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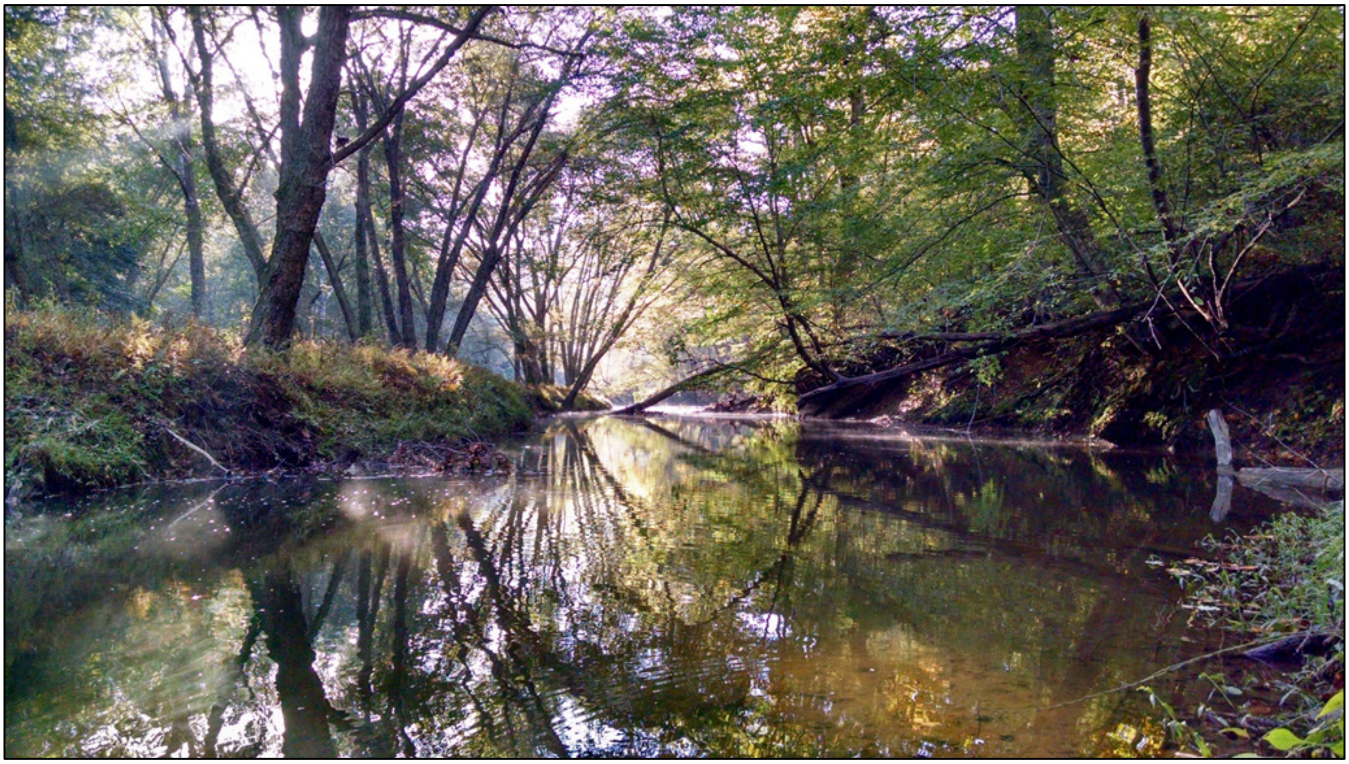
Natural Resource Stewardship and Science

Trends in Woody Forest Vegetation in Prince William Forest Park, 2006–2017

Natural Resource Report NPS/NCRN/NRR—2023/2495



ON THIS PAGE
NCRN Inventory and Monitoring crew collecting data at a quadrangle within a vegetation plot in Prince William Forest.
NPS / HASSLER

ON THE COVER
View of a stream in Prince William Forest Park.
NPS

Trends in Woody Forest Vegetation in Prince William Forest Park, 2006–2017

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Executive Summary

This report summarizes forest vegetation trends in Prince William Forest Park based on twelve years of monitoring data. One of the key findings of the report is a highly significant decline in saplings and tree seedlings throughout most of the park. This loss of forest regeneration can have profound impacts on the composition of forest communities in the future and can reduce the resilience of the park to respond to stressors such as invasive species, tree pests and diseases, and climate change.

A second major finding is that there are highly significant differences between the area burned in the B-Loop fire in 2006 and the rest of the park. The burned portion of the park has a much denser understory with significantly more saplings, seedlings and shrubs and, for many species, less browsing by deer. Additionally, in unburned portions of the park, the sapling layer is typically dominated by fire sensitive mesic species, such as American beech and red maple, whereas in the burned areas fire tolerant oak and hickory species dominate the saplings.

Beech leaf disease, a nematode pest capable of killing American beech trees, has recently been found in the park. American beech is the most common tree and sapling species in the park. Declines in this species would lead to a significant reduction in tree regeneration and may provide new opportunities for invasive species to become established.

Based on these findings, we make several recommendations for managers. The park should consider implementing a deer management program, with a goal of reducing browsing on seedlings and reversing the decline in forest regeneration. The park should evaluate the use of prescribed fires as a management tool to promote oak and hickory species regeneration, at least in some areas of the park. Finally, while the arrival of beech leaf disease is a serious concern, it is too early to determine its likely impacts. The spread and impacts of this disease should be monitored in the park to determine what management actions may be needed.

Acknowledgments

We would like to thank the staff of Prince William Forest Park for their continued help and support of forest monitoring program. We thank Crystal Chen, Jim Comiskey, Greg Kneipp, Paul Marten, Megan Nortrup, Suzy Sanders, Erin Shaw, Kristen Shelton and Rick Turcotte for helpful reviews. We would also like to thank the many field crew members who assisted with data collection, particularly Allen Dupre and John Parrish.

Glossary

Basal area: For individual trees or saplings, the cross-sectional area, as measured at breast height (1.37 m above the ground). For a stand, this is the sum of the basal area of all individual trees in that stand, typically reported on a per hectare basis.

Browse rate: The percentage of seedlings in an area that are browsed by deer.

CWD (Coarse Woody Debris): Large pieces of dead wood on the forest floor, defined here as having a diameter greater than ≥7.5 cm.

DBH (Diameter at Breast Height): The diameter of a tree or sapling at 1.37 m above the ground. Used as a way to track the growth of a tree or sapling over time.

EAB (Emerald Ash Borer): *Agrilus planipennis*, an insect native to Asia, that is infesting and killing ash (*Fraxinus*) trees in the US.

Early successional species: A tree species that colonizes an area transitioning from open habitat to forest. These species generally grow well where there is a high light, but not underneath a forest canopy.

Herbaceous: A term used to describe plants that are not woody. This can apply to broad-leaved forbs, grasses and other graminoids, and some vines.

Mesic: A term used to describe a habitat with an ample supply of water, but which is not a wetland. Mesic tree species are species which do well in such a habitat.

Mesophication: A process for forest change (Nowacki and Abrams, 2008) whereby the suppression of fires in forests promotes the growth of mesic tree species, which in turn alter the environment in ways which make fires less likely, resulting in a feedback loop.

Non-canopy: A non-canopy tree species is one which grows well in low light conditions and typically does not grow tall enough to reach the canopy. These species are sometimes referred to as “sub-canopy species” with the forest layer they occupy labeled the “sub-canopy.”

PRWI: Prince William Forest Park

Senescence: Deterioration and death of organisms, including trees, due to age.

Introduction

Forest structure and composition are dynamic and change continually in response to both internal processes (e.g., competition among species) and external stressors (e.g., climate change). In the eastern US, over timescales of thousands of years, tree species have migrated across the continent in response to fluctuations in global temperature and the ebb and flow of ice sheets. The deciduous forests found in the Mid-Atlantic region today reflect both long-term processes, such as movement of species across the continent, as well as processes operating on much shorter time scales. In the 1800s and 1900s, these forests were severely impacted by human activities, such as widespread logging, the introduction of non-native forest pests and pathogens, alteration of natural disturbance cycles (such as fire), and changes in the composition and abundance of the native wildlife community, particularly white-tailed deer (Whitney 1994; Dyer 2006; Ellison et al., 2005; Horsley et al 2003; Nowacki and Abrams 2008; Webster et al. 2018). Today's Mid-Atlantic forests are still responding to these alterations and to more recent human-driven disturbances, like landcover conversion (particularly from natural or agricultural landscapes to highly developed and urbanized landcover; Slonecker, Milheim and Clagett, 2010), additional introductions of exotic pests and pathogens (e.g., emerald ash borer; Morin et al., 2017), and accelerating anthropogenic climate change (Moser et al., 2020).

Even in the absence of human-mediated stressors and disturbance, forest structure and composition change through time due to natural succession. This is driven by species characteristics such as shade tolerance and life history. In Eastern US deciduous forests, the first woody species to colonize following disturbance are typically good dispersers and strong competitors in high-light environments (aka "pioneer species"). As pioneer species grow tall, the forest canopy closes and greatly reduces light availability for the regeneration layer (i.e., small trees, saplings, seedlings). The species that were competitive in the high-light environment following a disturbance now become less competitive, and are ultimately outcompeted by species that are tolerant of low-light environments (e.g., Peet and Christensen 1980).

The expected patterns of species dominance during forest succession in the Piedmont region of the US have been well-described (Oosting 1942; Peet and Christensen 1980; Orwig and Abrams 1994). Areas that are reverting to forest from other land-uses are typically dominated by shade-intolerant species, such as Virginia pine (*Pinus virginiana*) and tulip poplar (*Liriodendron tulipifera*). When these trees mature, reducing light under a closed canopy, their regeneration is suppressed and understory composition shifts towards shade-tolerant hardwood species including oaks (*Quercus* spp.), hickories (*Carya* spp.), red maple (*Acer rubrum*), and black gum (*Nyssa sylvatica*). Virginia pine's average life span is approximately 100 years (Loehle 1988). When the relatively short-lived pines die, the subsequent canopy gaps are filled by more shade-tolerant, longer-lived species. Composition may continue to shift over hundreds of years as early invaders, like red maple, are replaced by more slowly invading, often animal-dispersed species, like oaks and hickories (Oosting 1942; Peet and Christensen 1980; Christensen and Peet 1984; Druckenbrod et al. 2005). In the latter part of the 20th century, this "classic" pattern of forest succession in eastern deciduous forests and in the Piedmont region has been altered by "mesophication" processes. Primarily as a result of fire suppression, successional pathways favor shade-tolerant species that are fire-sensitive (Nowacki and Abrams 2008; Hanberry et al. 2012).

These same stressors and ecological processes drive forest dynamics at Prince William Forest Park (PRWI) today. The landscape that is now PRWI experienced a variety of human activities prior to its transfer to the National Park Service in 1936, including farming, mining, and human settlement and habitation. In the 1940s, the park was used as a training school for World War II-era Office of Strategic Services (National Park Service 2013, 2019). These activities directly impacted the forests through clear-cut tree harvests, conversion from forest to other land-cover and uses, and ground and soil disturbance from road-building and other human activities. In the mid to late 1940s, the park returned to recreational use, with much more limited direct human impacts, and most of the park has since reverted to forest (National Park Service, 2013). By the early 21st century, well over 90% of the park is forested (Walsh et al, 2015).

As a result of the spatial and temporal variation in land-use history, the forests of PRWI today are of different ages and represent different successional stages. The vegetation map of the park, which is based upon data collected in 2003–2006 (National Capital Region 2018), attributes approximately 30% of the park's forests to early successional vegetation types and 70% to more mature vegetation community types. The composition of the forest vegetation broadly conforms to the expected patterns of forest succession in the Piedmont region, as described above, with Virginia pine and tulip popular dominating younger forests and a mix of oak-hickory species dominating older forests. However, much of the small tree size classes are composed of American beech (*Fagus grandifolia*), black gum, and red maple (Schmit et al. 2012), which suggests a longer-term transition toward forests dominated by mesic species.

Overlaid on this patchy forest landscape, other factors are likely influencing forest dynamics and succession at PRWI. White-tailed deer, for example, are considered a keystone herbivore of deciduous forests in eastern North America, and at high densities are well-documented to drive shifts in species composition (McShea and Rappole 1992; Waller and Alverson, 1997; Rooney and Waller 2003). Many NPS units in the Mid-Atlantic have experienced years of sustained high deer density and now show the effects of browse on regeneration patterns (Rossell et al., 2005; Kraft and Hatfield 2011; Bourg et al. 2017; Epiphan and Handel 2020; Schmit et al. 2020). Areas with high deer density generally show a reduction in woody plant regeneration along with a shift towards less palatable species (Horsley et al. 2003; Rooney and Waller 2003; Nuttle et al. 2013; Nuttle et al. 2014, Webster et al. 2018). Further, a range of exotic pests and pathogens have invaded the forests of the Mid-Atlantic in recent decades. Many of these are specialists that attack a particular species or species group, leading to increased mortality and population declines within these groups. The most notable of these in the past century include: chestnut blight, hemlock wooly adelgid, dogwood anthracnose, spongy moth, emerald ash borer, and beech leaf disease (Matthews and Riedman 2015; Matthews and Nortrup, 2017, Sherald et al. 1996, Herms and McGullough 2014; Ewing et al 2018; Kantor et al 2021). Finally, in recent years the park has experienced unplanned wildfires, including one in 2006 that burned more than 120 ha of forest.

To better understand the woody plant composition and change in the forests at PRWI we document 12 years of trends based on data from the National Capital Region Network (NCRN) long-term forest vegetation monitoring program. This report builds on prior reporting on the status and trends of invasive plant species (Miller et al., 2021) using data that was also collected as part of this program. Our current analysis focuses on trends in woody vegetation over time, and the relationship to a single covariate. An unusually large and destructive fire, the B-Loop fire, took place in 2006 at the start of the monitoring program. As there is reason to believe that fire can be a strong influence on successional trajectories, we took this opportunity to compare outcomes between areas that were burned and un-burned by this fire.

Our goal is to provide information that can be integrated into forest resource management decision-making. Given a dynamic history of human and natural change at the park, coupled with ongoing and developing stressors (e.g., climate change, urban development), we expect park forest resources to change, now and into the future. In the management implications section at the end of this report, we discuss how park managers might respond to this change using the Resist-Accept-Direct framework (Crausbay et al. 2020, Schuurman, et al. 2020).

In particular, we answer three questions:

1) Are there trends over time in any of the response metrics at any of the analysis levels in unburned areas?

An important objective of the forest vegetation monitoring program is to determine trends in the abundance of species (response metric) found in the park. In addition to determining species level trends, we examined trends across groups of species with similar ecological characteristics (analysis levels) in order to provide a management context for the results.

2) How did the forest change in burned plots in the immediate aftermath of the B-Loop fire?

The B-Loop fire was a significant disturbance that drastically changed conditions on some monitoring plots. We quantified the changes in woody vegetation on these plots compared to unburned areas of the park. This allowed us to provide better context for trends observed in burned areas of the park.

3) Are there trends over time in any of the response metrics at any of the analysis levels in burned areas?

We also estimated trends in woody vegetation in the burned areas of the park. We then compared trends between burned and unburned areas to assess the effects of fire on the development of forests in PRWI.

Methods

Field Methods

There are 145 permanent NCRN forest vegetation monitoring plots at PRWI. Plots were randomly located within forested areas using a generalized random-tessellation stratified sampling procedure (Stevens and Olsen, 2004; Schmit et al., 2014) which was chosen to provide a spatially balance sample. Initial locations were chosen from the entire park, and then those locations that were not forested or which posed a safety concern were eliminated. The remaining plots were then assigned to one of four sampling panels. One panel is monitored each year, on a rotating basis, so that each plot is monitored once every four years.

Each plot consists of a 15m radius circle, with three 3m radius microplots located 10 meters out from plot center at 60°, 180° and 300°, and three 15m transects located at 360°, 120°, and 240° originating at plot center (Figure 1). In each plot, we monitor seven categories of woody vegetation. Trees are monitored within the 15m plot circle. Saplings and shrubs are monitored within the 3m microplots. Tree and shrub seedlings are monitored within twelve 2 x 0.5 m quadrats, located at 3, 8, 13 meters (3 quadrats per transect) on each of the three transects and in the center of each microplot. Vines are monitored when they are found growing on trees. Coarse woody debris is measured along the three 15m transects. A complete description of monitoring methods is provided in the protocol (Schmit et al., 2014).

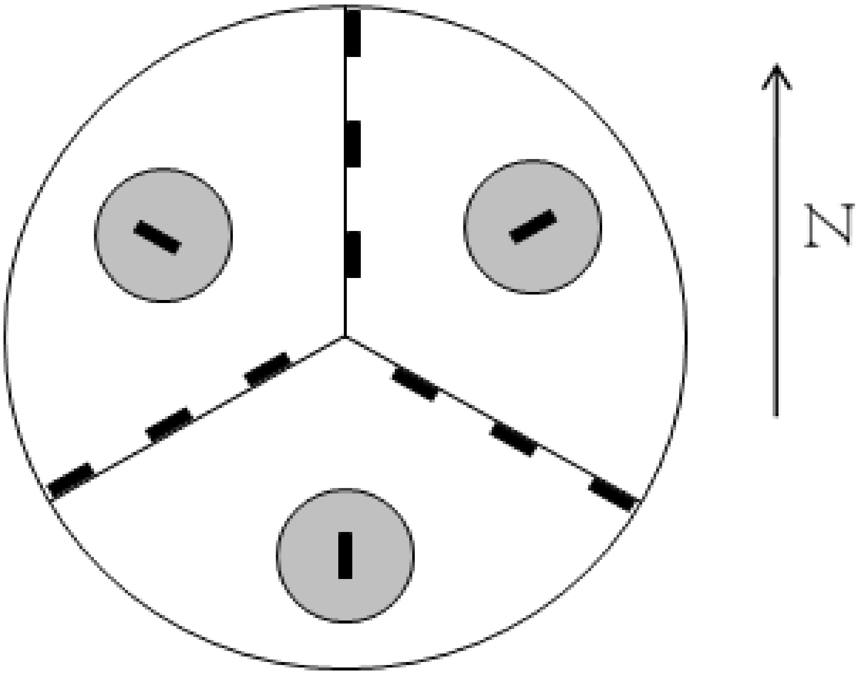

Figure 1. Layout of NCRN forest monitoring plots. Outer perimeter circle defines the 15m radius plot and grey circles represent the location of the 3m radius microplots. Black dashes are representative of each of the twelve locations for the quadrat measurements (3 along each transect and one at each microplot).

Monitoring Categories

Trees

For the purposes of monitoring, woody plants are divided into three monitoring categories: trees, saplings, and shrubs. Trees and saplings are woody plants that typically have a single stem at the base, whereas shrubs are typically multi-stemmed. Trees and saplings differ in their diameter. In practice, a tree is an individual woody plant that is not on the list of shrub species (as identified in Schmit et al., 2014), is located within the 15m radius plot, and that has a diameter or equivalent diameter of 10cm or more at DBH (diameter at breast height = 1.37m). All trees are tagged and identified. A variety of information is collected about each tree including DBH, presence of climbing vines on the trees, and evidence of pests or diseases.

Saplings

A sapling is a small tree located within the three microplots. To be counted as a sapling, a plant must have a DBH ≥ 1cm, but < 10 cm. All saplings are tagged and identified. Like trees, a variety of information is collected for each sapling.

Shrubs

Shrubs (multi-stemmed species included in the list of "shrub species" in Schmit et al., 2014) are monitored in one of two ways. Some shrub species typically grow as distinct individuals that can be easily distinguished by field crews. For these species individuals within the three microplots that have a diameter at root crown > 1cm are tagged and identified. A variety of information is collected for each shrub (similar to the methods for trees and saplings). Other shrub species typically grow in dense thickets where it can be challenging to distinguish individual plants. These species are monitored using percent cover in each of the 12 quadrats. A few species, primarily clonal shrubs (e.g., *Kalmia latifolia* and *Lindera benzoin*) were originally monitored as individuals, but their clonal growth made it difficult to determine where one individual begins and other ends. Starring in 2015, these species were monitored using percent cover. Table 12 in the Results section indicates which monitoring method was used for each species. For the purposes of this report, data from Highbush blueberry (*Vaccinium corymbosum*) and black highbush blueberry (*Vaccinium fuscatum*) was combined as these species are difficult to distinguish. Deerberry (*Vaccinium stamineum*) was often treated as *Vaccinium* spp. prior to 2013, so this species was not included in trend analysis.

Tree and Shrub Seedling

Tree and shrub seedlings are woody plants < 1 cm DBH and ≥ 15 cm tall that are counted and measured in the twelve quadrats. Each species' scientific name and height are recorded. Starting in 2012, evidence of browse on each seedling was also recorded.

Vines

Vines include both lianas (woody species) and herbaceous vines. We record which vine species climb on each tree to track their distribution and to monitor the presence of vines in the crowns of trees. This data is used to assess the effect of climbing vines on individual woody plants. Note that we do not tag or otherwise track the number, growth, recruitment, or mortality of individual vines, only the presence of vine species on each individual tree.

Coarse Woody Debris

Coarse woody debris (CWD) consists of large pieces of dead wood that are measured along three 15 meter transects in the plots. The dead wood can be from any woody plant and can be from a branch or a main stem. CWD is defined as dead wood which is lying on the ground or within 2m of the ground and has a diameter ≥7.5 cm and a length ≥1m. The diameter measurement only applies to the point where the wood crosses the transect. Dead trees that are still standing are not counted.

Ecological Group Identifiers

For this analysis, we identified four species groups (Table 3) with ecological and/or management relevance and assigned tree species to these groups based on species' association with dominant forested ecological systems in the park (National Capital Region 2018). Canopy tree species frequently found in upland successional forest types at PRWI were assigned to the "early successional" group. The most common "mature" forest types in the park can be divided two groups: dry or dry-mesic oak-hickory associations and mixed mesic hardwood types; in this report, species commonly found in the oak-hickory types were assigned to an "oak-hickory" group, whereas species commonly found in the mesic mixed hardwood types were assigned to the "mesic" group. We then assigned short-stature species to their own group, "Non-Canopy," regardless of their association with a particular upland vegetation type; our intent in putting these species in their own group is to illustrate the potential for changes to forest structure (i.e., canopy height) driven by species-level changes over time. Tree species that were not common in the park and which were not associated with one of the common forest types, were not assigned to a group and are listed referred to as "Additional Species." Our choice of grouping species in this manner allows us to directly address questions of management relevance (e.g., are species related to one successional pathway [aka climax forest] becoming more common in the park?).

Fire Status

We used fire history data provided by the park to determine the last time each plot was burned. During the study period, the park has not conducted any managed burns. However, prior to and since the start of monitoring, one large unplanned fire is known to have ignited in the park (Figure 2).

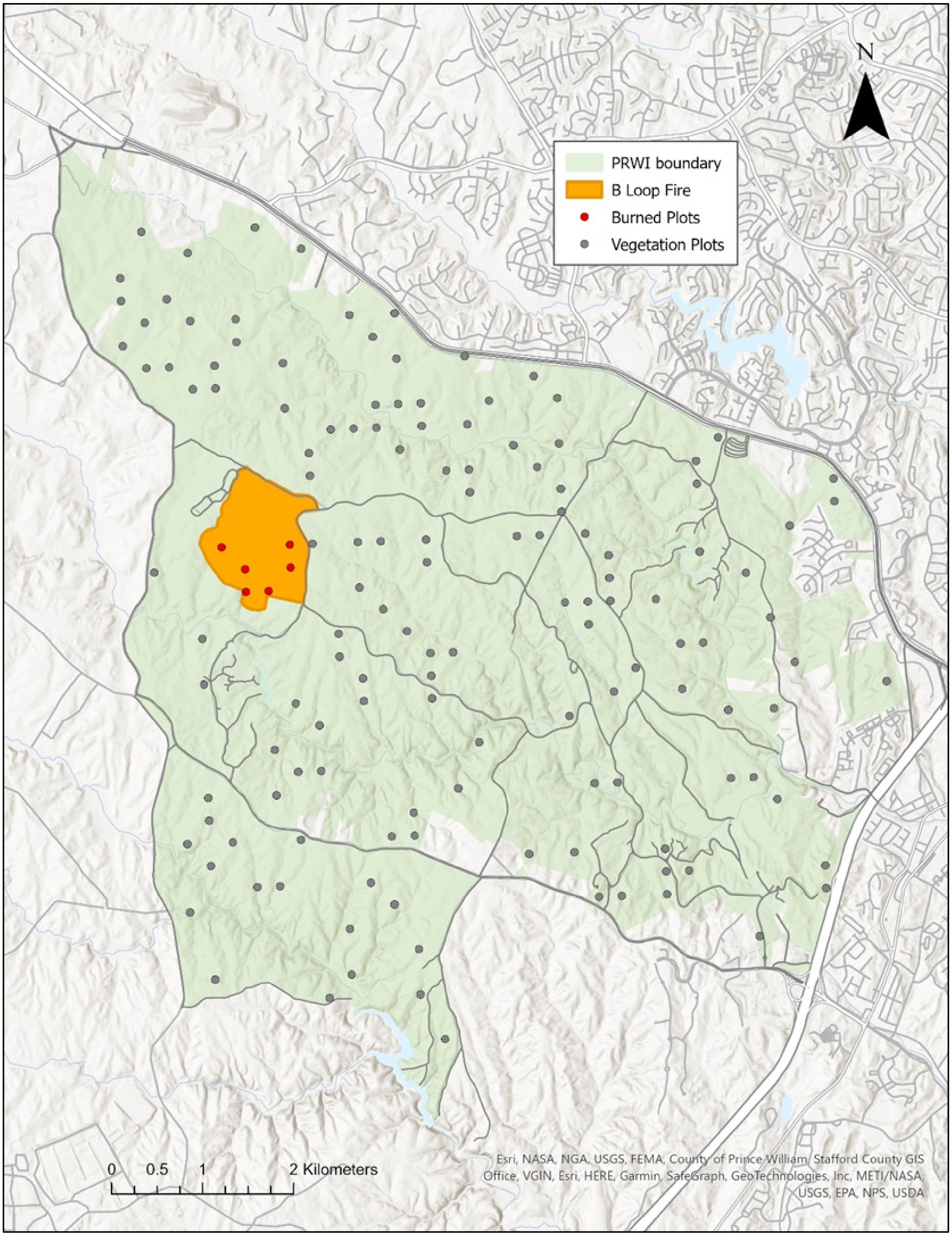

Figure 2. Fires at Prince William Forest Park. Red dots represent plots that fell within the B-Loop Fire (orange polygons). Other plots (grey circles) were treated as unburned in the analysis.

