



Forest Health Monitoring at Sleeping Bear Dunes National Lakeshore

2018 Field Season

Natural Resource Data Series NPS/GLKN/NRDS—2019/1241



ON THE COVER

Clockwise from top left: Northern hollyfern (*Polystichum lonchitis*) on North Manitou Island (NPS); measuring the length of a piece of coarse woody material (NPS); herbaceous quadrat at site near Burnham Rd. (NPS); collecting a diameter at breast height of a large tree (NPS).

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Suzanne Sanders and Jessica Kirschbaum

National Park Service
Great Lakes Inventory and Monitoring Network
2800 Lake Shore Dr. East
Ashland, Wisconsin 54806

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Executive Summary

Long-term monitoring of forest health provides managers with routine updates on which to base management decisions. Long-term monitoring can also be used to tease apart impacts and elucidate causal agents when novel problems or situations arise. Perhaps more importantly, monitoring can serve as an early warning of potential issues. This is especially true in areas experiencing new and changing stressors.

Sleeping Bear Dunes National Lakeshore (SLBE) protects over 27,000 ha of forests in northern lower Michigan. Here, a range of stressors, including climate change, high deer browse pressure, beech bark disease (BBD), and exotic earthworms are affecting park forests. We initiated a comprehensive forest monitoring program at Sleeping Bear Dunes National Lakeshore in 2009 with the establishment of 50 permanent plots; in 2018, we resampled these plots. Sampled and derived metrics included trees (density and basal area of live trees, seedlings, and snags), understory (frequency), browse (bite marks on woody species and presence and height of herbaceous species), richness, multivariate community change, and earthworm impacts.

In 2009, we classified plots into one of four broad forest types: Red Maple-Beech-Mixed Hardwood, Sugar Maple-Beech, Balsam Fir-Mixed Conifer, and Pine. Within each of the forest types, overall tree density changed little between the sampling periods. Across all forest types, density of live *F. grandifolia* increased from 408 trees/ha to 459 trees/ha between the two sampling periods. Like density, basal area changed little between sampling periods for all forest types, except Pine. Here it increased from 21 ± 5 m²/ha to 25 ± 5 m²/ha. Across all forest types, basal area of *F. grandifolia* decreased 4.5% to 6.64 m²/ha. Basal area of standing dead *F. grandifolia* nearly tripled, from 0.32 m²/ha to 0.95 m²/ha.

White-tailed deer browse was notable in the park. We recorded bite marks directly visible on woody species within each of 30 browse circles per plot. This occurred in greater than 30% of circles for only three species: *Sambucus racemosa* var. *racemosa* (36%), *Pinus strobus* (35%), and *Populus grandidentata* (34%). Browse on herbaceous species was assessed indirectly, by determining the frequency of presence in 30 quadrats per plot, for 16 preferred browse understory species. For each plot, we summed the frequencies of these 16 species. For sites on the mainland and on North Manitou Island, the summed frequency of presence of preferred herbaceous species decreased 30% and 15%, respectively. There was no change at sites on South Manitou Island.

The only broad-scale incidence of disease was BBD with signs and/or symptoms observed on 85% of *F. grandifolia* individuals. Generally BBD impacts were not observed on individuals smaller than about 4 cm DBH.

Of the 50 total plots, 11 did not show any evidence of earthworm invasion, while six were heavily invaded. Earthworm-free and minimally invaded plots were dispersed throughout the park.

Currently, the most significant threat to SLBE forests is the impending impacts of BBD. The park is engaged in a joint beech restoration effort with Pictured Rocks National Lakeshore. While a small

fraction ($<1\%$) of naturally-occurring beech trees are resistant to the scale, the overarching goal of the program is to propagate and cross this material, so that disease-resistant stock can be outplanted into the forest. The park should make every effort to ensure continuity of this project, as this will be one of the best ways to promote overall forest integrity.

Acknowledgments

We wish to thank the vegetation monitoring field crew of E. Blow, J. Franke, and T. Stephens. Their efforts through all sorts of working conditions, both good and bad, made this possible. We are also grateful to the staff at Sleeping Bear Dunes National Lakeshore, including J. Christian and N. Schafer for helping us negotiate logistics and planning efforts. Finally, R. Key of the Great Lakes Inventory and Monitoring Network provided invaluable assistance with database development and data storage.

Introduction

Long-term monitoring of forest health provides managers with routine updates on which to base management decisions (Blossey 1999). Long-term monitoring can also be used to tease apart impacts and elucidate causal agents when novel problems or situations arise (Pureswaran et al. 2015). Perhaps more importantly, monitoring can serve as an early warning of potential issues. This is especially true in areas experiencing new and changing stressors.

Sleeping Bear Dunes National Lakeshore (SLBE) was established, in part, to preserve and promote coastal dune habitats, even though nearly 95% of its land is forested. Historically, wind was the largest natural disturbance, acting in concert with fire in areas with coarse textured soils. Outbreaks of native insects, such as forest tent caterpillar (*Malacosoma disstria* Hubner) and eastern tent caterpillar (*Malacosoma americanum* Fabricius), occurred at regular intervals. Today, forest health issues include the presence of invasive plants and insects, altered fire regimes, non-native earthworms, climate change, and white-tailed deer (*Odocoileus virginianus* Zimm.) browse. Understanding their collective impacts requires an inclusive monitoring program that focuses not only on trees, but also the groundlayer and forest floor. We initiated such a program in 2009, at which time 50 permanent plots were established; we resampled those plots in 2018.

Here we report on the current status of SLBE forests, note changes in metrics since 2009, and discuss how these changes may impact the larger park ecosystem, as a whole.

Methods

Study Area

Sleeping Bear Dunes National Lakeshore is located in the northwestern lower peninsula of Michigan, on the shore of Lake Michigan, approximately 38 km west of Traverse City. The park consists of a mainland unit, North Manitou Island (NMI), and South Manitou Island (SMI); these two islands are part of the Beaver Island archipelago (Figure 1). A highlight of this park are the towering dunes that rise 135 m above the lake. Total forested area is 27,242 ha, and 13,175 ha of the park are designated as wilderness.

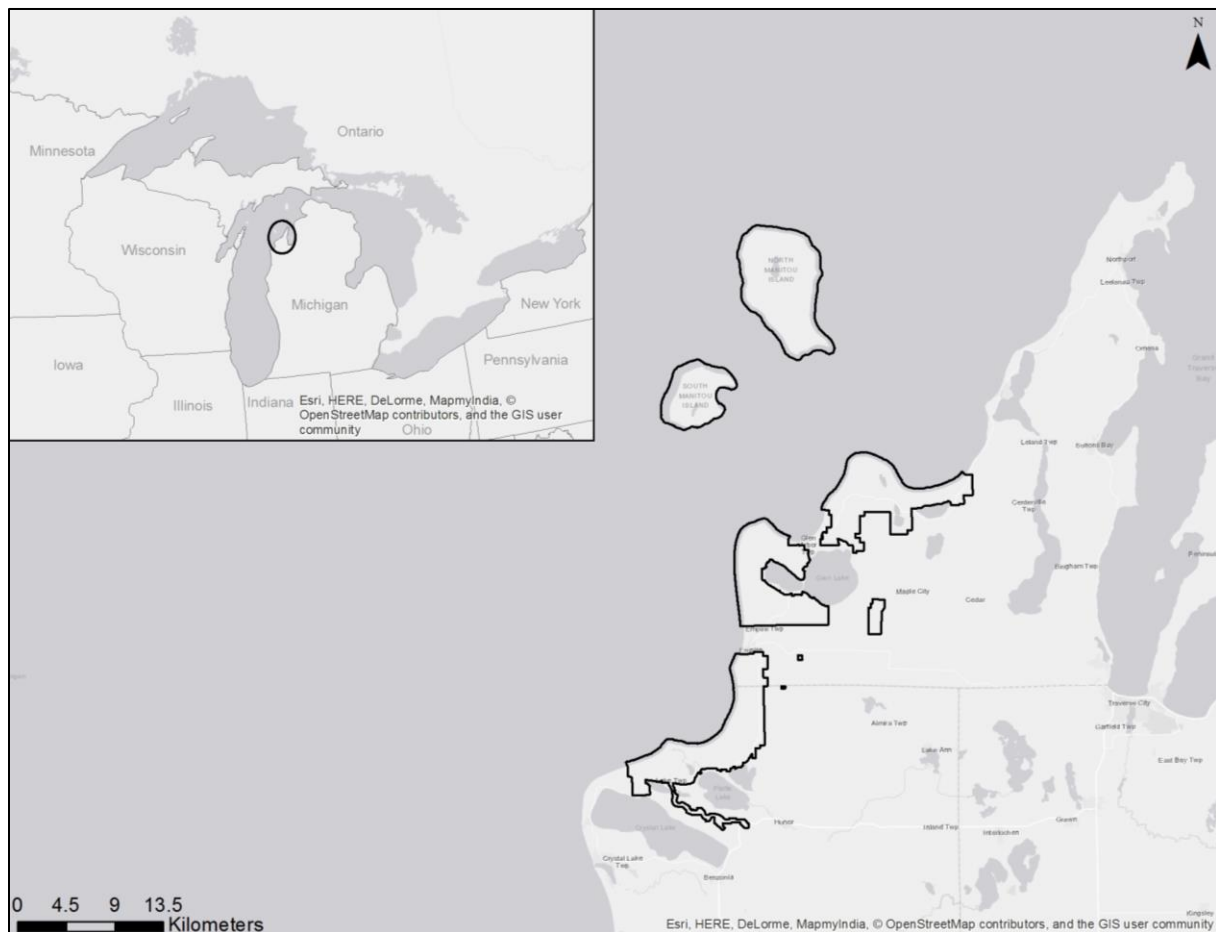


Figure 1. Great Lakes region (*inset*) and Sleeping Bear Dunes National Lakeshore (*main map*).

Forests dominate the terrestrial component of the park, with northern hardwood species being the most common. Pockets of fire-prone forests, typically dominated by *Pinus resinosa* Aiton (red pine) and *P. banksiana* Lamb (jack pine), occupy large areas in the Platte Plains in the southern portion of the park, as well as in dune and swale areas near Good Harbor Bay in the north.

Wind and fire historically shaped Great Lakes ecosystems (Stueve et al. 2011, Fahey 2014), but now, beech bark disease, browse pressure by white-tailed deer, and invasion of non-native earthworms are

altering those ecosystems. Beech bark disease (BBD), a disease complex that arises from the collective effects of a non-native scale (*Cryptococcus fagisuga* Lindinger) and two introduced fungal pathogens (*Neonectria ditissima* and *N. faginata*, Roy and Nolet 2018). At the time of our initial sampling, evidence of BBD was limited. By 2018, the scale had spread throughout the park and widespread tree mortality was evident.

Deer densities in the park are high, with target densities on the mainland largely managed by Michigan Department of Natural Resources. Deer history on North Manitou Island has been variable. They were intentionally introduced in 1926 and maintained at artificially high densities until a reduction program was initiated in the mid-1980s (Flaspohler et al. 2004). Current deer density on NMI is unknown. White-tailed deer are believed to never have been present on South Manitou Island. As a result, the understory there supports a richer component of herbaceous species than generally seen on the mainland. In addition, Canada yew (*Taxus canadensis* Marsh)—a species preferred by white-tailed deer and, therefore, rarely seen on the mainland—is common.

Sampling Design and Field Methods

Sampling Design

Sampling was conducted at SLBE 15 June–26 August 2018. Site selection was made in 2009 prior to the initial sampling event using a generalized random-tessellation stratified design (Stevens and Olsen 2004). This design ensured that our sites were both randomly located and spatially balanced throughout the park.

