ELSEVIER

Agriculture, Ecosystems and Environment 94 (2003) 73–87

Agriculture Ecosystems & Environment

www.elsevier.com/locate/agee

Importance of riparian habitats to flora conservation in farming landscapes of southern Québec, Canada

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Received 27 March 2001; received in revised form 3 January 2002; accepted 11 January 2002

Abstract

Plants of riparian habitats located between cropfields and linear watercourses, i.e., drainage ditches, streams, small rivers, situated in the Boyer river watershed were inventoried in Québec, eastern Canada. The main objectives of this study were to establish the contribution of narrow riparian habitat strips to plant biodiversity in farming landscape and to document whether they could be reservoir of weeds detrimental to agriculture. Twenty-nine sections (>400 m) of riparian habitats adjacent to cropfields were inventoried in summer 1996 and spring 1997, and these were grouped into five vegetation types: (1) herbaceous strips dominated by grasses and devoid of woody species, (2) herbaceous strips dominated by forbs also devoid of woody species, (3) strips with small (<2 m) shrubs, (4) strips with tall (between 2 and 10 m) shrubs, and (5) strips with mature trees (>10 m). A total of 280 (228 herbaceous and 52 woody) plant species were recorded. Overall habitats with trees contained a larger number of herb and woody species than other riparian habitats. However, this was not reflected in the species richness per unit area (quadrats) which meant that habitats with trees were more heterogeneous than other habitat types. Species composition differed considerably among the various riparian habitats when considering forest spring ephemerals, ferns, forbs in general, grasses and woody vegetation. Substantially more native wetland species (obligate and facultative) were recorded adjacent to watercourses than near fields. More weedy and in particular, introduced species, were found in quadrats sampled near cropfields. Although no plant species of special conservation value were located in the riparian habitats, they should deserve special protection in intensive agricultural areas because they harbour a suite of wetland plants (and animals) not found in other farmland habitats. This appears to be especially desirable for those habitats with a well-developed woody vegetation.

Keywords: Riparian habitats; Farming landscape; Plant biodiversity; Weeds; Conservation; Québec

1. Introduction

Riparian habitats situated between cropfields and watercourses are of prime importance for the maintenance of water and soil quality, for their role in filtering out pesticides and fertilisers thus preventing excessive leaching directly into water, and for trapping eroding soil particles (Jordan et al., 1993; Muscutt et al., 1993; Osborne and Kovacic, 1993; de Snoo and de Wit, 1998). The availability of water some time of the year and the riparian zone characteristics (e.g., slope, soil) create conditions for the support of plants and animals in farmland landscape different from those that inhabit neighbouring land, including croplands, hedgerows, fencerows, etc. Yet, their value as habitats for most wildlife taxa in intensively managed

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0167-8809/02/$ – see front matter.
PII: S0167-8809(02)00014-2

lands is largely unknown for eastern Canada (but see Naiman et al., 1993; Maisonneuve and Rioux, 2001; Deschênes et al., 2002). Few studies have been devoted to investigating their contribution to plant biodiversity within agricultural landscapes in other countries. In the Netherlands, where ditches and adjoining upland grounds constitute important and often unique vestiges of wildlife habitats among vast farmlands, wild flora and fungi have been surveyed along ditch banks, especially with regards to pesticide side-effects (de Jong et al., 1991; de Snoo, 1995, 1997). In the United States, effects of cattle grazing on riparian vegetation have been extensively studied (Kauffman and Krueger, 1984; Schulz and Leininger, 1990; Fleischner, 1994; Clary, 1999). Other linear habitats in agricultural landscape (hedgerows, fencerows) have been examined for their importance as wildlife refuge, including plants, in eastern Canada (Fritz and Merriam, 1994; Jobin et al., 1994; Jobin et al., 1996; Boutin and Jobin, 1998; Freemark et al., 2002) and elsewhere (Marshall and Hopkins, 1990; Burel, 1992; Boatman et al., 1994; Freemark and Boutin, 1995; Kleijn and Snoeijing, 1997; Corbit et al., 1999; Meunier et al., 1999a,b). In general, plant species composition and richness in farmland habitats is influenced by habitat structures and physical characteristics, soil components, microclimate, surrounding landscape attributes and agrochemical impact (Marshall and Smith, 1987; Marshall, 1989; Burel and Baudry, 1990; Barr and Gillespie, 2000; McCollin et al., 2000; Baudry et al., 2000).

In eastern Canada and in other countries where intensive farming prevails, agricultural and other rural development has led to land drainage and straightening of natural water channels such as streams and small rivers. In the process, many small streams have been degraded or disappeared altogether and wetlands have vanished. More than 44,000 km of watercourses have been straightened and about 1.5 million ha land has been drained in the St. Lawrence Valley over the last decades. This leaves less than 2% of this ecoregion as wetland habitats (Bélanger et al., 1999). The remaining wetlands and riparian habitats, although embodied within the farmland complex and subjected to various anthropogenic assaults, should be better known to assess their value in terms of biodiversity conservation in agricultural landscapes.

The objectives of this paper were (1) to establish the general contribution of different types of riparian habitats to plant biodiversity in agricultural landscapes, especially with regards to wetland plants, and (2) to document whether they may be of agronomic concern as reservoirs of weeds.

2. Methods

The present work was performed in the Boyer river watershed (46°46′N, 70°57′W), one of the major tributaries of the St. Lawrence River, located at about 30 km southeast of Québec City, southern Québec, Canada. It is a region of intensive agriculture, dominated by forage and pasture fields but with an increasing preponderance of corn and cereal cultures. The Boyer river watershed encompasses 345 km of linear watercourses within its 217 km^2 area, in which 60% of the land is occupied by agricultural activities (Maisonneuve and Rioux, 2001). It is estimated that 70% of the waterbodies (∼250 km) have been modified to satisfy agricultural needs. Several sections of relatively homogeneous riparian habitats were identified on topographic maps (1:20000) and aerial photographs (1:15000) covering the whole Boyer river watershed. Twenty-nine linear riparian habitats situated between cropfields and waterways were selected and categorised into five types representing a gradient in vegetation complexity (diversity and structure) from herbaceous to tree-dominated habitats. Their designation as one of each type of riparian habitat was confirmed by on-site visits. The five types were (1) herbaceous strips dominated by grasses and devoid of woody species, (2) herbaceous strips dominated by forbs also devoid of woody species, (3) strips with small (<2 m) shrubs, (4) strips with tall (between 2 and 10 m) shrubs, and (5) strips with mature trees (>10 m). Riparian habitats considered in this paper are located along drainage ditches, streams and small rivers; those beside creeks or around lakes and ponds were not considered.

