Deer Impacts on Vegetation in Ann Arbor Natural Areas:

Key Monitoring Metrics for 2018–2019

J.B. Courteau, Ph.D.

NatureWrite LLC

jbcourteau@gmail.com

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EXECUTIVE SUMMARY

Vegetation monitoring metrics for 2018 showed a decrease in deer browse damage on experimental red oak seedlings in many sites, including most areas where deer were actively managed in or near the site from 2016–2019. However, browse levels on oaks were still high, and deer were linked to significant reductions in blooming of trillium and experiment wildflowers at most sites.

Deer browsed 56% of experimental red oak seedlings across all Ann Arbor sites. Wildflower experimental plantings showed high levels of deer browse—higher than red oak seedlings planted in the same plots, suggesting that deer browse levels on red oak seedlings are a conservative estimator of damage to wildflowers. Deer were linked to considerable reductions in flowering of experimental asters and goldenrods.

Trillium abundance or flowering (or both) remained lower in plots where deer were present than in plots protected from deer in 2018. Deer browse levels on trillium in 3 of 5 sites are above the 5-15% level that previous studies have shown will allow for persistence of trillium populations over time. Fenced trillium populations protected from deer showed clear increases in trillium number and flowering from 2016-2018. Deer browse levels on trillium in 2018 were similar to those in 2016, suggesting that deer populations are still high enough to exert negative impacts on trillium.

RED OAK EXPERIMENTAL SEEDLINGS: % DEER BROWSED

- Overall, deer browsed 58% of red oak seedlings planted across sites.
- Deer browsed 60% of more of red oak seedlings at 8 city natural areas, and 40–60% at all but 1 of the remaining sites; at all sites, browse levels were above the 15% level beyond which oak regeneration may decline.
- Natural areas with the highest % deer browse in 2018 were White Oak, Huron Hills, and Bird Hills. Kuebler Langford had the lowest levels.
- Despite continued high levels, deer browsing on oaks decreased at many sites from 2016 to 2018, including at many deer management sites.
- Red oak seedlings can serve as a standardized gauge of deer impacts across parks, and as an indicator of potential impacts on wildflower species.
- Oak seedlings may be a conservative estimator of impacts to wildflowers: browsing on oaks was generally lower than on adjacent experimental wildflowers.

WILDFLOWER EXPERIMENTAL PLANTINGS: % deer browsed, % mortality, % flowering, # flowers

- Deer browsed 70% or more of planted asters and goldenrods across all sites.
- Deer were associated with higher mortality overall, however the more notable impact was a decrease in the % wildflowers blooming and # flowers.
- Deer were linked to significantly lower % flowering at all sites when comparing unfenced to fenced plots, with the largest differences at Bird Hills (-65%) and Furstenberg (-77%) and lowest differences at Black Pond Woods (-33%) and Mary Beth Doyle (-39%).
- Deer impacts on total # flowers were even larger, with deer-accessible plots at Bird Hills and Furstenberg having only 10% and 14% as many flowers, respectively, as protected plots.
- Reductions in flower # due to deer browsing led to significant reductions in the # of pollinators observed in a pilot study at Furstenberg.

TRILLIUM EXCLOSURE STUDY: TRILLIUM ABUNDANCE AND FLOWERING (# plants, # flowers)

- Total trillium abundance and flowering were lower in deer-accessible unfenced plots than in fenced plots protected from deer in 4 of 5 sites, including 3 sites where deer were managed, and 1 site where deer were not managed.
- Deer were linked to significantly lower trillium abundance overall, with unfenced deer-accessible plots having considerably fewer plants than fenced plots in 2018.
- Deer were linked to significantly lower trillium flowering, with unfenced deer-accessible plots having only 1/4 to 1/10 as many flowers as fenced plots when totaled by site in 2018.
- A comparison of total trillium abundance and flowering from 2016 to 2018 shows that trillium flowering and abundance increased steadily over time in fenced plots protected from deer, while it varied considerably but increased little in deer-accessible unfenced plots, despite similar initial abundance and flowering in 2016.
- Mary Beth Doyle showed a different pattern than other sites; deer impacts were not significant for any measures, but 2018 data suggest that deer may be starting to have an impact. Deer management occurred more 3/8 mile from trillium plots in this site, which may be too distant to affect them.

Table 1. Summary of metrics for deer impacts on vegetation, by site. For % deer browsed (oak seedlings, wildflowers, and trilliums), higher numbers indicate more severe deer impacts. For the remaining metrics, lower (more negative) numbers show more severe deer impacts. Metrics in brown are from the red oak experimental seedling study, those in purple are from the wildflower experimental study, and those in peach are from the trillium exclosure study.

	Metrics (higher=worse)			Metrics (lower=worse)			
Site	**% deer browsed Oaks**	**% deer browsed Wildflowers**	**% deer browsed Trilliums**	**Wildflower comparison** (unfenced-fenced) **% mortality**	**Wildflower relative difference** (unfenced-fenced)/fenced] **% flowering**	**Wildflower relative difference** (unfenced-fenced)/fenced] **# flowers**	**Trillium change 2016–18 # flowers**
Bird Hills*	73%	89%	20%	-7%	-65%	-90%	↓
Black Pond Woods	43%	84%	8%	-8%	-33%	-33%	↓
Cedar Bend	47%						
Dhu Varren	63%						
Furstenberg	63%	95%		-5%	-77%	-86%	
Hansen	50%						
Huron Hills Golf Course	81%						
Huron Parkway	65%						
Kuebler Langford	18%						
Lakewood	40%		3%				↓
Leslie Woods	44%						
Mary Beth Doyle	60%	65%	3%	-20%	-39%	-44%	—
Oakwoods/ Sugarbush	61%	86%		-36%	-52%	-41%	
White Oak	100%						
Nichols Arboretum, (UM)†	59%		17%				↓

* Bird Hills had 3 planting sites in 2018 (Bird Road, Newport Road, and Huron River Drive); this table averages across all three sites for comparison with wildflowers and trillium. †The Nichols Arboretum study was separately contracted by the Matthaei Botanical Gardens/Nichols Arboretum (University of Michigan), which has agreed to share results for comparison here.

OVERVIEW

Vegetation monitoring in Ann Arbor's natural areas in 2018–19 shows that deer browse levels on oaks remain over 50% in most sites, even though levels in some sites have decreased over time. However, deer are continuing to affect trilliums and experimental wildflowers, leading to reductions in abundance and/or flowering in most sites. This report highlights results for key vegetation metrics for 2018–19, and offers comparisons to previous years. Monitoring was conducted using 3 different monitoring methods to assess plants in Ann Arbor's natural areas:

- **Red oak experimental seedlings:** 456 seedlings were planted in 14 city parks/natural areas (at 3 locations in Bird Hills Nature Area) and in University of Michigan's Nichols Arboretum (under separate contract) for a total of 15 planting sites. The seedlings were assessed periodically for signs of deer browse for one full year (May-June 2018–2019). **Key metric: % oak seedlings deer browsed.**

- **Wildflower experimental plantings:** Nearly 1,000 small plants of 6 wildflower species were transplanted into 5 pairs of fenced and unfenced experimental plots in each of 5 different natural areas in fall 2017 and spring 2018. Plants were monitored throughout the 2018 growing season for survival, deer browse, flowering, and fruiting, and deer browse. Monitoring was also continued on wildflowers previously planted in spring 2017 (another 1,000 plants of 8 species, for a total of 2,000 plants of 10 unique species). Prolonged dry weather inhibited growth and flowering of many plants; data are reported for 3 species (two goldenrod species and an aster) that flowered during 2018. **Key metrics: % wildflowers deer browsed, % mortality, % flowering, and % fruiting.**

- **Trillium exclosure study:** 5 pairs of fenced and unfenced plots with existing trillium populations were established in 5 natural areas —4 City natural areas plus a separate study at Nichols Arboretum—and tracked for abundance and flowering. Data are presented on abundance and flowering of over 1,075 trillium plants after two full years of protection from deer compared to plants left open to deer (half of the plots were fenced *exclosures* that prevent deer access). **Key metrics: total trillium abundance (#), flowering (#), and % change from 2016 to 2018 in unfenced vs. fenced plots.**

This report presents monitoring results for **key metrics** for the 2018 growing season covering over 3,000 individual plants. Supplemental appendices offer additional analyses, as well as details on methods and references. Results for 2015–2016 and 2016–2017 were reported previously (*Deer Impacts on Vegetation in Ann Arbor Park Natural Areas, 2016–17 Monitoring Summary*, June 2018; *Deer Impacts on Vegetation in Ann Arbor Park Natural Areas, Complete Monitoring Methods and Results, 2016–17*, May 2018; and *A Pilot Study of Red Oak Seedlings as Experimental Indicators of Deer Browse Intensity (Sentinel Seedlings) Across 10 Ann Arbor Natural Areas, November 2015–January 2017*, April 2017.)

VEGETATION STUDY LOCATIONS

Research and monitoring plots were placed in 14 Ann Arbor City park natural areas and Nichols Arboretum (Figure 1, Table 2).

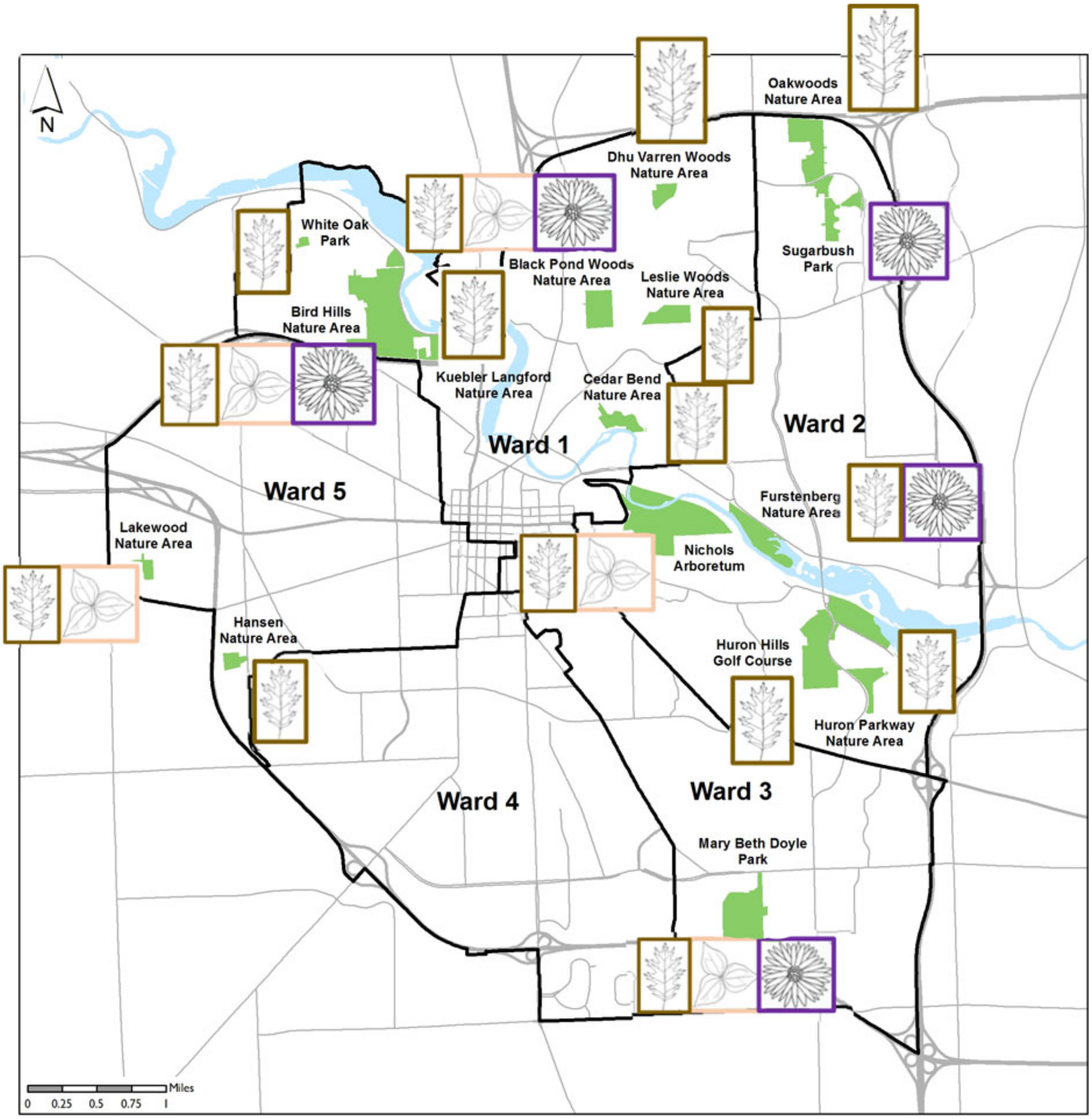

Figure 1. Study locations in Ann Arbor natural areas. Symbols show the different studies:

Red oak experimental seedlings

Trillium exclosure study

Wildflower experimental plantings

Table 2. Overview of Ann Arbor natural areas where vegetation was monitored for deer impacts. Monitoring included a ***red oak experimental seedling study*** (conducted in 2015–16, 2017–18, and 2018–19), an ***experimental wildflower study***, in which stems of a total of 10 perennial wildflower species were transplanted into fenced vs. unfenced plots and tracked for % mortality, % flowering, and % fruiting (2017 and 2018), and a ***trillium exclosure study*** (comparing abundance and flowering over time of existing population in fenced exclosures vs. unfenced plots, 2016–18). Studies were placed 14 Ann Arbor City natural areas, as well as University of Michigan's Nichols Arboretum (†contracted separately by Matthaei Botanical Gardens/Nichols Arboretum, which agreed to share results for comparison). Bird Hills Nature Area is large enough (166 acres) so that it had three different study locations for the oak study—but trillium and wildflower plots were placed throughout, so oak results are combined for comparing to trillium and wildflower data. Oakwoods Nature Area and Sugarbush Park, separated by Green Road, each hosted only one study (oaks in Oakwoods and wildflowers in Sugarbush), but are paired for comparison of oaks and wildflowers.

Site	**Oak (2016)**	**Oak (2017)**	**Oak (2018)**	**Wildflower (2017–18)**	**Trillium (2016–18)**
Bird Hills Nature Area (3 locations: Bird Road, Newport Road, Huron River Dr.)	X	X	X	X	X
Black Pond Woods Nature Area	X	X	X	X	X
Cedar Bend Nature Area		X	X		
Dhu Varren Nature Area		X	X		
Furstenberg Nature Area	X	X	X	X	
Hansen Nature Area	X	X	X		
Huron Hills Golf Course (Woods)	X	X	X		
Huron Parkway Nature Area	X	X	X		
Kuebler Langford			X		
Lakewood Nature Area	X	X	X		X
Leslie Woods Nature Area		X	X		
Mary Beth Doyle Park	X	X	X	X	X
Oakwoods Nature Area/ Sugarbush Park		X	X	X	
White Oak Park	X	X	X		
Nichols Arboretum (Univ. of Michigan)†	X	X	X		X

Sites were selected with several criteria:

- to encompass a range of larger and smaller natural areas, including those with high-quality plant communities (such as Bird Hills, Mary Beth Doyle, Black Pond Woods);
- to represent areas found in aerial surveys to have higher and lower deer densities;
- to achieve geographical coverage of the city.

The red oak experimental seedling study was initiated in 2015–16 and expanded to include more sites in 2017, with one more natural area (Kuebler Langford) and an additional planting area within Bird Hills (Huron River Drive) added in 2018. The experimental wildflower study was placed in five natural areas with high-quality vegetation and for good geographical coverage. The trillium study was conducted in natural areas larger than five acres with notable trillium populations. Three sites had all three studies, so that results of the different study methods could be compared.