Basic Measurements: Trees, Groundlayer, and Coarse Woody Material

We sampled trees, seedlings, coarse woody material, herbs, and deer browse using the Hybrid plot (Johnson et al. 2006, Johnson et al. 2008, Figure 2). Three 50-m parallel transects comprise the plot, with each in an east-west orientation and permanently marked with rebar sunk into the ground. We recorded the species, diameter at breast height (DBH), live/dead status, and damage or disease (see below) for all trees with a DBH ≥ 2.5 cm and standing within 3 meters of the central transect line (Sanders and Grochowski 2014b). The total area sampled for trees was 300 m² for each transect, or 900 m² for the entire plot.

We assessed the groundlayer in 1-m² quadrats placed every 5 m along each transect ($n = 30$ per plot). Within each quadrat, we recorded all herbaceous, vine, and shrub species present, allowing a frequency determination for all species-plot combinations. We also counted seedlings, defined as tree species < 2.5 cm DBH, but at least 15 cm in height and showing evidence of growth from the previous year (thus, we did not assess the current year's seedlings). Some species we commonly encountered reproduce vegetatively (e.g., *Populus tremuloides* Michx., *Acer rubrum* L.). Individual sprouts (i.e., both ramets and genets) were deemed “seedlings” if no aboveground connections between them and a parent tree were visible.

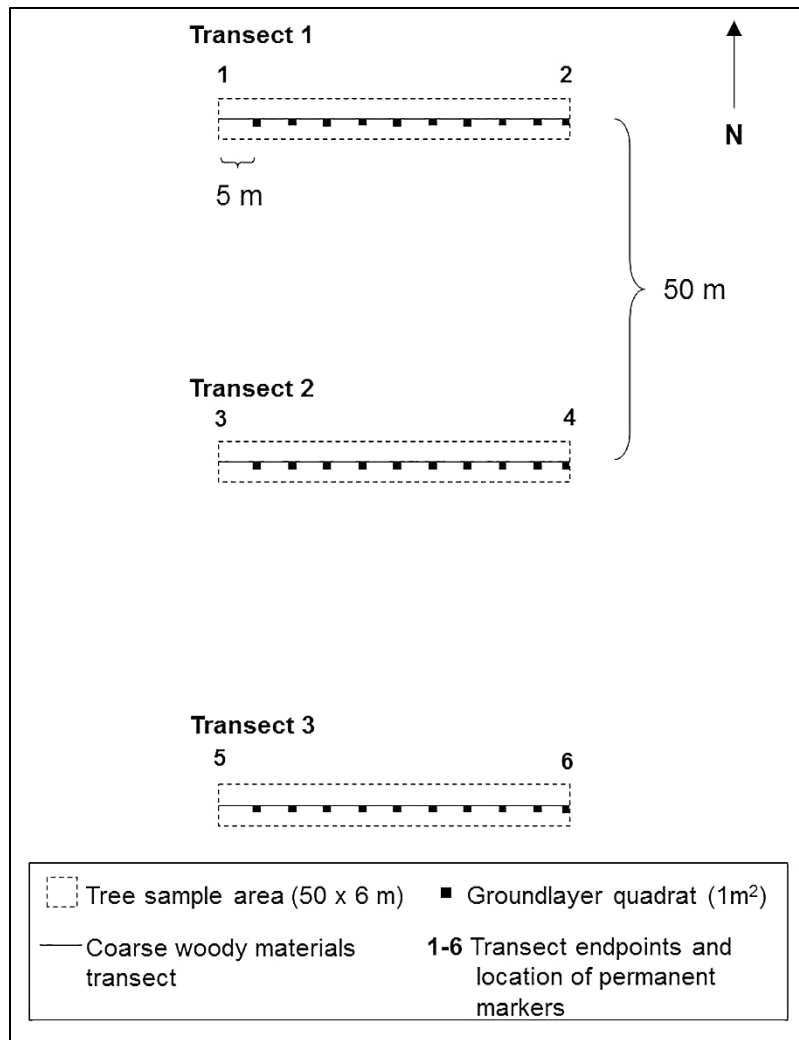


Figure 2. Great Lakes Network Hybrid plot showing three parallel transects (*solid lines*), tree sampling areas (*bounding dashed rectangles*), and quadrat locations (*solid squares*).

We assessed coarse woody material (CWM) using the planar intercept method (Brown 1974, Woodall and Monleon 2007). For all pieces with a diameter at transect intersect ≥ 7.5 cm and length ≥ 0.9 m, we measured the large end diameter, small end diameter, length, and decay class (Woodall and Monleon 2007). Our definition of CWM includes pieces with a diameter ≥ 7.5 cm; therefore, we recorded the length only along where the piece met this criterion.

Browse

We examined browse pressure using two distinct measures. *Direct browse* is an assessment of white-tailed deer browse visible on *woody species*. This includes bite marks and leaf stripping *directly evident and observable* on individual plants and determined to be from the current year's growth. Our methods did not include an assessment of bark stripping, nor did we include browse attributable to snowshoe hare (*Lepus americanus* Erxleben). *Indirect browse* was used to assess the impacts of herbivory on *herbaceous species*. This assessment measures changes in herbaceous demography, which are often *only indirectly observed over time* (Webster et al. 2001, Kirschbaum and Anacker

2005). These changes are typically manifested as fewer and smaller individuals of preferred herbaceous browse species (Anderson 1994, Webster et al. 2001, Knight et al. 2009).

We assessed direct browse in 3.14-m² (1-m radius) circles centered every five meters along each of the three 50-m transects, for a total of 30 direct browse circles per plot, equal to a total sampling area of 94.2 m² per plot. Within each direct browse sampling circle, we recorded all woody species present within the browse zone—defined as the space between ground level and 2.0 m in height—and noted those circles where we observed any evidence of deer browse, and on which species in the circle this occurred. Typically, woody browse surveys are conducted in the spring, prior to the new season's growth, but we are unable to sample at that time. We acknowledge that this limitation introduces bias into our sampling, whereby those sites sampled later in the season would be expected to show more browse than sites sampled earlier. Nonetheless, numerous studies indicate a shift in food preference from woody to herbaceous in the spring (Crawford 1982, McCullough 1985), suggesting that the bias in our summer woody browse sampling may be minimized. Despite this preference, however, a consistent use of woody material throughout the year has also been shown (Kohn and Mooty 1971, Cypher et al. 1988). We feel that our assessments of woody browse in the field are valuable in that they provide insight on general levels of pressure and on species preferences, but should be interpreted with these qualifiers in mind.

We used direct browse data to calculate the *Proportion of Browse* (Frerker and Waller 2013) for each species and plot. At the species level ($PB_{species}$), for each plot, we divided the total number of circles in which we observed browse on Species_A by the total number of circles in which Species_A was present. For each species, we then calculated the park-wide mean. At the plot level (PB_{plot}), the numerator is sum of the number of circles in which browse was observed for all species while the denominator is the sum of them number of circles present for all species.

The direct browse methods employed in 2018 differed from those used in 2009 when we assessed browse in both 2-m² circles (0.8-m radius) and 4-m² circles (1.1-m radius). Because of the differences in methods, no comparisons are made here between the two time periods.

We assessed the *indirect impacts* (typically evidenced by *fewer and smaller plants*) of summer browse on herbs by two means. We used our personal knowledge to identify *preferred* browse species as those that are both relatively common in the region and favored by white-tailed deer (Table 1). We then used the groundlayer data to assess abundance as the *Summed Frequency of Presence* of these preferred species. We did not count the number of individuals of these species in the groundlayer quadrats, but used frequencies of presence (from among the 30 quadrats per plot) as a measure of abundance. For this indicator, we then summed the frequencies of the 16 preferred species within each plot, then calculated the mean for all plots within each habitat. We also assessed indirect impacts of white-tailed deer browse by measuring the tallest of each of three *target taxa*—*Aralia nudicaulis* L. (wild sarsaparilla), *Streptopus lanceolatus* var. *roseus* (Michx.) Reveal (rosy twistedstalk), and *Clintonia borealis* (Aiton) Raf. (bluebead lily)—within each quadrat where they were present. For each species, we calculated a *Maximum Height* for each plot as the mean of the tallest individuals of each of the three species in each quadrat. We elected to replace one of our 2009

target taxa—*Arisaema triphyllum* (L.) Schott (Jack-in-the-pulpit)—with a different species in 2018 (*C. borealis*), leaving only two taxa in common between the two sampling periods for comparison.

Table 1. Preferred browse species at SLBE for calculating Summed Frequency of Presence.

Species	Common name
<i>Actaea pachypoda</i> Elliott	white baneberry
<i>Actaea rubra</i> (Aiton) Willd.	red baneberry
<i>Aralia nudicaulis</i> L.	wild sarsaparilla
<i>Arisaema triphyllum</i> (L.) Schott	Jack-in-the-pulpit
<i>Clintonia borealis</i> (Aiton) Raf.*	bluebead lily
<i>Erythronium americanum</i> Ker. Gawl.	yellow trout lily
<i>Maianthemum canadense</i> Desf.	Canada mayflower
<i>Maianthemum racemosum</i> (L.) Link	false Solomon's seal
<i>Maianthemum stellatum</i> (L.) Link	Starry false lily of the valley
<i>Medeola virginiana</i> L.	Indian cucumber
<i>Panax quinquefolius</i> L.	American ginseng
<i>Polygonatum biflorum</i> (Walter) Elliott	Solomon's seal
<i>Polygonatum pubescens</i> (Willd.) Pursh	hairy Solomon's seal
<i>Sanguinaria canadensis</i> L.	Bloodroot
<i>Streptopus lanceolatus</i> var. <i>roseus</i> (Michx.) Reveal*	rosy twistedstalk
<i>Trillium grandiflorum</i> (Michx.) Salisb.	great white trillium

*Focal taxa for assessing more detailed height, reproductive, and browse measures.

Tree Health

We used an evidence-based approach to assess tree health, whereby we examined each tree for the presence of broad classes of disease, damage, or injury (U.S. Department of Agriculture 2010). These classes included dieback, epicormic sprouting, wilted foliage, defoliation, discolored foliage, insect sign, and human induced stress. If a tree exhibited symptoms of one of these primary classes, a further classification of the damage or disease was made, based on predefined characteristics within each of the primary classes. For example, if a tree was classified as having discolored foliage, we would note whether this damage was in the form of (among other choices) marginal browning of the leaves, interveinal browning of the leaves, the leaves possessing a white coating, or a general yellowing of the leaves. Beech bark disease has been a widespread problem at SLBE since shortly prior to our 2009 sampling. We noted this in the class “insect presence” by “scale”. This symptom-based assessment of damage and disease allows us to easily classify tree health issues, from which a diagnosis of the root cause can possibly be assigned upon further investigation. We feel that this symptom-based approach is more accurate than directly assigning a root cause to problems observed

when at the field site. For some symptoms, there are dozens of possible causes and a pathologist or entomologist with specialization in the region would be needed to accurately assess the problem. Large-scale or persistent symptoms noted with this method can alert the park staff to potential disease or insect outbreaks, which would require further investigation by the park to identify the exact disease or pest.

Earthworm Impacts

Earthworm assessments were conducted at vegetation monitoring plots to determine the extent of invasive earthworm presence at SLBE. Earthworm presence was determined using a simple visual evaluation of the forest floor combined with a soil core assessment that followed methods developed for the Invasive Earthworm Rapid Assessment Tool (IERAT) (Loss et al. 2013). For the forest floor evaluation, we determined whether the forest floor was intact and layered, partially intact, or only present as the previous year's leaves. We noted and quantified the presence of earthworm casts, or excretions, as well as that of middens, or piles of cast material, created by the nightcrawler (*Lumbricus terrestris* L.) (Hale and Host 2005). We assessed organic layer depth using a core. We performed four assessments at four locations in each plot that we judged to be representative. From these evaluations, we ranked plots as earthworm-free, minimally invaded, moderately invaded, substantially invaded, or heavily invaded. For example, an earthworm-free sample has fresh litter, duff, and organic matter present; no evidence of earthworm casts or middens; and the presence of an E soil horizon. A moderately invaded sample has both fresh and decayed litter, but no organic matter present; earthworm casts are present but not abundant; and earthworm middens may be present or absent. A heavily invaded sample would have fresh litter but no decayed litter and no organic matter, and earthworm casts and middens would be abundant (Loss et al. 2013). No earthworm assessments were carried out in 2009, so comparisons in earthworm impacts between the two time periods will not be made.

