**INFLUENCE OF CANOPY COVER AND LANDSCAPE
STRUCTURE ON PROPORTION OF ALIEN AND
SHADE-INTOLERANT PLANT SPECIES IN FOREST SITES**

By

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The requirements for the degree of

Masters of Science

Department of Biology

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PLANT SPECIES IN FOREST SITES**

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Neil C. Charbonneau, B.Sc.H.

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Chair, Department of Biology

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ABSTRACT

Herbaceous and woody seedling vegetation was sampled in the summer of 1999 in 192 forest sites (2 X 1m² quadrats in each) across the Ottawa, Ontario region to test the prediction that proportion of alien/shade-intolerant plant species in forest sites is negatively related to openness of forest site canopy and distance to nearest forest edge, and positively related to amount of open habitat in the landscape surrounding the sites, and road density surrounding the sites. Open habitat and road density were measured within 50 m, 100 m, 200 m, 500 m, 1000 m, and 2000 m of each site to test for scale effects. Proportion of alien/shade-intolerant species in forest sites did not show strong relationships with any of the predictor variables, however, it was affected as follows, in decreasing order of strength of the relationships: canopy (negative; $R^2 = 0.0893$ to 0.1533 , $p < 0.0001$) > open habitat (positive; $R^2 = 0.0339$ to 0.0632 , $p < 0.0001$ to 0.0063) > road density (negative; $R^2 = 0.0216$ to 0.0316 , $p = 0.0084$ to 0.0323) >> distance to nearest edge (not significant). Most alien species will probably not become properly established in forest patches that have adequate canopy cover. We suggest that compared to overhead canopy cover, amount of open habitat and road density in the surrounding landscape are relatively unimportant in affecting alien/shade-intolerant plant establishment in forest patches. Although amount of surrounding open habitat and road density seemed to have the greatest effect at scales of 200 to 500 m and 100 m respectively, these scale effects are probably just reflections of the variability in those predictor data at those scales.

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INTRODUCTION

Alien plant species can displace and reduce populations of native plant and animal species within forests, and this, in turn, may have detrimental consequences for ecosystem functioning and structure (Hobbs and Huenneke, 1992; Trombulak and Frissell, 2000). Although many alien species may have little ecological impact (Robinson et al., 1994; Levine and D'Antonio, 1999), some are unpalatable to animal populations (Kourtev et al., 1999), can alter soil litter depth, nutrient cycling, and pH (Kourtev et al., 1998), suppress native tree species in the long-term and show allelopathy (Wyckoff and Webb, 1996; Meiners et al., 2002), and may even competitively exclude certain native plants altogether (Ehrenfeld, 1997).

Numerous site factors have been implicated in determining the distribution of alien plant species. These factors include: species diversity (see a review by Levine and D'Antonio, 1999), disturbance history (Johnstone, 1986; Hobbs and Huenneke, 1992; Cowie and Werner, 1993; Hobbs and Humphries, 1995; Kobayashi et al., 1997; Kourtev et al., 1998; Parendes and Jones, 2000), soil moisture (Wester and Juvik, 1983; Fleischmann, 1997), and site productivity (Robertson et al., 1994). Of the various site factors that may determine the abundance of alien/shade-intolerant plants in a forest, overhead canopy cover should be one of the most important. The majority of alien species are shade-intolerant probably because they were either advertently or inadvertently introduced through agriculture (for instance see Ehrenfeld, 1997; Kobayashi et al., 1997; Kourtev et al., 1998; Lugo and Gucinski, 2000; Meiners et al., 2002; Saunders et al., 2002). Therefore, a sparser canopy should facilitate the germination and establishment of these species (Brothers and Spingarn, 1992; Wein et

al., 1992; Hutchinson and Vankat, 1997). Germination and growth of many of these species in forests with dense canopy should be practically impossible. However, canopy may be temporarily thinned out due to crown loss by disturbances such fire, tornadoes, hurricanes, and ice storms, or by forest management practices. As a result, the propagules of alien/shade-intolerant plant species in forest soil may be released from suppression, which may have consequences for other forest plant species or other forest phyla (for instance see Wyckoff and Webb, 1996).

Most alien plant species, due to shade-intolerance, are also associated with open and disturbed habitat, particularly old fields and roadsides (Janzen, 1983; Wester and Juvik, 1983; Whitmore, 1989; Brothers and Spingarn, 1992; Wein et al., 1992; Cowie and Werner, 1993; Boutin et al., 1994; Lonsdale and Lane, 1994; Ehrenfeld, 1997; Kobayashi, 1997; Boutin and Jobin, 1998; Forman and Alexander, 1998; Kourtev et al., 1998; Spellerberg, 1998; Levine and D'Antonio, 1999; Lugo and Gucinski, 2000; Parendes and Jones, 2000; Trombulak and Frissell, 2000; Freemark et al., 2002; Meiners et al., 2002). Accessibility of forest patches to alien plant species from open and disturbed habitat affects woody and herbaceous species composition in forest patches (Hobbs and Huenneke, 1992). Therefore, the number of alien/shade-intolerant plant species in forest patches should increase with proximity to nearest forest edge and increasing amount of open and disturbed habitat surrounding the patches.

Since there are typically more alien/shade-intolerant plant species in open habitats, we should expect more of those species in forest sites that are closer to forest-field edges (Brothers and Spingarn, 1992; Hobbs and Huenneke, 1992; Forman and Deblinger, 2000; Laurance et al., 2002). This is based on the assumption that forest edges represent a

transition zone between forest and open habitat flora, and consequently will have species typical of both habitat types (Gysel, 1951; Matlack, 1994; Boutin and Jobin, 1998; Williams-Linera et al., 1998).

Clearing of forests for agriculture and urbanization is a worldwide phenomenon. In areas of intense agricultural activity, forests are often reduced to small, isolated “islands” in a matrix of agricultural/old field habitat, which is much different from forest in insolation levels, humidity, and plant species composition. Habitat loss and fragmentation have been the major focus of many deforestation studies. However, relatively few studies have looked into the association between landscape matrix and abundance of alien/shade-intolerant plant species in forest. Those that exist examine primarily the abundance of alien species with distance from forest-field edges (Brothers and Spingarn, 1992; Burke and Nol, 1998; Forman and Deblinger, 2000; Laurance et al., 2002). But there is a paucity of data relating the abundance of alien/shade-intolerant plants in forest patches to the relative amounts of open habitat (or road densities, for that matter) within a broader spatial context.

Road margins are edge-like and can be classified as disturbed habitat. They are essentially open habitat similar to abandoned old fields and many studies have shown that they are more hospitable than forests to alien/shade-intolerant plant species (Wester and Juvik, 1983; Cowie and Werner, 1993; Forman and Alexander, 1998; Spellerberg, 1998; Forman and Deblinger, 2000). Not only is there open habitat associated with road margins but there is evidence to suggest that traffic acts as a vector of seed dispersal (Lonsdale and Lane, 1994; Parendes and Jones, 2000). Roads also increase accessibility of forested areas to humans (Young, 1992; Matlack, 1993a; Jaeger, 2000; Trombulak and

Frissell, 2000). Human disturbances of the forest may disrupt and reduce native plant populations and increase invasibility of forest patches to alien/shade-intolerant plant species (Hobbs and Huenneke, 1992). Therefore, roads may also increase the invasion of forest patches by alien/shade-intolerant plant species.

The objective of this study was to assess how the proportion of alien/shade-intolerant plant species in forest sites was correlated with: (1) overhead forest canopy cover, (2) distance to nearest forest edge, (3) amount of surrounding open habitat, and (4) surrounding road density. I also wanted to see at which spatial scale(s) the matrix-related variables (3) and (4) had the greatest effect on the proportion of alien/shade-intolerant plant species in forest sites.

I predicted that canopy cover would have a strong negative effect on the percentage of plant species that are alien/shade-intolerant because shade-intolerant plants require high sunlight levels to grow and because most of the alien species that I looked at were shade intolerant. I expected that a higher percentage of forest plant species would be alien/shade-intolerant in forest sites located closer to forest edges and surrounded by more open habitat and higher road densities.

METHODS

Background and landscape characteristics

Twenty-nine 1 km² landscapes, with ten 25 m X 12.5 m vegetation sampling plots randomly distributed in each, were set up by Dr. Tom Contreras in 1997 to study the effects of forest cover on propagation of wind-dispersed versus animal-dispersed plants. Later, the plots were used to study glaze damage associated with the ice storm of 1998 in the summers of 1998 to 2001 (hereafter referred to as the Ice Storm Project). The landscapes were located in the Ottawa-Carleton region, a 2900 km² study region (Figure 1a).

The landscape surrounding the plots ranged from predominately forested to predominately open/agricultural (range in forest cover: 1% to 93% - see Appendix 1). There was a somewhat noticeable divide between the eastern and western portion of the region. The eastern portion was predominantly agricultural with greater forest fragmentation, while the western portion was more forested. In general, the dominant canopy species of eastern and western landscapes also differed. For most landscapes across the region, the major canopy species was *Acer saccharum* Marsh.. However, this species was more dominant in the western landscapes (Appendix 1). Many of the western landscapes also had *Ostrya virginiana* (Mill.) K. Koch as a predominant species (intermediate canopy class). This species did not contribute greatly to the relative canopy dominance in any of the eastern landscapes (Appendix 1). In contrast, many landscapes in the east were dominated by *Fraxinus* sp., *Populus tremuloides* Michx., and *Ulmus* sp.. In fact, *Ulmus* sp. was not a major canopy species in any of the western landscapes (Appendix 1). It is important to note, though, that these are broad generalizations about

the landscapes, and even more so about the individual plots. Tree species were distributed fairly evenly throughout the study region.

Understory stem density and species composition were highly variable among plots. The mean density of understory (DBH < 10 cm) stems among all forest plots was 0.83 (+/- 0.04) stems/m² (Appendix 1). The greatest plot understory density observed was 3.30 stems/m². Within all plots, 107 understory woody species were observed. *A. saccharum* accounted for the majority of understory stems in most plots. However, there were other species which accounted for large numbers of understory stems. *Fraxinus pennsylvanica* Marsh., *Populus tremuloides* Michx., and *O. virginiana* were also prevalent in many plots.

In general, soil characteristics are broadly different between the eastern and western portion of the Ottawa-Carleton region (unpublished data). Compared to the west, soils in the east are generally wetter, have lower litter thickness, and have deeper organic soil horizons. Soil litter in the east is slightly woodier than litter in the west. Soils in the west are sandier, while those in the east are more clayey. The presence of finer and richer soil levels in the eastern part of the Ottawa-Carleton region has resulted in greater agricultural intensity than in the west. However, most sandy or clayey soils across the region were of a loamy texture, and soil characteristics were highly variable even among plots within landscapes.

The vast majority of plots were on flat terrain (Appendix 1). Two notable exceptions are plots established in Landscapes 28 and 2 (of the Ice Storm Project) which were established on a hillside and along a ravine, respectively (slopes 45° and 39°; slope aspects 30° and 285°, respectively). Both plots were in the western part of the study

region. The median slope aspect for all plots was zero (Appendix 1).

Site design

Each vegetation sampling plot consisted of a 25 m X 12.5 m tree-sampling plot within which all stems at least 10 cm in DBH had been assessed for ice storm damage. A smaller, 12.5 m X 6.25 m “shrub-sampling” plot was nested within the larger plot wherein all stems of DBH 9.9 cm and less were assessed for damage. Within the shrub-sampling plot, two 1 m² quadrats were placed 10.5 m apart to sample woody seedling and herbaceous vegetation less than 1 m in height (Figure 1b). The long-axis of each plot was aligned in a north-south orientation with the exception of plots set up in fencerows which did not run in a north-south direction; those plots were aligned with fencerow orientation.

The mean distance between plots within landscapes (not between landscapes) was 370.8 (+/- 8.3) m (range: 29.4 m to 1012.1 m) (Table 1a). Since the (tree and shrub) plots themselves were not used in this study, locations with both quadrats will simply be referred to hereafter as sites.

Vegetation Sampling

Vegetation data in the 1 m² quadrats were collected in 1999 by Melissa Vance, David Ladd, Samantha Macko, and myself. Thus, a total of 580 quadrats (384 in forests, 196 in old fields and fencerows) was sampled. Species that could not be identified in the field were removed and stored in a vasculum (a cylindrical metal canister) supplemented with a damp paper towel to prevent drying of the specimens. Upon returning to the lab, the specimens were removed from the vasculum, pressed in herbarium sheets, and placed in a drying oven at 40°C for 24 hours. The dried specimens were later identified, in most cases to species, or at least to genus.

