	−0.48			
Rubus pubescens	woody	−0.45			
Ulmus rubra	woody	−0.45			
Onoclea sensibilis	herb	−0.44			
Carex sp.	herb	−0.43			
Aronia melanocarpa	woody	−0.43			
Viburnum cassinoides	woody	−0.41			
Malus pumila	woody	−0.40			
Brassica sp.	herb	0.41			
Sonchus arvensis	herb	0.44			
Chenopodium album	herb	0.45			
Polygonum convolvulus	herb	0.47			
Trifolium pratense	herb	0.49			
Tragopogon pratensis	herb	0.50			
Larix laricina	woody	0.53			
Arctium lappa	herb	0.53			
Pinus sylvaticus	woody	0.55			
Pinus resinosa	woody	0.56			
Pinus strobus	woody	0.64			

invertebrate communities which are also indispensable or assuredly attractive to birds and mammals (Johnson and Beck 1988).

The herbaceous vegetation also contributed to the difference between the five hedgerow types as seen in Appendix 2 and illustrated in Figure 3 and Table 5. Overall, perennial species constituted 70% of the plant composition in natural hedgerows but only 60% in planted hedgerows. More importantly the proportion of introduced species reached 58% in planted while it was less than 40% in natural hedgerows. In both cases values for herbaceous hedgerows were in between. Forty-seven species (36%) were common to the three types of hedgerows, nearly half of them being introduced

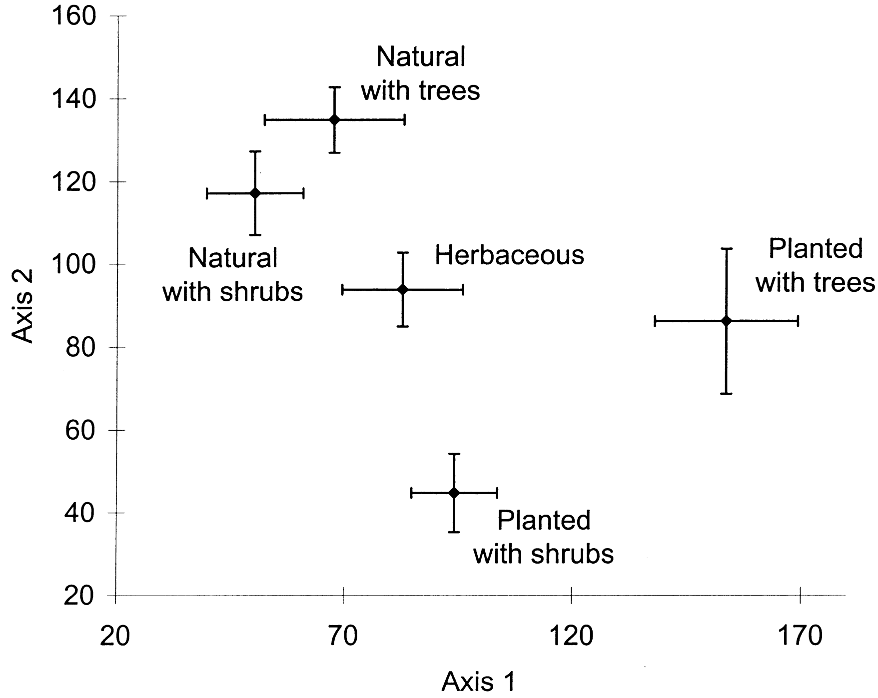

Figure 3. First plan of ordination of the DCA performed with the 131 herbaceous species observed in the 61 hedgerows: 27 natural hedgerows (12 with trees, 15 with shrubs), 17 planted hedgerows (six with trees, 11 with shrubs) and 17 herbaceous hedgerows. Mean site score (±SE) for each hedgerow type is shown. Species are presented in Appendix 2.