Plant Identification

We attempted to identify all plants to the species level while in the field. When this was not possible, we typically collected specimens for later identification. In some instances, it was not possible to distinguish between multiple species present in a park unless they were flowering or fruiting, which often was not the case. In these instances, we identified only to the genus or family level. Examples include *Carex* sp. L. (sedge) and Asteraceae (daisy family). For *Amelanchier* sp. Medik. (serviceberry), another genus that presented identification challenges, we assigned individual plants to one of three groups of species complexes, with Group 1 containing *A. bartramiana* (Tausch) M. Roem.; Group 2 containing *A. arborea* (F. Michx.) Fernald, *A. laevis* Wiegand, and *A. interior* E.L. Nielsen; and Group 3 containing an uncertain number of species (Smith 2008). Finally, if a grass was not in flower or fruit, it was typically only possible to identify to the family (Poaceae) level. All nomenclature follows that of the Integrated Taxonomic Information System (ITIS) (2019).

Classifications and Summaries

Forest Type Classification

We classified all plots in the field using both the Kotar classification system (Burger and Kotar 2003) and the National Vegetation Classification System (NVCS) (Hop et al. 2011). Each system resulted

in our plots falling into a large number of types with only a small number of plots in each type. We wanted to explore and summarize data in an efficient and practical manner, so after the field season, we grouped plots into similar broad forest types using cluster analysis (McCune and Grace 2002); thus, we identified groups that supported similar plots but had significant differences from other groups. To do this, we constructed a multivariate matrix based on abundance indices of both tree and groundlayer species within each plot. For trees, we calculated the importance value, determined by the mean of the relative density and relative basal area, for each species-plot combination (Dyer 2006, Elliott and Swank 2008). We calculated understory (herb and shrub) abundance for each species-plot combination as the proportion of quadrats in which each species was located within that plot. We limited inclusion in the cluster analysis to those taxa that were present in at least 10% (5 of 50) of the plots. For this classification, we used PC-ORD software version 5.33 (McCune and Grace 2002) and selected a Sørensen distance measure and a flexible beta linkage ($\beta = -0.25$). We assigned habitat type names based on the dominant trees in these groups. We used non-metric multidimensional scaling (NMS) to verify the legitimacy of these groups, again using PC-ORD.

Functional Groups

All taxa were assigned to classes within each of four larger groups. Within the *life history group*, taxa were assigned to either the annual, biennial, or perennial class. For taxa that are known to exhibit a range of life history strategies, we assigned the shortest strategy. For example, if a taxon is known to be either biennial or perennial, we assigned it to the biennial class. Within the *growth form group*, taxa were considered to be either woody (trees, shrubs, woody vines), graminoid (grasses, sedges, and rushes), or forbs (herbaceous vines and broadleaved herbs). For this report, the latter class included ferns and fern allies. For the *pollination group*, taxa were considered to be abiotically pollinated if the flowers are non-existent (conifers) or not showy, and not known to produce any sensory attractants (e.g., grasses and sedges). These are typically wind-pollinated. Otherwise, flowering taxa were considered to be biotically pollinated. Ferns and fern allies were assigned to the “not pollinated” class within this functional group. Within the *nativity group*, taxa were assigned to native, non-native, or native/non-native. Naturalized taxa (e.g., *Trifolium pretense* L. (red clover)) were considered non-native. In some instances taxa were identified only to the genus level and could not be assigned to a nativity group, as species within these genera are both native and non-native. Examples include *Hieracium* sp. L. (hawkweed) and *Salix* sp. L. (willow); such taxa were noted as “native/non-native.”

For each plot, we calculated the abundance of species in each group of each trait. We then calculated the means for all plots within each forest type.

Coefficients of Conservatism and the Modified Floristic Quality Index

We identified the coefficient of conservatism (CoC) values for all species located during the sampling at SLBE (Herman et al. 2001). These values quantify the habitat faithfulness of species (Swink and Wilhelm 1994) and range from 0 (either non-native species or generalists with no faithfulness to any particular habitat) to 10 (conservative species found only in high-quality, non-degraded habitats). We then used CoC values to calculate the modified floristic quality index (mFQI) (Rooney and Rogers 2002, Sanders and Grochowski 2014a), where mFQI is simply the mean of the

CoC values for all species present within that plot. We then summarized mFQI by year and forest type.

2018 Status and Short-term Change of Indices

We present the current (2018) tree densities by diameter class and species to elucidate successional status. We also present the current status of select indices where data are not available or comparable between the two sampling periods. These include proportion browse and earthworm impacts.

For most indices, we calculated means and standard errors and show short-term change between the sampling periods via graphs and tables. In some instances, we are not only interested in how these change between years, but also how they vary within forest types. These metrics include those for assessing trees (e.g., density, basal area). For other metrics (e.g., browse metrics) we are simply interested in the differences between years.

Results

All 50 plots originally sampled in 2009 were resampled in 2018 (Figure 3). The taxa sampled included 36 trees, 44 shrubs and woody vines, 148 forbs, 46 graminoids, and 17 fern species (Appendix A). The plots classified into four broad forest types (Table 2).

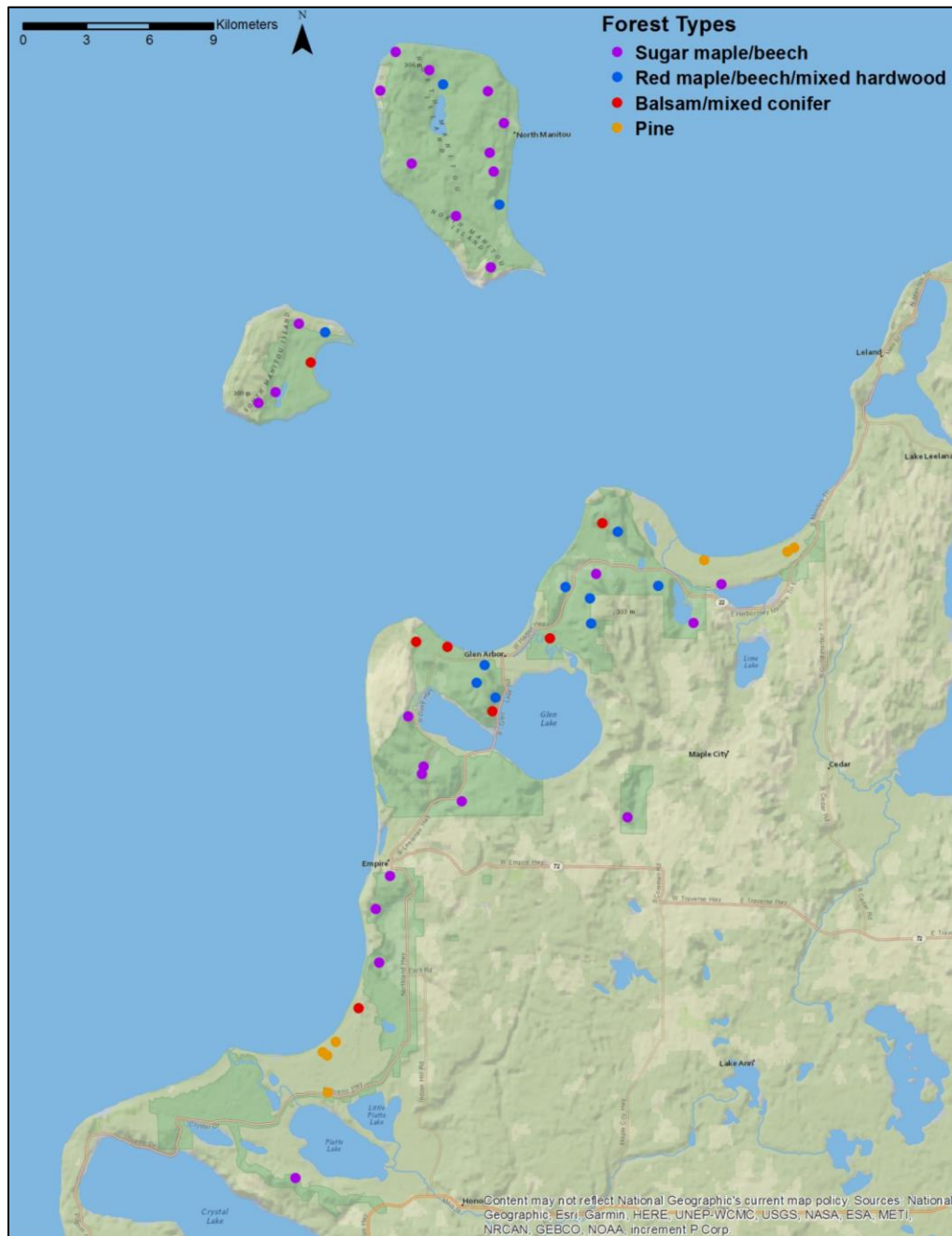


Figure 3. Locations and forest types (as of 2018) of the 50 permanent forest monitoring plots at SLBE, showing the broad forest type.

Table 2. Four forest types and the plots classified in each. All plots were initially sampled in 2009, then again in 2018.

Forest type	Plots
Balsam Fir-Mixed Conifer	8009*, 8010*, 8012, 8030, 8038, 8047, 8089
Pine	8003, 8021, 8022, 8023, 8040, 8049, 8051
Red maple-Beech-Mixed Hardwood	8002, 8006, 8029, 8034, 8036, 8045, 8053, 8060, 8067, 8073, 8079
Sugar Maple-Beech	8004, 8005, 8008, 8013, 8015, 8019, 8020, 8024, 8026, 8027, 8028, 8033, 8035, 8037, 8041, 8044, 8048, 8057, 8059, 8062, 8064, 8066, 8069, 8071, 8072

*plantation

Trees: 2018 Density by Diameter Classes

Among hardwoods, *Fagus grandifolia* Ehrh. (American beech) dominated the hardwood component across most size classes in Red Maple-Beech-Mixed Hardwood and in Sugar Maple-Beech forests (Figure 4, left column). In the former forest type, *Acer rubrum* is common throughout all size classes <25 cm DBH; at size classes equal to or greater than this, *Quercus rubra* L. (red oak) was common. In Pine forests, both *Q. rubra* and *Q. alba* L. were present across a range of size classes, although densities are limited in smaller size classes.

Among conifers, in Balsam Fir-Mixed Conifer forests, *A. balsamea* (L.) Mill (balsam fir) was common at size classes up to 20 cm DBH (Figure 4, right column). *Pinus resinosa* was common in large size classes, but not as abundant below 12 cm DBH and not present below 10 cm DBH. In Pine forests, *Pinus strobus* L. (eastern white pine) was common across most size classes, with *P. banksiana* only present at low density from 10 to 30 cm DBH classes.