The vegetation survey was performed during the summer of 1996 and spring of 1997. Six 600 m sections were inventoried in every strip types except for herbaceous strips dominated by forbs where five 400 m sections were visited. Particular efforts were oriented towards the location of homogeneous sections of this latter type of riparian habitat but its scarcity in the landscape rendered the location of suitable sites difficult, with the consequence that sampling effort was lower for this type of habitat. Hayfields and pastures were the dominant (>70%) cropfields abutting all types of habitats except for herbaceous strips dominated by forbs where 40% of adjacent fields were oldfields, 25% hayfields, and 20% pastures.

Biophysical description of each section was conducted in April 1996. Every section was divided in 100 m intervals and a measure of strip and watercourse width was taken at each interval. Cover (%) was estimated visually for each interval for the following categories: bare soil, grasses, forbs, low shrubs, tall shrubs, and trees. Estimates were made in 5% increments and the total cover of each interval equalled 100%. Descriptive variables were averaged for each of the 29 riparian sections.

Two complementary methods were used to survey the vegetation. In the first place, a quantitative assessment was performed during the summer of 1996. For this, 1 m^2 quadrats were positioned along three transects at 100, 300 and 500 m along each site (or 100, 200 and 300 m for those 400 m long). A minimum of two quadrats was surveyed along each transect, one immediately adjacent to the cropfield, one to the waterbody; riparian habitats with trees were sufficiently wide to place a third quadrat in their centre. Within quadrats, all the vegetation present in the herbaceous layer was listed together with the cover for each species and the overall cover. A total of 192 quadrats were sampled in the 29 sections of riparian habitats, i.e., 36 (18 adjacent to the cropfield, 18 to the waterway) in herbaceous strips dominated by grasses, 30 (15 adjacent to cropfields, 15 to waterways) in herbaceous strips dominated by forbs, 36 in strips with small shrubs, 36 in strips with tall shrubs, and 54 (18 adjacent to cropfields, 18 adjacent to waterways, 18 in the centre) in riparian habitats with trees. Altogether, 16.4 km or 5% of the total linear length of watercourses within the Boyer river watershed were studied. No survey of the submerged or floating vegetation in adjacent watercourses was performed.

The second method used to survey the plant composition of riparian habitats in summer 1996 and spring 1997 consisted of careful walking several times the 29 sections to perform an exhaustive inventory of all the vegetation present, regardless of abundance. It allowed a thorough listing of the species present in the summer and was also better suited for recording the very patchy spring vegetation. The spring inventory included only those species in flower at the time of visit.

Species were divided into several categories including weediness, lifespan, native or introduced status and wetland affinity. Introduced species are defined as plants that did not originally occur in the study area prior to European settlement, but which arrived as a result of human activity. Plant species were classified into three groups according to their weedy propensity: (1) noxious weeds if they were mentioned in the Noxious Weed Act (Anonymous, 1981), *Lythrum salicaria* L. was added to this category because of its weedy disposition, (2) other weeds were identified if repeatedly recorded as weeds in field surveys (Doyon et al., 1987; MAPAQ, 1989) which largely corresponds to unwanted plants found in pastures, and (3) non-weed species. Lifespan and status were attributed following Gleason and Cronquist (1991) and species were assigned to three different wetland affinity categories according to a xerophytic gradient: obligate or facultative wetland species and non-wetland (upland) species. The list of species growing predominantly in wet or humid habitats was taken from Gauthier (1997).

3. Statistical analyses

Biophysical characteristics were compared among the five different types of riparian habitats using the Kruskal–Wallis test; significant differences were followed by pairwise comparisons analogous to Tukey test (Zar, 1984). Non-parametric tests were preferred because of the low sample sizes.

A two-factor analysis of variance (SAS Institute Inc., 1988, GLM procedure) was used to test for differences in attributes of the vegetation recorded among the five types of riparian habitats and positioning of quadrats within riparian habitats (field versus water sides). For these analyses, transect and section numbers were nested within the type of habitat and the section number was randomised. Interactions among riparian habitat 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 riparian habitat type and differences among habitat types were tested 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 (DCAs) were performed using the down-weighting option for less common species using PC-ORD (McCune and Mefford, 1999) in order to group riparian habitats with respect to their vegetation composition. The first DCA incorporated the 280 species inventoried during the three surveys, and presence–absence data were used with the riparian habitats being the sample unit. The second analysis pertaining to the quantitative survey only included species reported within quadrats; only species recorded in five quadrats or more were included and cover of each species was the unit of analysis in the ordination. In order to identify plant species responsible for the positioning of the habitats or quadrats along axes, Pearson correlations between species presence or cover and species scores on the first two axes were calculated.

4. Results

Table 1 summarises the physical characteristics of the five types of riparian habitats. Percent cover of the different vegetation types fits accurately with our a priori classification of riparian habitats. Herbaceous sites were classified either as overwhelmingly grassy (77.6% cover in riparian habitats dominated by grasses) or mostly with broad leaves (53% cover in riparian habitats dominated by forbs). The two riparian habitats with shrubs harboured 53.9% cover of small shrubs or 46.9% of tall shrubs respectively. Tree cover was significantly higher in riparian habitats with trees than in other riparian habitat types (37.4%), and their width as well as the width of adjacent waterways were both significantly higher than those of other sites. Likewise, riparian habitats with trees harboured more herbaceous and woody species than the other types.

During the three surveys 280 (228 herbaceous and 52 woody) plant species were recorded. More species were identified in riparian strips with trees than in any other habitat (Table 1) but only two species were unique to quadrats positioned in the centre: *Laportea canadensis* and *Solidago flexicaulis*. On total, 167

Table 1
Biophysical characteristics of five types of riparian habitats studied in southern Québec, Canada[a]

