Impacts of Summer vs. Winter Logging on Understory Vegetation in the Chequamegon-Nicolet National Forest

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Abstract

In seasonal climates the timing of logging operations can be adjusted to avoid the major growing periods of understory plants and seedlings. We describe a field study of five pairs of sites in northern Wisconsin, U.S.A. where one site in each pair was logged during winter and the other during summer. Most (84%) of the 248 vascular plant species recorded during the study are native to the region. Winter-logged sites supported significantly higher numbers of ecologically vulnerable native plant species as defined by independently established coefficients of conservatism. Based on this finding, studies that fail to account for differences in species composition are likely to ignore important impacts of logging activities. Differences in plant species composition between winter-logged and summer-logged sites suggests that winter logging may benefit vulnerable species and, in the long run, may help maintain plant biodiversity in managed forests of this region. In both types of sites, understory plant richness and diversity were significantly higher near logging roads, due largely to higher numbers of alien species and early successional native plants. Away from roads, neither species richness nor diversity differed between winter-logged and summer-logged sites.

Key words: forest understory, winter vs. summer logging, sensitive species, forest roads

Introduction

Logging inevitably alters the composition and ecology of indigenous forests, but until recently few studies have documented the effects of logging on the abundance and distribution of understory plant species, particularly non-woody forbs and shrubs. Even less is known about the effects of different types of logging practices. Much of our knowledge about the ecological impacts of logging on understory plants is related to clearcutting (Dyrness 1973, Chen et al. 1995), habitat fragmentation (Benitez-Malvido and Martinez-Ramos 2003), or edge effects (Euskirchen et al. 2001).

Fredericksen et al. (1999) showed that the intensity of logging can influence understory plant community composition by creating different degrees of forest openings. Some species are more tolerant of logging than others, perhaps due to life history attributes such as mechanisms of seed dispersal or pollination (Meier et al. 1995, Wiegmann and Waller 2006). These and other studies suggest that the effects of logging and other human activities can be both direct and indirect. Logging roads, for example, have been shown to act as corridors for invasion of alien (non-native) species in managed forests (Parendes and Jones 2000). Watkins et al. (2003) found that alien species in northern Wisconsin were most prevalent within 15 m of road edges. A small but significant group of species tended to be more prevalent in forest interior than near roads. Wiegmann and Waller (2006) identified “winners” and “losers” among understory plants of upland forest stands in northern Wisconsin, suggesting that browsing by white-tailed deer (*Odocoileus virginiana*) might be a key factor responsible for community changes over the past 50 years. Duffy and Meier (1992) pointed out that the effects of logging, whether direct or indirect, might influence the herbaceous understory of eastern North American forests for decades.

Our study aims to compare the short-term effects of selective logging on understory plant species composition in winter-logged sites vs. summer-logged sites. Given the evidence that logging affects understory vegetation, our work is motivated by a desire to reduce the negative impacts of selective logging. Factors such as soil compaction, soil disturbance, and alien seed dispersal by logging equipment, for example, might be minimized in northern hardwood forests by restricting timber harvest to winter months. Efforts to preserve the ecological integrity of understory plant communities are important for several reasons. Not only are forest wildflowers and their biological associates aesthetically attractive, but they may play important ecological roles as reservoirs of mycorrhizae (Hagerman et al. 2001), microhabitats for native animals (Rangen et al. 1999), and possibly seasonal sinks for retention of soil nutrients (Muller and Bormann 1976).

Study Area

Field work was conducted in the Lakewood/Laona Districts of the Chequamegon-Nicolet National Forest in Forest and Oconto Counties of northeastern Wisconsin (Figure 1). This landscape is part of the Northern Continental Section (Albert 1995) of the Laurentian Mixed Forest Ecological Province (ECOMAP 1993). Topography is largely a glacially-derived mosaic of moraines, drumlins, outwash plains, depressions, and bedrock ridges (Albert 1995). Winters are moderately long, generally with persistent snow cover and frequent extreme cold temperatures. Temperatures of 50EF (10EC) or higher occur during more than 120 days, but the growing season is short; the frost-free season lasts from 100 to 140 days. Average annual temperatures range from 35 to 50EF (2 to 10EC).

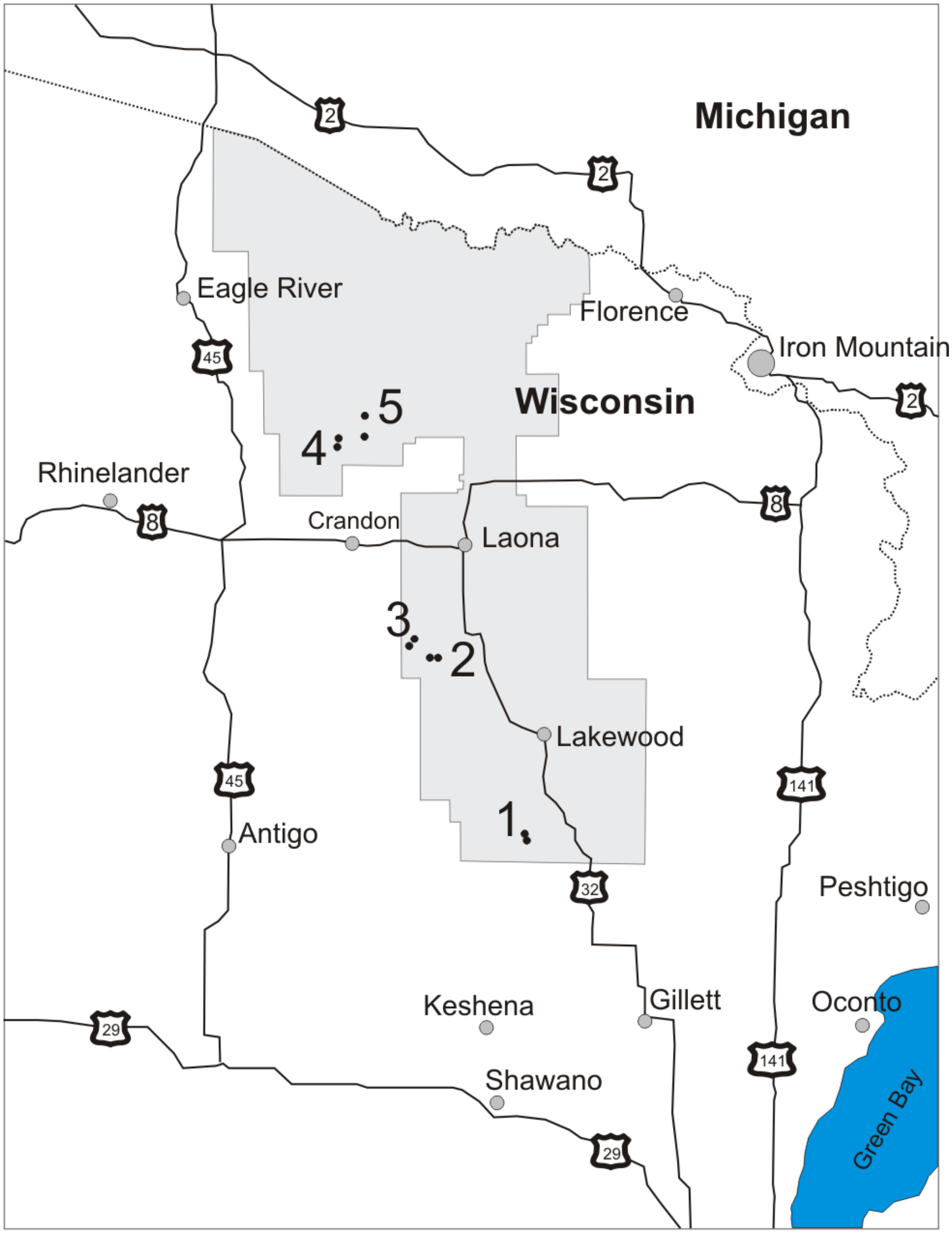

Figure 1. Map of study sites (•) in Chequamegon-Nicolet National Forest. Map was drawn from template provided by DeLorme Street Atlas 2003.