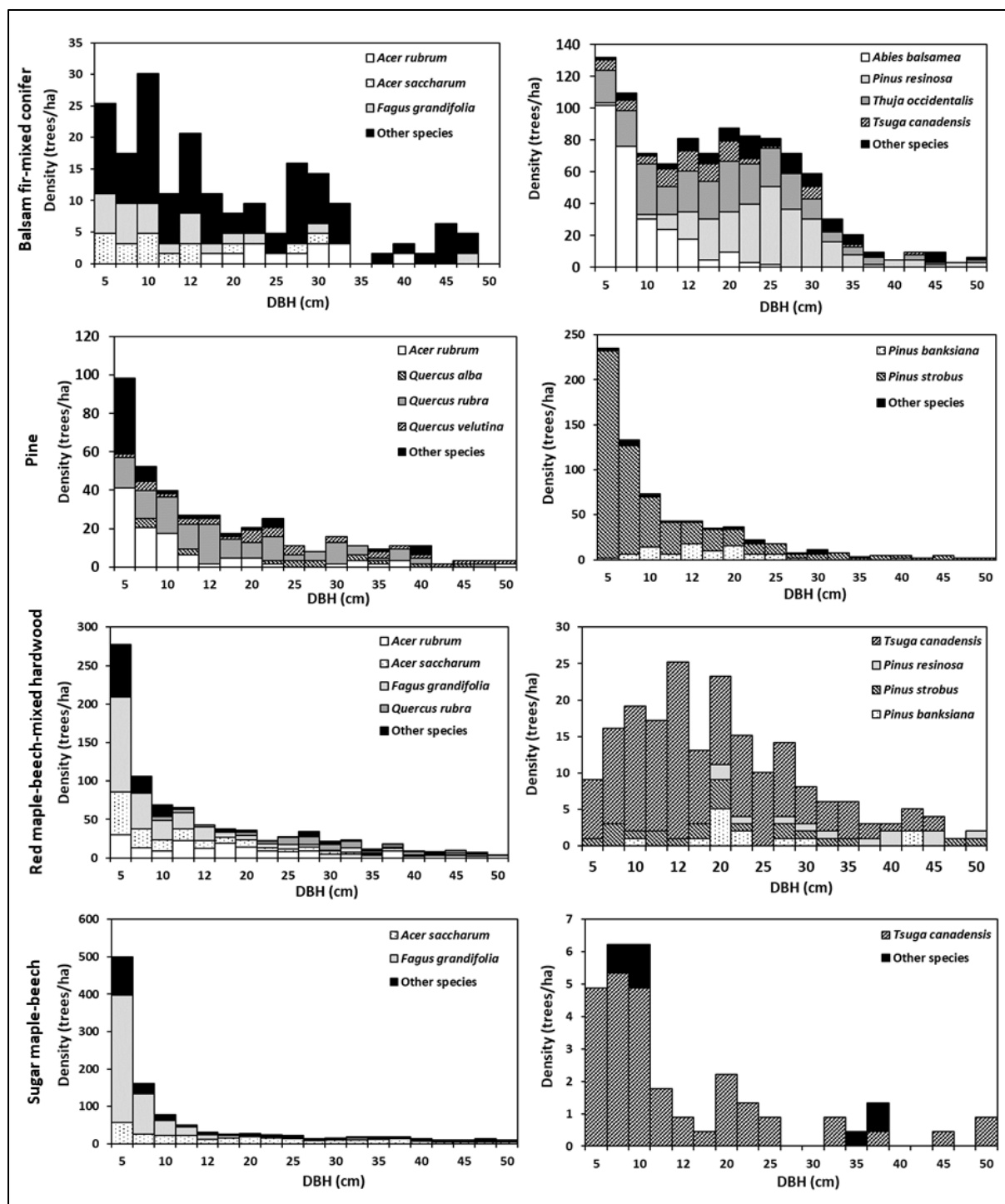


Figure 4. Diameter by size classes for plots in four forest types with conifers on left and hardwoods on right. Note the difference in scales on the y-axes.

Trees: Short-Term Change

Live tree density was generally higher in Balsam Fir-Mixed Conifer forests, but changed little between the sampling periods in all forest types (Figure 5, *left*). In Sugar Maple-Beech forests

(Figure 5, right), *F. grandifolia* density increased from 512 ± 106 trees/ha in 2009 to 582 ± 99 trees/ha in 2018 (Figure 5, right).

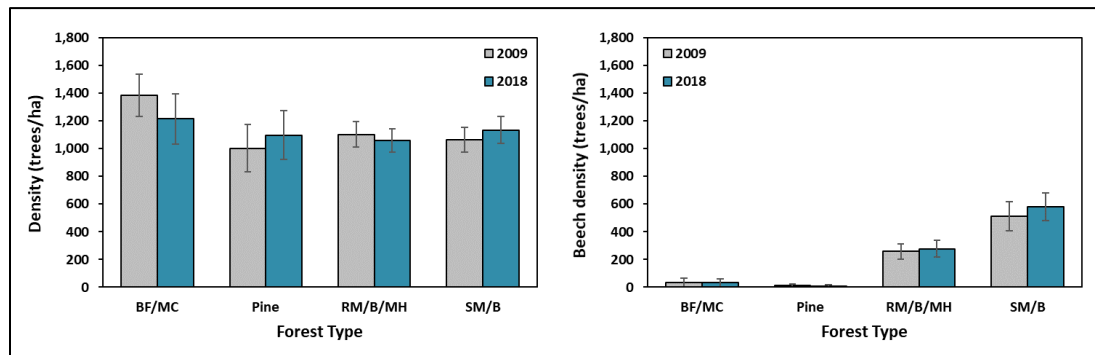


Figure 5. Stand density of live trees by forest type (left), and density of live *F. grandifolia* (right) across forest types. Error bars represent $\pm$ one standard error. Forest type abbreviations are: BF/MC: Balsam Fir-Mixed Conifer; RM/B/MH: Red Maple-Beech-Mixed Hardwood; SM/B: Sugar Maple-Beech.

Basal area of live trees was generally higher in Balsam Fir-Mixed Conifer forests and lower in Pine forests (Figure 6, left). Between the two sampling periods, live tree basal area changed little except for that of Pine forests; here it increased from 21 ± 5 m²/ha to 25 ± 5 m²/ha. Live *F. grandifolia* basal area decreased 10.7% to 3.50 ± 0.82 m²/ha and 4.0% to 8.61 ± 1.46 m²/ha in Red Maple-Beech-Mixed Hardwood and Beech-Sugar Maple forests, respectively (Figure 6, right).

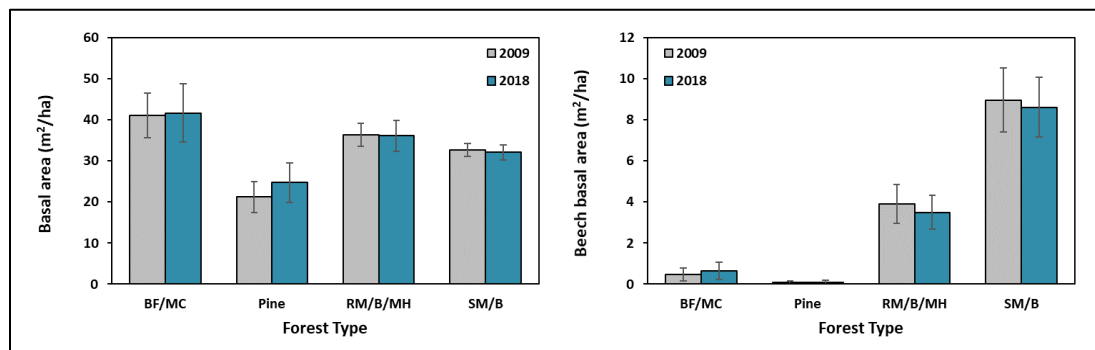


Figure 6. Basal area for live trees, by forest type (left), and basal area of live *F. grandifolia* (right) across all forest types. Note the difference in scales on the y-axes. Error bars represent $\pm$ one standard error. For forest type names, see Figure 5.

Across all forest types, density of live *F. grandifolia* increased from 408 trees/ha to 459 trees/ha between the two sampling periods (Figure 7, left). Basal area of *F. grandifolia* decreased 4.5% to 6.64 m²/ha, while basal area of standing dead *F. grandifolia* nearly tripled, from 0.32 m²/ha to 0.95 m²/ha (Figure 7, right).

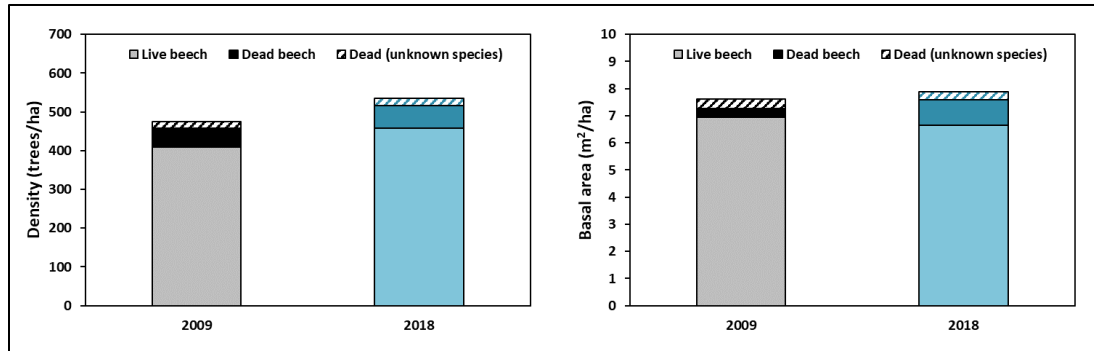


Figure 7. Density (left) and basal area (right) of living *F. grandifolia*, standing dead beech, and standing dead trees of unknown species during both sampling years.

Seedling density increased between the two sampling periods in all four forest types; this increase was greater than two-fold in Balsam Fir-Mixed Conifer and Red Maple-Beech-Mixed Hardwood forests. In Sugar Maple-Beech forests, seedling density increased 335% to 31,067 seedlings/ha (Figure 8). This was largely due to increases in a limited number of taxa: *Acer rubrum*, *A. saccharum*, *Fagus grandifolia*, and *Fraxinus* spp. (Table 3).

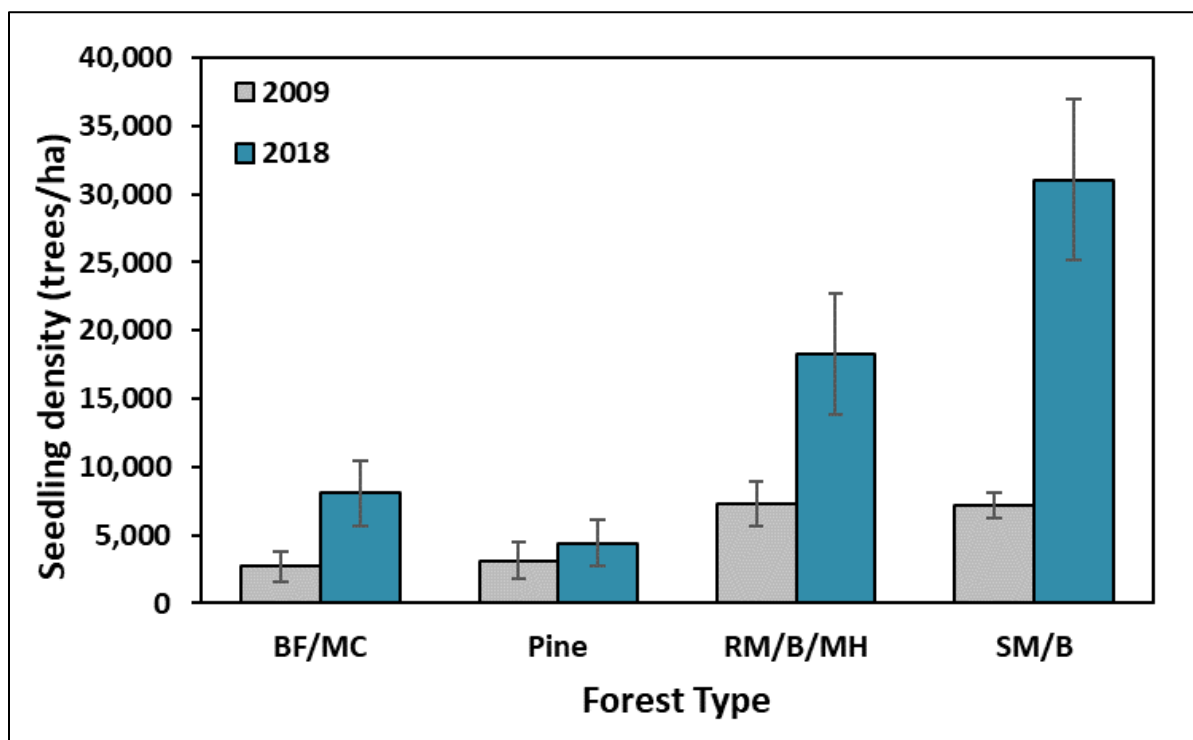


Figure 8. Seedling density by forest type. Error bars represent $\pm$ one standard error. For forest type names, see Figure 5.

