Do tip-up mounds create unique microsites that enhance biodiversity?

A case study in a northern hardwoods forest in Michigan

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Abstract

Tip-up mounds are a disturbance caused by windstorms that create differences in the ecosystem. Some studies have shown that they potentially promote diversity in forests worldwide. However, only a few studies evaluate how tip-up mounds contribute to forest diversity. I tested the hypothesis that tip-up mounds enhance biodiversity and that unique vegetation will form with all microsites. For this purpose, I sampled the cover percent of woody species at four microsites in 25 tip-up mounds in a Michigan forest. The results show that significant differences exists in species richness, total coverage percent of woody species and total coverage of the four most common woody species. I demonstrated, that the species that are favored in the top-surface were *Rubus idaeus* and *Sambucus racemosa*, this is due to its characteristics of fast-growing opportunism and seed dispersal by frugivorous birds respectively. On the other hand, I demonstrated that *Acer saccharum* and *Fraxinus pennsylvanica* are significantly higher in reference plots versus the mounds surface plots, and that the percent cover is significantly higher in top-surface versus the other plots. This disturbance benefits biodiversity in the same patch, creating microsites that differ from each other.

Introduction

Disturbance is a crucial factor that influences the structure and composition of forests (Pickett and White 1985). Disturbances are caused by windstorms, fires, senescence of trees, landslides, and logging, amongst other natural disturbance events (Pickett and White, 1985). Windstorms can topple trees and create structural changes, including the creation of standing dead and downed woody debris, uprooted trees, exposed mineral soil, large canopy gaps, and tip-up mounds (Ulanova, 2000). Tip-up mounds are defined as a disturbance caused by the fall of a tree from the root. This creates differences in the ecosystem by altering factors such as soil stability and the availability of light and below-ground resources (Long et al. 1998). In other words, the ecological conditions change and may favor the formation of plant communities that are distinct from adjacent areas (Nakashizuka 1989). Betras. et al (2018) concluded that the formation of tip-up mounds creates novel microsites, potentially promoting diversity in forests worldwide.

Each novel microsites has a particular composition of species which have differential success, due to different physical and chemical processes operating on them (McAlister el al 2000). Consequently, biodiversity depends on the microsite analyzed. Moreover, this disturbance favors and affords the creation of refuge to vertebrate herbivores and serves as landing sites for avian frugivores (Betras et al. 2019).For this reason, the study of tip-up mounds is important to understand as tip-up mounds formation can lead to changes in forest biodiversity.

However, only a few studies exist that evaluate succession on tip-up mounds (Betras et al, 2019). Hence, further research is required to more fully understand the degree to which the formation of tip-up mounds enhances biodiversity and serves to create unique early successional microsites.The purpose of this research is to evaluate the effect of tip-up mounds on patterns of local plant species richness. I locate 25 different tip-up mounds in a northern hardwoods forest in Michigan and on each one, I identified the woody species on the mounds and in three adjacent microsites (Figure 1). I calculated species richness and species coverage to compare all four microsites.

I tested the hypothesis that tip-up mounds enhance biodiversity and that unique vegetation will form with all microsites. Following previous studies (Lang et al. 2009, Frelich et al. 2018, Betras et al. 2018, Betras et al. 2019). I predicted that mound disturbed microsites would have unique plant species composition and higher diversity compared to undisturbed control microsites (Figure 1).

Methods and Materials

Study area. The study area is located on the border of Wisconsin and the Upper Peninsula of Michigan (46° 13' N, 89° 32' W) in a northern mesic hardwood forest at University of Notre Dame Environmental Research Center (UNDERC). This is situated in the Northern Highland Province, which is the southernmost extension of the Canadian Shield in the USA. The forest is mostly second-growth consisting chiefly of aspen-birch, pine, or swamp-conifer with some red or sugar maple-hemlock (UNDERC, n.d). I worked in two areas, Craig House and the Storage. Mainly because these sectors were affected by the windstorm in July of 2017, thus, creating numerous tip-up mounds (M. J. Cramer, University of Notre Dame, pers. comm).

Forest measurements. I selected and georeferenced 25 tip-up mounds at UNDERC. In each site, I localized two tip-up positions: (1) "top surface", (2) "upper surface", as well as two outside positions: (3) "Intact reference" (position adjacent two meters from the mound on the side of the downed tree) and (4) "closed canopy reference" (further away beneath the closed-canopy forest) (Figure 1). I measured the length, and width of each mound, to use the same size plots in the other microsites. I then randomly selected a plot with the same area in an intact reference and closed canopy reference. For each microsite, I visually estimated the coverage of woody species, and the number of individuals per plot.

Variables of interest. For each microsite, I worked with the variables richness, total coverage percent of woody species and total coverage percent of the four most common woody species.

Analysis of data. We used Shapiro-Wilk test to determine the normality of the data. To compare normal data, I used one-way ANOVA. To compare non-normal data I used Kruskal Wallis. All these tests were conducted using R version 3.6.1 (R Core Team) with R studio.

Results

I found a total of 16 woody species (Table 1) between all the plots, and we concluded these results in the following variables.

Richness. The results for the Kruskal-Wallis test in species richness are significant (df=3, H= 8.26; p-value = 0.041). The richness was marginally higher on reference plots versus mounds surface (Fig. 2).