	Herbaceous grassy ($n = 6$)		Herbaceous forbs ($n = 5$)		With shrubs < 2 m ($n = 6$)		With shrubs > 2 m ($n = 6$)		With trees > 10 m ($n = 6$)		Kruskal–Wallis	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	*H*	*P*
Length	600.0 a	0.0	400.0 b	0.0	600.0 a	0.0	600.0 a	0.0	600.0 a	0.0	28.00	0.0001
Width of riparian habitats	3.7 a	0.3	3.1 a	0.4	3.6 a	0.3	3.8 a	0.8	19.2 b	3.2	15.31	0.0041
Width of adjacent water	3.7 a	1.0	1.8 a	0.5	1.8 a	0.2	2.0 a	0.2	15.3 b	3.7	17.09	0.0019
Average per hedgerow												
Total number of species	59.7 a	3.1	65.6 a	3.7	60.3 a	2.3	72.3 a	5.3	107.3 b	3.7	17.62	0.0015
Total number of herb species	56.2 a	3.0	58.4 a	3.2	49.2 a	1.7	55.7 a	4.4	87.3 b	3.7	17.58	0.0015
Total number of woody species	3.5 a	0.7	7.2 ab	2.7	11.2 bc	0.9	16.7 cd	2.0	20.0 d	1.3	21.13	0.0003
Cover (%)												
Bare soil	0.3 a	0.3	0.0 a	0.0	0.0 a	0.0	0.0 a	0.0	0.3 a	0.3	2.94	0.5682
Grass species	77.6 a	5.8	35.3 b	1.6	23.9 bc	4.3	16.9 bc	2.2	14.9 c	5.1	19.52	0.0006
Forb species	17.5 a	4.6	53.0 b	3.5	17.6 a	1.6	11.4 a	1.6	16.4 a	1.9	15.22	0.0043
Shrub < 2 m	4.0 a	1.9	11.4 ac	3.7	53.9 b	3.8	24.1 c	4.0	15.4 c	3.3	21.73	0.0002
Shrub > 2 m	0.3 a	0.3	0.4 a	0.4	4.3 a	1.7	46.9 b	5.7	15.7 c	3.1	24.27	0.0001
Trees > 10 m	0.1 a	0.1	0.0 a	0.0	0.8 a	0.3	1.3 a	0.6	37.4 b	5.2	21.05	0.0003

[a] Kruskal–Wallis tests and multiple comparisons were performed; different letters following means in the same row indicate significant differences.

species were identified in the quadrat inventory, 90 new species were added to the list with the careful qualitative survey undertaken in summer, and an extra 23 in the following spring. A large number of the latter were forest spring ephemerals (species that emerge and photosynthesise primarily before tree leaf expansion and are associated with temperate deciduous mature forests). Riparian habitats with trees contained 41 species in flower during the spring survey, 26 (63%) of which were native non-weed species with several spring ephemerals among them (Table 2). At the other end of the scale, grassy riparian habitats sustained 15 spring species, of which only 6 (40%) were native non-weedy, with none being considered forest spring ephemerals. Other riparian habitat types embodied 26–28 spring species with between 12 and 18 (46–67%) species being native non-weedy. Interestingly, the number of spring species was almost twice as high (26 versus 15) in herbaceous sites dominated by forbs than in grassy riparian habitats. Obligate and facultative wetland species made up 35% (97/280) of the total species number. Riparian habitats dominated by grasses, forbs and small shrubs harboured 30, 34 and 32 wetland species, respectively, riparian habitats with tall shrubs, 51, and those with trees, 62.

The most common tree species found in the riparian habitats with trees were *Ulmus americana*, *Acer negundo*, *Acer saccharum*, *Fraxinus nigra* and *Populus tremuloides*. In riparian habitats with tall shrubs, a few small trees were recorded: *Acer rubrum*, *Fraxinus americana*, *P. tremuloides*. The shrub layer was composed of *Alnus rugosa*, *Rubus idaeus*, *Cornus stolonifera*, *Prunus virginiana*, *Spiraea latifolia* and several species of willow (*Salix rigida*, *S. bebbiana* and *S. discolor*) as well as the climbing woody species *Clematis virginiana*. Several woody species were sometimes present in the two herbaceous riparian habitats but in low abundance. In the three woody riparian habitats, *Prunus pensylvanica*, *Rubus allegheniensis*, *Sambucus canadensis*, *Amelanchier* spp., *Spiraea tomentosa* and *Viburnum trilobum* were also frequently inventoried.

Average species richness for quadrats abutted to waterways and those near cropfields showed no significant difference among habitat types or between quadrat positioning. This is in contrast to the overall total species richness across habitats whereby species numbers were higher in sites with trees. Although perennial herb species prevailed in all habitat types and locations, there was no significant difference in the number of perennial species among habitats or among quadrat positioning. Annual species richness, however, was significantly different among habitat types; riparian sites dominated by grasses accommodated more annual species than both riparian sites with a prevalence of shrubs ($p = 0.03$). Richness of annual species was also significantly higher in quadrats near water than beside fields ($p = 0.0001$), this difference being more manifest in riparian habitats with trees. Total percent cover of the herbaceous layer was significantly higher in quadrats near fields for all sites ($p = 0.0013$) except those with a dominance of grasses. Likewise, cover was more limited in sites with trees (83.1%) and tall shrubs (85.6%) than in the other sites (between 92.4 and 99.4%). Few woody species were present in quadrats near water in riparian habitats with trees.

Wetland species, both obligate and facultative, prevailed in quadrats near water ($p = 0.0001$) regardless of riparian habitat types whereas species typical of dry upland habitats were more abundant near fields ($p = 0.0001$) (Fig. 1). In all riparian habitat types, substantially more native species were recorded in quadrats adjacent to water courses (between 60.0 and 75.9% of total; $p < 0.002$) than near fields (31.7 and 41.3% of total; $p < 0.0005$). This is because most introduced species were of the upland type; very few were facultative or obligate wetland species (Fig. 1).

The number (and cover, not shown) of noxious weed species did not differ among habitats or quadrat positioning (Fig. 2). Quadrats near fields, however, supported more pasture weed types (other weeds) than those contiguous to water ($p = 0.0001$). In addition, sites with trees had less other weed species than the rest of all other habitats ($p = 0.007$) and especially those next to water. Non-weed species were overridingly situated near water ($p = 0.0003$) but they were equally numerous in all riparian habitat types. Very few wetland species are considered a nuisance in agriculture. The two most common wetland weeds were *Agrostis alba* found in 71 quadrats out of 192 and in all five types of riparian habitats, and *Polygonum hydropiper* found in 20 quadrats. Other species, *Cicuta maculata*, *Bidens cernua*, *Potentilla anserina*, *Polygonum lapathifolium*, *P. pensylvanicum*, *P. persicaria* were inventoried in one or two quadrats only. Two additional wetland weed species, *L. salicaria* and

Table 2
Frequency of presence of plant species inventoried in June 1997[a]