Table 3. Seedling density by species for both sampling years. Values reflect the mean across all four forest types.

Species	Density (m ² /ha)	
	2009	2018
<i>Abies balsamea</i>	1,733	1,333
<i>Acer pensylvanicum</i>	1,778	2,083
<i>Acer rubrum</i>	1,222	2,703
<i>Acer saccharum</i>	4,667	15,918
<i>Acer spicatum</i>	1,000	1,000
<i>Betula papyrifera</i>	500	556
<i>Fagus grandifolia</i>	3,613	6,649
<i>Fraxinus americana</i>	1,867	5,810
<i>Fraxinus pennsylvanica</i>	1,872	6,474
<i>Ostrya virginiana</i>	1,235	1,933
<i>Pinus banksiana</i>	333	667
<i>Pinus strobus</i>	1,667	1,818
<i>Populus grandidentata</i>	867	769
<i>Populus tremuloides</i>	333	2,000
<i>Prunus pensylvanica</i>	0	1,786
<i>Prunus serotina</i>	1,000	1,511
<i>Prunus virginiana</i>	1,917	3,400
<i>Quercus alba</i>	0	333
<i>Quercus rubra</i>	333	590
<i>Quercus velutina</i>	333	667
<i>Sorbus decora</i>	333	333
<i>Thuja occidentalis</i>	1,000	667
<i>Tilia americana</i>	1,000	500
<i>Tsuga canadensis</i>	778	667

Coarse Woody Material and Standing Dead Trees

Volume and biomass of coarse woody material changed little between the sampling periods (Table 4), while density increased 53%. Park-wide, the amount of large, advanced-decay, down, woody

material (≥ 2 m length, ≥ 30 cm diameter, decay class 3 or 4) increased from 4.38 ± 1.12 pieces/ha in 2009 to 6.34 ± 1.97 pieces/ha in 2018.

Table 4. Volume, biomass, and density of coarse woody material for both sampling years.

Year	Volume (m ³ /ha)	Biomass (kg/ha)	Density (pieces/ha)
2009	37.64 ± 5.55	$10,841 \pm 1,461$	296.35 ± 26.29
2018	38.00 ± 3.97	$11,718 \pm 1,424$	453.5 ± 36.14

Density of snags (standing dead trees) >30 cm DBH changed for all four forest types, increasing in three of the four (Figure 9). In Pine forests, snag density increased more than two-fold to 22.2 ± 4.2 large snags/ha. In Red Maple-Beech-Mixed Hardwood and Beech-Sugar Maple, large snag density increased 10.0% and 43.7%, respectively.

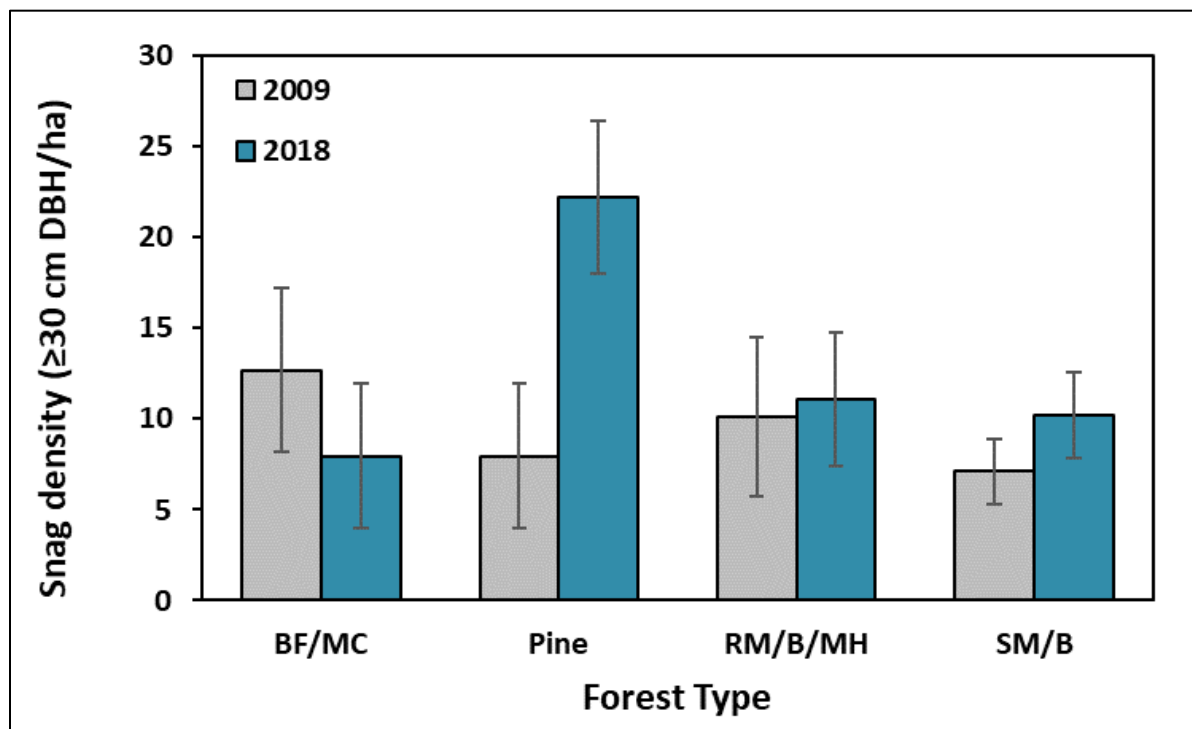


Figure 9. Density of snags ≥ 30 cm DBH for all four forest types. Error bars represent $\pm$ one standard error. For forest type names, see Figure 5.

Browse and Disease

Direct browse (i.e. bite marks on woody individuals) varied greatly across species, with three species—*Sambucus racemosa* L. (red elderberry), *Pinus strobus*, and *Populus grandidentata* Michx. (bigtooth aspen)—having bite marks in $>30\%$ of browse circles where they were present (Table 5). An additional three species had bite marks in greater than 20% of circles where present. No browse was noted for nine species.

Proportion browse by forest type varied somewhat and was generally higher in Pine forests (14.6% $\pm$ 5.9%) of circles had at least one species browsed (Figure 10).

Table 5. Proportion browse for all woody species present in at least five plots*.

Species	Common name	Proportion browse
<i>Sambucus racemosa</i> var. <i>racemosa</i>	red elderberry	0.3646
<i>Pinus strobus</i>	white pine	0.3500
<i>Populus grandidentata</i>	bigtooth aspen	0.3390
<i>Rubus sachalinensis</i> var. <i>sachalinensis</i>	red raspberry	0.2769
<i>Rubus allegheniensis</i>	common blackberry	0.2667
<i>Pinus banksiana</i>	jack pine	0.2174
<i>Tsuga canadensis</i>	eastern hemlock	0.1818
<i>Acer rubrum</i>	red maple	0.1642
<i>Acer spicatum</i>	mountain maple	0.1429
<i>Viburnum acerifolium</i>	mapleleaf viburnum	0.1333
<i>Betula papyrifera</i>	paper birch	0.125
<i>Ostrya virginiana</i>	hophornbeam	0.1229
<i>Prunus virginiana</i>	chokecherry	0.1205
<i>Fraxinus pennsylvanica</i>	green ash	0.1070
<i>Prunus serotina</i>	black cherry	0.0787
<i>Rubus flagellaris</i>	whiplash dewberry	0.0714
<i>Fagus grandifolia</i>	American beech	0.0693
<i>Tilia americana</i>	basswood	0.0667
<i>Acer saccharum</i>	sugar maple	0.0511
<i>Abies balsamea</i>	balsam fir	0.0462
<i>Acer pensylvanicum</i>	striped maple	0.0417
<i>Amelanchier</i> sp. (Group 2)	Serviceberry	0.0323
<i>Thuja occidentalis</i>	eastern white cedar	0.0244

*Species for which no browse was recorded were: *Arctostaphylos uva-ursi*, *Betula allegheniensis*, *Pinus resinosa*, *Quercus rubra*, *Symphoricarpos albus*, *Toxicodendron rydbergii*, *Vaccinium angustifolium*, *V. myrtilloides*, and *Vitis riparia*.

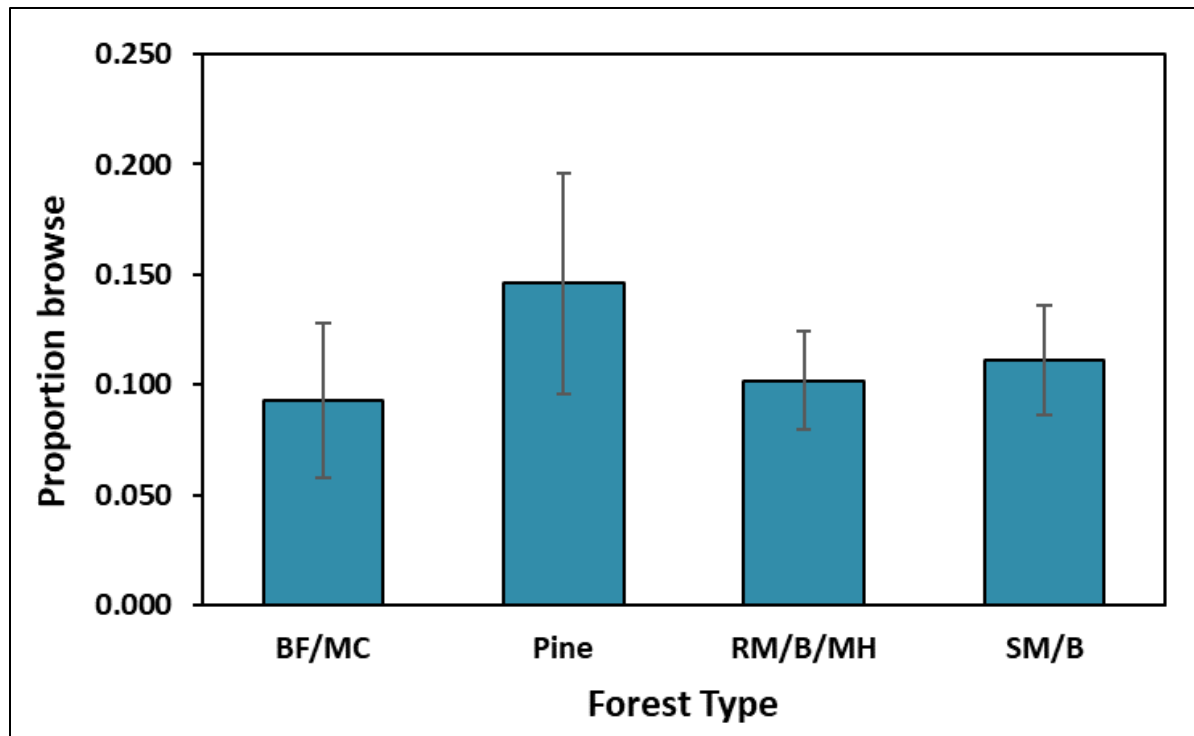


Figure 10. Proportion browse by forest type. Error bars represent $\pm$ one standard error. For forest type names, see Figure 5.

For the 16 herbaceous taxa identified as preferred browse species for indirect browse assessments, *Summed Frequency of Presence* ranged from 0.75 to 1.25 in 2009 and from 0.52 to 1.23 in 2018 (Figure 11). In both Mainland and North Manitou Island plots, this value decreased between the two sampling events.