species. Of these introduced species, five were commonly encountered in all hedgerows (D = High frequency, high cover). They are *Elytrigia repens*, *Equisetum arvense*, *Poa pratensis*, *Vicia cracca* and *Asclepias syriaca*, the latter, despite being considered a weed, is also an essential food source for the monarch butterfly (*Danaus plexippus*). Several plant species are unique to a given type of hedgerows, 22 in natural woody, 16 in herbaceous but only ten in planted hedgerows. In natural woody hedgerows unique species comprised several ferns, *Athyrum filix-femina*, *Dryopteris spinulosa*, *Osmunda claytoniana* and *Pteridium aquilinum* and some spring ephemerals, *Cornus canadensis*, *Aralia nudicaulis* and *Maianthemum canadense*. In planted hedgerows, unique species were mostly short-lived, introduced species of weedy propensity, e.g., *Avena sativa*, *Capsella bursa-pastoris*, *Euphorbia helioscopia*, *Setaria viridis* and *Sinapis arvensis*. In addition, Boutin et al. (in press) clearly demonstrated that planted hedgerows harboured more weed species than natural or herbaceous hedgerows. The apparent conclusion to these findings is that overall, natural hedgerows contain more plant species of conservation values than planted hedgerows, and, therefore, their preservation in farming landscapes should be recognized and encouraged.

Table 5. Pearson correlation coefficients between the 131 herbaceous species scores on the first two axis of a DCA and species presence in the 61 hedgerows. Only significant correlations at $P < 0.01$ are presented.

Axis 1 (eigenvalue = 0.23)		Axis 2 (eigenvalue = 0.17)	
Species	Correlation	Species	Correlation
Taraxacum officinale	−0.63	*Tragopogon pratensis*	−0.45
Phleum pratense	−0.61	*Arctium lappa*	−0.42
Poa pratensis	−0.59	*Trifolium pratense*	−0.42
Carex sp.	−0.52	*Chenopodium album*	−0.41
Ranunculus acris	−0.41	*Medicago lupulina*	−0.41
Chrysanthemum leucanthemum	−0.38	*Taraxacum officinale*	−0.38
Typha latifolia	−0.36	*Sonchus arvensis*	−0.37
Fragaria virginiana	−0.34	*Ambrosia artemisiifolia*	−0.35
Hypericum perfoliatum	−0.33	*Brassica* sp.	−0.35
Triticum aestivum	0.33	*Polygonum convolvulus*	−0.35
Tussilago farfara	0.34	*Cirsium arvense*	−0.34
Polygonum sp.	0.35	*Daucus carota*	−0.34
Alisma triviale	0.38	*Poa pratensis*	−0.34
Echinochloa crusgalli	0.38	*Sinapis arvensis*	−0.33
Sonchus sp.	0.38	*Potentilla anserina*	−0.33
Lythrum salicaria	0.40	*Sanguisorba canadensis*	−0.33
Sonchus asper	0.43	*Phragmites communis*	0.35
Polygonum fagopyrum	0.48	*Convolvulus sepium*	0.37
Ambrosia artemisiifolia	0.52	*Impatiens capensis*	0.37
Setaria glauca	0.52	*Agrostis* sp.	0.39
Chenopodium album	0.55	*Eupatorium maculatum*	0.41
Impatiens capensis	0.55	*Urtica procera*	0.48
Convolvulus sepium	0.56	*Onoclea sensibilis*	0.50
Cyperus esculantus	0.63	*Solidago rugosa*	0.50
		Typha latifolia	0.50

