**EFFECT OF LANDSCAPE CONTEXT
ON THE PLANT SPECIES RICHNESS OF FOREST FRAGMENTS**

By

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ABSTRACT

I hypothesized that similar forest fragments may not have the same potential for conserving indigenous vegetation, if they are situated in different landscape contexts. I tested the effects of three landscape context types, forest, agricultural, and urban landscapes, on the plant species richness of 50 small forest fragments near Ottawa, Ontario, Canada. Landscape context was determined within circular buffers of 200 m to 1400 m radius from the fragments. Native forest species richness was higher in fragments surrounded by higher forest cover, while the number of introduced species was higher in patches surrounded by urban areas. No correlation was found between native and introduced species richness. Native species results were strongest when landscape context was determined within 200 m of the forest fragment. To maintain native species richness in forest fragments found in human-dominated landscapes, 200 m buffers containing high forest cover should surround the fragments.

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INTRODUCTION

In eastern North America, agriculture and development have greatly modified the landscape. One result of the expansion and intensification of human land use is forest loss, which creates isolated forest fragments surrounded by human-dominated landscapes (Sharpe & Burgess 1981). Forest fragments play an important role in conserving the indigenous vegetation, including rare or endangered species (Bunce & Hallam 1993; Boutin et al. 1994; Galatowitsch & Vander der Valk 1996; Jobin et al. 1996; Boutin & Jobin 1998; Freemark et al. 2002). Depending on the landscape context of a forest fragment, its ability to conserve species may vary. Habitat amount and the composition of the matrix, or non-forest part of the landscape, are two landscape factors that may affect plant species richness of forest fragments. Understanding how they affect remaining forest fragments and at which spatial scale their effect is more important matters for the conservation of native plant species in human-dominated landscapes.

With less habitat in the landscape, local species extinction is more likely (Ouborg 1993; Andren 1994; Tilman et al. 1994; Bascompte & Rodriguez 2001). The destruction of forest patches inevitably eradicates suitable habitats and their local populations of forest-specific species (McLaughlin & Mineau 1995). Lower forest cover in the landscape can reduce the influx of seeds from other forest patches, reducing genetic diversity and population persistence (Ouborg 1993; Peterson & Carson 1996; Richards 2000; Geertsema et al. 2002). Therefore, with less forest in the landscape, there may be fewer forest-habitat plants in forest fragments, including native and rare forest species.

Low forest cover typically leaves greater distances between forest patches. This could reduce the movement of animal seed dispersers, and so decrease the recolonisation probability of patches where populations of animal-dispersed plants have gone extinct (Opdam 1988; Santos & Telleria 1994; Froborg & Eriksson 1997; Grashof-Bokdam 1997; Sarlöv Herlin & Fry 2000). If a decrease in dispersal abilities limits the distribution of plant species (Primack & Miao 1992; Matlack 1994; Malanson & Armstrong 1996), forest loss may negatively affect the species richness of animal-dispersed plant species found in forest habitat.

Beside forest loss, matrix composition is another landscape factor that may affect the species richness of forest fragments. The non-habitat part of the landscape can be composed of different kinds of cover, such as agricultural or urban covers. Because these matrix types have different characteristics, they are expected to have different effects on the species richness of forest fragments. Agricultural landscapes have higher proportions of open spaces and natural open habitat than urban landscapes (Johnson and Maxwell 2001). Most introduced plant species are open-habitat species (Charbonneau 2003), and it has been suggested that an increase in open habitat in the landscape may increase the number of introduced species in forest fragments through an increase in the supply of propagules (Cullen et al. 2001; Meekins & McCarthy 2001).

Because they have more open space, agricultural landscapes have less wind barriers such as forest cover or buildings, which may facilitate the dispersal of wind-dispersed plant species between forest patches (Johnson 1988; Matlack 1989). This may lead to an increase in wind-dispersed species richness in forest fragments that are surrounded by agricultural land cover. In addition, natural and semi-natural open habitats

may play a role as a source of open-habitat and edge-species propagules. Since open space is found in higher proportion in agricultural landscape, the probability of open and edge species seed influx from these habitats into forest fragments may be more frequent in agricultural landscapes, leading to higher open-habitat and edge-species richness in forest fragments in agricultural landscapes than in urban landscapes.

It is also important to determine the distance, or scale, at which the landscape context of a forest patch affects plant species richness within the forest patch. Finding the scale will allow more effective protection and conservation of forest fragments, as it indicates the distance from the forest fragment in which the surrounding land use should be considered. In the case of plant species richness, the scale may be determined by the distance to which seeds disperse, or by the distance that disturbances such as people or predators will travel to get into forest fragments.

In this research project, I tested the effects of different landscape contexts on the plant species richness of small forest fragments, and identified the scale at which landscape context affected plant species richness. I first looked at the effect of forest cover and predicted that sites with more forest in the surrounding landscape would have higher forest-habitat species richness, including native, rare and animal-dispersed forest species richness. I then tested the effect of matrix composition using two types of matrix cover, agriculture and urban. I predicted that forest fragments found in agricultural landscapes would have higher introduced, wind-dispersed, open-habitat and edge species richness than fragments in other landscape types.

METHODS

Site selection

The study took place in Ontario and Quebec, Canada, within 75 km of the city of Ottawa (45°25'N-75°42'W). Fifty forest fragments between 2.5 and 7.5 hectares were selected (Figure 1) using the digital DMTI Spatial Canmap Streetfiles 5.1. topographic maps (2001; source: Carleton University). The digital data provided detailed topographic and geographic information derived from the 1998 1:50 000 National Topographic Data Base. The maximum proportion of error of classification, omission, and commission was 5 % (Geomatics Canada 1996). The forest fragments were selected to represent different landscape contexts in terms of forested, agricultural, and urban areas. For each landscape type, fragments were chosen such that the surrounding landscapes had the highest possible percentage of the desired land cover and the minimum buffer overlap, within a 1400 m buffer. This resulted in a minimum of 35 % forest cover for forested landscapes, a minimum of 70 % agriculture cover for agricultural landscapes, and a minimum of 50 % urban cover for urban landscapes (Figure 2). Twenty fragments were selected within the agricultural landscape category, and 19 within the forested category. Only 11 forest fragments with non-overlapping buffers were found in urban landscapes.

An effort was made to select forest types that were similar in canopy tree composition. Most sites had their canopy cover dominated by deciduous trees such as *Acer rubrum*, *Acer saccharum*, *Fraxinus americana*, *Tilia americana* and *Populus tremuloides*. Despite this effort, one site had its canopy cover dominated by *Quercus rubra* and *Pinus barksiana*, and 5 sites were dominated by *Thuja occidentalis*.

Landscape context data

Landscape data were obtained using the digital DMTI Spatial Canmap Streetfiles. Landscape context was measured at 4 scales using buffers of 200 m, 500 m, 1000 m and 1400 m radius around each site starting from the fragment's edge (Figure 2). Percent land cover for forested, agricultural, and urban covers at each scale were measured with the ArcView 3.2 Geographical Information System (GIS). Percent forest cover was measured using the CanMap Streetfiles vegetation theme, while the land use theme was used to measure agricultural and urban covers. The two themes overlapped, so the area covered by vegetation was subtracted from the land uses categories. In the land use theme, the open area cover category was used to create the agricultural cover layer. The categories commercial, government and institutional, parks and recreational, residential, and resource and industrial were merged to create the category urban cover. Visual surveys around the forest fragments were done to insure the map classification corresponded to what was found in the field.

Two landscape predictor variables were created: Forest Cover was a continuous variable, while Landscape Type was categorical. Forest Cover was the percent forest cover found in the buffer surrounding a site, and was measured at the 4 scales for each site. Landscape Type included three types of landscape: forested, agricultural and urban. The variable was created using the land cover percentages and criteria used for the site selection: sites categorised in forested landscapes included a minimum of 35 % forest cover within their buffers, agricultural landscapes a minimum of 70 % agriculture cover, and urban landscapes a minimum of 50 % urban cover. Because the percentage of land

cover found in a buffer varied with scale, a site could be categorised in different landscape categories from one scale to another (Figure 3).