Total percent cover of woody species. The result for the ANOVA test in total percent cover of woody species yielded a p-value= 0.0428, df= 3. This is significantly higher in Top-surface when compared to the other plots (Fig 3). Generally, the differences in species cover between mound surface and references plots were significant (Fig 4).

Percent cover of the four most common woody species. The results for the Kruskal-Wallis test were all significant. The most common woody species were *Rubus idaeus* (df=3, p value=7.582E-12), *Acer saccharum* (df=3, p value=7.19E-13), *Sambucus racemosa* (df=3, p value=0.02232), and *Fraxinus pennsylvanica* (df=3, p value=1.981E-09). Each one of the results can be seen in Table 2. *Rubus idaeus* was marginally higher on munds surface versus reference plots; *Acer saccharum* was significantly higher in reference plots versus the mounds surface plots; *Sambucus racemosa* was significantly higher in top-surface versus the other plots and *Fraxinus pennsylvanica* was significantly higher in reference plots versus the mounds surface plots (Fig 5).

Discussion

Species richness. I demonstrated that the species richness is marginally higher on reference plots versus mounds surface. The species richness corresponded to the number of species present in a particular area, in this case, only woody species, which in general are not the first to colonize disturbed sites. These are the herbaceous and shrubs (Díaz, Wilmer and Elcoro 2009), as is the case with *Rubus idaeus* which is present significantly in the surface of the mound. For future studies, it would be interesting to analyze the stage in which the succession is, in order to know if the difference in the number of woody species is due to successional differences.

Total percent cover of woody species. I found that the percent of cover was significantly higher in top-surface versus the other plots. This is probably due to the high level of light penetration in this area, promoting the establishment of shade-intolerant species, which are good colonizers (Díaz, Wilmer and Elcoro 2009). Another reason is that tip-up mounds function as a refuge from vertebrate herbivores (Thompson 1980), which promotes the spreading of seeds and their establishment.

Percent cover of the four most common woody species. I demonstrate that *Rubus idaeus* and *Sambucus racemosa* were significantly higher in top-surface when compared to the other plots. This is because *Rubus idaeus* has a lifestyle of fast-growing opportunism and is an often monopolistic species that grows in gaps (Gaudio et al. 2007). Consequently, the tip-up mound is an ideal disturbance for their rapid growth. On the other hand, we found *Sambucus racemosa* significantly higher in top-surface, this species has a characteristic red fruit that encourages seed dispersal by frugivorous birds and mammals (Burns 2003). According to Thompson 1980 and Long et al. 1998, tree tip-up mounds provide a refuge from vertebrate herbivores and serve as landing sites for avian frugivores, which would be beneficial for the establishment of this species. In addition, I demonstrated that *Acer saccharum* and *Fraxinus pennsylvanica* are significantly higher in the reference plots when compared to the mound surface plots. This is probably because Green ash is moderately tolerant to shade (Kennedy 1990) and Sugar maple is shade tolerant (Tirmenstein 1991), which means that the intact forest is the ideal place for its growth.

Summarizing, the tip-up mound benefits biodiversity in the same patch and owes the creation of new disturbances in the ecosystem to abiotic factors such as light and structural changes (Long et al. 1998), creating microsites different from each other. This phenomenon is important because the forest durability is ensured by tree regeneration (Gaudio et al. 2007). These kind of disturbances guarantee the regeneration of woody species. I recommend that future studies of habitats associated with tip-up mounds calculate the number of species in order to calculate other index of biodiversity. Moreover, we recommend that the analysis include successional stage, in order to know if the difference in the number of woody species is due to the stage of the disturbance.

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Tables

Table 1. All the woody species found in the 25 tip-up mounds, with their respective Families and Growth Habits. For the elaboration of this table the web page of the United State Department of Agriculture was consulted (USDA, 2019).

Scientific name	**Common name**	**Family**	**Growth Habit**
Abies balsamia	Balsam fir	Pinaceae	Tree
Acer rubrum	Red maple	Aceraceae	Tree
Acer saccharum	Sugar Maple	Aceraceae	Tree
Betula alleghaniensis	Yellow birch	Betulaceae	Tree
Corylus spp. 1	Hazelnut	Betulaceae	Tree
Dirca palustris	Leatherwood	Thymelaeaceae	Shrub
Fraxinus pennsylvanica	Green ash	Oleaceae	Tree
Lonicera morrowii	Morrow's honeysuckle	Caprifoliaceae	Shrub
Morus spp. 1	Mulberry	Moraceae	Shrub
Prunus pensylvanica	Pin cherry	Rosaceae	Tree/Shrub
Prunus serotina	Black cherry	Rosaceae	Tree/Shrub
Ribes cynosbati	Prickly goosberry	Grossulariaceae	Shrub
Rubus hispidus	Swamp dewberry	Rosaceae	Subshrub
Rubus idaeus	Red raspberry	Rosaceae	Subshrub
Sambucus racemosa	Red-berried elder	Caprifoliaceae	Tree/Shrub

Tilia americana	American basswood	Tiliaceae	Tree

Table 2. The most common woody species: *Rubus idaeus*, *Acer saccharum*, *Sambucus racemosa*, *Fraxinus pennsylvanica* and the results for the Kruskal-Wallis test**.**

Species	**H**	**P-value**
Rubus idaeus	54.798	7.582E-12
Acer saccharum	59.588	7.19E-13
Sambucus racemosa	9.5968	0.02232
Fraxinus pennsylvanica	43.444	1.981E-09