RED OAK EXPERIMENTAL SEEDLINGS

To assess potential deer impacts on tree regeneration as well as to have a standardized gauge of deer impacts across site, we planted a total of 456 local-genotype red oak seedlings in 14 city parks/natural areas (with 3 sites in Bird Hills Nature Area) and in University of Michigan's Nichols Arboretum (under separate contract) for a total of 17 monitored planting sites within 15 different natural areas.

As outlined in methods developed at Cornell and used in previous studies in Ann Arbor, the goal of the red oak experimental (or "sentinel") seedling method is to assess browse damage on 20 seedlings per site, which has been reported to be a reliable indicator of deer browse impacts (Blossey et al 2017). To compensate for potential loss due to mortality, fallen trees, and vandalism, we planted more seedlings in each site than in previous years—6 plots of 4 seedlings each, for a total of 24 plants, increased from 20 seedlings (5 plots of 4) used in 2016 and 2017. However, challenging weather conditions[1] led to high transplant mortality (ranging from 8–58%), which effectively decreased the number of seedlings available to assess.[2] Large limbs or trees fell on or near 12 additional seedlings (just under 3% of the total), covering them and preventing access; these were also excluded from analysis. Some plots were vandalized (plot markers bent or moved), but the seedlings themselves were not damaged and we were able to locate them, so vandalism did not remove seedlings from this year's tallies. We calculated deer browse as the % of available seedlings after accounting for various sources of seedling loss.

Hansen and Leslie Woods Nature Areas each ended up fewer than 15 seedlings to assess; Bird Hills/Huron River Drive had only 11, but this represents 92% of the 12 seedlings were planted there. Results from sites with low seedling numbers may not fully reflect deer browse and should be interpreted with care. Seedling numbers are summarized in Table 3 (following page), and additional details on methods are provided in Appendix A.

Despite the challenges, browse levels on these red oak seedlings offer an indicator of deer impacts across natural areas. Comparison with data from previous years suggests that deer management activities are starting to reduce browse levels.

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[1] Cold and wet spring weather delayed planting to May-June, then dry conditions began as seedlings were planted, with <0.25" of rain from mid-June to early August, which caused drought stress across all sites.

[2] Transplant mortality is considered that which occurs during the first month after planting, before seedlings have rooted and established. Normally, seedlings that died during the first month would be replaced, but the hot, dry weather in July was not suitable for replanting, and early frost prevented replanting in October/November.

Table 3. Red oak experimental seedling numbers and % deer browsed in Ann Arbor sites, 2018. Most sites had 6 plots of 4 oaks each for a total of 24 seedlings, with a goal of having 20 seedlings to assess. Large natural areas, such as Bird Hills and Nichols Arboretum, had additional planting sites. Two new sites were planted in 2018: Kuebler Langford; and a third plot within Bird Hills (Huron River Drive, where oak plots were placed near trillium plots, but steep slopes prevented putting in place a full 24 seedlings (6 plots of 4 seedlings each). Bird Hills Bird Road and Newport areas are totaled for comparisons across years; Huron River Drive seedlings are included in the 2018-only combined total. The % of seedlings browsed by deer was calculated based on the number of ***available*** seedlings: the number planted minus seedlings that died in the first month (transplant mortality) or were covered by fallen trees or limbs. Shading indicates natural areas with an available seedling # of less than 15, where data on browse levels may not fully represent patterns for the site.

SITE	SEEDLINGS PLANTED	TRANSPLANT MORTALITY (DIED 1ST MONTH)		SEEDLINGS COVERED BY FALLEN TREES OR LIMBS	SEEDLINGS AVAILABLE	DEER BROWSE ON AVAILABLE SEEDLINGS	
	#	#	%	#	#	#	%
Bird Hills (Huron R Dr)	12	1	8%		11	8	73%
Bird Hills (Bird Rd)	24	6	25%		18	12	67%
Bird Hills (Newport Rd)	24	6	25%	2	16	8	50%
Bird Hills (combined)*	60	13	22%	2	45	28	62%
Black Pond Woods	24	2	8%	1	21	9	43%
Cedar Bend	24	6	25%	1	17	8	47%
Dhu Varren	24	8	33%		16	10	63%
Furstenberg	24	8	33%		16	10	63%
Hansen	24	12	50%		12	6	50%
Huron Hills Golf Course	24	3	13%		21	17	81%
Huron Parkway	48	19	40%	1	26	17	65%
Kuebler Langford	24	5	21%	2	17	3	18%
Lakewood	24	9	38%		15	6	40%
Leslie Woods	24	14	58%	1	9	4	44%
Mary Beth Doyle	24	4	17%		20	12	60%
Oakwoods	24	4	17%	2	18	11	61%
White Oak	24	9	38%		15	15	100%
Nichols Arboretum	60	6	10%	3	51	30	59%
TOTAL:	456	122	27%	13	319	186	58%

* The combined % browse for only the two sites at Bird Hills that were used in 2017, Bird Road and Newport Road, is 59%; that number is used in analyses comparing 2018 data to previous years.

% OAK SEEDLINGS DEER BROWSED

A total of 58% of seedlings were browsed by deer, with browse levels of 50% or higher in 12 of 16 planting locations, while 1 site had just 18%.

Deer browsed 58% of oak seedlings overall among 17 planting sites in 15 natural areas, with 12 sites having browse levels of 50% or more and 4 sites with 40–50% (Figure 2). Browse levels at all sites exceeded the 15% level that may inhibit oak regeneration.

Browse levels were highest at White Oak and Huron Hills Golf Course Nature Areas, with 100% and 81%, respectively, of oak seedlings that survived transplanting. Four nature areas had 60–70% browse levels: Huron Parkway (65%); Dhu Varren (63%); Furstenberg (63%); and Bird Hills (62% combined total for 3 planting sites). Sites in the western part of the city (Ward 5) had among the lower browse levels—40% at Lakewood and 50% at Hansen.

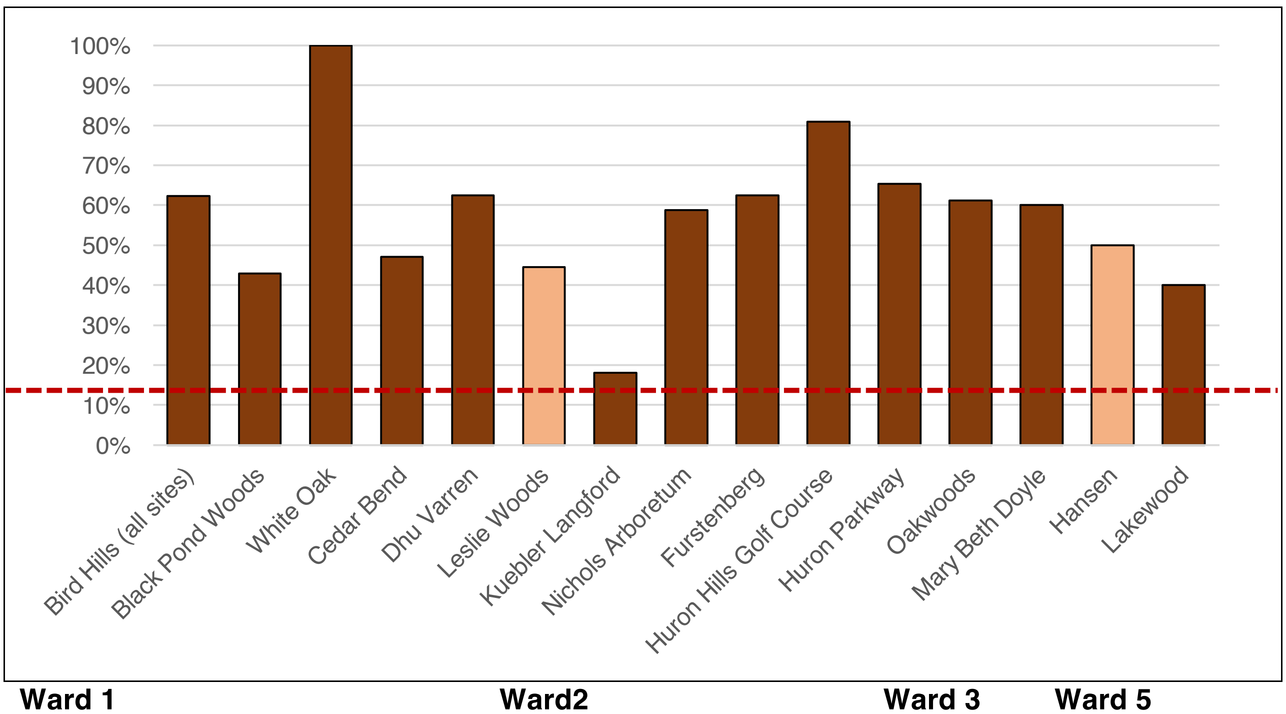


Figure 2. Deer browse on red oak seedlings in Ann Arbor natural areas, 2018–19. The red dashed line indicates the 15% annual browse level above which oak forest regeneration is likely to decline (Blossey 2014). Sites shown in lighter colors had low seedling numbers and may not fully represent browse levels.

Kuebler Langford, monitored for the first time in 2018, had just 18% browse—the lowest browse levels of any site monitored in Ann Arbor since 2016, when Fritz Park had 20%. However, browse data at this site were complicated by additional factors, including high overwinter mortality and high small mammal damage on seedlings, which might have outweighed the impacts of deer this year. Another year of monitoring will provide insight into whether deer browse is consistently low. Appendix A contains additional analyses of small mammal damage.

Deer browse levels in several deer management sites (Table 4) were under 50%, including at Cedar Bend (47%), Black Pond Woods (43%) and Leslie Woods (44%). However, deer browse levels remain high at some management sites, including Huron Hills (81%), Huron Parkway (65%), and Bird Hills (62%). Trend data in the next section offer further insight on how deer browse levels have responded to management since 2015.

Table 4. Deer management at monitoring sites, 2016–19. Information from White Buffalo reports and communications. Dark orange shows sites where deer have been managed in the area through both sterilization and removal; medium orange shows sites affected by proximate culls (on-site or within 3/8 mi of the site); light orange shows sites that might show effects but are likely too far from management areas to be affected; and unshaded sites are those not managed or unlikely to be within the effective radius of management.

SITE	DEER REMOVED				Deer Cull Area/ Sterilization Study Area
	2016	2017	2018	2019	
Bird Hills/Bird Road	X	X	X	X	Cull site proximate
Bird Hills/Newport Road	X	X	X	X	Cull site proximate
Bird Hills/Huron River Dr					>3/8 mile from cull site
Black Pond Woods	X	X	X	X	Cull & sterilization site proximate
Cedar Bend	X	X		X	Cull & sterilization site proximate
Dhu Varren					Partly covered by cull site but most plots >3/8 mi
Furstenberg	*	*	*	X	Cull site proximate*
Hansen					No deer management
HHGC Woods	X	X	X	X	Cull & sterilization site proximate
Huron Parkway	X	X	X	X	Cull & sterilization site proximate
Kuebler Langford					>3/8 mile from cull site
Lakewood					No deer management
Leslie Woods	X	X	X	X	Cull site proximate
Mary Beth Doyle					>3/8 mile from cull site
Oakwoods			X		Cull site proximate
Sugarbush					Partly covered by cull site but most plots >3/8 mi
White Oak			X	X	Cull site proximate
UM/Nichols Arboretum		X	X	X	Cull & sterilization site proximate

* Culls were at varying distances from monitoring plots in Furstenberg during 2016, 2017, and 2018, and may not have been within the 3/8-mile effective distance.

*

TRENDS IN DEER BROWSING: CHANGE FROM 2016–2018

Deer browse levels decreased from 2016–2018 at most sites where deer management has taken place.

Over a 3-year period, deer browsing on oaks declined 5% or more from 2016 to 2018 at Black Pond Woods, Huron Parkway, and Nichols Arboretum (Figure 3)—three areas where deer have been managed. Black Pond Woods had a steady decline, while levels at Huron Parkway increased in 2017 then decreased to below 2016 levels. However, deer browse declines were smaller at Bird Hills (from 61% total in 2016 to 59% total in 2018) despite deer management there, while browse levels increased at Huron Hills Golf Course (from 75% to 81%) and White Oak (from 80% in 2016 to 100% in 2018).

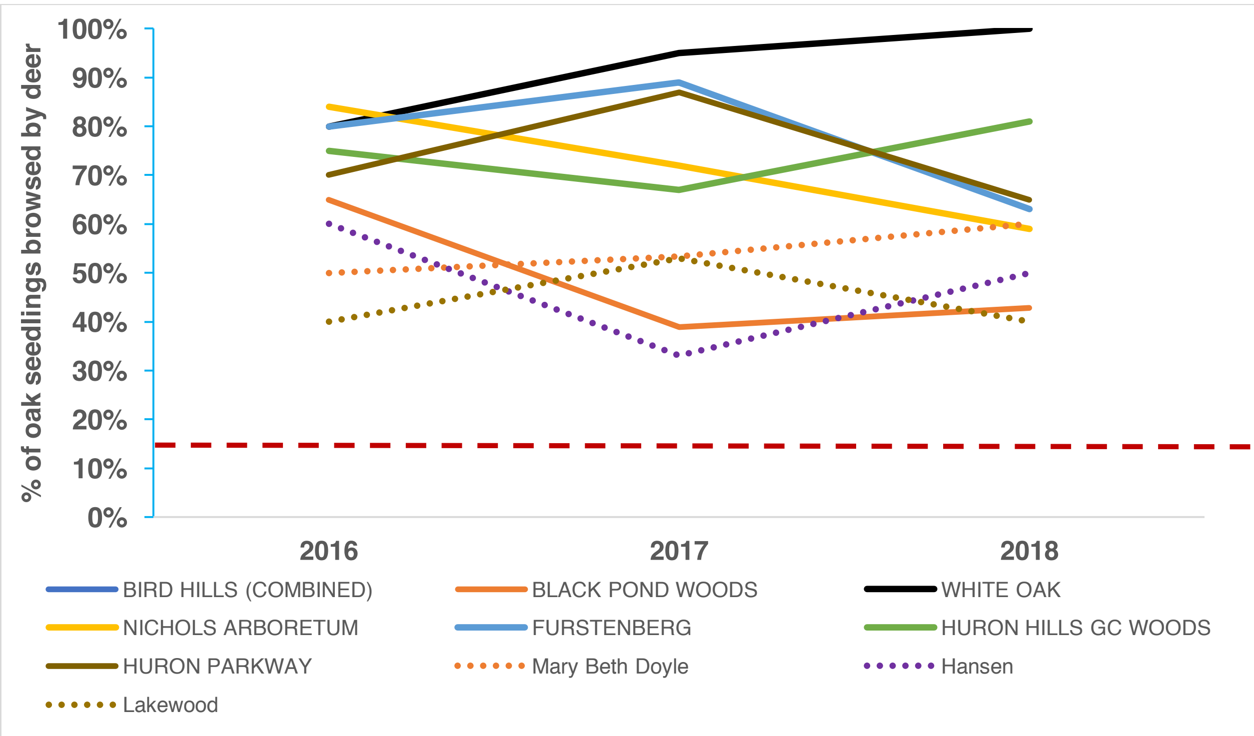


Figure 3. Changes in deer browse on red oak seedlings in Ann Arbor natural areas, 2016–18. 2016 seedlings were in place from Fall 2015–Fall 2016; 2017 seedlings were in place from Spring 2017–Spring 2018; and 2018 seedlings were in place from Spring 2018–Spring 2019. Data are shown for 10 sites that were monitored for 3 years. Bird Hills includes the combined total for the Bird Road and Newport Road sites. Solid lines indicate natural areas where deer have been managed (Table 4, above); dotted lines are areas that have not been managed or are likely too distant from management areas to be affected. The red dashed line indicates the 15% annual browse level above which oak forest regeneration is unlikely to succeed (Blossey 2014).