I categorized the species in the forest sites as either alien (i.e., introduced to the Ottawa-Carleton region, in most cases from Europe) or native, and either shade-intolerant or shade-tolerant (Appendix 2). Shade-intolerant species entailed species that were atypical of forest (shady) sites, i.e., they prefer or thrive in open habitat and/or grow well along roadsides. Of the 114 species that preferred open habitat, 73 were known to thrive along roadsides as well (Table 1b). However, some species were known to prefer solely open habitat (26 species) or solely roadsides (5 species – see Table 1b). (Gillett, 1958; Fernald, 1970; Newcomb, 1977; Niering and Olmstead, 1979; Preston, 1989; Soper and Heimbürger, 1994; Chambers et al., 1996)

Since not all shade-intolerant species were associated with both open habitat and roadsides, I examined two response variables: (1) percentage of species at each study site that prefer open habitat, and (2) percentage of species at each site that thrive along roadsides. Plants not identified to species, belonging to genera containing species in the study region of varying alien/shade-intolerant categorizations, were eliminated from the dataset because there was no way of determining what their true categorization should be. I also examined the percentage of species at each site that were alien (see Appendix 3). (Gillett, 1958; Fernald, 1970; Newcomb, 1977; Niering and Olmstead, 1979; Preston, 1989; Soper and Heimbürger, 1994; Chambers et al., 1996)

Canopy cover and distance to nearest edge were also measured at each forest study site. Canopy cover was measured using a plastic sight tube with crosshairs. An observation was made every 2 m, for a distance of 20 m, along each of four cardinal directions from the center of each vegetation sampling site. An observation entailed holding the sight tube vertically above the head and looking through the sight tube. If the

crosshairs intercepted no canopy, a "minus" was noted; otherwise, a "plus" was noted if canopy was intercepted (James and Shugart, 1970). The number of positive readings out of forty was taken as the canopy cover index for each site. Distances (in m) from forested plots to nearest forest edge were calculated using the digitized ArcView data and confirmed by measuring the distances in the field.

Quantification of Predictors in Buffers

The Carleton University library provided us with digitized topographic maps (National Topographic Data Base, Geomatics Canada) at 1:50,000 scale in MapInfo format (MapInfo Corp., Troy, NY) of forest and wetland cover, water bodies (rivers and lakes), and roads for the Ottawa-Carleton region (1997 topographic maps 31F/1, 31F/8, 31G/3, 31G/4, 31G/5, 31G/6). These maps were then converted to ArcView 3.2 format by Dr. Darren Bender. To quantify amount of open habitat and road density in landscapes surrounding the forested sites, I used Patch Analyst 2.1 in ArcView 3.2 GIS to create the following buffer radii around each of the 192 forested sites: 50 m, 100 m, 200 m, 500 m, 1000 m, 2000 m (Figure 1c). Any area that was not digitized in these maps as forest, wetland, or water body was considered open habitat such as old field or agricultural field. Percentages of buffers that were open habitat were calculated using the Avenue script `calcapl.ave`. Contreras (2002) determined that forest boundaries in the digitized maps were accurate and had changed little in the past 25 to 30 years based on comparisons between the topographic maps, air photos, unclassified Russian MK-4 satellite images (courtesy of Parks Canada; photos taken 21 May, 1991), and further ground-truthing.

I used the `calcapl.ave` script to measure the length of the road segments (in m) within each buffer. A correction factor was applied to the road lengths whereby the lengths of

paved roads that were two-lane, or city streets, were multiplied by two to represent possible wider roadside margins and higher traffic volume on these roads than on single-lane or dirt roads. Finally, I calculated road density in each buffer by summing the road lengths within the buffer and dividing by the buffer area. The results were expressed in units of km/km^2 .

Statistical Analysis

I calculated the following for forest sites: percentage of species that are alien (peralien), percentage of species that prefer open habitat (peropen), and percentage of species that thrive along roadsides (perroad) (Appendix 3). I hypothesized that these response variables were positively correlated with the amount of open habitat surrounding those forest fragments. This pre-supposes that the number of alien and shade-intolerant species is generally higher in open habitats than forest habitats. I tested this by comparing mean percentages of alien, open habitat, and roadside-thriving species in forest and open habitat (old field and fencerow) sites.

To determine if there was co-linearity between canopy cover, distance to nearest forest edge, open habitat, and road density, I calculated Pearson correlation (r) coefficients and their associated p-values for pairwise comparisons of those variables.

I performed simple linear regressions using SAS (SAS Institute, 1990) with open habitat and road density measured within the six scales as separate predictors and the variables peralien, peropen, and perroad as separate response variables. To determine at which scales open habitat and road density had the greatest effects on the variables peralien, peropen, and perroad, I compared the R^2 values among the six regressions having the same predictor variable (at each of the six scales) and same response variable.

The buffer radius (scale) that showed the highest associated R^2 value was presumed to be the distance at which the response variable was responding to that predictor most strongly.

I then conducted stepwise forward multiple regressions with the predictors open habitat and road density at the scales where they had the greatest effect on the response variables (separate multiple regressions for peralien, peropen, and perroad). These regressions also included canopy cover ("canopy") and distance to nearest forest edge ("edgedist") (see Appendix 3). To correct for lack of normality of the model residuals, square-root transformations were applied. The significance of predictor variables was based on F-values calculated for each of the variables using Type III sums of squares (SAS Institute, 1990). I conducted additional simple linear regressions to see if distance to nearest forest edge was a significant predictor of peralien, peropen, and perroad.

Additional multiple regressions were conducted with the predictors open habitat and road density measured at other scales while keeping all other variables constant. The purpose of this was to see if the trends observed in R^2 peaks derived from the simple linear regressions above were the same with the partial R^2 peaks associated with open habitat and road density in these multiple regressions.

Due to lack of spatial independence of larger buffers (500, 1000, 2000 m radii), a re-analysis of R^2 and partial R^2 values was conducted with the FOCUS software developed by Jeff Holland and Dan Bert in Dr. Fahrig's Landscape Ecology Lab at Carleton University. The FOCUS software conducts regressions many times, with each regression done on a different random set of spatially independent buffers (Holland et al. in review). In essence, this process is similar to boot strapping. If R-squares peaked at the same

buffer sizes in both the regular regressions and the FOCUS runs, I could conclude that lack of spatial independence was not relevant to the validity of the results. Peralien, peropen, and perroad were not always negatively correlated with road density at all buffer scales. As a result, instead of using peaked R^2 values to determine whether or not there was an influence of lack of spatial independence on the results associated with road density, Pearson correlation (r) coefficients were used.

RESULTS

A total of 325 plant species was sampled - 65 were alien, 114 preferred open habitat, and 79 were roadside thriving (Table 1c). Of the alien species, 3 were known to prefer neither open habitat nor roadsides, 61 preferred open habitat, and 47 were roadside thriving (Table 1b). Of the species that prefer open habitat, 73 were known to thrive along roadsides as well (Table 1b). There were 46 species that fit into all three categories (alien, open habitat, and roadside) (Table 1b).

There were, on average, higher percentages of alien, open habitat, and roadside-thriving species in open habitat (old field and fencerow) sites compared to forest sites (Figure 2; all t-test p-values < 0.0001). Canopy cover within the forest sites was significantly negatively correlated with the percentages of alien, open habitat, and roadside species (Figures 3a to 3c).

The variable canopy was not correlated with the other predictor variables ($r = -0.05$ to 0.09 ; all p-values $\gg 0.05$ - see Tables 2a,b). Correlation coefficients between distance to nearest edge and the other predictor variables were between -0.59 and -0.04 (Table 2b). Distance to nearest edge was more strongly negatively correlated with amount of surrounding open habitat than with road density (Table 2b). Open habitat and road density were weakly to moderately correlated with each other. Correlation coefficients between open habitat and road density at all buffer scales were between 0.18 and 0.39 (all p-values < 0.05) (Table 2c). The largest correlation ($r = 0.39$, $p < 0.0001$) was found at 500 m and the weakest correlation ($r = 0.18$, $p = 0.0148$) was at a buffer radius of 1000 m. The response variables peralien, peropen, and perroad were strongly correlated with each other, indicating that most of the alien species I looked at were also shade-intolerant

(Table 2d).

As forested site buffer size increased, the percentage of buffer that was open habitat generally increased (Figure 4a). About 75% of the entire study region is open habitat (i.e., old field, agricultural fields, urban areas). Buffers that had a radius of 500 m showed the greatest variability among sites in amount of open habitat (Figures 4a,b).

Likewise, mean road density among buffers increased as buffer size increased (Figure 5a). The average road density for the entire region is about 2.8 km/km². Without the correction factor (see Methods), the average road density for the region is approximately 1.7 km/km². Buffers of 50 m radius showed the greatest variability among sites in road density, followed closely by 100 m buffers (Figures 5a,b).

The variable peralien was most strongly correlated with surrounding open habitat within 200 m of the forested sites (Table 3, Figures 6a,b). The variables peropen and perroad were most strongly correlated with surrounding open habitat within 500 m of the forested sites (Table 3, Figures 6a,b). Peralien, peropen, and perroad were most strongly correlated with road density within 100 m (Table 3, Figures 7a,b). The trends in predictor data variability (i.e., open habitat and road density) among buffer sizes was similar to the R²/partial R² trends among buffer sizes (compare Figures 4b and 5b with Figures 6 and 7).

Table 3 shows combinations of the variables canopy (canopy cover measured directly above sites), open habitat (within given buffer sizes), and road density (within given buffer sizes) that produced the best (model R²) fit predictive models of the variables peralien, peropen, and perroad. The buffer sizes in which the response variables were most strongly correlated with open habitat and road density were the same as those

at the which the R^2 /partial R^2 values peaked in Figures 6 and 7. Distance to nearest forest edge was not a significant predictor of peralien, peropen, and perroad (Table 3). It also was not a significant predictor of them in simple linear regressions (Table 4). Generally, the response variables were correlated with the predictors in the following order: canopy > open habitat > road density >> distance to nearest edge.

Canopy cover was the strongest predictor of every response variable. All response variables were positively correlated with amount of open habitat in surrounding landscapes (Table 3). Surrounding open habitat was always a stronger predictor than road density as shown by its greater partial R^2 values. It was also a stronger predictor of peropen (percentage of species that prefer open habitat) than it was of peralien and perroad (highest partial R^2 value – see Table 3). All of the response variables were negatively correlated with road density in the surrounding landscape. Surrounding road density was a stronger predictor of perroad (percentage of species that thrive along roadsides) than it was of peralien, and peropen.

In terms of the predictor variable open habitat, lack of spatial independence of buffers did not seem to influence the results for peropen and perroad, although it might have slightly affected the results for peralien. Figure 8 shows the R^2 values associated with separate repeated FOCUS regressions with amount of surrounding open habitat as a predictor of proportion of alien/shade-intolerant species in forest sites (peralien, peropen, and perroad). No additional variation could be explained past the 500 m buffer size for peropen or perroad. However, for peralien, R^2 values peaked at 500 m but were also very close at 200, 1000, and 2000 m (Figure 8).

Peralien, peropen, and perroad were most strongly negatively correlated with road

density at 50 to 100 m (Figure 9 – notice the overlap in standard error bars). Yet at a very large scale (2000 m), the proportion of alien/shade-intolerant species in forest sites seemed to be slightly positively correlated with road density (Figure 9). Nonetheless, using the peaks of r -values associated with certain buffer scales as a guide, spatial independence did not seem to statistically affect the results associated with road density as a predictor variable (R^2 values peaked at a scale of 100m in Figures 7a,b).

DISCUSSION

Of the predictor variables studied here, canopy cover was most strongly (negatively) correlated with the proportion of alien/shade-intolerant plant species in forest sites (Table 3). My hypothesis for surrounding open habitat was weakly supported. But my hypotheses concerning road density and distance to nearest forest were not supported. The proportion of alien/shade-intolerant species in forest sites was significantly negatively correlated with surrounding road density and not significantly correlated with distance to nearest edge (Tables 3 and 4).

In order to quantify the independent effects of the predictor variables on the proportion of alien/shade-intolerant plant species in forest sites, I needed to know whether or not there were strong correlations between them. Canopy cover was not correlated with any other predictor variables (Tables 2a,b). Therefore, correlations between canopy and proportion of alien/shade-intolerant species were not likely confounded by any other predictors quantified in this study. Distance to nearest edge, on the other hand, was appreciably negatively correlated with amount of surrounding open habitat (Table 2b). Again, this is to be expected since forest sites surrounded by high amounts of open habitat are more likely to be closer to the nearest forest edge, thus producing an overall negative correlation.

Unfortunately, amount of open habitat and road density were weakly to moderately correlated with each other. This was somewhat expected. If an area has been inhabited by people for some length of time, it will probably be more open due to agricultural practices (or urbanization), which will mean there are probably more roads (Trombulak and Frissell, 2000). However, since the correlations (r) between open habitat and road

density among the six scales ranged from 0.18 to 0.39 (Table 2c), I initially concluded that amount of open habitat and road density were not appreciably confounded by each other. But it is still questionable if the independent effects of open habitat and road density on the proportion of forest site plant species that are alien/shade-intolerant were detected. In fact, at most buffer scales, open habitat and road density were slightly more correlated with each other than with the response variables (i.e., *peralien*, *peropen*, *perroad* – results not shown). At any rate, both predictors explained little variation in the proportion of forest species that are alien/shade-intolerant.

I also wanted to know if “open habitat” (old field/fencerow) sites indeed differed from the sites we classified as “forest” in terms of proportion of alien/shade-intolerant species. As Figure 2 shows, alien/shade-intolerant plant species were a significantly more prominent feature of open habitat sites. This makes sense because open habitat plots are sunnier, drier, and likely more susceptible to invasion and establishment of the propagules of plants species that are shade-intolerant. Boutin et al. (1994) and Freemark et al. (2002) found alien plant species to account for a larger portion of old field and woody fencerow flora than woodlot flora (see also Fritz and Merriam, 1993). Additionally, where there were high percentages of species in forest sites that were alien, there were likely also high percentages of species that were shade-intolerant (see Table 2d).