During winter, the region lies north of the main cyclonic belt; during summer this climatic pattern extends into the region, leading to more changeable weather conditions. Average annual precipitation ranges from 610 to 1,150 mm (24 to 45 in), with maximum precipitation during summer. Winter precipitation is intermediate between that of drier continental regions to the west and Great Lakes-influenced regions to the north and east (Albert 1995). Between 14 to 29 percent of the annual precipitation occurs between November and February.

Vegetation of the study area prior to EuroAmerican settlement consisted mainly of upland mixed northern hardwood/conifer forests dominated by sugar maple (*Acer saccharum*), eastern hemlock (*Tsuga canadensis*), basswood (*Tilia americana*), yellow birch (*Betula alleghaniensis*), and white pine (*Pinus strobus*). Within this upland forest matrix, other important vegetation types included lowland conifer forests, lowland hardwoods, drier upland forests dominated by oaks (*Quercus* spp.), jack pine (*Pinus banksiana*), and red pine (*Pinus resinosa*), and successional forests of aspen (*Populus* spp.) and white birch (*Belula papyrifera*). Aspen and birch forests covers a much larger area today (approximately 25%) of the eastern (Nicolet) portion of the Chequamegon-Nicolet National Forest (Wolter 2006) than they did prior to logging in the 1800's and early 1900's (Frelich 1995). Today, successional northern hardwoods and mixed northern hardwoods/conifers are the dominant upland forest types in this area.

We selected five pairs of sites in upland northern hardwood forest dominated by sugar maple and basswood, with varying amounts of yellow birch, white ash (*Fraxinus americana*), and American elm (*Ulmus americana*). Sites within each pair were similar in forest type and were located within approximately 1 km of one another. Before harvest the dominant trees were classified as pole-sized (15.2 – 25.4 cm diameter) or sawtimber (30.5 - 40.6 cm diameter). One site from each pair was selectively logged during summer months (June – October) of 2003, 2003 or 2004, while the second site was selectively logged during winter months (November – March) of 2002-03, 2003-04 or 2004-05. Cutting consisted of thinning (in one case), improvement, or selection harvest as prescribed by U.S. Forest Service guidelines. During winter logging, snow was typically present and the ground was frozen during most or all of the period, which extended as long as 4 months (Table 1).

Table 1. Characteristics and recent logging history of paired study sites. Sites in the same group were located within 1 km of one another.

Group	Season*	Harvest Dates	Management Goal	Harvest Method	Dominant Tree Species#
1	S	July-Aug 2004	Even-age	Thinning	Mixed Hwds (SM, BW, WA, YB)
1	W	Nov 2004 – Mar 2005	Even-age	Thinning	Mixed Hwds (SM, BW, WA, YB)
2	S	June – Sept 2003	Uneven-age	Improvement	SM, BW
2	W	Jan – Feb 2005	Uneven-age	Selection	SM, BW
3	S	May – Oct 2002	Uneven-age	Improvement	Mixed Hwds (SM, BW, WA, YB)
3	W	Feb 2002	Uneven-age	Improvement	SM, BW
4	S	July – Oct 2004	Uneven-age	Improvement/ Selection	Mixed Hwds (SM, YB, BW)
4	W	Jan – Mar 2005	Uneven-age	Improvement/ Selection	Mixed Hwds (SM, YB, BW)
5	S	Aug – Sept 2004	Uneven-age	Improvement/ Selection	SM, BW, RM
5	W	Jan – Mar 2005	Uneven-age	Selection	SM, BW, BA, AE, RM

*S = summer; W = winter

#SM = sugar maple; BW = basswood; WA = white ash; YB = yellow birch; RM = red maple; AE = American elm

Methods

During late spring (14 May – 18 May 2006), mid-summer (12 June – 17 June 2006) and late summer (21 August – 1 September 2006), we evaluated understory vegetation at 10 study sites (5 summer-logged sites and 5 paired, nearby winter-logged sites) of approximately 250 x 100 m. One or more logging roads extended through or adjacent to the logged portion of the stand. At each site we sampled 30 random 2 m x 2 m *roadside plots* (10 during each sampling period) located 15-50 m apart along logging roads and a corresponding set of 30 *interior plots* located at randomly selected distances 20-50 m perpendicular from the road plots.

We estimated percent cover for all identifiable vascular plant species < 1 m in height within the 2 m x 2 m plots. Percent cover was assigned to one of 5 categories: < 1%, 1-5%, 5-10%, 10-50%, and > 50%. The midpoint of each range was used in quantitative analyses that used cover as a variable. Questionable species were collected for later identification at the University of Wisconsin-Green Bay Herbarium. We estimated canopy density at pilot plots during summer 2005 using a spherical densiometer (Lemmon 1956). Densiometer readings were taken from north, south, east, and west directions and later averaged. Percent cover of canopy tree species within 50 m was estimated at each of the pilot points.

Data Analysis

We used two-way analysis of variance (SYSTAT Version 11) to test for the effects of logging treatment (winter vs. summer) and location (roadside vs. interior). Several dependent variables were compared, including 1) overall species richness (S_{tot}), where S_{tot} = total number of species among all 10 plots at a given locality (roadside or interior at a given site) over all 3 sampling periods; 2) species richness of native species (S_{nat}), where S_{nat} = total number of native species among all 10 plots over all 3 sampling periods; 3) species richness of non-native species (S_{non}), where S_{non} = number of non-native species among all 10 plots over all 3 sampling periods; 4) Shannon-Wiener Diversity (H'), where H' = - 3 p_i $\log_2 p_i$, and p_i = the proportional importance of species i; 5) Shannon-Wiener Evenness (E), where E = H'/($\log_2 S_{tot}$); 6) Floristic Quality Index (FQI), where FQI = mean C x $S_{tot}^{0.5}$ (Swink and Wilhelm 1994) and C = standard species-specific *coefficient of conservatism* from the Wisconsin State Herbarium's WISFLORA (http://www.botany.wisc.edu/wisflora/); and 6) number of ecologically sensitive (define?) species (S_{sens}), where S_{sens} = number of species with C > 6 among all 10 plots over all 3 sampling periods. Importance value was calculated as the average of relative cover (= maximum average cover value for species i among the 3 seasons ($MAXCOV_i$) / total of maximum average cover values for all species at the locality) and relative frequency (= maximum proportion of plots where species i was observed among the 3 seasons ($MAXFREQ_i$) / total of all species' maximum frequencies at a given locality). Maximum average cover values for individual species ($MAXCOV_i$) were selected among the 3 seasonal sets of 10 sampling points. For example, if the average cover value for species i (among 10 plots) was 3.5% during late spring, 3.1% during summer, and 1.2% during late summer, the value of $MAXCOV_i$ would be 3.5%. Note that in most analyses we have pooled data from the 10 sampling plots at a given site, locality (roadside vs. interior), and sampling period. A more detailed analysis of alpha (point) diversity is beyond the scope of this report.