Between the two target indirect browse species sampled at both time periods, changes in the frequency of quadrats where present varied (Figure 12). For *Aralia nudicaulis*, this changed little for plots on the mainland, North Manitou Island, and South Manitou Island. In contrast, frequency of quadrats supporting *Trillium grandiflorum* decreased markedly between the two sampling periods. This value decreased 51%, 46%, and 81% for mainland, North Manitou Island, and South Manitou Island plots, respectively.

The maximum height of *A. nudicaulis* was slightly greater in 2018 than in 2009 in all three sampling areas (Figure 13). For *T. grandiflorum*, maximum height was similar between the two sampling periods for mainland and South Manitou Island plots, and slightly lower in 2018 at North Manitou Island sites.

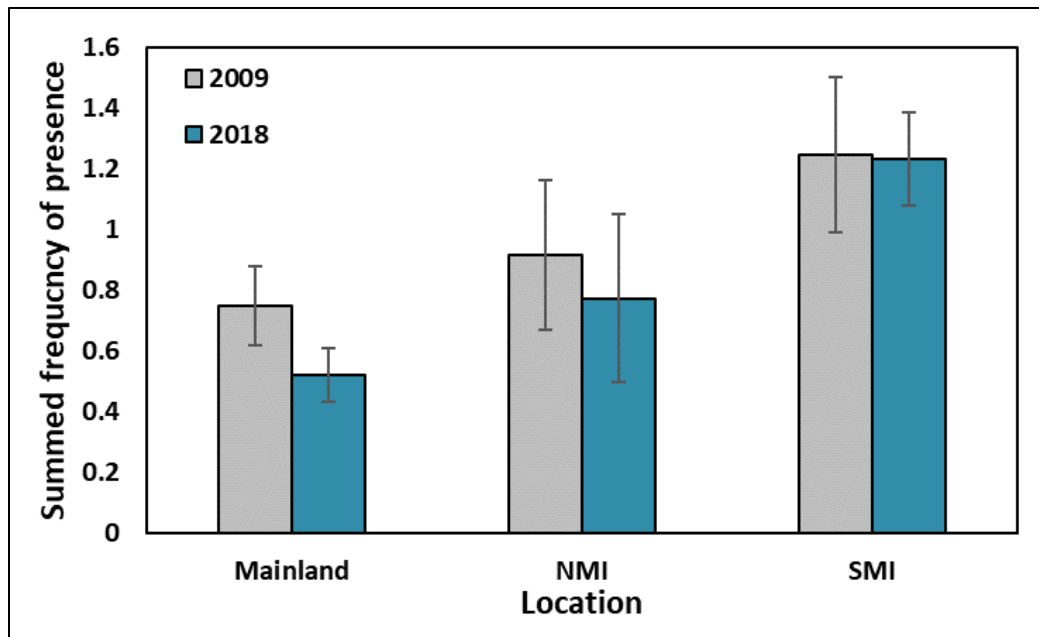


Figure 11. The summed frequency of presence for ten preferred browse species, across all forest types. For both the Mainland and NMI plots, this was slightly lower during the second sampling interval. Error bars represent $\pm$ one standard error.

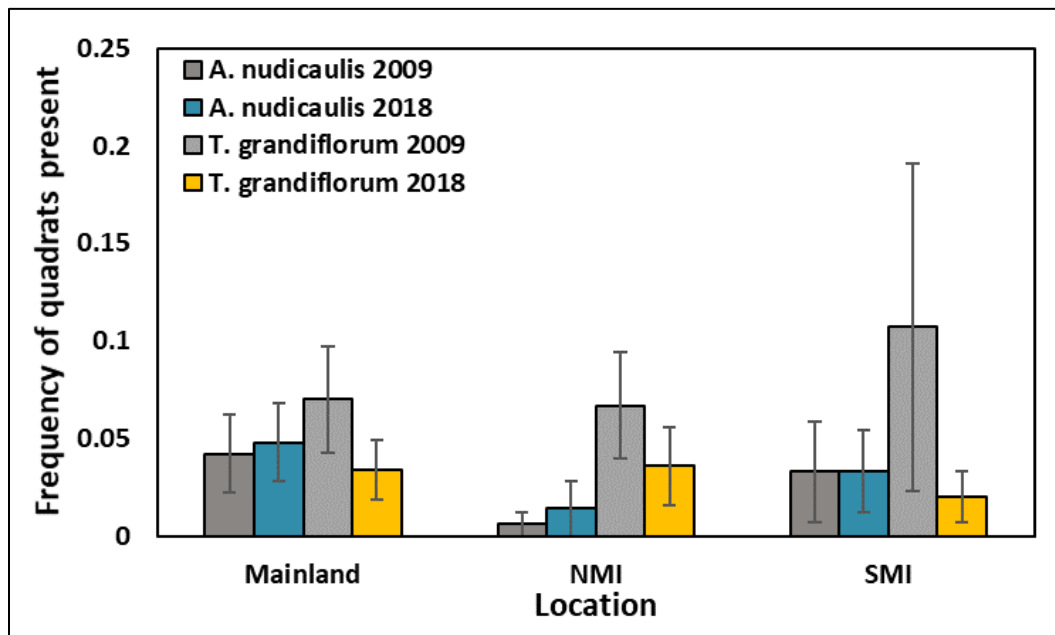


Figure 12. The summed frequency of presence for the two target indirect browse species (*Aralia nudicaulis* and *Trillium grandiflorum*) in common between the two sampling periods.

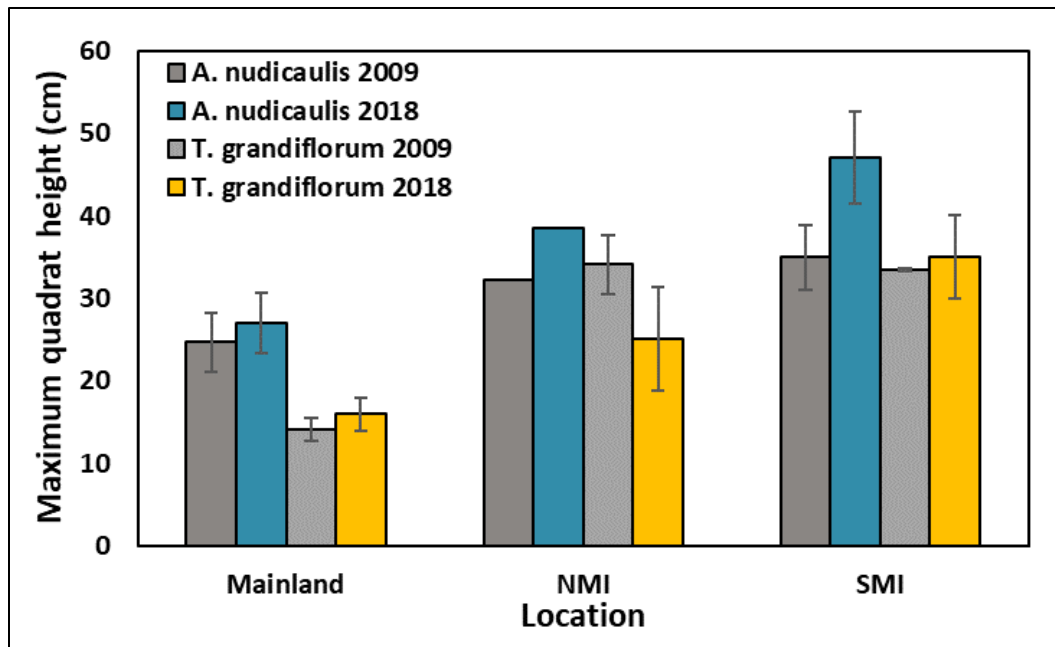


Figure 13. Maximum height in quadrats for the two target indirect browse species (*Aralia nudicaulis* and *Trillium grandiflorum*) in common between the two sampling periods. Error bars are not shown for *A. nudicaulis* on NMI since it was only located in two plots.

Tree Health

Beech scale (*Cryptococcus fagisuga* Lindinger) was observed in three forest types, and was present on greater than half of individuals (Table 6). Both *Fraxinus americana* and *F. pennsylvanica* were present as scattered individuals throughout the park; D-shaped exit holes were observed on two individuals. All other incidents of damage or pests were limited to a few individuals (at most) of various species.

Table 6. Number of *Fagus grandifolia* trees in each forest type (where present) and number of those showing beech scale. Note: these numbers include all size classes, down to 2.5 cm DBH.

Category	Number of Trees (by Forest Type)		
	Sugar Maple-Beech	Red Maple-Beech-Mixed Hardwood	Balsam Fir-Mixed Conifer
Present	1,309	274	20
With scale	1,169	184	12

Community Indices

Species richness was slightly higher in all four forest types in 2018 (Figure 14).

The coefficient of conservatism ranged from 3.5 (Balsam Fir-Mixed Conifer forests) to 4.3 (Pine forests) and varied little between forest type and year (Figure 15).

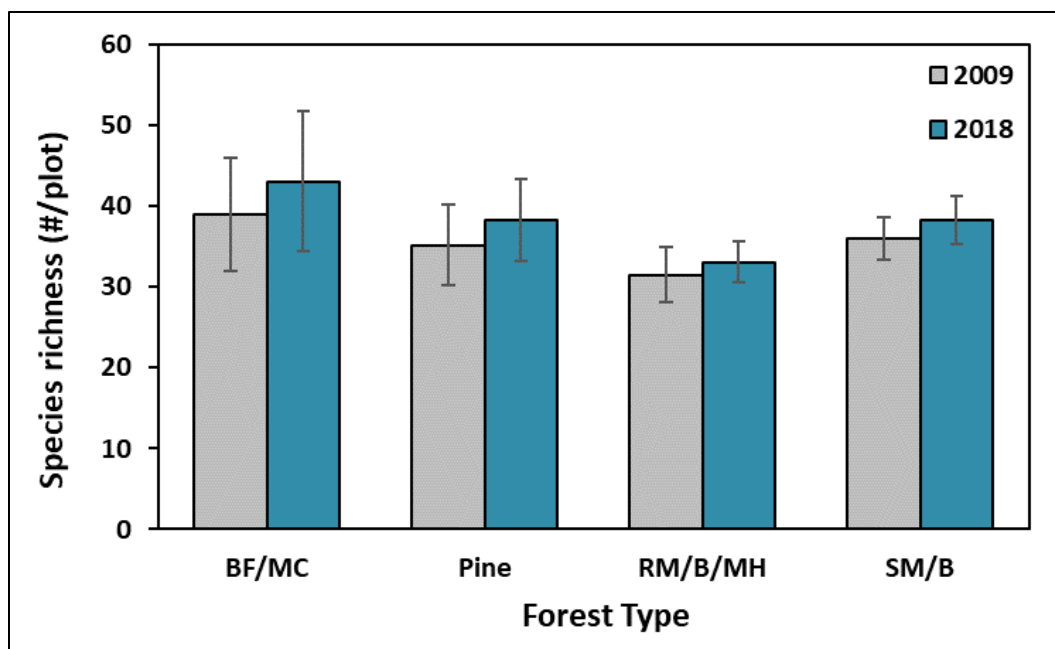


Figure 14. Species richness for all four forest types, 2009 and 2018. Error bars represent $\pm$ one standard error. See Figure 5 for forest type names.