Species	Status	Weed class	Herbaceous		With shrubs		With trees	Total (*n* = 29)
			Grassy (*n* = 6)	Forbs (*n* = 5)	<2 m (*n* = 6)	>2 m (*n* = 6)	>10 m (*n* = 6)	
Achillea millefolium	N	2	–	1	–	–	–	1
Actaea pachypoda	N	3	–	–	–	1	4	5
Actaea rubra	N	3	–	–	1	–	2	3
Anemone canadensis	N	3	–	–	–	–	1	1
Aralia nudicaulis	N	3	–	–	1	–	–	1
Arisaema atrorubens	N	3	–	1	–	2	4	7
Barbarea vulgaris	I	2	5	5	5	4	6	25
Brassica kaber	I	1	1	–	–	–	1	2
Caltha palustris	N	3	–	–	–	3	1	4
Cardamine pensylvanica	N	3	1	5	2	4	2	14
Chelidonium majus	I	3	–	–	–	–	2	2
Chrysanthemum leucanthemum	I	1	3	3	5	5	3	19
Clintonia borealis	N	3	–	–	–	1	–	1
Cornus canadensis	N	3	–	–	1	–	1	2
Dentaria diphylla	N	3	–	–	–	1	1	2
Dicentra canadensis	N	3	–	–	–	–	3	3
Eleocharis sp.	U	U	–	–	–	1	–	1
Erysimum cheiranthoides	I	2	3	1	2	1	2	9
Erythronium americanum	N	3	–	1	1	1	6	9
Fragaria virginiana	N	3	3	4	6	6	6	25
Galium aparine	N	2	–	2	1	2	3	8
Galium palustre	N	3	4	–	1	3	2	10
Geum macrophyllum	N	3	–	1	1	–	3	5
Glechoma hederacea	I	2	4	2	–	–	2	8
Hieracium sp.	U	U	–	–	–	1	1	2
Hieracium vulgatum	I	1	–	–	–	3	–	3
Maianthemum canadense	N	3	–	–	3	1	4	8
Polygonatum canaliculatum	N	3	–	–	–	–	1	1
Ranunculus abortivus	N	3	–	1	1	–	1	3
Ranunculus acris	I	1	–	4	3	3	2	12
Rhus radicans	N	1	–	–	–	–	2	2
Rumex acetosella	I	2	–	1	–	–	1	2
Sanguinaria canadensis	N	3	–	–	–	–	1	1
Smilacina racemosa	N	3	–	–	–	1	4	5
Smilacina stellata	N	3	–	–	–	–	1	1
Stellaria graminea	I	2	–	1	1	–	–	2
Symplocarpus foetidus	N	3	–	–	–	–	1	1
Taraxacum officinale	I	1	6	5	6	6	6	29
Thalictrum pubescens	N	3	4	2	2	3	6	17
Thlaspi arvense	I	1	3	1	–	–	2	6
Tiarella cordifolia	N	3	–	1	1	–	5	7
Trientalis borealis	N	3	–	–	1	–	–	1
Trillium erectum	N	3	–	–	–	1	5	6
Tussilago farfara	I	2	2	3	4	5	2	16
Veratrum viride	N	3	2	2	3	2	6	15
Veronica americana	N	3	–	–	1	–	–	1
Veronica serpyllifolia	I	3	1	3	2	1	1	8
Vicia sativa	I	3	–	1	–	–	–	1
Viola cucullata	N	3	3	5	5	4	3	20
Viola pallens	N	3	–	4	–	2	–	6

Table 2 (*Continued*)

Species	Status	Weed class	Herbaceous		With shrubs		With trees	Total ($n = 29$)
			Grassy ($n = 6$)	Forbs ($n = 5$)	<2 m ($n = 6$)	>2 m ($n = 6$)	>10 m ($n = 6$)	
Viola pubescens	N	3	–	1	1	1	5	8
Zizia aurea	N	3	–	–	1	–	–	1
Total number of species			15	26	27	28	41	52

[a] N: native; I: introduced; 1: noxious weeds; 2: pasture weeds; 3: non-weed species; U: unknown. In bold: spring ephemeral species.

Gnaphalium uliginosum were recorded in low numbers during the qualitative survey of the 29 sections of riparian habitats.

The DCA performed with all herbaceous and woody species presence (hedgerows as the unit) shows that overall, riparian habitats with trees and those dominated by grasses accommodated a different suite of species than the three other types of habitats (Fig. 3) but no type of vegetation was overwhelmingly important in the positioning of the sites along axes (Table 3). A second DCA using species cover in quadrats confirmed the separation along axis 1 between quadrats near fields and those near water (Fig. 4). Species separating quadrats adjacent to water from those located near fields were clearly of different xerophytic affinities, i.e., association with wetland species on the negative side of axis 1 (*Impatiens capensis*, *Phalaris arundinaceae*, *Calamagrostis canadensis*, *P. hydropiper*, *Thalictrum polygamum*) in contrast to plant of dry habitats on the positive side (*Bromus inermis*, *Fragaria virginiana*, *Urtica procera*, *Poa* sp., etc.) (Table 4). No clear trend emerged from axis 2.