Browse levels also declined at some sites that were not directly managed but were affected by management in adjacent areas—such as Furstenberg, near management sites on University of Michigan properties. However, seedlings at this site were affected by drought and had poor survival, so the lower browse levels may be partly due to poor seedling condition—dying seedlings may not be preferred deer browse. Appendix A contains additional information on seedling mortality. Data from the wildflower and trillium studies offer additional insights for interpreting trends. And additional information on correlations between deer impacts on vegetation and areas targeted for deer management in 2018 and 2019 appears in the final section of this report.

Among sites where deer management activities were not close enough to affect monitoring plots (>3/8 mile distance), Mary Beth Doyle showed a steady increase in deer impacts over three years; Hansen had no net increase (levels increased in 2017 but in 2018 dropped back to 2016 levels); and deer impacts decreased at Lakewood (after an increase in 2017). Aerial deer surveys (single-day counts) suggest that both Hansen and Lakewood, in Ward 5, have lower deer densities than many other sites (Figure 4). Additional information about aerial deer counts and deer management can be found on the city deer management website: https://www.a2gov.org/departments/community-services/Pages/Deer-Management-Project-.aspx).

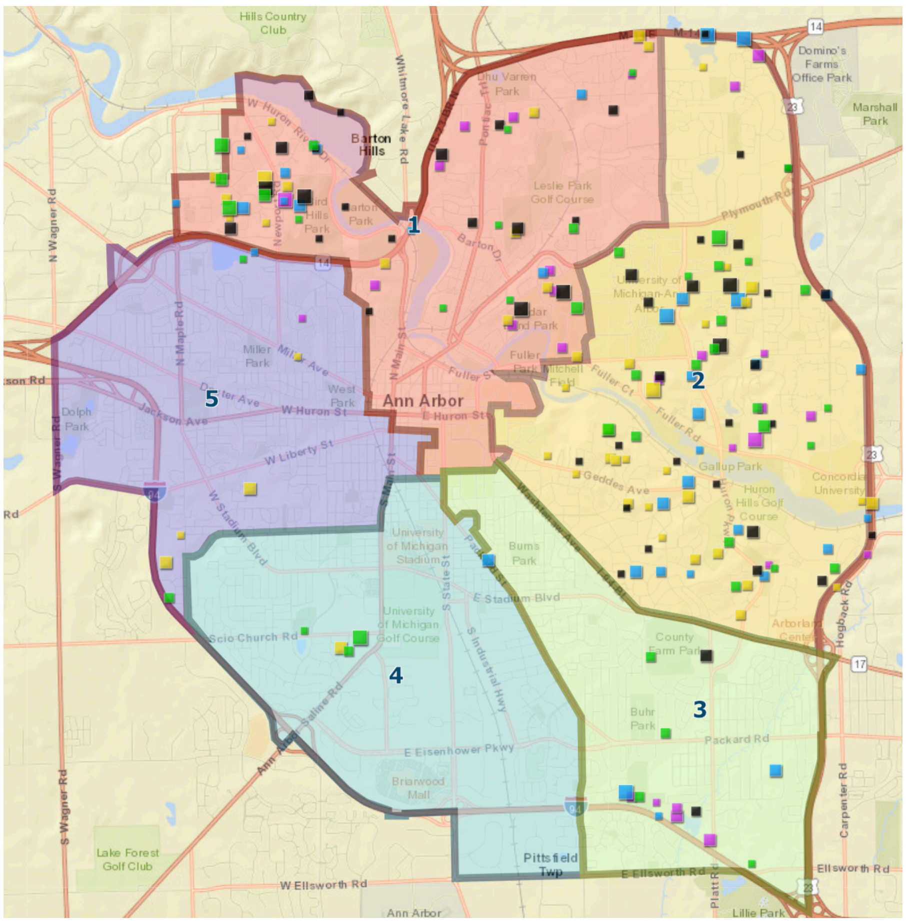


Figure 4. Aerial deer surveys from 2015 to 2018 in Ann Arbor. Different colors represent different survey years (green—2018; black—2017; yellow—2016; blue and purple—2015 (different dates). Larger boxes indicate larger deer numbers, but the scale varies each year, and not all areas were assessed at all survey dates. Survey numbers and additional details on the Deer Data Tool/Ann Arbor Deer App. These data show snapshots of deer locations on one point in time rather than a comprehensive population count, but the locations are one indication of deer activity in areas monitored for deer impacts. (https://www2.a2gov.org/GIS/MapAnnArbor/DeerManagement.

Deer browse levels decreased at 4 sites monitored from 2017–2018.
Deer browse levels decreased the most at Leslie Woods (from 90% to 44%, Figure 5) and at Cedar Bend (from 68% to 47%), as well as a slight decrease at Oakwoods (from 63% to 61%); deer were managed in or adjacent to all three sites. Oak seedlings in Leslie Woods had high mortality in 2018–19, largely due to high levels of rodent damage, so data for this site might not fully reveal deer impacts. Browse levels also decreased at Dhu Varren, where plots may or may not have been within the 3/8 of a mile radius that deer management would likely affect. Reduced browsing at these sites could indicate that vegetation may be starting to show a response to management. However, across-the board decreases suggest that weather might also have played a role, because these 4 sites were planted at the onset of drought; many seedlings wilted and remained in poor condition or died.

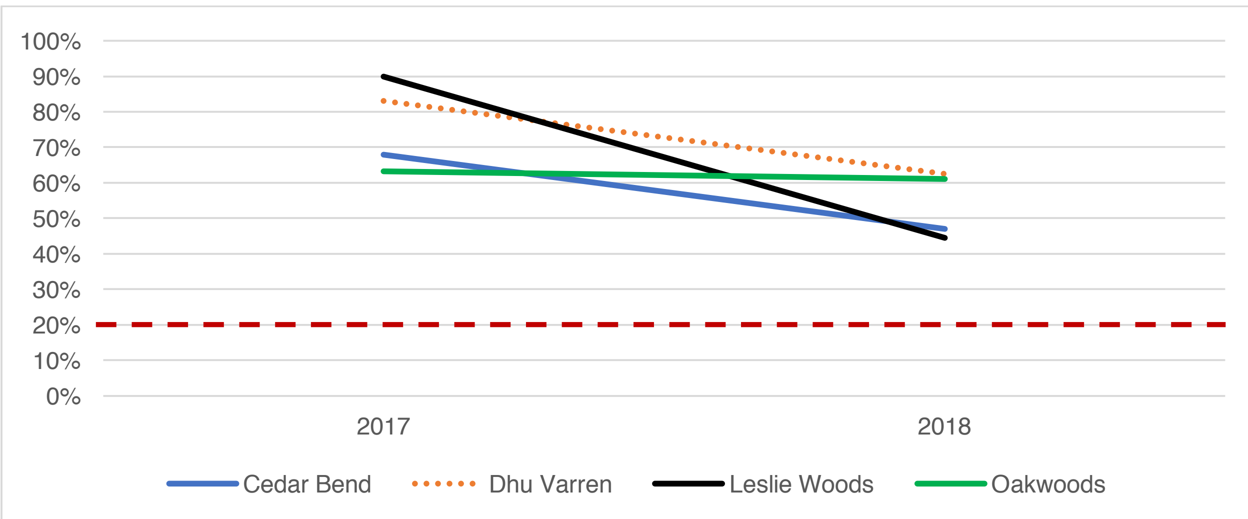


Figure 5. Changes in deer browse on red oak seedlings in Ann Arbor natural areas, 2017–18. 2016 seedlings were in place from Fall 2015-Fall 2016; 2017 seedlings were in place from Spring 2017-Spring 2018; and 2018 seedlings were in place from Spring 2018-Spring 2019. Data shown for 4 sites that have been monitored for 2 years. Solid lines indicate natural areas where deer have been managed (Table 4, above); dotted lines are areas that have not been managed or are likely too distant from management areas to be affected. The red dashed line indicates the 15% annual browse level above which oak forest regeneration is unlikely to succeed (Blossey 2014).

In addition to drought, small mammals (squirrels, chipmunks, and raccoons) excavated numerous plants at several parks in 2018, leaving seedlings on the surface of the ground with roots exposed. Many were in poor condition or died due to desiccation, rather than direct damage (gnawing). This is primarily an artifact of experimental conditions—potting soil around plants and the soil loosened during planting makes an easy place for small mammals to cache seeds or search for underground fungus to feed on—and is unlikely to occur on seedlings naturally rooted in the site. Appendix A contains additional information on small mammal damage.

In sum, oak seedling data suggest that browsing has decreased over a 3-year period most natural areas where deer management has occurred (Table 5, following page). Browsing decreased overall at Bird Hills (for the Bird Road and Newport sites combined)[3], and decreased at all but two other natural areas where deer were managed (Huron Hills and White Oak).

Despite the decreasing levels of deer browse on oaks, browse levels were still high enough to inhibit successful oak regeneration at all natural areas except Kuebler Langford. And browse levels on oaks served as an indicator of continued negative impacts on experimental wildflower plantings and trilliums in 2018, assessed in the following sections.

[3] Although there was a net increase at the Bird Hills/Newport Road area from 2016 to 2018, the 2016 levels might have been low due to poor seedling initial condition. There was a clear decline from 2017 levels at this area.

Table 5. Proportion of red oaks seedlings browsed by deer from 2016–2018 in Ann Arbor natural areas. Dark orange indicates sites where deer have been managed since 2016; **light orange** indicates sites where management has taken place fewer years or at a distance so that it would be less likely (or unlikely) to affect monitoring plots—see Table 4, above). ND: No data (not monitored); NA: Not applicable.

Natural Area	% Deer Browse 2016	% Deer Browse 2017	% Deer Browse 2018	Change, 2016–18
Bird Hills/Bird Rd⅄	**90%**	**72%**	**67%**	↓
Bird Hills/Newport Rd⅄	**32%**	**75%**	**50%**	↑
Bird Hills (combined) ⅄	**61%**	**73%**	**59%**	↓
Bird Hills/Huron River Drive	ND	ND	73%	NA
Black Pond Woods	**65%**	**39%**	**43%**	↓
Cedar Bend	**ND**	**68%**	**47%**	↓
Dhu Varren	**ND**	**83%**	**83%**	↓
Fritz	20%	ND	ND	NA
Furstenberg	**80%**	**89%**	**63%**	↓
Hansen	60%	30%	50%	↓
Huron Hills Golf Course	**75%**	**67%**	**81%**	↑
Huron Parkway	**70%**	**87%**	**65%**	↓
Lakewood	40%	50%	40%	—
Leslie Woods	**ND**	**90%**	**44%**	↓
Mary Beth Doyle	50%	53%	60%	↑
Oakwoods	**ND**	**74%**	**61%**	↓
White Oak	**80%**	**95%**	**100%**	↑
UM Nichols Arboretum*	**84%**	**72%**	**59%**	↓

* Data for 2017 may be lower than actual browse levels because vandalism on many plots prevented final measurements.

⅄ Bird Hills is Ann Arbor's largest Nature Area (162 acres), so seedlings were planted and monitored in two different areas within it during 2016–18, with a third site added for 2018. Deer browsing decreased on plants near Bird Road, but increased near Newport Road; when the two areas are grouped for analysis (Bird Hills combined), there was a net decrease in deer browsing from 2016 to 2018. Browse levels were higher in the Huron River Drive site in 2018 than in either of the other two sites, but this site is too distant from management areas to be affected by deer management activities.

WILDFLOWER EXPERIMENTAL PLANTINGS

To complement experimental red oak seedlings as a standardized gauge of deer browse intensity, and to assess damage to wildflower species that provide important resources for native pollinators, songbirds, and other forest wildlife, we set up an array of experimental plantings using a standard set of forest wildflower species transplanted into 10 plots per site and tracked over time. Half the plots were fenced to prevent deer access and to provide a standard for comparison. There are 5 plot pairs at each of 5 sites: Bird Hills; Black Pond Woods; Furstenberg; Mary Beth Doyle; and Sugarbush.

For 2018, we planted new stock of two species of goldenrods that transplanted and grew well during 2017, and added a new aster species, a spring wildflower, and a milkweed species. We selected species with differing levels of deer browse preference and pollinator value; complete details are provided in Appendix B.

Conditions during the 2018 growing season were challenging for plant establishment, with early cold and wet weather followed by 6 weeks of hot and dry weather with minimal precipitation. Many plants grew poorly or died back then resprouted in the fall, staying under 2 inches tall—too small to be in the deer browse zone.

All plants were tracked throughout the growing season for condition and survival, browsing by deer (and other herbivores, including rodents and insects), flowering, and fruiting (although early frost and snow prevented accurate fruit counts despite repeated measurement attempts). We analyzed the following metrics:

- **% wildflower plants deer browsed**
- **% mortality (or reduced % survival)**
- **% flowering and fruiting**
- **# flowers**

This report focuses on the only three species that grew well enough to flower and fruit during 2018 so that all metrics can be analyzed. All three are summer wildflowers with moderate to high pollinator value and moderate to high deer browse preference:

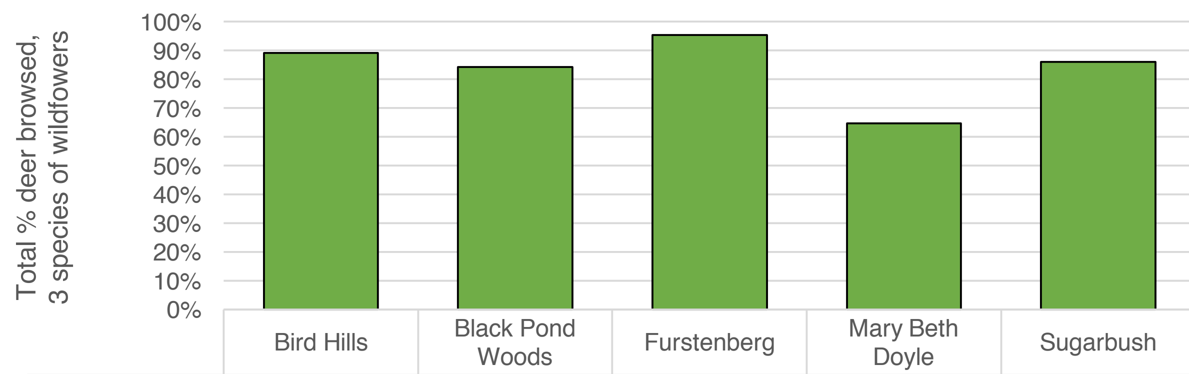
- heart-leaved aster, *Symphyotrichum cordifolium*
- bluestem goldenrod, *Solidago caesia*
- zigzag goldenrod, *Solidago flexicaulis*

In addition to wildflower plants, we planted 4 red oak seedlings in each plot—in addition to the 24 red oaks planted in other locations for the red oak experimental seedling study—so that we could directly correlate deer browse on oaks with deer browse on wildflowers. These oak seedlings were planted during November–December 2017, at the same time as wildflower plants, so they offer a direct comparison.