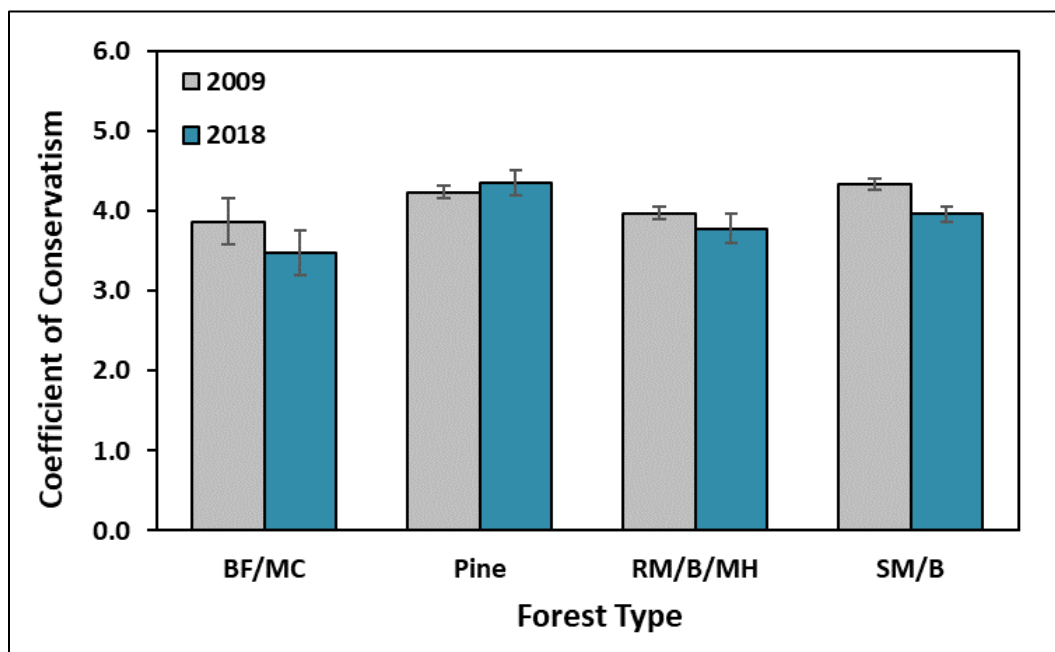


Figure 15. Coefficient of conservatism for four forest types and both sampling events. Error bars represent $\pm$ one standard error. For forest type names, see Figure 5.

Earthworm Impacts

Impacts of earthworms varied greatly throughout the park. Eleven plots were earthworm-free, while six were heavily invaded (Figure 16, Table 7).

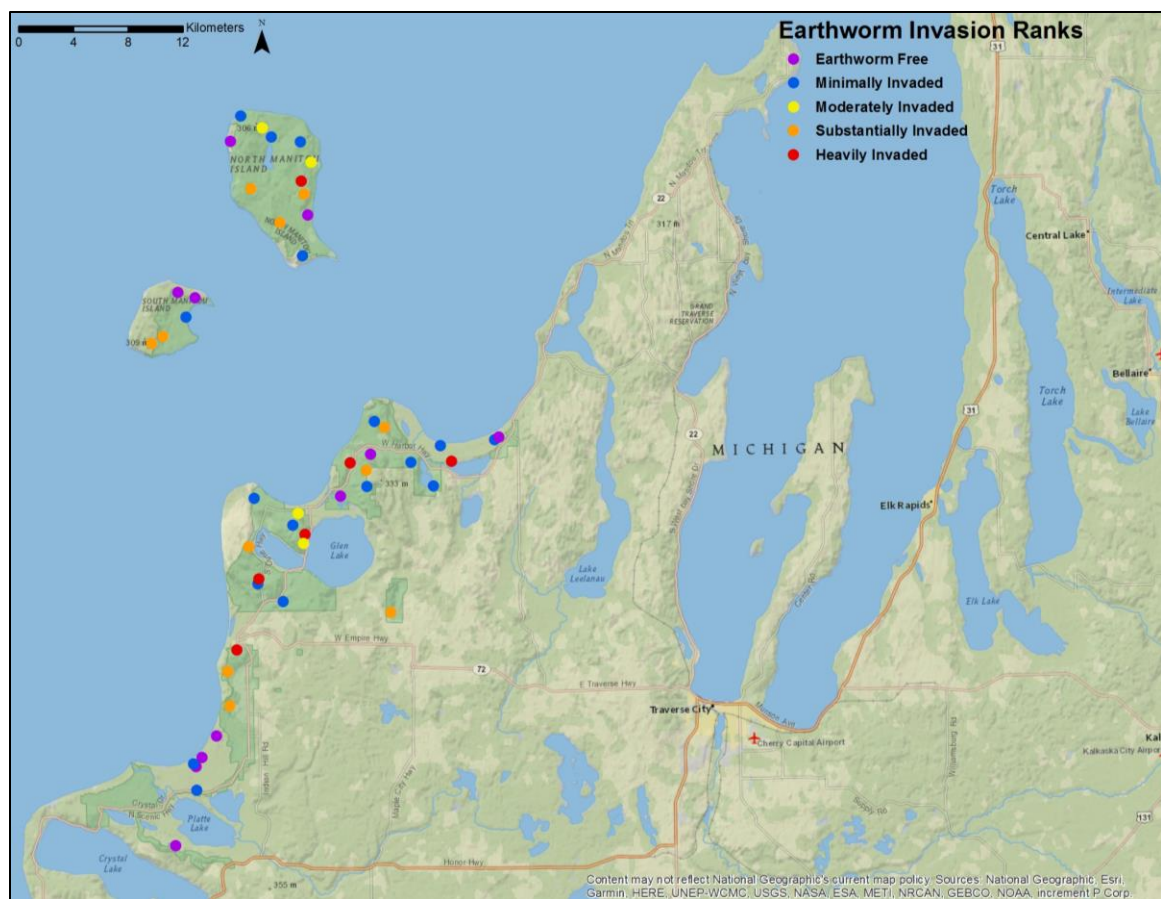


Figure 16. Earthworm invasion ranks at each plot, 2018. These designations show the highest level of impairment of the four assessments completed at each plot.

Table 7. Classification of plots into categories denoting severity of earthworm invasion. For severity, we used the most severe (i.e., “worst”) classification of the four samples collected at each plot. No assessment was made at plot 8012 near the D.H. Day Campground, since ground disturbance there was not permitted.

Habitat	Severity of Invasion				
	<i>Earthworm-free</i>	<i>Minimally invaded</i>	<i>Moderately invaded</i>	<i>Substantially invaded</i>	<i>Heavily invaded</i>
Balsam fir/mixed conifer	2	3	1	0	0
Pine	3	4	0	0	0
Red maple-beech-mixed hardwood	2	4	1	2	2
Sugar maple-beech	4	6	2	9	4

Wilderness Character Assessment

Six invasive plant taxa were distributed over eight of the 28 plots in wilderness in 2009 (Table 8). Eighteen invasive species were identified in 2018, spread over 21 wilderness plots.

Table 8. Invasive species present in 28 wilderness plots in both 2009 and 2018. Frequency is shown for species found in quadrats. A “W” indicates a species that was only found during the walkthrough.

Plot	2009		2018	
	Species	Frequency	Species	Frequency
8003	<i>Lonicera</i> sp.	W	W	–
8004	–	–	<i>Epipactis helleborine</i>	W
8020	–	–	<i>Epipactis helleborine</i>	W
8021	–	–	<i>Hypericum perforatum</i>	W
8021	–	–	<i>Poa compressa</i>	0.37
8021	–	–	<i>Rumex acetosella</i>	W
8022	–	–	<i>Epipactis helleborine</i>	W
8022	–	–	<i>Phalaris arundinacea</i>	W
8024	–	–	<i>Epipactis helleborine</i>	0.13
8027	–	–	<i>Epipactis helleborine</i>	W
8029	<i>Hieracium piloselloides</i>	W	<i>Hypericum perforatum</i>	W
8029	<i>Lonicera</i> sp.	W	<i>Poa compressa</i>	0.03
8030	–	–	<i>Gypsophila paniculata</i>	W
8030	–	–	<i>Eleagnus umbelata</i>	W
8030	–	–	<i>Epipactis helleborine</i>	0.33
8030	–	–	<i>Poa compressa</i>	W
8030	–	–	<i>Rosa multiflora</i>	W
8036	–	–	<i>Epipactis helleborine</i>	W
8044	–	–	<i>Epipactis helleborine</i>	W
8047	<i>Cynoglossum officinale</i>	0.07	<i>Centaurea stoebe</i> ssp. <i>micranthos</i>	0.03
8047	<i>Lonicera</i> sp.	W	<i>Cynoglossum officinale</i>	0.03
8047	–	–	<i>Eleagnus umbelata</i>	W
8047	–	–	<i>Epipactis helleborine</i>	0.17
8047	–	–	<i>Hypericum perforatum</i>	0.13

Table 8 (continued). Invasive species present in 28 wilderness plots in both 2009 and 2018. Frequency is shown for species found in quadrats. A “W” indicates a species that was only found during the walkthrough.

2009			2018	
Plot	Species	Frequency	Species	Frequency
8047	–	–	<i>Leucanthemum vulgare</i>	W
8048	–	–	<i>Epipactis helleborine</i>	W
8048	–	–	<i>Vinca minor</i>	W
8049	<i>Phragmites australis</i>	W	<i>Phragmites australis</i>	W
8051	–	–	<i>Hieracium aurantiacum</i>	W
8051	–	–	<i>Rumex acetosella</i>	0.10
8059	<i>Lonicera</i> sp.	W	<i>Epipactis helleborine</i>	0.33
8062	<i>Arctium minus</i>	0.03	<i>Arctium minus</i>	0.03
8062	–	–	<i>Cirsium arvense</i>	0.03
8062	–	–	<i>Epipactis helleborine</i>	W
8062	–	–	<i>Hesperis matronalis</i>	0.17
8062	–	–	<i>Leonuris cardiac</i>	0.10
8062	–	–	<i>Poa compressa</i>	W
8064	–	–	<i>Epipactis helleborine</i>	0.27
8066	–	–	<i>Epipactis helleborine</i>	W
8071	<i>Epipactis helleborine</i>	0.10	<i>Epipactis helleborine</i>	0.17
8072	–	–	<i>Epipactis helleborine</i>	0.07
8089	<i>Hieracium piloselloides</i>	0.13	<i>Convallaria majalis</i>	W

Discussion

There is a great deal of uncertainty in the projected successional trajectory of Sugar Maple-Beech forests. These forests are the most widespread in the park, with 25 of the 50 plots falling into this classification. Density-diameter graphs (see Figure 4) show an overwhelming dominance of *F. grandifolia* and a small fraction of *Acer saccharum* and other species. The current forest structure may largely be a reflection of the high white-tailed deer density at SLBE. Deer almost exclusively avoid *F. grandifolia* in the region, while maples are generally consumed (S. Sanders, personal observation). A loss of the beech overstory without a subsequent reduction in deer abundance will likely cause these forests to transition to beech thickets, characteristic of the aftermath phase of a BBD invasion (Hane 2003, Duchesne et al. 2005).

The park is currently involved in a beech restoration effort, working jointly with Pictured Rocks National Lakeshore (PIRO). As part of this project, disease-resistant individuals are being developed by grafting shoots of known resistant trees onto rootstock, cross-pollinating flowers on resistant shoots, and planting the resulting beech nuts. Unfortunately, this program is in its infancy and resistant stock for outplanting will likely not be available for six to eight years.

In addition to restoration of beech, any reduction in abundance of white-tailed deer would benefit SLBE forests. Deer management by Michigan DNR seeks to strike a balance between mitigating deer impacts (which includes limits to forest regeneration) and providing hunter opportunities. They reported the Leelanau County deer population as stable to slightly increasing from 2006 to 2015 (Michigan Department of Natural Resources 2019). Our indirect browse assessments showing a reduction in the summed frequencies of preferred browse species at both mainland and North Manitou Island sites support this.

One notable surprise in our data is the marked reduction in *Trillium grandiflorum* frequency between the two sampling periods. Although this species is preferred by white-tailed deer, reductions due to browse do not explain its drop in frequency on South Manitou Island. Knight (2003) showed increased fruit set of *T. grandiflorum* in response to supplemental pollination, though greater fruit set did not appreciatively lead to increases in population growth under high browse pressure (Knight 2004). Thus, pollinator limitation could be influencing the population. Alternatively, *T. grandiflorum* individuals may simply be dormant. Vegetative dormancy in *Trillium grandiflorum* is documented (Hanzawa and Kalisz 1993), but is believed to be associated with a drop in the production and storage of photosynthate. We are unaware of any park-wide events that could have triggered this.