We also computed and plotted a nonmetric multidimensional scaling (NMS) ordination (McCune et al. 2002) of sample plots (n = 200) based on presence (1) or absence (0) of species in order to illustrate differences in species assemblages among sites, logging treatments (summer vs. winter) and types of plot (road vs. non-road). Two outliers were removed from the ordination analysis in order to better illustrate differences among the other plots. Species that were observed in fewer than 5 plots (of 202 total plots) were excluded. Ordinations were calculated in PCORD Version 5.0 using Sorenson's Index of similarity among sites.

Results

We recorded 249 plant species (3 identified only to genus) at the 600 sample plots (Appendix 1), including 194 species at the summer-logged roadside plots, 199 at the winter-logged roadside plots, 137 at the summer-logged non-road plots, and 140 at the winter-logged non-road plots. Most (207) of the 246 species identified to the species level are native to the western Great Lakes region. A significant number of plant species (39), however, were alien (non-native), and several of these were widespread throughout the study area. Across all sites, the most important species in terms of cover (in decreasing order of total % cover) were *Carex pensylvanica*, *Athyrium filix-femina*, *Rubus idaeus*, *Fraxinus* sp. (seedlings), *Amphicarpaea bracteata*, *Aralia nudicaulis*, and *Acer saccharum* (Appendix 1). The most frequently recorded species were not necessarily those with the highest total cover. In non-road plots, the most frequent species (in decreasing order) were *Acer saccharum*, *Carex pensylvanica*, *Maianthemum canadense*, *Aster macrophyllus*, *Fraxinus* sp., *Trillium* sp. and *Trientalis borealis,* all native species that are not normally associated with disturbance. The most frequently recorded species at roadside plots were *Acer saccharum*, *Taraxacum officinale* (alien), *Aster macrophyllus*, *Athyrium filix-femina*, *Rubus idaeus (*disturbance-associated), *Fraxinus* species, and *Carex pensylvanica* (disturbance-associated).

Species richness and species diversity were significantly greater at roadside plots compared with non-road plots at both winter and summer-logged localities (Table 1), but neither variable differed significantly between winter-logged and summer-logged sites. Species evenness (E) was only marginally different ($p = 0.06$, ANOVA) between road and non-road plots and not significantly different between winter- and summer-logged localities.

Table 2. Mean attributes of sites with different logging treatments (summer vs. winter). Species variables (columns 2-5) give the mean number of species recorded among 5 sites in a given category (Road vs. Off-Road). Species list for a given site and category was formed by pooling results from 3 samples (late spring, early summer, and late summer). Standard errors are given in parentheses.

Site Category (n = 5)	Species (all)	Species (native)	Species (alien)	Species (CC > 6)	Mean CC	FQI	H'	E
Winter / Off Road	70.6 (3.8)	66.6 (3.3)	3.2 (0.6)	22.6 (1.3)	5.4 (0.1)	45.4 (1.6)	5.5 (0.1)	0.89 (0.01)
Winter / Road	103.2 (4.6)	84.2 (2.8)	**17.2 (2.4)**	18.2 (1.0)	4.5 (0.1)	46.0 (0.9)	6.0 (0.06)	0.90 (0.01)
Summer / Off Road	70.2 (2.6)	65.0 (3.0)	3.8 (0.6)	19.6 (1.5)	5.2 (0.04)	43.6 (0.8)	5.5 (0.05)	0.90 (0.01)
Summer / Road	99.4 (2.8)	80.6 (1.9)	**16.6 (2.3)**	15.2 (1.1)	4.4 (0.08)	43.7 (0.8)	6.0 (0.07)	0.91 (0.01)

CC = Coefficient of Conservatism   FQI = Floristic Quality Index
H' = Shannon-Wiener Diversity Index   E = Shannon-Weiner Evenness

Although overall numbers of species were not significantly different between winter- and summer-logged sites, the types of species revealed some important contrasts. Numbers of non-native species were much higher along roads ($p < 0.01$, ANOVA) but were nearly identical between winter- and summer-logged sites. Significant differences between winter- and summer-logged sites occurred mainly among ecologically sensitive native species; specifically, winter-logged sites tended to support more species with high coefficients of conservatism (Figure 2). Both the mean coefficient of conservatism and number of species with a coefficient > 6 were significantly higher in winter-logged sites than in summer-logged sites ($p < 0.05$, ANOVA). Both of these variables also were much higher in the off-road than in the road plots. Species that showed particularly higher frequencies in winter-logged sites than in summer-logged sites included *Actaea* sp., *Allium tricoccum, Anemone americana, Aralia nudicaulis, Aster* *macrophyllus, Dicentra cucullaria, Dryopteris carthusiana, Erythronium sp., Medeola virginiana, Mitchella repens*, *Mitella diphylla, Oryzopsis asperifolia, Osmunda claytoniana, Schizachne purpurascens,* and *Viola canadensis*. Only 2 species with a coefficient of