Vegetation surveys

Plant species percent cover was measured for each site. Because edge effects change with aspect (Palik & Murphy 1990; Fraver 1994), all transects were oriented in the north-south direction. The transects had their 0 m position along the outermost tree trunks on the north side of the forest fragment. The first transect started at 50 m from the east edge, and all transects were separated by 50 m. Quadrats of 1 m² were placed at the 0 m position and at every 50 m along the transects (Figure 4). This technique allowed standardising the sampling effort among fragments, such that the same percentage of fragment area was surveyed at each site.

All herbaceous, shrubs and trees with DBH smaller than 10 cm found in a quadrat were identified. Percent cover of each herbaceous species and stem counts of shrubs and trees with DBH smaller than 10 cm were recorded for each quadrat. Species identification for trees and shrubs with DBH greater than or equal to 10 cm were done at every two quadrat using the point-centered quarter method (Bonham 1989). The center of the quadrats were used as sampling point, and the north-south and east-west directions were used to establish the four 90° sectors. The species of the closest tree in each sector was identified, and its DBH and distance to the sampling point measured.

Sites were surveyed twice, once between May 15th and June 21st 2003 to survey spring ephemeral species, and once between July 2nd and August 21st to survey the rest of the vegetation. Specimens that could not be identified in the field were collected and

pressed. The dried specimens were identified to species or genus, using Gleason & Cronquist (1991). Species that could not be identified but were clearly different from other collected species were included in the species count.

Species richness data

All identified species were classified by origin, habitat preference, rarity and dispersal mechanism. Species origin was native or introduced. An introduced species was defined as a species that did not occur in the study area before European settlement and that arrived as a result of human activity. The classification was based on Gleason and Cronquist (1991) and Farrar (1996), which were also used to classify species into three habitat categories: forest species, edge species, and open-habitat species. Species found exclusively in forest were classified as forest species. Species growing either in forest or open habitat were called edge species. Open-habitat species were species growing in any non-forest habitat and rarely found in forest habitat.

Species found on the Quebec and Ontario threatened species lists for the Ottawa region (Ontario Ministry of Natural Resources, 2003; Centre de données sur le patrimoine naturel du Québec, 2003) and in the Distributionally significant vascular flora of the region of Ottawa-Carleton (Brunton 1998) were classified as rare. Species were classified according to their dispersal mechanisms as animal or wind-dispersed (van der Pijl 1969; Bullock & Primack 1977; Cox 1985; Piper 1986; Fenner 1992; Soper & Heimbürger 1994; Honnay et al. 1999; Sheley & Petroff 1999; Bellemare et al. 2002; Natural Resources Conservation Service 2003). When origin, habitat preference, or

dispersal mechanism could not be identified, the species were omitted from the relevant analyses.

I then determined, for each fragment, total species richness, native forest species richness, introduced species richness, rare forest species richness, total forest species richness, edge species richness, open-habitat species richness, animal-dispersed forest species richness and wind-dispersed species richness, using the lists of species present in each site.

Local variables

Forest age, fragment area, fragment heterogeneity, and canopy cover have been shown to affect the plant composition of forest fragments (Honnay et al. 1999; Ford et al. 2000). These variables were included in the analyses to control for their potential effects on variation in species richness. The minimum age of the forest at each site was evaluated using time series of aerial photos and topographic maps going from 1940 to present (National Air Photo Library, 1933-2001; Canada Surveys and Mapping Branch, 1933-1968). The date of first observable forest presence was traced back and used to calculate the forest age. Due to the large error in estimating forest ages, they were lumped into 3 classes, i.e. < 40 years old, 40 to 60, and >60 years old.

Fragment area was calculated with the Avenue script *calcapl.ave* in ArcView 3.2 GIS, using the digital DMTI Canmap Streetfiles. The difference in elevation at each site was used as a surrogate for fragment heterogeneity. The fragment elevation differences were taken from the Ontario Base Maps (Ontario Ministry of Natural Resources, 1988-1992) and Quebec topographic maps (Service de la cartographie du Québec, 1983-1984).

The distance between consecutive contour lines were 1 m and 10 m respectively, and the maximum error for the Quebec map is ± 5 m.

Canopy cover was estimated at every second quadrat on every second transect during the second inventory. At each quadrat, the canopy cover directly above the site was estimated on a 10-point scale, 1 being between 0 and 10% canopy cover, and 10 being between 91 and 100% canopy cover. The average percent canopy cover for the site was taken as the canopy cover index.

For each forest fragment, signs of human activity were recorded and compiled into a human-use index. The number of fire pits, fences, tree stumps, tree houses, and abandoned houses seen were recorded, as well as the number of trails crossed by the transects. For each fragment, the values were summed and used as human-use index.

Data analysis

Correlations among the predictor variables canopy cover, fragment elevation difference, fragment area, fragment age, and the forest cover at each of the 4 scales were measured using Pearson correlation (r) coefficients. One-way ANOVAs were used to evaluate differences in canopy cover, fragment elevation difference, fragment age and fragment area between the three landscape types at all scales. Correlations between the human-use index and the urban cover at each scale, and between native forest species and introduced species richness were also calculated.

Stepwise multiple regressions and ANCOVAs were used to test the predictions. The predictor landscape variable Forest Cover was used to test the prediction that with an

increase in forest cover in the landscape, the forest species richness and the native, rare, and animal-dispersed forest plant species richness would increase.

The categorical variable Landscape Type was used to test the matrix composition predictions that forest fragments found in agricultural landscapes should have higher introduced, wind-dispersed, edge and open-habitat species richness. To control for potential variation in the species richness of sites surrounded by different types of landscape, proportion of species were used as response variables instead of species richness, for the analyses using the predictor variable Landscape Type. Proportions were calculated as the number of species in a category found in a fragment divided by the total number of species found in that fragment.

All analyses were done at the 4 scales using SAS (SAS Institute 1990), and included the control predictor variables forest age, fragment area, fragment elevation difference and canopy cover. The F-values calculated for each of the variables using type III sums of squares were used to test the significance of the predictor variables.

To determine at which scales Forest Cover and Landscape Type had the largest effects on the response variables, partial R^2 values were used. The scale that had the highest partial R^2 value was considered to be the scale at which the response variable responded most strongly to the predictor variable.

RESULTS

Species richness

A total of 396 plant species were sampled; 148 were forest species, 34 were open-habitat species, and 180 preferred edge habitats. Of the forest species, 141 were native, 12 were classified rare, and 37 were animal-dispersed. Sixty-four species were introduced species, and 70 were classified as being dispersed by wind. The list of species surveyed and the number of species found per site for each of these categories can be seen respectively in Appendices 1 and 2.

The total species richness ranged from 26 to 90 species per site, with an average of 54.9 species. Forest and native forest species richness had similar averages of 20 and 19.4 species per site. The categories rare, animal-dispersed, introduced and open-habitat species richness included fewer species, with averages of 0.5, 6.8, 7 and 2 species per site. Wind-dispersed and edge species richness had averages of 15.3 and 30.3 species per site respectively (Table 1).

Landscape data

The mean percent forest cover increased with scale, and the observed range of forest cover was lower for the 200 m scale compared to the 3 other scales (Table 1). Table 2 shows the number of sites per landscape type at each scale. The number of agricultural and urban sites was relatively constant across scales, but the number of forested sites increased from 4 sites at the 200 m scale to 19 sites at the 1400 m scale. Appendix 3 shows the forest percent cover for the 50 landscapes at different spatial scales and which sites were categorised in which landscape category at different scales.

Local variables

Fragment areas ranged from 2.6 to 7.3 hectares ($4.52 \text{ hectares} \pm \text{SE} = 0.206$ hectares). Canopy cover ranged from 35 to 95%, and the youngest forest fragment surveyed was 28 years old. Five sites were found to be younger than 40 years old, 17 were between 40 and 60 years old, and 28 sites had been present for more than 60 years. Elevation difference values ranged from 0 to 20 m (Table 1).