My hypothesis concerning canopy cover was supported. It was the strongest predictor of the proportion of alien/shade-intolerant plant species in forest sites (Table 3). Generally, there were fewer alien, open habitat, and roadside-thriving species in forest sites with more canopy (Figures 3a-c). These are the results I expected for the variables

peropen and perroad, as well as peralien based on the fact that most of the alien species were shade intolerant (Table 1b, see also Appendix 2).

Forests with thick vegetation (especially at the edge) and low disturbance levels are notably resistant to invasion (Brothers and Spingarn, 1992). Conversely, very young, disturbed forests with sparse canopy often have more alien plant species (Wein et al., 1992; Hutchinson and Vankat, 1997). Forest patch disturbances were not directly measured in this study, but my results are consistent with the above studies on the assumption that canopy cover is an index of disturbance (Robertson et al., 1994).

It is important to note, though, that there were limitations here in terms of canopy data collection and analysis. First, the method used to measure canopy cover was somewhat crude. An alternative method such as fish-eye lens exposure might have yielded more accurate canopy cover indices. For instance, fine-scale (0.5 m to 1.0 m) patchiness in canopy cover might have been accounted for. Certainly, this could be a determining factor in the success of germination of many alien/shade-intolerant plants on the forest floor. Additionally, any shading by thick ground vegetation was not accounted for because canopy readings were taken approximately 2 m above the ground.

Secondly, much stronger relationships between canopy cover and proportion of alien/shade-intolerant species would likely have been observed if the exact shade-intolerance level of each individual species (i.e., lowest percentage of full sunlight in which photosynthesis still occurs) had been factored into the analysis. Rather, species were simply classified as shade-intolerant (open habitat-preferring and/or roadside-thriving) or shade-tolerant (neither open habitat-preferring nor roadside-thriving) (Appendix 2). Consequently, the data is binary in nature and somewhat simplistic which

probably yields weaker relationships. Unfortunately, exact shade-intolerance levels of many species are simply unknown.

Forests, nevertheless, are probably more resistant than grasslands and wetlands to invasion from alien/shade-intolerant plant species because of the presence of canopy cover (Figure 2; see Wester and Juvik, 1983; Brothers and Spingarn, 1992). It is well accepted that grasslands, in particular, are prone to invasion from alien/shade-intolerant plants (for instance, see Cowie and Werner, 1992). Since most of the alien plant species in this region are shade-intolerant, it is reasonable to assume that grassland and wetland flora here will have greater invasions of alien species effected by anthropogenic land features such as old fields and possibly roads (for instance see Findlay and Houlihan, 1997; Findlay and Bourdages, 2000; see also Tyser and Worley, 1992). I predict that even in forest patches where alien/shade-intolerant species make up a large proportion of the seed bank, a dense canopy will prevent the establishment of such propagules even though they may arrive there in high numbers.

I predict that there will be more successful invasions of forests in the Ottawa-Carleton region by alien woody and herbaceous species that are shade tolerant (see also Brothers and Spingarn, 1992). For example, shade-tolerant alien species such as European Buckthorn (*Rhamnus cathartica* L.), Norway maple (*Acer platanoides* L.), Japanese Honeysuckle (*Lonicera japonica* (L.) Thunb.), Japanese Wiregrass (*Microstegium vimineum* (Trin.) A. Camus.), and Japanese Barberry (*Berberis thunbergii* DC.) can grow in forest interiors (Kourtev et al., 1998; Robertson et al., 1994; Wyckoff and Webb, 1996). These species can out-compete native forest interior species for resources and space, and may have negative impacts on forest animal populations.

Forests themselves may also act as conduits for the propagation of such species. For instance, Hutchinson and Vankat (1998) found that the spread of the shade-tolerant alien shrub Amur Honeysuckle (*Lonicera maackii* (Rupr.) Herder) was actually hindered by open habitat and facilitated very strongly by well connected forests. Therefore, we must make a diligent effort to prevent the importation of shade-tolerant alien woody and herbaceous species which may successfully invade mature forests since they will likely have a competitive advantage over native forest species and, by definition, be able to tolerate low light conditions as well.

Distance to nearest edge was not a significant predictor of proportion of alien/shade-intolerant plant species in my forest sites. I expected it to be strongly negatively correlated in this respect since forest edges should be more susceptible to invasion (Burke and Nol, 1998). First, they are spatially closer to surrounding open habitat. Secondly, forest edges are generally more disturbed habitats. There is greater plant mortality (due to higher levels of disturbance) but yet often greater growth rates in edges (due to more insolation), and there is often greater plant recruitment in edges (e.g., Williams-Linera, 1990a,b), which is why forest interiors and edges differ in species composition (Gysel, 1951; Wales, 1972; Matlack, 1993a,b; Matlack, 1994; Chen et al., 1995; Boutin and Jobin, 1998; Burke and Nol, 1998; Williams-Linera et al., 1998; but see Williams-Linera, 1990a). However, some forest patches have been noted to have much denser vegetation in the edges than in the interiors (Brothers and Spingarn, 1992; Malcolm, 1994). This thick edge vegetation may impede alien/shade-intolerant plant recruitment into forests. This may have been the case with many of the woodlots that I studied.

It is important to note, though, that this study was not originally designed to quantify edge effects, *per se*. Instead of the scattered, paired 1 m² quadrats used here, a transect design based on the protocol used by Brothers and Spingarn (1992), for instance, would likely detect more species altogether (especially those typical of the forest edge). There were also fairly large woodlots that were very convoluted in shape and had sites situated near narrow clearings that protruded into them for landowner access (pers. obs.). Sites located in such woodlots would have a relatively low proportion of species that are alien/shade-intolerant (since they have relatively little surrounding open habitat) even though they are close to a forest edge. This is likely an important confounding factor.

My hypothesis concerning amount of surrounding open habitat (see Introduction) was weakly supported. It seems that there may be a small effect of alien/shade-intolerant seed rain into forest patches. The seeds of pioneer species (most of which are shade intolerant, including aliens) are often much smaller and more well-dispersed than those of typical, shade-tolerant forest species (Whitmore, 1989). The open fields surrounding the woodlots that I looked at represent very rich sources of alien/shade-intolerant plant seeds (Figure 2). Over time, these seeds are bound to find their way into woodlots that are surrounded by large amounts of open habitat. Some of the fields surrounding my forested plots were agricultural which likely also had a positive influence on the proportion of alien/shade-intolerant species in these forest sites (see Boutin and Jobin, 1998).

It seemed that alien/shade-intolerant plant species proportion in forest sites was most strongly influenced by surrounding open habitat within 200 to 500 m (Table 3; Figures 6a,b). However, upon comparison of Figure 4b and Figures 6a,b, it became apparent that these scales of greatest correlation are probably only a reflection of the variability in the

(open habitat) predictor data at the different scales. In essence, proportion of alien/shade-intolerant species may be maximally responding to open habitat at 200 to 500 m because of the high variability in the amounts of open habitat measured at those scales within the Ottawa-Carleton region.

Unless equal variability exists in predictor variable data among different scales, it may be practically impossible to determine at which of those scales the predictor variable is truly affecting the response variable(s) most strongly. This is an important consideration because studies have found scale effects for various taxa but tell nothing of the variability in the predictor data at the various scales analysed. However, one suggested solution to this problem is to convert predictor values to z-scores (Dr. D. King, pers. comm.). Nevertheless, at all scales of measurement here, amount of surrounding open habitat was significantly (but weakly) positively correlated with percentages of species in forest sites that are alien/shade-intolerant.

Proportions of alien/shade-intolerant species in the forested sites were negatively correlated with road density (Table 3). This is a perplexing result. I expected a positive relationship based on the observation that roadsides are continually disturbed regimes, which are ideal for the germination and growth of alien/shade-intolerant species (Wester and Juvik, 1983; Hobbs and Huenneke, 1992; Trombulak and Frissell, 2000). Theoretically, more seeds of alien/shade-intolerant plants should passively (by wind) find their way into forest patches surrounded by higher road densities. There should also be more active dispersal of alien/shade-intolerant plant seeds into forest patches surrounded by higher road densities based on the premise that humans and vehicles can act as vectors of such seeds (Lonsdale and Lane, 1994). Humans and vehicles, as well as the roads

themselves, can also act as disturbance agents to facilitate the establishment of alien/shade-intolerant plants in forest patches (Matlack, 1993a; Aizen and Feinsinger, 1994; Spellerberg, 1998; Jaeger, 2000; Forman, 2000; Trombulak and Frissell, 2000).

The negative relationship between road density and alien/shade-intolerant plant species proportion in forest sites may be attributable to an overall loss of old field/agricultural habitat in areas of very high road density. The roads themselves are totally inhospitable environments for plant germination. Road margins that consist of thick crushed rock/stone dust substrate may also be inhospitable for most alien/shade-intolerant plants. Additionally, many of the country road margins in my study region are regularly mowed for visibility (pers. obs.). This may prevent many of the alien/shade-intolerant species there from setting seed, reducing the number of seeds that find their way into nearby forest patches. In effect, roads may actually decrease alien/shade-intolerant plant seed rain by reducing the amount of open habitat. It is also conceivable that the degree of alien/shade-intolerant plant invasion from roads does not manifest itself in forests or other ecosystems until after a certain period of time. Since seed rain from road margins is probably low, sufficient time may be required for adequate numbers of seeds to be deposited in forest seedbanks from roads.

The negative effect of roads on alien and shade-intolerant species in forest sites was strongest at a short distance of 100 m (Table 3; Figures 7a,b). Again, though, this scale effect is probably an artifact of the variability in the road density data (Figure 5b and Figures 7a,b; see discussion on open habitat above).

This study was limited in that abundances of alien/shade-intolerant plants along the individual road segments themselves were not quantified due to time constraints. Instead,

overall road densities, quantified with GIS, were used as a fast and easy predictor variable. It is possible that many road margins in the Ottawa-Carleton region (and others for that matter) contain no alien or shade-intolerant plant species. In fact, the occasional road margin was observed to have dense native tree growth almost abutting the road itself (pers. obs.). These road margins would likely contribute no seeds of alien/shade-intolerant plants into adjacent forest.

Implications and Future Research Recommendations

The variation in proportion of alien/shade-intolerant species explained by all of the predictor variables in this study was quite low (Tables 3 and 4). At least 77% of the total variation was not explained by the models presented here (Table 3). In particular, landscape features (open habitat and roads) seemed, overall, to be negligible determinants of the proportion of species in forest sites that are alien/shade-intolerant. It seems unlikely that surrounding open habitat, and especially roads, have a large impact in this regard.

Canopy cover, a site variable on the other hand, turned out to be a stronger predictor. From the perspective of plant establishment, this makes sense. Theoretically, canopy cover should have a strong effect on what grows on the forest floor, especially when shade-intolerant plants are considered. Due to the methodological and analytical limitations associated here with the variable canopy (see discussion on canopy above), it is likely that relationships between canopy and the variables *peralien*, *peropen*, and *perroad* were weaker than they should have been (Figures 3a-c). Regardless, it seems very plausible that shade-tolerant alien species would be better able to establish themselves than shade-intolerant alien species in the Ottawa-Carleton region, even in

forests with dense canopy cover.

I postulate that there are other site factors that determine the distribution of alien/shade-intolerant plants in forests. Certainly, overhead canopy cover should be a strong determinant. But soil-related variables like seedbank species composition, soil moisture, porosity, nutrient levels, and litter depth, as well as slope aspect, coarse woody debris, ground cover, disturbance history, site productivity, and species composition of plants originally on site should also be strong determinants (for instance see Levine and D'Antonio, 1999). To ascertain what exactly determines the success of alien/shade-intolerant plant invasions in forests, these variables need to be accurately quantified.

Unfortunately, some of these additional variables were not measured thoroughly, and most were not measured at all in this study. I strongly suspect that they would help to explain much of the roughly remaining 80% of the variation in the proportion of alien/shade-intolerant species that the models here failed to explain. There may be synergistic interactions between the landscape features open habitat and roads and some of the site variables listed above that a more inclusive study might uncover. But until such a study is conducted, it is presently unknown whether such interactions exist. A lot of the variation in the distribution of alien/shade-intolerant species in forests may also not be readily explained because it may simply depend on whether or not vacant soil patches are available for establishment. Inclusion of site ground cover may explain much of that variation. However, it did not factor in as a significant variable here (not shown).

Finally, conclusions of scale effects associated with species responses to landscape features are probably meaningless if those scale effects simply reflect the level of

variability in the matrix-associated predictor data at those scales. I suspect that in some past studies this may have been the case. If researchers are truly convinced that there is a scale effect associated with species response to some landscape variable (e.g., roads), then other statistical methods/indices may be more appropriate to quantify this (e.g., mean square error instead of R^2). It may also be conceptually difficult or impossible to select sites in a region which, when predictor data are quantified in surrounding multiple buffers, buffers of identical sizes have equal variability in that predictor data among the sites.