Figures

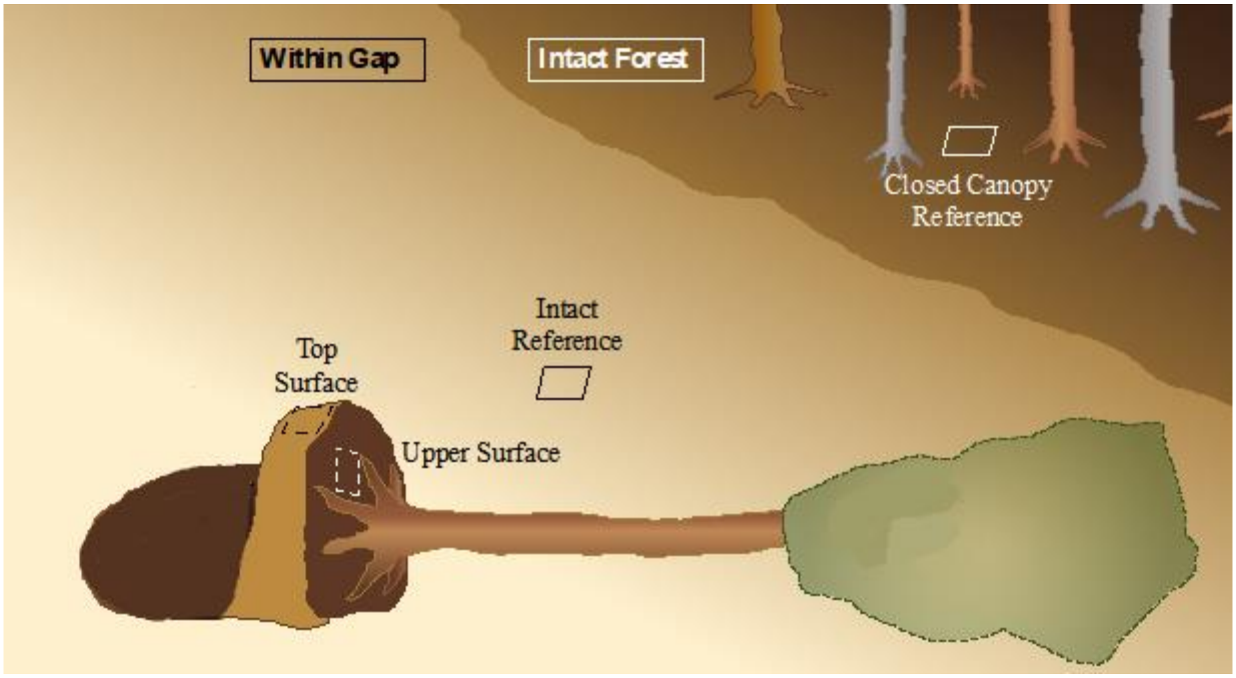


Figure 1. Depiction of a single tip-up mound and the positions sampled: (1) "top surface", (2) "upper surface", (3) "Intact reference", and (4) "closed canopy reference". I used Betras et al 2018 as a reference to this edition.