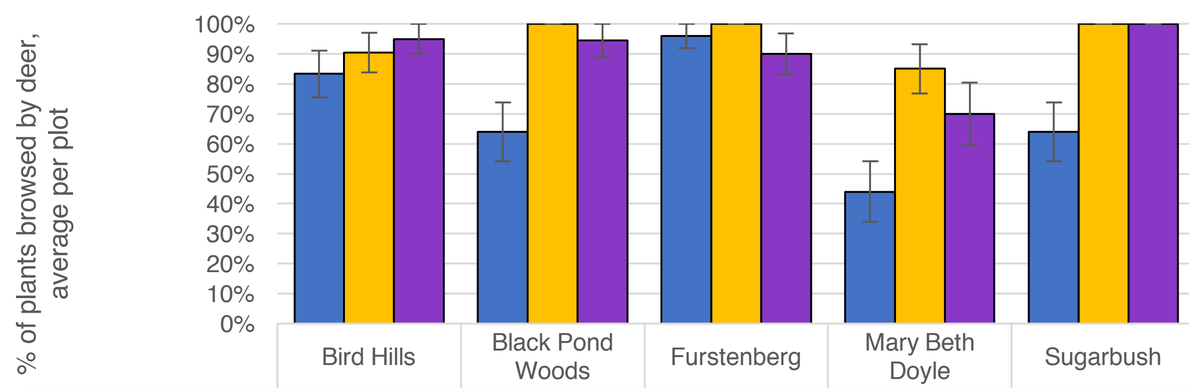
WILDFLOWERS, % DEER BROWSED

Deer browsed more than 60% of unfenced experimental aster and goldenrod at all sites; zigzag goldenrod and heart-leaved aster were most preferred.
More than three quarters of unfenced aster and goldenrod plants were browsed by deer (Figure 6). Levels of deer browse on wildflower plants were highest at Furstenberg (95%) and Bird Hills (89%), followed by Sugarbush (86%) and Black Pond Woods (84%). Mary Beth Doyle had the lowest levels of deer browse on wildflowers (65%). Tallied across all plots and sites, deer browsed 84% of aster and goldenrod plants.

Zigzag goldenrod and heart-leaved aster had the highest rates of deer browse, with 90–100% of stems of each species browsed at all sites except Mary Beth Doyle (Figure 6). Browse levels on bluestem goldenrod were somewhat lower at some sites.



	Bird Hills	Black Pond Woods	Furstenberg	Mary Beth Doyle	Sugarbush
% deer browse	89%	84%	95%	65%	86%



	Bird Hills	Black Pond Woods	Furstenberg	Mary Beth Doyle	Sugarbush
Bluestem goldenrod	83%	64%	96%	44%	64%
Zigzag goldenrod	90%	100%	100%	85%	100%
Heart-leaved aster	95%	94%	90%	70%	100%

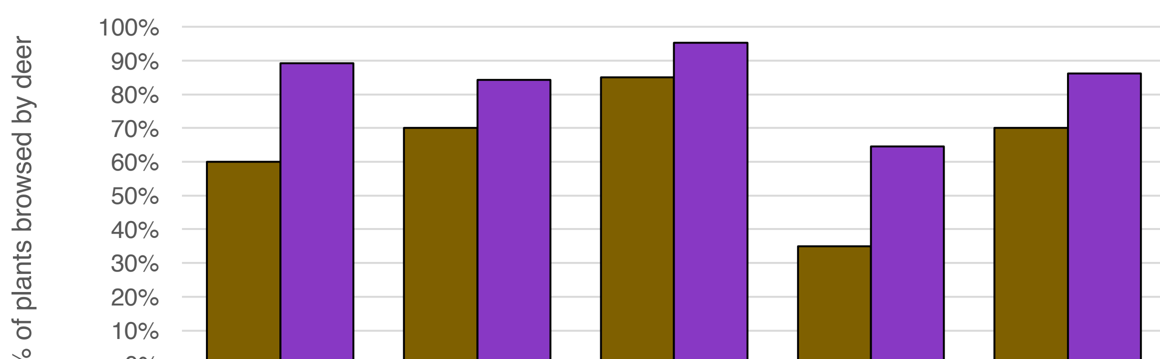
Figure 6. % deer browse on experimental wildflowers at 5 Ann Arbor sites, 2018. A total of 65 plants of bluestem goldenrod (5/plot), zigzag goldenrod (4/plot), and heart-leaved aster (4/plot) were tracked in unfenced plots in each site. The upper figure shows total % deer browse for each site, while the lower figure shows average % plants deer browsed per plot. This analysis focuses on unfenced plants and does not include six fenced plants that were deer-browsed through the fencing.

Deer browsed significantly more wildflowers overall than oak seedlings planted in the same plots at most sites.

Overall, deer browsed a significantly higher proportion of wildflower plants than of red oak seedlings planted in the same experimental plots (statistical analysis of plot data shows less than 1/10 of 1% probability that differences between oaks and wildflowers are due to chance); largest differences were at Bird Hills and Mary Beth Doyle.

These browse levels suggest that, overall, deer prefer wildflowers, and will eat a higher proportion of wildflower plants than of oak seedlings—providing evidence that, in Ann Arbor sites, oaks are of lower preference to deer, whatever their palatability rating. Because deer browse levels on oaks are lower than on wildflowers, using oak seedlings as an indicator of deer impacts will generally underestimate damage to wildflowers overall. However, there are clear differences among species and across sites: while zigzag goldenrod and heart-leaved aster are consistently browsed at higher rates than oaks, bluestem goldenrod does not differ significantly from oaks. Further analyses are included in Appendix B.

Because deer browse levels vary across sites and species, it is not possible to develop a single generalized equation of how deer impacts on oaks are correlated with damage to wildflower species. These data suggest that % browse on oaks will generally be lower than % browse on wildflowers. The following section shows how deer browsing on wildflowers can lead to significantly lower rates of flowering and fewer flowers.



	Bird Hills	Black Pond Woods	Furstenberg	Mary Beth Doyle	Sugarbush
Oaks	60%	70%	85%	35%	70%
Wildflowers	89%	84%	95%	65%	86%

Figure 7. Total % of experimental wildflower plants (asters and goldenrods) vs. red oak seedlings deer browsed in unfenced plots 5 Ann Arbor sites, 2018. A total of 65 plants of heart-leaved aster (4 per plot), bluestem goldenrod (5 per plot), and zigzag goldenrod (4 per plots) were tracked in unfenced plots in each site, along with 20 red oak seedlings (4 per plot). Oak data shown here differ somewhat from those reported in previous sections on the red oak experimental seedlings; these data are from separate red oak seedlings planted in wildflower plots to allow for direct comparison to wildflower plants.

Many wildflower plants were browsed repeatedly. Although it is difficult to measure the exact amount of leaf material that deer remove during browsing, visual estimates based on the number of stems and leaves removed suggest in general, browse intensity correlates with browse proportion, with the highest average browse damage at Bird Hills and Sugarbush, with over half the stem and leaves removed per plant, on average (57% and 58%, respectively, averaged across all stems of all 3 species). Average browse damage was 45% at Black Pond Woods, 46% at Furstenberg, and 37% at Mary Beth Doyle. Further details on amount of browse damage are in Appendix B.

The following sections show the impacts of deer browse damage—whether wildflower plants survive and bloom.

WILDFLOWERS, % MORTALITY

Deer presence was linked to significantly higher wildflower mortality overall. Mortality was significantly higher overall (totaled across all stems of bluestem and zigzag goldenrods and heart-leaved aster) in unfenced plots accessible to deer at all sites (Figure 8). Overall, mortality was 21% in plots where deer were allowed, compared to 6% in fenced plots. Mortality levels varied somewhat by site and species—mortality was highest at Mary Beth Doyle and Sugarbush, and was higher for heart-leaved aster than for either species of goldenrod—but statistical analysis showed significant differences across sites and species. Appendix B contains additional details.

High mortality levels at Sugarbush were partly due to heavy small mammal damage, which appeared to increase mortality on plants already browsed by deer. Fences allowed access by most small mammals, but likely excluded rabbits, which may have contributed to higher mortality in unfenced plots at that site.

Although many unfenced wildflower plants at Bird Hills, Black Pond Woods, and Furstenberg were browsed by deer, differences in mortality between unfenced deer-accessible plots and fenced plots were under 10% at each site. However, deer impacts may be cumulative—plants browsed this year may have survived, but may be less likely to grow and bloom next season. Furthermore, even if deer browsing doesn't outright kill plants, it can reduce flowering, as outlined in the following section.

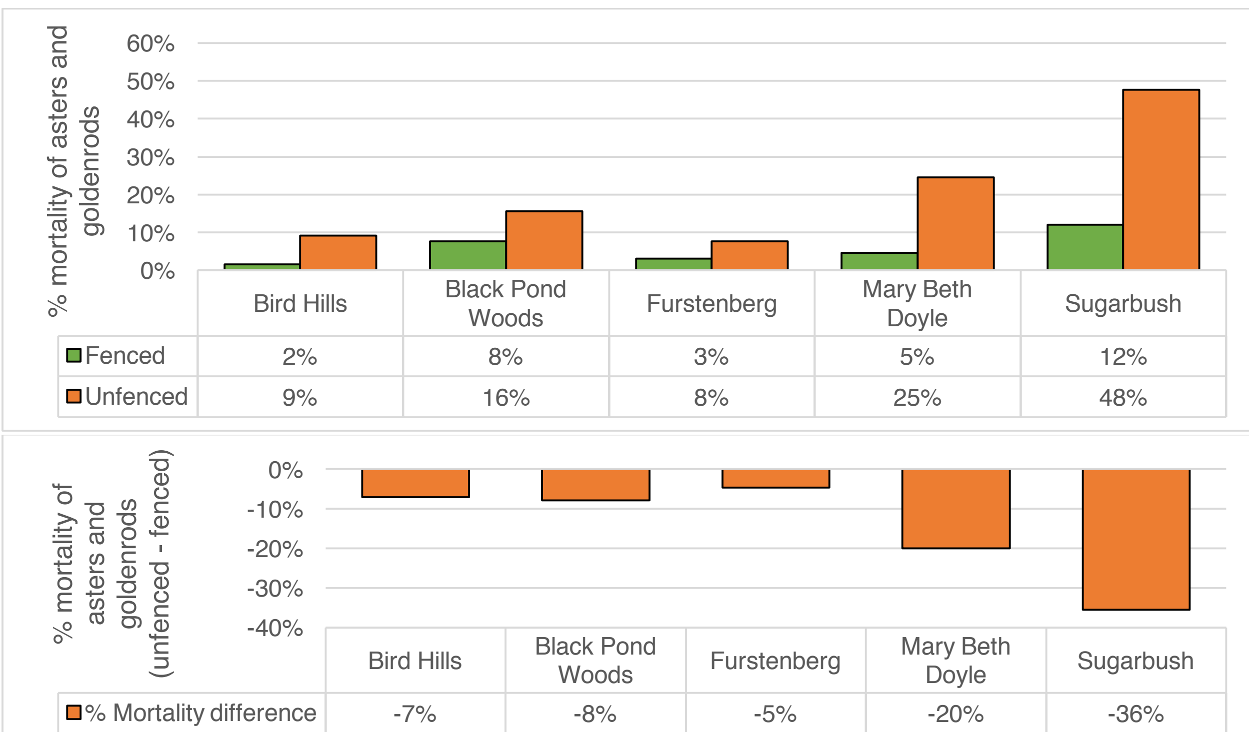
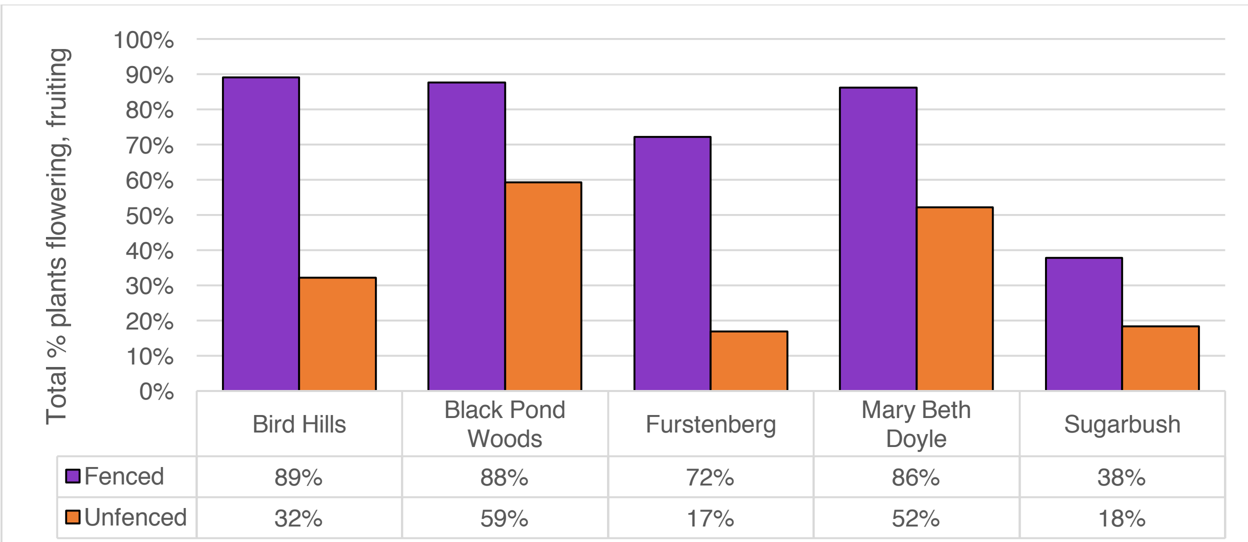


Figure 8. Total % mortality of experimental wildflower plants (asters and goldenrods) in deer-accessible unfenced plots vs. fenced plots in 5 Ann Arbor sites, 2018. A total of 65 plants of heart-leaved aster (4 per plot), bluestem goldenrod (5 per plot), and zigzag goldenrod (4 per plot) were tracked in 5 pairs of unfenced and fenced plots in each site.

WILDFLOWERS, % FLOWERING AND FRUITING

Deer reduced the total % flowering of asters and goldenrods across all sites. Flowering rates were significantly lower overall in deer-accessible unfenced plots than in fenced plots at all sites (Figure 9). At Bird Hills and Furstenberg, where deer browse levels on wildflowers were the highest (Figure 8, above), deer browsing led to the largest reductions in % flowering deer. At Bird Hills, 89% of aster and goldenrod plants flowered when protected from deer, compared with only 32% of plants in deer-accessible unfenced plots. Results for % fruiting are discussed in Appendix B.