Six monitoring plots are located in the area affected by the B-Loop fire which burned from March 27th to April 4th, 2006. This fire was noted for being exceptionally hot and active, and spread into the canopy which is unusual for the park. By the summertime, park staff had noticed that the forest floor was already becoming revegetated (Prince William Forest Park 2006). These plots were from different panels and were established and monitored throughout the first sampling cycle (2006–2009). They were all treated as "burned" plots in all analysis, but fire intensity and vegetation impacts varied between plot (Figure 3). Several much smaller fires are known to have occurred in the park prior to the B-Loop fire. A preliminary analysis of the data indicated these fires had no discernable effect on the trends in woody vegetation discussed in this report. For the purpose of analysis all plots not impacted by the B-Loop fire were considered to be unburned.

Figure 3. Varying effects of the B-Loop fire on vegetation, likely a result of different fire intensity experienced within the burn area. Left: PRWI-0205 in 2009. Right: PRWI-0276 2006.

Trends Analysis

We carried out trends analysis on data collected from 2006 through 2017. During this period, every plot was sampled three times.

Separate analyses were carried out on each of seven monitoring categories forms: trees, saplings, tree seedlings, shrubs, shrub seedlings, vines, and coarse woody debris (Table 1). Within each monitoring category, analyses were carried out on all data from all species combined and each species individually. However, ecological groups and individual species were only analyzed if their abundance was greater than 0.1 individuals per plot, averaged across all plots and years. In some cases, common species were too rare to analyze in burned plots. For that reason, we only reported results from burned plots when a species was encountered in the burned plots 15 times across all and years. Additionally, for the tree, sapling, and tree seedling monitoring categories, analyses were carried out on species aggregated to ecological group.

Table 1. Metrics analyzed for each monitoring category and analysis level. The term "All" includes data for all species combined; the term "Ecological Group" indicates data from all species in an ecological group combined; and the term "Species" represents individual taxa.

Monitoring Category	Analysis Level	Response Metrics
Trees	All, Ecological Groups, Species	Abundance, Basal Area
Saplings	All, Ecological Groups, Species	Abundance, Basal Area
Tree Seedlings	All, Ecological Groups, Species	Abundance, Browse
Shrubs	Species	Abundance or Cover
Shrub Seedlings	All, Species	Abundance, Browse
Vines	All, Species	Abundance
Coarse Woody Debris	All	Volume

To analyze this data, we used generalized linear mixed models in a Bayesian framework (referred to as "statistical modeling" hereafter). Our response variables included the abundance of every growth form except for some shrubs and coarse woody debris (CWD). We also analyzed the basal area of trees and saplings, browse rates of saplings, the percent cover of some shrubs, and the volume of CWD. Every response variable except percent cover was regressed against fire status (an indicator of which plots were burned during the B-Loop fire), centered sample year (sample year – mean sample year), and the interaction between fire status and centered sample year (see Equation 1). Plot ID was used as a random intercept.

$$\text{Response} = \text{Fire} + \text{Year} + \text{Fire}*\text{Year} + 1|\text{Plot} \quad [1]$$

Percent cover was modeled by using only the Fire term, but both the percent of plots occupied by each species, as well as the percent cover on occupied plots were response variables. Browse was modeled by using browse status of each seedling (Yes=1, No=0) as the response variable. As vines are only measured when they are present on trees, and the number of trees varies between plots, models of vine abundance included number of trees as an offset term.

Question 1, trends over time, was assessed using the coefficient of the Year term. Question 2, the immediate effect of fire, was assessed using the coefficient for the Fire term, and Question 3, trends in burned plots, was assessed using the sum of the coefficients for the Fire and Fire*Year terms. We used the posterior probability to determine the significance of the results. If the posterior probability of a term(s) was 85% above or 85% below zero, then we report the result as **somewhat certain,** and if it was over 95% above or below zero, then we report the result as **highly certain**.

Analyses were conducted in R version 4.0.3 (R Core Team, 2020) using the brms package version 2.14 (Bürkner 2017, 2018). We used four MCMC chains of 25,000 steps each, half of which were warmup steps, adapt_delta was set to 0.99 and we had a maximum tree depth of 20. Default uninformative priors were used for all models. We verified for all models that the point scale reduction factor (R-hat, Gelman and Rubin 1992) was less than 1.10, in almost every case they equaled 1.0.

For many of our response variables we had a choice of error structures. For all measures of abundance, we modeled the data using both a Poisson and a negative binomial error structure. The final model was then selected using Pareto smoothed importance sampling leave-one-out cross validation (PSIS-LOO) from the loo package version 2.4.1 (Vehtari et al., 2017). When possible, moment matching was used in the cross validation.

For basal area and CWD volume, we used hurdle-gamma models to accommodate data that was continuous and always positive or zero. For models of all trees, tree groups, and species where presence changed (gain or loss) in ≤4 plots over the course of the study, we assumed that the percent of plots occupied was constant (e.g., hu~1). For species whose occupancy changed ≥ 5 plots, we fit models both with constant occupancy and with occupancy changing as a function of centered sample year. Final models were then selected using PSIS-LOO.

Percent cover was modeled using a zero-inflated model with a beta error structure. Because we changed which species were monitored using percent cover over time, analysis was limited to determining if there were differences between occupancy and percent cover of burned vs unburned plots in the 2014–2017 monitoring cycle.

Browse was modeled as a logistic regression, using a Bernoulli error structure with a logit link. Because browse data was not collected prior to 2012, trend analysis was not possible. Instead, the model simply estimated the browse rates in the 2014–2017 sampling cycle and compared rates between burned and unburned plots.

Results

PRWI is currently home to over 2 million trees, almost 6 million saplings and over 26 million tree seedlings (Table 2). We estimate that there are over 700,000 of the eight species of shrubs that we collect density data on, and 16 million shrub seedlings of all shrub species.

Table 2. Density and basal area from the most recent monitoring cycle (2014–2017).

Monitoring Category	# Monitored	Species Found	Density (plants/ha)	Basal Area (m^2/ha)	Estimated Total Population
Trees	5730	38	460	28.7	2,260,000
Snags	614	22	60	3.2	293,000
Saplings	1458	25	1200	2.2	5,810,000
Tree seedlings	935	25	5400	—	26,300,000
Shrubs	190	8	150	—	735,000
Shrub seedlings	569	16	3700	—	16,000,000
Vines on trees	507	11	49	—	242,000
CWD	1049	19	—	—	—

Trees

Current Status

Overall, thirty-six species and two hybrids were detected during tree monitoring in the 2014–2017 sampling cycle (Table 3). The major tree species in the park include red maple*,* American beech, tulip poplar, black gum, Virginia pine and white oak (*Quercus alba*). Nine species were represented by only a single individual.

Four ecological groups, including early successional, mesic, non-canopy, and oak-hickory, were extremely common and represented the vast majority of trees, measured by both abundance and basal area. Trees of mesic species were the most abundant, followed by early successional and oak-hickory species. Oak hickory and early successional species had the highest biomass, as measured by basal area, followed by mesic species. Species that are not members of these groups had a low density and low basal area and were found in only a few plots.

Table 3. Trees in the 2014–2017 monitoring cycle. Density indicates the number of living trees/ha, and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual.

Ecological Group	Species	Common name	Density (trees/ha)	Basal Area (m^2/ha)	Frequency (% of Plots)
Early Successional	*Juniperus virginiana*	Eastern red cedar	1.3	0.04	6
Early Successional	*Liquidambar styraciflua*	Sweetgum	5.2	0.19	10

Table 3 (continued). Trees in the 2014–2017 monitoring cycle. Density indicates the number of living trees/ha, and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual.

Ecological Group	Species	Common name	Density (trees/ha)	Basal Area (m^2/ha)	Frequency (% of Plots)
Early Successional	*Liriodendron tulipifera*	Tulip poplar	68.6	6.42	85
Early Successional	*Pinus virginiana*	Virginia pine	62.2	4.83	53
Early Successional	*Populus grandidentata*	Bigtooth aspen	0.6	0.08	2
Early Successional Total	**—**	**—**	**137.8**	**11.56**	**92**
Mesic	*Acer rubrum*	Red maple	52.1	1.53	84
Mesic	*Diospyros virginiana**	Common persimmon	0.1	<0.01	<1
Mesic	*Fagus grandifolia*	American beech	90.1	2.68	82
Mesic	*Fraxinus americana*	White ash	1.6	0.03	8
Mesic	*Ilex opaca*	American holly	14.0	0.20	38
Mesic	*Nyssa sylvatica*	Black gum	38.1	0.83	77
Mesic	*Prunus serotina*	Black cherry	0.8	0.03	3
Mesic	*Ulmus americana**	American elm	0.1	<0.01	<1
Mesic Total	**—**	**—**	**196.7**	**4.71**	**100**
Non-Canopy	*Acer negundo**	Box elder	0.1	<0.01	<1
Non-Canopy	*Amelanchier arborea**	Common serviceberry	0.1	<0.01	<1
Non-Canopy	*Carpinus caroliniana*	American hornbeam	2.5	0.03	10
Non-Canopy	*Cornus florida*	Flowering dogwood	4.9	0.06	20
Non-Canopy	*Prunus americana**	American plum	0.1	<0.01	<1
Non-Canopy	*Sassafras albidum*	Sassafras	2.1	0.03	12
Non-Canopy Total	**—**	**—**	**9.9**	**0.12**	**35**
Oak Hickory	*Carya alba*	Mockernut hickory	8.2	0.31	31
Oak Hickory	*Carya glabra*	Pignut hickory	11.7	0.69	39
Oak Hickory	*Carya ovalis*	Red hickory	2.0	0.19	10
Oak Hickory	*Quercus alba*	White oak	51.3	5.04	78
Oak Hickory	*Quercus coccinea*	Scarlet oak	15.2	2.21	38
Oak Hickory	*Quercus falcata*	Southern red oak	7.5	0.82	26
Oak Hickory	*Quercus prinus*	Chestnut oak	6.8	0.93	10
Oak Hickory	*Quercus rubra*	Northern red oak	6.1	0.78	24
Oak Hickory	*Quercus stellata*	Post oak	0.7	0.07	3
Oak Hickory	*Quercus velutina*	Black oak	5.8	0.54	25

Table 3 (continued). Trees in the 2014–2017 monitoring cycle. Density indicates the number of living trees/ha, and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual.

Ecological Group	Species	Common name	Density (trees/ha)	Basal Area (m^2/ha)	Frequency (% of Plots)
Oak Hickory	*Quercus X benderi**	Bender oak	0.1	0.02	<1
Oak Hickory	*Quercus X willdenowiana**	Willdenow's oak	0.1	0.03	<1
Oak Hickory Total	**—**	**—**	**115.6**	**11.63**	**95**
Additional Species	*Ailanthus altissima*	Tree of heaven	0.2	<0.01	<1
Additional Species	*Pinus echinata*	Shortleaf pine	0.4	0.03	3
Additional Species	*Pinus rigida*	Pitch pine	0.3	0.03	2
Additional Species	*Platanus occidentalis*	American sycamore	0.2	0.01	1
Additional Species	*Pyrus communis**	Common pear	0.1	<0.01	<1
Additional Species	*Quercus pagoda**	Cherrybark oak	0.1	0.01	<1
Additional Species	*Quercus phellos*	Willow oak	0.3	0.02	1

Trend Analysis – Unburned Plot

Twenty-one species and all four ecological groups had sufficient data for analysis. For trend results for individual species, see Appendix A, for model coefficient tables for all analyses, see Appendix B. Here we present modeled estimates for status in 2006, when monitoring began, and trends over time.

In 2006, mesic species had the highest density in the park (Figure 4), followed closely by early successional species and then oak-hickory species. Non-canopy species were much less common (Table 4). In unburned plots there was no trend in overall tree density. However, this seemingly static situation is the result of contrasting trends in the ecological groups. The densities of early successional and oak-hickory species are declining by 2% and 1% per year respectively, but this is balanced by a 2% per year increase in mesic species.

Figure 4. A typical mesic forest in PRWI. Note the dominance of American beech and the lack of vegetation on the forest floor.

Table 4. Trends in tree density and basal area by ecological group, in unburned plots, from 2006 to 2017. Trees/ha 2006 and Basal Area (m^2/ha) 2006 are modeled estimates for 2006. Percent change per year is the estimated annual increase (green shading with a plus sign ["+"]) or decrease (orange shading with a negative sign ["−"]). Darker shading and ** indicates a highly certain trend, lighter shading and single * indicates a somewhat certain trend. An em-dash ("—") with no shading indicates that there is no evidence of a trend.

Ecological Group	**Density (trees/ha) 2006**	**Density: % Change/yr**	**Basal Area (m^2/ha) 2006**	**Basal Area: % Change/yr**
All Trees	460	—	26.0	+1%**
Early Successional	160	−2%**	7.9	—
Mesic	170	+2%**	3.1	+4%**
Non-Canopy	8.4	—	0.07	+2%*
Oak Hickory	120	−1%*	7.2	+1%**

We were also able to detect trends for some individual tree species (Figure 5). Amongst the early successional species, only sweetgum (*Liquidambar styraciflua*) had a somewhat certain increase in density, but sweetgum and tulip poplar both had highly certain increases in basal area. Virginia pine, on the other hand, had highly certain declines in density and basal area, whereas eastern red cedar (*Juniperus virginiana*) had a somewhat certain decline in density.

Tree basal area tells a somewhat different story. In 2006, early successional species had the highest basal area, followed by oak-hickory species. Mesic species had less than half the basal area of the early successional species. Overall basal area is increasing by 1% per year, indicating a maturing forest. The greatest increase, 4% per year, is seen in mesic species, with more modest increases seen in non-canopy species (2%) and oak hickory species (1%).

Apart from white ash (*Fraxinus americana*), all mesic species showed somewhat or highly certain increases in both basal area and abundance. The lack of trends in white ash may be due to infestation with emerald ash borer, which has caused some mortality in the monitoring plots.

Non-canopy species were similar to mesic species, in that they showed somewhat or highly certain increases in density and basal area. The only species to show decreases was flowering dogwood (*Cornus florida*), which is subject to infection by dogwood anthracnose in the park.

Individual oak-hickory species showed few trends in density, except for scarlet oak (*Quercus coccinea*), which showed a somewhat certain decline. All oak-hickory species had a highly certain or somewhat certain increases in basal area.

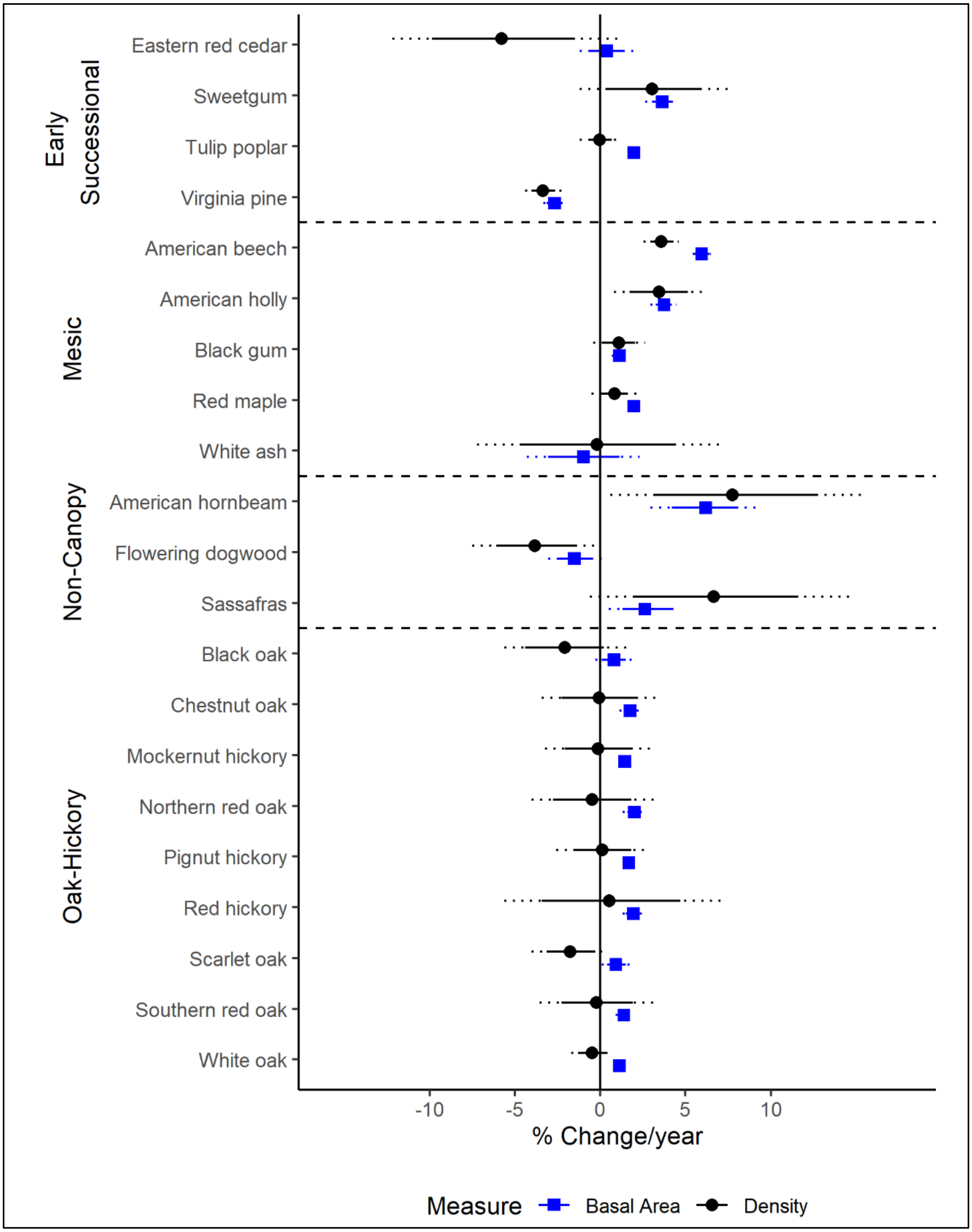

Figure 5. Trends for tree species in unburned plots, 2006 to 2017. Black dots = tree density, blue squares = basal area. Change per year is highly certain to be within the range indicated by dotted lines and somewhat certain to be within the range indicated by solid lines. If zero (vertical line) is outside of the dotted line there is a highly certain trend, outside the solid line there is a somewhat certain trend, and intersecting the solid line there is no evidence of a trend.

Trend Analysis – Burned Plots

The plots that were affected by the B-Loop fire were starkly different from those that were not (Table 5). Overall tree density and that of mesic and oak-hickory species was lower in 2006 compared to unburned plots. The only trend seen in tree density was a 4% yearly increase in mesic tree species, but this increase is not enough to reach densities seen in unburned plots (Figure 6).

Table 5. Trends in tree density and basal area by ecological group in burned plots, from 2006 to 2017. Trees/ha 2006 and Basal Area (m^2/ha) 2006 are the modeled estimates for 2006. Percent change per year is the estimated percent annual increase (green shading with a plus sign ["+"] and single *) or decrease (orange shading with a negative sign ["−"] and single *). For 2006 estimates, darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and single * indicates a somewhat certain difference; "dec" indicates a decrease while "inc" indicates an increase compared to unburned plots. For the percent change columns darker shading and ** indicates a highly certain trend, lighter shading and single * and indicates a somewhat certain trend. An em-dash ("—") and no shading indicates that there is no evidence of a trend.

Ecological Group	**Density (trees/ha) 2006**	**Density: % Change/yr**	**Basal Area (m^2/ha) 2006**	**Basal Area: % Change/yr**
All Trees	310**(dec)	—	19**(dec)	−1%**
Early Successional	170	—	8.5	—
Mesic	77**(dec)	+4%*	1.3**(dec)	+3%**
Non-Canopy	5.9	—	0.06	+5%*
Oak Hickory	57**(dec)	—	3.6**(dec)	−2%**

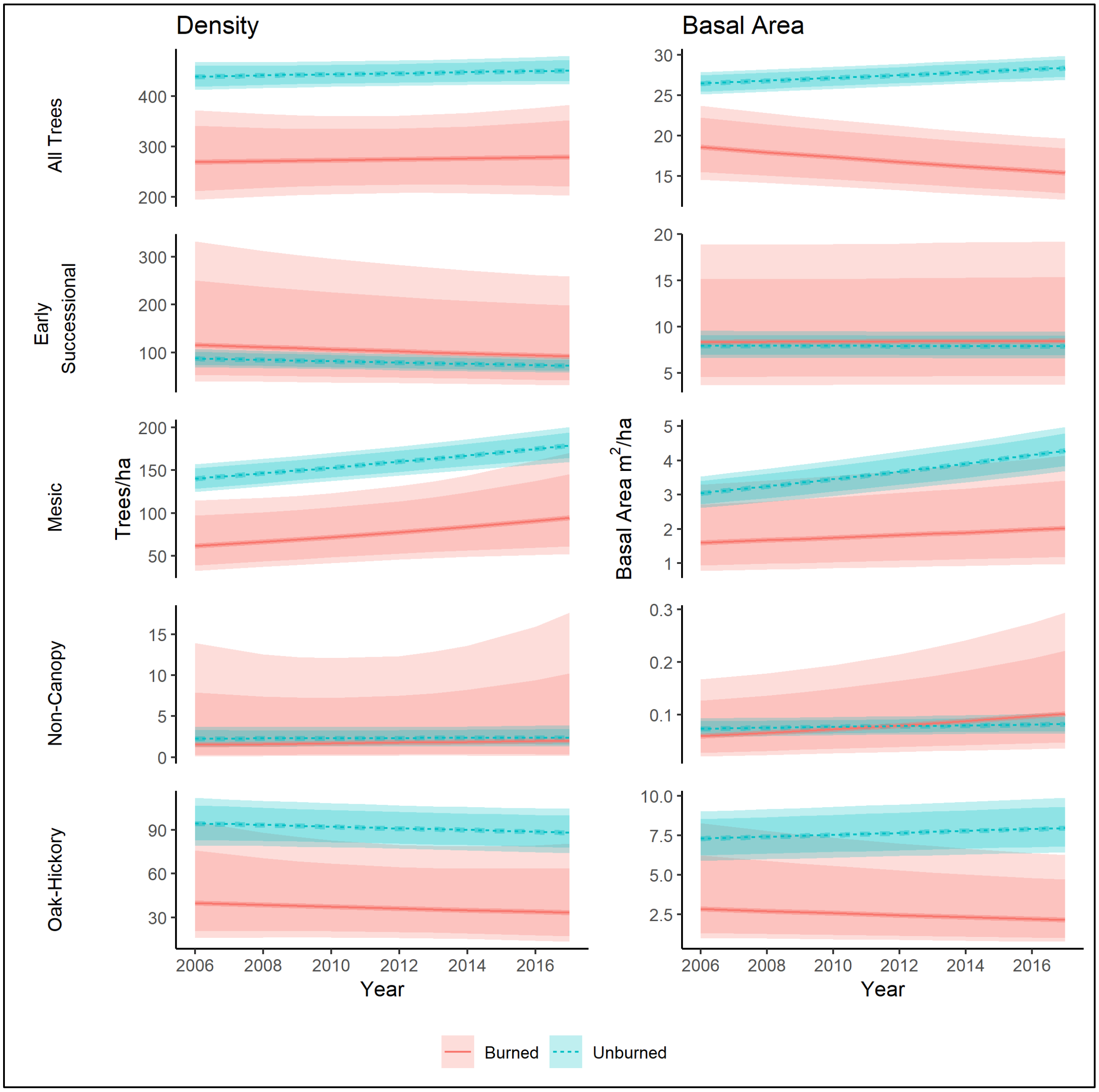

Figure 6. Trends in tree density and basal area by ecological group from 2006 to 2017. Graphs show main effects from the modeling. Density in trees / ha in the left column, basal area in m^2 / ha in the right. Blue dashed lines and shading indicate modeled trends in unburned plots, red solid lines and shading indicate modeled trends in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

Burned plots also showed a significant reduction in tree basal area, as well as reductions in basal area of oak-hickory and mesic species. Whereas basal area was generally increasing in unburned plots, it declined at 1% per year in burned plots (Figure 6). This trend was driven by a 2% per year decline in oak-hickory species, which have a relatively large basal area compared to mesic and non-canopy species. Non-canopy and mesic species, however, responded positively to fire, gaining 5% and 3% basal area per year, respectively.

Trends analysis for species observed in burned plots is presented in Figure 7. There were few trends in tree density. American beech had a somewhat certain increase in density while scarlet oak and Virginia pine had a somewhat certain decrease. There were highly certain increases in basal area for all three mesic species, as well as tulip poplar, and highly certain decreases in basal area for Virginia pine and white oak.

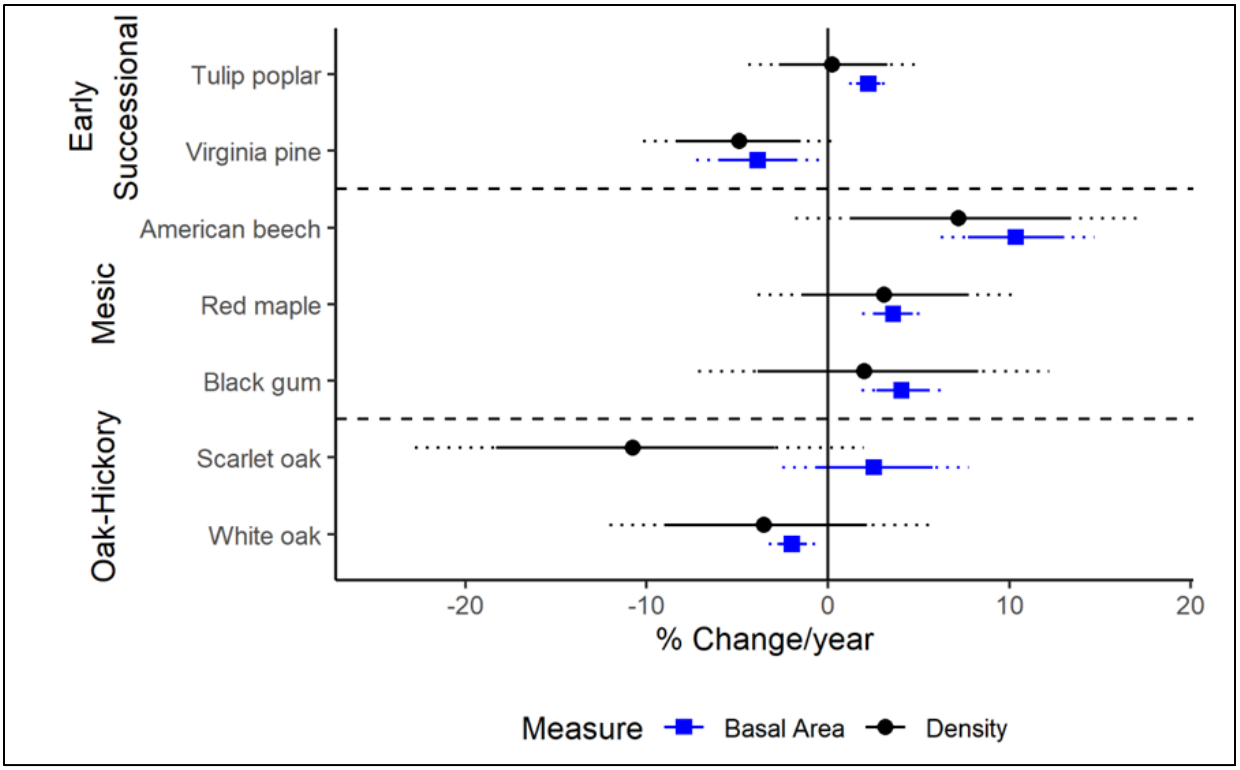

Figure 7. Trends for tree species in burned plots 2006 to 2017. Black dots = tree density, blue squares = basal area. Change per year is highly certain to be within the range indicated by dotted lines and somewhat certain to be within the range indicated by solid lines. If zero (vertical line) is outside of the dotted line there is a highly certain trend, outside the solid line there is a somewhat certain trend, and intersecting the solid line there is no evidence of a trend.