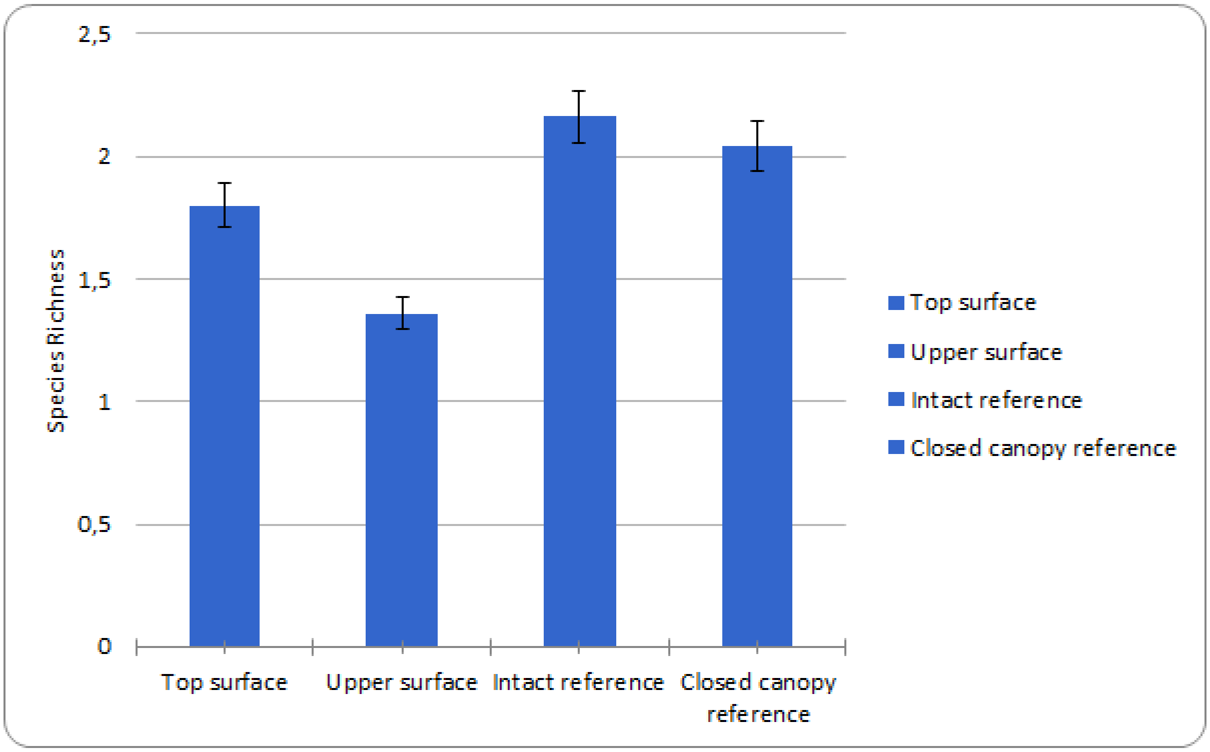


Figure 2. Species richness, calculated with the total number of species per microsite. The results for the Kruskal-Wallis test in species richness are significant (df=3, H= 8.26; p-value = 0.041).

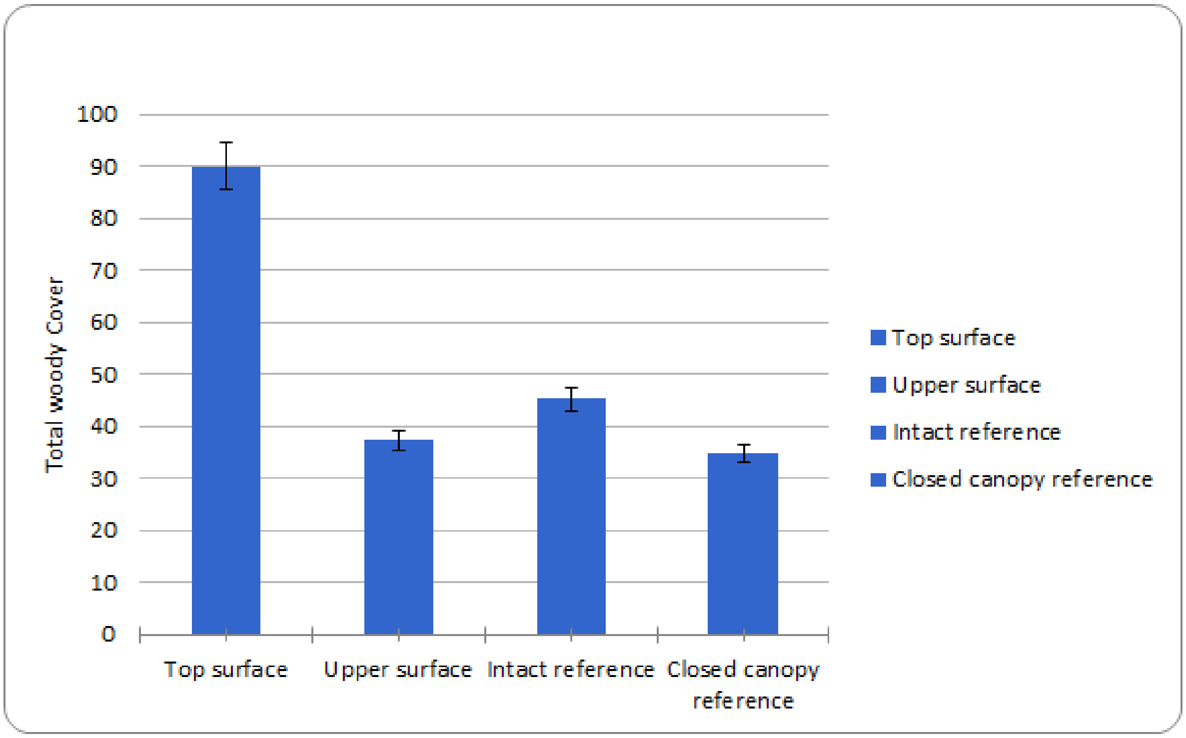


Figure 3. Total, percentage of cover per microsite. The result for the ANOVA test in total percent cover of woody species yielded a p-value= 0.0428, df= 3. This is significantly higher in Top-surface when compared to the other plots