Our wilderness character assessment details only invasive species and does not include all non-native or naturalized species. For example, *Trifolium* spp. would not be included since it is generally limited to trails and edges. Our assessment shows an increased number of sites with invasive species, as well as increased abundance at these sites. Some of these increases may be due simply to our later sampling period (15 June–26 August 2018 vs. 27 May–30 June 2009), allowing us to identify, for example, grasses to species. However, some patterns are clearly evident, particularly for the orchid *Epipactis helleborine* (L.) Crantz. This species, a native of Eurasia, was likely introduced to the Buffalo, New York, area by the 1870s. The earliest report of this species in Michigan is in East

Lansing from 1940 (Drew and Giles 1951). This species is capable of selfing (Tałałaj and Brzosko 2008) and has been slowly spreading outward since that time.

Management Recommendations

While our results quantitatively demonstrate several forest health concerns, SLBE park staff are generally aware of these issues and are actively addressing them. This includes not only the implementation of a beech restoration program, but also the introduction of prescribed fire at the lakeshore. In May 2019, a 371 hectare tract in the Platte Plains unit was burned to restore this fire-dependent habitat. Two additional burns are planned in the Platte Plains area, as are three in the Good Harbor Bay area. Our data from plots in pine forests (see Figure 4) show that both *Quercus alba* and *Pinus banksiana* lack the high densities at smaller size classes necessary to ensure demographic inertia for continued transition into larger size classes. Controlled burns will address regeneration of these and other fire-dependent species.

High browse pressure continues to be a problem in the lakeshore. Deer abundance is largely controlled by winter severity (Michigan Department of Natural Resources 2019), but is further regulated by the Michigan Department of Natural Resources via quotas, establishment of additional seasons, and other means. The park should engage with the Michigan DNR whenever possible with regard to both overstory and groundlayer regeneration problems.

Of all of our results, we were perhaps most surprised by the decline in frequency of *Trillium grandiflorum*. Arguably, this is a flagship understory species in the park, drawing in visitors and enhancing their experience. Park staff may wish to review ecological processes associated with dormancy (Shefferson 2009, Shefferson et al. 2018) and consider a mark-recapture study of *T. grandiflorum*, including populations both on the mainland and on South Manitou Island.

Finally, park staff should make all efforts for continued involvement in the beech restoration project. In this era of limited budgets and uncertain funding, the realities of implementing a project of this stature are immense. A staff with a continuing incentive to make this project happen is perhaps the most important safeguard for SLBE forests.

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Appendix A. All species located during 2018 sampling.

Herbaceous - Fern / Fern Allies

Dennstaedtiaceae

Pteridium aquilinum

Dryopteridaceae

Dryopteris carthusiana

Dryopteris intermedia

Polystichum lonchitis

Equisetaceae

Equisetum hyemale

Equisetum arvense

Lycopodiaceae

Lycopodium dendroideum

Huperzia lucidula

Lycopodium obscurum

Lycopodium annotinum

Onocleaceae

Onoclea sensibilis

Matteuccia struthiopteris

Ophioglossaceae

Botrychium virginianum

Pteridaceae

Adiantum pedatum

Thelypteridaceae

Thelypteris palustris

Woodsiaceae

Gymnocarpium dryopteris

Athyrium filix-femina

Herbaceous – Forb

Amaranthaceae

Chenopodium capitatum

Amaryllidaceae

Allium tricoccum

Apiaceae

Cicuta maculata

Daucus carota

Sium suave

Osmorhiza sp.

Heracleum sphondylium ssp. *montanum*

Apocynaceae

Apocynum androsaemifolium

Asclepias syriaca

Araceae

Arisaema triphyllum

Araliaceae

Aralia nudicaulis

Aralia racemosa

Panax quinquefolius

Asparagaceae

Convallaria majalis

Polygonatum pubescens

Maianthemum canadense

Maianthemum stellatum

Maianthemum racemosum ssp. *racemosum*

Asteraceae

Achillea millefolium

Artemisia sp.

Erigeron strigosus

Taraxacum officinale

Solidago sp.

Solidago flexicaulis

Cirsium arvense

Cirsium discolor

Cirsium vulgare

Anaphalis margaritacea

Arctium minus

Antennaria sp.

Conyza canadensis

Hieracium sp.

Hieracium aurantiacum

Hieracium venosum

Krigia virginica

Leucanthemum vulgare
Prenanthes alba
Tragopogon sp.
Tragopogon dubius
Artemisia campestris ssp. *caudata*
Hieracium caespitosum
Hieracium umbellatum
Eurybia macrophylla
Symphyotrichum lateriflorum
Symphyotrichum sp.
Symphyotrichum puniceum var. *puniceum*
Eutrochium maculatum
Centaurea stoebe ssp. *micranthos*

Berberidaceae

Caulophyllum thalictroides

Boraginaceae

Cynoglossum officinale
Hackelia virginiana
Lithospermum canescens
Lithospermum officinale

Brassicaceae

Cardamine concatenata
Cardamine diphylla
Berteroa incana
*Hesperis matronalis**
*Alliaria petiolata**
Arabidopsis lyrata ssp. *lyrata*

Campanulaceae

Campanula rotundifolia

Caryophyllaceae

Minuartia michauxii
Silene vulgaris
Gypsophila paniculata

Colchicaceae

Uvularia grandiflora

Ericaceae

Gaultheria procumbens
Pyrola sp.

Pyrola asarifolia
Chimaphila umbellata
Monotropa uniflora

Fabaceae

Melilotus sp.
Trifolium sp.

Geraniaceae

Geranium robertianum

Hydrophyllaceae

Hydrophyllum virginianum

Hypericaceae

Hypericum sp.
Hypericum perforatum

Lamiaceae

Lycopus americanus
Lycopus uniflorus
Prunella vulgaris
Leonurus cardiaca
Scutellaria lateriflora
Clinopodium vulgare

Liliaceae

Clintonia borealis
Medeola virginiana
Lilium philadelphicum
Streptopus lanceolatus var. *roseus*

Linnaeaceae

Linnaea borealis

Malvaceae

Malva neglecta

Melanthiaceae

Trillium grandiflorum

Menyanthaceae

Menyanthes trifoliata

Onagraceae

Epilobium ciliatum
Circaea alpina
Circaea canadensis ssp. *canadensis*

Orchidaceae

Platanthera orbiculata

Spiranthes lacera

Epipactis helleborine

Cypripedium sp.

Cypripedium acaule

Goodyera oblongifolia

Orobanchaceae

Melampyrum lineare

Conopholis americana

Epifagus virginiana

Oxalidaceae

Oxalis sp.

Oxalis stricta

Papaveraceae

Dicentra canadensis

Dicentra cucullaria

Sanguinaria canadensis

Corydalis sempervirens

Phytolaccaceae

Phytolacca americana

Plantaginaceae

Plantago lanceolata

Plantago major

Veronica officinalis

Veronica arvensis

Nuttallanthus canadensis

Plantago rugelii

Polygalaceae

Polygala paucifolia

Polygonum sp.

Rumex acetosella

Rumex crispus

Rumex obtusifolius

Primulaceae

Lysimachia thyrsiflora

Trientalis borealis

Ranunculaceae

Ranunculus abortivus
Ranunculus recurvatus
Thalictrum dioicum
Actaea sp.
Actaea pachypoda
Actaea rubra
Aquilegia canadensis
Coptis trifolia
Anemone acutiloba

Rosaceae

Fragaria virginiana
Agrimonia gryposepala
Agrimonia striata

Rubiaceae

Galium aparine
Galium trifidum
Galium lanceolatum
Galium pilosum
Galium triflorum
Houstonia longifolia
Mitchella repens

Santalaceae

Comandra umbellata

Saxifragaceae

Mitella diphylla

Scrophulariaceae

Verbascum thapsus

Solanaceae

Solanum ptychanthum

Urticaceae

Urtica dioica ssp. *gracilis*

Violaceae

Viola sp.

Herbaceous/vine**Apocynaceae**

Vinca minor

Convolvulaceae

Calystegia sepium

Ericaceae

Epigaea repens

Fabaceae

Vicia sp.

Polygonaceae

Fallopia cilinodis

Herbaceous/graminoid**Cyperaceae**

Carex sp.

Carex intumescens

Carex rosea

Carex stipata

Carex brunnescens

Carex canescens

Carex hystericina

Carex rostrata

Carex albursina

Carex arctata

Carex bebbii

Carex communis

Carex cryptolepis

Carex deweyana

Carex disperma

Carex eburnea

Carex gracillima

Carex laxiflora

Carex leptoneura

Carex pedunculata

Carex pennsylvanica

Carex plantaginea

Juncaceae

Juncus sp.

Poaceae

Andropogon gerardii

Cinna latifolia

Glyceria sp.

Glyceria canadensis

Phleum pratense
Phragmites australis
Poa sp.
Poa compressa
Poa nemoralis
Phalaris arundinacea
Danthonia spicata
Dichanthelium sp.
Melica smithii
Milium effusum
Oryzopsis asperifolia
Schizachne purpurascens
Schizachyrium scoparium
Dactylis glomerata
Koeleria macrantha
Elymus repens
Elymus trachycaulus ssp. *trachycaulus*
Piptatherum pungens
Avenella flexuosa
Piptatherum racemosum

Shrub

Adoxaceae

Viburnum acerifolium
Sambucus racemosa var. *racemosa*

Anacardiaceae

Rhus typhina

Araliaceae

Aralia hispida

Berberidaceae

Berberis thunbergii
Berberis vulgaris

Caprifoliaceae

Lonicera sp. (exotic)
Lonicera canadensis
Lonicera hirsuta
Lonicera oblongifolia
Symphoricarpos albus

Celastraceae

Euonymus europaeus

Cornaceae

Cornus rugosa

Cornus alternifolia

Cornus sericea ssp. *sericea*

Cupressaceae

Juniperus communis

Juniperus horizontalis

Diervillaceae

Diervilla lonicera

Elaeagnaceae

Elaeagnus umbellata

Shepherdia canadensis

Ericaceae

Arctostaphylos uva-ursi

Vaccinium angustifolium

Vaccinium myrtilloides

Gaylussacia baccata

Grossulariaceae

Ribes cynosbati

Hamamelidaceae

Hamamelis virginiana

Rosaceae

Amelanchier sp. (group 2)

Amelanchier sp. (group 3)

Rosa sp.

Rosa acicularis

Rosa blanda

Rosa multiflora

Rubus occidentalis

Rubus allegheniensis

Rubus flagellaris

Rubus pubescens

Rosa rubiginosa var. *rubiginosa*

Rubus sachalinensis var. *sachalinensis*

Taxaceae

Taxus canadensis

Thymelaeaceae

Dirca palustris

Shrub/woody vine**Anacardiaceae**

Toxicodendron rydbergii

Caprifoliaceae

Lonicera dioica

Solanaceae

Solanum dulcamara

Vitaceae

Vitis riparia

Tree**Betulaceae**

Betula alleghaniensis

Betula papyrifera

Ostrya virginiana

Cupressaceae

Thuja occidentalis

Fagaceae

Quercus alba

Quercus rubra

Quercus velutina

Fagus grandifolia

Malvaceae

Tilia americana

Oleaceae

Fraxinus pennsylvanica

Fraxinus americana

Pinaceae

Abies balsamea

Picea glauca

Picea pungens

Pinus banksiana

Pinus resinosa

Pinus strobus

Pinus sylvestris

Tsuga canadensis

Rosaceae

Prunus serotina

Prunus pensylvanica

Prunus virginiana

Sorbus decora

Salicaceae

Populus deltoides

Populus deltoides ssp. *monilifera*

Populus grandidentata

Populus tremuloides

Sapindaceae

Acer rubrum

Acer saccharum

Acer pensylvanicum

Acer spicatum

Ulmaceae

Ulmus Americana

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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National Park Service
U.S. Department of the Interior



[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525