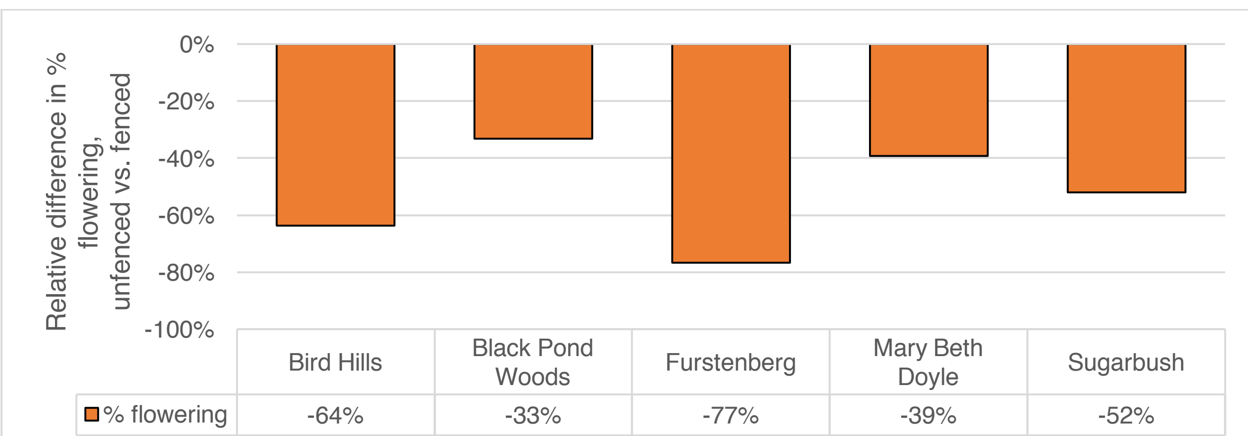
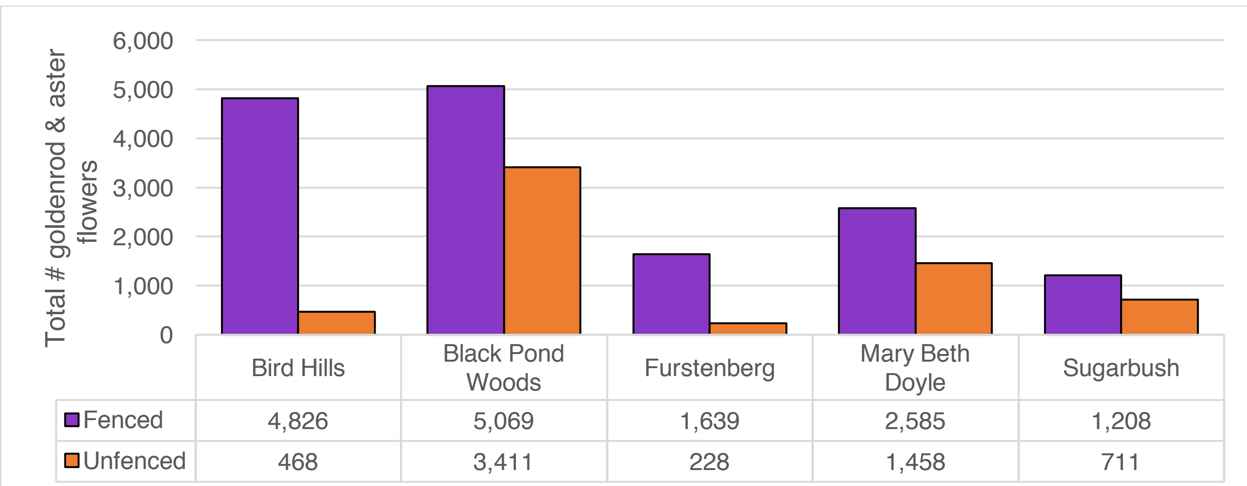


Figure 9. Total % flowering of experimental wildflower plants (asters and goldenrods) in deer-accessible unfenced plots vs. fenced plots in 5 Ann Arbor sites, 2018. A total of 65 plants of heart-leaved aster (4/plot), bluestem goldenrod (5/plot), and zigzag goldenrod (4/plot) were tracked in 5 pairs of unfenced and fenced plots in each site. The lower figure shows the relative (proportional) difference in flowering rates between fenced and unfenced plots. Figures show total flowering to convey cumulative impacts; statistical analysis of average plot data shows highly significant impacts of deer overall (less than a 1% probability that differences could be due to random factors rather than deer fencing), with some difference across site and species.

Deer impacts varied by species and site. Reductions in % flowering of zigzag goldenrod and heart-leaved aster were greater overall than those of bluestem goldenrod, which were more variable across sites. Flowering rates of bluestem goldenrod in deer-accessible plots were significantly lower at Bird Hills and Furstenberg, but did not differ significantly at Black Pond Woods, where a combination of lower levels of browse damage and good site conditions appear to have allowed the species to recover from deer browse impacts enough to flower. Appendix B contains analysis of individual species.

WILDFLOWERS, # FLOWERS OVERALL

Deer browsing led to significant overall reductions in total # of flowers. Goldenrod and aster plants in deer-accessible unfenced plots produced fewer flowers than those protected from deer by fences (Figure 10). Although some deer-browsed plants flowered despite browse damage, these plants typically had fewer flowers, adding to differences of hundreds or thousands of flowers when totaled across sites. At Bird Hills, for example, there was a 90% reduction in flower # in plots where deer had browsed and trampled compared to fenced plots. Deer-linked reductions in flowering varied across species, with highest reductions for heart-leaved aster and zigzag goldenrod. (Individual species analyses are included in Appendix B). Reductions of this magnitude could diminish resources for pollinators and for wildlife that feed on flowers, as suggested by a pilot study of pollinator visits described below.



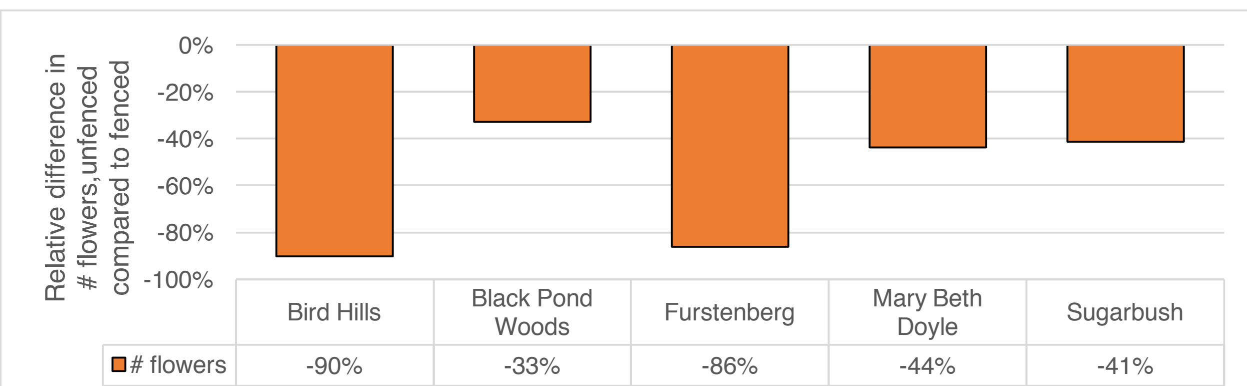
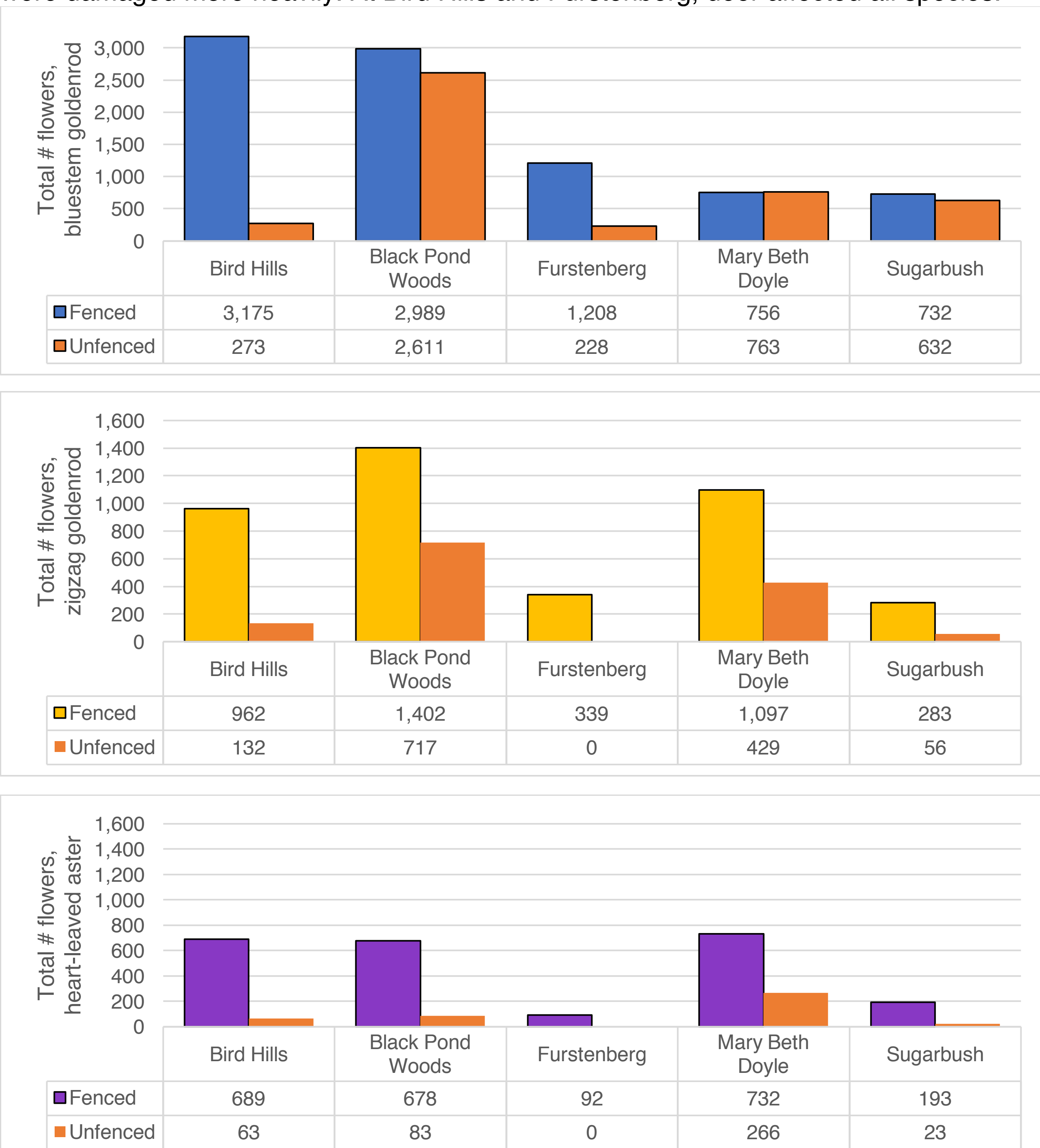


Figure 10. Total # of flowers produced by experimental wildflower plants (asters and goldenrods) in deer-accessible unfenced plots vs. fenced plots in 5 Ann Arbor sites. A total of 65 plants of heart-leaved aster (4/plot), bluestem goldenrod (5/plot), and zigzag goldenrod (4/plot) were tracked in 5 pairs of unfenced and fenced plots in each site. The lower figure shows the relative difference in # flowers between fenced and unfenced plots. Figures show total flowering to convey cumulative impacts; statistical analysis of average plot data shows highly significant impacts of deer overall (less than a 1% probability that differences could be due to random factors rather than deer fencing), with some difference across site and species.

WILDFLOWERS, # FLOWERS BY SPECIES AND SITE

Deer led to particularly large flower reductions of zigzag goldenrod and heart-leaved aster.

Deer generally reduced flowering of zigzag goldenrod and heart-leaved aster more than bluestem goldenrod (Figure 11); these two species were more likely to be browsed, and were damaged more heavily. At Bird Hills and Furstenberg, deer affected all species.



	Bird Hills	Black Pond Woods	Furstenberg	Mary Beth Doyle	Sugarbush
Fenced	3,175	2,989	1,208	756	732
Unfenced	273	2,611	228	763	632

	Bird Hills	Black Pond Woods	Furstenberg	Mary Beth Doyle	Sugarbush
Fenced	962	1,402	339	1,097	283
Unfenced	132	717	0	429	56

	Bird Hills	Black Pond Woods	Furstenberg	Mary Beth Doyle	Sugarbush
Fenced	689	678	92	732	193
Unfenced	63	83	0	266	23

Figure 11. Total # flowers on experimental goldenrods and asters in deer-accessible unfenced plots vs. fenced plots in 5 Ann Arbor sites, 2018. Figures show cumulative totals per site.

Deer impacts, although statistically significant overall, varied considerably by site and by species. At Furstenberg, which had the highest rates of deer browsing on wildflowers, flowering rates and numbers were already low even in fenced plots due to drought, but deer were linked with a complete failure of zigzag goldenrod and heart-leaved aster to produce any flowers at all. Bird Hills also had high rates of deer browsing on wildflower plants, which led to across-the-board reductions in flower number for all three species of experimental wildflowers.

Mary Beth Doyle had the lowest rate of deer browse on wildflowers, and bluestem goldenrod produced a similar number of flowers whether or not it was protected from deer. However, deer were still linked to significant reductions in # flowers for both zigzag goldenrod and heart-leaved aster. Lower deer browsing at this park suggests that deer are browsing more selectively, and affecting some species more than others.

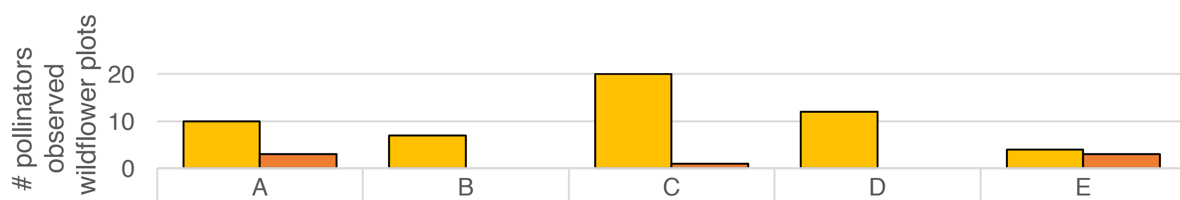
Similarly, at Black Pond Woods, although deer browsed wildflowers at high rates overall, zigzag goldenrod and heart-leaved aster were browsed more intensely (with more damage to the plants), and yielded fewer flowers, with heart-leaved aster flowering particularly reduced.

Finally, flowering was low at Sugarbush overall due to serious small mammal damage to both fenced and unfenced plants in 3 of 5 plot pairs; only one bluestem plant in those plot pairs flowered, with a total of 31 flowers. However, the remaining two plot pairs, in a different part of the park, indicate that deer had more of a negative impact on flowering of zigzag goldenrod and on heart-leaved aster than on bluestem goldenrod. These data are suggestive but not statistically significant due to high variability within the site due to small mammal impacts.

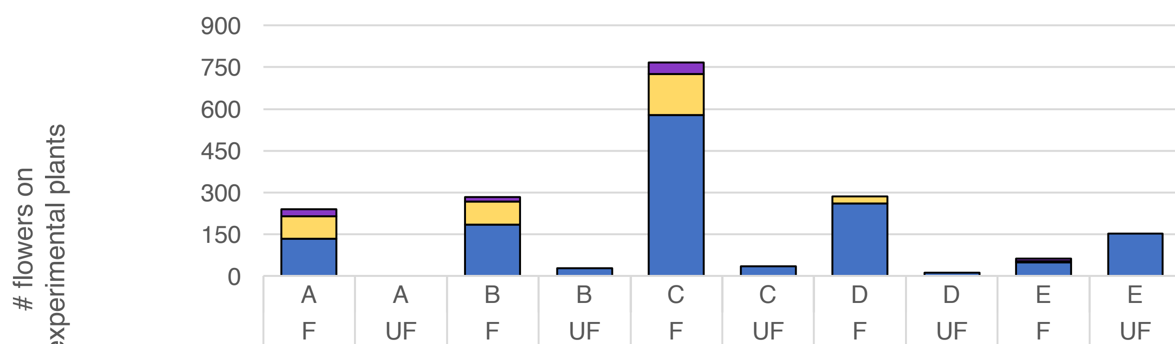
In sum, deer impacts on wildflowers were highly significant overall, but varied considerably by site and by species. Deer browsing eliminated or reduced to very low levels zigzag goldenrod and heart-leaved aster at some sites, while deer impacts were not significant on bluestem goldenrod at some sites. Despite the species differences, reductions in total flowering were significant, and those reductions can, in turn, affect pollinators, as described below.