As pointed out by Baudry (1988), no species are restricted to hedgerows. This also holds for eastern Canada. Instead, hedgerows harbour a very diverse suite of plants: cropland, grassland, wetland, as well as old field and woodland species. In contrast, Fritz and Merriam (1993) in their transplant experiment in eastern Canada suggested that hedgerow habitat quality was not appropriate for woodland plants. Kiss et al. (1997) found that arable fields (cereals, pea, lucerne (*Medicago sativa*), sunflower (*Helianthus annuus*)) in Hungary contained only seven species whereas 22 plants species were inventoried in field margins and only six were common to both fields and margins. They also found that the species spectrum was dominated by opportunistic species in both habitats although there was no evidence of weeds invading from the margins into the fields. In a companion study (Boutin et al. in press), it was discovered that among eight hedgerows and their adjacent fields surveyed in 1996, between 45 and 86% of the total species, inventoried were unique to hedgerows whereas only between 8 and 20% were restricted to fields, and the latter were mostly weed species. This count does not include the numerous woody plants that were exclusively found in hedgerows. The fact that hedgerows were crucial for conserving biodiversity of vegetation when compared to agricultural land was also demonstrated in Britain (Bunce and Hallam 1993; McCollin et al. 2000), France (Burel and Baudry 1990) and Italy (Zanaboni and Lorenzoni 1989).

Conversely, when considering the average number of species per quadrat, species richness was higher in planted and lower in natural woody hedgerows. Furthermore, the number of perennial species was higher in the centre of planted hedgerows than in the other types, but many of the species were introduced species (Table 3). Thus, it looks as though planted hedgerows in their entirety consisted of an ecotone type of vegetation such as found in field edges which usually support high plant diversity and productivity, but where transient plant species predominate (Levenson 1981; Ranney et al. 1981; Boutin and Jobin 1998). In contrast natural hedgerows harbour a suite of species that are characteristic of a more permanent community (e.g., ferns and spring ephemeral species). These results also serve to demonstrate that high diversity should not be used as an unqualified index of environmental quality or biodiversity because edge species, especially perhaps in agriculture, invariably encompass common and opportunistic species, often weeds, that rarely are in danger of extinction or of conversation interest (see also Boutin and Jobin 1998).

These results also illustrate that the diversity among natural hedgerows is substantial and that collectively, planted hedgerows are more homogeneous in their plant species composition. According to the species richness estimates (Table 2), this was not an artifact of the different sample sizes. This element is crucial to consider at the landscape level.

The fact that natural hedgerows were closer to woodlots (approximately 300 m compared to between 753 and 1362 m for planted hedgerows, Table 1) did not seem to influence species richness but may have altered species composition. Intersections and proximity to woodland have been shown to positively affect the density and diversity of plants (Burel and Baudry 1990; Fry 1991; Marshall and Arnold 1995). There is evidence that the ability for plant species to colonise neighbouring habitats or persist in remnants woody hedgerows is influenced by the dispersability of their seeds or, for those relic habitats, by a persistent seed bank (Verkaar 1990). Many of the woodland type species in the natural hedgerows investigated, were ferns which disperse readily through their small spores.

All hedgerows in this study were adjacent to intensively farmed cropfields therefore a low plant diversity was expected because they were probably subjected to pesticide drift, fertilizer runoff and other perturbation that seems to reduce plant diversity (Boutin and Jobin 1998). Nevertheless, diversity was inferior to what would have been predicted from the study carried out in an adjacent area of southern Quebec by Boutin and Jobin (1998). In the latter, species richness was roughly twice as high in natural hedgerows, i.e., approximately six and seven species per quadrat in those hedgerows adjacent to high intensity of farming practices, as opposed to the current inventory which comprised 2.7 and 4.0 species per quadrat in the centre and side respectively. This discrepancy is likely due to the different sampling methods used where only abundant species were inventoried ($\geq$5%) in the current study whereas all species were recorded in Boutin and Jobin (1998). Furthermore, the woody species composition of natural hedgerows of this study was dominated by trees of early succession and pioneer tendency (*Salix* spp., *Populus* spp., *Betula populifolia*, *Rhus typhina*, etc.) which indicates that the hedgerows surveyed had probably been only recently established.