Saplings

Current Status

Overall, twenty-five species were detected during sapling monitoring in the 2014–2017 sampling cycle (Table 6). Three non-canopy species—devil's walkingstick (*Aralia spinosa*), pawpaw (*Asimina triloba*) and red mulberry (*Morus rubra*), were found as saplings but not as trees. Sixteen species or hybrids were found as trees but not as saplings. Five species were represented by only a single individual. The major sapling species included red maple, American beech, American holly (*Ilex opaca*), black gum and white oak. Notably, the early successional species tulip poplar and Virginia pine are nearly absent in the sapling layer despite being some of the most important species in the tree layer.

Table 6. Saplings in the 2014–2017 monitoring cycle. Density indicates the estimated number of living saplings/ha, and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual.

Ecological Group	**Species**	**Common name**	**Density (trees/ha)**	**Basal Area (m^2/ha)**	**Frequency (% of Plots)**
Early Successional	*Juniperus virginiana*	Eastern red cedar	3.3	0.010	3
Early Successional	*Liquidambar styraciflua*	Sweetgum	20.0	0.025	7
Early Successional	*Liriodendron tulipifera*	Tulip poplar	4.9	0.024	3
Early Successional	*Pinus virginiana*	Virginia pine	6.5	0.007	<1
Early Successional Total	—	—	**34.1**	**0.066**	**12**
Mesic	*Acer rubrum*	Red maple	65.0	0.21	34
Mesic	*Fagus grandifolia*	American beech	420.0	0.752	79
Mesic	*Fraxinus americana**	White ash	0.8	0.001	<1
Mesic	*Ilex opaca*	American holly	160.0	0.312	46
Mesic	*Nyssa sylvatica*	Black gum	170.0	0.460	57
Mesic	*Ulmus americana**	American elm	0.8	<0.001	<1
Mesic Total	—	—	**820.0**	**1.736**	**98**
Non-Canopy	*Aralia spinosa*	Devil’s walkingstick	3.3	0.001	1
Non-Canopy	*Asimina triloba*	Pawpaw	11.0	0.003	3
Non-Canopy	*Carpinus caroliniana*	American hornbeam	27.0	0.040	7
Non-Canopy	*Cornus florida*	Flowering dogwood	36.0	0.102	26
Non-Canopy	*Morus rubra**	Red mulberry	0.8	0.001	<1
Non-Canopy	*Sassafras albidum*	Sassafras	11.0	0.043	7
Non-Canopy Total	—	—	**87.0**	**0.190**	**40**
Oak Hickory	*Carya alba*	Mockernut hickory	5.7	0.013	4
Oak Hickory	*Carya glabra*	Pignut hickory	18.0	0.038	10
Oak Hickory	*Carya ovalis**	Red hickory	0.8	<0.001	<1
Oak Hickory	*Quercus alba*	White oak	170.0	0.123	18
Oak Hickory	*Quercus coccinea*	Scarlet oak	20.0	0.012	3
Oak Hickory	*Quercus falcata*	Southern red oak	19.0	0.022	8
Oak Hickory	*Quercus prinus**	Chestnut oak	0.8	0.001	<1
Oak Hickory	*Quercus rubra*	Northern red oak	1.6	0.005	1
Oak Hickory	*Quercus velutina*	Black oak	11.0	0.024	6
Oak Hickory Total	—	—	**250**	**0.239**	**27**

Two ecological groups, mesic and oak-hickory, were extremely common and made up the vast majority of saplings, measured by both abundance and basal area. Saplings of mesic species were the most abundant with nearly 70% of all individuals belonging to this group. Oak-hickory species were the second most abundant group with approximately 20% of all individuals. No saplings were found that were not part of these four ecological groups.

Trend analysis – Unburned Plots

Trend analysis was carried out on the four ecological groups, 13 individual species, and all saplings combined. For trend results for individual species, see Appendix A, for model coefficient tables for all analyses, see Appendix B. Here we present modeled estimates for status in 2006, when monitoring began, and trends over time.

At the start of the study in 2006 there were 1300 saplings/ha in unburned plots (Table 7). Mesic species had the highest density while early successional species had a very low density. This is consistent with the age of the forest, as the closed canopy and low rates of disturbance have likely provided few opportunities for individuals of early successional species to become established in recent years.

Table 7. Trends in sapling density and basal area by ecological group in unburned plots from 2006 to 2017. Saplings/ha 2006 and Basal Area (m^2/ha) 2006 are the modeled estimates for 2006. Percent change per year is the estimated percent increase (green shading with a plus sign ["+"] and single *) or decrease (orange shading with a negative sign ["−"] and single *). Darker shading and ** indicates a highly certain trend, lighter shading and single * indicates a somewhat certain trend. An em-dash ("—") and no shading indicates that there is no evidence of a trend.

Ecological Group	Density (saplings/ha) 2006	Density: % Change/yr	Basal Area (m^2/ha) 2006	Basal Area: % Change/yr
All Saplings	1300	−1%**	2.2	−0.5%*
Early Successional	34	−4%*	<0.1	—
Mesic	886	−1%*	1.6	+1%**
Non-Canopy	120	−5%**	0.2	−3%**
Oak Hickory	190	−2%**	0.1	—

In unburned plots there was a highly certain negative trend in density of all saplings of 1% per year. All four ecological groups showed somewhat or highly certain decreases in density of between 1 and 5% per year.

In 2006, mesic species accounted for almost all sapling basal area. Since then, mesic species have shown a highly certain increase of 1% per year, but non-canopy species have shown a highly certain decrease of 3% per year. These opposing trends lead to a somewhat certain decline in basal area of 0.5% per year of all species combined. Sapling basal area was much lower than that of trees in unburned plots in 2006. The sole exception was the basal area of non-canopy saplings which was higher than that of non-canopy trees. These species tend to be relatively small and are less likely to reach the tree size class compared to other groups.

Trends were detected for several sapling species (Figure 8). The only early successional sapling with sufficient data to analyze was sweetgum, which showed a somewhat certain increase in basal area.

Amongst mesic species, the only trends in density were highly certain declines of red maple and black gum density. Both American beech and American holly had highly certain increases in basal area, whereas black gum had a somewhat certain decrease.

Amongst non-canopy species, all species showed highly or somewhat certain declines in density. Flowering dogwood also showed a highly certain decline in basal area, whereas American hornbeam (*Carpinus caroliniana*) had a highly certain increase.

The only trends in density of oak hickory species were somewhat certain declines in scarlet oak and southern read oak, but all species except for scarlet oak had highly or somewhat significant trends of increasing basal area.

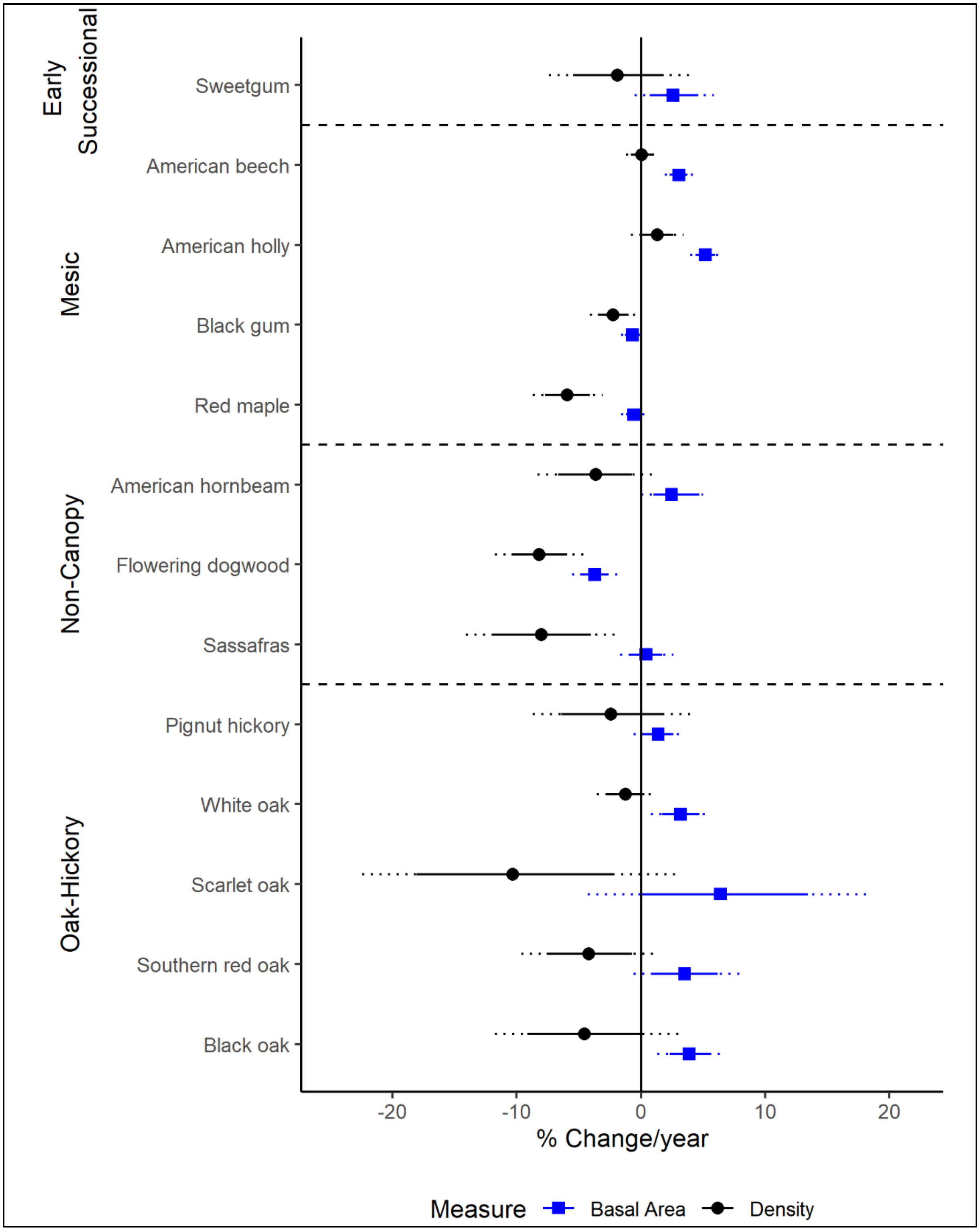

Figure 8. Trends for sapling species in unburned plots. Black dots = tree density, blue squares = basal area. Change per year is highly certain to be within the range indicated by dotted lines and somewhat certain to be within the range indicated by solid lines. If zero (vertical line) is outside of the dotted line there is a highly certain trend, outside the solid line there is a somewhat certain trend, and intersecting the solid line there is no evidence of a trend.

Trend Analysis – Burned Plots

In burned plots, overall sapling density was lower than that of unburned plots in 2006, as was density of early successional and mesic species (Table 8). Oak-hickory species, however, had dramatically increased sapling density in 2006. Overall sapling density increased at 15% per year after 2006 (Figure 9). All ecological groups except mesic species saw increases, but the early successional species had the most dramatic increase at 80% per year. The magnitude of the increase in early successional species is due to the fact that they were absent in the burned plots in 2006.

Table 8. Trends in sapling density and basal area by ecological group in burned plots, from 2006 to 2017. Saplings/ha 2006 and Basal Area (m^2/ha) 2006 are the modeled estimates for 2006. Percent change per year is the estimated percent increase (green shading with a plus sign ["+"]) or decrease (orange shading with a negative sign ["−"]). For 2006 estimates, darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and single * indicates somewhat certain difference; "dec" indicates a decrease while "inc" indicates an increase compared to unburned plots.. For the percent change columns darker shading and ** indicates a highly certain trend, lighter shading and single * indicates a somewhat certain trend. An em-dash ("—") and no shading indicates that there is no evidence of a trend.

Ecological Group	Density (saplings/ha) 2006	Density: % Change/yr	Basal Area (m^2/ha) 2006	Basal Area: % Change/yr
All Trees	960**(dec)	+15%**	1.3**(dec)	+10%**
Early Successional	1.4**(dec)	+80%**	<0.1**(dec)	+150%**
Mesic	280**(dec)	—	0.8**(dec)	+4%*
Non-Canopy	87	+12%**	0.1**(dec)	+5%*
Oak Hickory	540**(inc)	+20%**	0.1*(dec)	+20%**

By 2017, in terms of abundance, burned plots had a dramatically different sapling community compared to unburned plots (Figure 10). While the unburned plots are dominated by mesic species, the burned plots are dominated by oak-hickory species and have rapidly increasing numbers of early successional and non-canopy species. Trends in burned plots have wider credible intervals compared to unburned plots. This is due to both the smaller sample size of burned plots and greater variability between burned plots, possibly due to variation in fire intensity.

Figure 9. Burned Plot (PRWI-0276) within B Loop Fire. Top left image is the plot in 2006, top right 2010, bottom left 2014 and bottom right 2018.

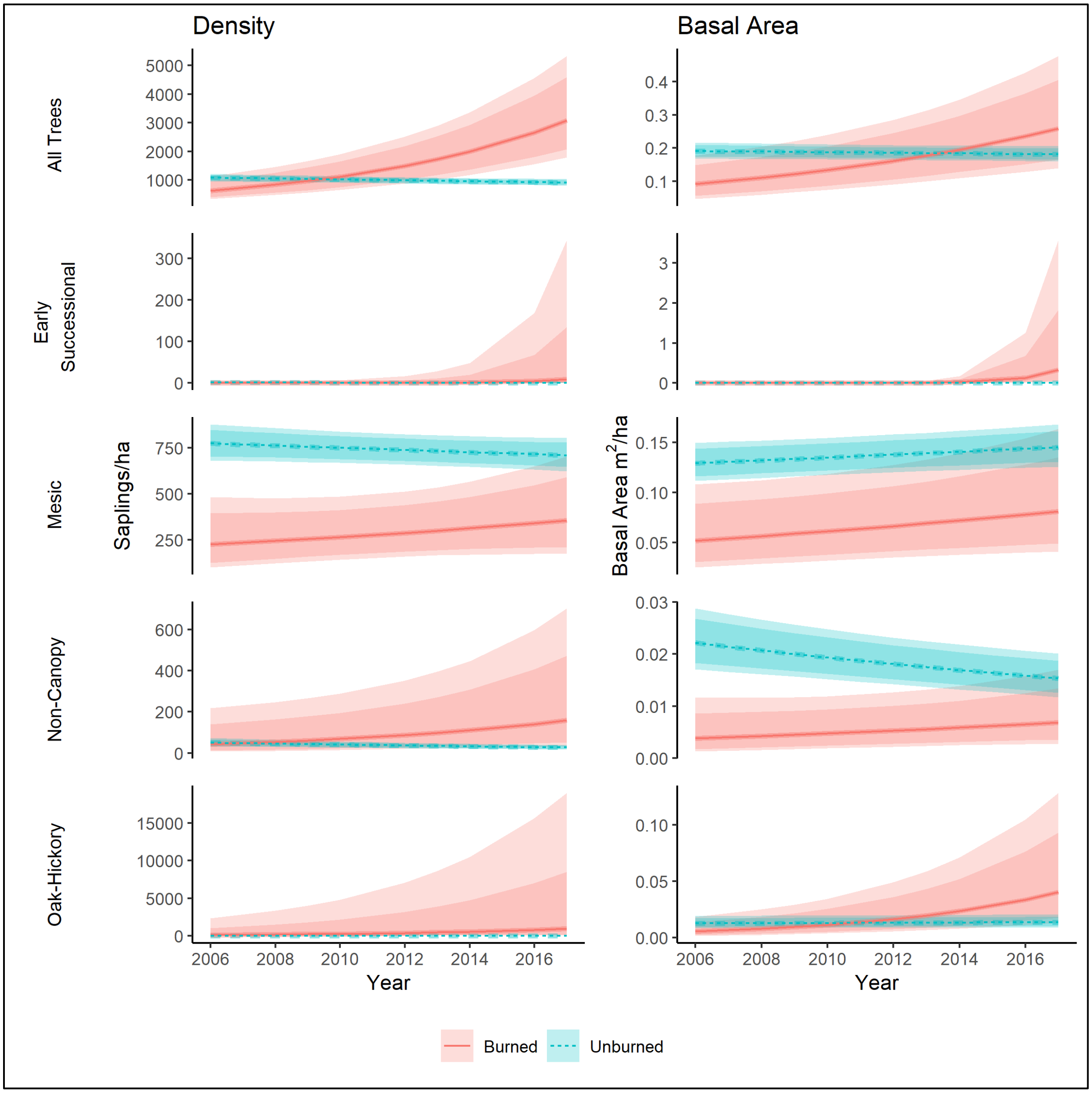

Figure 10. Trends in sapling density by ecological group 2006 to 2017. Graphs show main effects from the modeling. Density in saplings/ha in the left column, basal area in m^2/ha in the right. Blue dashed lines and shading indicate modeled trends in unburned plots, red solid lines and shading indicate modeled trends in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

In 2006, basal area of saplings of all groups on burned plots was lower than that of unburned plots. All groups showed somewhat or highly certain increasing trends in basal area. As with sapling density, the largest trend was the increase seen in early successional species which were absent from the plots at the start of monitoring. By 2017, overall basal area, as well as basal area of early successional and oak-hickory species had surpassed that seen on unburned plots (Figure 10). For all ecological groups, sapling basal area increased more quickly on burned plots.

In burned plots, five species had enough data to allow us to do trends analysis (Figure 11). Neither mesic species exhibited a trend in density, but red maple did show a highly certain increase in basal area. The only non-canopy species we could analyze, Flowering dogwood, showed no trends, but this was a marked improvement from the sharp declines seen in unburned plots. The two oak-hickory species, on the other hand, responded favorably to fire, with highly certain increases in density and basal area.

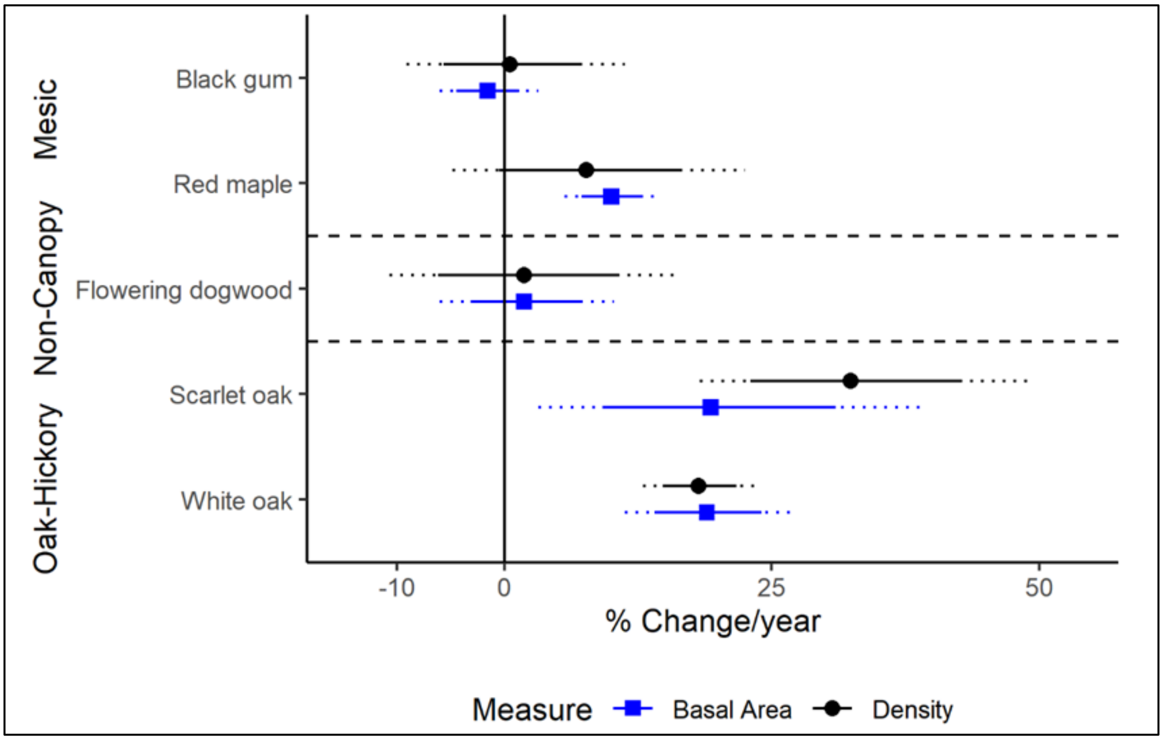

Figure 11. Trends in sapling species in burned plots. Black dots = tree density, blue squares = basal area. Change per year is highly certain to be within the range indicated by dotted lines and somewhat certain to be within the range indicated by solid lines. If zero (vertical line) is outside of the dotted line there is a highly certain trend, outside the solid line there is a somewhat certain trend, and intersecting the solid line there is no evidence of a trend.

Tree Seedlings

Current Status

Overall, twenty-five species were detected during seedling monitoring in the 2014–2017 sampling cycle (Table 9). Sixteen species or hybrids were found as trees or saplings, but not as seedlings. Seven species were represented by only a single individual, including some species that are common as trees such as tulip poplar and northern red oak (*Quercus rubra*). The most abundant seedling species included pawpaw, American hornbeam, American beech, American holly, white oak, and scarlet oak.

As with saplings, early successional species are uncommon in the seedling ecological group. Seedlings from the oak-hickory group were the most abundant, followed by the mesic and non-canopy groups. No seedlings were found from species that are not part of these groups.

Table 9. Seedlings in the 2014–2017 monitoring cycle. Density indicates the estimated number of seedlings/ha and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with an asterisk were represented by a single individual.

Ecological Group	Species	Common name	Density (seedlings/ha)	Frequency (% of Plots)
Early Successional	*Juniperus virginiana**	Eastern red cedar	5.7	1
Early Successional	*Liquidambar styraciflua*	Sweetgum	69.0	2
Early Successional	*Liriodendron tulipifera**	Tulip poplar	5.7	1
Early Successional	*Pinus virginiana*	Virginia pine	120.0	9
Early Successional Total	**—**	**—**	**200.0**	**11**
Mesic	*Acer rubrum*	Red maple	140.0	10
Mesic	*Diospyros virginiana*	Common persimmon	11.0	1
Mesic	*Fagus grandifolia*	American beech	400.0	28
Mesic	*Ilex opaca*	American holly	1000.0	50
Mesic	*Nyssa sylvatica*	Black gum	180.0	12
Mesic	*Prunus serotina*	Black cherry	11.0	1
Mesic Totals	**—**	**—**	**1800.0**	**74**
Non-Canopy	*Amelanchier arborea*	Common serviceberry	160.0	10
Non-Canopy	*Aralia spinosa**	Devil's walkingstick	5.7	1
Non-Canopy	*Asimina triloba*	Pawpaw	380.0	10
Non-Canopy	*Carpinus caroliniana*	American hornbeam	240.0	8
Non-Canopy	*Cornus florida**	Flowering dogwood	5.7	1
Non-Canopy	*Sassafras albidum*	Sassafras	98.0	8
Non-Canopy Total	**—**	**—**	**890**	**32**
Oak Hickory	*Carya alba*	Mockernut hickory	57.0	5
Oak Hickory	*Carya glabra*	Pignut hickory	130.0	12
Oak Hickory	*Carya ovalis**	Red hickory	5.7	1
Oak Hickory	*Carya* spp.	Hickory spp.	29.0	2
Oak Hickory	*Quercus alba*	White oak	1800.0	23
Oak Hickory	*Quercus coccinea*	Scarlet oak	210.0	6
Oak Hickory	*Quercus falcata*	Southern red oak	69.0	4
Oak Hickory	*Quercus prinus*	Chestnut oak	110.0	6
Oak Hickory	*Quercus rubra**	Northern red oak	5.7	1
Oak Hickory	*Quercus velutina*	Black oak	5.7	8
Oak Hickory	*Quercus* spp.*	Oak spp.	5.7	1
Oak Hickory Total	**—**	**—**	**2500**	**41**

Trend Analysis – Unburned and Burned Plots

In 2006, tree seedlings in unburned plots had a density of only 5800/ha (Table 10). Oak-hickory species had the greatest density of seedlings, whereas early successional species had the lowest density. Overall, there was a highly certain decline in seedling density of 4% per year. Oak hickory species had the greatest decline at 7% per year, but smaller declines were also seen in early successional and mesic species.

Table 10. Trends in seedling density by ecological group in unburned and burned plots 2006 to 2017. Seedlings/ha 2006 is the estimated densities of each seedling group in 2006. Percent change per year is the estimated percent increase (green shading with a plus sign [“+”]) or decrease (orange shading with a negative sign [“−”]). For 2006 estimates, darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and single * indicates somewhat certain difference; “dec” indicates a decrease while “inc” indicates an increase compared to unburned plots. For the per cent change columns, darker shading and ** indicates a highly certain trend, lighter shading and single * indicates a somewhat certain trend. An em-dash (“—”) and no shading indicates that there is no evidence of a trend.

Ecological Group	Unburned Plots (seedlings/ha) 2006	Unburned Plots: % Change/yr	Burned Plots (seedlings/ha) 2006	Burned Plots: % Change/yr
All Trees	5800	−4%**	21000**(inc)	+3%*
Early Successional	200	−4%*	1100**(inc)	—
Mesic	1800	−1%*	1200	+14%**
Non-Canopy	750	—	3400**(inc)	+4%*
Oak Hickory	3200	−7%**	15000**(inc)	—

Burned plots in 2006 were dramatically different from unburned plots (Figure 12). Seedling density was 21,000 seedlings / ha, nearly four times that of unburned plots.