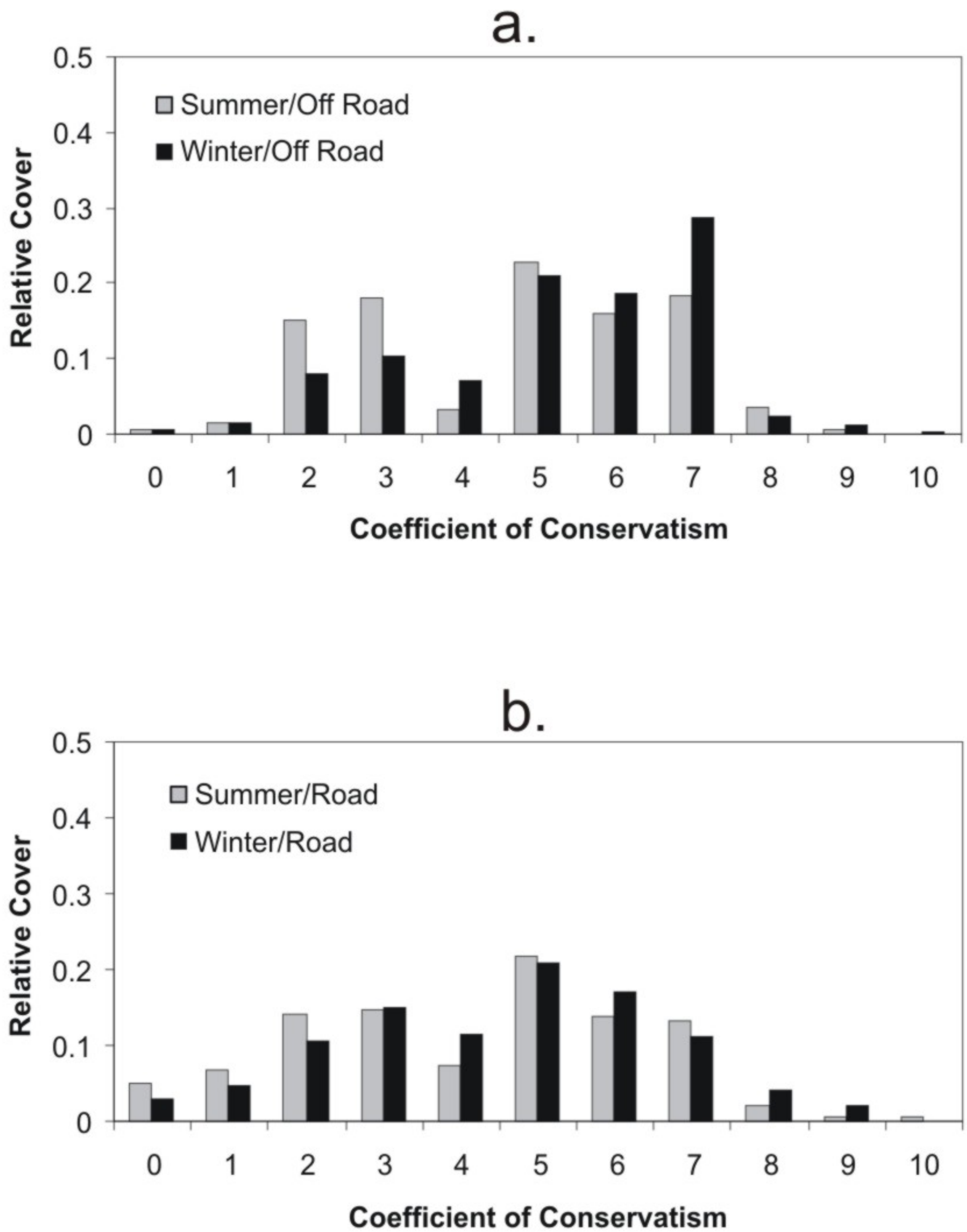

Figure 2. Distribution of relative cover among understory plant species with different coefficients of conservatism (Swink and Wilhelm 1994), where a value of 0 indicates low sensitivity to disturbance and a value of 10 indicates high sensitivity to disturbance. Relative cover is the proportion of all cover estimates for 2 m x 2 m plots (n = 150) over 3 sampling periods for each category.

conservatism of 6 or higher (*Fagus grandifolia* and *Asarum canadense*) tended to be more common at summer-logged sites than at winter-logged sites (Appendix 1). The Floristic Quality Index (FQI), which combines species richness and coefficients of conservatism, did not differ significantly between either road vs. non-road plots or winter- vs. summer-logged sites ($p > 0.05$, ANOVA). .

The list of 249 species observed during this study (Appendix 1) includes 61 with a coefficient of conservatism of 7 or greater. On average, these sensitive species covered 3.02% (S.E. = 0.62) of the off-road plots in winter-logged sites, 1.85% (S.E. = 0.34) of off-road sites in summer-logged sites, 1.50% (S.E. = 0.33) in roadside plots of winter-logged sites and 1.09% (S.E. = 0.24) in roadside plots of summer-logged sites. Sensitive species with highest percent cover in winter-logged sites included *Gymnocarpium dryopteris*, *Schizachne purpurascens*, *Uvularia grandiflora*, *Adiantum pedatum*, *Erythronium* sp., *Viola canadensis*, and *Caulophyllum thalictroides*. Another notable species, *Aralia nudicaulis* (coefficient of conservatism = 6), had a mean cover of 37.3% in off-road plots and 30.5% in roadside plots of winter-logged sites, compared with 21.5% in off-road plots and 9.0% in roadside plots of summer-logged sites.

An ordination of plots based on presence/absence of plant species (Figure 3) illustrates patterns of species composition among sites and types of samples. The differences in species composition between road and non-road plots are clearly apparent (Figure 3a). Roadside plots were more variable than off-road plots, but they tended to include alien species like *Taraxacum officianale*, *Plantago major*, *Medicago lupulina*, *Cirsium palustre*, and *Trifolium* spp. in addition to widespread native species like *Prunella vulgaris*, *Erigeron annuus*, *Equisetum arvense*, and *Solidago canadensis* . Differences among sites (Figure 3b) also are apparent. The particularly distinct southernmost sites contained several species found almost exclusively there, including *Acer rubrum*, *Amphicarpaea bracteata*, *Diphasiastrum complanatum*, *Equisetum arvense*, *Impatiens*, sp., *Fagus grandifolia*, *Rubus allegheniensis, Silene vulgaris, Lobelia inflata,* and *Prenanthes alba*.

Differences in species composition between plots at winter-logged vs. summer-logged sites were not reflected in the ordination pattern of the first two axes (Figure 3c) and showed no consistent correlation with any of the first 5 axes.

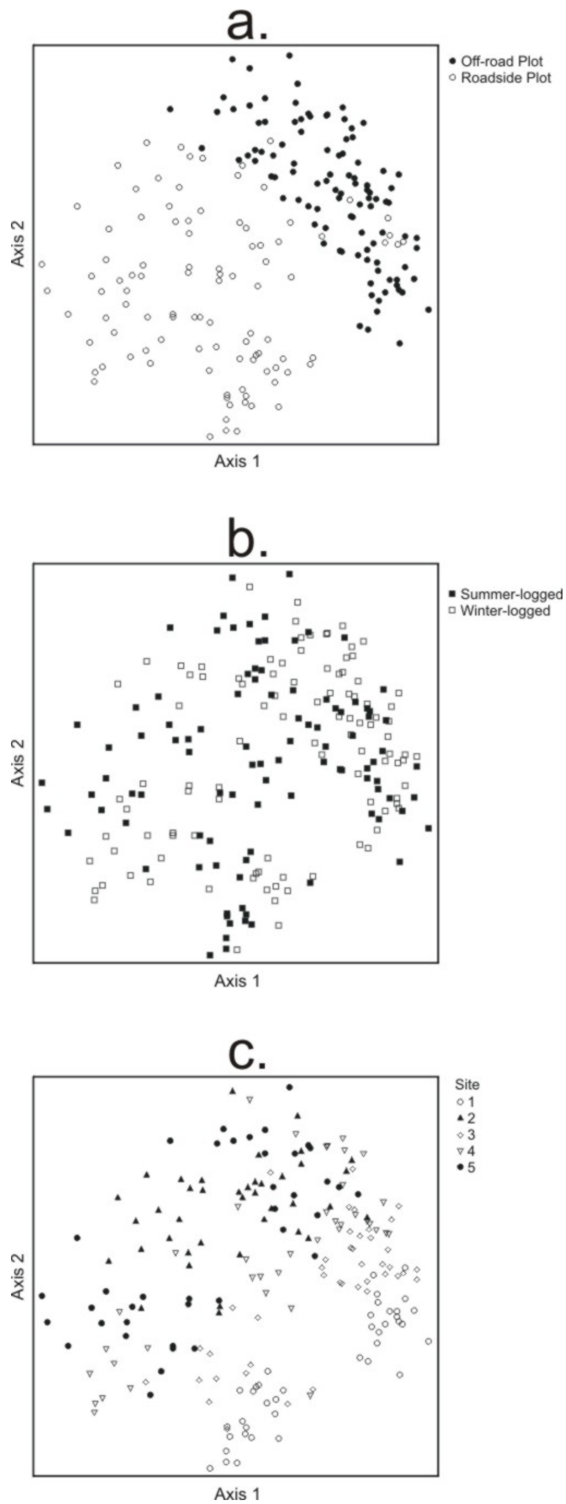

Figure 3. Nonmetric multidimensional scaling ordination of plant species composition (presence/absence) in 2 m x 2 m plots in the Chequamegon-Nicolet National Forest. Plot positions in the ordination are identical in all 3 figures (a-c); overlays illustrate the location of the plot within the site (a), the type of logging treatment applied to the site (b), and the location of the site itself, as shown in Figure 1.