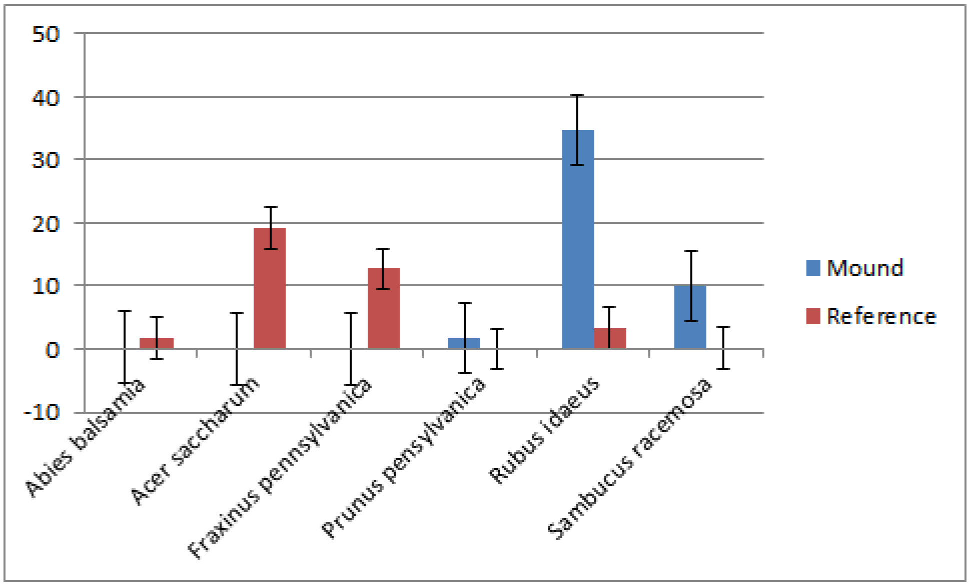
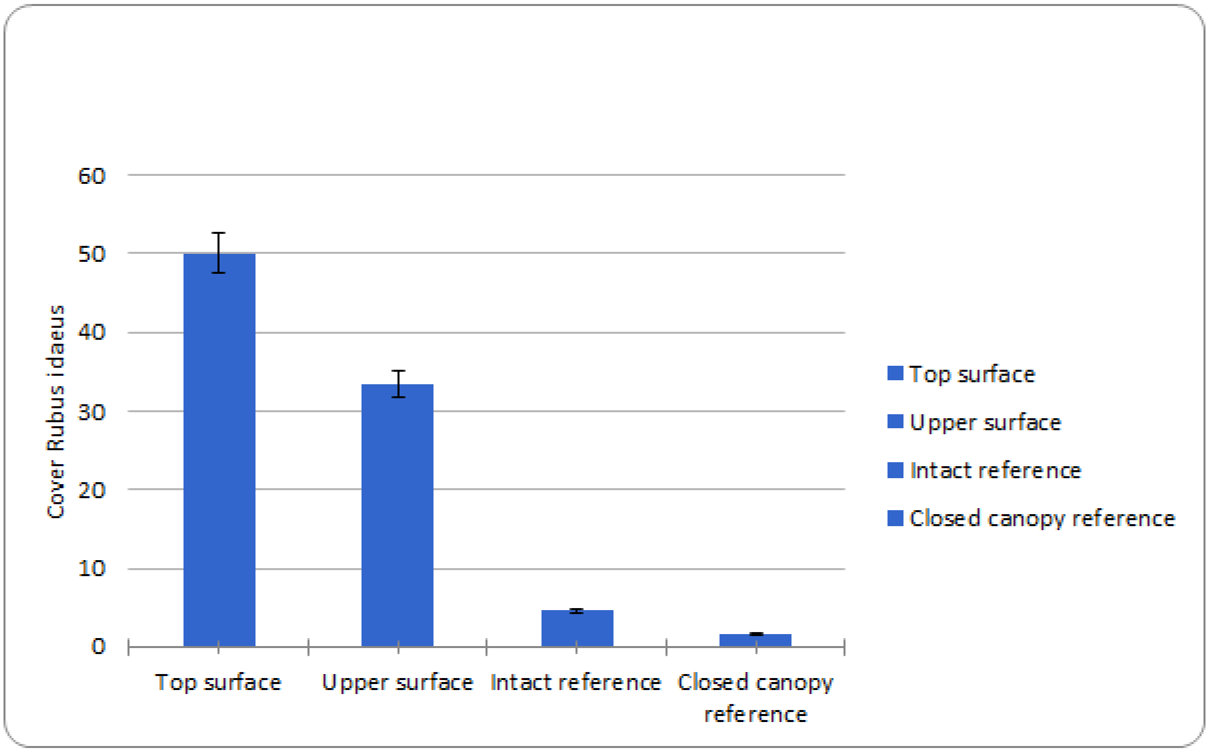
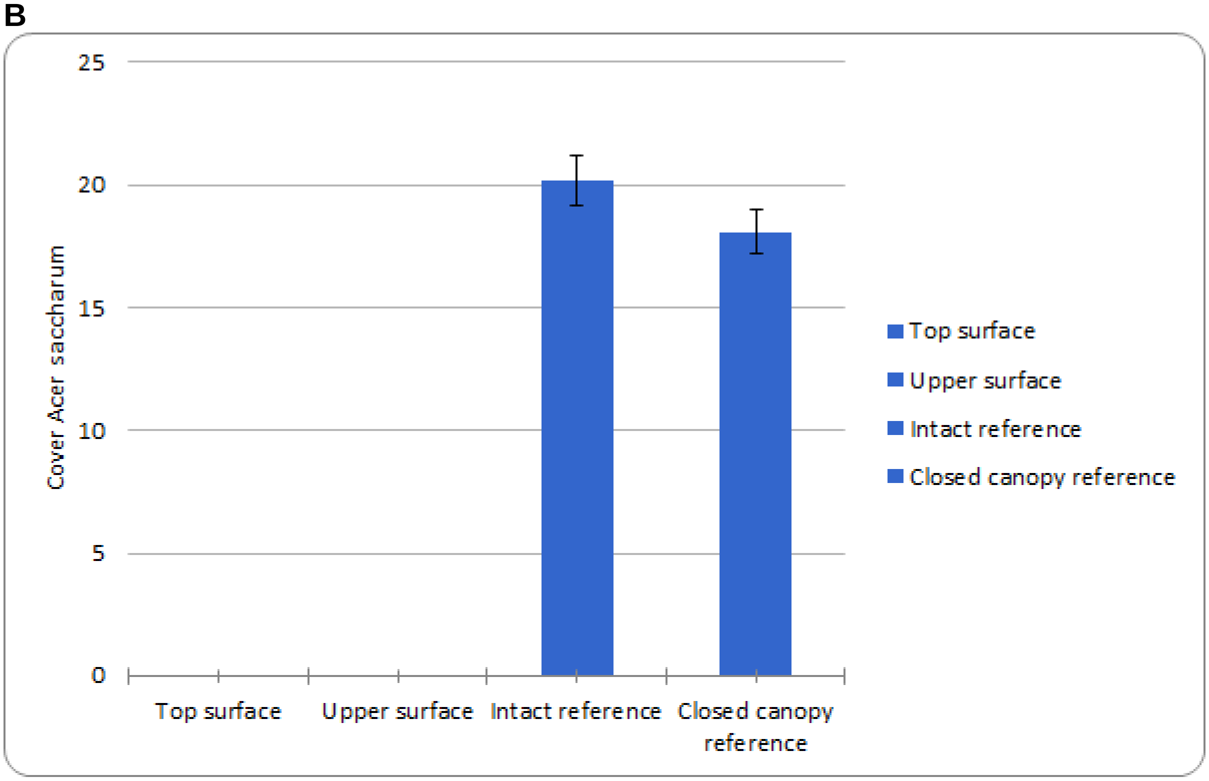