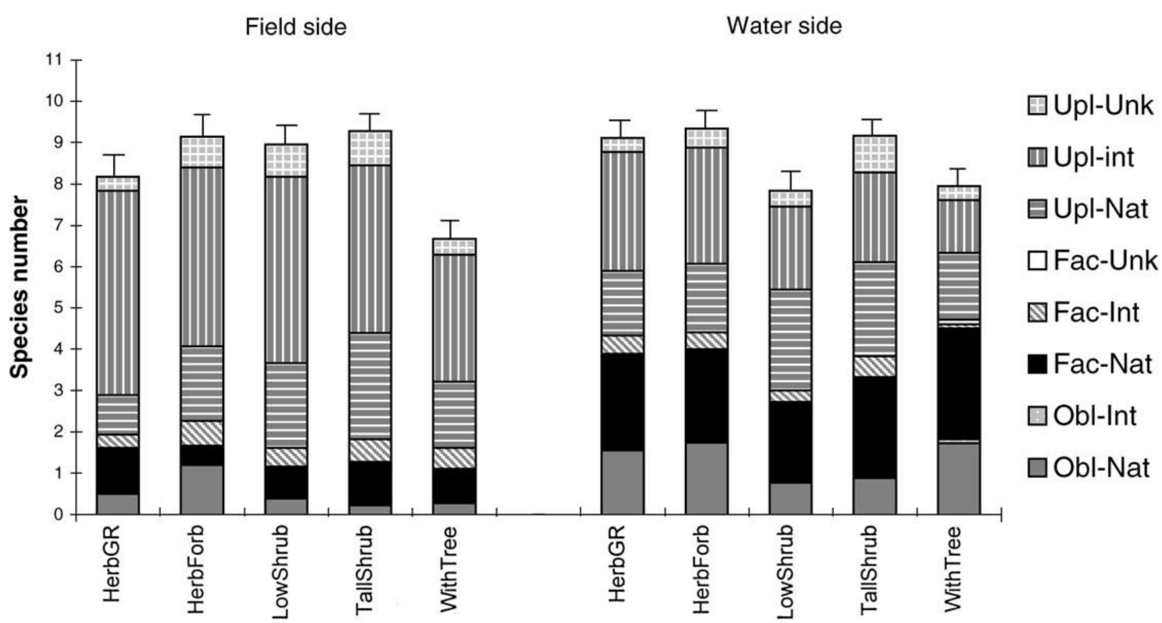

Fig. 1. Mean number of herbaceous species (±S.E.) with different affinity for water (Obl: obligate wetland species, Fac: facultative wetland species, Upl: species of dry upland habitats) inventoried in the five types of riparian habitats in quadrats situated near fields or water. Within categories, native (Nat) and introduced (Int) species are separated, as well as plants only identified at the genus level for which the status in unknown (Unk). HerbGr: herbaceous strips dominated by grasses ($n = 18$ quadrats near fields and 18 near water); HerbForb: herbaceous strips dominated by forbs ($n = 15$); LowShrub: strips with small (<2 m) shrubs ($n = 18$); TallShrub: strips with tall (between 2 and 10 m) shrubs ($n = 18$); WithTrees: strips with mature trees (>10 m) ($n = 18$).

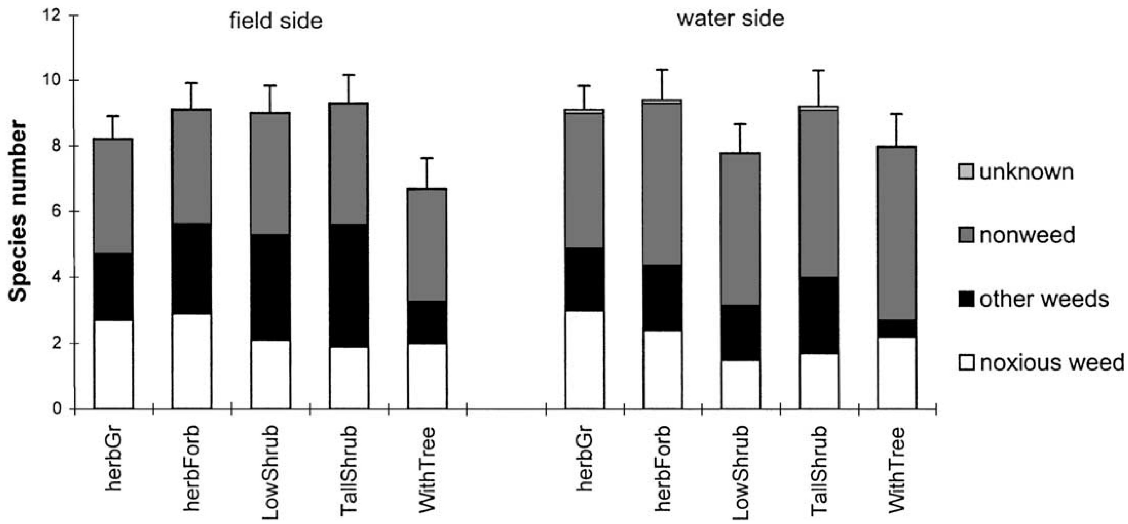

Fig. 2. Mean number of herbaceous species (±S.E.) of different weedy propensity (see methods for details) inventoried in the five types of riparian habitats in quadrats situated near fields or water. HerbGr: herbaceous strips dominated by grasses; HerbForb: herbaceous strips dominated by forbs; LowShrub: strips with small (<2 m) shrubs; TallShrub: strips with tall (between 2 and 10 m) shrubs; WithTrees: strips with mature trees (>10 m).

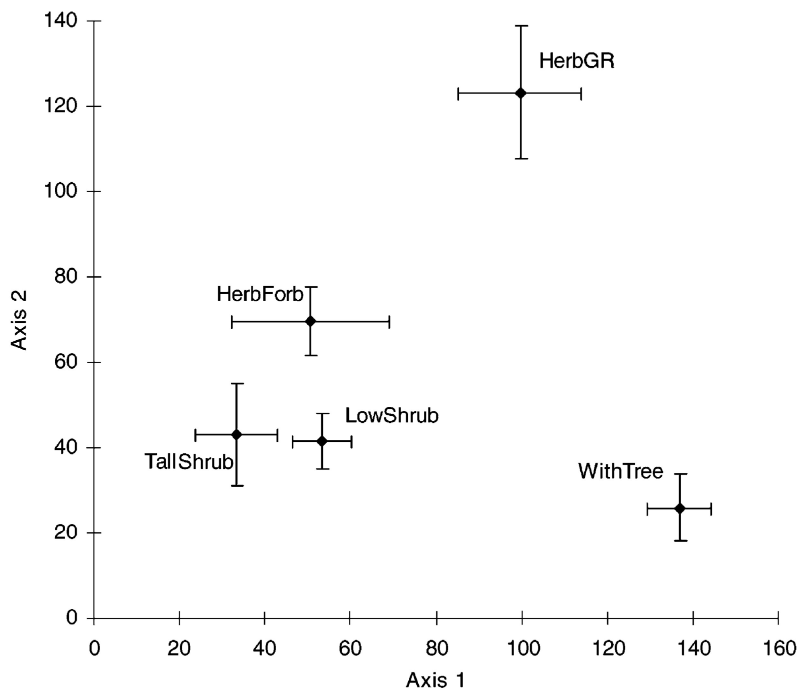

Fig. 3. DCA using presence–absence of all 280 herbaceous and woody species inventoried in the 29 riparian sections in 1996 and 1997. Mean site score (±S.E.) for each type of riparian habitat is shown.