Discussion

Effects of logging activities on understory plants are now well documented for a variety of forest types (Metzger and Schultz 1981, Reader 1987, Gilliam et. al. 1995, Roberts and Gilliam 1995, Greenberg et al. 1997, Crow et al. 2002 and others). In northern hardwood forests, logging is associated with increased species richness and total cover of understory species, although the added species tend to be common in the first place (or alien) and don't contribute significantly to the overall native species diversity at a given site (Crow et al. 2002). The impacts of logging are particularly evident along roads and skid trails, which are created to provide access for logging equipment (Buckley et al. 2003, Watkins et al. 2003). Our results clearly are consistent with these findings. For every site, overall species richness and species diversity were significantly higher in the roadside plots than in off-road plots.

At both winter-logged and summer-logged sites, understory plants near logging roads were profoundly different than understory plants away from roads. Overall differences between winter-logged and summer-logged plots were not as striking, but our investigation revealed an important pattern: species that differed between winter- and summer-logged sites tended to be those with previously-known vulnerability to disturbance (i.e., species with a coefficient of conservatism > 6). Species with a high coefficient of conservatism were more numerous in winter-logged sites than in summer-logged sites, suggesting that summer logging operations might be deleterious to these species. Coefficients of conservatism for Wisconsin vascular plants were developed by a group of experts solicited by the Wisconsin State Herbarium at the University of Wisconsin-Madison, following guidelines described by Swink and Wilhelm (1994) and Wilhelm and Masters (1995). The coefficients, which range from 0 to 10, represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from pre-settlement conditions.

Wiegmann and Waller (2006) identified understory plant species that have declined in upland northern hardwood forests of northern Wisconsin and Upper Michigan since the 1950's. At least 6 of their declining species ("losers") also tended to favor winter-logged sites in our investigation, including *Aralia nudicaulis, Aster macrophyllus, Mitchella repens, Mitella diphylla*, *Osmorhiza claytonii*, and *Viola canadensis* (*Viola* spp.). Another species, *Uvularia sessilifolia*, was not found in our study area, although its congener, *Uvularia grandiflora,* was consistently more common in winter-logged plots (Appendix 1). Only two species, the grasses *Oryzopsis asperifolia* and *Schizachne purpurascens*, were more abundant in winter-logged sites but had been reported as increasing ("winners") by Wiegmann and Waller (2006).

Meier et al. (1995) outlined several mechanisms that might be responsible for disappearance or decline of understory plant species in logged stands of eastern deciduous forests. These factors include direct reduction of populations that are already rare, shifts in competitive interactions toward earlier successional species, intensity of disturbance that exceeds or overwhelms the ability of certain species to recover, rate of local disturbance that inhibits effective recolonization of microsites by clonal, ant-dispersed, or gravity-dispersed species, and long-term modification of forest-floor microhabitats. Over repeated entries of logging operations, these and possibly other mechanisms might lead to the complete elimination of vulnerable species from the forest understory. Road width and road substrate, for example, might be important variables in the establishment of invasive species or in favoring early successional native plant species. Studies like ours and that of Wiegmann and Waller (2006) have identified some of the most vulnerable species, which might be on a path of eventual elimination from managed forests in northern Wisconsin and nearby states. Further investigations into the microhabitat needs and population dynamics of these species might be needed to avoid continued declines. At least in a few cases winter logging appears to be a positive step toward minimizing the impacts of logging on vulnerable understory plants. In regions where the ground freezes seasonally, winter logging is less likely to cause soil compaction, introduction of exotic species, and direct mortality of uncommon or rare plant species. We have found that differences between winter-logged and summer-logged sites are apparent 2-4 years after logging operations; other effects on understory plant assemblages might require additional years before they are manifest. Nevertheless, our study provides an early warning that repeated summer logging might negatively affect local populations of understory plants, including several species that have been recognized by others as vulnerable to disturbance.

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Appendix 1. List of species observed at 2 m x 2 m summer-logged roadside plots (SR), winter-logged roadside plots (WR), summer-logged non-road plots (SNR), and winter-logged non-road plots. Origin indicates whether the species in native (N) or alien (A) to western Great Lakes forests. CC = coefficient of conservatism published by the Wisconsin State Herbarium's WISFLORA project (http://www.botany.wisc.edu/wisflora/). Numbers in the 4 right columns give the maximum average % cover (at a given site) among 3 visits.

Species	Code	Origin	CC	Form	SR	WR	SNR	WNR
Abies balsamea	ABIBAL	N	5	T	0.17	0.50	2.50	0.03
Acer rubrum	ACERUB	N	3	T	0.20	0.53	0.05	0.13
Acer saccharum	ACESAC	N	2	T	3.27	6.60	4.48	8.67
Achillea millefolium	ACHMIL	N	1	F	0.12	0.23	0.00	0.00
Actaea sp.	ACTSP	N	6	F	0.10	1.25	0.10	1.67
Adiantum pedatum	ADIPED	N	7	FN	1.10	0.12	1.27	4.77
Agrostis gigantea	AGRGIG	A		G	2.50	2.00	0.00	0.12
Allium tricoccum	ALLTRI	N	6	F	0.15	0.13	0.72	1.80
Ambrosia artemisiifolia	AMBART	N	0	F	0.02	0.03	0.00	0.00
Amelanchier sp.	AMESP	N	6	SH	0.03	0.02	0.10	0.10
Amphicarpaea bracteata	AMPBRA	N	5	HV	4.73	9.70	10.20	9.55
Anaphalis margaritiacea	ANAMAR	N	3	F	0.00	0.80	0.00	0.02
Anemone acutiloba	ANEACU	N	7	F	0.00	0.32	0.23	0.27
Anemone americana	ANEAME	N	7	F	0.02	0.50	0.12	2.02
Anemone quinquifolia	ANEQUI	N	6	F	1.73	1.57	1.47	0.98
Antennaria neglecta	ANTNEG	N	3	F	0.02	0.00	0.00	0.00
Apocynum androsaemifolium	APOAND	N	2	F	0.03	0.10	0.00	0.00
Arabis glabra	ARAGLA	N	5	F	0.00	0.02	0.00	0.00
Aralia nudicaulis	ARANUD	N	6	F	2.98	10.00	4.97	8.48
Aralia racemosa	ARARAC	N	7	F	0.25	2.62	1.00	0.00
Arisaema triphyllum	ARITRI	N	5	F	0.05	0.02	0.13	0.33
Artemisia sp.	ARTSP	A		F	0.00	0.02	0.00	0.00
Asarum canadense	ASACAN	N	7	F	1.10	0.13	0.23	0.10
Aster ciliolatus	ASTCIL	N	4	F	0.90	1.32	0.00	0.10
Aster lateriflorus	ASTLAT	N	3	F	1.08	4.03	0.00	1.32
Aster macrophyllus	ASTMAC	N	4	F	5.30	18.75	3.12	10.38
Aster umbellatus	ASTUMB	N	6	F	0.03	4.42	0.02	0.00
Athyrium filix-femina	ATHFIL	N	5	FN	16.20	15.67	5.08	23.47
Barbarea vulgaris	BARVUL	A		F	0.05	0.00	0.00	0.00
Betula alleghaniensis	BETALL	N	7	T	1.10	0.35	0.13	1.02
Betula papyrifera	BETPAP	N	3	T	1.52	0.30	0.25	0.00
Bidens frondosus	BIDFRO	N	1	F	0.02	0.10	0.00	1.00
Botrychium matricariifolium	BOTMAT	N	5	FN	0.00	0.00	0.00	0.02