Data analysis

For each analysis testing the forest cover predictions, 50 landscapes were used in the analysis. On the other hand, the number of landscapes used in the matrix composition analyses ranged between 41 and 50, depending on the spatial scale of the analysis (Table 2). The amount of forest, agriculture or urban cover surrounding a site varied from one scale to another (figure 3). At scales smaller than 1400 m, some sites did not have high enough amounts of forest, agriculture or urban covers in their buffers to be classified in one of the three landscape categories. They were therefore excluded from the relevant analysis.

Of the response variables that were predicted to respond to Forest Cover, only native forest species richness was significantly related to the amount of forest present in the landscape, and only at the 200 m scale. At that scale, it had positive relationships with two predictor variables, forest cover and fragment area (Table 3 and Figure 5).

Total forest and animal-dispersed forest species richness had significant positive relationships with fragment area (Table 3). Animal-dispersed forest species richness was

also related to fragment age, with fragments between 40 and 60 years old having more animal-dispersed species than younger or older sites. No significant relationship was found between the rare species richness and the predictor variables (Table 3).

Results for the matrix composition predictions showed significant relationships at all scales between the proportion of introduced species in a fragment and Landscape Type, where forest fragments in urban landscapes had significantly higher proportions of introduced species than sites found in other landscapes (Table 4 and Figure 6). The relationship at the 200 m scale had the lowest R^2 value of 0.22 and the three other scales had an equal R^2 value of 0.23 (Table 4).

No significant relationships were found for wind-dispersed, open-habitat and edge species proportions (Table 4).

Correlations among canopy cover, fragment elevation difference, fragment area, fragment age and the landscape variable forest cover at all scales are given in Table 5. The only significant correlation found was a weak positive correlation between fragment area and elevation difference. The one-way anova results showed no significant differences in canopy cover, fragment elevation difference, fragment age, and fragment area among the three landscape types at any scale. The human-use index was correlated to urban cover at all scales (table 6). No correlation was found between the number of introduced species and the number of native forest species found in a fragment (Pearson Correlation Coefficient = -0.05, $P = 0.71$, $N = 50$)

DISCUSSION

To help with the selection of protected areas and with the restoration of plant communities, much attention has been given in the literature to forest patch size and local characteristics, such as forest age and heterogeneity, and to the effects of those variables on the conservation value of a forest fragment (Shafer 1990; Honnay et al. 2002). Fewer studies have looked at the influence of the landscape context on plant species richness of forest fragments (de Blois et al. 2001). In this study, I found that landscape context of forest patches affected plant species richness, even after controlling for patch size and local factors. Forest patches in predominantly forested landscapes had higher native forest species richness, and forest patches in largely urban landscapes had higher introduced species richness.

Based on my results, the landscape factor to consider in selection of sites for the protection of indigenous vegetation should be the surrounding amount of forest. Forest patches surrounded by more forest should be selected first as they support a higher richness of native forest species. Then, if we want to limit the number of introduced species in forest fragments, sites with low urban cover should be selected. However, the presence of introduced species may not be a problem for native species conservation, since no correlation was found between native forest and introduced species richness. Therefore, if the main concern is to maintain native species richness, matrix composition may not be an important factor to consider.

The scale at which landscape context was found to have the most significant effect on native plant species richness was the area around the patch out to 200m. For

the urban category were surrounded by urban cover at all scales. No additional information was added with scales larger than 200 m. Similarly, Houlahan et al. (in review) found that landscape context within 250 to 300 m of wetlands affected wetland plant species richness. This distance and the lack of correlation between introduced and native species richness imply that even sites close to a city could be used for conservation of plant species, as long as they are surrounded by a high percentage of forest cover.

However, it may not be possible to apply the scales found in this project to larger forest patches. The forest fragments used in my research were between 2.5 and 7.5 ha. Findlay and Houlahan (1997) found that the effect of landscape context on wetland plant species richness was most pronounced within 1000 m of a set of rather large wetlands, averaging 390 ha. This distance contrasts with their more recent study (Houlahan et al. in review) in which they found a much smaller scale of effect of landscape context (250 m). The wetlands in their recent study were smaller, averaging 66.7 ha. Therefore, the scale over which landscape context affects species richness in a patch may increase with increasing patch size. It is possible that the scale of effect is linked to dispersal distance; for many plants, it may represent the distance an animal disperser will travel to get to a site. Larger sites may be more attractive than smaller sites, so dispersers may travel longer distances to get to them, resulting in larger scales for larger sites.

Small fragment size may also explain why no effects of landscape structure were found for rare species richness. Species with narrower ecological tolerances such as rare species occur more frequently in forest fragments larger than 20 hectares (Burke & Nol 1998). Since the fragments surveyed in the present study ranged between 2.5 and 7.5 hectares, it is possible that there were not enough rare species in the fragments to detect

an effect of landscape context. To confirm this, research using sites larger than 20 hectares would be needed.

The amount of urban cover around forest fragments was correlated to the human-use index at all scales. Therefore, I do not know whether the effect of urban land cover on introduced species richness is due to local or landscape effects of human activity. It could be due to human disturbances within the forest, allowing for the establishment of introduced species. It could also be due to an increased number of introduced species in the surrounding landscape due to the human introductions, for example in urban gardens. This could increase the probability of finding introduced species in forest fragments in urban areas.

In this study, no attention was given to past land uses in and around the forest fragments; only present land uses surrounding the fragments were used as predictor variables. Historical land use within and around sites has been found to affect the vegetation of forested sites (Koerner et al. 1997; de Blois et al. 2001). Findlay and Bourdages (2000) found a stronger effect of landscape context on wetland plant species richness when they considered land use (road density) over a 40-year time period. It is likely that my results would be stronger if I were also to consider previous land use around the sites.

It could be argued that species richness is not as sensitive a measure of the ecological effects of human activity as is species abundance. I conducted preliminary analyses using percent cover data for each species rather than simply presence/absence. The results were similar to the ones found using species richness. Therefore, because it is

simple and one of the most frequently used measures of biodiversity (Brose et al. 2003), species richness was used as the response variable.

Few studies have looked at the effects of landscape context on vegetation. These studies only looked at the effect of forest cover (Matlack 1994; Grashof-Bokdam 1997; Sarlöv Herlin & Fry 2000; Hersperger & Forman 2003), and did not consider the matrix composition. This project showed that landscape context, including amount of forest cover and matrix composition, does have an effect on plant species richness. For conservation purposes, sites surrounded by low urban cover within a 200 m radius should be selected to reduce the number of introduced species. However, if the main concern is to maintain native forest species richness of forest fragments in human dominated landscapes, forest cover in the landscape factor that should be considered. Buffers including a high proportion of forest cover within a minimum radius of 200 m should surround the fragments.

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Table 1: Summary data of the species richness for the different species categories and for the response variables measured within or around forested sites, including the percent forest cover at each scale (scale size in m indicated by number in heading) and the four local variables. N = 50.

	Mean	Standard Error	Observed Range	
Response variables	Total species richness	54.9	1.7	26-90
	Total forest species richness	20.0	1.0	7-46
	Native forest species richness	19.4	1.3	6-43
	Rare forest species richness	0.5	0.1	0-4
	Animal-dispersed forest species richness	6.8	0.5	0-16
	Introduced species richness	7.0	0.4	1-14
	Wind-dispersed species richness	15.3	0.6	7-28
	Open-Habitat species richness	2.0	0.2	0-5
	Edge species richness	30.3	0.8	17-46
Predictor Variables	Percent Forest Cover - 200 m	13.1	2.1	0-53.7
	Percent Forest Cover - 500 m	21.4	2.5	0-75.3
	Percent Forest Cover -1000 m	24.7	2.8	0-73.6
	Percent Forest Cover - 1400 m	25.2	2.6	0.3-74.7
	Fragment Area	4.5	0.2	2.6-7.3
	Canopy Cover (%)	76.9	1.2	35-95
	Forest Age	56.1	1.4	28-63
	Fragment Elevation Difference (m)	5.0	0.6	0-20

Table 2: Number of sites per landscape types at the 200 m, 500 m, 1000 m, and 1400 m scale (size of the buffer surrounding the forest fragments). At scales smaller than 1400 m, some sites did not have high enough amounts of forest, agriculture or urban covers in their buffers to be classified as one of the three landscape types; they were excluded from the analyses at that scale.