The average size of the study hedgerows was between 0.3 and 0.5 ha, with hedgerows having a tree layer covering a larger area primarily because of their more extensive width. According to some authors a forest patch needs only to be over 3 ha (providing it is non-linear) in order to sustain microclimatic conditions that can accommodate the sylvan and understorey climax vegetation (Levenson 1981; Ranney et al. 1981). Matlack (1993) demonstrated that significant edge effects were recorded up to 50 m into woodlots for several microclimatic factors such as light, temperature, litter moisture, humidity, etc. In the current study, hedgerows with their average width of between 4.3 and 9.1 m (range between 1.6 and 12.0 m) were far from being ideal for the establishment of an understorey vegetation composed of mesic species. In addition, heavy human activities through agrochemical drift, selective wood removal by farmers, or use of these habitats for stone piling taken from neighbouring agricultural fields seemingly maintained a continual state of disturbance. For instance, no hickory was found in any of the hedgerows. In spite of that, even the most disturbed planted hedgerows contained plant species of some conservation interest (Appendices 1 and 2), e.g., *Quercus rubra*, *Fraxinus pennsylvanica* and *Ulmus rubra*, *Juglans nigra*, *Sambucus canadensis* and several additional trees and shrubs of importance to wildlife, as well as a few shade-tolerant herbs such as *Onoclea sensibilis* and *Sanguisorba canadensis*.

In a concurrent study on bird using the same 61 hedgerows, Jobin et al. (in press) demonstrated that, although planted hedgerows (windbreaks) overall sheltered fewer bird species than natural hedgerows (25 vs. 39), they sustained a more abundant bird community than herbaceous hedgerows (19 species), primarily because of their more complex structural diversity. Hairy woodpecker (*Picoides villosus*), northern flicker (*Colaptes auratus*), grey catbird (*Dumetella carolinensi*), brown thrasher (*Toxostoma rufum*), and rose-breasted grosbeak (*Pheucticus ludovicianus*), among others, were not observed in herbaceous hedgerows but were observed on several occasions in natural and planted hedgerows thus emphasizing the importance of these habitats for the conservation of biodiversity at other trophic levels in the agricultural landscape.

In conclusion, the preservation of natural woody hedgerows emerges as pivotal for the conservation of wildlife (including plants) in intensively farmed areas otherwise flagrantly deficient in woody habitats. As alluded to above, it has been documented that less than 30% of the area studied was covered with a very fragmented woodland cover, the fragmentation process being largely related to the intensity and types of agricultural practices (Bélanger and Grenier 1998; Bélanger et al. 1999). This holds for a number of intensively farmed areas in Canada and in many other countries (Baudry et al. 2000). The maintenance and enhancement of a high plant diversity indubitably testifies to a healthy invertebrate and animal populations because all are ultimately dependent on plants for survival and reproduction (Best 1983; Morris and Webb 1987; Povey et al. 1993; Macdonald and Johnson 1995). This study indicates that natural hedgerows unequivocally fare better than planted or herbaceous hedgerows in terms of biodiversity of organisms of conservation interest and should be favoured. Conceivably a diverse mixture of deciduous and conifer trees should be encouraged in further windbreak planting programs. In addition, the management regime should optimise the establishment of plants that will accommodate both the conservation and agronomic objectives in areas where hedgerows were removed and are not re-establishing naturally.

Acknowledgments

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Appendix 1

Woody species ($n = 79$.) identified in the tree layer (>5 m height; $n = 35$ spp.) and in the shrub layer (<5 m height; $n = 78$ spp.) of the 61 hedgerows studied in southern Quebec. Species characteristic of the two typical forest vegetation associations in the study area (Grandtner 1966) are in bold. Number of ×s identifies common species.

Species	Status[a]	Tree layer			Shrub layer			Wildlife food[b]
		Natural	Planted	Herbac.	Natural	Planted	Herbac.	
Acer negundo	I	×	×		××	××	×	×
Acer rubrum	N	××	×		×××	×	×	×
Acer saccharinum	N		×			×		×
Acer saccharum	N	×			×	×		×
Alnus rugosa	N	×			×	×		×
Amelanchier laevis	N	×			××	×	×	×
Aronia melanocarpa	N				××			×
Betula papyrifera	N	×			×	×		×
Betula populifolia	N	××××	×	×	××××	×	××	×
Cornus alternifolia	N				×			×
Cornus stolonifera	N				××××	×	×××	×
Corylus cornuta	N				×			×

Appendix 1. Continued.