Table 3
Species correlated with axes 1 and 2 of the DCA performed with the 280 species inventoried in 29 riparian strips[a]

Species name	Axis 1(eigenvalue = 0.20)			Species name	Axis 2 (eigenvalue = 0.11)		
	Type of vegetation		Correlation coefficient		Type of vegetation		Correlation coefficient
Achillea millefolium	Herb-P	Dry	−0.62	*Poa* sp.	Herb-U	Dry	−0.69
Hieracium sp.	Herb-U	Dry	−0.59	*Crataegus* sp.	Woody	Dry	−0.64
Tussilago farfara	Herb-P	Dry	−0.58	*Fragaria virginiana*	Herb-P	Dry	−0.64
Spiraea latifolia	Woody	Dry	−0.54	*Solidago rugosa*	Herb-P	Dry	−0.63
Anaphalis margaritacea	Herb-P	Dry	−0.52	*Aster umbellatus*	Herb-P	Fac	−0.62
Salix discolor	Woody	Fac	−0.51	*Cornus stolonifera*	Woody	Fac	−0.58
Sanguisorba canadensis	Herb-P	Fac	−0.51	*Ranunculus acris*	Herb-P	Dry	−0.57
Geum macrophyllum	Herb-P	Fac	0.47	*Vicia cracca*	Herb−P	Dry	−0.57
Poa compressa	Herb-P	Dry	0.47	*Maianthemum canadense*	Herb-P	Dry	−0.56
Potentilla anserina	Herb-P	Fac	0.47	*Populus tremuloides*	Woody	Dry	−0.55
Acer spicatum	Woody	Dry	0.49	*Salix bebbiana*	Woody	Fac	−0.53
Hierochloe odorata	Herb-P	Fac	0.49	*Trillium erectum*	Herb-P	Dry	−0.53
Polygonum hydropiper	Herb-A	Obl	0.49	*Prunus virginiana*	Woody	Dry	−0.5
Dicentra canadensis	Herb-P	Dry	0.50	*Actaea pachypoda*	Herb-P	Dry	−0.49
Glechoma hederacea	Herb-P	Dry	0.50	*Salix rigida*	Woody	Fac	−0.48
Lilium canadense	Herb-P	Dry	0.50	*Athyrium filix-femina*	Herb-P	Dry	−0.47
Veratrum viride	Herb-P	Fac	0.50	*Brassica rapa*	Herb-A	Dry	0.49
Smilacina racemosa	Herb-P	Dry	0.53	*Glechoma hederacea*	Herb-P	Dry	0.49
Actaea pachypoda	Herb-P	Dry	0.54	*Raphanus raphanistrum*	Herb-A	Dry	0.50
Geum sp.	Herb-U	Dry	0.54	*Thlaspi arvense*	Herb-A	Dry	0.53
Erythronium americanum	Herb-P	Dry	0.55	*Polygonum persicaria*	Herb-A	Fac	0.55
Arctium minus	Herb-B	Dry	0.56	*Lolium perenne*	Herb-P	Dry	0.57
Prunella vulgaris	Herb-P	Dry	0.56	*Lycopus europaeus*	Herb-P	Obl	0.57
Trillium erectum	Herb-P	Dry	0.56	*Raphanus sativus*	Herb-P	Dry	0.57
Verbena hastata	Herb-P	Fac	0.56	*Capsella bursa-pastoris*	Herb-A	Dry	0.60
Brassica rapa	Herb-A	Dry	0.57	*Polygonum lapathifolium*	Herb-A	Fac	0.65
Galeopsis tetrahit	Herb-A	Dry	0.57				
Ulmus americana	Woody	Fac	0.57				
Thalictrum polygamum	Herb-P	Fac	0.58				
Viburnum trilobum	Woody	Dry	0.58				
Matteuccia struthiopteris	Herb-P	Fac	0.59				
Geum aleppicum	Herb-P	Dry	0.60				
Polygonum cilinode	Herb-P	Dry	0.60				
Acer negundo	Woody	Dry	0.61				
Elymus virginicus	Herb-P	Fac	0.62				
Steironema ciliatum	Herb-P	Fac	0.62				
Rorippa islandica	Herb-A	Fac	0.63				
Polygonum pensylvanicum	Herb-A	Fac	0.73				
Phalaris arundinacea	Herb-P	Fac	0.75				
Urtica procera	Herb-P	Dry	0.76				
Bidens frondosa	Herb-A	Fac	0.81				
Echinocystis lobata	Herb-A	Dry	0.81				

[a] Level of significance of Pearson correlation = 0.01. Herb: herbaceous, P: perennial, U: unknown, A: annual, B: biennial, Fac: facultative wetland species, Obl: obligatory wetland species, Dry: species of dry habitats.

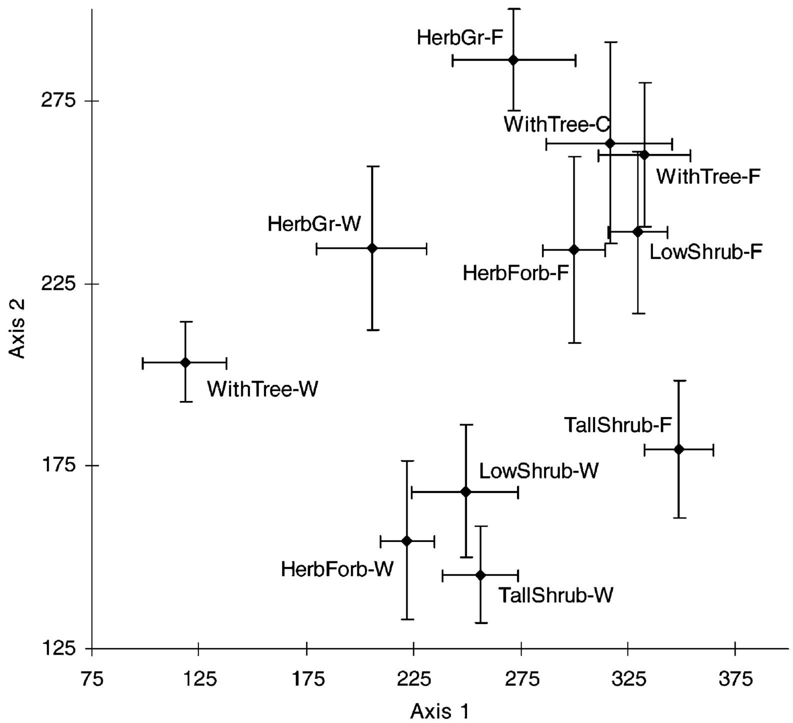

Fig. 4. DCA using cover of 55 species recorded in five quadrats or more during the quadrat inventory of summer 1996 ($n = 192$ quadrats). Letter F beside riparian habitat types: field side, letter W: water side. Letter C: centre quadrats. Mean site score (±S.E.) for each type of riparian habitat is shown.