Landscape Types	Scale			
	200 m	500 m	1000 m	1400 m
Forest	4	15	19	19
Agriculture	24	18	19	20
Urban	13	11	11	11
Total number of sites	41	44	49	50

Table 3: Results for the forest cover analyses. The response variables used were native forest, rare forest, forest and animal-dispersed forest species richness. The predictor variables included forest cover at the 200 m, 500 m, 1000 m, and 1400 m scales (size of the buffer surrounding the forest fragments) and the local variables forest age, fragment area, fragment elevation difference and canopy cover. Only predictor variables that were significant at $\alpha=0.05$ are included in the table. N = 50.

Response variable	Predictor variables	Scale of predictor variable	Mean Square	F value	P value	Model R ²
Native forest species richness	forest cover	200m	1150.84	7.98	0.001	0.25
	fragment area		1328.89			
Rare forest species richness	-	n.a.	-	-	-	-
Total Forest species richness	fragment area	n.a.	571.81	7.19	0.010	0.13
Animal-dispersed forest species richness	fragment area	n.a.	226.20	4.41	0.008	0.22
	fragment age		66.45			

Table 4: Results for the matrix composition analyses. Landscape Type at the 200 m, 500 m, 1000 m, and 1400 m scales (size of the buffer surrounding the forest fragments), forest age, fragment area, fragment elevation difference, and canopy cover were used as predictor variables. The response variables were the proportion of introduced, open-habitat, edge, and wind-dispersed species over the total number of species per site. Only predictor variables that were significant at $\alpha = 0.05$ are included in the table. f = forest landscape; a = agriculture landscape; u = urban landscape.

Response variable	Predictor variable	Scale of predictor variable	N	Mean square	F value	P value	Model R ²	Significant comparisons
Introduced species proportion	landscape types	200 m	41	0.05	5.22	0.01	0.22	u > f; u > a
	landscape types	500 m	44	0.05	6.12	0.004	0.23	u > f; u > a
	landscape types	1000 m	49	0.06	6.95	0.002	0.23	u > f; u > a
	landscape types	1400 m	50	0.06	7.20	0.002	0.23	u > f; u > a
Wind-dispersed species proportion	-	n.a.	-	-	-	-	-	-
Open-habitat species proportion	-	n.a.	-	-	-	-	-	-
Edge species proportion	-	n.a.	-	-	-	-	-	-

Table 5. Correlations among the local variables and forest cover. Pearson correlation coefficients (r) are given for each predictor variable combination with their p-values underneath. The scale (radius in m of the buffer surrounding the forest fragments) for the percent forest cover is given in parentheses. N = 50.

	Canopy Cover	Forest Age	Fragment Elevation difference	Forest Cover (200 m)	Forest Cover (500 m)	Forest Cover (1000 m)	Forest Cover (2000 m)
Fragment Area	-0.11	0.17	0.28	0.06	0.01	0.00	-0.00
	0.46	0.24	0.05	0.70	0.96	0.99	0.98
Canopy Cover	1	-0.15	0.17	0.11	0.07	0.14	0.16
		0.29	0.25	0.43	0.63	0.32	0.28
Forest Age	-	1	0.10	0.02	0.00	-0.04	-0.08
			0.48	0.86	0.97	0.80	0.58
Elevation Difference	-	-	1	-0.05	-0.11	-0.10	-0.09
				0.75	0.44	0.50	0.52

Table 6. Correlations between the human-use index and the percent urban cover at four scales. Pearson correlation coefficients (r) are given for each combination with their p -values underneath. The scale (radius in m of the buffer surrounding the forest fragments) for the percent forest cover is given in parentheses. $N = 50$.

	Urban Cover (200 m)	Urban Cover (500 m)	Urban Cover (1000 m)	Urban Cover (1400 m)
Human-use index	0.36 0.00	0.33 0.00	0.25 0.01	0.25 0.01

Figure 1: Locations of the 50 forest fragments surveyed in the Ottawa region, surrounded by a 1000 m radius buffer.

Figure 2: Examples of landscape context surrounding forest fragments within buffers of 200 m, 500 m, 1000 m and 1400 m radius. Landscapes were categorised into: a) forested, b) agricultural, and c) urban

Figure 3: Categorisation of a forest fragment according to landscape types at different scales. Depending on the scale, a site may change from one type of landscape to another. Figure 3 a) and b) show a site at scales 200 m and 500 m surrounded mainly by agriculture. Figure c) and d) show the same site at scales 1000 m and 1400 m, and it is now mostly surrounded by forest cover.

Figure 4: Sampling design for forest fragments of 2.5 to 7.5 hectares.

Figure 5: Native forest species richness in forest fragments surrounded by different amount of forest cover at a 200m scale (size of the buffer surrounding the forest fragments). N=50.

Figure 6: Introduced species richness of forest fragments surrounded by different land covers at a 200m scale (size of the buffer surrounding the forest fragments). N=44.

Appendices

Appendix 1. Species categorised by origin (n: native, i: introduced), habitat (f: forest, e: edge, o: open), rarity (y: yes, n: no), and dispersal mechanism (a: animal, w: wind).

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Abies balsamea</i> (L.) Mill.	n	e	n	w
<i>Acer negundo</i> L.	i	e	n	w
<i>Acer rubrum</i> L.	n	e	n	w
<i>Acer saccharinum</i> L.	n	f	n	w
<i>Acer saccharum</i> Marsh.	n	e	n	w
<i>Acer spicatum</i> Lam.	n	e	n	w
<i>Achillea millefolium</i> L.	i	e	n	w
<i>Actaea pachypoda</i> Ell.	n	f	n	a
<i>Actaea</i> sp.	n	f	n	a
<i>Actaea rubra</i> Ait.	n	f	n	a
<i>Agrimonia gryposepala</i> Wallr.	n	e	n	a
<i>Agrimonia parviflora</i> Ait.	n	f	n	.
<i>Agrostis gigantea</i> Roth.	i	e	n	.
<i>Agrostis hyemalis</i> (Walter) BSP.	n	e	n	.
<i>Agrostis</i> sp.	.	.	.	.
<i>Alliaria petiolata</i> Bieb.	i	f	n	.
<i>Allium canadense</i> L.	n	e	y	.
<i>Allium tricoccum</i> Ait.	n	f	y	a
<i>Alnus incana</i> (L.) Moench ssp. <i>rugosa</i> (Du Roi)	n	o	n	w
<i>Ambrosia artemisiifolia</i> L.	n	o	n	a
<i>Amelanchier bartramiana</i> Roemer	n	f	y	a
<i>Amelanchier laevis</i> Wieg.	n	e	n	a
<i>Amelanchier</i> sp.	n	e	n	a
<i>Amphicarpa bracteata</i> (L.) Fern.	n	f	n	a
<i>Anemone canadensis</i> L.	n	e	n	w
<i>Anemone</i> sp. L.	n	e	n	.
<i>Anemone virginiana</i> L.	n	e	n	.
<i>Antennaria neglecta</i> Greene	n	e	n	.
<i>Apocinum androsaemifolium</i> L.	n	e	n	.
<i>Aquilegia canadensis</i> L.	n	e	n	.
<i>Aralia nudicaulis</i> L.	n	f	n	a
<i>Aralia racemosa</i> L.	n	f	n	.
<i>Arctium lappa</i> L.	i	o	n	a