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Table 1a. Summary data of predictor and response variables measured within forested sites, where: plot distance = distance between all plot pairs within landscapes; canopy = canopy index (out of 40); edgedist = distance to nearest forest edge (in m); peralien = percentage of species in site that are alien; peropen = percentage of species in site that prefer open habitat; perroad = percentage of species in site that are known to thrive along roadsides; open = percentage of surrounding buffer which is open habitat (radius in m indicated by number in heading); road = road density (km/km^2) in surrounding buffers (radius in m indicated by number in heading).

	plot distance	canopy	edgedist	peralien	peropen	perroad
mean	370.8	29.04	71.60	8.54	19.21	14.65
standard deviation	207.1	5.93	66.12	12.73	18.65	16.94
standard error	8.3	0.43	4.77	0.92	1.35	1.22
observed range	29.4 - 1012.1	7.0 - 39.0	0 to 308	0 - 100	0 - 100	0 - 100

	open50	open100	open200	open500	open1000	open2000
mean	10.69	17.82	29.50	48.81	59.73	64.59
standard deviation	18.43	21.18	25.27	28.46	27.58	22.62
standard error	1.33	1.53	1.82	2.05	1.99	1.63
observed range	0 - 100	0 - 100	0 - 100	0 - 100	1.9 - 98.4	18.8 - 93.2

	road50	road100	road200	road500	road1000	road2000
mean	0.57	0.82	0.85	1.37	1.80	1.98
standard deviation	2.88	2.68	1.80	1.23	0.77	0.77
standard error	0.21	0.19	0.13	0.09	0.06	0.06
observed range	0 - 20.5	0 - 18.3	0 - 9.5	0 - 4.4	0.4 - 6.3	1 - 5.9

Table 1b. Numbers of species categorized by habitat preference, in forest sites, open habitat sites, and all sites combined (forest and open habitat). Some species were found in both forest and open habitat sites.

<u>Species categorization</u> <u>(habitat preference)</u>	Number of species in particular habitat types		
	forest sites	open habitat sites	all sites
alien only	2	0	3
open habitat only	6	8	26
roadside only	4	0	5
alien and open habitat	42	53	61
alien and roadside	34	40	47
open habitat and roadside	30	37	73
alien, open habitat, and roadside	33	40	46

Table 1c. Numbers of categorized species found solely in forest and open habitat sites and found in both forest and open habitat sites. Exact information on species and their categorizations are in Appendix 2.

	alien	open	roadside
forest	10	19	16
forest/open	36	63	45
open	19	32	18
total	65	114	79

Table 2a. Correlations (r) between canopy and open habitat, and canopy and road density.
N = 192 for each buffer size.

	buffer radius (m)	correlation with canopy (Pearson correlation coefficient (r))	p-value
open habitat	50	-0.02	0.8251
	100	0.00	0.9826
	200	-0.02	0.7879
	500	-0.02	0.7727
	1000	0.01	0.8701
	2000	-0.05	0.5220
road density	50	0.07	0.3640
	100	-0.02	0.7587
	200	-0.02	0.7894
	500	0.02	0.7631
	1000	0.09	0.2198
	2000	0.07	0.3488

Table 2b. Correlations (r) between distance to nearest edge and all other predictor variables. N = 192 for each buffer size.

	buffer radius (m)	correlation with distance to nearest edge (Pearson correlation coefficient (r))	p-value
open habitat	50	-0.43	<0.0001
	100	-0.57	<0.0001
	200	-0.59	<0.0001
	500	-0.49	<0.0001
	1000	-0.40	<0.0001
	2000	-0.31	<0.0001
road density	50	-0.13	0.0628
	100	-0.17	0.0202
	200	-0.15	0.0427
	500	-0.19	0.0084
	1000	-0.14	0.0557
	2000	-0.06	0.3735
canopy	na	-0.04	0.5511

Table 2c. Correlations (r) between amount of open habitat and road density in the Ottawa-Carleton region at the six scales of study. N = 192 for each buffer size.

Buffer radius (m)	Pearson correlation coefficient (r)	p-value
50	0.28	0.0001
100	0.20	0.0055
200	0.22	0.0025
500	0.39	<0.0001
1000	0.18	0.0148
2000	0.27	0.0002

Table 2d. Correlations (r) between the response variables peralien, peropen, and perroad.

Correlation	Pearson correlation coefficient (r)	p-value
peralien vs. peropen	0.75	< 0.0001
peralien vs. perroad	0.76	< 0.0001
peropen vs. perroad	0.82	< 0.0001

Table 3. Significant predictors of response variables in multiple regressions. Response variables were measured in 192 forest sites.

<u>Response Variable</u>	<u>Predictor Variables</u>	<u>Buffer Radius (m)</u>		<u>p-value</u>	<u>Partial R-square</u>	<u>Model R-square</u>
			<u>Correlation (Type III SS)</u>			
percentage of species that are alien (square root transformed)	canopy	n.a.	-	<0.0001	0.0893	0.1392
	open habitat	200	+	0.0063	0.0339	
	road density	100	-	0.0323	0.0216	
percentage of species that prefer open habitat (square root transformed)	canopy	n.a.	-	<0.0001	0.1533	0.2341
	open habitat	500	+	<0.0001	0.0632	
	road density	100	-	0.0214	0.0222	
percentage of species that prefer roadsides (square root transformed)	canopy	n.a.	-	<0.0001	0.1089	0.1708
	open habitat	500	+	0.0040	0.0353	
	road density	100	-	0.0084	0.0316	

Table 4. Results of simple linear regressions with distance to nearest (forest) edge as a predictor of the response variables.

<u>Response Variable</u>	<u>Predictor Variable</u>	<u>p-value</u> (Type III SS)	<u>R-square</u>
percentage of species that are alien (square root transformed)	distance to nearest edge	0.6529	0.0011
percentage of species that prefer open habitat (square root transformed)	distance to nearest edge	0.0736	0.0167
percentage of species that prefer roadsides (square root transformed)	distance to nearest edge	0.5748	0.0017

Figure 1a. A. Map showing layout of 29 1km² landscapes with sites used in this study across the Ottawa-Carleton region. Blackened region in the upper center/right portion represents the highly urbanized City of Ottawa. B. Diagram of one 1km² landscape with 10 randomly placed vegetation sampling plots located within. Courtesy of Contreras (2002).

Figure 1b. Schematic diagram of a vegetation sampling plot used in the Ice Storm Project. A smaller shrub-sampling plot (12.5 m X 6.25 m) was nested within larger tree-sampling plot (25 m X 12.5 m). Within the shrub-sampling plot two 1m² quadrats (black squares) were set up to sample woody seedling and herbaceous plants < 1 m in height. Most plots were oriented in the cardinal direction shown except in some fencerows where plots were oriented along the long-axis of fencerow (see Methods). Diagram not exactly to scale.

Figure 1c. View of buffers (50 m, 100 m, 200 m, 500 m, 1000 m, 2000 m) created around a forest site that was geo-referenced in ArcView 3.2 (GIS). Darker areas represent mostly forest and some wetlands and water bodies. Light areas represent areas that are strictly dry, open habitat (old field/agricultural field). Dark black lines represent roads, while lighter black lines represent forest or water body edges.

Figure 2. Mean percentages of species in forest (N = 192) sites and open habitat (old field/fencerow) (N = 98) sites that are alien, prefer open habitat, and thrive along roadsides. All comparisons are significantly different (t-test: $p < 0.0001$).

Figure 3a. Correlation between canopy cover over forested sites and percentage of species that are alien (N = 192). Some data points overlap.

Figure 3b. Correlation between canopy cover over forested sites and percentage of species that prefer open habitat (N = 192). Some data points overlap.

Figure 3c. Correlation between canopy cover over forested sites and percentage of species that are roadside thriving (N = 192). Some data points overlap.

Figure 4a. Mean percentage of buffer that is open habitat as a function of buffer radius.

Figure 4b. Standard error of mean percentages of buffer that is open habitat as a function of buffer radius.

Figure 5a. Mean road density in buffers of varying radii.

Figure 5b. Standard error of mean road density among buffers as a function of buffer radius.

Figure 6a. R-square for effect of amount of open habitat in various buffer sizes on percentages of forest site species that are alien, prefer open habitat, and thrive along roadsides.

R-squares are derived from simple linear regressions.

Legend: peralien (▲), peropen (●), perroad (■)

Figure 6b. Partial R-square for effect of amount of open habitat in various buffer sizes on percentages of forest site species that are alien, prefer open habitat, and thrive along roadsides.

Partial R-squares are derived from separate multiple regressions for each radius.

Legend: peralien (▲), peropen (●), perroad (■)

Figure 7a. R-square for effect of road density in various buffer sizes on percentages of forest site species that are alien, prefer open habitat, and thrive along roadsides. R-squares are derived from simple linear regressions.

Legend: peralien (▲), peropen (●), perroad (■)

Figure 7b. Partial R-square for effect of road density in various buffer sizes on percentages of forest site species that are alien, prefer open habitat, and thrive along roadsides.

Partial R-squares are derived from separate multiple regressions for each radius.

Legend: peralien (▲), peropen (●), perroad (■)

Figure 8. Results of FOCUS runs to test R-square for effect of amount of open habitat in various buffer sizes on percentages of forest site species that are alien, prefer open habitat, and thrive along roadsides.

Legend: peralien (▲), peropen (●), perroad (■)

Figure 9. Results of FOCUS runs to test Pearson correlation coefficient (r) for effect of road density in various buffer sizes on percentages of forest site species that are alien, prefer open habitat, and thrive along roadsides.

Legend: peralien (▲), peropen (●), perroad (■)

Appendix 1. General characteristics of landscapes used in this study. Canopy species compositions were calculated by Dr. T. Contreras. Landscapes are grouped into those in the eastern and western portions of the study region. LS = Landscape number.

Landscapes in the western portion of the region.

<u>LS</u>	<u>% forest cover</u>	<u>Canopy species composition in order of relative dominance</u>
<u>in landscape</u>		<u>(estimated using relative density of trees => 10 cm dbh)</u>
1	13	Acer saccharum, Acer rubrum, Fraxinus pennsylvanica
2	41	Thuja occidentalis, Fraxinus pennsylvanica
4	39	Acer saccharum, Thuja occidentalis, Ostrya virginiana
5	42	Acer saccharum, Thuja occidentalis, Ostrya virginiana
6	40	Acer saccharum, Fraxinus pennsylvanica, Ostrya virginiana
7	24	Fraxinus pennsylvanica, Fraxinus nigra, Quercus alba, Acer rubrum
8	58	Tsuga canadensis, Acer saccharum, Fraxinus pennsylvanica, Ostrya virginiana
9	38	Acer saccharum, Ostrya virginiana, Thuja occidentalis, Salix fragilis
10	28	Acer saccharum, Ostrya virginiana, Tilia americana
11	86	Acer saccharum, Ostrya virginiana, Quercus rubra
23	60	Acer saccharum, Fagus grandifolia, Fraxinus pennsylvanica
26	62	Acer saccharum, Thuja occidentalis, Fraxinus pennsylvanica, Fraxinus nigra
27	73	Acer saccharum, Ostrya virginiana
28	71	Quercus rubra, Acer rubrum
29	65	Acer saccharum, Fagus grandifolia, Ostrya virginiana
30	93	Thuja occidentalis, Ostrya virginiana

Appendix 1 continued.

Landscapes in the eastern portion of the region.

<u>% forest cover</u>			<u>Canopy species composition in order of relative dominance</u>
<u>LS</u>	<u>in landscape</u>	<u>(estimated using relative density of trees => 10 cm dbh)</u>	
3	17	Fraxinus sp., Tilia americana, Acer saccharinum	
12	33	Acer saccharum, Fraxinus pennsylvanica	
13	7	Fraxinus pennsylvanica, Fraxinus americana, Ulmus sp.	
14	21	Acer saccharum, Populus tremuloides, Tilia americana	
15	14	Fraxinus pennsylvanica, Acer rubrum, Populus tremuloides, Tilia americana	
16	10	Fraxinus pennsylvanica, Ulmus sp.	
17	29	Acer saccharum, Fagus grandifolia, Carya cordiformis, Tilia americana	
18	42	Fraxinus americana, Ulmus sp., Acer saccharum	
19	1	Tilia americana, Acer saccharum, Ulmus sp.	
20	4	Thuja occidentalis, Fraxinus americana, Tilia americana, Acer saccharum	
21	7	Fraxinus pennsylvanica, Acer saccharum, Carya cordiformis	
24	62	Populus tremuloides, Fraxinus nigra	
25	13	Acer rubrum, Populus tremuloides	

Summary information for percentage (%) forest cover in each landscape.

	<u>all landscapes</u>	<u>western landscapes</u>	<u>eastern landscapes</u>
mean	37.7	52.1	20.0
stdev	25.4	22.6	17.4
N	29	16	13
s.e.	4.7	5.7	4.8
range	1 - 93	13 - 93	1 - 62

Summary information for understory woody stem density in shrub plots in forest and open habitat (old field and fencerow) sites. Area of shrub plot = 78.125 m².

	<u>forest</u>	<u>open habitat</u>
mean	0.83	1.39
s.d.	0.61	3.64
N	192	98
s.e.	0.04	0.37
range	0.05 - 3.30	0.01 - 28.24

Appendix 1 continued.