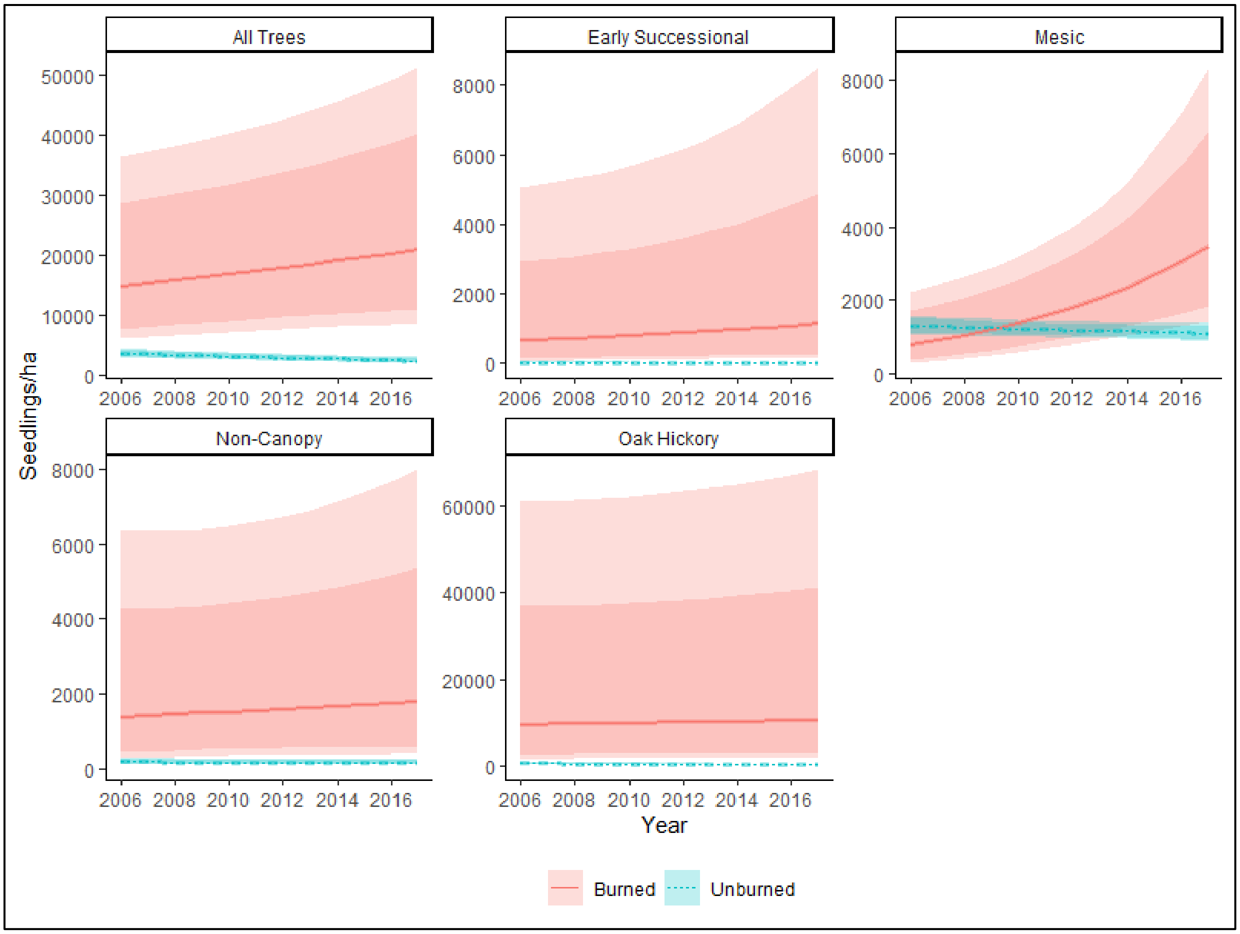

Figure 12. Trends in seedling density by ecological group. Graphs show main effects from the modeling. Blue dashed lines and shading indicate modeled trends in unburned plots, red solid lines and shading indicate modeled trends in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

Mesic species on burned plots did not have an immediate increase in seedling density and were the least abundant group in 2006. The other three ecological groups had highly certain increases of over fourfold compared to unburned plots in 2006 (Figure 13).

Figure 13. Abundant oak seedlings on plot PRWI-0273 in 2008, two years after being burned by the B-loop fire.

There was a somewhat certain increasing trend in overall seedling density of 3% per year. Mesic and non-canopy species also showed increasing trends. There were no trends in early successional and oak hickory species.

Trends were assessed for seventeen seedling species (Figure 14) in unburned plots. The only trends seen in early successional or non-canopy species were somewhat certain declines in sweetgum and American hornbeam. Two mesic species (red maple and American beech) and six oak hickory species (mockernut hickory (*Carya alba*) and the five oak species) showed somewhat or highly certain declines. Only black gum showed a somewhat certain increase. For three species (red maple, mockernut hickory and scarlet oak) the declines were in excess of 10% per year, indicating that seedlings of these species are rapidly disappearing from the park.

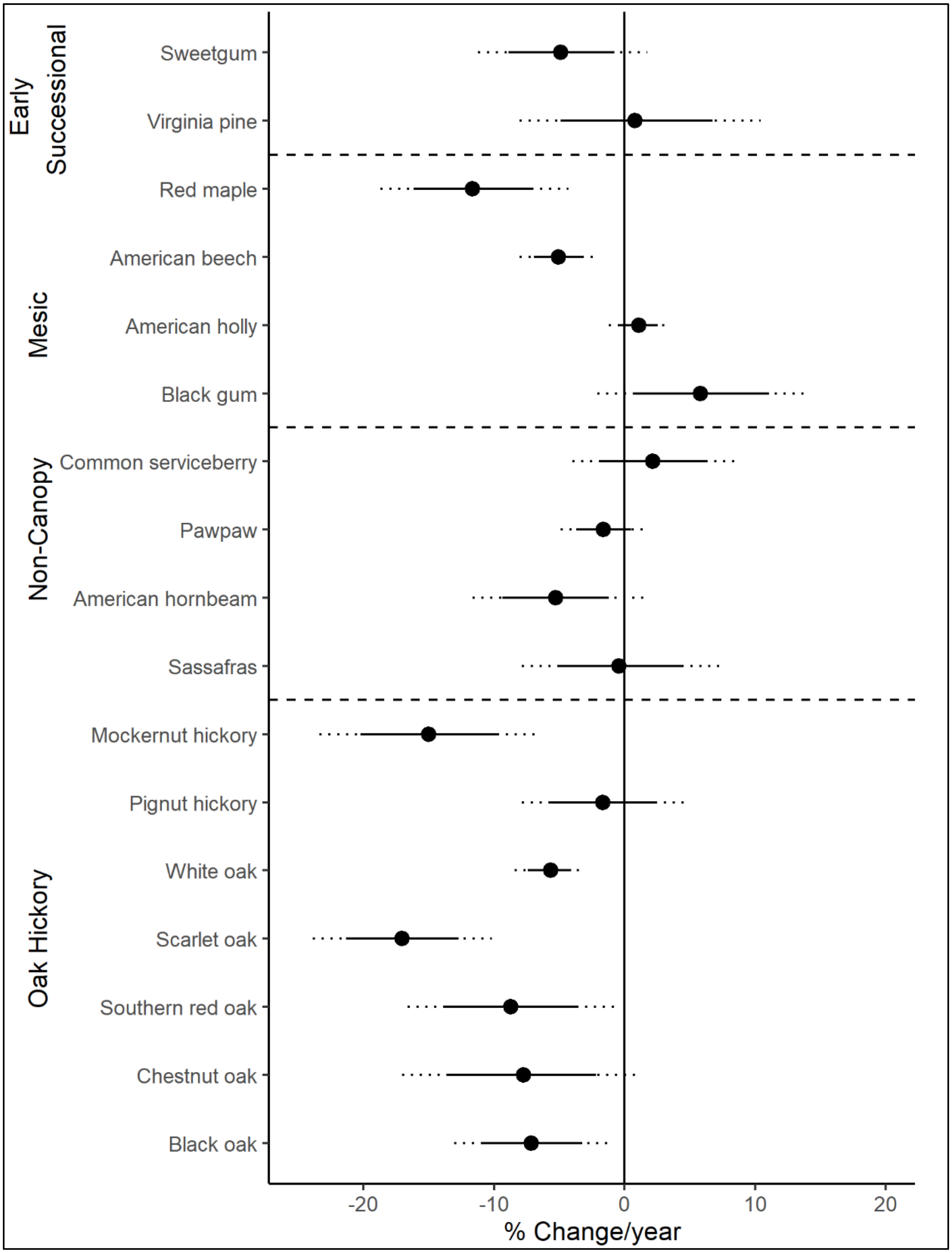

Figure 14. Trends in seedling density in unburned plots. Change per year is highly certain to be within the range indicated by dotted lines and somewhat certain to be within the range indicated by solid lines. If zero (vertical line) is outside of the dotted line there is a highly certain trend, outside the solid line there is a somewhat certain trend, and intersecting the solid line there is no evidence of a trend.

Trends were assessed for seven seedling species (Figure 15) in burned plots. In contrast to unburned plots, oak-hickory species were the only group to show no trends. All four species from the other ecological groups showed highly or somewhat certain increases, by as much as 20% per year.

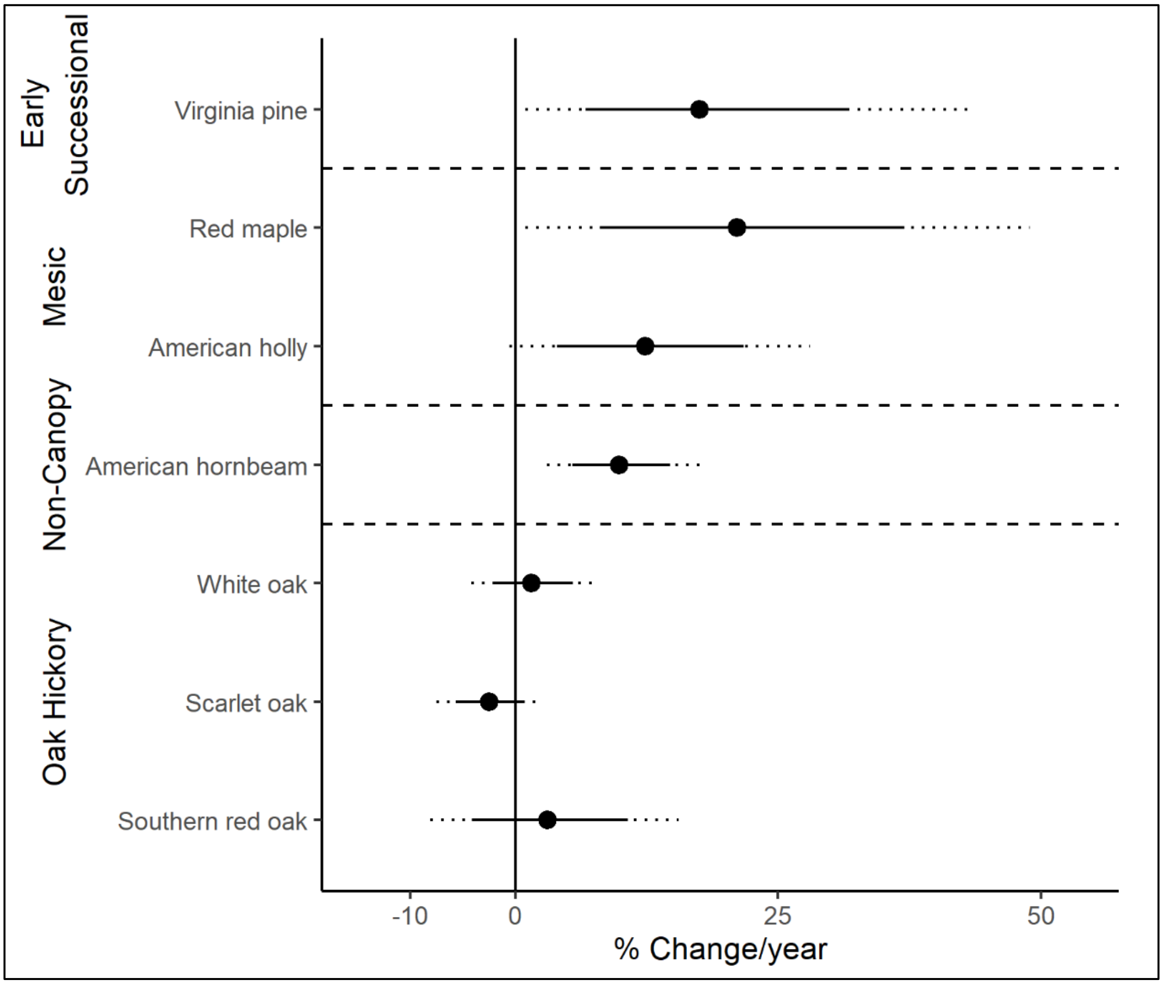

Figure 15. Trends in seedling density in burned plots. Change per year is highly certain to be within the range indicated by dotted lines and somewhat certain to be within the range indicated by solid lines. If zero (vertical line) is outside of the dotted line there is a highly certain trend, outside the solid line there is a somewhat certain trend, and intersecting the solid line there is no evidence of a trend.

Browse Rates

Data from 2014 to 2017 showed that seedlings were frequently browsed. 21% of seedlings in unburned plots and 10% of seedlings in burned plots were browsed (Table 11). While there is considerable variation in browse rates between groups, in general there was less browse on burned plots than on unburned plots. The one exception to this trend is non-canopy species which are more commonly browsed in burned plots.

Table 11. Estimated browse rates of seedlings by ecological group in burned and unburned plots 2014 to 2017. Darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and single * indicates a somewhat certain difference. Green shading with "inc" indicates more browse in burned plots while orange shading with "dec" indicates less browse in burned plots.

Ecological Group	**Unburned: % Browsed**	**Unburned: 95% Credible Interval**	**Burned: % Browsed**	**Burned: 95% Credible Interval**
All Trees	21%	18-24%	10%**(dec)	6-14%
Early Successional	16%	5-34%	8%	<1-35%
Mesic	30%	25-35%	7%**(dec)	1-21%
Non-Canopy	13%	8-20%	38%**(inc)	23-55%
Oak Hickory	17%	13-22%	2%**(dec)	<1-5%

There was considerable variation in browse rates between species (Figure 16). In unburned plots, mesic species generally had high browse rates as did some oak species, common serviceberry (*Amelanchier arborea*) and American hornbeam. For species with sufficient data, browse rates on burned plots were also calculated. For most species, browse was lower on burned plots. The exception was scarlet oak, which had a somewhat certainly higher level of browse on burned plots (Figure 16).

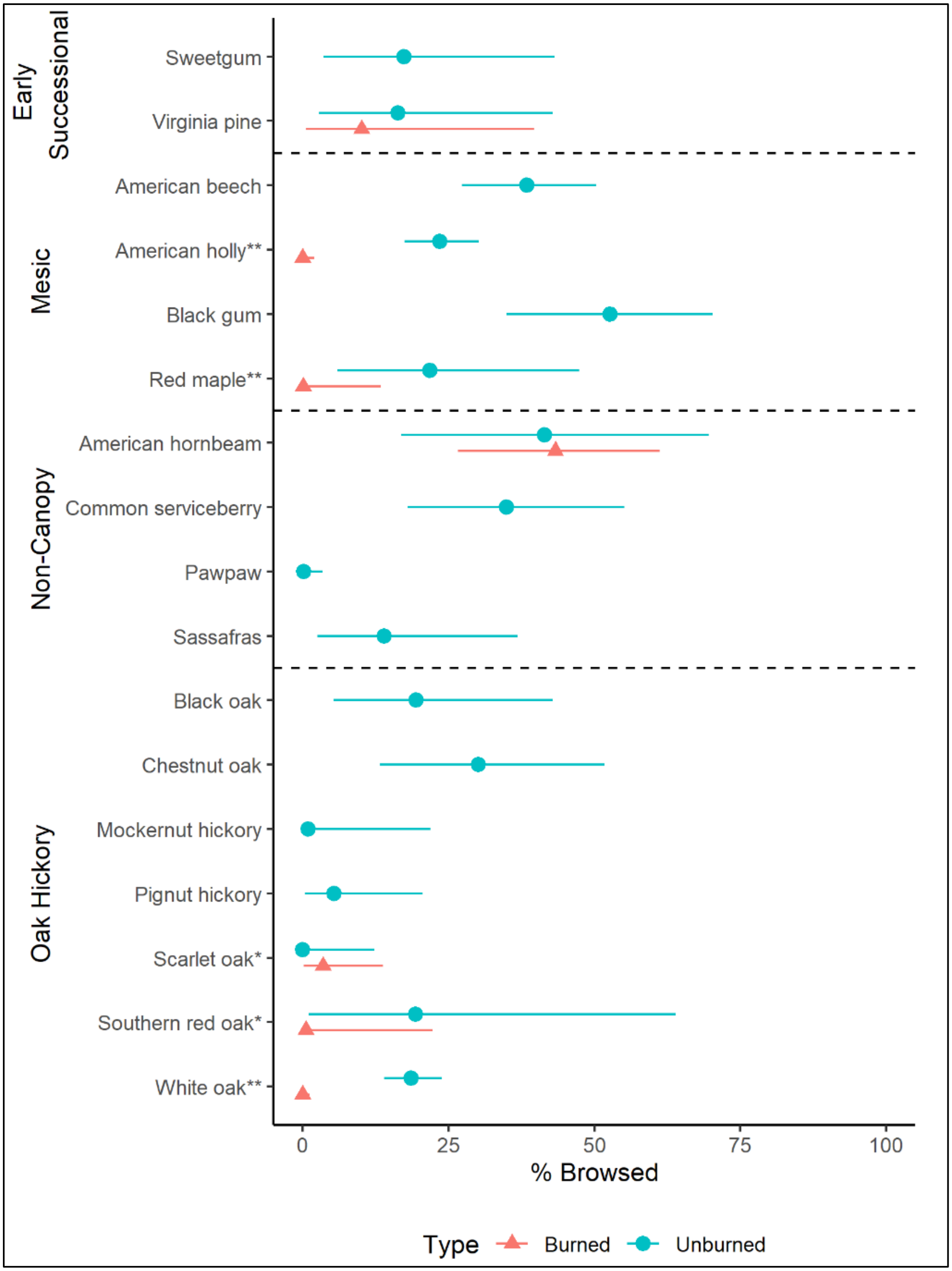

Figure 16. Seedling browse rates in burned and unburned plots 2014–2017. Blue circles = unburned plots, red triangles = burned plots, solid lines = 95% credible intervals. Species names with * and ** indicate somewhat and highly certain differences in browse rates between burned and unburned plots. Many species do not have estimates for browse in burned plots due to low numbers of seedlings growing there.

Shrubs

Sixteen taxa of shrubs were found during the 2014–2017 sampling cycle (Table 12). Common shrubs include several species of blueberries (*Vaccinium*) as well as the closely related maleberry (*Lyonia ligustrina*). Mountain laurel (*Kalmia latifolia*) had the highest percent cover of any individual species.

Table 12. Shrubs in the 2014–2017 monitoring cycle. Density indicates the estimated number of shrubs/ha, precent cover is the average percent cover of the species in 12 quadrats, and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual or were only found in a single quadrat. Species with (2015–2017) after their name were sampled only during those years, so cover estimates do not include all plots in the park.

Species	Common name	Density (shrubs/ha)	% Cover	Frequency (% of Plots)
*Castanea pumila**	Chinkapin	0.8	—	1
Celastrus orbiculatus	Oriental bittersweet	—	<0.1	1
Elaeagnus umbellata	Autumn olive	1.6	—	1
Gaylussacia spp.	Huckleberry	—	1.8	46
Hamamelis virginiana	American witchhazel	4.9	—	3
Kalmia latifolia (2015–2017)	Mountain laurel	—	2.3	27
*Lindera benzoin** (2015–2017)	Spicebush	—	<0.1	1
Lonicera japonica	Japanese honeysuckle	—	0.1	12
Lyonia ligustrina	Maleberry	35.0	—	5
Smilax glauca	Cat greenbrier	—	0.2	66
Smilax rotundifolia	Roundleaf greenbrier	—	1.0	79
Toxicodendron radicans	Poison ivy	—	<0.l	12
Vaccinium corymbosum/fuscatum	Highbush blueberries	98.4	—	26
Vaccinium stamineum	Deerberry	13.0	—	6
Vaccinium spp.	Lowbush blueberries	—	3.2	76
*Viburnum dentatum**	Southern arrowwood	0.8	—	1

Trends Analysis – Density on Unburned and Burned Plots

Only two of the species monitored as individuals has sufficient data for trends analysis. For those species, shrub density was relatively low in unburned plots in 2006 (Table 13). Maleberry showed an increased trend of 19% per year after 2006, but given the small number of shrubs present at the start of monitoring such a large growth rate is not unreasonable. The highbush blueberries (*Vaccinium corymbosum/fuscatum*) showed no trend.

Table 13. Trends in shrub density in burned and unburned plots 2006-2017. Shrubs/ha 2006 are the estimated densities of each shrub species in 2006. Percent change per year is the estimated percent increase. For the burned plots, shrubs/ha 2006 with **, darker shading, and "inc" indicates a highly certain increase difference between burned and unburned plots. For the percent change columns, ** and darker shading indicate a highly certain trend, a single * and lighter shading indicates a somewhat certain trend. Green shading indicates an increasing trend, orange shading indicates a decreasing trend. An em-dash ("—") and no shading indicates that there is no evidence of a trend.

Species	**Unburned (shrubs/ha) 2006**	**Unburned: % Change/yr**	**Burned (shrubs/ha) 2006**	**Burned: % Change/yr**
Highbush blueberries	75.7	—	382.8**(inc)	+5%*
Maleberry	0.8	+19*%	118.3**(inc)	+27%**

Both shrub species started with a much greater density in burned plots in 2006 when compared to unburned plots. Similarly, both species showed increasing trends in burned plots. Maleberry had a highly certain trend of 27% per year, whereas the highbush blueberries had a somewhat certain trend of 5% per year (Figure 17).

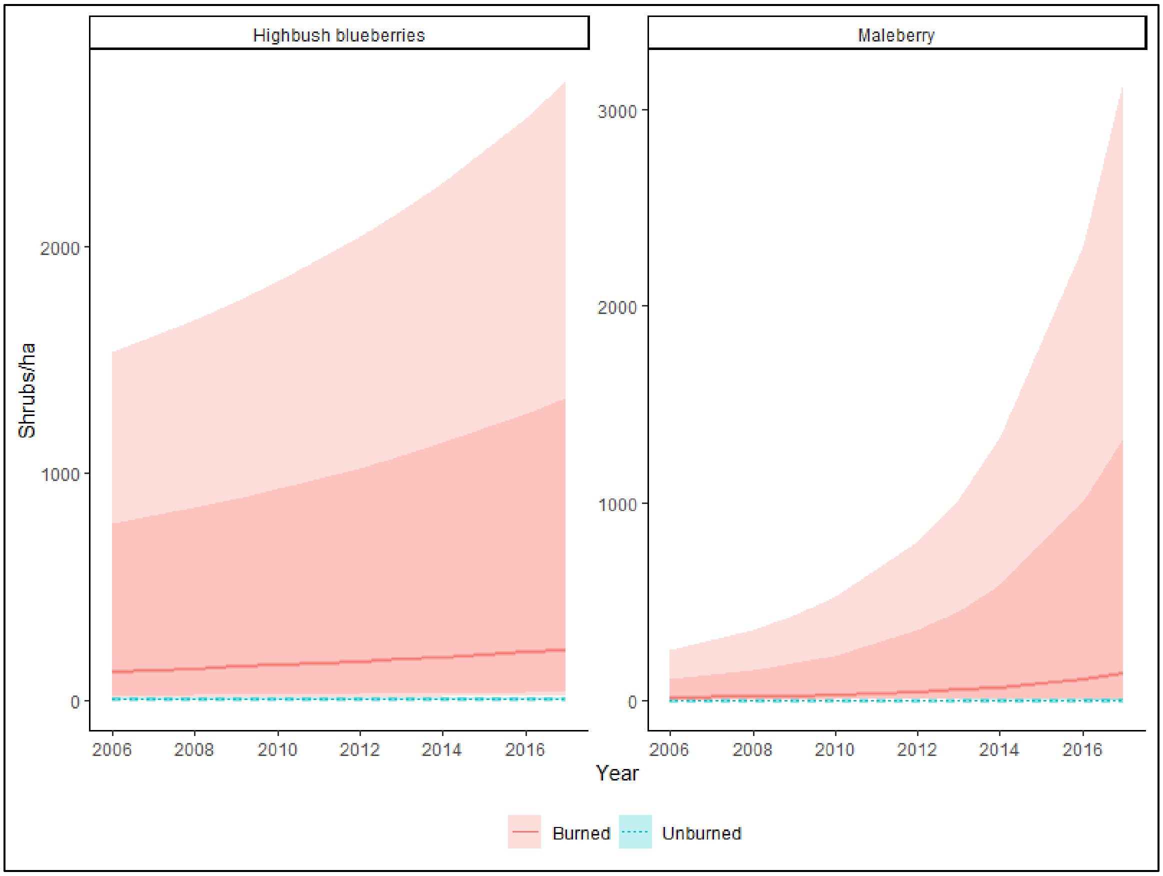

Figure 17. Trends in shrub density by species. Density in shrubs/ha by year. Graphs show main effects from the modeling. Blue dashed lines and shading indicate modeled trends in unburned plots, red solid lines and shading indicate modeled trends in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

Trend Analysis – Shrub and Vine Cover on Unburned and Burned Plots

Seven species of shrubs and shrub-like vines had sufficient data for comparisons between burned and unburned plots (Table 14). All species showed either a highly or somewhat certain response to burning. Huckleberry (*Gaylussacia*), mountain laurel (*Kalmia latifolia*), greenbrier (*Smilax* spp.) and lowbush blueberries (*Vaccinium* spp.) all had increased percent cover on burned plots, whereas Japanese honeysuckle (*Lonicera japonica*) and poison ivy (*Toxicodendron radicans*) were absent from burned plots.

Table 14. Shrub and Shrub-like Vine Cover 2014-2017. Frequency is the percent of plots where each species was found. Percent Cover Occupied Plots is the percent cover of a species on those plots where it is present. Percent Cover Total is the percent cover of a species averaged across occupied and unoccupied pots. For the burned plots, results with ** and darker shading indicate a highly certain difference between burned and unburned plots, a single * and lighter shading indicates a somewhat certain difference; "dec" indicates a decrease while "inc" indicates an increase compared to unburned plots. Green shading indicates an increase on burned plots orange shading indicates a decrease. Analysis of mountain laurel includes data from 2015-2017 only.

Species	Unburned: Frequency	Burned: Frequency	Unburned: % Cover Occupied Plots	Burned: % Cover Occupied Plots	Unburned: % Cover Total	Burned: % Cover Total
Cat greenbrier	65	87*(inc)	1	1	1	1*(inc)
Huckleberry	44	100**(inc)	9	13*(inc)	4	13**(inc)
Japanese honeysuckle	13	0**(dec)	2	0	<1	0*(dec)
Lowbush blueberries.	74	100**(inc)	4	8**(inc)	3	8**(inc)
Mountain laurel (2015-2017)	27	50	26	43*(inc)	7	20*(inc)
Poison ivy	13	0**(dec)	1	0	<1	0*(dec)
Roundleaf greenbrier	78	100**(inc)	2	6**(inc)	2	6**(inc)

Shrub Seedlings

Nineteen taxa of shrub seedlings were found in the 2014–2017 sampling cycle (Table 15). Common shrubs include strawberry bush (*Euonymus americanus*), mountain laurel, maleberry and deerberry (*Vaccinium stamineum*).