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Arctium minus</i> (Hill) Bernh.	i	e	n	a
<i>Arctium</i> sp.	i	e	.	a
<i>Arisaema atrorubens</i> (Ait.) Blume	n	f	n	.
<i>Asarum canadense</i> L.	n	f	n	.
<i>Asclepias syriaca</i> L.	n	o	n	w
<i>Asparagus officinalis</i> L.	i	e	n	.
<i>Aster acuminatus</i> Michx.	n	f	n	.
<i>Aster ciliolatus</i> Lindl.	n	e	n	.
<i>Aster cordifolius</i> L.	n	e	n	w
<i>Aster lanceolatus</i> Willd.	n	e	n	.
<i>Aster lateriflorus</i> (L.) Britt.	n	f	n	.
<i>Aster macrophyllus</i> L.	n	e	n	w
<i>Aster novae-angliae</i> L.	n	e	n	w
<i>Aster ontarionis</i> Wieg.	n	e	y	.
<i>Aster racemosus</i> Elliott.	n	e	n	.
<i>Aster</i> sp.	n	e	n	.
<i>Aster umbellatus</i> Mill.	n	o	n	.
<i>Asteraceae</i> sp.	.	.	.	.
<i>Athyrium filix-femina</i> (L.) Roth	n	e	n	w
<i>Barbarea vulgaris</i> R.Br.	i	o	n	.
<i>Betula alleghaniensis</i> Britt.	n	f	n	w
<i>Betula papyrifera</i> Marsh.	n	f	n	w
<i>Bidens</i> sp.	n	.	.	a
<i>Blephilia hirsuta</i> (Pursh) Benth	n	f	n	.
<i>Botrychium</i> sp.	n	e	n	.
<i>Botrychium virginianum</i> (L.) Sw.	n	e	n	.
<i>Brachyelytrum erectum</i> (Schreber) P. Beauv.	n	f	n	.
<i>Brassicaceae</i> sp.	.	.	.	.
<i>Bromus ciliatus</i> L.	n	f	n	.
<i>Bromus erectus</i> Hudson	i	o	n	.
<i>Calystegia spithamea</i> (L.) Pursh.	n	e	n	.
<i>Carex sprengelii</i> Dew.	n	e	n	.
<i>Carex arctata</i> W. Boott.	n	e	n	.
<i>Carex bromoides</i> Willd.	n	e	n	.
<i>Carex communis</i> L. Bailei	n	f	n	.
<i>Carex crinita</i> Lam.	n	f	n	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Carex debilis</i> Michx.	n	f	y	.
<i>Carex deweiana</i> Schwein.	n	f	n	.
<i>Carex eburnea</i> F. Boott.	n	.	n	.
<i>Carex folliculata</i> L.	n	f	y	.
<i>Carex gracillima</i> Schwein.	n	f	n	.
<i>Carex granularis</i> Muhl.	n	o	n	.
<i>Carex grayi</i> Carey.	n	f	n	.
<i>Carex gynandra</i> Lam.	n	f	n	.
<i>Carex hirtifolia</i> Mackenzie	n	f	y	.
<i>Carex hitchcockiana</i> Dew.	n	f	y	.
<i>Carex intumescens</i> Rudge	n	f	n	.
<i>Carex laxiflora</i> Lam.	n	f	n	.
<i>Carex laxiflorae</i> sp.	n	f	n	.
<i>Carex lupulina</i> Muhl.	n	e	n	.
<i>Carex ovaes</i> sp.	n	.	n	.
<i>Carex peckii</i> Howe.	n	e	n	.
<i>Carex pendunculata</i> Muhl.	n	f	n	.
<i>Carex pensylvanica</i> Lam.	n	f	n	.
<i>Carex plantaginea</i> Lam.	n	f	n	.
<i>Carex radiata</i> (Wahlenb.) Small or <i>Carex</i> <i>appalachica</i> Webber and Ball.	n	e	n	.
<i>Carex retrorsa</i> Schweinitz.	n	e	n	.
<i>Carex rosea</i> Schk.	n	e	n	.
<i>Carex scabrata</i> Schwein.	n	f	n	.
<i>Carex</i> sp.	n	e	n	.
<i>Carex sparganioides</i> Muhl.	n	f	y	.
<i>Carex tuckermanii</i> F. Boott.	n	e	n	.
<i>Carex vulpinoidea</i> Michx.	n	e	n	.
<i>Carpinus caroliniana</i> Walt.	n	f	n	w
<i>Carya cordiformis</i> Wang.	n	f	n	.
<i>Caulophyllum thalictroides</i> (L.) Michx.	n	f	y	a
<i>Ceanothus americanus</i> L.	n	e	y	.
<i>Cerastium vulgatum</i> L.	i	e	n	.
<i>Chelone glabra</i> L.	n	f	n	w
<i>Chrysanthemum leucanthemum</i> L.	i	e	n	.
<i>Chrysosplenium americanum</i> Schwein.	n	f	y	.
<i>Circaea alpina</i> L.	n	f	n	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Circaea lutetiana</i> L.	n	f	n	a
<i>Circaea</i> sp.	n	e	.	.
<i>Cirsium arvense</i> (L.) Scop.	i	e	n	w
<i>Cirsium discolor</i> (Muhl.) Spreng.	n	o	n	.
<i>Cirsium</i> sp.	.	.	.	.
<i>Cirsium vulgare</i> (Savi) Tenore	i	o	n	w
<i>Claytonia caroliniana</i> Michx.	n	f	n	.
<i>Clematis virginiana</i> L.	n	e	n	w
<i>Clintonia borealis</i> (Ait.) Raf.	n	f	n	a
<i>Convallaria majalis</i> L.	i	f	n	.
<i>Conyza canadensis</i> (L.) Cronq.	n	o	n	w
<i>Coptis groenlandica</i> (Oeder) Fern.	n	e	n	.
<i>Coptis trifolia</i> (L.) Salisb.	n	e	n	.
<i>Cornus alternifolia</i> L.	n	f	n	a
<i>Cornus amomum</i> var. <i>schuetzeana</i> (Meier) Rickett.	n	f	n	a
<i>Cornus canadensis</i> L.	n	f	n	a
<i>Cornus rugosa</i> Lam.	n	e	n	a
<i>Cornus stolonifera</i> Michx.	n	e	n	a
<i>Coronilla varia</i> L.	i	o	n	.
<i>Corylus cornuta</i> Marsh.	n	f	n	a
<i>Crataegus</i> sp.	n	o	n	.
<i>Crepis capillaris</i> (L.) Wallr.	i	o	n	.
<i>Cuphea viscosissima</i> Jacq.	n	.	n	.
<i>Cypripedium</i> sp.	n	f	y	.
<i>Cystopteris bulbifera</i> (L.) Bernh.	n	f	n	.
<i>Danthonia</i> sp.	.	.	.	.
<i>Danthonia spicata</i> (L.) F. Beauv.	n	f	n	.
<i>Daucus carota</i> L.	i	e	n	a
<i>Dennstaedtia punctilobula</i> (Michx.) Moore.	n	e	n	.
<i>Dentaria diphylla</i> Michx.	n	f	n	.
<i>Dianthus armeria</i> L.	i	o	n	.
<i>Dicentra canadensis</i> (Goldie) Walp.	n	f	n	.
<i>Dicentra cucullaria</i> (L.) Bernh.	n	f	n	.
<i>Dicentra</i> sp.	n	f	n	.
<i>Diervilla lonicera</i> Mill.	n	f	n	.
<i>Dirca palustris</i> L.	n	f	n	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Dryopteris carthusiana</i> (O.F. Muell.) Watt	n	f	n	w
<i>Dryopteris intermedia</i> (Muhl.) Grai.	n	f	n	w
<i>Dryopteris marginalis</i> (L.) Grai	n	f	n	w
<i>Dryopteris</i> sp.	n	f	n	.
<i>Echinocystis lobata</i> (Michx.) T.& G.	n	e	n	.
<i>Elymus hystrix</i> L.	n	f	n	.
<i>Elymus virginicus</i> L.	n	e	n	.
<i>Elytrigia repens</i> (L.) Nevski.	i	.	n	.
<i>Epifagus virginiana</i> (L.) Barton	n	f	n	.
<i>Epilobium glandulosum</i> Lehm.	n	f	n	w
<i>Epipactis helleborine</i> (L.) Crantz	i	e	n	w
<i>Equisetum palustre</i> L.	n	e	y	.
<i>Equisetum arvense</i> L.	n	e	n	.
<i>Equisetum hiemale</i> L.	n	e	n	.
<i>Equisetum scirpoides</i> Michx.	n	f	n	.
<i>Equisetum</i> sp.	n	e	.	.
<i>Equisetum sylvaticum</i> L.	n	f	n	.
<i>Erigeron annuus</i> (L.) Pers.	n	e	n	w
<i>Erigeron philadelphicus</i> L.	n	e	n	w
<i>Erythronium americanum</i> L.	n	f	n	.
<i>Eupatorium maculatum</i> L.	n	e	n	.
<i>Eupatorium perfoliatum</i> L.	n	e	n	.
<i>Eupatorium rugosum</i> Houtt.	n	f	n	w
<i>Eupatorium</i> sp.	n	e	n	.
<i>Euthamia graminifolia</i> (L.) Nutt	n	o	n	.
<i>Fagus grandifolia</i> Ehrh.	n	f	n	a
<i>Fragaria</i> sp.	n	e	n	a
<i>Fraxinus americana</i> L.	n	f	n	w
<i>Fraxinus nigra</i> Marsh.	n	f	n	w
<i>Fraxinus pennsylvanica</i> Marsh.	n	e	n	w
<i>Galeopsis tetrahit</i> L.	i	.	n	.
<i>Galium asprellum</i> Michx.	n	e	n	.
<i>Galium palustre</i> L.	n	.	n	.
<i>Galium triflorum</i> Michx.	n	e	n	a
<i>Gaultheria procumbens</i> L.	n	f	n	a
<i>Geranium robertianum</i> L.	n	f	n	.
<i>Geum canadense</i> Jacq.	n	f	n	a