Summary information for soil characteristics between the eastern (e) and western (w) landscapes.

moisture	w < e
litter thickness	w > e
litter texture	e - slightly woodier
organic thickness	w < e
organic texture	w-sand ; e-clay
mineral thickness	w = e
mineral texture	w-sand ; e-clay

Summary information for slope and slope aspect of study sites.

	slope of all sites (forest and open habitat)	slope (forest sites only)
mean	2.0	2.6
s.d.	4.6	5.3
N	290	192
s.e.	0.3	0.4
range	0 - 45	0 - 45
Median slope aspect	0	0

Note: The above information, especially for soil characteristics, is very broad and generalistic. Many sites over the entire region were outliers with respect to these trends.

Appendix 2. Categorization of species in forest and open (old field, fencerow) sites as alien, open habitat-preferring, and roadside-thriving (y = yes, n = no). "Habitat" indicates habitat type (f = forest, o = open habitat, f/o = both) where species were found. Species are sorted according to habitat type where they were found.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Acalypha rhomboidea</i> Raf.	f	n	y	y
<i>Acer saccharinum</i> L.	f	n	n	n
<i>Actaea pachypoda</i> Ell.	f	n	n	n
<i>Actaea</i> sp. L.	f	n	n	n
<i>Agrimonia striata</i> Michx.	f	n	n	n
<i>Alisma subcordatum</i> Raf.	f	n	n	n
<i>Alisma triviale</i> Pursh	f	n	n	n
<i>Allium tricoccum</i> Ait.	f	n	n	n
<i>Amelanchier arborea</i> (Michx.fil.) Fern.	f	n	y	y
<i>Amelanchier humilis</i> Wieg.	f	n	n	n
<i>Amphicarpa bracteata</i> (L.) Fern.	f	n	n	n
<i>Anemone quinquefolia</i> L.	f	n	n	n
<i>Anemone virginiana</i> L.	f	n	n	n
<i>Aralia nudicaulis</i> L.	f	n	n	n
<i>Arisaema atrorubens</i> (Ait.) Blume	f	n	n	n
<i>Arisaema triphyllum</i> (L.) Schott	f	n	n	n
<i>Asarum canadense</i> L.	f	n	n	n
<i>Aster acuminatus</i> Michx.	f	n	n	n
<i>Aster lateriflorus</i> (L.) Britt.	f	n	y	n
<i>Aster ptarmicoides</i> (Nees) T. & G.	f	n	y	n
<i>Betula alleghaniensis</i> Britt.	f	n	n	n
<i>Betula papyrifera</i> Marsh.	f	n	n	n
<i>Bidens connata</i> Muhl.	f	n	n	n
<i>Bidens frondosa</i> L.	f	n	y	n
<i>Boehmeria cylindrica</i> (L.) Sw.	f	n	n	n
<i>Brachyelytrum erectum</i> (Schreb.) Beauv.	f	n	n	n
<i>Carpinus caroliniana</i> Walt.	f	n	n	n
<i>Carya cordiformis</i> Wang.	f	n	n	n
<i>Cardamine bulbosa</i> (Schreb.) B.S.P.	f	n	n	n
<i>Carex communis</i> Bailey	f	n	y	y
<i>Carex crinita</i> Lam.	f	n	n	n
<i>Carex disperma</i> Dew.	f	n	n	n
<i>Carex intumescens</i> Rudge	f	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Carex pendunculata</i> Muhl.	f	n	n	n
<i>Carex trisperma</i> Dew.	f	n	n	n
<i>Caulophyllum thalictroides</i> (L.) Michx.	f	n	n	n
<i>Celastrus scandens</i> L.	f	n	n	n
<i>Circaea alpina</i> L.	f	n	n	n
<i>Clintonia borealis</i> (Ait.) Raf.	f	n	n	n
<i>Cornus alternifolia</i> L.	f	n	n	n
<i>Corylus cornuta</i> Marsh.	f	n	n	n
<i>Cypripedium</i> sp. L.	f	n	n	n
<i>Cystopteris bulbifera</i> (L.) Bernh.	f	n	n	n
<i>Danthonia spicata</i> (L.) Beauv.	f	n	y	y
<i>Dentaria diphylla</i> Michx.	f	n	n	n
<i>Diervilla lonicera</i> Mill.	f	n	y	n
<i>Dirca palustris</i> L.	f	n	n	n
<i>Dryopteris carthusiana</i> (O.F. Muell.) Watt	f	n	n	n
<i>Dryopteris disjuncta</i> (Ledeb.) C.V. Mort.	f	n	n	n
<i>Dryopteris marginalis</i> (L.) Gray	f	n	n	n
<i>Dryopteris noveboracensis</i> (L.) Gray	f	n	n	n
<i>Fagus grandifolia</i> Ehrh.	f	n	n	n
<i>Fragaria</i> sp. L.	f	n	n	n
<i>Fraxinus americana</i> L.	f	n	n	n
<i>Fraxinus nigra</i> Marsh.	f	n	n	n
<i>Galium circaezans</i> Michx.	f	n	n	n
<i>Gaultheria procumbens</i> L.	f	n	n	n
<i>Gaylussacia baccata</i> (Wang.) K. Koch	f	n	n	n
<i>Geranium robertianum</i> L.	f	n	n	n
<i>Habenaria viridis</i> var. <i>bracteata</i> (Muhl.) Gray	f	n	n	n
<i>Hepatica americana</i> (DC.) Ker	f	n	n	n
<i>Hepatica</i> sp. Mill.	f	n	n	n
<i>Hieracium vulgatum</i> Fries	f	y	y	y
<i>Hypochoeris radicata</i> L.	f	y	y	n
<i>Ilex verticillata</i> (L.) Gray	f	n	n	y
<i>Impatiens</i> sp. L.	f	n	n	n
<i>Liatris borealis</i> Nutt.	f	n	n	n
<i>Lycopodium annotinum</i> L.	f	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Maianthemum canadense</i> Desf.	f	n	n	n
<i>Medeola virginiana</i> L.	f	n	n	n
<i>Melampyrum lineare</i> Desr.	f	n	n	n
<i>Mitchella repens</i> L.	f	n	n	n
<i>Parthenium integrifolium</i> L.	f	n	n	n
<i>Pilea pumila</i> (L.) Gray	f	n	n	n
<i>Pinus</i> sp. L.	f	n	n	n
<i>Pinus strobus</i> L.	f	n	n	n
<i>Polygonatum pubescens</i> (Willd.) Pursh	f	n	n	n
<i>Polygonatum</i> sp. Mill.	f	n	n	n
<i>Polygonum cilinode</i> Michx.	f	n	n	n
<i>Polygonum pennsylvanicum</i> L.	f	n	y	y
<i>Polypodium virginianum</i> L.	f	n	n	n
<i>Populus</i> sp. L.	f	n	n	n
<i>Prenanthes altissima</i> L.	f	n	n	n
<i>Prenanthes</i> sp. L.	f	n	n	n
<i>Prenanthes trifoliata</i> (Cass.) Fern.	f	n	y	n
<i>Pteridium aquilinum</i> (L.) Kuhn	f	n	n	y
<i>Pyrola rotundifolia</i> var. <i>americana</i> L.	f	n	n	n
<i>Pyrola</i> sp. L.	f	n	n	n
<i>Quercus alba</i> L.	f	n	n	n
<i>Quercus</i> sp.L.	f	n	n	n
<i>Quercus rubra</i> L.	f	n	n	n
<i>Ranunculus abortivus</i> L.	f	n	n	n
<i>Ribes glandulosum</i> Grauer	f	n	n	n
<i>Ribes hirtellum</i> Michx.	f	n	n	n
<i>Ribes triste</i> Pall.	f	n	n	n
<i>Rubus pubescens</i> Raf.	f	n	n	n
<i>Rubus odoratus</i> L.	f	n	n	n
<i>Salix alba</i> L.	f	y	y	y
<i>Sambucus canadensis</i> L.	f	n	n	y
<i>Sanicula marilandica</i> L.	f	n	n	n
<i>Salix purpurea</i> L.	f	y	n	n
<i>Scleranthus annuus</i> L.	f	y	y	n
<i>Scutellaria lateriflora</i> L.	f	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Silene cucubalus</i> Wiebl	f	y	y	y
<i>Smilacina racemosa</i> (L.) Desf.	f	n	n	n
<i>Solidago caesia</i> L.	f	n	n	n
<i>Solidago hispida</i> Muhl.	f	n	n	n
<i>Solidago nemoralis</i> Ait.	f	n	n	n
<i>Solidago squarrosa</i> Muhl.	f	n	y	n
<i>Sonchus asper</i> (L.) Hill	f	y	y	y
<i>Sonchus oleraceus</i> L.	f	y	y	y
<i>Streptopus amplexifolius</i> (L.) DC.	f	n	n	n
<i>Streptopus roseus</i> Michx.	f	n	n	n
<i>Symphoricarpos albus</i> (L.) Blake	f	n	n	y
<i>Taxus canadensis</i> Marsh.	f	n	n	n
<i>Trientalis borealis</i> Raf.	f	n	n	n
<i>Trifolium repens</i> L.	f	y	y	y
<i>Trillium grandiflorum</i> (Michx.) Salisb.	f	n	n	n
<i>Trillium</i> sp. L.	f	n	n	n
<i>Tsuga canadensis</i> (L.) Carr.	f	n	n	n
<i>Ulmus</i> sp. L.	f	n	n	n
<i>Uvularia perfoliata</i> L.	f	n	n	n
<i>Vaccinium angustifolium</i> Ait.	f	y	n	y
<i>Viburnum acerifolium</i> L.	f	n	n	n
<i>Viburnum</i> sp. L.	f	n	n	n
<i>Viburnum cassinoides</i> L.	f	n	n	n
<i>Viola fimbriatula</i> Sm.	f	n	n	n
<i>Viola pensylvanica</i> Michx.	f	n	n	n
<i>Viola pubescens</i> Ait.	f	n	n	n
<i>Viola renifolia</i> Gray	f	n	n	n
<i>Viola rostrata</i> Pursh	f	n	n	n
<i>Abies balsamea</i> (L.) Mill.	f/o	n	n	n
<i>Achillea millefolium</i> L.	f/o	y	y	y
<i>Acer negundo</i> L.	f/o	y	y	y
<i>Acer nigrum</i> Michx. f.	f/o	n	n	n
<i>Acer rubrum</i> L.	f/o	n	n	n
<i>Acer saccharum</i> Marsh.	f/o	n	n	n
<i>Acer spicatum</i> Lam.	f/o	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Amelanchier laevis</i> Wieg.	f/o	n	n	n
<i>Anemone canadensis</i> L.	f/o	n	y	n
<i>Apocynum androsaemifolium</i> L.	f/o	n	y	y
<i>Aquilegia canadensis</i> L.	f/o	n	n	n
<i>Arctium minus</i> (Hill) Bernh.	f/o	y	y	y
<i>Arctium</i> sp. L.	f/o	y	y	y
<i>Aronia melanocarpa</i> (Michx.) Ell.	f/o	n	n	n
<i>Asclepias syriaca</i> L.	f/o	n	y	y
<i>Aster ciliolatus</i> Lindl.	f/o	n	n	n
<i>Aster cordifolius</i> L.	f/o	n	n	n
<i>Aster macrophyllus</i> L.	f/o	n	n	n
<i>Aster novae-angliae</i> L.	f/o	n	y	n
<i>Aster vimineus</i> Lam.	f/o	n	y	n
<i>Athyrium felix-femina</i> (L.) Roth	f/o	n	n	n
<i>Botrychium virginianum</i> (L.) Sw.	f/o	n	n	n
<i>Bromus ciliatus</i> L.	f/o	n	y	y
<i>Calamagrostis canadensis</i> (Michx.) Nutt.	f/o	n	y	n
<i>Carex arctata</i> (Boott)	f/o	n	n	n
<i>Carex bebbii</i> Olney	f/o	n	n	n
<i>Carex brunnescens</i> (Pers.) Poir.	f/o	n	n	n
<i>Cerastium vulgatum</i> L.	f/o	y	y	n
<i>Chrysanthemum leucanthemum</i> L.	f/o	y	y	y
<i>Circaea quadrisulcata</i> (Maxim.) Franch & Sav.	f/o	n	n	n
<i>Circaea</i> sp. L.	f/o	n	n	n
<i>Cirsium arvense</i> (L.) Scop.	f/o	y	y	y
<i>Clematis virginiana</i> L.	f/o	n	y	n
<i>Coptis groenlandica</i> (Oeder) Fern.	f/o	n	n	n
<i>Cornus stolonifera</i> Michx.	f/o	n	n	n
<i>Dalibarda repens</i> L.	f/o	n	n	n
<i>Daucus carota</i> L.	f/o	y	y	y
<i>Desmodium</i> sp. Desv.	f/o	n	n	n
<i>Elymus repens</i> (L.) Gould	f/o	y	y	y
<i>Epipactis helleborine</i> (L.) Crantz	f/o	y	n	n
<i>Equisetum arvense</i> L.	f/o	n	n	n
<i>Equisetum pratense</i> Ehrh.	f/o	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Equisetum</i> sp. L.	f/o	n	n	n
<i>Erigeron annuus</i> (L.) Pers.	f/o	n	y	y
<i>Erigeron canadensis</i> L.	f/o	n	y	y
<i>Erigeron philadelphicus</i> L.	f/o	n	n	n
<i>Eupatorium maculatum</i> L.	f/o	n	y	n
<i>Eupatorium perfoliatum</i> L.	f/o	n	n	n
<i>Fragaria vesca</i> L.	f/o	n	n	n
<i>Fragaria virginiana</i> Duchesne	f/o	n	y	n
<i>Fraxinus</i> sp. L.	f/o	n	n	n
<i>Fraxinus pennsylvanica</i> Marsh.	f/o	n	n	n
<i>Galium asprellum</i> Michx.	f/o	n	y	n
<i>Galium triflorum</i> Michx.	f/o	n	n	n
<i>Geum aleppicum</i> var. <i>strictum</i> (Ait.) Fern.	f/o	n	y	n
<i>Geum canadense</i> Jacq.	f/o	n	y	n
<i>Geum laciniatum</i> Murr.	f/o	n	y	y
<i>Hepatica acutiloba</i> DC.	f/o	n	n	n
<i>Hieracium aurantiacum</i> L.	f/o	y	y	y
<i>Hieracium pratense</i> Tausch	f/o	y	y	y
<i>Hydrocotyle americana</i> L.	f/o	n	n	n
<i>Hypericum mutilum</i> L.	f/o	n	n	n
<i>Hypericum perforatum</i> L.	f/o	y	y	y
<i>Hystrix patula</i> Moench	f/o	n	n	n
<i>Impatiens capensis</i> Meerb.	f/o	n	n	n
<i>Juniperus communis</i> L. var. <i>depressa</i> Pursh	f/o	n	n	n
<i>Linaria vulgaris</i> Hill	f/o	y	y	y
<i>Lonicera canadensis</i> Bartr.	f/o	n	n	n
<i>Lotus corniculatus</i> L.	f/o	y	y	y
<i>Lycopodium</i> sp. L.	f/o	n	n	n
<i>Lycopus americanus</i> Muhl.	f/o	n	n	n
<i>Lycopus uniflorus</i> Michx.	f/o	n	n	n
<i>Lysimachia hybrida</i> Michx.	f/o	n	n	n
<i>Lythrum salicaria</i> L.	f/o	y	y	n
<i>Matteuccia struthiopteris</i> (L.) Todaro	f/o	n	n	y
<i>Medicago sativa</i> L.	f/o	y	y	n
<i>Onoclea sensibilis</i> L.	f/o	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Ostrya virginiana</i> (Mill.) K. Koch	f/o	n	n	n
<i>Oxalis europaea</i> Jord.	f/o	n	y	y
<i>Oxalis acetosella</i> ssp. <i>montana</i> Raf.	f/o	n	n	n
<i>Pastinaca sativa</i> L.	f/o	y	y	y
<i>Parthenocissus vitacea</i> (Knerr) Hitchc.	f/o	n	n	n
<i>Phleum pratense</i> L.	f/o	y	y	y
<i>Plantago major</i> L.	f/o	y	y	y
<i>Poa saltuensis</i> Fern. & Weig.	f/o	n	y	y
<i>Populus balsamifera</i> L.	f/o	n	n	n
<i>Populus grandidentata</i> Michx.	f/o	n	n	n
<i>Polygonum convolvulus</i> L.	f/o	y	n	n
<i>Potentilla recta</i> L.	f/o	y	y	y
<i>Populus tremuloides</i> Michx.	f/o	n	n	n
<i>Prunus pensylvanica</i> L.	f/o	n	y	y
<i>Prunus serotina</i> Ehrh.	f/o	n	n	n
<i>Prunella vulgaris</i> L.	f/o	y	y	y
<i>Prunus virginiana</i> L.fil.	f/o	n	y	y
<i>Quercus macrocarpa</i> Michx.	f/o	n	n	n
<i>Ranunculus acris</i> L.	f/o	y	y	n
<i>Ranunculus pensylvanicus</i> L. f.	f/o	n	n	n
<i>Ranunculus recurvatus</i> Poir.	f/o	n	n	n
<i>Rhamnus alnifolia</i> L'Her.	f/o	n	n	n
<i>Rhamnus cathartica</i> L.	f/o	y	y	y
<i>Rhamnus frangula</i> L.	f/o	y	y	y
<i>Rhus radicans</i> L.	f/o	n	n	n
<i>Ribes americanum</i> Mill.	f/o	n	n	n
<i>Ribes cyanobasti</i> L.	f/o	n	n	n
<i>Ribes lacustre</i> (Pers.) Poir.	f/o	n	n	n
<i>Rubus alleghaniensis</i> Porter	f/o	n	y	y
<i>Rudbeckia hirta</i> L.	f/o	n	y	y
<i>Rubus idaeus</i> L. var. <i>strigosus</i> (Michx.) Maxim.	f/o	n	y	y
<i>Rumex acetosella</i> L.	f/o	y	y	y
<i>Rubus pubescens</i> Raf.	f/o	n	n	n
<i>Sanicula canadensis</i> L.	f/o	n	n	n
<i>Sanicula gregaria</i> Bickn.	f/o	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Satureja vulgaris</i> (L.) Fritsch	f/o	y	y	y
<i>Solanum dulcamara</i> L.	f/o	y	y	n
<i>Solidago canadensis</i> L.	f/o	n	y	y
<i>Solidago gigantea</i> Ait.	f/o	n	y	n
<i>Solidago graminifolia</i> (L.) Salisb.	f/o	n	y	y
<i>Solidago rugosa</i> Ait.	f/o	n	y	y
<i>Sonchus arvensis</i> L.	f/o	y	y	y
<i>Spiraea alba</i> Du Roi	f/o	n	y	n
<i>Taraxacum officinale</i> Weber	f/o	y	y	y
<i>Thuja occidentalis</i> L.	f/o	n	n	n
<i>Tilia americana</i> L.	f/o	n	n	n
<i>Tiarella cordifolia</i> L.	f/o	n	n	n
<i>Trifolium pratense</i> L.	f/o	y	y	y
<i>Trillium erectum</i> L.	f/o	n	n	n
<i>Ulmus americana</i> L.	f/o	n	n	n
<i>Urtica dioica</i> L.	f/o	y	y	y
<i>Verbascum thapsus</i> L.	f/o	y	y	y
<i>Veronica officinalis</i> L.	f/o	y	y	n
<i>Vicia cracca</i> L.	f/o	y	y	n
<i>Viburnum lentago</i> L.	f/o	n	n	n
<i>Viola canadensis</i> L.	f/o	n	n	n
<i>Vitis riparia</i> Michx.	f/o	n	n	n
<i>Vitis</i> sp. L.	f/o	n	n	n
<i>Waldsteinia fragarioides</i> (Michx.) Tratt.	f/o	n	n	n
<i>Zanthoxylum americanum</i> Mill.	f/o	n	y	y
<i>Agrimonia gryposepala</i> Wallr.	o	n	n	n
<i>Agrostis gigantea</i> Roth	o	y	y	y
<i>Alnus incana</i> (L.) Moench ssp. <i>rugosa</i> (Du Roi) Clausen	o	n	n	n
<i>Ambrosia artemisiifolia</i> L.	o	n	y	y
<i>Amelanchier sanguinea</i> (Pursh) DC.	o	n	n	n
<i>Arctium lappa</i> L.	o	y	y	n
<i>Asclepias incarnata</i> L.	o	n	n	n
<i>Aster puniceus</i> L.	o	n	n	n
<i>Aster umbellatus</i> Mill.	o	n	y	n
<i>Brassica</i> sp. L.	o	y	y	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Cardamine parviflora</i> L.	o	n	n	n
<i>Carex paupercula</i> Michx.	o	n	n	n
<i>Chenopodium album</i> L.	o	y	y	y
<i>Cirsium altissimum</i> (L.) Spreng.	o	n	n	n
<i>Cirsium discolor</i> (Muhl.) Spreng.	o	n	y	y
<i>Cirsium vulgare</i> (Savi) Tenore	o	y	y	y
<i>Eupatorium rugosum</i> Houtt.	o	n	n	n
<i>Galium boreale</i> L.	o	n	y	n
<i>Galium verum</i> L.	o	y	y	n
<i>Geranium pratense</i> L.	o	y	y	n
<i>Geum macrophyllum</i> Willd.	o	n	n	n
<i>Glechoma hederacea</i> (L.)	o	y	y	y
<i>Gratiola neglecta</i> Torr.	o	n	n	n
<i>Hydrophyllum virginianum</i> L.	o	n	n	n
<i>Lactuca scariola</i> L.	o	y	y	y
<i>lithospermum officinale</i> L.	o	y	y	y
<i>Lysimachia ciliata</i> L.	o	n	n	n
<i>Medicago lupulina</i> L.	o	y	y	y
<i>Melilotus alba</i> Desr.	o	y	y	y
<i>Mitella nuda</i> L.	o	n	n	n
<i>Nepeta cataria</i> L.	o	y	y	n
<i>Oenothera biennis</i> L.	o	n	y	y
<i>Oenothera</i> sp. L.	o	n	y	n
<i>Phlox paniculata</i> L.	o	n	n	n
<i>Phlox pilosa</i> L.	o	n	y	n
<i>Polygonum aviculare</i> L.	o	y	y	y
<i>Potentilla norvegica</i> L.	o	n	y	y
<i>Potentilla palustris</i> (L.) Scop.	o	n	n	n
<i>Potentilla simplex</i> Michx.	o	n	n	n
<i>Prunus nigra</i> Ait.	o	n	y	n
<i>Pyrola secunda</i> L.	o	n	n	n
<i>Ranunculus fascicularis</i> Muhl.	o	n	y	n
<i>Ranunculus sceleratus</i> L.	o	n	n	n
<i>Saxifraga virginiana</i> Michx.	o	n	n	n
<i>Scirpus cyperinus</i> (L.) Kunth	o	n	n	n