Table 15. Shrub seedlings in the 2014–2017 monitoring cycle. Density indicates the estimated number of shrubs/ha and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual.

Species	Common name	Density (seedlings/ha)	Frequency (% of Plots)
Aronia arbutifolia	Red chokeberry	11.0	1
Aronia spp.*	Chokeberry spp.	5.7	1
*Castanea pumila**	Chinkapin	5.7	1
*Elaeagnus umbellata**	Autumn olive	5.7	1

Table 15 (continued). Shrub seedlings in the 2014–2017 monitoring cycle. Density indicates the estimated number of shrubs/ha and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual.

Species	Common name	Density (seedlings/ha)	Frequency (% of Plots)
Ericaceae family	Heath spp.	11.0	1
Euonymus americanus	Strawberry bush	280.0	17
Hamamelis virginiana	American witchhazel	11.0	1
Kalmia latifolia	Mountain laurel	460.0	16
*Ligustrum sinense**	Chinese privet	5.7	1
Lyonia ligustrina	Maleberry	954.0	17
Rhododendron periclymenoides	Pinxter flower	52.0	4
Vaccinium corymbosum/fuscatum	Highbush blueberries	240.0	13
Vaccinium stamineum	Deerberry	1100.0	31
Vaccinium spp.*	Lowbush blueberry spp.	5.7	1
Viburnum acerifolium	Mapleleaf viburnum	40.0	3
*Viburnum dentatum**	Southern arrowwood	5.7	1
*Viburnum dilatatum**	Linden arrowwood	5.7	1
*Viburnum prunifolium**	Blackhaw	5.7	1
Unknown spp.	—	17.0	2

Trend Analysis – Unburned and Burned Plots

Trend analysis was carried out on three individual species, blueberries (all *Vaccinium* species combined) and all shrub seedlings combined (Table 16). Deerberry was not included in the analysis as its seedlings were not monitored prior to 2013. With the exception of mountain laurel*,* all taxa showed highly certain increases of between 11% and 31% per year in unburned plots. No trends were detected in mountain laurel density.

In 2006, mountain laurel and maleberry had highly certain or somewhat certain increases in density in burned plots as compared to unburned plots (Figure 18). Due in large part to the increase in these species, shrub seedlings in general were highly certain to have greater density in burned plots in 2006. Strawberry bush was absent on burned plots. Maleberry and blueberries had highly certain increasing trends in burned areas, whereas the extremely abundant mountain laurel showed a highly certain decreasing trend.

Table 16. Trends in shrub seedling density in burned and unburned plots, 2006 to 2017. Seedlings/ha 2006 are the estimated densities of each shrub species in 2006. Percent change per year is the estimated percent increase (green shading with a plus sign [“+”]) or decrease (orange shading with a negative sign [“−”]). For the burned plots, seedling/ha 2006 with ** and darker shading indicate a highly certain difference between burned and unburned plots. For the Percent Change columns ** and darker shading indicates a highly certain trend, a single* and lighter shading indicates a somewhat certain trend; “dec” indicates a decrease while “inc” indicates an increase compared to unburned plots. An em-dash (“—”) and no shading indicates that there is no evidence of a trend.

Species	**Unburned (seedlings/ha) 2006**	**Unburned: % Change/yr**	**Burned (seedlings/ha) 2006**	**Burned: % Change/yr**
All shrubs	860.0	+11%**	4300.0**(inc)	—
Blueberries	42.0	+26%**	120.0	+59%**
Maleberry	140.0	+31%**	240.0*(inc)	+43%**
Mountain laurel	560.0	—	5200.0**(inc)	−46%**
Strawberry bush	38.0	+28%**	0.0**(dec)	—

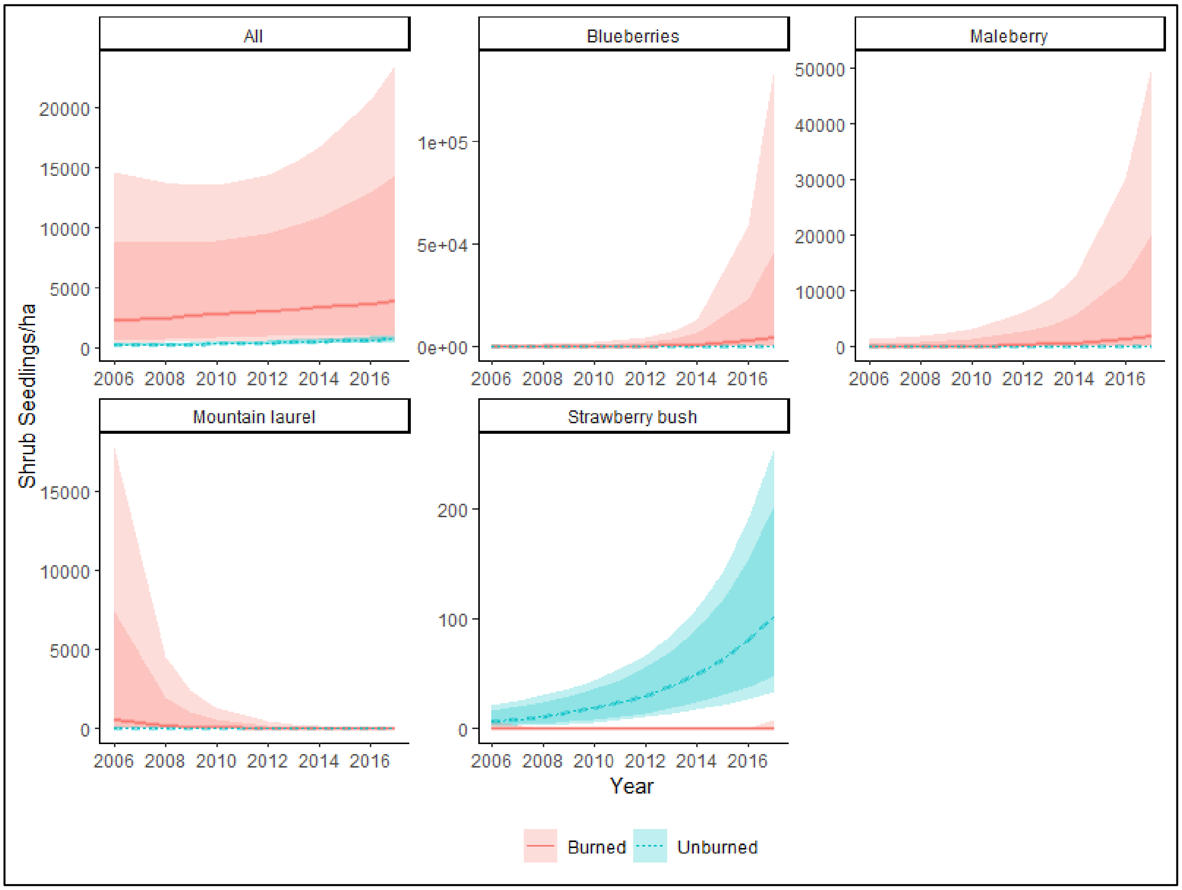

Figure 18. Trends in shrub seedling density by species. Graphs show main effects from the modeling. Blue dashed lines and shading indicate estimated trends in unburned plots, red solid lines and shading indicate estimated trends in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

Browse Rates

Data from 2014 to 2017 showed that shrub seedlings were frequently browsed. 25% of seedlings in unburned plots and 18% of seedlings burned plots were browsed (Table 17) which is slightly higher than the corresponding tree seedling numbers. Browse rates of mountain laurel are much lower than that of other species, both on burned and unburned plots. The blueberry species have the highest browse rates and are the only species to have higher browse rates on the burned plots.

Table 17. Estimated browse rates of seedlings in burned and unburned plots 2014-2017. Darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and a single * indicates a somewhat certain difference. Green shading indicates more browse in burned plots orange shading indicates less browse in burned plots; "dec" indicates a decrease while "inc" indicates an increase compared to unburned plot. An em-dash ("—") indicates a species was no present in burned plots.

Species	Unburned: % Browsed	Unburned: 95% Credible Interval	Burned: % Browsed	Burned: 95% Credible Interval
All Shrubs	25%	22-28%	18%**(dec)	11-26%
Blueberries	52%	41-63%	71%**(inc)	52-87%
Strawberry bush	45%	4-55%	—	—
Maleberry	31%	26-36%	6%**(dec)	1-20%
Mountain laurel	6%	4-9%	0%**(dec)	0-2%

Vines on Trees

Eleven species of vines were found on trees in the 2014–2017 sampling cycle (Table 18). Roundleaf greenbrier (*Smilax rotundifolia*) was by far the most common vine. The remaining species were relatively rare and were found on only a handful of plots.

Table 18. Vines on trees in the 2014–2017 monitoring cycle. Density indicates the estimated number of shrubs/ha and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual or were only found in a single quadrat.

Species	Common name	Density (trees with vines/ha)	Frequency (% of Plots)
*Akebia quinata**	Chocolate vine	0.10	1
Apios americana	Groundnut	0.20	1
Dioscorea villosa	Wild yam	0.20	1
Lonicera japonica	Japanese honeysuckle	1.27	5
Parthenocissus quinquefolia	Virginia creeper	1.37	5
Smilax glauca	Cat greenbrier	0.20	1
Smilax rotundifolia	Roundleaf greenbrier	42.44	39

Table 18 (continued). Vines on trees in the 2014–2017 monitoring cycle. Density indicates the estimated number of shrubs/ha and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual or were only found in a single quadrat.

Species	Common name	Density (trees with vines/ha)	Frequency (% of Plots)
Toxicodendron radicans	Poison ivy	1.27	3
*Vitis aestivalis**	Summer grape	0.10	1
Vitis labrusca	Fox grape	0.20	1
Vitis spp.*	Grape spp.	0.10	1
Vitis vulpina	Frost grape	2.05	4

Trend Analysis – Unburned and Burned Plots

Trend analysis was carried out on Japanese honeysuckle, all greenbrier (*Smilax*) species combined, all grape (*Vitis*) species combined, and all vines combined (Table 19). In unburned plots, there were no changes in vine density.

Table 19. Trends in density of vines on trees in a plot with median tree density, for a burned and unburned plot 2006 to 2017. Vines/ha 2006 are the estimated densities of each vine species in 2006. Percent change per year is the estimated percent increase. For the burned plots, vines/ha 2006 with ** and darker shading indicate a highly certain difference between burned and unburned plots. For the percent change columns, ** and darker shading indicates a highly certain trend, a single * and lighter shading indicates a somewhat certain trend. As the number of trees on a plot influences the density of vines on trees, densities are calculated assuming a median tree density. Green shading indicates an increasing trend, orange shading indicates a decreasing trend; "dec" indicates a decrease while "inc" indicates an increase compared to unburned plot. An em-dash ("—") and no shading indicates that there is no evidence of a trend.

Monitoring Category	Unburned Plots (vines/ha) 2006	Unburned Plots: % Change/yr	Burned Plots (vines/ha) 2006	Burned Plots: % Change/yr
All Vines	29.3	—	2.9	+43%**
Grapes	2.9	—	0.0**(dec)	—
Greenbriers	21.9	—	2.9	+43%**
Japanese honeysuckle	1.3	—	0.0**(dec)	—

Japanese honeysuckle and grapes were absent on burned plots. Greenbriers underwent a highly certain rapid increase in density on burned plots, and this increase led to an identical increase in the density of all vines combined (Figure 19).

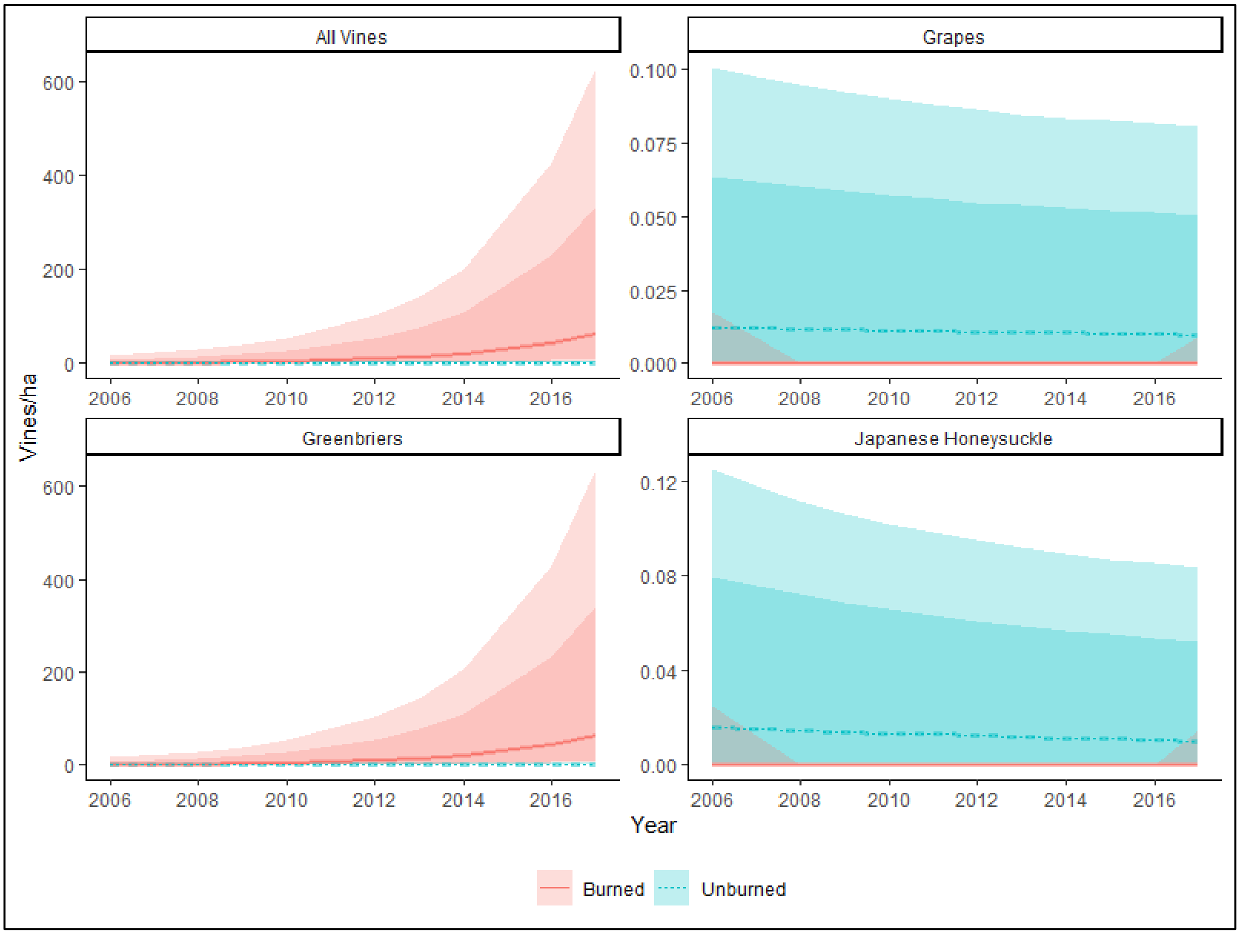

Figure 19. Trends in density of vines on trees. Graphs show main effects from the modeling. Blue dashed lines and shading indicate modeled trends in unburned plots, red solid lines and shading indicate modeled trends in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

Coarse Woody Debris

Coarse woody debris from nineteen species was recorded during the 2014–2017 sampling cycle (Table 20). Much of the woody debris could not be identified or could only be identified to genus due to its advanced state of decay. Virginia pine was the species with the greatest volume of CWD. Large amounts of oak and tulip poplar were also present.

Table 20. Coarse woody debris the 2014–2017 monitoring cycle. Volume indicates the estimated volume of dead wood in m^3 per ha and frequency is the percent of the 145 monitoring plots occupied by each species. Species whose name ends with * were represented by a single individual or were only found in a single quadrat.

Species	Common name	Volume (m^3/ha)	Frequency (% of Plots)
Acer rubrum	Red maple	5.04	9
Acer spp.	Unidentified maple	1.75	1
*Carya alba**	Mockernut hickory	2.74	1
Carya spp.	Unidentified hickory	5.52	2
Cornus florida	Flowering dogwood	2.52	3
*Fagus grandifolia**	American beech	2.22	1
Fraxinus americana	White ash	3.63	1
Juniperus virginiana	Eastern red cedar	4.52	4
Liriodendron tulipifera	Tulip poplar	12.89	6
Nyssa sylvatica	Blackgum	2.25	1
Pinus spp.	Unidentified pine	19.72	20
Pinus virginiana	Virginia pine	52.65	57
Populus grandidentata	Bigtooth aspen	7.57	1
Prunus serotina	Black cherry	9.69	1
Quercus alba	White oak	7.39	13
Quercus coccinea	Scarlet oak	23.74	11
Quercus falcata	Southern red oak	3.53	2
Quercus prinus	Chestnut oak	16.71	2
Quercus rubra	Northern red oak	28.05	2
*Quercus stellata**	Post oak	4.63	1
Quercus velutina	Black oak	20.98	1
Quercus spp.	Unidentified oak	38.06	61
*Robinia pseudoacacia**	Black locust	1.98	1
Unknown spp.	—	15.02	32

Trend Analysis – Unburned and Burned Plots

Due to the difficulties in identifying highly decayed wood, trend analysis was only carried out on CWD as a whole and not on individual species (Table 21).

Table 21. Trends in volume of Coarse Woody Debris (CWD). Statistical model results for trends in CWD volume in unburned plots and those that were burned by the B-Loop fire. CWD volume (m^3/ha) is the estimated volume of CWD in 2006. Percent change per year is the estimated percent increase or decrease. For the burned plots, CWD volume 2006 with a single * and lighter shading indicates a somewhat certain difference between burned and unburned plots. For the percent change columns, ** and darker shading indicate a highly certain trend, a single * and lighter shading indicates a somewhat certain trend. Green shading indicates an increasing trend, orange shading indicates a decreasing trend; "dec" indicates a decrease while "inc" indicates an increase compared to unburned plot. An em-dash ("—") and no shading indicates that there is no evidence of a trend.

Group	Unburned: CWD Volume (m^3/ha) 2006	Unburned: % Change/yr	Burned: CWD Volume (m^3/ha) 2006	Burned: % Change/yr
All Trees	71	—	104*(inc)	—

There was no evidence of a trend in CWD in either burned or unburned plots. There was a somewhat certain increase in CWD volume in burned plots as compared to unburned (Figure 20).

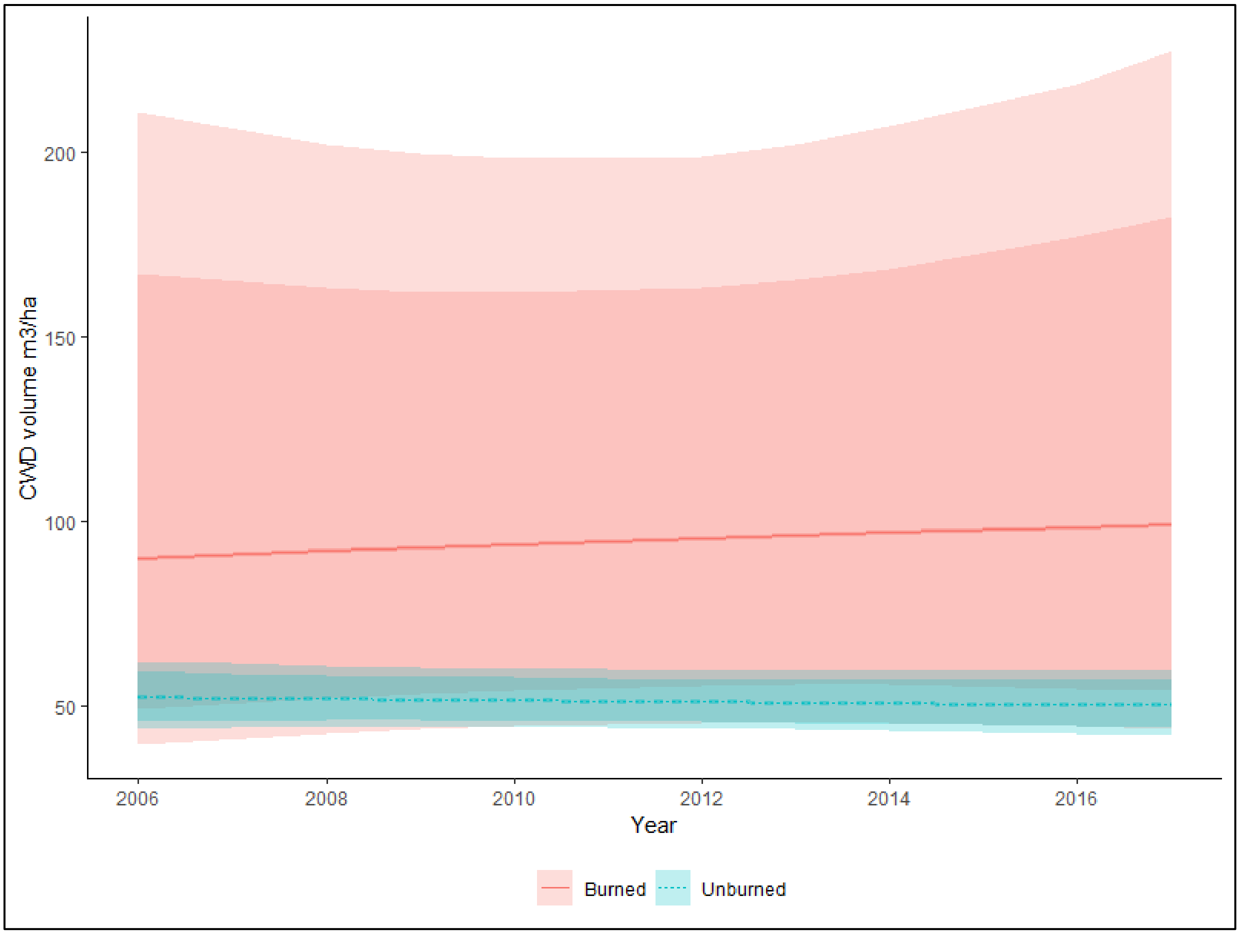

Figure 20. Trends in volume of coarse woody debris. Graph shows main effects from the modeling. Blue dashed line and shading indicate modeled trend in unburned plots, red solid line and shading indicate modeled trend in burned plots. Darker shading indicates the 85% credible interval, lighter shading the 95% credible interval.

Discussion

Forests in PRWI are undergoing a wide variety of changes, as evidenced by the many trends identified above. At first glance, these trends may appear contradictory or chaotic. However, a clearer picture emerges if we view these trends as the result of several processes simultaneously acting on the park's forests.

Some of the trends are the result of forest succession. As the forest matures, early successional species are becoming less important in the canopy, as they are less abundant and occupy a smaller proportion of the canopy, but overall basal area of the forest is increasing. Similarly, while oak-hickory species are currently major components in mature forests, they are no longer increasing in importance. In contrast, mesic species are rapidly increasing in importance as canopy trees.

In addition to successional changes, threats to forest health are also impacting the park. In unburned plots, both seedlings and saplings are decreasing in density. Exotic diseases are attacking individual trees species and resulting in sharp declines. Finally, trends from the burned plots are often starkly different from unburned plots. This indicates that fire regimes can play an important role in determining forest composition and structure.

In future years, climate change will likely bring additional changes and challenges to the park forest resources. For the 31 common species included in the USFS Climate Change Tree Atlas, 20% are expected to have large decreases in habitat suitability in PRWI by 2100 (Peters et al. 2020). While we recognize response to climate as a potential driver of forest change, many of the stressors and processes described above are occurring at a faster rate.

Succession

Early Successional Species

Seedlings and saplings of early successional species require high light conditions to become established. Forests in PRWI generally have a closed canopy that shades the forest floor and creates low light conditions. Likely due to the lack of large light gaps, early successional species make up less than 4% of seedlings and less than 3% of saplings, despite accounting for almost 30% of trees.

While the early successional group has an overall decline in tree density and no trend in basal area, individual species have contrasting trends depending on their life history. Virginia pine and tulip poplar are the dominant early successional tree species and are two of the most abundant species in the park. Virginia pines typically live for approximately 100 years (Loehle 1988), whereas the park is 85 years old, and an ongoing study has found that forests in most plots are even older (Elmore, et al. in review). Many of the Virginia pine trees are likely reaching the age of senescence, and the low levels of regeneration are insufficient to balance this loss. This has led to a highly certain loss of both density and basal area of this species (see Appendix A for details). Tulip poplar, on the other hand, typically lives to 200 years or more (Loehle 1988). Forests in the park are much younger than that, so tulip poplar trees are not reaching senescence, and high levels of regeneration are not necessary to balance mortality. As a result, there has not been a decrease in tree density, and basal area is still increasing. In the coming years, we expect that Virginia pine will continue to decline, and that tulip poplar will remain an important component of the canopy.

Oak-Hickory Species

Given current trends, we expect that oak-hickory species will continue to be a major part of forest canopies for the foreseeable future, but their importance will not increase and may slowly decline due to mortality of mature trees. Oak-hickory species have the second highest tree basal area of any ecological group, only slightly less than that of early successional species and over twice that of mesic species, making it the dominant group in mature canopies. The basal area of oak-hickory trees is increasing but tree density is declining. In unburned plots, sapling density is currently only a quarter of that of mesic species and declining, while at the same time seedling density is also declining. These trends make it likely that declines in tree density will continue.

It is not surprising that established oak-hickory forests would trend toward fewer, larger trees as this commonly occurs as forests mature. What is striking, is that the decline in oak-hickory density is occurring at the same time as the reduction in the density in early successional species. At some point in the past, conditions were suitable for oak-hickory species to become established as early successional species declined. Currently, that does not seem to be taking place, and oak-hickory forests are not expanding. Trends for individual species generally mirrored that of the entire ecological group, with either no trend or decreases in density for all growth stages, but with increases in basal area.

Mesic Species

Mesic species, unlike oak-hickory species, are increasing in importance. Currently, mesic species are the most abundant trees, but they have less than half of the basal area of early successional or oak-hickory species. Mesic species account for almost 70% of all saplings. In unburned plots, they are the only ecological group that is increasing in tree density as well as basal area, the only group with increasing sapling basal area, and the group with the smallest declines in sapling and seedling density. Due to their dominance of the sapling layer, we anticipate that their tree density and basal area will continue to increase. Overall conditions in the park, such as the stand age, canopy closure and lack of fire, appear to be favorable for the growth of mesic species, allowing them to increase in importance as early successional species decline.