Botrychium virginianum	BOTVIR	N	6	FN	0.12	0.02	0.03	0.13
Brachyelytrum erectum	BRAERE	N	7	G	0.17	0.20	1.23	0.27
Calla palustris	CALPAL	N	9	A	0.00	0.00	0.00	0.10
Calystegia sepium	CALSEP	N	2	HV	0.03	0.25	0.00	0.00
Carex arctata	CARARC	N	8	S	1.63	2.02	0.58	0.13
Carex bebbii	CARBEB	N	4	S	0.10	1.20	0.00	0.00
Carex communis	CARCOM	N	6	S	0.00	0.12	0.25	0.00
Cardamine concatenata	CARCON	N	6	F	0.70	0.33	1.22	0.28
Carya cordiformis	CARCOR	N	6	T	0.02	0.00	0.00	0.00
Carex crinita	CARCRN	N	6	S	0.00	1.73	0.00	0.00
Carex cristatella	CARCRS	N	4	S	0.00	0.02	0.00	0.00
Carex dewyana	CARDEW	N	7	S	2.60	0.80	1.25	2.00
Carex gracillima	CARGRA	N	5	S	3.90	1.60	4.85	1.10
Carex hirtifolia	CARHIR	N	5	S	0.00	0.10	0.00	0.00
Carex intumescens	CARINT	N	5	S	1.25	1.40	1.52	0.55
Carex leptonervia	CARLEP	N	6	S	10.98	2.90	0.45	0.32
Carex ormostachya	CARORM	N	6	S	0.00	0.00	0.25	0.00
Carex ovales	CAROVA	A		S	2.98	2.05	3.00	0.10
Carex pedunculata	CARPED	N	7	S	0.02	0.20	0.35	0.35
Carex pensylvanica	CARPEN	N	3	S	9.28	27.30	30.45	36.25
Carex plantaginea	CARPLA	N	10	S	0.00	0.00	0.00	0.20
Carex sparganioides	CARSPA	N	6	S	0.10	1.00	0.00	0.00
Carex stipata	CARSTI	N	2	S	0.12	0.22	0.00	0.00
Carex stricta	CARSTR	N	7	S	1.00	0.25	0.12	0.00
Carex tenera	CARTEN	N	4	S	0.10	0.40	0.00	0.00
Carex woodii	CARWOO	N	9	S	0.60	1.00	0.20	0.10
Caulophyllum thalictroides	CAUTHA	N	8	F	0.23	0.22	1.43	2.88
Cerastium fontanum	CERFON	A		F	0.32	0.92	0.10	0.00
Cirsium arvense	CIRARV	A		F	0.02	1.02	0.10	0.00
Circaea lutetiana	CIRLUT	N	2	F	0.97	0.00	3.82	0.10
Cirsium palustre	CIRPAL	A		F	0.97	1.33	0.02	0.00
Cirsium sp.	CIRSP	A		F	0.12	0.10	0.00	0.10
Cirsium vulgare	CIRVUL	A		F	0.25	0.20	0.10	0.00
Claytonia caroliniana	CLACAR	N	8	F	0.25	0.60	2.37	1.03
Claytonia virginica	CLAVIR	N	6	F	0.03	0.40	0.40	0.35
Clintonia borealis	CLIBOR	N	7	F	0.65	2.30	3.83	1.52
Conyza canadensis	CONCAN	N	0	F	0.05	0.02	0.12	0.00
Convolvulus sp.	CONSP	A		HV	0.07	0.03	0.00	0.10
Cornus alternifolia	CORALT	N	7	T	0.22	0.35	0.63	0.53
Cornus canadensis	CORCAN	N	7	SH	0.00	0.00	0.00	0.10
Corylus sp.	CORSP	N	5	SH	0.33	0.37	0.40	1.35
Corallorhiza striata	CORSTR	N	9	F	0.00	0.00	0.00	0.02
Cardamine pensylvanica	CRDPEN	N	3	F	0.00	0.02	0.00	0.00
Cryptotaenia canadensis	CRYCAN	N	4	F	0.58	0.32	0.25	0.25
Dactylis glomerata	DACGLO	A		G	0.30	0.00	0.00	0.00
Desmodium glutinosum	DESGLU	N	6	F	0.27	0.45	0.00	0.00
Dicentra canadensis	DICCAN	N	8	F	0.02	0.00	1.25	0.00