Table 4
Species correlated with axes 1 and 2 of the DCA performed with the 55 species inventoried in more than five occasions in quadrats during summer 1996[a]

Species name	Axis 1 (eigenvalue = 0.71)			Species name	Axis 2 (eigenvalue = 0.59)		
	Type of vegetation		Correlation coefficient		Type of vegetation		Correlation coefficient
Impatiens capensis	Herb-A	Fac	−0.47	*Solidago rugosa*	Herb-P	Dry	−0.50
Phalaris arundinacea	Herb-P	Fac	−0.47	*Fragaria virginiana*	Herb-P	Dry	−0.33
Calamagrostis canadensis	Herb-P	Fac	−0.34	*Hieracium* sp.	Herb-U	Dry	−0.24
Polygonum hydropiper	Herb-A	Obl	−0.27	*Aster puniceus*	Herb-P	Fac	−0.23
Thalictrum polygamum	Herb-P	Fac	−0.21	*Aster umbellatus*	Herb-P	Fac	−0.22
Barbarea vulgaris	Herb-B/P	Dry	−0.20	*Agrostis alba*	Herb-P	Fac	−0.21
Galeopsis tetrahit	Herb-A	Dry	−0.19	*Solidago canadensis*	Herb-P	Dry	−0.19
Polygonum sagittatum	Herb-A	Obl	−0.19	*Phleum pratense*	Herb-P	Dry	0.21
Leersia oryzoides	Herb-P	Obl	−0.19	*Echinocystis lobata*	Herb-A	Dry	0.22
Trifolium pratense	Herb-P	Dry	0.20	*Artemisia vulgaris*	Herb-U	Dry	0.33
Taraxacum officinale	Herb-P	Dry	0.21	*Aster simplex*	Herb-P	Fac	0.40
Poa sp.	Herb-U	Dry	0.23	*Elytrigia repens*	Herb-P	Dry	0.40
Urtica procera	Herb-P	Dry	0.25				
Fragaria virginiana	Herb-P	Dry	0.28				
Bromus inermis	Herb-P	Dry	0.53				

[a] Level of significance of Pearson correlation = 0.01. Herb: herbaceous, P: perennial, U: unknown, A: annual, B: biennial, Fac: facultative wetland species, Obl: obligatory wetland species, Dry: species of dry habitats.

5. Discussion

This paper is part of a series describing plant, and to a lesser extent animal biodiversity and habitat fragmentation, in farmland habitats in eastern Canada (Jobin et al., 1994, 1996, 1998, 2001; Boutin and Jobin, 1998; Maisonneuve and Rioux, 2001; Freemark et al., 2002; Boutin et al., 2001, 2002; Bélanger and Grenier, 2002; Deschênes et al., 2002). In all studies, non-crop habitats such as hedgerows, fencerows, woodlots, old fields and others were found to harbour a suite of plant species (and animals) that contributed substantially to the reserve of biodiversity, unmistakably more so than the crop fields in these areas of intensive agriculture. Riparian habitats surveyed in the current study were no exception although the five types, from grassy herbaceous to mature with a fully developed tree canopy, differed considerably in structure and plant species composition. Their contribution to the biodiversity of wetland plant species was overall significant, although, no species of high conservation status in Québec was encountered (Lavoie, 1992). This is in contrast with another study performed in the same general area where three plant species considered rare in Québec were found in an extensive inventory of several terrestrial habitats, in agricultural landscapes (Jobin et al., 1996). Likewise, in Britain it has been documented that hedgerows contained mostly common species but a few accommodated rare species (McCollin, 2000) partly because intensification of agriculture has induced some arable plants to become rare in field margins (Wilson, 1988). Nilsson et al. (1988) noted that the likelihood of discovering rare species is increased in well-developed riparian banks because they harbour a high diversity of plants.

In agricultural areas, overall biodiversity includes non-native species, many with weedy propensity, and species with high edge affinities (Noss, 1983). The aim of some of the above papers further encompassed the evaluation of unwanted plant and animal species that may be economically detrimental to adjacent croplands. In the riparian habitats studied, among the 97 wetland plant species inventoried, only six are considered noxious weeds (*Cicuta maculata*, *L. salicaria*, *P. hydropiper*, *P. persicaria*, *P. lapathifolium*, *P. pensylvanicum*) and four as other weeds (*A. alba*, *G. uliginosum*, *P. anserina*, *B. cernua*), and except for *A. alba* they were of low cover and low frequency. Many of the farmlands in the study area were originally wetlands that were drained between the 1960s and the 1980s which explains why some species with obligate wet condition requirements, e.g., *B. cernua* and *P. hydropiper*, are regarded as significant weeds in some nearby farming areas (Benoit and Bélanger, 1994). Furthermore, 10 out of 97 species inventoried were non-native to the area, all of them but *A. alba* being of low importance in riparian habitats (*L. salicaria*, *Salix alba*, *Polygonum persicaria*, *Epilobium hirsutum*, *P. anserina*, *Mentha spicata*, *Veronica beccabunga* and *Lycopus europaeus*). *Phalaris arundinaceae* is a special case having both native (near the Great Lakes and large rivers of eastern Canada) and introduced, mostly inland (White et al., 1993). Most weeds and introduced species were upland species; approximately 30% of the upland plants were noxious weeds. This compares with Boutin and Jobin (1998) who showed that the proportion of weeds reached 32% in hedgerows adjacent to forage crop fields, yet most of them do not appear to invade adjoining crop fields (Jobin et al., 1997; Boutin and Jobin, 1998; but see also Marshall, 1989).

The woody vegetation, when present, was primarily dominated by deciduous trees and shrubs. Only a few small coniferous plants (*Abies balsamea*, *Picea glauca*, *Thuya occidentalis*) were found scattered among other vegetation types. In general, an abundant variety of deciduous tree and shrub species provided necessary conditions for shade loving plants to thrive. For example, in our study, eight fern species were exclusively associated with riparian habitats that had trees and/or shrubs (*Athyrium filix-femina*, *Athyrium thelypteroides*, *Dryopteris phegopteris*, *D. spinulosa*, *Matteuccia struthiopteris*, *Osmunda cinnamomea*, *O. claytoniana*, *Pteridium aquilinum*). One more fern species (*Onoclea sensibilis*) was found in both woody and non-woody habitats dominated by grasses and forbs. The diversity of forest spring ephemerals is a good indicator of ecosystem integrity (Keddy and Drummond, 1996). Many were only recorded in riparian habitats with trees (*Anemona canadensis*, *Polygonatum biflorum*, *Dicentra canadensis*, *P. biflorum*, *Sanguinaria canadensis*, *Smilacina stellata*, *Symplocarpus foetidus*; Table 2). None were unique to quadrats situated in the centre of riparian habitats with trees. Some of these vernal and fern species may have been responsible for the positioning of the riparian strips with trees apart from the other habitats

(*M. struthiopteris*, *T. polygamum*, *Trillium erectum*); Fig. 3, Table 3).