Individual mesic species are generally increasing in tree density and basal area but have stable to decreasing sapling density. American beech has recently become the most abundant species in the park and has rapidly increasing basal area. However, as discussed below, the presence of beech leaf disease in the park could sharply reverse this trend.

Non-Canopy Species

Non-canopy tree species have a much lower tree density and tree basal area compared to the other major ecological groups. This is not necessarily a problem as these trees are typically much smaller than canopy species and often do not grow large enough to be classified as a tree. Unfortunately, trends for this group are negative for both sapling density and basal area. As these species are generally adapted to survive in the lower light levels below the canopy, this is not simply a successional change. These trends are particularly pronounced in flowering dogwood, which is the most common non-canopy tree and is susceptible to a fungal disease. Possible explanations for these declines are discussed under threats to forest health below.

Threats to Forest Health

Declining Forest Regeneration

Forest regeneration, as measured by the density of seedlings and saplings, is declining in the park, except for the areas affected by the B-Loop fire. In unburned areas, sapling density is declining for every ecological group and is flat or declining for every species analyzed. Basal area is flat or increasing for almost all species, with the notable exception of a sharp decline in flowering dogwoods. Sapling density is declining because recruitment is not keeping up with losses from the death of saplings or their growth into the tree category. As sapling density dwindles, basal area will likely also decline for all ecological groups.

Seedling density in unburned areas is also declining for all ecological groups except for the non-canopy trees. Density is declining for almost all species, with black gum being the sole increasing species. The ongoing declines in seedling density will likely drive further declines in sapling density in coming years.

These declines are a serious threat to forest health. Seedlings and saplings growing under the canopy are sometimes referred to advanced regeneration. Advanced regeneration is a crucial as these individuals will become the new canopy layer when a forest suffers a large disturbance. Many species rely on advanced regeneration (Vickers et al. 2019) including many oak species (Brose 2008).

There has been growing concern in recent years regarding a lack of advanced regeneration in many forest types in eastern North America. Studies have shown that two thirds of eastern forests have insufficient advanced regeneration to adequately recover from canopy removal (Vickers 2019). This phenomenon, called regeneration debt, is most severe in the Mid-Atlantic, including northern Virginia (Miller and McGill 2019).

One way to assess the adequacy of advanced regeneration is to use the stocking index (McWilliams et al. 1995) which determines if a forest has sufficient regeneration to recover from a disturbance. All parks in the NCRN, including PRWI, have insufficient regeneration based on this index (National Park Service 2020). In fact, only four plots, less than 3% of all plots in PRWI have sufficient regeneration. Three of the four plots with sufficient regeneration were burned plots.

One major contributor to regeneration debt in eastern forests is over-browsing by white-tailed deer (*Odocoileus virginianus*). White-tailed deer are known to have been present in high densities in the park during the years covered by this report (Bates 2017). Deer density from 2006–2017 varied considerably but was typically between 10 and 20 deer /km^2, much higher than historic deer densities in eastern deciduous forest, which are believed to be about 4 deer/ km^2 (McCabe and McCabe 1984, Alverson et al. 1988, McCabe and McCabe 1997). High deer density is considered a threat to forest health, as over-browsing by deer can lead to a loss of vegetation on the forest floor, including a loss of tree regeneration. Numerous studies have examined the effect of high deer densities on forest vegetation (reviews in Russell et al. 2001, Rooney and Waller 2003, and Webster et al. 2018) and it has been concluded that deer density higher than 8.5 deer/ km^2 can lead to reductions in tree regeneration (Horsley et al. 2003, Russell et al. 2001).

Additional results from this report support that over-browsing is contributing to regeneration debt. Approximately 1 in 5 seedlings in unburned plots shows evidence of browse, (Table 11) indicating widespread deer impacts on seedlings. Furthermore, not only is seedling density low and declining, but sapling density is also declining. This indicates that current seedling density is insufficient to maintain sapling density. Without a reduction in deer density, these trends are likely to continue.

Pests and Diseases

Plant pests and diseases can cause sharp declines in individual tree species and dramatic changes in community composition. Several tree species in the park have been impacted by plant pests and diseases. American chestnut (*Castanea dentata*) is perhaps the most famous case of a tree decline caused by disease, in this case the fungus *Cryphonectria parasitic*a (Anagnostakis, 1987). American chestnut trees may have once been common in the park, and while they persist (Matthews and Riedman, 2015), the species is now so rare that it was not recorded in any plot.

Similarly, eastern hemlock (*Tsuga canadensis*) is present in isolated stands in the park (Matthews and Nortrup, 2018), but not in any of the monitoring plots. This species is rapidly declining due to the insect pest hemlock wooly adelgid (*Adelges tsugae*; Danoff-Burg and Bird 2002, Orwig and Foster 1998), but trees in the park are currently unaffected. The park recently completed a two-year project to treat all hemlock trees to prevent infestation by this pest.

During monitoring, we detected one disease and two insect pests. Dogwood anthracnose (*Discula destructiva*; Redlin 1991) is a fungal disease that attacks the leaves of flowering dogwood. This disease was recorded in the monitoring data twelve times between 2006 and 2017. Flowering dogwood is the only non-canopy species that has a rapidly declining density and basal area in both the trees and sapling monitoring categories (Appendix A). Sherald et al. (1996) showed that dogwood anthracnose can cause dramatic declines in flowering dogwood in parks and was associated with a 94% decline in flowering dogwood at Catoctin Mountain Park. The ongoing declines in flowering dogwood at PRWI are likely due to a combination of low regeneration due to deer browse and elevated adult mortality from the continued presence of the disease.

White ash is currently being decimated by the emerald ash borer (EAB), an exotic insect originally from Asia (*Agrilus planipennis*, Siegert et al. 2009). This pest has caused rapid declines in ash trees through the northeast United States (Herms and McCullough 2014) and in NCRN parks in particular (Matthews and Nortrup 2018). White ash is a relatively minor component of the forest in PRWI, and EAB was not observed in the park until 2016. While EAB did not cause mortality during the time period covered by this report, in subsequent years mortality of infected trees has been observed.

Spongy moth *(Lymantria dispar*), formerly known as “Gypsy Moth,” is a well-established insect pest that causes tree mortality through defoliation on a variety of tree species, including many oaks

(Elkinton and Liebhold 1990). Although widespread outbreaks of spongy moth can occur, so far it has only been observed on three trees in two plots in PRWI. These observations occurred in 2015 and 2016, and the moths were not present when these plots were later revisited.

In the summer of 2021, a new pathogen was observed in the park. Beach leaf disease (BLD), caused by *Litylenchus crenatae mccannii* a nematode that attacks American beech, was identified in the park based on the characteristic symptoms of the leaves and a subsequent confirmation based on DNA (Kantor et al 2021). While this disease is currently restricted to a few locations in the park, it will likely rapidly spread and cause diebacks in the canopy of beech trees, as well as mortality in smaller trees and saplings (Ewing et al. 2019). American beech is the most abundant species in the tree and sapling layers. In the 2014–17 monitoring data 20% of trees and 35% of saplings are American beech (Figure 4). It currently has increasing trends for basal area and increasing tree density, so declines in this species will have long lasting consequences for forest communities. Beech is an important source of food and shelter for a wide variety of bird and mammal species (Tubbs and Houston, 1990) whose populations could decline as BLD spreads. The loss of canopy cover will certainly allow more light to reach the forest floor which will provide new opportunities for invasive plants. We currently cannot predict which, if any, tree species will benefit from the decline of American beech. Large light gaps could provide new opportunities for early successional species to establish, but smaller gaps may favor mesic species which are currently increasing.

Exotic vines and herbs

The results presented here indicate that invasive vines are not currently a pressing problem for the park. Few exotic vines were found in the park, and the most common, Japanese honeysuckle, was only found on approximately 1 tree / ha. This is particularly important as prior research (Matthews et al., 2016) has indicated that invasive vines can cause elevated mortality in the forests of network parks.

In a study of invasive plants of northeastern units of the National Park service, Miller et al. (2021) found that PRWI is one of the least invaded National Park units in the northeastern US. Furthermore, PRWI and Roosevelt-Vanderbilt National Historic Site in New York are the only two units with significant negative trends in overall invasive plant abundance. The lack of invasive vines is further evidence that PRWI is unusually free of invasive plants and highlights the value of this park for regional conservation.

Fire Regime

Plots that were burned in the B-loop fire are markedly different from those that were not. Vegetation in the burned plots generally had a spatially varied response to fire, likely in response to fire intensity varying from plot to plot. Tree seedlings were 3.5 times more abundant (Table 10), and shrub seedlings were five times more abundant (Table 16) in burned plots compared to unburned plots. Except for mesic species, seedlings had an immediate positive response to the fire, as seen by the large increases in seedling density in 2006 (Table 10). This response was particularly strong for oak-hickory species. As time went on, however, mesic species increased at 14% per year, whereas oak hickory species had no trend. It therefore appears that the benefit of fire to oak-hickory establishment was large but short lived, whereas other species responded more strongly over time. It is especially noteworthy that Virginia pine, which is sharply declining as a tree and nearly absent as a sapling, showed strong increases in seedling density in the burned plots. A smaller percentage of seedlings were browsed in burned plots (Table 11, Table 17), possibly due to the increased density of vegetation making seedlings less accessible or perhaps there were simply more seedlings than the deer could consume.

Sapling density and basal area were lower in 2006 on burned plots compared to unburned plots with the notable exception of oak-hickory species which had a higher density (Table 8). Sapling density and basal area, particularly of early successional and oak-hickory species, also had large increasing trends on burned plots, in contrast to decreases in unburned plots. This has resulted in oak-hickory species dominating the sapling layer in burned plots while mesic species dominate unburned plots.

Shrub density and cover also immediately increased on burned plots and shows increasing trends (Table 13, Table 14). Only two species showed decreases due to fire, poison ivy and the invasive shrub Japanese honeysuckle. On the other hand, huckleberries, greenbrier, and blueberries were all more common on burned plots.

Trees generally declined on burned plots, with lower density and basal area in the immediate aftermath of the fire, and a decreasing trend in basal area as trees continue to die on burned plots (Table 5). Non-canopy and mesic trees, however, had an increasing trend in basal area in burned plots. These contrasting results are likely due to variations in fire intensity. In some plots, the fire killed trees leading to a decrease in tree density, and a corresponding increase in coarse woody debris (Table 21). In other areas, the fire did not kill trees, and in those areas, basal area increased much like in the unburned portions of the park. As the number of live trees decline after the fire, the number of vines on trees also declined but has had an increasing trend since then (Table 19). As the forest continues to recover from the fire, tree density and basal area should begin to increase, but based on trends in the sapling layer, the new canopy is likely to be dominated by early successional and oak-hickory species.

In the absence of fire or a similar disturbance, oak-hickory and early successional species will likely continue to decline in the unburned areas of the park. Mesic species will increase in importance and come to dominate the canopy layer.

Management Implications

PRWI is unique in the NPS system as the only park that protects a large tract of Piedmont forest that is generally in very good condition. The list of fundamental resources, which is intended to focus planning and management on what is truly significant about the park, in Prince William Forest Park’s Foundation Document explicitly includes its forests (National Park Service, 2013). Compared to nearby forests, PRWI forests more closely resemble old forest structure, harboring more large trees and more coarse woody debris (Miller et al 2016), and host higher tree diversity than surrounding landscapes (Miller et al 2018). PRWI forests are also among the least invaded by exotic plant species among all eastern NPS units (Miller et al 2021). Researchers have used the bird conservation index (BCI), a measure of ecological integrity, to assess the bird community in PRWI. PRWI was found to have a higher ecological integrity than both the surrounding areas (Goodwin and Shriver, 2014) and other Mid-Atlantic NPS sites (Ladin et al., 2016). Maintaining, and when possible, improving upon, this strong baseline should be a high priority for the park.

It is challenging to identify desired conditions or target forest composition for PRWI's forests as a whole. Indeed, the park's management documents instead focus on "regeneration process" and "structural diversity" rather than specific woody plant composition or community types (National Park Service, 2019). On the other hand, trends that indicate a change in resource health are fairly straightforward to identify. For example, if forests in a park had severe declines in regeneration and substantial increases of exotic plant species abundance it would suggest forest resource deterioration, whereas increasing (or steady) park-level plant diversity might be a favorable or desirable trend.

Resist – Accept – Direct Framework

Given the large number of trends in forest vegetation, it is important to consider what, if anything, resource managers do in response. For this purpose, the *Resist – Accept – Direct* (RAD) framework (Crausbay et al 2021, Schuurman et al., 2020) may be useful. This framework, developed in the context of responding to climate change, groups management responses to change into three categories. Changes that are unacceptable fall in the *Resist* category, and managers should focus on stopping or reversing those trends in order to maintain current or restore historic conditions. Resisting change, however, requires high intensity interventions (e.g., costly interventions requiring substantial capacity and/or long-term commitment to action). Where there is limited opportunity to intervene (whether the result of limited resources, public support, or other drivers), managers may decide to *Accept* change, either because the trend doesn't pose a direct threat to resources or because the intervention required to resist the chance is too intense (e.g., beyond available resources). Finally, change that is undesirable, but which cannot be resisted, can be directed by using management to steer resource trajectories to an acceptable state, even if that state differs from current or historic conditions.

Forest Regeneration

One of the most striking forest trends at PRWI is the loss of regeneration in unburned plots. This lack of regeneration lowers the resilience of the forest to respond to stresses that may increase tree mortality, such as diseases, invasive vines and potential impacts from climate change. This trend is undesirable and using the RAD framework, it should be resisted.

Insufficient forest regeneration is a grave threat to long term forest health. In other NCR parks, deer density reduction is an important management action which has successfully led to increases in forest tree regeneration (Schmit et al. 2020). Deer management could play an important role in addressing a lack of forest regeneration in PRWI and should be considered by the park. Marine Corps Base Quantico, which borders the park on the south and west sides, has an active hunting program, which includes deer hunting (https://quantico.isportsman.net/huntinginfo.aspx). In recent years, deer hunters have killed between 200 and 400 deer each fall (https://quantico.isportsman.net/harvest.aspx). While these actions help to reduce deer densities in the region, on their own they are not sufficient to control deer populations in PRWI. Since 2001, deer densities were below 8/km^2 in 2007, 2014, 2020 and 2021 (Bates 2017, pers comm.). However, recent research has shown that deer density must remain low for over a decade for regeneration to start recovering (Schmit et al. 2020, Nagy et al.

2022). Deer monitoring should continue in the park. If recent declines in deer density are not sustained, park managers should consider implementing a deer management program. If deer density remains below 8 deer/km^2 and regeneration does begin to improve in coming years, then other measures, such as prescribed burning or mechanically opening canopy gaps could be considered. However, such measures will inevitably be limited in spatial extent.

Trends in Ecological Groups

Changes in the importance of the dominant ecological group of trees in the park may be less of a concern. The decline in early successional species, particularly Virginia pine is expected, given the age of the forests in the park. Further, this species is common on the greater Mid-Atlantic landscape and is expected to maintain or increase its range in the face of climate change over the next 100 years (Peters et al. 2020). Applying the RAD framework, the park may choose to accept the reduced importance of Virginia pine in the park forests, which requires no management response and therefore frees up resources to intervene in (i.e., resist or direct) changes that may be more ecologically meaningful.

How park managers should respond to the rise of the mesic species and the lack of oak-hickory regeneration is less clear. Oak dominated forests are uniquely important in supporting a wide variety of other plant and animal species. Acorns are a crucial food source for many vertebrates (Brose et al., 2014). Naragano et al. (2020), found that *Quercus* is the most important keystone genera in supporting Lepidoptera (butterfly and moth) diversity in North America. This is particularly troubling as the next most important genera are *Salix* and *Prunus*, which are not common in the park and *Pinus,* which is declining. Birds are more abundant in oak dominated forests than maple dominated forests, likely due to the greater food availability (Rodewald and Abrams, 2002). The diversity of herbaceous species is also affected by the overstory, with pure oak stands having significantly higher diversity than those with maples (Fralish 2004, Rogers et al. 2008).

Using the RAD framework, park managers should consider if actions should be taken to resist the loss of oak-hickory forests, or at least direct this change by promoting regeneration of oak-hickory forests in parts of the park. Prescribed fires are often recommended as a tool for promoting oak regeneration (Brose et al 2014), and the trends seen in regeneration in the burned plots support this. PRWI is unique in having large patches of forest that are at a distance from public view and that could offer spaces for park managers to implement forest management to promote resiliency. However, prescribed fires would have wide ranging effects, including impacts to the visitor experience, and should be considered within broader context of overall park management goals.

Pests and Diseases

Tree pests and diseases are sharply reducing the populations of some species in the park which is clearly an undesirable change. Unfortunately, little can be done to resist this change as many pest species are already established, and in most cases treatment options are limited. The park has already treated eastern hemlock stands for hemlock wooly adelgid. These stands should be monitored, and treatment should continue, to ensure that the adelgid does not become established.

Beech leaf disease is a particularly worrisome pest. There is currently no way to stop the spread of this disease in the park as there is no treatment for infected trees. As the beech canopy declines, many areas in the forest will receive increased light on the forest floor. While this could encourage the establishment of more seedlings, it could also lead to an increase in exotic invasive plants. As gaps are created, it will be important to continue monitoring vegetation and to take action as necessary to ensure that there is regeneration of desirable species and to manage any invasive plants. Management to increase regeneration and the use of prescribed fire could be important in this context, as without sufficient regeneration invasive plants will have more opportunities to become established.

Conclusions

In sum, by addressing current forest health issues, PRWI managers can promote resilience in park forests. By increasing resilience now, forests will be better able to respond to future stressors, which include a changing climate, and the park may have more management options when change does occur.

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Appendix A: Trend Results for Individual Species

Trend data by species

Trend analysis results for species not presented in the text.

Table A1. Statistical model results for trends in tree density. Trees/ha 2006 is the modeled density of each tree species in 2006 on unburned and burned plots. Percent change per year is the estimated percent increase or decrease. Darker shading and ** indicates a highly certain trend, lighter shading and a single * indicates a somewhat certain trend. Green shading and a plus sign (“+”) indicates an increasing trend; orange shading and a negative sign (“−”) indicates a decreasing trend. An em-dash (“—”) and no shading indicates that there is no evidence of a trend. For Burned (trees/ha) 2006, darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and a single * indicates a somewhat certain difference; “inc” indicates an increase while “dec” indicates a decrease compared to unburned plots. Species with insufficient data are indicated by “i.d.”

Species	Unburned (trees/ha) 2006	Unburned: % Change/yr	Burned (trees/ha) 2006	Burned: % Change/yr
Acer rubrum	48.0	+1%*	34.0	—
Carpinus caroliniana	1.0	+8%**	i.d.	i.d.
Carya alba	7.4	—	i.d.	i.d.
Carya glabra	11.0	—	i.d.	i.d.
Carya ovalis	1.7	—	i.d.	i.d.
Cornus florida	5.9	−4%**	i.d.	i.d.
Fagus grandifolia	69.0	+4%**	19.0**(dec)	+7%*
Fraxinus americana	1.3	—	i.d.	i.d.
Ilex opaca	10.0	+3%**	i.d.	i.d.
Juniperus virginiana	1.9	−6%*	i.d.	i.d.
Liquidambar styraciflua	4.0	+3%*	i.d.	i.d.
Liriodendron tulipifera	67.0	—	86.0	—
Nyssa sylvatica	34.0	+1%*	19.0	—
Pinus virginiana	81.0	−3%**	75.0	−5%*
Quercus alba	53.0	—	26.0*(dec)	—
Quercus coccinea	17.0	−2%*	15.0	−11%*
Quercus falcata	6.9	—	i.d.	i.d.
Quercus prinus	6.9	—	i.d.	i.d.
Quercus rubra	5.9	—	i.d.	i.d.
Quercus velutina	5.8	—	i.d.	i.d.
Sassafras albidum	0.9	+7%*	i.d.	i.d.

Table A2. Statistical model results for trends in tree basal area. Tree Basal Area (m²/ha) 2006 is the modeled basal area of each tree species in 2006 on unburned and burned plots. Percent change per year is the estimated percent increase or decrease. Darker shading and ** indicates a highly certain trend, lighter shading and a single * indicates a somewhat certain trend. Green shading with a plus sign ("+") indicates an increasing trend, orange shading with a negative sign ("−") indicates a decreasing trend. An em-dash ("—") and no shading indicates that there is no evidence of a trend. For Burned: Tree Basal Area (m²/ha) 2006, shading and symbology indicate the difference between burned and unburned plots. Species with insufficient data are indicated by "i.d."

Species	**Unburned: Tree Basal Area (m²/ha) 2006**	**Unburned: % Change/yr**	**Burned: Tree Basal area (m²/ha) 2006**	**Burned: % Change/yr**
Acer rubrum	1.20	+2%**	0.69	+4%**
Carpinus caroliniana	0.01	+6%**	i.d.	i.d.
Carya alba	0.20	+1%**	i.d.	i.d.
Carya glabra	0.44	+2%**	i.d.	i.d.
Carya ovalis	0.10	+2%**	i.d.	i.d.
Cornus florida	0.06	−1%*	i.d.	i.d.
Fagus grandifolia	1.50	+6%**	0.72	+10%**
Fraxinus americana	0.03	—	i.d.	i.d.
Ilex opaca	0.11	+4%**	i.d.	i.d.
Juniperus virginiana	0.03	—	i.d.	i.d.
Liquidambar styraciflua	0.07	+4%**	i.d.	i.d.
Liriodendron tulipifera	5.21	+2%**	5.80	+2%**
Nyssa sylvatica	0.69	+1%**	0.61	+4%**
Pinus virginiana	4.70	−3%**	6.20	−4%**
Quercus alba	4.20	+1%**	2.72	−2%**
Quercus coccinea	1.70	+1%**	1.10	—
Quercus falcata	0.48	+1%**	i.d.	i.d.
Quercus prinus	0.37	+2%**	i.d.	i.d.
Quercus rubra	0.38	+2%**	i.d.	i.d.
Quercus velutina	0.40	+1%*	i.d.	i.d.
Sassafras albidum	0.01	+3%**	i.d.	i.d.

Table A3. Statistical model results for trends in sapling density. Saplings/ha 2006 is the modeled density of each sapling species in 2006 on unburned and burned plots. Percent change per year is the estimated percent increase or decrease. Darker shading and ** indicates a highly certain trend, lighter shading and a single * indicates a somewhat certain trend. Green shading with a plus sign ("+") indicates an increasing trend, orange shading with a negative sign ("−") indicates a decreasing trend; "inc" indicates an increase while "dec" indicates a decrease compared to unburned plots. An em-dash ("—") and no shading indicates that there is no evidence of a trend. For Burned (saplings/ha) 2006, shading and symbology indicate the difference between burned and unburned plots. Species with insufficient data are indicated by "i.d."

Species	**Unburned (saplings/ha) 2006**	**Unburned: % Change/yr**	**Burned (saplings/ha) 2006**	**Burned: % Change/yr**
Acer rubrum	89.0	−6%**	70.0	—
Carpinus caroliniana	31.0	−4%*	i.d.	i.d.
Carya glabra	15.0	—	i.d.	i.d.
Cornus florida	54.0	−8%**	81.0	—
Fagus grandifolia	420.0	—	i.d.	i.d.
Ilex opaca	140.0	—	i.d.	i.d.
Liquidambar styraciflua	20.0	—	i.d.	i.d.
Nyssa sylvatica	200.0	−2%**	150.0	—
Quercus alba	120.0	—	420.0**(inc)	+18%**
Quercus coccinea	3.8	−10%*	44.0**(inc)	+32%**
Quercus falcata	22.0	−4%*	i.d.	i.d.
Quercus velutina	11.0	—	i.d.	i.d.
Sassafras albidum	17.0	−8%**	i.d.	i.d.

Table A4. Statistical model results for trends in sapling basal area. Sapling Basal Area (m^2/ha) 2006 is the modeled density of each sapling species in 2006 on unburned and burned plots. Percent change per year is the estimated percent increase or decrease. Darker shading and ** indicates a highly certain trend, lighter shading and a single * indicates a somewhat certain trend. Green shading and a plus sign ("+") indicates an increasing trend; orange shading and a negative sign ("−") indicates a decreasing trend. An em-dash ("—") and no shading indicates that there is no evidence of a trend. For Burned: Sapling Basal Area (m^2/ha) 2006, shading and symbology indicate the difference between burned and unburned plots; "inc" indicates an increase while "dec" indicates a decrease compared to unburned plots. Species with insufficient data are indicated by "i.d."

Species	**Unburned: Sapling Basal Area (m^2/ha) 2006**	**Unburned: % Change/yr**	**Burned: Sapling Basal area (m^2/ha) 2006**	**Burned: % Change/yr**
Acer rubrum	0.24	—	0.12	+10%**
Carpinus caroliniana	<0.01	+2%**	i.d.	i.d.
Carya glabra	<0.01	+1%*	i.d.	i.d.
Cornus florida	0.12	−4%**	0.12	—
Fagus grandifolia	0.59	+3%**	i.d.	i.d.
Ilex opaca	0.12	+5%**	i.d.	i.d.
Liquidambar styraciflua	<0.01	+3%*	i.d.	i.d.
Nyssa sylvatica	0.47	−1%*	0.47	—
Quercus alba	0.12	+3%**	<0.01**(dec)	+19%**
Quercus coccinea	<0.01	—	<0.01	+19%**
Quercus falcata	<0.01	+4%*	i.d.	i.d.
Quercus velutina	<0.01	+4%**	i.d.	i.d.
Sassafras albidum	<0.01	—	i.d.	i.d.

Table A5. Statistical model results for trends in seedling density. Seedlings/ha 2006 is the modeled density of each seedling species in 2006 on unburned and burned plots. Percent change per year is the estimated percent increase or decrease. Darker shading and ** indicates a highly certain trend, lighter shading and * indicates a somewhat certain trend. Green shading with a plus sign (“+”) indicates an increasing trend, orange shading with a negative sign (“−”) indicates a decreasing trend; “inc” indicates an increase while “dec” indicates a decrease compared to unburned plots. An em-dash (“—”) and no shading indicates that there is no evidence of a trend. Species with insufficient data are indicated by “i.d.”

Species	**Unburned (seedlings/ha) 2006**	**Unburned: % Change/yr**	**Burned (seedlings/ha) 2006**	**Burned: % Change/yr**
Acer rubrum	110	−12%**	360*(inc)	+21%**
Amelanchier arborea	92	—	i.d.	i.d.
Asimina triloba	430	—	i.d.	i.d.
Carpinus caroliniana	94	−5%*	1800*(inc)	+10%**
Carya alba	88	−15%**	i.d.	i.d.
Carya glabra	88	—	i.d.	i.d.
Fagus grandifolia	560	−5%**	i.d.	i.d.
Ilex opaca	850	—	440*(dec)	+12%*
Liquidambar styraciflua	120	−5%*	i.d.	i.d.
Nyssa sylvatica	60	+5%*	i.d.	i.d.
Pinus virginiana	50	—	500**(inc)	+18%**
Quercus alba	2100	−6%**	9000**(inc)	—
Quercus coccinea	110	−17%**	4800**(inc)	—
Quercus falcata	57	−9%**	760*(inc)	—
Quercus prinus	220	−8%*	i.d.	i.d.
Quercus velutina	120	−7%**	i.d.	i.d.
Sassafras albidum	53	—	i.d.	i.d.