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Geum macrophyllum</i> Willd.	n	f	n	.
<i>Geum</i> sp.	n	e	.	.
<i>Geum virginianum</i> L.	n	f	n	.
<i>Glechoma hederacea</i> L.	i	e	n	.
<i>Glyceria melicaria</i> (Michx.) C. E. Hubbard.	n	e	y	.
<i>Glyceria</i> sp.	.	.	.	.
<i>Glyceria striata</i> (Lam.) A. Hitchc.	n	o	n	.
<i>Gymnocarpium dryopteris</i> (L.) Newman.	n	f	n	.
<i>Hackelia virginiana</i> (L.) Johnston.	n	f	n	.
<i>Helianthus</i> sp.	n	e	.	.
<i>Hemerocallis fulva</i> (L.) L.	i	.	n	.
<i>Hepatica</i> sp.	n	f	n	.
<i>Hesperis matronalis</i> L.	i	e	n	.
<i>Hieracium caespitosum</i> Dumort.	i	e	n	.
<i>Hieracium flagellare</i> Wild.	i	e	n	.
<i>Hieracium</i> sp.	.	.	.	.
<i>Hydrocotyle americana</i> L.	n	.	y	.
<i>Hydrophyllum</i> sp.	n	e	.	.
<i>Hypericum perforatum</i> L.	i	o	n	w
<i>Hypericum punctatum</i> Lam.	n	e	n	.
<i>Hypericum</i> sp.	.	.	.	.
<i>Ilex verticillata</i> (L.) Grai	n	f	n	.
<i>Impatiens capensis</i> Meerb.	n	e	n	a
<i>Impatiens</i> sp.	n	e	.	.
<i>Iris versicolor</i> L.	n	o	n	w
<i>Juglans cinerea</i> L.	n	f	n	.
<i>Juglans nigra</i> L.	i	f	n	a
<i>Juncus inflexus</i> L.	i	o	n	.
<i>Juncus secundus</i> P. Beauv.	n	.	n	.
<i>Juncus</i> sp.	.	.	.	.
<i>Juniperus communis</i> L. var. <i>depressa</i> Pursh	n	e	n	a
<i>Lactuca biennis</i> (Moench) Fern.	n	e	n	.
<i>Lactuca canadensis</i> L.	n	e	n	.
<i>Lactuca serriola</i> L.	i	o	n	.
<i>Lamiaceae</i> sp.	.	.	.	.
<i>Laportea canadensis</i> (L.) Wedd.	n	f	n	.
<i>Lathyrus latifolius</i> L.	i	.	n	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Ledum groenlandicum</i> Oeder.	n	e	n	.
<i>Leonurus cardiaca</i> L.	i	.	n	.
<i>Liliaceae</i> sp.	i	f	.	.
<i>Linaria vulgaris</i> Miller.	i	e	n	w
<i>Lithospermum officinale</i> L.	i	e	n	.
<i>Lonicera canadensis</i> Bartr.	n	e	n	a
<i>Lonicera oblongifolia</i> (Goldie) Hook	n	e	n	a
<i>Lycopodium complanatum</i> L.	n	f	n	.
<i>Lycopodium obscurum</i> L.	n	f	y	.
<i>Lycopodium</i> sp.	n	f	.	.
<i>Lycopus</i> sp.	.	.	.	.
<i>Lycopus uniflorus</i> Michx.	n	e	n	.
<i>Lysimachia ciliata</i> L.	n	e	n	w
<i>Lysimachia nummularia</i> L.	i	e	n	.
<i>Lythrum salicaria</i> L.	i	e	n	w
<i>Maianthemum canadense</i> Desf.	n	f	n	a
<i>Matteuccia struthiopteris</i> (L.) Torado.	n	f	n	.
<i>Medeola virginiana</i> L.	n	f	n	.
<i>Medicago lupulina</i> L.	i	o	n	.
<i>Medicago sativa</i> L.	i	e	n	w
<i>Mentha arvensis</i> L.	n	e	n	.
<i>Mentha</i> sp.	.	.	.	.
<i>Mitchella repens</i> L.	n	f	n	a
<i>Mitella diphylla</i> L.	n	f	n	.
<i>Monotropa uniflora</i> L.	n	f	n	w
<i>Morus alba</i> L.	i	o	n	a
<i>Nemopanthus mucronatus</i> (L.) Loes	n	.	y	.
<i>Nepeta cataria</i> L.	i	o	n	.
<i>Onoclea sensibilis</i> L.	n	e	n	w
<i>Oryzopsis racemosa</i> (Smith) Ricker.	n	f	n	.
<i>Oryzopsis</i> sp.	n	f	.	.
<i>Osmorhiza</i> sp.	.	f	.	.
<i>Osmunda cinnemomea</i> L.	n	e	n	.
<i>Osmunda claytoniana</i> L.	n	e	n	w
<i>Osmunda regalis</i> L.	n	e	n	.
<i>Ostrya virginiana</i> (Mill.) K. Koch	n	e	n	w
<i>Oxalis</i> sp.	n	e	.	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Oxalis stricta</i> L.	n	e	n	.
<i>Panax trifolius</i> L.	n	f	y	.
<i>Panicum</i> L.	.	.	.	.
<i>Parthenocissus vitacea</i> (Knerr) Hitchc.	n	e	n	a
<i>Pastinaca sativa</i> L.	i	e	n	w
<i>Phalaris arundinacea</i> L.	n	e	n	.
<i>Phleum pratense</i> L.	i	e	n	.
<i>Phlox divaricata</i> L.	n	o	n	.
<i>Phryma leptostachya</i> L.	n	f	n	.
<i>Physalis heterophylla</i> Nees.	n	e	n	a
<i>Picea glauca</i> (Moench) Voss.	n	e	n	w
<i>Picea mariana</i> (Miller) BSP.	n	e	n	.
<i>Pinus banksiana</i> Lambert.	n	e	y	w
<i>Pinus resinosa</i> Aiton.	n	e	n	w
<i>Pinus strobes</i> L.	n	f	n	w
<i>Plantago major</i> L.	i	e	n	a
<i>Plantago</i> sp.	.	.	.	a
<i>Poa annua</i> L.	i	o	n	.
<i>Poa palustris</i> L.	n	o	n	.
<i>Poa pratensis</i> L.	i	o	n	.
<i>Poa</i> sp. 2	.	.	.	.
<i>Poa</i> sp.	.	.	.	.
<i>Poaceae</i> sp. 2	.	.	.	.
<i>Poaceae</i> sp.	.	.	.	.
<i>Polygala paucifolia</i> Wild.	n	f	n	.
<i>Polygonatum pubescens</i> (Willd.) Pursh	n	f	n	a
<i>Polygonum cilinode</i> Michx.	n	f	n	.
<i>Polygonum convolvulus</i> L.	i	e	n	.
<i>Polygonum sagittatum</i> L.	n	e	n	a
<i>Polygonum</i> sp.	.	.	n	.
<i>Populus balsamifera</i> L.	n	e	n	w
<i>Populus deltoides</i> Marshall.	n	e	n	w
<i>Populus grandidentata</i> Michx.	n	e	n	w
<i>Populus</i> sp.	.	.	.	.
<i>Populus tremuloides</i> Michx.	n	e	n	w
<i>Potentilla argentea</i> L.	i	o	n	.
<i>Potentilla norvegica</i> L.	n	o	n	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Potentilla recta</i> L.	i	e	n	w
<i>Prenanthes alba</i> L.	n	f	n	.
<i>Prenanthes altissima</i> L.	n	f	n	w
<i>Prunella vulgaris</i> L.	i	e	n	.
<i>Prunus nigra</i> Ait.	n	o	n	a
<i>Prunus pennsylvanica</i> L.	n	e	n	a
<i>Prunus pumila</i> L.	n	o	n	a
<i>Prunus serotina</i> Ehrh.	n	e	n	a
<i>Prunus virginiana</i> L.fil.	n	e	n	a
<i>Pteridium aquilinum</i> (L.) Kuhn	n	f	n	w
<i>Pyrola elliptica</i> Nutt.	n	f	n	w
<i>Pyrola rotundifolia</i> L.	n	f	n	.
<i>Pyrus malus</i> L.	i	e	n	.
<i>Quercus macrocarpa</i> Michx.	n	e	n	.
<i>Quercus rubra</i> L.	n	f	n	.
<i>Ranunculus abortivus</i> L.	n	f	n	a
<i>Ranunculus acris</i> L.	i	e	n	a
<i>Ranunculus recurvatus</i> Poir.	n	f	n	.
<i>Rhamnus alnifolia</i> L'Her.	n	e	n	.
<i>Rhamnus cathartica</i> L.	i	e	n	a
<i>Rhamnus frangula</i> L.	i	e	n	a
<i>Rhus typhina</i> L.	n	o	n	a
<i>Ribes americanum</i> Mill.	n	e	n	a
<i>Ribes cynosbati</i> L.	n	e	n	a
<i>Ribes glandulosum</i> Grauer	n	f	n	a
<i>Ribes hirtellum</i> Michx.	n	f	n	a
<i>Ribes lacustre</i> (Pers.) Poir.	n	e	n	a
<i>Ribes sativum</i> Sime.	i	e	n	a
<i>Ribes sp.</i>	.	e	n	a
<i>Ribes triste</i> Pall.	n	f	n	a
<i>Rosa blanda</i> Aiton.	n	e	n	.
<i>Rosa sp.</i>	n	e	n	.
<i>Rubus alleghaniensis</i> Porter	n	e	n	a
<i>Rubus flagellaris</i> Willd.	n	e	y	a
<i>Rubus hispidus</i> L.	n	e	n	a
<i>Rubus idaeus</i> L.	n	e	n	a
<i>Rubus occidentalis</i> L.	n	e	n	a