Dicentra cucullaria	DICCUC	N	7	F	0.25	0.60	1.57	2.35
Diervilla lonicera	DIELON	N	6	SH	0.77	1.45	0.13	0.02
Diphasiastrum complanatum	DIPCOM	N	7	FA	0.25	0.10	0.45	0.10
Diphasiastrum digitatum	DIPDIG	N	6	FA	1.20	0.00	1.80	2.50
Diphasiastrum tristachyum	DIPTRI	N	7	FA	0.00	0.00	0.10	1.12
Dirca palustris	DIRPAL	N	9	SH	0.02	0.00	0.45	0.35
Dryopteris carthusiana	DRYCAR	N	7	FN	0.00	0.35	0.20	0.45
Dryopteris cristata	DRYCRI	N	7	FN	0.00	0.02	0.00	0.02
Dryopteris intermedia	DRYINT	N	7	FN	1.67	1.12	0.85	2.60
Elymus hystrix	ELYHYS	N	6	G	0.52	0.00	0.10	0.00
Epilobium ciliatum	EPICIL	N	3	F	0.30	0.00	0.02	0.00
Epilobium sp.	EPISP	N	3	F	0.00	0.10	0.02	0.00
Epifagus virginiana	EPIVIR	N	9	F	0.00	0.00	0.00	0.02
Equisetum arvense	EQUARV	N	1	FA	3.25	0.63	0.00	0.02
Equisetum fluviatile	EQUFLU	N	7	FA	0.02	0.00	0.00	0.00
Equisetum palustre	EQUPAL	N	10	FA	0.10	0.00	0.00	0.00
Equisetum sylvaticum	EQUSYL	N	7	FA	0.05	0.10	0.00	0.00
Erechtites hieracifolia	EREHIE	N	2	F	0.10	0.00	0.27	0.00
Erigeron annuus	ERIANN	N	0	F	4.50	2.42	0.20	0.27
Erigeron philadelphicus	ERIPHI	N	2	F	0.10	0.00	0.00	0.00
Erigeron strigosus	ERISTR	N	2	F	1.10	0.20	0.00	0.00
Erysimum cheiranthoides	ERYCHE	A		F	0.00	0.02	0.00	0.00
Erythronium sp.	ERYSP	N	7	F	1.55	2.98	2.63	4.23
Eupatorium maculatum	EUPMAC	N	4	F	0.00	0.13	0.00	0.00
Eupatorium perfoliatum	EUPPER	N	6	F	0.00	0.10	0.00	0.00
Euthamia graminifolia	EUTGRA	N	4	F	1.27	0.50	0.00	0.00
Fagus grandifolia	FAGGRA	N	8	T	0.57	0.10	0.22	0.13
Festuca subverticillata	FESSUB	N	4	G	0.00	0.22	0.25	0.10
Fraxinus sp.	FRASP	N	2	T	3.12	10.95	13.88	8.57
Fragaria vesca	FRAVES	N	3	F	0.10	0.02	0.00	0.00
Fragaria virginiana	FRAVIR	N	1	F	1.78	2.02	0.00	0.02
Galium lanceolatum	GALLAN	N	7	F	0.00	0.00	0.00	0.25
Galium obtusum	GALOBT	N	6	F	0.05	0.00	0.00	0.00
Galeopsis tetrahit	GALTET	A		F	0.97	1.92	13.28	1.78
Galium tinctorium	GALTIN	N	5	F	0.00	0.00	0.00	0.02
Galium triflorum	GALTRI	N	6	F	0.38	1.10	0.27	0.60
Geranium sp	GERSP	A	4	F	0.02	0.00	0.00	0.00
Geum aleppicum	GEUALE	N	3	F	0.22	0.00	0.02	0.00
Geum sp.	GEUSP		3	F	0.02	0.12	0.02	0.00
Glyceria striata	GLYSTR	N	4	G	0.30	0.10	0.00	0.00
Gymnocarpium dryopteris	GYMDRY	N	7	FN	1.50	0.30	0.92	3.85
Hamamelis virginiana	HAMVIR	N	7	S	0.00	0.00	0.10	0.12
Hieracium aurantiacum	HIEAUR	A		F	0.95	0.65	0.00	0.00
Hieracium piloselloides	HIEPIL	A		F	0.03	0.63	0.00	0.00
Hieracium scabrum	HIESCA	N	6	F	0.02	0.00	0.00	0.00
Hieracium sp	HIESP			F	0.02	0.02	0.02	0.00
Huperzia lucidula	HUPLUC	N	3	FA	0.00	0.10	1.00	0.00

Hydrophyllum virginianum	HYDVIR	N	4	F	1.95	2.97	1.32	1.23
Hypericum perforatum	HYPPER	A		F	0.10	0.02	0.00	0.00
Hypericum pyramidatum	HYPPYR	N	6	F	0.02	0.03	0.00	0.00
Impatiens capensis	IMPCAP	N	2	F	6.70	1.40	1.00	1.00
Juncus dudleyi	JUNDUD	N	4	R	0.00	0.12	0.00	0.00
Juncus effusus	JUNEFF	N	4	R	0.60	0.52	0.00	0.02
Juncus tenuis	JUNTEN	N	1	R	1.88	1.32	0.00	0.00
Lactuca sp	LACSP		2	F	1.10	0.65	0.12	0.03
Laportea canadensis	LAOCAN	N	4	F	1.10	0.25	0.25	4.60
Larix laricina	LARLAR	N	8	T	0.02	0.00	0.00	0.00
Leucanthemum vulgare	LEUVUL	A		F	1.03	0.17	0.00	0.00
Lobelia inflata	LOBINF	N	2	F	2.85	0.62	0.25	0.00
Lonicera canadensis	LONCAN	N	8	SH	0.37	2.60	0.02	0.35
Luzula acuminata	LUZACU	N	6	R	0.28	0.00	0.02	0.35
Luzula multiflora	LUZMUL	N	5	R	0.02	0.00	0.00	0.00
Lycopodium annotinum	LYCANN	N	7	FA	0.02	0.00	0.02	0.00
Lycopodium clavatum	LYCCLA	N	6	FA	0.25	0.10	1.27	0.12
Lycopodium dendroideum	LYCDEN	N	7	FA	0.23	0.35	1.82	0.10
Lycopus uniflorus	LYCUNI	N	4	F	0.02	0.00	0.00	0.10
Maianthemum canadense	MAICAN	N	5	F	2.23	0.98	6.88	5.12
Maianthemum racemosum	MAIRAC	N	5	F	0.12	0.65	1.33	0.47
Matteuccia struthiopteris	MATSTR	N	5	FN	1.00	1.00	0.00	1.00
Medicago lupulina	MEDLUP	A		F	1.08	0.57	0.00	0.00
Medeola virginiana	MEDVIR	N	9	F	0.02	0.10	0.02	1.10
Melilotus sp	MELSP	A		F	0.12	0.35	0.00	0.00
Milium effusum	MILEFF	N	7	G	0.00	0.10	0.00	0.00
Mitella diphylla	MITDIP	N	8	F	0.00	0.03	0.20	0.45
Mitchella repens	MITREP	N	6	EA	0.00	0.10	0.22	0.27
Monarda fistulosa	MONFIS	N	3	F	0.00	0.10	0.00	0.00
Muhlenbergia mexicana	MUHMEX	N	4	G	0.00	2.00	0.00	0.00
Oenothera biennis	OENBIE	N	1	F	0.10	0.23	0.02	0.00
Onoclea sensibilis	ONCSEN	N	5	FN	1.55	4.92	0.00	0.12
Oryzopsis asperifolia	ORYASP	N	6	G	1.50	2.10	4.07	6.20
Osmunda cinnamomea	OSMCIN	N	7	FN	0.00	0.10	0.00	0.00
Osmorhiza claytonii	OSMORC	N	5	F	0.40	1.63	3.33	1.03
Osmunda claytoniana	OSMUNC	N	6	FN	2.85	5.22	1.00	3.85
Ostrya virginiana	OSTVIR	N	5	T	3.45	1.30	1.02	1.40
Oxalis stricta	OXASTR	N	0	F	3.88	1.17	0.00	0.00
Panax quinquefolius	PANQUI	N	10	F	0.00	0.00	0.02	0.00
Panicum sp.	PANSP			G	0.02	0.00	0.00	0.00
Panax trifolius	PANTRI	N	8	F	0.00	0.00	0.00	0.27
Parthenocissus sp.	PARSP	N		WV	0.00	0.00	0.03	0.25
Phegopteris connectilis	PHECON	N	7	FN	0.85	1.07	0.12	1.10
Phelum pratense	PHLPRA	A		G	1.02	1.35	0.00	0.00
Phryma leptostachya	PHRLEP	N	5	F	0.77	0.20	0.13	0.47
Picea glauca	PICGLA	N	7	T	0.03	0.02	0.00	0.00
Picea mariana	PICMAR	N	8	T	0.02	0.00	0.00	0.00