Figure 4. Mean percent cover by species and plot type. The mound is "top surface" and "upper surface", and reference is "intact reference", and "closed canopy reference". Only species representing more than 1% mean cover on either mounds or reference plots are included here.

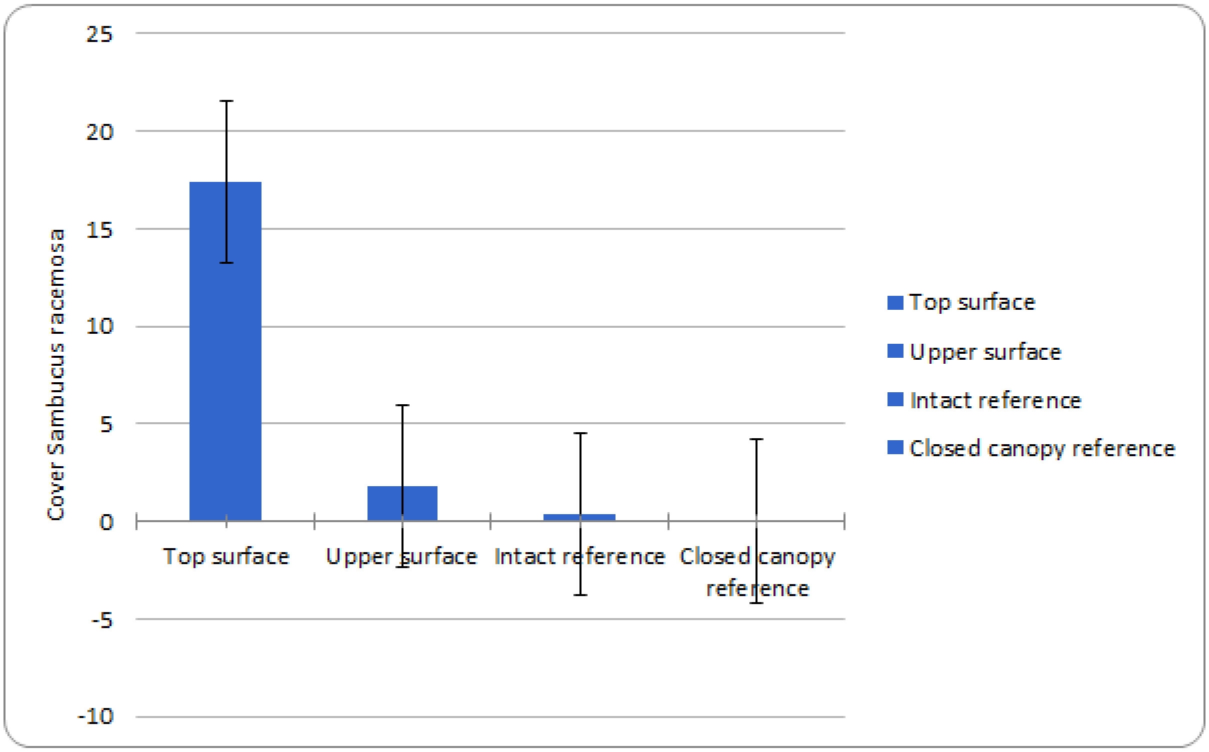
A


60
50
40
30
20
10
0
Cover Rubus idaeus
Top surface
Upper surface
Intact reference
Closed canopy reference

B


25
20
15
10
5
0
Cover Acer saccharum
Top surface
Upper surface
Intact reference
Closed canopy reference

C


25
20
15
10
5
0
-5
-10
Cover Sambucus racemosa
Top surface
Upper surface
Intact reference
Closed canopy reference
Top surface
Upper surface
Intact reference
Closed canopy reference