Appendix 2 continued.

<u>species</u>	<u>habitat</u>	<u>alien</u>	<u>open</u>	<u>roadside</u>
<i>Silene noctiflora</i> L.	o	y	y	n
<i>Solidago altissima</i> L.	o	n	y	y
<i>Solidago tenuifolia</i> Pursh	o	n	y	n
<i>Sonchus</i> sp. L.	o	y	y	y
<i>Stachys tenuifolia</i> Willd.	o	n	n	n
<i>Strophostyles helvola</i> (L.) Ell.	o	n	y	n
<i>Symplocarpus foetidus</i> (L.) Nutt.	o	n	n	n
<i>Tragopogon porrifolius</i> L.	o	y	y	y
<i>Trifolium agrarium</i> L.	o	y	y	y
<i>Trifolium hybridum</i> L.	o	y	y	y
<i>Typha latifolia</i> L.	o	n	n	n

Appendix 3. Dataset used in the analyses. Headings are as follows: site = forest site number derived from the formula: landscape number X 100 + plot id number (plots used in the Ice Storm Project); canopy = canopy index (out of 40); edgedist = distance to nearest forest edge; open = percentage of surrounding buffer that is open habitat (radius in m indicated by number in heading); road = road density (km/km²) in surrounding buffers (radius in m indicated by number in heading); peralien = percentage of species in site that are alien; peropen = percentage of species in site that prefer open habitat; perroad = percentage of species in site that are known to thrive along roadsides.

site	canopy	edgedist	open50	open100	open200	open500	open1000	open2000
101	37	23	25.315	58.386	72.260	87.249	92.067	85.819
102	33	50	0	25.190	60.314	86.014	91.616	86.268
103	33	40	23.023	36.163	51.920	82.964	90.410	84.289
104	38	57	12.449	33.700	48.026	81.733	91.427	79.829
105	31	82	0	7.501	49.205	83.175	90.671	78.264
106	32	53	0	12.913	42.257	82.549	90.359	81.418
107	32	29	43.643	50.011	61.283	84.348	89.723	79.461
109	33	10	24.556	39.312	54.326	83.452	91.214	77.375
110	34	90	0	0.163	38.848	81.567	90.654	79.793
201	29	15	17.049	34.513	53.301	49.499	47.215	60.211
202	27	43	19.762	35.410	51.995	55.016	52.310	59.389
203	28	33	25.213	37.223	47.486	64.481	54.634	60.615
204	24	34	23.379	26.073	21.110	34.484	49.091	57.290
205	31	45	0.753	14.852	24.063	34.643	45.930	58.511
206	26	38	10.027	28.584	33.496	50.124	74.965	64.083
207	36	25	5.604	25.514	45.698	67.882	70.045	64.097
301	31	14	62.137	66.406	79.556	85.051	93.980	93.083
302	23	20	24.446	43.370	58.144	82.991	61.220	92.928
303	34	25	12.249	34.003	54.003	82.991	95.116	93.189
306	22	22	54.749	42.500	41.181	82.991	95.688	92.659
307	26	26	0	19.121	60.192	83.667	95.068	92.167
309	19	20	32.984	52.313	64.451	82.991	95.725	92.114
401	34	14	34.786	55.633	70.648	58.380	67.424	70.757
402	34	52	31.166	40.472	34.724	52.082	66.274	69.476
403	21	60	0	13.165	30.546	51.492	67.004	68.048
404	27	61	0	0	10.619	59.276	68.122	64.245
405	30	56	0	9.487	30.894	56.786	67.226	63.087
406	21	0	3.625	21.513	34.823	56.999	66.771	64.150
407	23	88	0	8.908	25.882	53.656	66.880	66.517
408	35	37	0	4.461	24.303	55.228	66.738	65.884

Appendix 3 continued.