Species	Status[a]	Tree layer			Shrub layer			Wildlife food[b]
		Natural	Planted	Herbac.	Natural	Planted	Herbac.	
Crataegus sp.	N	×			××	×	×	×
Diervilla lonicera	N				×			
Fagus grandifolia	N	×			×			×
Fraxinus americana	N	×			×	×	×	×
Fraxinus pennsylvanica	N		×			×		×
Fraxinus sp.	N	×						×
Ilex verticillata	N				×			×
Juglans cinerea	N					×		×
Juglans nigra	N					×		×
Kalmia angustifolia	N				×			×
Larix laricina	N	×	×			××	×	×
Lonicera canadensis	N				×	×		×
Malus pumila	I	××			××			×
Nemopanthus mucronatus	N				×			
Parthenocissus vitacea	N				×			×
Picea glauca	N					×	×	
Picea mariana	N					×		
Pinus resinosa	N		×			××		×
Pinus strobus	N	×				××	×	×
Pinus sylvestris	I					×		×
Populus balsamifera	N	×××		×	×××		×	×
Populus deltoides	N	×××	×	×	××	××	×	×
Populus grandidentata	N	×	×		×	×		×
Populus tremuloides	N	××××	×	×	××××	×	×	×
Prunus pensylvanica	N	×××			×××		×	×
Prunus virginiana	N	×			×××	×××	×	×
Quercus rubra	N		×			×		×
Rhamnus alnifolius	N				×	×		×
Rhus radicans	N				×		×	×
Rhus typhina	N	×			×	×		×
Ribes americanum	N				×			×
Ribes cynosbati	N				××			×
Ribes glandulosum	N				×			×
Ribes hirtellum	N				×			×
Ribes lacustre	N				×			×
Ribes sativum	N				×			×
Rubus allegheniensis	N				××	×	×	×
Rubus hispidus	N				××		×	×
Rubus idaeus	N				××××	××	×××	×
Rubus odoratus	N				×			×
Rubus pubescens	N				××			×
Rubus setosus	N						×	×
Salix alba	I	××			××		×	×
Salix bebbiana	N	×××			××××	×	××	×
Salix discolor	N	××	×		××××	××	×	×
Salix fragilis	I	×			××	×	×	×
Salix interior	N	×			×	×		×
Salix lucida	N	×			×××		×	×
Salix nigra	N				×			×

Appendix 1. Continued.

Species	Status[a]	Tree layer			Shrub layer			Wildlife food[b]
		Natural	Planted	Herbac.	Natural	Planted	Herbac.	
Salix petiolaris	N	×			××××	××	××	×
Salix rigida	N	×××			××××	××	×××	×
Sambucus canadensis	N				×	×		×
Solanum dulcamara	I						×	×
Sorbus americana	N				×	×		×
Spiraea latifolia	N				××××	×	××	
Spiraea tomentosa	N				×	×	×	
Symphoricarpos albus	N					×		
Syringa vulgaris	I					×		
Thuja occidentalis	N				×	×		×
Tilia americana	N	×			×	×		×
Ulmus rubra	N	×××	×		×××	×	×	×
Vaccinium corymbosum	N				×	×		×
Vaccinium myrtilloides	N				×			×
Viburnum cassinoides	N				××			×
Viburnum lentago	N				×			×
Viburnum trilobum	N				×	×		×
Vitis riparia	N				×			×
Total number of species		31	13	4	63	47	31	71

[a] Status – I: introduced, N: native.
[b] Importance as wildlife food derived from Martin et al. 1951.

Appendix 2

Herbaceous species ($n = 131$) found in the 61 hedgerows studied in southern Quebec. A: low cover (<10%) and low frequency of presence (<10%), B: low cover and high frequency (≥10%), C: high cover (≥10%) and low frequency, D: high cover and high frequency of presence, –: absent.