Table A6. Statistical model results for browse rates of seedlings in burned and unburned plots. Percent browse is based on statistical modeling. Darker shading and ** indicates a highly certain difference between burned and unburned plots, lighter shading and a single * indicates a somewhat certain difference. Green shading indicates an increasing trend, orange shading indicates a decreasing trend; "inc" indicates an increase while "dec" indicates a decrease compared to unburned plots. Species with insufficient data are indicated by "i.d."

Species	**Unburned: % Browse**	**Burned: % Browse**
Acer rubrum	22%	<1%**(dec)
Amelanchier arborea	35%	i.d.
Asimina triloba	<1%	i.d.
Carpinus caroliniana	42%	43%
Carya alba	<1%	i.d.
Carya glabra	5%	i.d.
Fagus grandifolia	38%	i.d.
Ilex opaca	24%	0%**(dec)
Liquidambar styraciflua	17%	i.d.
Nyssa sylvatica	53%	i.d.
Pinus virginiana	16%	10%
Quercus alba	19%	0%**(dec)
Quercus coccinea	0%	4%*(inc)
Quercus falcata	19%	1%*(dec)
Quercus prinus	30%	i.d.
Quercus velutina	20%	i.d.
Sassafras albidum	14%	i.d.

Appendix B: Model Coefficient Tables

Model Coefficient Tables

Table B1. Tree density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients; Estimate is the estimate of the coefficient; Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Acer rubrum	Intercept	0.80	0.10	0.59	1.00	1.00
Acer rubrum	Year (centered)	0.01	0.01	−0.01	0.02	1.00
Acer rubrum	Fire	0.07	0.49	−0.87	1.04	1.00
Acer rubrum	Year (centered): Fire	0.02	0.04	−0.05	0.11	1.00
Acer rubrum	Random Plot Intercept SD	1.09	0.09	0.93	1.28	1.00
Carpinus caroliniana	Intercept	−6.04	1.02	−8.38	−4.39	1.00
Carpinus caroliniana	Year (centered)	0.07	0.04	−0.01	0.16	1.00
Carpinus caroliniana	Fire	2.12	1.92	−1.63	5.99	1.00
Carpinus caroliniana	Year (centered): Fire	−0.08	0.15	−0.38	0.22	1.00
Carpinus caroliniana	Random Plot Intercept SD	3.29	0.67	2.22	4.84	1.00
Cary alba	Intercept	−2.70	0.41	−3.59	−2.00	1.00
Cary alba	Year (centered)	−0.00	0.02	−0.04	0.04	1.00
Cary alba	Fire	−0.53	1.45	−3.48	2.25	1.00
Cary alba	Year (centered): Fire	0.08	0.15	-.0.20	0.38	1.00
Cary alba	Random Plot Intercept SD	2.59	0.36	1.97	3.40	1.00
Cary glabra	Intercept	−1.91	0.31	−2.57	−1.36	1.00
Cary glabra	Year (centered)	0.00	0.02	−0.03	0.03	1.00
Cary glabra	Fire	−0.89	1.29	−3.52	1.54	1.00
Cary glabra	Year (centered): Fire	0.04	0.10	−0.17	0.24	1.00
Cary glabra	Random Plot Intercept SD	2.29	0.29	1.80	2.93	1.00
Carya ovalis	Intercept	−6.24	1.21	−9.04	−4.36	1.00
Carya ovalis	Year (centered)	0.01	0.04	−0.07	0.08	1.00
Carya ovalis	Fire	−336.44	1070.72	−1454.67	−14.26	1.00
Carya ovalis	Year (centered): Fire	13.17	135.75	−73.66	107.38	1.00
Carya ovalis	Random Plot Intercept SD	3.65	0.81	2.39	5.54	1.00
Cornus florida	Intercept	−3.38	0.47	−4.40	−2.57	1.00
Cornus florida	Year (centered)	−0.04	0.02	−0.09	0.01	1.00
Cornus florida	Fire	−0.95	1.72	−4.57	2.24	1.00
Cornus florida	Year (centered): Fire	0.10	0.15	−0.19	0.40	1.00
Cornus florida	Random Plot Intercept SD	2.67	0.39	2.01	3.53	1.00

Table B1 (continued). Tree density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients; Estimate is the estimate of the coefficient; Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin’s (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Fagus grandifolia	Intercept	1.03	0.14	0.76	1.30	1.00
Fagus grandifolia	Year (centered)	0.04	0.01	0.02	0.05	1.00
Fagus grandifolia	Fire	−2.08	0.78	−3.66	−0.57	1.00
Fagus grandifolia	Year (centered): Fire	0.03	0.05	−0.07	0.14	1.00
Fagus grandifolia	Random Plot Intercept SD	1.50	0.12	1.28	1.76	1.00
Fraxinus americana	Intercept	−6.42	1.25	−9.34	−4.48	1.00
Fraxinus americana	Year (centered)	−0.00	0.04	−0.09	0.08	1.00
Fraxinus americana	Fire	−242.69	368.05	−1142.61	−13.78	1.00
Fraxinus americana	Year (centered): Fire	1.76	44.53	−74.89	83.56	1.00
Fraxinus americana	Random Plot Intercept SD	3.48	0.81	−9.34	−4.48	1.00
Ilex opaca	Intercept	−2.14	0.33	−2.84	−1.55	1.00
Ilex opaca	Year (centered)	0.03	0.02	0.00	0.06	1.00
Ilex opaca	Fire	−2.26	1.63	−5.75	0.70	1.00
Ilex opaca	Year (centered): Fire	0.01	0.20	−0.38	0.41	1.00
Ilex opaca	Random Plot Intercept SD	2.41	0.30	1.89	3.06	1.00
Juniperus virginiana	Intercept	−7.07	1.46	−10.49	−4.84	1.00
Juniperus virginiana	Year (centered)	−0.06	0.04	−0.14	0.02	1.00
Juniperus virginiana	Fire	−260.98	376.58	−1199.02	−14.33	1.00
Juniperus virginiana	Year (centered): Fire	−0.28	49.48	−87.31	85.54	1.00
Juniperus virginiana	Random Plot Intercept SD	3.86	0.92	2.47	6.06	1.00
Liquidambar styraciflua	Intercept	−7.00	1.34	−10.11	−4.90	1.00
Liquidambar styraciflua	Year (centered)	0.03	0.03	−0.02	0.08	1.00
Liquidambar styraciflua	Fire	−84.44	112.07	−386.44	−2.00	1.00
Liquidambar styraciflua	Year (centered): Fire	−15.80	20.08	−69.97	−0.79	1.00
Liquidambar styraciflua	Random Plot Intercept SD	4.32	0.89	2.94	6.40	1.00
Liriodendron tulipifera	Intercept	0.98	0.11	0.75	1.19	1.00
Liriodendron tulipifera	Year (centered)	−0.00	0.01	−0.01	0.01	1.00
Liriodendron tulipifera	Fire	0.58	0.52	−0.45	1.60	1.00
Liriodendron tulipifera	Year (centered): Fire	0.00	0.03	−0.05	0.06	1.00
Liriodendron tulipifera	Random Plot Intercept SD	1.21	0.10	1.04	1.42	1.00
Nyssa sylvatica	Intercept	0.41	0.12	0.17	0.63	1.00
Nyssa sylvatica	Year (centered)	0.01	0.01	−0.01	0.03	1.00
Nyssa sylvatica	Fire	−0.15	0.54	−1.22	0.92	1.00

Table B1 (continued). Tree density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients; Estimate is the estimate of the coefficient; Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Nyssa sylvatica	Year (centered): Fire	0.01	0.06	−0.10	0.12	1.00
Nyssa sylvatica	Random Plot Intercept SD	1.19	0.11	0.99	1.41	1.00
Pinus virginiana	Intercept	−0.62	0.31	−1.26	−0.05	1.00
Pinus virginiana	Year (centered)	−0.03	0.01	−0.05	−0.02	1.00
Pinus virginiana	Fire	−0.10	1.37	−2.84	2.26	1.00
Pinus virginiana	Year (centered): Fire	−0.02	0.04	−0.09	0.05	1.00
Pinus virginiana	Random Plot Intercept SD	2.94	0.29	2.43	3.56	1.00
Quercus alba	Intercept	0.68	0.13	0.42	0.93	1.00
Quercus alba	Year (centered)	−0.00	0.01	−0.02	0.01	1.00
Quercus alba	Fire	−0.91	0.65	−2.20	0.36	1.00
Quercus alba	Year (centered): Fire	−0.03	0.06	−0.14	0.08	1.00
Quercus alba	Random Plot Intercept SD	1.37	0.12	1.15	1.63	1.00
Quercus coccinea	Intercept	−1.91	0.33	−2.61	−1.32	1.00
Quercus coccinea	Year (centered)	−0.02	0.01	−0.04	0.01	1.00
Quercus coccinea	Fire	0.49	1.19	−1.84	2.85	1.00
Quercus coccinea	Year (centered): Fire	−0.10	0.09	−0.27	0.07	1.00
Quercus coccinea	Random Plot Intercept SD	2.51	0.30	2.00	3.15	1.00
Quercus falcata	Intercept	−3.15	0.47	−4.17	−2.34	1.00
Quercus falcata	Year (centered)	−0.00	0.02	−0.04	0.04	1.00
Quercus falcata	Fire	−1.29	1.83	−5.14	2.06	1.00
Quercus falcata	Year (centered): Fire	0.02	0.13	−0.24	0.29	1.00
Quercus falcata	Random Plot Intercept SD	2.83	0.40	2.14	3.71	1.00
Quercus prinus	Intercept	−8.00	1.67	−11.93	−5.45	1.00
Quercus prinus	Year (centered)	−0.00	0.02	−0.04	0.04	1.00
Quercus prinus	Fire	−306.64	457.98	−1518.26	−16.57	1.00
Quercus prinus	Year (centered): Fire	3.49	59.61	−94.57	117.31	1.00
Quercus prinus	Random Plot Intercept SD	5.19	1.11	3.50	7.80	1.00
Quercus rubra	Intercept	−3.39	0.51	−4.50	−2.52	1.00
Quercus rubra	Year (centered)	−0.00	0.02	−0.05	−0.04	1.00
Quercus rubra	Fire	−172.09	227.04	−757.64	−15.45	1.00
Quercus rubra	Year (centered): Fire	1.55	32.08	−50.08	57.28	1.00
Quercus rubra	Random Plot Intercept SD	2.84	0.43	2.12	3.80	1.00

Table B1 (continued). Tree density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients; Estimate is the estimate of the coefficient; Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Quercus velutina	Intercept	−2.72	0.38	−3.53	−2.05	1.00
Quercus velutina	Year (centered)	−0.02	0.02	−0.07	0.02	1.00
Quercus velutina	Fire	−2.90	2.12	−7.63	0.66	1.00
Quercus velutina	Year (centered): Fire	0.54	0.35	0.01	1.38	1.00
Quercus velutina	Random Plot Intercept SD	2.32	0.34	1.74	3.05	1.00
Sassafras albidum	Intercept	−4.75	0.74	−6.42	−3.55	1.00
Sassafras albidum	Year (centered)	0.06	0.04	−0.02	0.15	1.00
Sassafras albidum	Fire	−213.55	370.49	−990.56	−13.84	1.00
Sassafras albidum	Year (centered): Fire	1.32	49.08	−63.50	69.22	1.00
Sassafras albidum	Random Plot Intercept SD	2.58	0.52	−6.42	−3.55	1.00
All Trees	Intercept	3.45	0.03	3.39	3.50	1.00
All Trees	Year (centered)	0.00	0.00	−0.00	0.01	1.00
All Trees	Fire	−0.48	0.14	−0.77	−0.20	1.00
All Trees	Year (centered): Fire	0.00	0.02	−0.03	0.03	1.00
All Trees	Random Plot Intercept SD	0.31	0.02	0.28	0.36	1.00
Early Successional	Intercept	1.72	0.11	1.50	1.93	1.00
Early Successional	Year (centered)	−0.02	0.00	−0.03	−0.01	1.00
Early Successional	Fire	0.26	0.54	−0.80	1.31	1.00
Early Successional	Year (centered): Fire	−0.00	0.02	−0.05	0.04	1.00
Early Successional	Random Plot Intercept SD	1.25	0.09	1.09	1.44	1.00
Mesic	Intercept	2.42	0.05	2.31	2.52	1.00
Mesic	Year (centered)	0.02	0.00	0.01	0.03	1.00
Mesic	Fire	−0.73	0.27	−1.27	−0.19	1.00
Mesic	Year (centered): Fire	0.02	0.03	−0.04	0.07	1.00
Mesic	Random Plot Intercept SD	0.60	0.04	0.42	0.68	1.00
Non-Canopy	Intercept	−1.81	0.26	−2.37	−1.34	1.00
Non-Canopy	Year (centered)	0.00	0.02	−0.03	0.04	1.00
Non-Canopy	Fire	−0.32	1.06	−2.48	1.71	1.00
Non-Canopy	Year (centered): Fire	0.02	0.10	−0.17	0.22	1.00
Non-Canopy	Random Plot Intercept SD	1.95	0.23	1.54	2.46	1.00
Oak Hickory	Intercept	1.86	0.08	1.70	2.02	1.00
Oak Hickory	Year (centered)	−0.01	0.01	−0.02	0.00	1.00
Oak Hickory	Fire	−0.92	0.41	−1.74	−0.11	1.00

Table B1 (continued). Tree density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients; Estimate is the estimate of the coefficient; Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Oak Hickory	Year (centered): Fire	−0.01	0.04	−0.08	0.06	1.00
Oak Hickory	Random Plot Intercept SD	0.90	0.07	0.78	1.05	1.00

Table B2a. Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Acer rubrum	Intercept	−2.76	0.11	−2.96	−2.55	1.02
Acer rubrum	Year (centered)	0.02	0.00	0.01	0.02	1.00
Acer rubrum	Fire	−0.14	0.50	−1.12	0.83	1.00
Acer rubrum	Year (centered): Fire	0.02	0.01	−0.00	0.04	1.00
Acer rubrum	Shape	51.9	4.73	4309	61.57	1.00
Acer rubrum	Hu	0.16	0.02	0.12	0.19	1.00
Acer rubrum	Random Plot Intercept SD	1.19	0.08	1.05	1.35	1.00
Carpinus caroliniana	Intercept	−4.29	0.22	−4.73	−3.86	1.00
Carpinus caroliniana	Year (centered)	0.06	0.02	0.02	0.09	1.00
Carpinus caroliniana	Fire	0.03	0.64	−1.22	1.30	1.00
Carpinus caroliniana	Year (centered): Fire	0.03	0.05	−0.07	0.13	1.00
Carpinus caroliniana	Shape	12.78	4.18	6.01	22.21	1.00
Carpinus caroliniana	Hu	0.92	0.01	0.89	0.94	1.00
Carpinus caroliniana	Random Plot Intercept SD	0.77	0.17	0.51	1.18	1.00
Cary alba	Intercept	−3.22	0.16	−3.54	−2.90	1.00
Cary alba	Year (centered)	0.01	0.00	0.01	0.02	1.00
Cary alba	Fire	−0.99	0.81	−2.57	0.59	1.00
Cary alba	Year (centered): Fire	0.03	0.01	0.01	0.06	1.00
Cary alba	Shape	175.23	26.85	126.68	232.42	1.00
Cary alba	Hu	0.69	0.02	0.65	0.73	1.00
Cary alba	Random Plot Intercept SD	1.10	0.12	0.90	1.38	1.00

Table B2a (continued). Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Cary glabra	Intercept	−2.80	0.17	−3.13	−2.47	1.00
Cary glabra	Year (centered)	0.02	0.00	0.01	0.02	1.00
Cary glabra	Fire	−0.93	0.92	−2.74	0.89	1.00
Cary glabra	Year (centered): Fire	0.01	0.02	−0.02	0.04	1.00
Cary glabra	Shape	137.04	18.57	102.97	175.81	1.00
Cary glabra	Hu	0.61	0.02	0.56	0.65	1.00
Cary glabra	Random Plot Intercept SD	1.26	0.12	1.05	1.53	1.00
Carya ovalis	Intercept	−2.76	0.34	−3.43	−2.07	1.00
Carya ovalis	Year (centered)	0.02	0.00	0.01	0.03	1.00
Carya ovalis	Fire	24.83	95.21	−147.18	239.05	1.00
Carya ovalis	Year (centered): Fire	−3.53	76.52	−131.88	124.50	1.00
Carya ovalis	Shape	147.24	38.78	81.81	231.66	1.00
Carya ovalis	Hu	0.90	0.01	0.87	0.92	1.00
Carya ovalis	Random Plot Intercept SD	1.31	0.28	0.89	1.97	1.00
Cornus florida	Intercept	−4.12	0.12	−4.35	−3.88	1.00
Cornus florida	Year (centered)	−0.02	0.01	−0.03	0.00	1.00
Cornus florida	Fire	0.20	0.73	−1.24	1.65	1.00
Cornus florida	Year (centered): Fire	0.11	0.05	0.01	0.20	1.00
Cornus florida	Shape	16.44	3.37	10.53	23.66	1.00
Cornus florida	Hu	0.80	0.02	0.76	0.84	1.00
Cornus florida	Random Plot Intercept SD	0.69	0.09	−4.35	−3.88	1.00
Fraxinus americana	Intercept	−3.73	0.27	−4.27	−3.20	1.00
Fraxinus americana	Year (centered)	−0.01	0.02	−0.05	0.03	1.00
Fraxinus americana	Fire	48.84	107.25	−130.98	254.79	1.00
Fraxinus americana	Year (centered): Fire	−4.16	80.80	−138.93	129.27	1.00
Fraxinus americana	Shape	9.03	2.85	4.31	15.36	1.00
Fraxinus americana	Hu	0.92	0.01	0.90	0.95	1.00
Fraxinus americana	Random Plot Intercept SD	0.91	0.22	0.58	1.46	1.00
Ilex opaca	Intercept	−3.85	0.12	−4.08	−3.61	1.00
Ilex opaca	Year (centered)	0.04	0.00	0.03	0.05	1.00
Ilex opaca	Fire	−0.15	0.89	−1.91	1.60	1.00
Ilex opaca	Year (centered): Fire	−0.01	0.03	−0.07	0.05	1.00
Ilex opaca	Shape	35.97	5.28	26.33	47.05	1.00

Table B2a (continued). Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Ilex opaca	Hu	0.65	0.02	0.61	0.70	1.00
Ilex opaca	Random Plot Intercept SD	0.87	0.09	0.72	1.07	1.00
Juniperus virginiana	Intercept	−3.49	0.28	−4.03	−2.95	1.00
Juniperus virginiana	Year (centered)	0.00	0.01	−0.02	0.02	1.00
Juniperus virginiana	Fire	45.05	110.88	−132.71	269.23	1.00
Juniperus virginiana	Year (centered): Fire	−4.20	79.70	−137.37	129.33	1.00
Juniperus virginiana	Shape	47.04	16.17	20.88	83.42	1.00
Juniperus virginiana	Hu	0.93	0.01	0.90	0.95	1.00
Juniperus virginiana	Random Plot Intercept SD	0.91	0.23	0.59	1.48	1.00
Liquidambar styraciflua	Intercept	−2.99	0.41	−3.80	−2.19	1.00
Liquidambar styraciflua	Year (centered)	0.04	0.01	0.02	0.05	1.00
Liquidambar styraciflua	Fire	17.26	88.92	−162.36	201.77	1.00
Liquidambar styraciflua	Year (centered): Fire	3.18	15.89	−28.95	36.17	1.00
Liquidambar styraciflua	Shape	81.01	22.98	42.41	131.63	1.00
Liquidambar styraciflua	Hu	0.90	0.01	0.87	0.93	1.00
Liquidambar styraciflua	Random Plot Intercept SD	1.54	0.32	1.06	2.29	1.00
Liriodendron tulipifera	Intercept	−1.17	0.11	−1.39	−0.97	1.01
Liriodendron tulipifera	Year (centered)	0.02	0.00	0.02	0.02	1.00
Liriodendron tulipifera	Fire	0.24	0.49	−0.71	1.20	1.00
Liriodendron tulipifera	Year (centered): Fire	0.00	0.01	−0.01	0.01	1.00
Liriodendron tulipifera	Shape	134.11	12.10	111.57	158.94	1.00
Liriodendron tulipifera	Hu	0.15	0.02	0.12	0.18	1.00
Liriodendron tulipifera	Random Plot Intercept SD	1.15	0.08	1.02	1.32	1.00
Nyssa sylvatica	Intercept	−3.05	0.10	−3.24	−2.87	1.00
Nyssa sylvatica	Year (centered)	0.01	0.00	0.01	0.02	1.00
Nyssa sylvatica	Fire	−0.12	0.43	−0.96	0.73	1.00
Nyssa sylvatica	Year (centered): Fire	0.03	0.01	0.00	0.05	1.00
Nyssa sylvatica	Shape	47.75	4.60	39.17	57.23	1.00
Nyssa sylvatica	Hu	0.24	0.02	0.20	0.28	1.00
Nyssa sylvatica	Random Plot Intercept SD	1.01	0.07	0.89	1.15	1.00
Pinus virginiana	Intercept	−0.93	0.13	−1.19	−0.67	1.00
Pinus virginiana	Year (centered)	−0.03	0.00	−0.04	−0.02	1.00
Pinus virginiana	Fire	0.52	0.70	−0.86	1.89	1.00

Table B2a (continued). Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Pinus virginiana	Year (centered): Fire	−0.01	0.02	−0.06	0.03	1.00
Pinus virginiana	Shape	23.07	2.62	18.23	28.50	1.00
Pinus virginiana	Hu	0.46	0.02	0.41	0.50	1.00
Pinus virginiana	Random Plot Intercept SD	1.16	0.09	0.99	1.36	1.00
Quercus alba	Intercept	−1.36	0.11	−1.57	−1.14	1.01
Quercus alba	Year (centered)	0.01	0.00	0.01	0.01	1.00
Quercus alba	Fire	−0.34	0.60	−1.52	0.85	1.00
Quercus alba	Year (centered): Fire	−0.03	0.01	−0.05	−0.02	1.00
Quercus alba	Shape	164.47	15.86	134.73	196.79	1.00
Quercus alba	Hu	0.23	0.02	0.19	0.27	1.00
Quercus alba	Random Plot Intercept SD	1.18	0.08	1.03	.35	1.00
Quercus coccinea	Intercept	−1.38	0.16	−1.70	−1.05	1.00
Quercus coccinea	Year (centered)	0.01	0.01	−0.00	0.02	1.00
Quercus coccinea	Fire	−0.55	0.65	−1.83	0.72	1.00
Quercus coccinea	Year (centered): Fire	0.02	0.03	−0.05	0.08	1.00
Quercus coccinea	Shape	22.93	3.11	17.22	29.43	1.00
Quercus coccinea	Hu	0.61	0.02	0.56	0.65	1.00
Quercus coccinea	Random Plot Intercept SD	1.24	0.12	1.03	1.49	1.00
Quercus falcata	Intercept	−2.24	0.22	−2.66	−1.81	1.00
Quercus falcata	Year (centered)	0.01	0.00	0.01	0.02	1.00
Quercus falcata	Fire	−0.48	1.39	−3.17	2.25	1.00
Quercus falcata	Year (centered): Fire	0.01	0.02	−0.03	0.04	1.00
Quercus falcata	Shape	99.22	16.54	69.45	134.30	1.00
Quercus falcata	Hu	0.73	0.02	0.69	0.77	1.00
Quercus falcata	Random Plot Intercept SD	1.36	0.16	1.08	1.71	1.00
Quercus prinus	Intercept	−1.49	0.47	−2.44	−0.47	1.00
Quercus prinus	Year (centered)	0.02	0.00	0.01	0.02	1.00
Quercus prinus	Fire	−2.57	105.52	−175.79	−224.54	1.00
Quercus prinus	Year (centered): Fire	−3.35	74.80	−129.27	121.30	1.00
Quercus prinus	Shape	176.40	46.51	97.02	278.10	1.00
Quercus prinus	Hu	0.89	0.01	0.86	0.92	1.00
Quercus prinus	Random Plot Intercept SD	1.80	0.36	1.25	2.65	1.00

Table B2a (continued). Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Constant Occupancy.