D

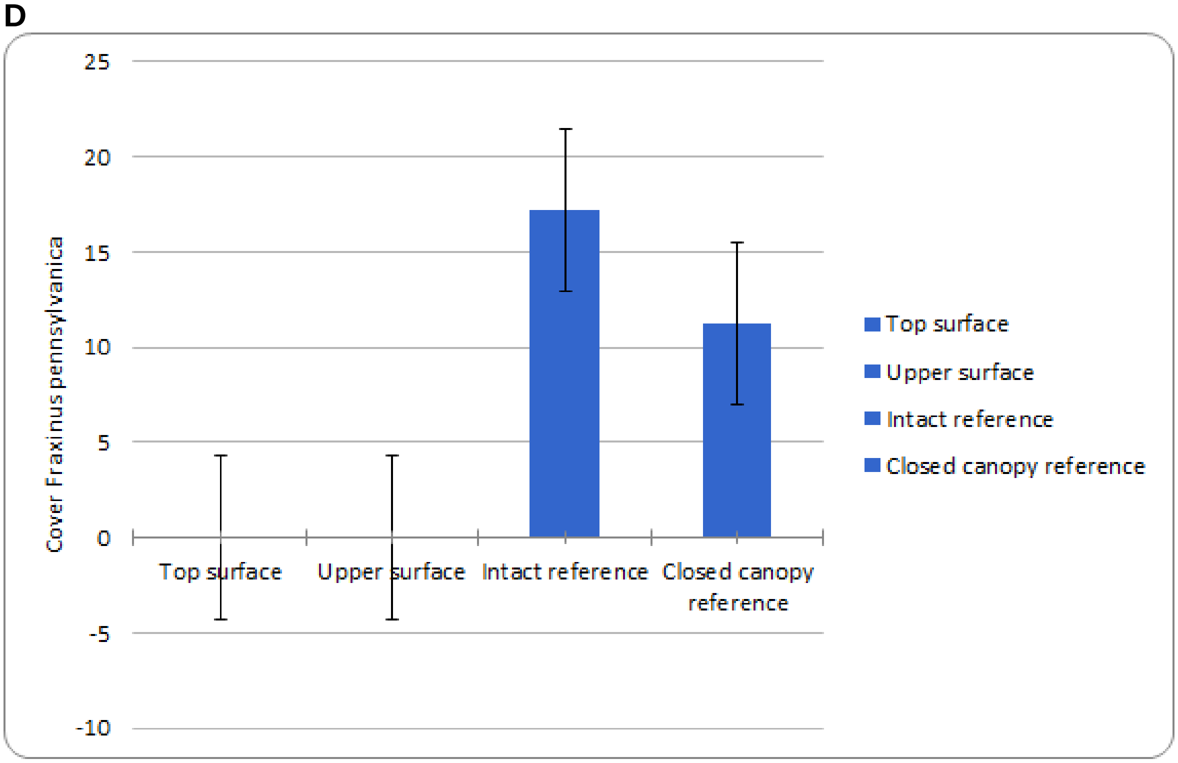

25
20
15
10
5
0
-5
-10
Cover Fraxinus pennsylvanica
Top surface
Upper surface
Intact reference
Closed canopy reference
Top surface
Upper surface
Intact reference
Closed canopy reference

Figure 5. (A) Mean percent cover of *Rubus idaeus*, (B) mean percent cover of *Acer saccharum*, (C) mean percent cover of *Sambucus racemosa*, (D) mean percent cover of *Fraxinus pennsylvanica.* The results for the Kruskal-Wallis test were all significant. The most common woody species were *Rubus idaeus* (df=3, p value=7.582E-12), *Acer saccharum* (df=3, p value=7.19E-13), *Sambucus racemosa* (df=3, p value=0.02232), and *Fraxinus pennsylvanica* (df=3, p value=1.981E-09).

Appendix

Raw data

N	Top shape (cm)	Scientific name	Common name	TOP	UPPER SURFACE	INTACT REFERENCE	CLOSED CANOPY REFERENCE
1	120x61			%	%	%	%
		Rubus idaeus	Red raspberry	45	90		
		Acer saccharum	Sugar Maple			70	40
2	45x155			%	%	%	%
		Rubus idaeus	Red raspberry	90	40		5
		Acer saccharum	Sugar maple				1
3	40x160			%	%	%	%
		Rubus idaeus	Red raspberry	50	15		1

		Sambucus racemosa	Red-berried elder		7	2	
		Acer saccharum	Sugar Maple			12	7
4	47x225			%	%	%	%
		Rubus idaeus	Red raspberry	82	25		
		Fraxinus pennsylvanica	Green ash			5	
		Acer saccharum	Sugar maple			60	45
5	56x230			%	%	%	%
		Rubus idaeus	Red raspberry	25	20		

		Prunus pensylvanica	Pin cherry		12		
		Abies balsamia	Balsam fir		15		
		Betula alleghaniensis	Yellow birch				6
		Acer saccharum	Sugar maple			65	22
		Morus spp. 1	Mulberry			2	
		Corylus spp. 1	Hazelnut				6
		Betula alleghaniensis	Yellow birch				12
6	35 x 190			%	%	%	%
		Rubus idaeus	Red raspberry	70	92		1

		Acer saccharum	Sugar maple			99	99
7	45 x 185			%	%	%	%
		Rubus idaeus	Red raspberry	86	50	15	
		Prunus serotina	Black cherry	8			
		Sambucus racemosa	Red-berried elder	5			
		Fraxinus pennsylvanica	Green ash			50	
		Ribes cynosbati	Prickly goosberry			2	
		Tilia americana	American basswood			5	