Species	Lifespan[a]	Status[b]	Hedgerow type			Wildlife food[c]
			Natural	Planted	Herbaceous	
Achillea millefolium	P	N	A	C	C	×
Agrostis sp.	U	U	D	A	D	
Alisma triviale	P	N	A	A	C	
Amaranthus retroflexus	A	I	A	C	C	×
Ambrosia artemisiifolia	A	N	C	B	D	×
Apocynum androsaemifolium	P	N	C	C	C	
Aralia nudicaulis	P	N	C	–	–	
Arctium lappa	B	I	–	C	C	
Asclepias syriaca	P	N	D	D	D	
Aster simplex	P	N	D	D	A	×
Aster sp.	U	U	A	–	–	×
Aster umbellatus	P	N	C	A	–	×
Athyrium filix-femina	P	N	C	–	–	

Appendix 2. Continued.

Species	Lifespan[a]	Status[b]	Hedgerow type			Wildlife food[c]
			Natural	Planted	Herbaceous	
Avena sativa	A	I	–	A	–	×
Brassica sp.	U	U	A	C	A	×
Bromus inermis	P	I	C	C	C	×
Calamagrostis canadensis	P	N	C	–	–	
Capsella bursa-pastoris	A	I	–	A	–	
Carex crinita	P	N	C	–	–	×
Carex sp.	U	U	A	–	C	×
Cerastium vulgatum	P	I	A	–	A	
Chenopodium album	A	I	C	D	A	×
Chrysanthemum leucanthemum	P	I	C	–	A	
Cichorium intybus	P	I	–	C	A	
Cicuta maculata	B	N	A	–	A	
Cirsium arvense	P	I	A	C	A	
Cirsium vulgare	B	I	A	C	A	
Convolvulus sepium	P	N	C	C	C	
Cornus canadensis	P	N	C	–	–	×
Cyperus esculentus	P	N	C	C	C	×
Dactylis glomerata	P	I	C	C	–	×
Daucus carota	B	I	C	C	C	
Dryopteris spinulosa	P	N	A	–	–	
Echinochloa crusgalli	A	I	A	A	–	×
Echinocystis lobata	A	N	–	–	A	
Eleocharis sp.	U	U	–	–	C	×
Elytrigia repens	P	I	D	D	D	×
Epilobium coloratum	P	N	A	–	–	×
Epilobium hirsutum	P	I	C	C	–	×
Equisetum arvense	P	N	D	D	D	×
Equisetum scirpoides	P	N	C	–	C	×
Erigeron canadensis	A	I	A	C	–	
Erigeron philadelphicus	A/B	N	C	–	–	
Erigeron strigosus	A	N	A	–	A	
Eupatorium maculatum	P	N	C	–	–	
Eupatorium perfoliatum	P	N	C	–	–	
Euphorbia helioscopia	A	I	–	A	–	×
Festuca rubra	P	N	–	–	C	×
Fragaria virginiana	P	N	A	C	C	×
Galium palustre	P	N	–	–	A	
Galium sp.	U	U	A	C	A	
Geum allepicum	P	N	–	–	C	
Geum canadense	P	N	A	–	–	
Glecoma hederacea	P	I	–	–	C	
Glyceria striata	P	N	A	–	C	
Hypericum perforatum	P	I	A	–	A	
Impatiens capensis	A	N	D	C	C	×
Juncus effusus	P	N	–	–	C	
Juncus sp.	U	U	–	–	A	
Lactuca biennis	B	N	C	–	C	×
Lactuca serriola	A/B	I	–	A	A	×
Lactuca sp.	U	U	A	A	–	×

Appendix 2. Continued.