OTHER IMPACTS ON WILDFLOWERS: POLLINATORS

Reduced flower numbers were linked to reduced pollinator visits at Furstenberg.
Deer-associated reductions in the proportion of wildflower plants flowering, and in the total number of flowers, can affect plant reproduction, but also affects other species in food webs that rely on wildflowers, such as pollinators. To explore potential impacts of deer on pollinators, we conducted a pilot study of pollinator visits to unfenced vs. fenced plots at Furstenberg. Flowering of experimental wildflowers species was significantly lower in unfenced plots. Pollinator visits (by honeybees, bumblebees and other native bees, syrphid flies, and butterflies) were also significantly lower in unfenced than fenced plots (Figure 12), with number of visitors fairly well correlated with total flower numbers (additional discussion in Appendix B). Although this pilot study did not have large enough sample size to be generalizable, the finding was statistically significant and suggests how deer can indirectly affect pollinators through reducing flower numbers.



	A	B	C	D	E
Fenced	10	7	20	12	4
Unfenced	3	0	1	0	3



	A F	A UF	B F	B UF	C F	C UF	D F	D UF	E F	E UF
Heart-leaved aster	24	0	17	0	41	0	0	0	10	0
Zigzag goldenrod	80	0	82	0	147	0	26	0	4	0
Bluestem goldenrod	135	0	185	28	579	35	260	12	49	153

Figure 12. Pilot study of pollinator visits vs. flower numbers in unfenced deer-accessible plots vs. fenced plots in Furstenberg Nature Area, October 2018. Pollinators were counted for 15-minute intervals at each plot, on the same day that flower totals were assessed. Flower totals include only experimental plants; totals including naturally-occurring flowers are not reported here, but could affect plot totals. Statistical analysis (1-tailed t-test in Excel) showed a probability of 2% that pollinator visits differed due to random chance (p=0.018).

TRILLIUM EXCLOSURE STUDY

To assess deer impacts on spring flora, we established paired fenced (exclosure) and unfenced plots in natural areas in four city natural areas during May 2016: Bird Hills; Black Pond Woods; Lakewood; and Mary Beth Doyle. A similar study, contracted and paid for by the University of Michigan Matthaei Botanical Gardens/Nichols Arboretum, was set up in Nichols Arboretum, offering a 5th site for comparison. At the four City Natural Areas, plot pairs were selected to have similar initial population sizes and number of flowering plants (within 5–10% of each other); one plot of each pair was randomly selected for fencing. Initial plant numbers did not differ significantly when fences were put in place, except at Mary Beth Doyle, where random selection led to fenced plots having there were fewer total plants but more flowering plants at the outset. Plots at Nichols Arboretum were not censused in advance because they were put in place during winter; rather, they were placed randomly based on photo monitoring of the site. Based on the random placement, fenced plots had somewhat higher initial trillium abundance than unfenced plots. Analyses of change over time compensates for some of these initial differences.

Evidence of deer browse on tender herbaceous plants, such as trillium, can be difficult to observe and document. Browsed stems wilt and disappear within a couple of weeks of being browsed, in contrast to woody stems, which show identifiable signs of deer browse for two or more years. Documenting all deer browse would require weekly observations throughout the growing season, which was not possible in within the time and budget constraints of this study. **Thus, the *observed* deer browse estimates reported here should be considered a *minimum*; *actual* deer browse is likely higher.** However, counts of plant abundance and flowering in fenced vs. unfenced plots can show deer impacts even without definitive counts of deer-browsed stems.

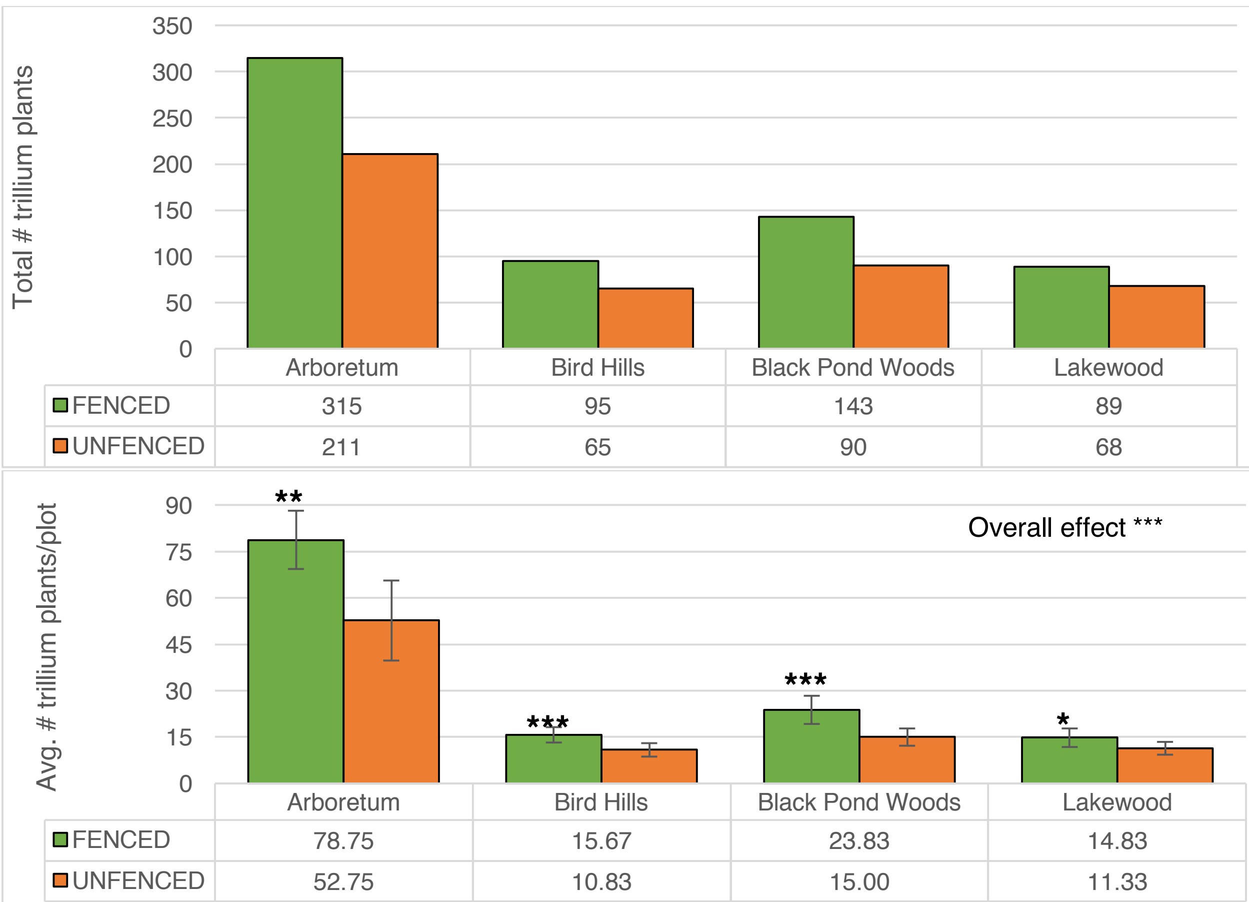
Data are presented for 2018 for the following metrics:

- **total trillium abundance (plant #)**
- **trillium flowering (flower #)**
- **observed % deer browse on trillium**

We also summarize trends from 2016 to 2018 in unfenced vs. fenced plots by site, and assess changes in populations and flowering over time. Correlations with other studies (oaks and experimental wildflowers) are presented in the final section of the report.

TRILLIUM ABUNDANCE (# plants)

Deer presence was linked to lower trillium abundance in 4 sites.
After two growing seasons, there were significantly fewer trillium plants in unfenced deer-accessible plots compared to fenced plots from which deer were excluded in 4 sites (Figure 13). (Mary Beth Doyle is discussed separately in the following section because larger populations there make it difficult to display numbers on the same graphs.) Initial plant numbers did not differ significantly between fenced and unfenced plots when fences were put in place in 2016, except at the Arboretum, where random plot placement led to somewhat more plants (but not flowers) in two fenced plots.



	Arboretum	Bird Hills	Black Pond Woods	Lakewood
FENCED	315	95	143	89
UNFENCED	211	65	90	68

	Arboretum	Bird Hills	Black Pond Woods	Lakewood
FENCED	78.75	15.67	23.83	14.83
UNFENCED	52.75	10.83	15.00	11.33

Figure 13. Total trillium abundance (above) and average # per plot (below) in fenced vs. deer-accessible unfenced plots across 4 Ann Arbor sites, 2018. Top figure shows the total # of plants, summed across all plots within a site; lower figure shows average # per plot. Each site had 5–6 pairs of fenced and unfenced 1-meter-square (10.8-square-foot) plots. In a statistical analysis of average data (lower figure), asterisks show the probability that differences between fenced and unfenced plots (green vs. orange bars) are due to fencing rather than random chance: *** $p<0.01$, indicates less than a 1% chance; ** $0.01 < p < 0.05$, indicates less than a 5% chance, typically the standard for scientific studies; * $0.05 < p < 0.10$, indicates a 5–10% chance that differences were due to random factors rather fencing.

Although total abundance of trillium plants varied across sites, statistical analysis of plot-level averages across all sites showed a less than ½ of 1% probability that lower abundance of trillium in unfenced vs. fenced plots was due to chance rather than the effect of fencing. Within sites, although total abundances at Bird Hills and Black Pond Woods were considerably smaller than at the Arboretum, deer impacts were still highly significant.

Differences between fenced and unfenced plots were smaller and less significant at Lakewood, where a spring 2018 prescribed burn affected small trillium plants in many plots, complicating comparisons. Data for 2019 will offer a better comparison here.

TRILLIUM FLOWERING (# flowers)

Deer were associated with notably fewer trilliums flowering in 4 sites.

Fewer trilliums flowered in unfenced deer-accessible plots than in fenced plots in 2018, despite initial flower numbers being similar in 2016 (Figure 14). The reduced flowering was statistically significant at Nichols Arboretum and Black Pond Woods despite deer management efforts there, suggesting that deer levels continue to be high enough to affect spring wildflowers. Flowering was also significantly lower at Lakewood, where deer have not been managed.

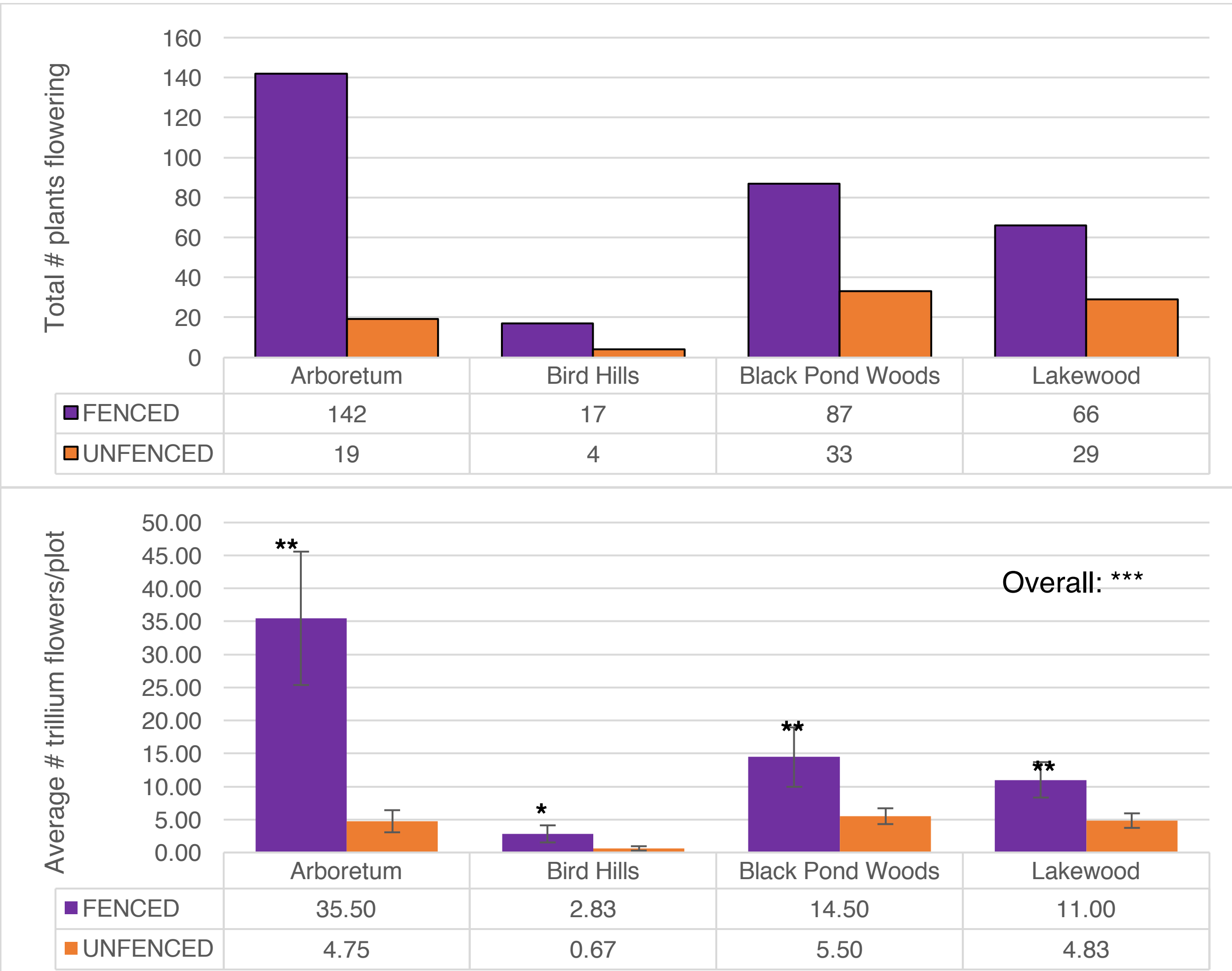


Figure 14. Total # trillium flowers (above) and average # flowers per plot trillium flowering in fenced vs. deer-accessible unfenced plots across 4 Ann Arbor sites, 2018. Top figure shows the total # of flowers, summed across all plots within a site; lower figure shows average # per plot. Each site had 5–6 pairs of fenced and unfenced 1-meter-square (10.8-square-foot) plots. In a statistical analysis of average data (lower figure), asterisks show the probability that differences between fenced and unfenced plots (green vs. orange bars) are due to fencing rather than random chance: *** $p<0.01$, indicates less than a 1% chance; ** $0.01 < p < 0.05$, indicates less than a 5% chance, typically the standard for scientific studies; * $0.05 < p < 0.10$, indicates a 5–10% chance that differences were due to random factors rather fencing.

Totaled across plots, there were more flowers in fenced than unfenced plots at Bird Hills, but total flower numbers are low and flowering was variable. Several plots had no flowers, or only one. Low numbers make it harder to confirm that differences are due to excluding deer, but even with the small numbers, the probability is less than 10% that fenced and unfenced plots differ due to random chance. The low flower number at Bird Hills, even in fenced plots, suggests that recovery is slow due to the duration and/or intensity of past deer impacts. Flowering rates (below) and trends over time (in a later section) offer further insight on recovery.

Patterns for trillium fruiting are not shown here but were similar to those for flowering. There were significantly fewer fruits in unfenced deer-accessible plots than fenced plots overall, with some variations across sites. Reduced trillium fruit production can lead to population declines over time.

Deer led to lower trillium flowering rates in 4 sites in 2018.

The proportion of trillium plants that flowered was lower in unfenced deer-accessible plots than in fenced plots protected from deer at 4 sites (Figure 15). In the Arboretum, Bird Hills, and Black Pond Woods, the flowering rate was at or below the 30% level found in other trillium studies as a useful indicator of deer impacts high enough to require management. At Bird Hills, the trillium flowering rate was lower than 30% in fenced plots, suggesting that flowering has not yet recovered from past deer impacts.

Lakewood presented an exception, with flowering rates above 30% in both fenced and unfenced plots. However, prescribed burns during spring 2018 appeared to reduce the number of smaller non-flowering plants for the season, whereas larger flowering plants were less affected, so the higher flowering rates could be an anomaly.