		Acer saccharum	Sugar maple			5	12
8	30 x 280			%	%	%	%
		Sambucus racemosa	Red-berried elder	90			
		Rubus idaeus	Red raspberry	6	2		
		Acer saccharum	Sugar maple			2	1
9	35 x 235			%	%	%	%
		Sambucus racemosa	Red-berried elder	98			
		Rubus idaeus	Red raspberry		5		

		Fraxinus pennsylvanica	Green ash			75	9
		Acer saccharum	Sugar maple				10
10	40x225			%	%	%	%
		Rubus idaeus	Red raspberry	70	65		
		Prunus pensylvanica	Pin cherry	5			
		Rubus hispidus	Swamp dewberry	5	6		15
		Fraxinus pennsylvanica	Green ash			12	15
		Acer saccharum	Sugar maple				27
11	30x160			%	%	%	%

		Rubus idaeus	Red raspberry	6	20		
		Sambucus racemosa	Red-berried elder	87			
		Rubus hispidus	Swamp dewberry	5	7		
		Fraxinus pennsylvanica	Green ash			37	5
		Ribes cynosbati	Prickly gooseberry				7
		Acer saccharum	Sugar maple				2
12	50x270			%	%	%	%
		Rubus idaeus	Red raspberry	40	50		

		Sambucus racemosa	Red-berried elder	25		2	
		Prunus pensylvanica	Pin cherry	8	5		
		Fraxinus pennsylvanica	Green ash			40	20
		Acer saccharum	Sugar maple			3	8
13	42x205			%	%	%	%
		Rubus idaeus	Red raspberry	7	10	12	20
		Fraxinus pennsylvanica	Green ash			17	
		Acer saccharum	Sugar maple			27	8

		Tilia americana	American basswood				5
14	35 x 180			%	%	%	%
		Fraxinus pennsylvanica	Green ash			65	50
		Rubus idaeus	Red raspberry			3	
15	37x185			%	%	%	%
		Rubus idaeus	Red raspberry	5	3		
		Prunus pensylvanica	Pin cherry			5	
		Fraxinus pennsylvanica	Green ash			8	17
		Acer saccharum	Sugar maple			8	1

16	40 x 230			%	%	%	%
		Rubus idaeus	Red raspberry	8	20		
		Sambucus racemosa	Red-berried elder	25			
		Acer saccharum	Sugar maple			15	10
		Fraxinus pennsylvanica	Green ash			12	45
17	33 x 260			%	%	%	%
		Sambucus racemosa	Red-berried elder	70	10		
		Rubus idaeus	Red raspberry	7	8	25	

		Prunus pensylvanica	Pin cherry		5		
		Fraxinus pennsylvanica	Green ash			20	25
		Acer saccharum	Sugar maple			6	5
18	30 x 240			%	%	%	%
		Rubus idaeus	Red raspberry	12	10		
		Prunus pensylvanica	Pin cherry	25			
		Rubus hispidus	Swamp dewberry	10			
		Acer saccharum	Sugar maple		4	15	7
19	55 x 145			%	%	%	%

		Rubus hispidus	Swamp dewberry	8			
		Rubus idaeus	Red raspberry	40	30		
		Prunus pensylvanica	Pin cherry	10			
		Acer saccharum	Sugar maple			70	55
		Abies balsamia	Balsam fir			15	
		Acer rubrum	Red maple			7	
20	59 x 230			%	%	%	%
		Fraxinus pennsylvanica	Green ash			20	10
		Rubus idaeus	Red raspberry	50	65	5	

		Rubus hispidus	Swamp dewberry			20	
		Abies balsamia	Balsam fir				10
		Acer saccharum	Sugar maple				25
		Dirca palustris	Leatherwood				10
		Prunus pensylvanica	Pin cherry	7			
21	47 x 195			%	%	%	%
		Sambucus racemosa	Red-berried elder	60	28		
		Rubus idaeus	Red raspberry	30	15	15	2

		Prunus pensylvanica	Pin cherry	7			
		Acer saccharum	Sugar maple			25	25
		Fraxinus pennsylvanica	Green ash			10	25
		Lonicera morrowii	Morrow's honeysuckle				
22	75 x 143			%	%	%	%
		Rubus idaeus	Red raspberry	15	50		
		Acer saccharum	Sugar maple				
		Fraxinus pennsylvanica	Green ash			7	7

		Abies balsamia	Balsam fir				60
23	85x185			%	%	%	%
		Rubus idaeus	Red raspberry	90	95	50	10
		Acer saccharum	Sugar Maple			5	17
		Sambucus racemosa	Red-berried elder			5	
		Morus spp. 1	Mulberry			5	
		Fraxinus pennsylvanica	Green Ash			5	17
		Betula alleghaniensis	Yellow birch			2	
24	45x235			%	%	%	%

		Rubus idaeus	Red raspberry	17	7		
		Betula alleghaniensis	Yellow birch	7	6		
		Prunus serotina	Black cherry	3	x		
		Conium maculatum	Hemlock	5	6		
		Fraxinus pennsylvanica	Green ash			7	6
25	35x140			%	%	%	%
		Rubus idaeus	Red raspberry	45	50	1	x
		Fraxinus pennsylvanica	Green ash			40	30

		Acer saccharum	Sugar maple			17	25