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Rubus odoratus</i> L.	n	f	n	a
<i>Rubus pubescens</i> Raf.	n	f	n	a
<i>Salix bebbiana</i> Sarg.	n	e	n	w
<i>Salix discolor</i> Muhl.	n	e	n	w
<i>Salix</i> sp.	n	e	n	w
<i>Sambucus canadensis</i> L.	n	f	n	a
<i>Sambucus racemosa</i> L.	n	f	n	a
<i>Sanguinaria canadensis</i> L.	n	f	n	.
<i>Sanicula</i> sp.	n	f	.	.
<i>Sanicula marilandica</i> L.	n	f	n	.
<i>Satureja vulgaris</i> (L.) Fritsch	i	e	n	w
<i>Schizachne purpurascens</i> (Torr.) Swallen	n	f	n	.
<i>Scirpus atrovirens</i> Willd.	n	o	n	.
<i>Scirpus cyperinus</i> (L.) Kunth	n	o	n	.
<i>Scirpus</i> sp.	.	.	.	.
<i>Scutellaria lateriflora</i> L.	n	f	n	.
<i>Shrub</i> sp.	.	.	.	.
<i>Silene vulgaris</i> (Moench) Garcke.	i	e	n	.
<i>Sisyrinchium montanum</i> Greene.	n	o	n	.
<i>Smilacina racemosa</i> (L.) Desf.	n	f	n	a
<i>Smilacina stellata</i> (L.) Desf.	n	e	n	.
<i>Solanum dulcamara</i> L.	i	e	n	a
<i>Solidago caesia</i> L.	n	f	n	w
<i>Solidago canadensis</i> L.	n	e	n	w
<i>Solidago flexicaulis</i> L.	n	f	n	w
<i>Solidago nemoralis</i> Ait.	n	f	n	.
<i>Solidago rugosa</i> Ait.	n	e	n	w
<i>Solidago</i> sp.	n	e	.	.
<i>Sorbus Americana</i> Marshall.	n	e	n	.
<i>Sorbus decora</i> (Sarg.) Schneider.	n	e	n	a
<i>Spiraea alba</i> Du Roi	n	e	n	w
<i>Stachys tenuifolia</i> Willd.	n	o	n	.
<i>Streptopus</i> sp. Michx.	n	f	n	a
<i>Taraxacum officinale</i> Weber	i	e	n	.
<i>Thalictrum dioicum</i> L.	n	f	n	.
<i>Thalictrum pubescens</i> Pursh.	n	e	n	.
<i>Thalictrum</i> sp.	n	e	.	.

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Thelypteris noveboracensis</i> L.	n	f	n	.
<i>Thelypteris palustris</i> Schott.	n	e	n	.
<i>Thelypteris phegopteris</i> L.	n	f	n	.
<i>Thuja occidentalis</i> L.	n	e	n	w
<i>Tiarella cordifolia</i> L.	n	e	n	.
<i>Tilia americana</i> L.	n	e	n	w
<i>Toxicodendron radicans</i> (L.) Kuntze.	n	e	n	.
<i>Tree</i> sp.	.	.	.	.
<i>Triadenum virginicum</i> (L.) Raf.	n	o	y	.
<i>Trientalis borealis</i> Raf.	n	f	n	.
<i>Trifolium pratense</i> L.	i	e	n	a
<i>Trifolium repens</i> L.	i	e	n	.
<i>Trifolium</i> sp.	.	e	.	.
<i>Trillium cernuum</i> L.	n	f	n	.
<i>Trillium erectum</i> L.	n	e	n	a
<i>Trillium grandiflorum</i> (Michx.) Salisb.	n	f	n	.
<i>Trillium</i> sp.	n	f	n	.
<i>Tsuga canadensis</i> (L.) Carr.	n	f	n	w
<i>Tussilago farfara</i> L.	i	o	n	.
<i>Ulmus americana</i> L.	n	e	n	w
Unknown	.	.	.	.
<i>Urtica dioica</i> var. <i>procera</i> (Muhl.) Wedd.	n	.	n	.
<i>Urtica dioica</i> var. <i>dioica</i> L.	i	e	n	.
<i>Uvularia grandiflora</i> L.	n	f	n	.
<i>Uvularia</i> sp.	n	f	n	.
<i>Vaccinium angustifolium</i> Ait.	i	f	n	a
<i>Vaccinium corymbosum</i> L.	n	e	n	.
<i>Vaccinium myrtilloides</i> Michx.	n	e	n	.
<i>Vaccinium</i> sp.	n	e	n	.
<i>Verbascum thapsus</i> L.	i	e	n	w
<i>Verbena hastata</i> L.	n	o	n	.
<i>Veronica officinalis</i> L.	i	e	n	w
<i>Veronica serpyllifolia</i> L.	n	e	n	.
<i>Viburnum acerifolium</i> L.	n	f	n	a
<i>Viburnum cassinoides</i> L.	n	f	n	a
<i>Viburnum lentago</i> L.	n	e	n	a
<i>Viburnum opulus</i> var. <i>americanum</i> Aiton	n	f	n	a