5.1. Structure and cover

Plants are commonly used as buffers to trap nutrients and pesticides likely to run off directly into waters (Jeppesen et al., 1999). The density and types of vegetation bordering stream and river banks are crucial elements, largely responsible for the maintenance of water quality in areas with high inputs of agrochemicals (Osborne and Kovacic, 1993; Jordan et al., 1993; Blanchard and Lerch, 2000; Clausen et al., 2000; Schulz and Peall, 2001). The total cover of the herbaceous vegetation ranged from 83 to 96.9% in quadrats close to water and between 93.3 and 96.4% in quadrats abutting cropfields. Bare soil was minimal (1% of the 16% of total area). However, underground tiles placed to drain wetlands of excess water also transport nutrients and pesticides applied to the soil, circumventing some of the positive effects of vegetated strips (Osborne and Kovacic, 1993). It may also be that some species are better for retention of nutrients, for instance those with extensive root systems, woody species or those often large species thriving in nutrient rich soils. Tilman (2000) contends that lower plant diversity leads to greater rates of loss of nutrients through leaching. The fact that plant diversity is considerably higher in hedges than in croplands likely suffices to reduce nutrient inputs into adjacent waters.

As farmers spray pesticides onto crops, wind captures a portion of the mist and the smaller droplets can be carried away from crop fields. Trees, shrubs and herbaceous vegetation at the edges of sprayed fields also act as filter to catch droplets of agrochemicals from the air. This is demonstrated by the scorched and distorted foliage, partial or complete transient defoliation and dead trees and shrubs in hedgerows, windbreaks, shelterbelts and forest edges abutting cropfields regularly sprayed with herbicides (Conacher and Conacher, 1986; Lamarre et al., 1993). Yet, many pesticides are applied early in the growing season; to enhance protection of waterbodies, it is advocated that some native evergreen woody species be planted at the edge of cropfields along with the naturally growing deciduous vegetation. Benefits to wildlife would also accrue since coniferous species, together with deciduous shrubs and trees, contribute to winter wind protection and act as nest sites and food resources for birds and mammals (Roth, 1976; Yahner, 1982a,b, 1983; Schroeder et al., 1992; Jobin et al., 2001).

5.2. Size of the riparian habitats

Non-crop areas in farmland landscape enhance the selection of vertical and horizontal reproductive and foraging sites for birds, mammals and other species such as invertebrates (Roth, 1976; Geier and Best, 1980; Johnson and Beck, 1988; Merriam and Lanoue, 1990; Wegner and Merriam, 1990; Schroeder et al., 1992). In a companion study carried out on the same sites, Maisonneuve and Rioux (2001) revealed that shrubby riparian strips harboured a higher diversity of amphibians and herpetofauna, whereas a higher diversity of small mammals was found in herbaceous riparian habitats and in those with trees. Thus, different types of riparian zones appear to be complementary. On the other hand, Deschênes et al. (2002) in their study of the same riparian habitats established that bird diversity and abundance were enhanced with the presence of riparian habitats with trees and to a lesser extent with shrubs, and that bird species considered as nuisance by farmers (e.g., Red-winged blackbird *Agelaius phoeniceus*) did not increase significantly in cropfields adjacent to woody riparian habitats.

Overall it emerged that wide linear habitats with a diverse structure, including riparian corridors, favour the diversity of plants and other wildlife. Spackman and Hughes (1995) in north-eastern US have examined trends in plant, bird and mammal species richness of riparian zones bordering small streams in an agricultural/woodland landscape. They found that corridor widths between 10 and 30 m above the high water mark were necessary to protect 90% of streamside plant species, but corridors between 75 and 175 m were needed for bird species. In the US, Keller et al. (1993) recommended that riparian forested strips be at least 100 m wide to provide nesting habitats for area-sensitive species. Stauffer and Best (1980), found that bird species richness increased sharply with the width of farmland riparian habitats. Given the constraints imposed by modern agriculture, height and structural diversity should be favoured rather than size in order to both satisfy agronomic, environmental and conservation demands. Under provincial laws in Québec, a buffer strip of 3 m is required for the protection of riparian areas adjacent to cropfields with no specification as to the type of vegetation. As a result farmers maintenance is often intensive, by mowing, burning or even using pesticides against weeds, insects or some animals. A 3 m wide riparian habitat would be sufficient for most functions described above (barrier to trap agrochemicals, habitat/corridor for some wildlife) but inadequate for species, plants or animals, most in need of protection, e.g., wetland or forest interior species.

6. Conclusion

The number and proportion of plant species typical of man-made habitats is likely to dominate areas of regular and extensive disturbance. They constitute the typical ruderal species according to Grime (1977). Conversely, the number of plant species naturally found in pristine wetland (or woody) areas is expected to be small but significant compared to farmed areas. This work showed that riparian habitats contribute a unique suite of plant species in otherwise vast terrestrial agricultural landscapes. Riparian habitats with trees supported less weedy species than other habitat types, therefore because also of their conservation value to wildlife (Deschênes et al., 2002) they should be encouraged. Factors that control species richness, abundance and composition are not specifically known in this study but could be related to the heterogeneity of the environment, disturbance due to drifts of agrochemicals and other anthropogenic factors such as distance from source populations, size and shape of habitats and perhaps historical background (Freemark and Boutin, 1995; Boutin and Jobin, 1998; Corbit et al., 1999; Tilman, 2000). Considerable research is needed to assess the role of these variables in shaping the biodiversity of plants and animals in farmland habitats in agricultural landscapes.

Acknowledgements

We thank L. Choinière and M. Salathé from the Bureau d'écologie Appliquée Inc., as well as S. Gagnon, G. Couture, and A. Cossette of the Fondation les Oiseleurs du Québec, for their valuable fieldwork in collecting data on habitat description and vegetation surveys. We also want to thank C. Maisonneuve for his collaboration in site selection and for providing advice throughout the project. Our sincere thanks also go to farmers of the Boyer River watershed who kindly granted us access to their land. Funding for the project was provided by Environment Canada, under the Canadian Biodiversity Strategy and the Eastern Habitat Joint Venture, a component of the North American Waterfowl Management Plan.

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