site	canopy	edgedist	open50	open100	open200	open500	open1000	open2000
409	26	112	0	0	22.029	51.281	66.333	68.059
410	27	33	22.842	30.931	55.345	64.005	68.225	71.402
501	31	73	0	0	10.931	45.280	71.370	74.427
502	20	0	32.471	42.116	55.099	53.858	70.586	74.201
504	37	37	10.199	26.392	33.512	51.786	70.391	75.940
505	33	42	40.609	44.585	39.051	52.985	70.744	76.047
506	32	72	0	1.228	18.899	60.423	70.639	76.196
507	27	105	0	0	16.904	55.183	72.462	75.328
508	37	16	1.256	19.425	34.163	54.209	72.389	75.478
509	30	90	0	0	2.249	54.823	73.082	75.528
602	34	86	0	0	14.286	35.094	54.826	74.362
603	14	209	0	0	0	30.439	56.299	73.715
604	37	166	0	0	0.089	31.603	61.938	73.936
605	31	10	11.840	22.158	23.067	39.264	65.586	72.246
606	24	31	36.468	53.800	67.863	83.474	62.631	65.117
607	34	55	0	11.213	59.284	81.928	64.532	65.180
608	31	180	0	0	4.508	55.000	71.532	70.850
609	28	142	0	0	0.244	52.594	71.413	70.556
610	27	62	0.733	9.506	29.258	63.839	74.054	70.756
701	29	0	61.488	62.948	70.722	82.333	91.475	89.926
702	38	40	24.449	29.098	42.395	75.774	91.719	90.084
703	29	67	0	21.866	62.329	80.996	91.609	90.539
705	34	73	5.286	31.120	43.356	72.516	86.079	89.753
707	31	0	0.861	18.223	29.986	71.793	86.611	87.661
708	35	50	0	3.860	24.218	69.234	88.157	88.051
709	32	0	20.829	33.966	44.305	70.313	89.346	86.302
801	39	89	0	0	2.489	35.928	47.243	60.994
802	36	23	0	14.020	23.854	34.256	45.669	60.913
803	27	3	14.737	31.488	39.614	31.865	38.064	61.355
805	31	121	0	0	6.900	31.410	44.669	78.272
806	32	45	20.389	16.731	11.379	27.125	50.418	61.991
807	29	151	0	0	3.673	33.029	50.390	62.019
808	31	121	0	2.004	14.668	32.619	55.604	64.321
809	31	101	0	0	1.271	23.207	53.342	65.132
810	31	78	29.946	32.469	36.716	29.214	54.243	62.895
906	35	24	1.536	20.869	33.360	40.385	65.773	75.202

Appendix 3 continued.

site	canopy	edgedist	open50	open100	open200	open500	open1000	open2000
907	28	19	15.457	37.093	42.862	64.685	66.502	74.257
908	30	137	0	0	7.252	49.108	63.306	75.036
909	37	96	0	0	2.189	47.188	62.397	75.085
910	35	120	0	0	6.936	49.674	62.110	74.967
1002	36	60	0	0	5.078	26.691	58.028	61.085
1003	35	80	0	0	10.460	29.390	58.759	61.546
1004	32	30	0	0	0.600	27.515	54.067	57.851
1005	32	120	0	0	0	15.285	58.386	60.861
1006	36	100	0	0	0	20.842	57.256	60.938
1008	35	120	0	0	18.681	37.535	60.118	63.585
1009	38	75	0	24.196	37.444	47.178	61.700	65.152
1010	36	80	0	0	18.432	53.198	63.025	67.218
1101	26	5	22.214	26.301	19.715	16.192	16.197	23.501
1102	36	165	0	0	0	10.142	15.541	27.572
1103	22	180	0	0	0	8.782	19.305	27.820
1104	28	267	0	0	0	11.076	20.744	27.617
1105	17	0	0	0	7.611	17.100	20.393	23.429
1106	33	230	0	0	0	15.714	28.071	30.737
1107	31	40	0	0	0.006	4.293	21.572	31.045
1108	37	22	3.052	0.939	0.387	3.287	14.415	30.070
1109	34	100	0	0	0.311	15.507	14.005	26.224
1110	29	90	0	0	0.054	9.537	13.182	27.818
1201	19	47	9.297	39.586	54.283	75.457	85.343	75.335
1202	7	26	0	16.179	38.991	76.145	86.959	75.069
1203	25	66	0	6.237	27.350	70.427	86.060	74.985
1205	24	21	9.061	32.707	51.131	66.194	79.742	74.220
1301	21	88	0	4.284	40.592	81.887	90.675	84.737
1302	31	31	22.217	38.634	56.507	84.055	92.090	85.655
1304	34	40	0	12.449	51.343	81.120	91.471	84.475
1401	27	168	0	0	9.038	61.293	86.502	86.609
1402	29	157	0	0	10.848	13.804	85.991	86.787
1403	23	161	0	0	14.419	60.275	85.380	85.902
1404	30	90	0	14.028	30.143	60.134	85.994	85.232
1406	25	23	73.021	76.105	85.852	80.022	79.515	82.538
1408	23	20	15.291	34.114	63.577	75.399	84.084	86.243
1409	21	163	0	2.432	29.008	64.145	87.130	85.735

Appendix 3 continued.

site	canopy	edgedist	open50	open100	open200	open500	open1000	open2000
1410	34	78	0	16.472	48.586	70.588	87.726	87.624
1503	30	25	48.043	62.200	66.173	82.503	86.728	92.474
1504	28	70	0	6.808	38.236	82.359	86.380	92.278
1505	27	67	19.054	34.151	54.321	82.081	85.536	92.241
1506	31	13	38.495	44.225	50.390	82.065	85.140	92.313
1509	22	88	0	4.341	38.031	82.065	84.993	92.301
1605	15	66	0	16.226	44.372	73.649	76.706	81.151
1606	27	70	0	11.221	55.079	79.854	78.384	82.215
1608	25	5	63.498	68.042	73.755	84.945	76.901	77.400
1702	26	21	25.831	43.615	62.711	86.191	59.949	85.054
1704	29	38	4.690	11.084	37.893	69.754	82.901	87.284
1705	34	13	24.978	52.428	60.145	73.641	83.324	87.513
1706	26	40	19.208	32.543	29.903	68.355	84.315	86.129
1707	21	36	0	14.551	36.482	68.763	83.448	86.700
1801	29	40	0	0.238	23.285	56.940	79.263	77.641
1802	32	59	0	4.316	30.110	61.734	77.659	76.267
1803	31	31	3.003	26.613	60.432	71.819	75.070	73.845
1805	24	17	16.308	28.438	34.673	49.991	77.702	75.333
1806	30	25	12.616	17.808	11.458	50.055	78.908	77.506
1807	19	21	0	0.817	20.412	50.565	81.382	80.541
1809	27	30	14.652	24.410	48.173	54.302	81.446	82.001
1901	23	10	45.677	47.839	53.327	76.522	90.619	87.007
1902	25	32	7.402	21.566	47.222	81.875	90.052	86.698
1903	33	49	29.977	67.844	91.961	96.041	89.391	87.471
1905	31	0	37.248	63.780	79.082	84.449	90.480	86.523
2001	33	23	9.455	28.214	59.070	88.733	96.412	88.501
2006	34	44	21.002	38.631	71.859	91.653	92.004	87.722
2007	30	47	18.331	39.776	68.689	94.242	88.976	87.207
2101	39	20	19.009	48.000	76.341	91.830	93.701	78.543
2102	26	23	39.132	59.602	77.536	88.600	95.340	83.864
2109	19	0	100.000	100.000	100.000	100.000	96.521	90.540
2301	27	23	0	0	0.346	39.441	53.048	63.041
2302	37	110	0	0	1.752	44.212	54.171	63.468
2304	30	40	0	0	10.261	38.222	49.940	57.712
2305	36	13	0.532	26.462	59.601	82.863	66.536	66.526
2306	36	50	10.938	21.333	28.503	39.207	47.919	55.123

Appendix 3 continued.

site	canopy	edgedist	open50	open100	open200	open500	open1000	open2000
2307	37	146	0	0	3.712	35.668	48.096	55.166
2309	33	90	0	0	8.538	25.171	37.650	51.891
2310	15	190	0	0	0	17.620	42.245	55.096
2403	16	25	0	0	9.252	22.032	68.822	87.978
2405	30	165	0	0.135	14.915	47.875	68.504	87.928
2406	23	117	0	0	17.639	54.276	70.183	87.749
2407	13	87	0	13.632	30.823	66.612	73.369	87.783
2408	21	121	0	0.140	27.431	72.249	75.380	87.882
2409	23	84	0	18.298	52.831	77.273	75.420	87.904
2503	30	19	100.000	91.898	89.999	97.576	98.347	88.688
2507	32	5	23.776	48.777	73.834	95.813	97.915	90.340
2601	32	5	55.515	52.762	52.578	35.811	41.311	36.599
2603	31	150	0	1.918	12.216	23.359	27.133	37.115
2604	31	73	0	0	0	12.172	25.155	37.846
2605	35	273	0	0	0	15.813	28.631	37.409
2606	23	117	0	0	0	4.602	23.828	38.694
2608	34	224	0	0	0	2.344	17.418	38.006
2609	34	15	0	0	0	0	19.827	38.619
2610	36	10	11.016	33.467	54.615	58.166	49.396	35.859
2702	26	150	0	0	12.294	10.918	11.669	86.266
2703	25	260	0	0	0.648	10.349	11.058	22.048
2704	32	213	0	0	0	6.270	10.731	23.799
2705	29	20	0	0	0	0.794	8.590	23.160
2706	20	15	19.116	40.795	42.212	12.600	9.029	19.584
2707	24	50	9.519	21.684	32.350	11.824	8.983	20.048
2708	25	10	0	13.901	30.765	11.280	10.105	20.929
2709	35	214	0	0	0	7.884	12.718	23.909
2710	11	100	0	0	0	10.440	17.347	24.246
2801	37	26	0	0	2.286	28.659	34.614	44.938
2802	34	308	0	0	0	0.875	22.527	35.991
2803	22	290	0	0	0	0	11.183	31.578
2804	29	142	0	0	0	0	10.595	34.817
2805	27	180	0	0	0	11.392	24.951	41.848
2806	25	39	0	0	5.693	26.640	32.617	45.838
2807	34	62	0	0.441	9.990	26.084	33.071	47.408
2808	26	150	0	0	0.981	20.516	31.779	48.000

Appendix 3 continued.

site	canopy	edgedist	open50	open100	open200	open500	open1000	open2000
2809	17	282	0	0	0	5.743	21.197	40.775
2810	30	203	0	0	0	7.868	22.913	40.156
2901	28	44	0.675	14.278	31.966	33.228	49.636	44.045
2902	23	41	0	0	18.011	41.217	55.443	44.283
2903	26	40	0	0	3.629	50.932	52.621	43.863
2904	38	10	38.000	29.357	43.299	38.371	45.681	42.586
2906	35	25	27.203	23.440	31.484	42.622	45.119	43.464
2907	29	10	0	0	20.330	34.147	44.149	43.439
2908	34	0	42.457	60.228	57.996	36.012	35.950	41.212
3001	32	64	68.134	25.894	12.640	16.640	20.359	23.769
3002	29	91	0	0	0	0	6.201	19.438
3003	34	36	0	0	0	0	4.104	20.134
3004	29	186	0	0	0	0	1.927	18.823
3005	24	148	0	0	0	0	2.101	20.728
3007	22	28	0	0	0	2.077	10.370	21.597
3008	33	72	0	0	0	8.376	13.687	21.636
3009	32	77	0	0	0	8.884	13.737	21.482
3010	28	3	35.683	24.969	13.910	21.960	22.099	24.642

site	road50	road100	road200	road500	road1000	road2000	peralien	peropen	perroad
101	0	0	0	2.294	3.036	1.729	0	0	0
102	0	8.818	5.965	2.528	2.956	1.739	0	0	0
103	16.662	11.746	6.275	2.543	2.607	1.886	0	0	0
104	0	0	0	3.024	2.034	1.948	0	0	0
105	0	0	4.078	3.508	1.952	2.012	33.33	33.33	33.33
106	0	6.999	5.794	3.098	1.961	1.965	10.00	10.00	10.00
107	20.498	12.120	6.316	3.682	1.899	2.046	0	0	0
109	0	0	0	3.422	1.970	2.001	0	11.11	11.11
110	0	0	4.688	3.328	1.977	1.998	0	0	0
201	0	0	2.139	1.658	2.074	1.621	25.00	25.00	25.00
202	0	0	0	2.045	2.183	1.575	5.56	27.78	16.67
203	0	0	0	1.866	2.300	1.539	5.00	10.00	5.00
204	0	0	0	0.779	1.969	1.589	0	6.67	6.67
205	0	0	0	1.103	1.824	1.612	0	16.67	0
206	0	0	0	2.949	2.562	1.464	15.38	38.46	15.38
207	0	0	3.179	4.214	2.330	1.530	14.29	14.29	14.29

Appendix 3 continued.