Appendix 1 continued

<u>species</u>	<u>origin</u>	<u>habitat</u>	<u>rare</u>	<u>dispersal</u>
<i>Viburnum opulus</i> var. <i>opulus</i> L.	i	f	n	a
<i>Viburnum rafinesquianum</i> Shultes.	n	f	n	a
<i>Vicia cracca</i> L.	i	e	n	.
<i>Viola palustris</i> L.	n	f	n	.
<i>Viola blanda</i> Willd.	n	f	n	.
<i>Viola canadensis</i> L.	n	e	n	.
<i>Viola conspersa</i> Reichb.	n	e	n	.
<i>Viola cucullata</i> Aiton.	n	e	n	.
<i>Viola macloskeyi</i> Lloid.	n	f	n	.
<i>Viola pubescens</i> Ait.	n	f	n	a
<i>Viola sororia</i> Willd.	n	e	n	.
<i>Viola</i> sp.	n	e	n	.
<i>Vitis riparia</i> Michx.	n	e	n	.
<i>Waldsteinia fragarioides</i> (Michx.) Tratt.	n	e	n	.
<i>Zanthoxylum americanum</i> Mill.	n	e	n	a

Appendix 2: Number of species found per site in the following species richness

categories: total, total forest, native forest, rare forest, animal-dispersed forest,

introduced, wind-dispersed, open-habitat and edge.

Site	Total species richness	Total forest species richness	Native forest species richness	Rare forest species richness	Animal- dispersed forest species richness	Introduced species richness	Wind- dispersed species richness	Open- habitat species richness	Edge species richness
1	46	9	8	0	4	6	9	2	29
2	71	27	27	1	9	9	23	3	36
3	79	28	28	1	9	10	20	5	40
4	33	15	14	1	6	2	8	0	17
5	53	22	21	0	8	5	16	0	28
6	46	22	21	0	7	5	10	0	24
7	62	32	32	0	8	5	24	1	27
8	73	21	20	0	5	12	16	5	40
9	62	18	17	0	6	7	18	3	39
10	49	9	9	0	2	13	12	4	30
11	83	33	33	2	9	4	23	4	43
12	54	14	13	0	4	10	17	0	38
13	66	13	13	1	4	9	19	4	45
14	62	20	20	0	4	7	27	4	35
15	71	32	31	1	15	6	19	2	32
16	60	20	19	1	9	2	13	3	32
17	45	16	16	1	6	4	8	3	24
18	51	10	10	0	4	12	13	2	34
19	69	24	24	0	8	10	21	1	40
20	58	30	30	1	9	1	17	1	26
21	26	7	6	0	0	3	11	1	18
22	72	21	21	0	11	11	14	4	45
23	33	10	10	1	5	4	8	1	20
24	34	11	11	0	2	4	13	1	22
25	42	10	10	0	3	3	16	0	30
26	46	16	16	1	7	7	10	2	28
27	74	44	43	0	12	4	18	0	29
28	56	20	20	1	8	3	15	3	28
29	51	16	16	0	7	10	19	2	29
30	76	42	40	1	10	7	28	3	31
31	90	46	43	4	16	11	15	4	40
32	34	10	10	0	4	6	8	2	21
33	61	23	23	1	8	4	16	1	35
34	30	9	9	1	3	5	9	0	20
35	34	13	13	0	4	2	11	1	19
36	40	20	20	1	7	6	7	2	17
37	88	37	36	2	14	7	22	1	46
38	49	17	17	0	6	5	11	2	26

Appendix 2 continued.

Site	Total species richness	Total forest species richness	Native forest species richness	Rare forest species richness	Animal- dispersed forest species richness	Introduced species richness	Wind- dispersed species richness	Open- habitat species richness	Edge species richness
39	53	20	20	1	9	9	15	2	29
40	68	30	30	1	8	5	24	2	31
41	52	19	19	1	9	7	21	1	31
42	54	9	8	0	3	13	15	5	37
43	50	17	17	0	5	7	15	1	30
44	31	10	10	0	4	6	10	1	19
45	51	20	18	0	6	14	15	2	28
46	47	18	16	0	10	11	9	0	27
47	55	16	15	0	6	11	17	5	33
48	58	23	21	1	8	11	11	1	31
49	41	13	12	0	2	7	11	2	25
50	54	16	16	0	7	8	18	1	33

Appendix 3: Percent forest cover and landscape types of each site at four scales. f: forest land cover, a: agriculture land cover, u: urban land cover.

Sites	<u>Percent Forest Cover at Different Scales</u>				<u>Landscape Types at Different Scales</u>			
	200 m	500 m	1000 m	1400 m	200 m	500 m	1000 m	1400 m
1	28.8	46.6	60.6	51.1	.	f	f	f
2	53.3	58.9	52.4	50.7	f	f	f	f
3	49.0	66.8	72.4	70.1	f	f	f	f
4	31.2	35.1	36.0	42.1	.	f	f	f
5	3.0	17.9	38.8	42.3	a	.	f	f
6	3.5	24.5	41.9	49.5	.	.	f	f
7	34.1	38.0	47.3	44.7	.	f	f	f
8	31.6	42.1	40.8	41.7	.	f	f	f
9	9.0	12.7	19.3	19.3	u	u	u	.
10	12.9	40.6	46.7	36.0	u	f	f	f
11	27.8	35.2	46.5	48.7	a	f	f	f
12	15.6	25.0	35.3	39.8	a	a	f	f
13	33.5	51.7	55.1	58.3	.	f	f	f
14	53.7	75.3	73.6	74.7	f	f	f	f
15	30.5	53.3	56.5	47.6	.	f	f	f
16	20.5	44.8	44.3	52.4	a	f	f	f
17	5.5	49.7	64.8	60.3	a	f	f	f
18	13.5	50.3	58.4	50.1	a	f	f	f
19	21.8	38.0	44.4	40.6	a	f	f	f
20	10.6	31.0	41.5	46.6	a	.	f	f
21	17.1	17.6	24.9	22.9	.	a	.	a
22	6.8	7.0	4.2	3.9	.	.	a	a
23	9.3	7.6	5.2	5.9	a	a	a	a
24	0.0	0.0	0.3	0.3	a	a	a	a
25	11.2	14.0	14.0	21.5	.	.	a	a
26	0.0	2.9	3.7	10.0	a	a	a	a
27	0.0	1.4	6.9	7.2	a	a	a	a
28	11.8	12.3	14.5	12.2	a	a	a	a
29	0.0	0.4	4.1	5.4	a	a	a	a
30	35.6	33.8	22.1	18.6	f	.	a	a
31	6.7	3.3	1.2	0.8	a	a	a	a
32	2.5	2.1	0.7	1.8	a	a	a	a
33	1.5	10.5	13.1	23.7	a	a	a	a
34	0.0	13.5	9.4	9.5	a	a	a	a
35	10.0	2.6	3.4	10.9	a	a	a	a
36	0.0	1.5	13.7	15.1	a	a	a	a
37	5.5	4.7	11.2	14.0	a	a	a	a
38	0.0	0.0	0.0	1.3	a	a	a	a
39	20.4	30.2	22.5	18.6	a	a	a	a
40	0.9	15.5	22.1	25.1	a	a	a	a

Appendix 3 continued.

<u>Sites</u>	<u>Percent Forest Cover at Different Scales</u>				<u>Landscape Types at Different Scales</u>			
	200 m	500 m	1000 m	1400 m	200 m	500 m	1000 m	1400 m
41	9.0	9.4	7.0	5.9	u	u	u	u
42	0.6	12.4	11.0	10.6	u	u	u	u
43	5.0	12.7	15.9	15.2	u	u	u	u
44	5.0	5.2	2.6	4.2	u	u	u	u
45	6.5	3.3	7.9	9.7	u	u	u	u
46	0.0	0.2	6.0	6.3	u	u	u	u
47	0.9	5.6	6.0	10.1	u	u	u	u
48	0.0	0.0	0.4	0.5	u	u	u	u
49	0.0	0.0	2.0	1.3	.	u	u	u
50	1.7	0.8	0.5	1.1	u	u	u	u