Pilea pumila	PILPUM	N	3	F	0.10	0.00	0.00	0.00
Pilea sp.	PILSP	N	3	F	0.10	0.00	0.00	0.02
Plantago major	PLAMAJ	A		F	3.28	1.68	0.00	0.02
Plantago rugelii	PLARUG	N	0	F	1.05	1.67	0.00	0.00
Poa alsodes	POAALS	N	5	G	0.10	0.00	0.00	0.00
Poa annua	POAANN	A		G	0.00	0.18	0.00	0.00
Poa compressa	POACOM	A		G	0.02	0.12	0.00	0.00
Poa pratensis	POAPRA	A		G	1.82	1.00	0.00	0.00
Polygonum aviculare	POLAVI	A		F	0.00	0.02	0.00	0.00
Polygonatum biflorum	POLBIF	N	4	F	0.00	0.00	0.13	0.00
Polygonum cilinode	POLCIL	N	1	F	0.15	0.35	2.02	0.02
Polygonum hydropiper	POLHYD	A		F	0.00	0.02	0.00	0.00
Polygonum persicaria	POLPER	A		F	0.00	0.02	0.00	0.00
Polygonatum pubescens	POLPUB	N	6	F	0.23	0.13	0.95	1.50
Polygunum punctatum	POLPUN	N	5	F	1.10	0.02	0.00	0.00
Polygonum sagittatum	POLSAG	N	6	F	0.02	0.12	0.10	0.00
Populus grandidentata	POPGRA	N	3	T	0.55	0.12	0.22	0.20
Populus tremuloides	POPTRE	N	2	T	3.52	0.65	1.77	0.15
Potentilla norvegica	POTNOR	N	0	F	0.65	0.40	0.10	0.00
Potentilla recta	POTREC	A		F	0.02	0.02	0.00	0.00
Prenanthes alba	PREALB	N	5	F	0.13	0.37	0.10	0.10
Prunus pensylvanica	PRUPEN	N	4	T	0.12	0.02	0.03	0.02
Prunus serotina	PRUSER	N	3	T	0.02	0.10	0.12	0.10
Prunus virginiana	PRUVIR	N	3	T	0.12	0.40	0.62	0.10
Prunella vulgaris	PRUVUL	N	1	F	1.37	1.08	0.02	0.00
Pteridium aquilinum	PTEAQU	N	2	FN	2.12	2.20	0.37	1.80
Pyrola elliptica	PYRELL	N	6	F	0.93	0.10	0.52	0.45
Quercus rubra	QUERUB	N	5	T	0.12	0.25	0.35	0.13
Ranunculus abortivus	RANABO	N	1	F	0.43	0.33	0.02	0.10
Ranunculus acris	RANACR	A		F	2.67	0.25	0.00	0.00
Ranunculus hispidus	RANHIS	N	6	F	0.03	0.10	0.00	0.10
Ranunculus recurvatus	RANREC	N	5	F	2.27	0.28	0.13	0.25
Ribes cynosbati	RIBCYN	N	3	SH	0.20	0.20	1.23	0.58
Rorippa sp.	RORSP				0.02	0.00	0.00	0.00
Rosa blanda	ROSBLA	N	4	SH	0.10	0.00	0.00	0.00
Rubus allegheniensis	RUBALL	N	2	SH	0.47	4.03	0.03	0.10
Rubus idaeus	RUBIDE	N	3	SH	17.35	4.37	14.55	0.82
Rubus pubescens	RUBPUB	N	7	F	0.00	0.47	0.00	0.12
Rumex obtusifolius	RUMOBT	A		F	0.20	0.10	0.00	0.00
Rumex sp.	RUMSP			F	0.00	0.02	0.00	0.10
Salix bebbiana	SALBEB	N	7	T	0.00	0.28	0.00	0.00
Salix eriocephala	SALERI	N	4	SH	0.00	0.10	0.00	0.00
Salix petiolaris	SALPET	N	6	SH	0.00	0.10	0.00	0.00
Salix sp	SALSP	N		SH	0.02	0.10	0.00	0.00
Sambucus racemosa	SAMRAC	N	5	SH	0.37	0.67	2.82	0.47
Sanguinaria canadensis	SANCAN	N	6	F	0.28	0.03	2.37	0.52
Schizachne purpurascens	SCHPUR	N	7	G	0.10	0.10	2.10	3.08

Scirpus atrovirens	SCIATR	N	3	S	2.82	2.67	0.00	0.00
Scirpus cyperinus	SCICYP	N	4	S	0.00	0.02	0.00	0.00
Scrophularia lanceolata	SCRLAN	N	4	F	0.13	0.10	0.10	0.00
Scutellaria lateriflora	SCULAT	N	5	F	0.30	0.00	0.00	1.00
Silene noctiflora	SILNOC	A		F	0.00	0.37	0.12	0.00
Silene vulgaris	SILVUL	A		F	0.27	0.32	0.00	0.00
Solidago canadensis	SOLCAN	N	1	F	0.93	1.23	0.22	0.03
Solanum dulcamara	SOLDUL	A		WV	0.02	0.00	0.00	0.00
Solidago flexicaulis	SOLFLE	N	6	F	0.32	0.33	0.20	1.90
Solidago gigantea	SOLGIG	N	3	F	2.62	7.57	0.00	0.12
Spirea alba	SPIALB	N	4	SH	0.10	0.00	0.00	0.00
Streptopus lanceolatus	STRLAN	N	7	F	0.38	0.42	1.58	1.43
Taraxacum officinale	TAROFF	A		F	4.57	1.82	0.25	0.18
Taxus canadensis	TAXCAN	N	10	SH	0.00	0.00	0.02	0.00
Thalictrum dioicum	THADIO	N	7	F	0.00	0.00	0.02	0.00
Tilia americana	TILAME	N	5	T	1.13	1.60	0.10	0.82
Trientalis borealis	TRIBOR	N	7	F	0.33	0.43	2.17	1.28
Trifolium hybridum	TRIHYB	A		F	0.97	1.80	0.00	0.00
Trillium sp.	TRILSP	N	6	F	0.42	0.77	1.78	1.92
Trifolium pratense	TRIPRA	A		F	1.52	1.70	0.00	0.00
Trifolium repens	TRIREP	A		F	1.22	3.87	0.10	0.00
Tsuga canadensis	TSUCAN	N	8	T	0.00	0.00	0.00	0.02
Ulmus americana	ULMAME	N	3	T	0.02	0.10	0.12	0.12
Urtica dioica	URTDIO	N	1	F	0.00	0.45	0.00	0.10
Uvularia grandiflora	UVUGRA	N	7	F	0.35	2.17	2.20	3.98
Vaccinium myrtilloides	VACMYR	N	6	SH	0.00	0.10	0.00	0.00
Veronica officinalis	VEROFF	A		F	0.35	0.02	0.00	0.10
Veronica serpyllifolia	VERSER	N	0	F	0.10	0.00	0.00	0.00
Verbascum thapsus	VERTHA	A		F	1.03	0.37	0.23	0.32
Viburnum acerifolium	VIBACE	N	7	SH	0.00	0.20	1.00	1.00
Viola blanda	VIOBLA	N	5	F	0.58	0.17	0.00	1.05
Viola canadensis	VIOCAN	N	7	F	0.00	0.03	0.12	4.20
Viola pubescens	VIOPUB	N	5	F	0.38	0.73	0.42	6.67
Viola sororia	VIOSOR	N	3	F	0.37	0.00	0.00	0.00
Total species					194	198	137	140
Total alien species					32	35	10	9
Total native species					159	162	125	129