site	road50	road100	road200	road500	road1000	road2000	peralien	peropen	perroad
301	0	1.117	2.778	1.252	0.635	1.576	5.00	35.00	20.00
302	0	0	0	1.142	0.622	1.629	30.00	50.00	50.00
303	0	0	0	1.114	1.011	1.631	6.67	60.00	46.67
306	0	0	0	0.369	1.063	1.697	36.36	59.09	40.91
307	0	0	0	0	0.911	1.720	12.50	25.00	6.25
309	0	0	0	0.764	0.984	1.686	13.33	53.33	26.67
401	0	0	0	3.267	2.510	2.022	46.15	69.23	53.85
402	0	0	0	2.207	2.664	1.878	14.29	28.57	14.29
403	0	0	0	1.542	2.582	1.764	16.67	33.33	33.33
404	0	0	0	0	2.391	1.743	0	33.33	0
405	0	0	0	0	2.384	1.819	14.29	14.29	28.57
406	0	0	0	1.272	2.470	1.866	12.50	50.00	37.50
407	0	0	0	1.909	2.606	1.867	14.29	28.57	28.57
408	0	0	0	1.793	2.570	1.872	16.67	33.33	33.33
409	0	0	0	2.244	2.685	1.795	12.50	25.00	25.00
410	0	0	0	3.862	2.247	2.061	9.09	9.09	9.09
501	0	0	0	2.040	2.292	2.044	25.00	25.00	25.00
502	0	0	0	0.635	1.753	2.180	0	50.00	50.00
504	0	0	0	0	1.803	2.066	25.00	25.00	0
505	0	0	0	0.635	1.720	2.141	0	0	0
506	0	0	0	1.993	1.213	2.249	25.00	25.00	25.00
507	0	0	0	1.083	1.650	2.084	14.29	14.29	14.29
508	0	0	0	0.434	1.738	2.039	16.67	33.33	33.33
509	0	0	0	0	1.782	1.975	0	0	0
602	0	0	0	1.170	1.669	4.482	0	0	0
603	0	0	0	0.050	1.966	4.096	46.67	66.67	46.67
604	0	0	0	0	2.061	3.694	0	7.69	7.69
605	0	0	0	0	2.651	3.161	0	16.67	16.67
606	0	0	0	1.470	2.521	2.572	11.11	44.44	22.22
607	0	0	0	1.956	2.922	2.534	13.33	26.67	20.00
608	0	0	0	1.527	2.547	2.834	0	20.00	0
609	0	0	0	0.934	2.816	2.835	25.00	50.00	37.50
610	0	0	0	2.583	2.458	2.639	42.86	28.57	28.57
701	0	0	2.019	2.425	1.263	1.719	28.57	50.00	42.86
702	0	0	0.642	2.345	1.252	1.885	20.00	33.33	20.00
703	0	3.978	2.800	2.506	1.269	1.743	6.25	25.00	12.50

Appendix 3 continued.

site	road50	road100	road200	road500	road1000	road2000	peralien	peropen	perroad
705	0	0	4.989	2.424	1.261	2.268	18.18	45.45	36.36
707	0	0	0	2.024	1.215	2.151	6.67	40.00	26.67
708	0	0	0	2.064	1.218	2.107	0	25.00	12.50
709	0	0	0	1.531	1.443	1.964	11.11	38.89	22.22
801	0	0	0	0.398	1.279	1.459	40.00	40.00	40.00
802	0	0	0	0	1.342	1.275	15.38	15.38	7.69
803	0	0	0	0	0.966	1.297	10.00	20.00	10.00
805	0	0	0	0	1.055	1.440	0	0	0
806	0	0	0	0	1.323	1.363	12.50	12.50	25.00
807	0	0	0	0	1.343	1.452	0	33.33	16.67
808	0	0	0	0	1.380	1.533	16.67	27.78	11.11
809	0	0	0	0	1.251	1.644	0	15.38	7.69
810	0	0	0	0.808	0.777	1.704	10.00	0	0
906	0	9.051	6.134	2.740	2.223	1.796	0	0	0
907	0	0	0	2.838	2.067	1.754	0	16.67	8.33
908	0	0	4.548	3.191	2.128	1.811	0	14.29	14.29
909	0	0	4.422	3.673	2.155	2.029	0	0	0
910	0	0	3.512	4.175	2.164	2.106	0	0	0
1002	0	0	0	0	1.876	1.587	0	0	0
1003	0	0	0	0	1.887	1.604	0	0	0
1004	0	0	0	1.611	1.628	1.568	0	0	0
1005	0	0	0	0	2.002	1.364	10.00	10.00	10.00
1006	0	0	0	0	1.883	1.505	0	0	0
1008	0	0	0	0	1.918	1.598	0	0	0
1009	0	0	0	0	1.892	1.749	14.29	14.29	14.29
1010	0	0	0	1.000	1.787	1.731	0	0	0
1101	0	0	0	1.119	0.820	1.000	23.08	53.85	30.77
1102	0	0	0	0.448	0.646	1.117	0	0	0
1103	0	0	0	0.466	0.748	1.087	0	0	0
1104	0	0	0	0.627	0.792	1.068	0	22.22	22.22
1105	0	0	0	1.412	0.910	0.961	9.09	31.82	18.18
1106	0	0	0	0	0.925	1.076	28.57	71.43	85.71
1107	0	0	0	0	0.614	1.158	0	0	0
1108	0	0	0	0	0.489	1.197	0	0	10.00
1109	0	0	0	0.474	0.604	1.130	12.50	12.50	12.50
1110	0	0	0	0	0.489	1.184	0	0	0

Appendix 3 continued.

site	road50	road100	road200	road500	road1000	road2000	peralien	peropen	perroad
1201	0	0	5.285	3.595	2.184	1.753	16.67	16.67	0
1202	0	6.924	5.155	4.205	2.226	1.611	11.11	38.89	27.78
1203	0	0	0	4.335	2.262	1.621	0	0	0
1205	0	0	0	1.556	2.168	1.874	9.09	27.27	9.09
1301	0	0	2.125	2.366	1.729	2.394	8.33	25.00	16.67
1302	0	0	4.259	2.437	2.083	2.278	5.00	35.00	20.00
1304	0	0	0	2.244	1.999	2.267	8.33	33.33	16.67
1401	0	0	0	0	0.889	1.759	0	16.67	16.67
1402	0	0	0	0	0.778	1.759	0	0	12.50
1403	0	0	0	0	0.944	1.749	0	9.09	9.09
1404	0	0	0	0	1.496	1.750	12.50	25.00	6.25
1406	0	0	0	0	1.689	1.711	25.00	25.00	25.00
1408	0	0	0	0.995	2.020	1.755	0	0	0
1409	0	0	0	0	1.588	1.757	0	0	0
1410	0	0	0	1.040	1.377	1.748	0	11.11	11.11
1503	0	0	0	0.450	2.101	1.969	16.67	33.33	27.78
1504	0	0	0	1.416	2.053	1.955	9.52	19.05	9.52
1505	0	0	0	2.069	1.977	1.940	0	23.08	0
1506	0	0	0	2.289	2.074	1.925	0	16.67	0
1509	0	0	0	2.311	2.195	1.910	25.00	37.50	18.75
1605	0	0	0	3.205	1.868	1.574	12.50	12.50	25.00
1606	0	0	0	2.703	1.841	1.596	18.18	27.27	9.09
1608	0	0	0.843	1.732	1.523	1.679	0	36.36	27.27
1702	0	0	0	0	1.086	1.561	11.11	11.11	11.11
1704	0	0	0	0	0.403	2.858	9.09	36.36	36.36
1705	0	0	0	0	0.500	3.258	0	0	0
1706	0	0	0	0	1.027	2.402	0	22.22	0
1707	0	0	0	0	0.516	2.451	0	0	16.67
1801	0	0	0	1.728	1.699	2.463	0	8.33	8.33
1802	0	0	0	2.019	2.118	2.369	16.67	25.00	25.00
1803	0	0	0	2.885	2.675	2.214	0	10.00	20.00
1805	0	0	0	0	2.364	2.049	20.00	33.33	20.00
1806	0	0	0	1.082	2.084	2.238	0	0	0
1807	0	0	0	0.675	1.629	2.747	15.38	30.77	23.08
1809	0	0	0	0	1.540	3.170	0	28.57	0
1901	0	0	1.546	1.195	1.386	1.945	20.00	40.00	30.00

Appendix 3 continued.

site	road50	road100	road200	road500	road1000	road2000	peralien	peropen	perroad
1902	8.006	5.843	3.133	1.271	1.549	1.786	25.00	37.50	50.00
1903	0	4.884	3.025	1.647	2.252	1.739	0	0	0
1905	0	3.795	2.921	1.262	1.386	1.713	0	0	14.29
2001	0	0	1.306	2.439	2.391	2.418	0	0	50.00
2006	0	0	0	0.746	2.233	2.387	7.69	7.69	7.69
2007	0	0	0	1.050	2.140	2.307	0	0	0
2101	0	0	0	1.112	1.704	3.259	33.33	44.44	44.44
2102	0	0	0	1.480	3.046	3.263	11.11	27.78	11.11
2109	11.972	18.306	9.514	4.415	2.920	2.785	20.00	46.67	20.00
2301	0	0	0	0.939	6.245	5.876	0	14.29	14.29
2302	0	0	0	1.167	6.258	5.781	0	0	12.50
2304	0	0	0	0.870	2.340	4.214	0	0	0
2305	0	0	1.345	4.073	4.422	4.931	0	14.29	14.29
2306	0	0	1.600	1.163	2.035	3.559	0	0	0
2307	0	0	0.885	1.103	1.920	3.728	0	0	0
2309	0	0	0	1.265	0.962	3.783	0	28.57	0
2310	0	0	0	0	1.852	4.459	100.00	100.00	100.00
2403	0	0	0	0.278	0.562	1.717	0	26.67	6.67
2405	0	0	2.187	1.234	0.900	1.972	7.14	7.14	0
2406	0	5.194	2.749	1.273	1.377	1.879	0	25.00	16.67
2407	0	4.596	2.995	2.340	1.774	1.732	9.09	45.45	9.09
2408	0	0	2.712	3.082	1.837	1.709	11.11	33.33	33.33
2409	0	0	0	3.313	1.855	1.693	0	30.00	10.00
2503	0	0	0	1.086	1.854	2.238	11.11	33.33	22.22
2507	0	0	2.309	1.226	2.068	1.973	7.69	38.46	23.08
2601	0	0	0.665	1.864	1.548	2.143	0	0	0
2603	0	0	0	0	1.154	2.140	0	0	0
2604	0	0	0	0	1.282	2.122	0	0	0
2605	0	0	0	0.771	1.930	2.076	0	0	0
2606	0	0	0	0	1.921	2.091	0	0	0
2608	0	0	0	3.022	2.328	1.782	0	0	0
2609	0	0	0	0	2.307	1.774	6.25	18.75	6.25
2610	0	3.442	2.307	3.187	1.664	2.108	0	8.33	0
2702	0	0	0	1.160	1.744	1.797	0	0	0
2703	0	0	0	0	1.712	1.794	7.14	7.14	7.14
2704	0	0	0	0	1.465	1.837	0	0	0

Appendix 3 continued.

site	road50	road100	road200	road500	road1000	road2000	peralien	peropen	perroad
2705	0	0	0	0.540	1.138	1.809	0	11.11	11.11
2706	0	0	0	1.515	1.692	1.710	9.09	9.09	9.09
2707	0	0	0	0.990	1.714	1.709	11.11	11.11	11.11
2708	0	0	0	0	1.718	1.747	0	28.57	28.57
2709	0	0	0	0	1.496	1.865	0	0	0
2710	0	0	0	0	1.417	1.900	56.25	81.25	68.75
2801	18.650	12.949	7.350	3.179	1.763	1.420	0	0	0
2802	0	0	0	2.268	1.660	1.387	0	0	0
2803	0	0	0	0	1.413	1.367	20.00	40.00	60.00
2804	0	0	0	0	1.295	1.402	0	11.11	11.11
2805	0	0	0	2.430	1.591	1.421	16.67	33.33	33.33
2806	0	10.871	6.392	2.911	1.668	1.406	0	14.29	0
2807	0	8.668	5.688	2.765	1.578	1.413	0	10.00	0
2808	0	0	3.773	2.461	1.741	1.417	0	16.67	16.67
2809	0	0	0	1.937	1.475	1.427	20.00	40.00	60.00
2810	0	0	0	2.338	1.599	1.419	0	0	0
2901	0	0	0	0.484	2.615	1.960	0	0	0
2902	0	0	0	0.253	2.592	2.062	0	0	0
2903	0	0	0	0.947	2.304	2.089	0	0	0
2904	0	0	0	0.156	2.322	1.971	0	0	0
2906	12.583	6.438	3.122	2.954	2.605	2.050	0	14.29	14.29
2907	0	0	0.891	1.019	2.420	2.020	20.00	20.00	20.00
2908	0	0	0	1.158	1.534	1.979	0	33.33	0
3001	9.920	6.107	3.144	2.963	1.685	1.092	0	0	0
3002	0	0	0	0	1.613	1.102	0	9.09	9.09
3003	0	0	0	0	1.565	1.229	0	17.65	17.65
3004	0	0	0	0	1.387	1.220	20.00	20.00	20.00
3005	0	0	0	0	1.209	1.323	9.09	9.09	0
3007	0	0	0	1.230	1.714	1.216	12.50	12.50	12.50
3008	0	0	0	2.261	1.734	1.073	0	0	0
3009	0	0	0	2.526	1.729	1.075	11.11	33.33	22.22
3010	11.820	6.366	3.240	3.121	1.695	1.110	0	0	0