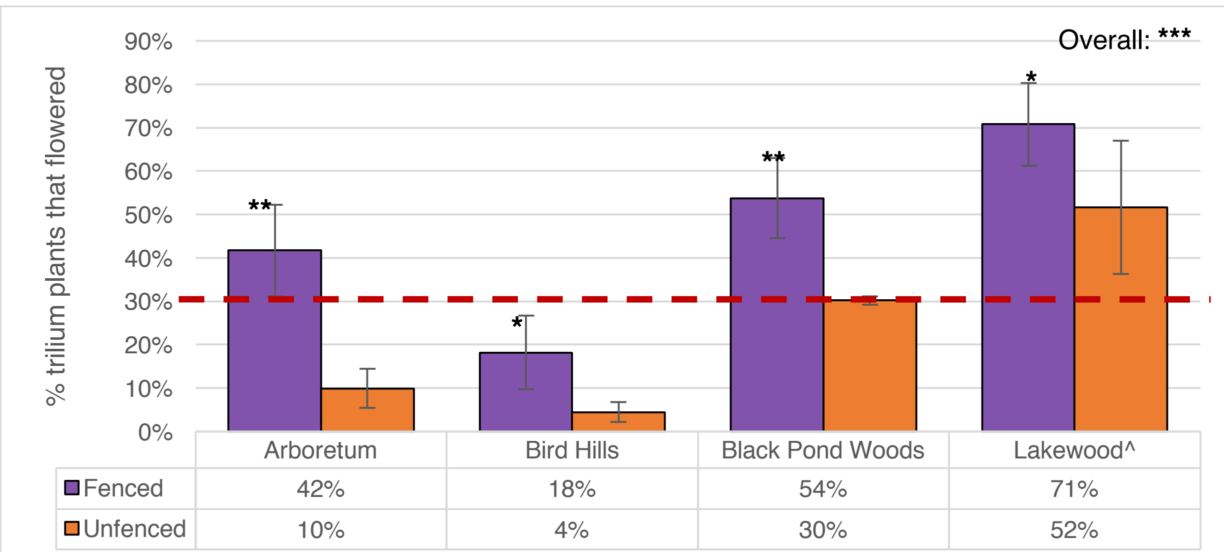


Figure 15. Trillium flowering rates in fenced vs. deer-accessible unfenced plots across 4 Ann Arbor sites, 2018. Flowering rates are averaged across plots within a site. Other studies have found that trillium flowering rates below 30% indicate high deer impacts and the need for management of the deer population. Asterisks show the probability that differences are due to fencing rather than random chance, based on statistical analysis of plot-level data: *** $p<0.01$, indicates less than a 1% chance that differences are due to random factors; ** $0.01 < p < 0.05$, indicates less than a 5% chance that differences are due to random factors, typically the standard for scientific studies; * $0.05 < p < 0.10$, indicates a 5-10% chance that differences are due to random factors—in many cases, variability due to different initial population sizes makes it difficult to confirm a trend. ^ A prescribed burn at Lakewood during spring 2018 affected trilliums this season and complicated comparisons.

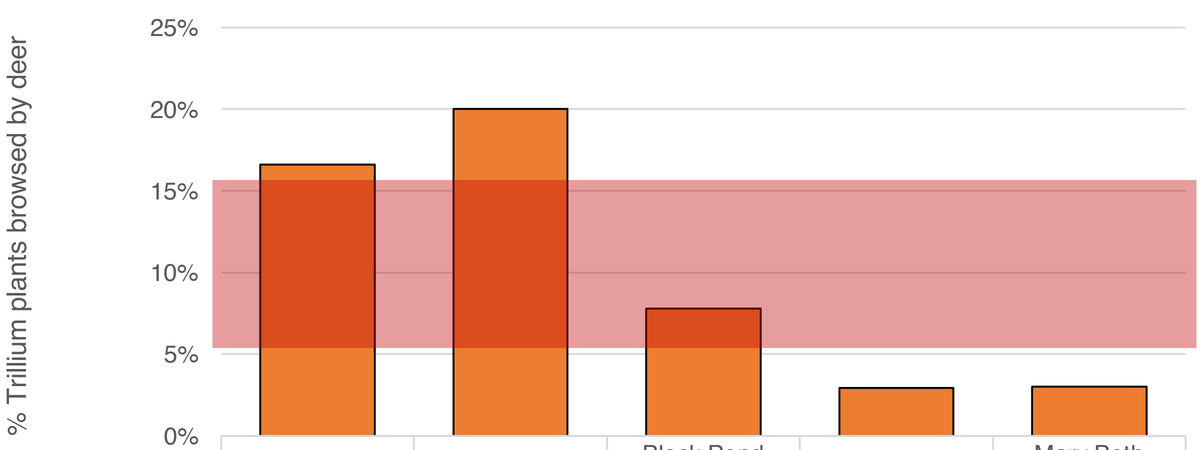
% DEER BROWSE ON TRILLIUM (OBSERVED)

Deer browsed up to 20% of trillium plants in unfenced study plots—a low estimate due to the difficulty in observing browse.

Observed deer browse on trillium plants in unfenced plots was relatively high at Bird Hills and the Arboretum (20% and 17%, respectively), despite deer management at both sites (Figure 16). Browse on trillium was lower at Black Pond Woods (8%), but still high enough to be a potential concern. Lakewood and Mary Beth Doyle had the lowest observed damage on trillium plants (3% each).

However, as noted above, browse damage on tender herbaceous plants is hard to document. Observed browse levels reported here likely underestimate actual browse levels. Furthermore, we often noted higher deer browse levels near study plots—for example, up to 43% of trillium stems browsed in unfenced areas near study plots Black Pond Woods, compared to the average of 8% in unfenced study plots (Figure 16, below)—which serves as a reminder that, although deer browse is inherently patchy, our study plots may not be capturing the full range and intensity of impacts.

Studies by various researchers suggest that deer browse of higher than 5–15% will lead to trillium population declines over time. Even at lower browse levels, deer can decrease trillium reproductive rates: deer generally browse larger plants that are budding, flowering, or fruiting; browsing can reduce resources for an individual plant, making it less likely to bloom in the following year, while also preventing reproduction in that year. Deer typically browse off the flower or bud as well as leaves, which reduces resources for pollinators and species that rely on the fruit.



	Arboretum	Bird Hills	Black Pond Woods	Lakewood	Mary Beth Doyle
% Deer Browse	17%	20%	8%	3%	3%

Figure 16. Total observed deer browse on trillium plants deer-accessible unfenced plots across 5 sites in Ann Arbor, 2018. Figures show the proportion of the total number of plants that were browsed by deer, summed across 5–6 pairs of fenced and unfenced 1-meter-square (10.8-square-foot) plots per site. Previous studies have suggested that deer browse on 5–15% (highlighted) of trillium stems can lead to population declines and reproductive failure.

TRILLIUM TRENDS FROM 2016 TO 2018

Observed deer browse on trillium has been consistently high at Bird Hills from 2016—2018.

Observed deer browse has varied from year to year, with Bird Hills consistently having high deer browse (ranging from 17–34% of deer-accessible stems browsed), and the Arboretum having high browse in 2016 and 2018 (Table 6). Overall, Black Pond Woods, Lakewood, and Mary Beth Doyle have had observed lower browse levels, although levels were high at Lakewood (21%) in 2017.

Deer browse may vary considerably within and across plots; established unfenced plots may not fully represent browse levels site-wide. Deer browse levels recorded in established study plots were lower than levels observed in some nearby areas. Although we did not comprehensively survey sites to find maximum deer browse on trillium populations, we did survey a few additional plots adjacent to unfenced plots where browse levels appeared notable. In 2018, we recorded deer browsing levels higher than levels observed in established plots, with maximum observed deer browse on trilliums of up to 54% in the Arboretum, 43% in Black Pond Woods, and 29% at Mary Beth Doyle. Thus, experimental plots do not fully capture the range of deer browse levels, and may understate deer impacts.

Table 6. Observed deer browse damage on trillium plants in deer-accessible unfenced plots across 5 sites in Ann Arbor from 2016 to 2018. Fenced plots had deer-browsed plants in 2016 because deer browsed between the time plots were established and surveyed and when fences were constructed. Some edge plants within fences were browsed in 2017. The "maximum observed" indicates additional plots surveyed, adjacent to established study plots, where deer browse was higher; ND indicates no data, because areas adjacent to existing plots had few trilliums, and time constraints prevented scouting for additional plots to survey.

	% TRILLIUM STEMS DEER BROWSED						
	FENCED			UNFENCED			MAXIMUM OBSERVED
SITE	2016	2017	2018	2016	2017	2018	2018
Arboretum	2%	2%	0%	25%	4%	21%	54%
Bird Hills	17%	0%	0%	17%	34%	22%	ND
Black Pond Woods	4%	0%	0%	6%	0%	6%	43%
Lakewood	0%	0%	0%	0%	21%	3%	ND
Mary Beth Doyle	6%	2%	0%	3%	0%	3%	29%

Trillium abundance increased over time in protected plots from deer but was variable where deer had access.

Trillium populations increased steadily in fenced plots where protected from deer for most of three growing seasons (Figure 17). However, trillium in unfenced deer-accessible plots showed a different pattern, with population declines from 2016 to 2017, but then some rebound from 2017 to 2018. In both Bird Hills and the Arboretum, populations in unfenced plots were higher in 2018 than in 2016—though still lower than in fenced plots. Increases at these sites may signal that trilliums recovered somewhat in 2018 following management. However, deer browse levels at both sites were high in 2018, so trillium abundance could decline again. Trillium abundance at Black Pond Woods and Lakewood also declined in 2017, followed by a slight increase in 2018, but an overall decline over time, with fewer total trillium plants in 2018 than 2016.

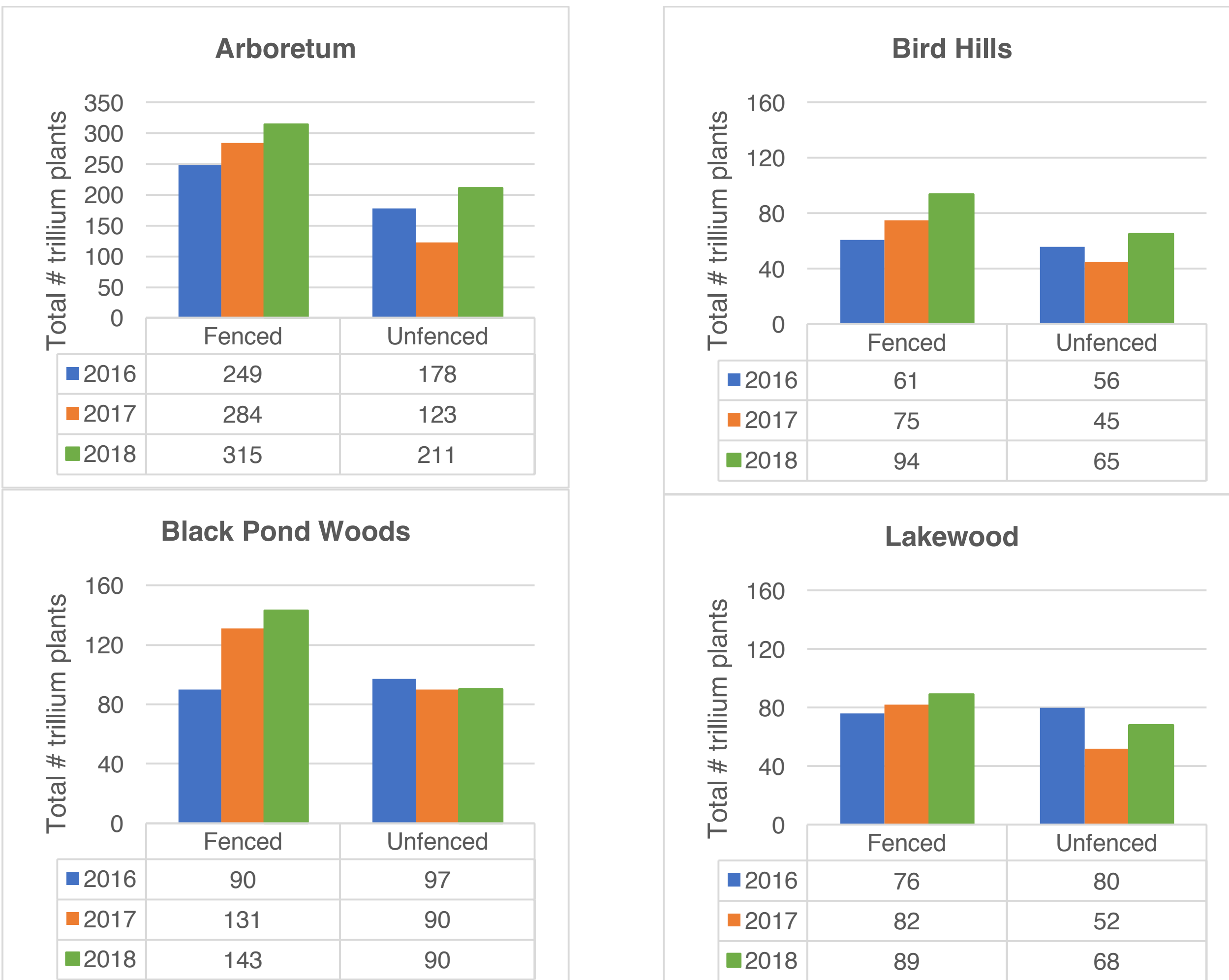
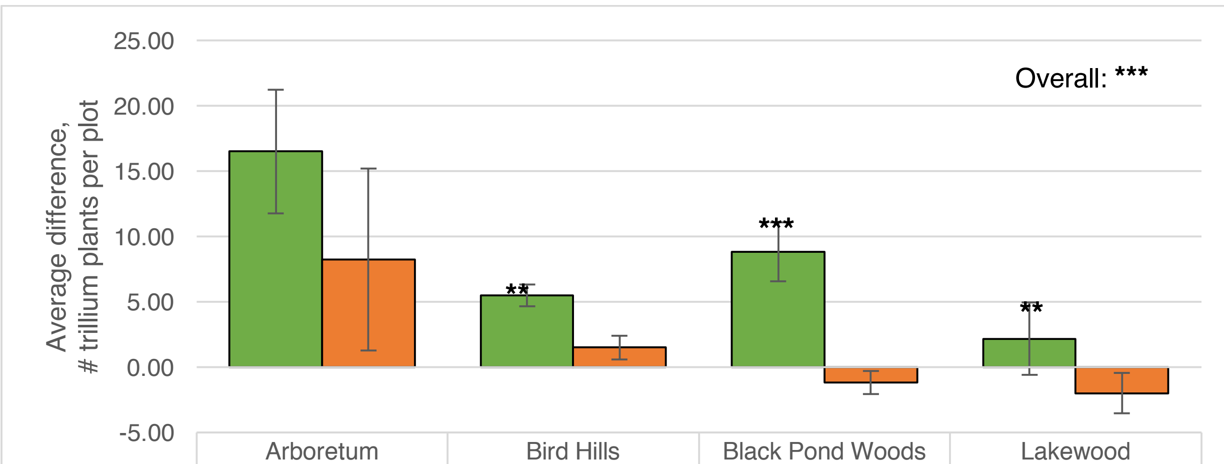


Figure 17. Change in trillium abundance from 2016 to 2018 in deer-accessible unfenced plots vs. fenced plots across 4 sites in Ann Arbor. Initial populations were within 8% of each other at Bird Hills, Black Pond Woods, and Lakewood (not statistically significant), but differed by more at Nichols Arboretum, where plots were located during the winter based on photos; note also the scale is different at this site due to larger populations.