Species	Lifespan[a]	Status[b]	Hedgerow type			Wildlife food[c]
			Natural	Planted	Herbaceous	
Leersia oryzoides	P	N	C	C	C	×
Leontodon autumnalis	P	I	–	–	C	
Linaria vulgaris	P	I	A	–	C	
Lithospermum officinale	P	I	–	–	A	
Lotus corniculatus	P	I	A	–	–	×
Lycopus americanus	P	N	A	C	A	
Lycopus uniflorus	P	N	–	–	A	
Lysimachia nummularia	P	I	A	–	–	
Lythrum salicaria	P	I	A	C	A	
Maianthemum canadense	P	N	A	–	–	×
Medicago lupulina	A	I	A	A	A	×
Medicago sativa	P	I	C	C	–	×
Melilotus alba	A	I	–	C	–	×
Mentha canadensis	P	N	–	–	A	
Oenothera biennis	B	N	C	–	–	
Onoclea sensibilis	P	N	C	C	C	
Osmunda claytoniana	P	N	C	–	–	
Oxalis stricta	P	I	A	C	C	×
Panicum sp.	U	U	A	–	A	×
Pastinaca sativa	B	I	–	C	–	
Phalaris arundinacea	P	N	A	C	C	×
Phleum pratense	P	I	D	C	D	×
Phragmites communis	P	N	C	C	C	
Plantago major	P	I	A	A	A	×
Poa pratensis	P	I	D	D	D	×
Polygonum convolvulus	A	I	C	C	C	×
Polygonum fagopyrum	A	I	C	C	C	×
Polygonum persicaria	A	I	–	A	A	×
Polygonum sagittatum	A	N	A	–	–	×
Polygonum sp.	U	U	A	C	A	×
Potentilla anserina	P	I	A	C	A	×
Potentilla norvegica	A/B	N	A	–	A	×
Prunella vulgaris	P	N	–	–	A	
Pteridium aquilinum	P	N	C	–	–	
Pyrola elliptica	P	N	–	A	–	
Ranunculus acris	P	I	A	C	C	×
Rudbeckia hirta	P	N	–	A	A	
Rumex acetosella	P	I	C	–	–	×
Rumex crispus	P	I	C	A	A	×
Sanguisorba canadensis	P	N	–	C	C	
Scirpus atrovirens	P	N	C	–	–	×
Scirpus rubrotinctus	P	N	–	–	C	×
Scirpus sp.	U	U	A	–	A	×
Senecio vulgaris	A	I	–	–	C	
Setaria glauca	A	I	–	A	A	×
Setaria viridis	A	I	–	C	–	×
Sinapis arvensis	A	I	–	C	–	×
Sium suave	P	N	C	–	–	
Solidago altissima	P	N	D	D	C	×

Appendix 2. Continued.

Species	Lifespan[a]	Status[b]	Hedgerow type			Wildlife food[c]
			Natural	Planted	Herbaceous	
Solidago canadensis	P	N	D	D	C	×
Solidago graminifolia	P	N	C	C	C	×
Solidago rugosa	P	N	C	C	A	×
Sonchus arvensis	P	I	–	C	–	
Sonchus asper	A	I	–	A	C	
Sonchus sp.	U	U	–	A	A	
Stellaria graminea	P	I	A	–	C	×
Taraxacum officinale	P	I	C	D	B	×
Tragopogon pratensis	P	I	–	A	–	
Trifolium agrarium	A	I	A	–	C	×
Trifolium hybridum	P	I	A	A	C	×
Trifolium pratense	P	I	–	C	C	×
Trifolium repens	P	I	C	–	A	×
Triticum aestivum	A	I	–	A	A	×
Tussilago farfara	P	I	C	C	C	
Typha angustifolia	P	N	C	C	C	×
Typha latifolia	P	N	C	A	C	×
Urtica procera	P	N	C	–	C	
Verbascum thapsus	B	I	–	–	A	
Vicia cracca	P	I	D	D	D	×
Total number of species			94	76	92	71

[a] Lifespan – A: annual, B: biennial, A/B: annual/biennial, P: perennial, U: unknown.
[b] Status – I: introduced, N: native, U: unknown.
[c] Importance as wildlife food derived from Martin et al. 1951.

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