Summarizing the differences between 2016 and 2018 shown in Figure 17 (above), the average number of trilliums per plot was significantly lower overall in unfenced plots where deer were actively browsing and trampling than in fenced plots where trilliums were protected from deer (Figure 18). Average trillium # per plot in unfenced plots decreased or increased only slightly at Black Pond Woods, Lakewood, and Bird Hills, while increasing significantly in fenced plots. At the Arboretum, trillium abundance increased in both deer-accessible fence plots and unfenced plots over the 3-year period; the increased abundance was greater in fenced than unfenced plots but the difference between them was not statistically significant.



	Arboretum	Bird Hills	Black Pond Woods	Lakewood
Fenced	16.50	5.50	8.83	2.17
Unfenced	8.25	1.50	-1.17	-2.00

Figure 18. Average difference from 2016 to 2018 in number of trillium plants per plot, 4 Ann Arbor sites. Asterisks show the probability that differences are due to fencing rather than random chance, based on statistical analysis of plot-level data: *** $p<0.01$, indicates less than a 1% chance that differences are due to random factors; ** $0.01 < p < 0.05$, indicates less than a 5% chance that differences are due to random factors, typically the standard for scientific studies; no asterisks indicates that there is more than a 10% chance that the difference is due to chance.

Total trillium flowering increased from 2016 to 2018 in plots protected from deer, but was variable in deer-accessible unfenced plots.

Trillium flowering increased overall in fenced plots where protected from deer from 2016 to 2018 (Figure 19), with notable increases at the Arboretum and Bird Hills. However, trillium in unfenced deer-accessible plots showed a different pattern, with flowering declines from 2016 to 2017, but some increase from 2017 to 2018, perhaps suggesting a larger influence of weather on deer-affected plants. In both Bird Hills and the Arboretum, flowering in unfenced plots was somewhat higher in 2018 than in 2016—although still lower than in fenced plots—suggesting that deer management may be lowering impacts. However, at both Black Pond Woods and Lakewood, total flowering was lower in 2018 than in 2016, even though *observed* browse levels have been low.

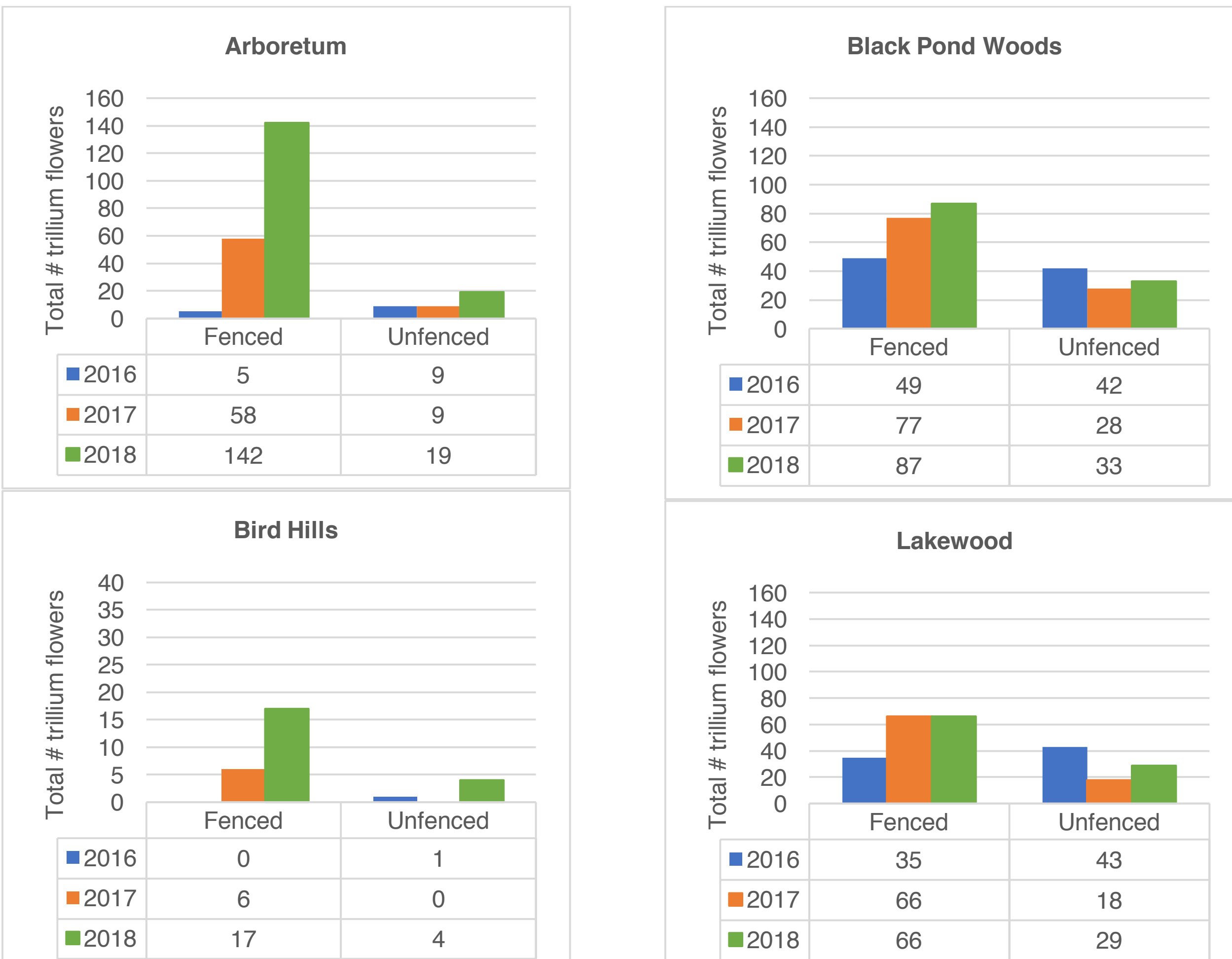


Figure 19. Change in trillium flowering from 2016 to 2018 in deer-accessible unfenced plots vs. fenced plots across 4 sites in Ann Arbor. Total number of flowering trillium plants, summed across 5–6 pairs of fenced and unfenced 1-meter-square (10.8-square-foot) plots per site. Scale is different for Bird Hills, due to considerably fewer flowers there.

Summarizing the changes from 2016 and 2018 shown in Figure 19 (above), average # trillium flowers per plot increased significantly in fenced plots protected from deer, while it did or decreased unfenced deer-accessible plots at any site (Figure 20). Average trillium flower # per plot in unfenced plots decreased at Black Pond Woods and Lakewood, while increasing in fenced plots. At the Arboretum, flowering increased a small amount in unfenced plots, compared to a large increase in flowering in fenced plots.

Figure 19 (above) shows cumulative totals for all plots on a site, which is important because it indicates the amount of resources for pollinators, and can suggest overall trends. Figure 20 (below) is based on plot-level averages for statistical analysis. A statistically significant result suggests that results from the five plot pairs can be considered representative of the full site, with confidence that there is less than a 5% probability that observed patterns are due to random chance rather than the experimental treatment (fencing to exclude deer).

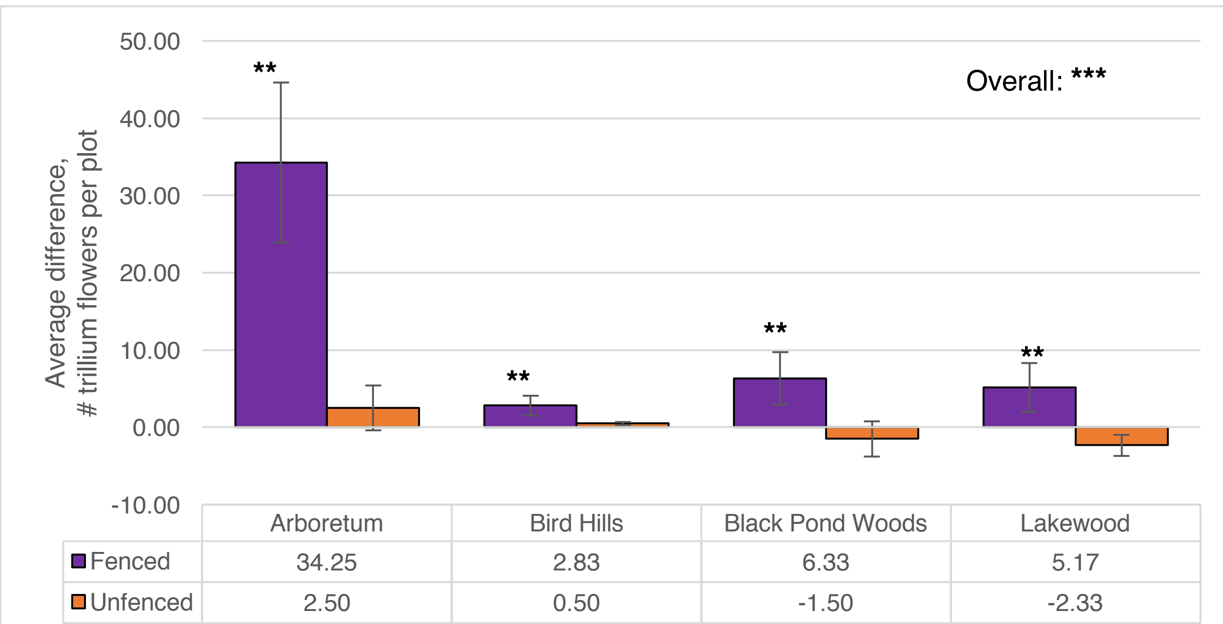
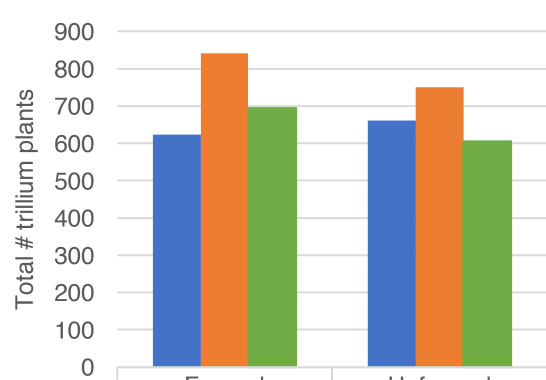


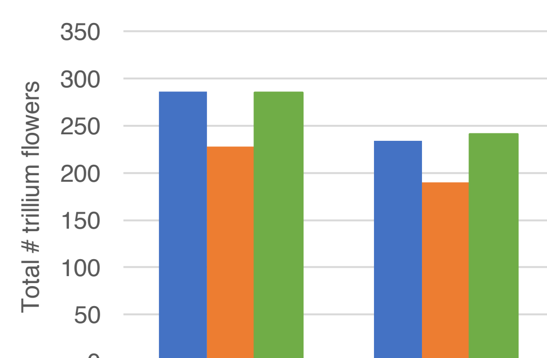
Figure 20. Average difference from 2016 to 2018 in number of trillium flowers per plot, 4 Ann Arbor sites. Asterisks show the probability that differences are due to fencing rather than random chance, based on statistical analysis of plot-level data. Overall, across all sites, fenced plots where deer were excluded had a highly significant increase in flowers compared to unfenced plots: *** $p<0.01$, indicating less than a 1% chance that differences are due to random factors, while at each individual site, differences were ** $0.01 < p < 0.05$, indicating less than a 5% chance that differences are due to other factors or random variability.

Mary Beth Doyle does not show significant deer impacts, but total trillium abundance decreased from 2016 to 2018 in deer-accessible unfenced plots.
Mary Beth Doyle, which has different soils and dominant tree species than other sites, has significantly higher trillium populations than any other site, and does not show significant differences between fenced and unfenced plots. The total number of trilliums decreased overall in unfenced deer-accessible plots from 2016 to 2018, but increased in fenced plots where trilliums are protected. The difference is not large enough to be statistically significant, but it may signal that deer are starting to have an impact. Observed deer browse levels outside established study plots were as high as 30% in 2018, suggesting that deer impacts might be increasing, and/or might not be fully represented by established study plots.

Both fenced and unfenced plots showed an increase in total abundance in 2017, paired with a decrease in flowering. Abundance decreased in 2018, while flowering rebounded. These patterns may be linked to weather and resource availability, but may also indicate demographic changes due to increased seedling numbers in 2017, followed by declines in 2018 when some seedlings failed to establish. However, studies tracking individual trillium have found that the plants can respond to deer browse or poor conditions (such as drought) in complicated ways, with plants regressing to smaller sizes (even 1-leaf rather than 3-leaf forms) or even going dormant for one or more years, then re-emerging later. Data from another year may suggest whether the decrease in trillium in unfenced plots signals a trend.



	Fenced	Unfenced
2016	623	662
2017	842	751
2018	695	606



	Fenced	Unfenced
2016	286	234
2017	228	190
2018	285	241

Figure 21. Trillium abundance and flowering in fenced vs. deer-accessible unfenced plots at Mary Beth Doyle, 2016—2018. Figures show the total number of plants or flowers, summed across all plots within the site. There were initially 6 pairs of fenced and unfenced 1-meter-square (10.8-square-foot) plots, but 1 fenced plot was destroyed by a tree that fell on it and covered more than half the plot, so only 5 plot pairs can be used for analysis. Although some plot pairs showed clear deer-impacts, no plot-level average differences between fenced and unfenced plots were statistically significant at this site.

CONCLUSIONS

Vegetation monitoring for 2018 continued to show large deer impacts across all metrics for experimental red oak seedlings, experimental wildflower plantings, and trillium exclosures. Despite deer management in 2015–2018, deer are still at high enough populations to potentially reduce forest regeneration and trillium populations, and to significantly decrease wildflowers that provide important resources for pollinators and other wildlife.

Although decreasing with deer management at many sites, deer browsing on red oaks in all sites exceeds the 15% level beyond which tree regeneration may be impaired. Wildflower experimental plantings also showed high levels of deer browse, and that browsing was linked to large reductions in the % flowering and # flowers of asters and goldenrods. Flowering was reduced 80–90% at heavily browsed sites (Bird Hills and Furstenberg), and a pilot study of pollinators showed that was linked to a significant reduction in pollinator visits. Deer browse rates on wildflower plantings were higher than on red oak seedlings planted in the same plots, suggesting that deer browse levels on red oak seedlings are a conservative estimator of damage to wildflowers.

In 2018, trillium abundance and flowering were lower in plots where deer were present. Plots that have been fenced since 2016 to keep out deer have shown increases in trillium abundance and flowering, while these metrics have stayed the same or decreased in unfenced plots open to deer. Observed deer browse levels on unfenced trillium plants are above the 5–15% levels recommended other trillium studies as the maximum levels at which trillium populations can persist over time. Flowering rates at three sites were at or below 30%, a level that indicates the need for reducing deer numbers (according to other studies). Flowering rates were low in 2018 even in fenced plots at Bird Hills that have been protected from deer since 2016; the slow recovery suggests that deer impacts were intense or occurred for multiple years.

Changes in trillium abundance and flowering may lag behind changes in deer population or behavior due to management activities, so 2018 data may not yet show a response to 2017–2018 deer management activities. Reduced deer populations should eventually allow recovery in unfenced plots: over time, trillium plant and flower numbers should become similar in fenced and unfenced plots. However, deer continued to browse trilliums at the same levels in 2018 as in 2016 in experimental plots. And we found several places outside experimental plots where deer browse levels on trilliums were considerably higher—so these data do not show the maximum deer browse that is occurring. These data do show, however, that deer are still damaging trillium populations despite deer management efforts to date.

Overall, data from three different monitoring methods provide many lines of evidence of high deer impacts on plants in Ann Arbor's natural areas. Details on methods, additional analyses, and references are included in a separate set of Appendices.