Species	**Coefficient**	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Quercus rubra	Intercept	−2.36	0.27	−2.89	−1.84	1.00
Quercus rubra	Year (centered)	0.02	0.00	0.01	0.03	1.00
Quercus rubra	Fire	16.89	101.33	−158.10	235.67	1.00
Quercus rubra	Year (centered): Fire	−3.93	75.77	−132.06	121.61	1.00
Quercus rubra	Shape	66.27	11.69	45.44	90.68	1.00
Quercus rubra	Hu	0.77	0.02	0.73	0.81	1.00
Quercus rubra	Random Plot Intercept SD	1.56	0.19	1.24	1.99	1.00
Quercus velutina	Intercept	−2.42	0.18	−2.77	−2.07	1.00
Quercus velutina	Year (centered)	0.01	0.01	−0.01	0.02	1.00
Quercus velutina	Fire	−2.61	1.23	−5.03	−0.18	1.00
Quercus velutina	Year (centered): Fire	0.22	0.08	0.06	0.38	1.00
Quercus velutina	Shape	20.31	3.46	14.14	27.69	1.00
Quercus velutina	Hu	0.73	0.02	0.69	0.77	1.00
Quercus velutina	Random Plot Intercept SD	1.17	0.13	0.95	1.47	1.00
All Trees	Intercept	0.66	0.03	0.61	0.71	1.00
All Trees	Year (centered)	0.01	0.00	0.00	0.01	1.00
All Trees	Fire	−0.49	0.12	−0.73	−0.24	1.00
All Trees	Year (centered): Fire	−0.02	0.01	−0.04	−0.01	1.00
All Trees	Shape	145.86	12.04	123.18	170.37	1.00
All Trees	Hu	0.00	0.00	0.00	0.01	1.00
All Trees	Random Plot Intercept SD	0.29	0.02	0.26	0.33	1.00
Early Successional	Intercept	−0.51	0.09	−0.68	−0.32	1.01
Early Successional	Year (centered)	−0.00	0.00	−0.00	0.00	1.00
Early Successional	Fire	0.06	0.43	−0.78	0.90	1.00
Early Successional	Year (centered): Fire	0.00	0.01	−0.01	0.02	1.00
Early Successional	Shape	93.40	8.08	78.45	110.08	1.00
Early Successional	Hu	0.07	0.01	0.05	0.10	1.00
Early Successional	Random Plot Intercept SD	1.02	0.06	0.90	1.16	1.01
Mesic	Intercept	−1.36	0.08	−1.51	−1.21	1.01
Mesic	Year (centered)	0.03	0.00	0.03	0.04	1.00
Mesic	Fire	−0.70	0.37	−1.43	0.02	1.00
Mesic	Year (centered): Fire	−0.01	0.01	−0.03	0.01	1.00
Mesic	Shape	43.20	3.59	36.47	50.51	1.00

Table B2a (continued). Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin’s (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Mesic	Hu	0.00	0.00	0.00	0.01	1.00
Mesic	Random Plot Intercept SD	0.88	0.05	0.79	0.99	1.00
Non-Canopy	Intercept	−4.11	0.09	−4.29	−3.93	1.00
Non-Canopy	Year (centered)	0.01	0.01	−0.041	0.02	1.00
Non-Canopy	Fire	0.00	0.51	−1.00	1.00	1.00
Non-Canopy	Year (centered): Fire	0.04	0.03	−0.02	0.10	1.00
Non-Canopy	Shape	15.21	2.37	10.93	20.20	1.00
Non-Canopy	Hu	0.67	0.02	0.62	0.71	1.00
Non-Canopy	Random Plot Intercept SD	0.69	0.07	0.57	0.84	1.00
Oak Hickory	Intercept	−0.56	0.11	−0.77	−0.34	1.01
Oak Hickory	Year (centered)	0.01	0.00	0.00	0.01	1.00
Oak Hickory	Fire	−1.12	0.54	−2.17	−0.06	1.00
Oak Hickory	Year (centered): Fire	−0.03	0.01	−0.06	−0.01	1.00
Oak Hickory	Shape	39.02	3.36	32.70	45.88	1.00
Oak Hickory	Hu	0.06	0.01	0.04	0.08	1.00
Oak Hickory	Random Plot Intercept SD	1.18	0.07	1.05	1.33	1.00

Table B2b. Tree Basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle Gamma distribution, Non-Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Fagus grandifolia	Intercept	−2.26	0.12	−2.50	−2.03	1.01
Fagus grandifolia	Year (centered)	0.06	0.00	0.05	0.06	1.00
Fagus grandifolia	Fire	−0.09	0.91	−1.89	1.68	1.00
Fagus grandifolia	Year (centered): Fire	0.04	0.02	−0.01	0.09	1.00
Fagus grandifolia	Shape	29.96	2.83	24.63	35.72	1.00
Fagus grandifolia	hu Intercept	−1.28	0.12	−1.51	−1.05	1.00
Fagus grandifolia	hu: Year(centered)	−0.07	0.03	−0.13	−0.00	1.00
Fagus grandifolia	Random Plot Intercept SD	1.28	0.08	1.12	1.46	1.00
Sassafras albidum	Intercept	−4.40	0.13	−4.66	−4.14	1.00
Sassafras albidum	Year (centered)	0.03	0.01	0.00	0.05	1.00
Sassafras albidum	Fire	62.68	97.26	−111.12	266.08	1.00
Sassafras albidum	Year (centered): Fire	−4.07	81.71	−139.61	131.67	1.00
Sassafras albidum	Shape	26.55	8.49	12.56	45.25	1.00
Sassafras albidum	hu Intercept	2.32	0.17	1.99	2.67	1.00
Sassafras albidum	hu: Year(centered)	−0.08	0.05	−0.18	0.01	1.00
Sassafras albidum	Random Plot Intercept SD	0.53	0.11	0.36	0.79	1.00

Table B3. Sapling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Acer rubrum	Intercept	−1.51	0.22	−1.98	−1.10	1.00
Acer rubrum	Year (centered)	−0.06	0.02	−0.10	−0.02	1.00
Acer rubrum	Fire	0.76	0.81	−0.84	2.35	1.00
Acer rubrum	Year (centered): Fire	0.14	0.08	−0.02	0.29	1.00
Acer rubrum	Random Plot Intercept SD	1.69	0.20	1.32	2.13	1.00
Carpinus caroliniana	Intercept	−6.38	1.11	−8.90	−4.59	1.00
Carpinus caroliniana	Year (centered)	−0.04	0.03	−0.10	0.02	1.00
Carpinus caroliniana	Fire	0.10	2.55	−5.13	4.92	1.00
Carpinus caroliniana	Year (centered): Fire	0.36	0.20	0.02	0.82	1.00
Carpinus caroliniana	Random Plot Intercept SD	3.85	0.75	2.64	5.57	1.00
Cary glabra	Intercept	−6.12	1.07	−8.58	−4.41	1.00
Cary glabra	Year (centered)	−0.02	0.04	−0.10	0.05	1.00
Cary glabra	Fire	3.14	1.87	−0.34	7.04	1.00
Cary glabra	Year (centered): Fire	0.23	0.14	−0.02	0.53	1.00
Cary glabra	Random Plot Intercept SD	3.47	0.70	2.35	5.10	1.00
Cornus florida	Intercept	−2.25	0.29	−2.88	−1.74	1.00
Cornus florida	Year (centered)	−0.09	0.02	−0.13	−0.04	1.00
Cornus florida	Fire	0.32	1.01	−1.72	2.26	1.00
Cornus florida	Year (centered): Fire	0.10	0.08	−0.06	0.27	1.00
Cornus florida	Random Plot Intercept SD	1.87	0.26	1.42	2.44	1.00
Fagus grandifolia	Intercept	0.77	0.12	0.53	0.99	1.00
Fagus grandifolia	Year (centered)	0.00	0.01	−0.01	0.02	1.00
Fagus grandifolia	Fire	−2.63	0.76	−4.20	−1.19	1.00
Fagus grandifolia	Year (centered): Fire	0.03	0.11	−0.17	0.24	1.00
Fagus grandifolia	Random Plot Intercept SD	1.23	0.11	1.04	1.46	1.00
Ilex opaca	Intercept	−1.35	0.28	−1.95	−0.85	1.00
Ilex opaca	Year (centered)	0.01	0.01	−0.01	0.04	1.00
Ilex opaca	Fire	−3.84	1.91	−8.08	−0.56	1.00
Ilex opaca	Year (centered): Fire	0.31	0.33	−0.23	1.08	1.00
Ilex opaca	Random Plot Intercept SD	2.29	0.27	1.83	2.87	1.00
Liquidambar styraciflua	Intercept	−8.68	1.89	−13.17	−5.84	1.00
Liquidambar styraciflua	Year (centered)	−0.02	0.04	−0.09	0.05	1.00
Liquidambar styraciflua	Fire	1.08	3.26	−5.60	7.47	1.00
Liquidambar styraciflua	Year (centered): Fire	0.27	0.30	−0.25	0.95	1.00

Table B3 (continued). Sapling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	**Coefficient**	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Liquidambar styraciflua	Random Plot Intercept SD	4.68	1.12	2.99	7.35	1.00
Nyssa sylvatica	Intercept	−0.39	0.17	−0.73	−0.08	1.00
Nyssa sylvatica	Year (centered)	−0.02	0.01	−0.05	0.00	1.00
Nyssa sylvatica	Fire	−0.14	0.75	−1.61	1.35	1.00
Nyssa sylvatica	Year (centered): Fire	0.03	0.06	−0.10	0.15	1.00
Nyssa sylvatica	Random Plot Intercept SD	1.57	0.16	1.29	1.90	1.00
Quercus alba	Intercept	−5.23	0.83	−7.06	−3.83	1.00
Quercus alba	Year (centered)	−0.01	0.01	−0.04	0.02	1.00
Quercus alba	Fire	5.73	1.90	2.20	9.74	1.10
Quercus alba	Year (centered): Fire	0.18	0.03	0.12	0.24	1.00
Quercus alba	Random Plot Intercept SD	4.08	0.62	3.04	5.48	1.00
Quercus coccinea	Intercept	−8.32	1.82	−12.64	−5.63	1.00
Quercus coccinea	Year (centered)	−0.11	0.09	−0.28	0.05	1.00
Quercus coccinea	Fire	6.40	2.19	2.83	11.39	1.00
Quercus coccinea	Year (centered): Fire	0.39	0.11	0.18	0.62	1.00
Quercus coccinea	Random Plot Intercept SD	3.53	0.95	2.12	5.77	1.00
Quercus falcata	Intercept	−6.79	1.23	−9.64	−4.87	1.00
Quercus falcata	Year (centered)	−0.04	0.03	−0.11	0.02	1.00
Quercus falcata	Fire	3.60	2.07	−0.17	8.03	1.00
Quercus falcata	Year (centered): Fire	0.19	0.15	−0.08	0.50	1.00
Quercus falcata	Random Plot Intercept SD	3.72	0.77	2.52	5.50	1.00
Quercus velutina	Intercept	−7.37	1.47	−10.83	−5.12	1.00
Quercus velutina	Year (centered)	−0.05	0.05	−0.14	0.05	1.00
Quercus velutina	Fire	3.69	2.15	−0.29	8.26	1.00
Quercus velutina	Year (centered): Fire	0.09	0.12	−0.15	0.34	1.00
Quercus velutina	Random Plot Intercept SD	3.67	0.87	2.34	5.71	1.00
Sassafras albidum	Intercept	−5.72	1.02	−8.06	−4.11	1.00
Sassafras albidum	Year (centered)	−0.08	0.04	−0.16	−0.00	1.00
Sassafras albidum	Fire	−217.28	284.65	−1014.84	−14.06	1.00
Sassafras albidum	Year (centered): Fire	0.88	37.84	−70.24	73.19	1.00
Sassafras albidum	Random Plot Intercept SD	3.23	0.69	2.14	4.82	1.00
All Trees	Intercept	2.13	0.06	2.02	2.24	1.00
All Trees	Year (centered)	−0.02	0.00	−0.02	−0.01	1.00

Table B3 (continued). Sapling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
All Trees	Fire	0.35	0.27	−0.19	0.88	1.00
All Trees	Year (centered): Fire	0.16	0.02	0.12	0.20	1.00
All Trees	Random Plot Intercept SD	0.63	0.04	0.55	0.72	1.00
Early Successional	Intercept	−5.09	0.80	−6.89	−3.77	1.00
Early Successional	Year (centered)	−0.04	0.03	−0.10	0.01	1.00
Early Successional	Fire	−1.11	2.27	−5.89	3.09	1.00
Early Successional	Year (centered): Fire	0.67	0.25	0.28	1.25	1.00
Early Successional	Random Plot Intercept SD	3.43	0.59	2.45	4.78	1.00
Mesic	Intercept	1.84	0.06	1.72	1.95	1.00
Mesic	Year (centered)	−0.01	0.01	−0.02	0.00	1.00
Mesic	Fire	−0.96	0.30	−1.56	−0.37	1.00
Mesic	Year (centered): Fire	0.05	0.04	−0.03	0.13	1.00
Mesic	Random Plot Intercept SD	0.61	0.05	0.53	0.71	1.00
Non-Canopy	Intercept	−1.19	0.20	−1.60	−0.83	1.00
Non-Canopy	Year (centered)	−0.06	0.02	−0.09	−0.02	1.00
Non-Canopy	Fire	0.82	0.74	−0.65	2.29	1.00
Non-Canopy	Year (centered): Fire	0.17	0.07	0.05	0.31	1.00
Non-Canopy	Random Plot Intercept SD	1.59	0.18	1.28	1.97	1.00
Oak Hickory	Intercept	−3.49	0.55	−4.68	−2.53	1.00
Oak Hickory	Year (centered)	−0.02	0.01	−0.04	0.00	1.00
Oak Hickory	Fire	4.56	1.60	1.51	7.81	1.00
Oak Hickory	Year (centered): Fire	0.20	0.03	0.15	0.25	1.00
Oak Hickory	Random Plot Intercept SD	3.61	0.46	2.81	4.63	1.00

Table B4a. Sapling basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Cary glabra	Intercept	−5.94	0.30	−6.52	−5.34	1.00
Cary glabra	Year (centered)	0.01	0.01	−0.01	0.04	1.00
Cary glabra	Fire	−2.30	0.70	−3.70	−0.93	1.00
Cary glabra	Year (centered): Fire	0.13	0.04	0.05	0.21	1.00
Cary glabra	Shape	19.40	5.25	10.55	31.09	1.00
Cary glabra	Hu	0.89	0.01	0.86	0.92	1.00
Cary glabra	Random Plot Intercept SD	1.07	0.22	0.73	1.59	1.00
Cornus florida	Intercept	−5.81	0.11	−6.02	−5.60	1.00
Cornus florida	Year (centered)	−0.04	0.01	−0.06	−0.02	1.00
Cornus florida	Fire	0.54	0.53	−0.50	1.59	1.00
Cornus florida	Year (centered): Fire	0.06	0.05	−0.04	0.15	1.00
Cornus florida	Shape	6.91	1.10	4.90	9.23	1.00
Cornus florida	Hu	0.70	0.02	0.66	0.74	1.00
Cornus florida	Random Plot Intercept SD	0.69	0.08	0.54	0.86	1.00
Fagus grandifolia	Intercept	−5.25	0.10	−5.45	−5.04	1.00
Fagus grandifolia	Year (centered)	0.03	0.01	0.02	0.04	1.00
Fagus grandifolia	Fire	−1.33	0.82	−2.94	0.27	1.00
Fagus grandifolia	Year (centered): Fire	−0.06	0.07	−0.20	0.08	1.00
Fagus grandifolia	Shape	6.85	0.64	5.64	8.17	1.00
Fagus grandifolia	Hu	0.22	0.02	0.19	0.26	1.00
Fagus grandifolia	Random Plot Intercept SD	1.06	0.08	0.92	1.22	1.00
Ilex opaca	Intercept	−6.02	0.18	−6.37	−5.67	1.00
Ilex opaca	Year (centered)	0.05	0.01	0.04	0.06	1.00
Ilex opaca	Fire	−3.55	1.52	−6.53	−0.56	1.00
Ilex opaca	Year (centered): Fire	0.52	0.12	0.29	0.75	1.00
Ilex opaca	Shape	9.97	1.22	7.73	12.50	1.00
Ilex opaca	Hu	0.55	0.02	0.50	0.60	1.00
Ilex opaca	Random Plot Intercept SD	1.45	0.13	1.22	1.74	1.00
Liquidambar styraciflua	Intercept	−6.28	0.50	−7.24	−5.24	1.00
Liquidambar styraciflua	Year (centered)	0.03	0.02	−0.01	0.06	1.00
Liquidambar styraciflua	Fire	−0.85	1.56	−4.03	2.22	1.00
Liquidambar styraciflua	Year (centered): Fire	0.56	0.12	0.33	0.79	1.00
Liquidambar styraciflua	Shape	11.33	3.83	5.14	19.98	1.00

Table B4a (continued). Sapling basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Liquidambar styraciflua	Hu	0.93	0.01	0.91	0.95	1.00
Liquidambar styraciflua	Random Plot Intercept SD	1.41	0.42	0.84	2.46	1.00
Nyssa sylvatica	Intercept	−5.35	0.11	−5.56	−5.14	1.00
Nyssa sylvatica	Year (centered)	−0.01	0.01	−0.02	0.00	1.00
Nyssa sylvatica	Fire	−0.20	0.52	−1.22	0.82	1.00
Nyssa sylvatica	Year (centered): Fire	−0.01	0.03	−0.07	0.05	1.00
Nyssa sylvatica	Shape	12.76	1.39	10.19	15.63	1.00
Nyssa sylvatica	Hu	0.41	0.02	0.36	0.45	1.00
Nyssa sylvatica	Random Plot Intercept SD	1.00	0.08	0.86	1.16	1.00
Quercus alba	Intercept	−5.66	0.21	−6.07	−5.25	1.00
Quercus alba	Year (centered)	0.03	0.01	0.00	0.06	1.00
Quercus alba	Fire	−0.44	0.52	−1.46	0.58	1.00
Quercus alba	Year (centered): Fire	0.14	0.04	0.06	0.23	1.00
Quercus alba	Shape	7.86	1.56	5.11	11.21	1.00
Quercus alba	Hu	0.81	0.02	0.78	0.85	1.00
Quercus alba	Random Plot Intercept SD	1.01	0.15	0.76	1.35	1.00
Quercus coccinea	Intercept	−7.04	0.84	−8.59	−5.26	1.00
Quercus coccinea	Year (centered)	0.06	0.07	−0.07	0.20	1.00
Quercus coccinea	Fire	0.34	1.32	−2.41	2.89	1.00
Quercus coccinea	Year (centered): Fire	0.12	0.11	−0.11	0.35	1.00
Quercus coccinea	Shape	3.75	1.80	1.10	8.01	1.00
Quercus coccinea	Hu	0.96	0.01	0.94	0.97	1.00
Quercus coccinea	Random Plot Intercept SD	1.62	0.63	0.76	3.20	1.00
Quercus falcata	Intercept	−6.63	0.43	−7.47	−5.77	1.00
Quercus falcata	Year (centered)	0.03	0.03	−0.01	0.08	1.00
Quercus falcata	Fire	−1.39	0.96	−3.32	0.50	1.00
Quercus falcata	Year (centered): Fire	0.02	0.07	−0.12	0.15	1.00
Quercus falcata	Shape	7.18	2.35	3.36	12.50	1.00
Quercus falcata	Hu	0.92	0.01	0.89	0.94	1.00
Quercus falcata	Random Plot Intercept SD	1.41	0.32	0.93	2.17	1.00
Quercus velutina	Intercept	−6.04	0.49	−6.99	−5.02	1.00
Quercus velutina	Year (centered)	0.04	0.02	0.01	0.07	1.00
Quercus velutina	Fire	−0.18	1.16	−2.56	2.10	1.00

Table B4a (continued). Sapling basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle gamma distribution, Constant Occupancy.

Species	**Coefficient**	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Quercus velutina	Year (centered): Fire	0.09	0.03	0.02	0.15	1.00
Quercus velutina	Shape	24.07	8.70	10.17	43.86	1.00
Quercus velutina	Hu	0.93	0.01	0.91	0.96	1.00
Quercus velutina	Random Plot Intercept SD	1.42	0.39	0.87	2.38	1.00
Sassafras albidum	Intercept	−5.51	0.20	−5.91	−5.11	1.00
Sassafras albidum	Year (centered)	0.00	0.01	−0.02	0.03	1.00
Sassafras albidum	Fire	92.70	104.22	−81.80	313.49	1.00
Sassafras albidum	Year (centered): Fire	−5.57	85.43	−147.77	136.69	1.00
Sassafras albidum	Shape	18.58	5.47	9.43	30.66	1.00
Sassafras albidum	Hu	0.91	0.01	9.43	30.66	1.00
Sassafras albidum	Random Plot Intercept SD	0.69	0.04	0.61	0.78	1.00
All Trees	Intercept	−4.14	0.06	−4.26	−4.02	1.00
All Trees	Year (centered)	−0.00	0.00	−0.01	0.00	1.00
All Trees	Fire	−0.18	0.30	−0.77	0.40	1.00
All Trees	Year (centered): Fire	0.10	0.03	0.05	0.15	1.00
All Trees	Shape	11.27	0.93	9.52	13.17	1.00
All Trees	Hu	0.01	0.03	0.05	0.15	1.00
All Trees	Random Plot Intercept SD	0.69	0.04	0.61	0.78	1.00
Early Successional	Intercept	−5.86	0.21	−6.29	−5.44	1.00
Early Successional	Year (centered)	0.00	0.01	−0.03	0.03	1.00
Early Successional	Fire	−0.75	1.04	−2.80	1.33	1.00
Early Successional	Year (centered): Fire	0.92	0.12	0.68	1.16	1.00
Early Successional	Shape	9.68	2.24	5.82	14.55	1.00
Early Successional	Hu	0.86	0.02	0.82	0.89	1.00
Early Successional	Random Plot Intercept SD	0.98	0.17	0.71	1.37	1.00
Mesic	Intercept	−4.43	0.07	−4.57	−4.30	1.00
Mesic	Year (centered)	0.01	0.00	0.00	0.02	1.00
Mesic	Fire	−0.74	0.34	−1.40	−0.07	1.00
Mesic	Year (centered): Fire	0.03	0.03	−0.02	0.08	1.00
Mesic	Shape	11.02	0.92	9.30	12.89	1.00
Mesic	Hu	0.02	0.01	0.01	0.04	1.00
Mesic	Random Plot Intercept SD	0.79	0.05	0.70	0.89	1.00

Table B4a (continued). Sapling basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin’s (1992) potential scale reduction factor. All models used a hurdle gamma distribution, Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Non-Canopy	Intercept	−5.66	0.11	−5.88	−5.44	1.00
Non-Canopy	Year (centered)	−0.03	0.01	−0.05	−0.01	1.00
Non-Canopy	Fire	−1.26	0.46	−2.15	−0.37	1.00
Non-Canopy	Year (centered): Fire	0.09	0.05	−0.00	0.17	1.00
Non-Canopy	Shape	6.44	0.84	4.90	8.19	1.00
Non-Canopy	Hu	0.55	0.02	0.51	0.60	1.00
Non-Canopy	Random Plot Intercept SD	0.90	0.08	0.75	1.07	1.00
Oak Hickory	Intercept	−5.54	0.19	−5.92	−5.16	1.00
Oak Hickory	Year (centered)	0.01	0.01	−0.02	0.03	1.00
Oak Hickory	Fire	0.15	0.58	−1.00	1.30	1.00
Oak Hickory	Year (centered): Fire	0.18	0.04	0.09	0.26	1.00
Oak Hickory	Shape	7.36	1.18	5.23	9.85	1.00
Oak Hickory	Hu	0.72	0.02	0.67	0.76	1.00
Oak Hickory	Random Plot Intercept SD	1.19	0.14	0.95	1.51	1.00

Table B4b. Sapling basal area model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a hurdle gamma distribution, Non-Constant Occupancy.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Acer rubrum	Intercept	−5.86	0.13	−6.12	−5.59	1.00
Acer rubrum	Year (centered)	−0.01	0.01	−0.02	0.01	1.00
Acer rubrum	Fire	0.18	0.56	−0.91	1.28	1.00
Acer rubrum	Year (centered): Fire	0.10	0.03	0.05	0.15	1.00
Acer rubrum	shape	17.25	2.41	12.86	22.23	1.00
Acer rubrum	hu Intercept	0.42	0.10	0.22	0.61	1.00
Acer rubrum	hu: Year(centered)	0.04	0.03	−0.01	0.10	1.00
Acer rubrum	Random Plot Intercept SD	1.07	0.10	0.90	1.28	1.00
Carpinus caroliniana	Intercept	−5.85	0.36	−6.55	−5.13	1.00
Carpinus caroliniana	Year (centered)	0.02	0.01	−0.00	0.05	1.00
Carpinus caroliniana	Fire	−1.82	1.49	−4.78	1.14	1.00
Carpinus caroliniana	Year (centered): Fire	0.13	0.09	−0.05	0.32	1.00
Carpinus caroliniana	shape	17.13	5.51	8.13	29.41	1.00
Carpinus caroliniana	hu Intercept	2.35	0.17	2.03	2.70	1.00
Carpinus caroliniana	hu: Year(centered)	0.04	0.05	−0.06	0.13	1.00
Carpinus caroliniana	Random Plot Intercept SD	1.39	0.28	0.96	2.06	1.00

Table B5a. Tree seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Amelanchier arborea	Intercept	−5.27	0.82	−7.13	−3.94	1.00
Amelanchier arborea	Year (centered)	0.02	0.04	−0.05	0.10	1.00
Amelanchier arborea	Fire	1.92	1.72	−1.44	5.34	1.00
Amelanchier arborea	Year (centered): Fire	0.02	0.10	−0.18	0.23	1.00
Amelanchier arborea	Random Plot Intercept SD	3.02	0.57	2.10	4.32	1.00
Asimina triloba	Intercept	−5.32	0.84	−7.24	−3.95	1.00
Asimina triloba	Year (centered)	−0.02	0.02	−0.06	0.02	1.00
Asimina triloba	Fire	−215.40	307.50	−993.34	−13.99	1.00
Asimina triloba	Year (centered): Fire	1.43	37.11	−66.35	74.61	1.00
Asimina triloba	Random Plot Intercept SD	3.35	0.60	2.38	4.73	1.00
Carpinus caroliniana	Intercept	−4.60	0.63	−6.01	−3.53	1.00
Carpinus caroliniana	Year (centered)	−0.05	0.04	−0.14	0.03	1.00
Carpinus caroliniana	Fire	2.90	1.36	0.23	5.60	1.00
Carpinus caroliniana	Year (centered): Fire	0.15	0.06	0.04	0.27	1.00
Carpinus caroliniana	Random Plot Intercept SD	2.59	0.46	1.83	3.63	1.00
Cary glabra	Intercept	−3.62	0.45	−4.62	−2.85	1.00
Cary glabra	Year (centered)	−0.02	0.04	−0.10	0.06	1.00
Cary glabra	Fire	2.33	0.99	0.48	4.36	1.00
Cary glabra	Year (centered): Fire	0.06	0.11	−0.16	0.29	1.00
Cary glabra	Random Plot Intercept SD	1.89	0.34	1.32	2.64	1.00
Fagus grandifolia	Intercept	−1.39	0.19	−1.79	−1.04	1.00
Fagus grandifolia	Year (centered)	−0.05	0.02	−0.09	−0.01	1.00
Fagus grandifolia	Fire	−1.03	0.93	−2.92	0.71	1.00
Fagus grandifolia	Year (centered): Fire	0.17	0.15	−0.11	0.49	1.00
Fagus grandifolia	Random Plot Intercept SD	1.47	0.18	1.16	1.85	1.00
Ilex opaca	Intercept	−0.73	0.17	−1.08	−0.42	1.00
Ilex opaca	Year (centered)	0.01	0.01	−0.02	0.04	1.00
Ilex opaca	Fire	−0.56	0.78	−2.14	0.94	1.00
Ilex opaca	Year (centered): Fire	0.11	0.08	−0.04	0.27	1.00
Ilex opaca	Random Plot Intercept SD	1.50	0.15	1.22	1.82	1.00
Liquidambar styraciflua	Intercept	−9.85	2.51	−15.90	−6.30	1.00
Liquidambar styraciflua	Year (centered)	−0.05	0.04	−0.13	0.03	1.00
Liquidambar styraciflua	Fire	−105.79	158.65	−493.86	−0.28	1.00

Table B5a (continued). Tree seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Liquidambar styraciflua	Year (centered): Fire	−20.00	28.44	−89.42	−0.83	1.00
Liquidambar styraciflua	Random Plot Intercept SD	4.75	1.36	2.83	8.04	1.00
Quercus coccinea	Intercept	−4.33	0.54	−5.52	−3.42	1.00
Quercus coccinea	Year (centered)	−0.19	0.05	−0.29	−0.09	1.00
Quercus coccinea	Fire	4.87	1.02	2.96	7.01	1.00
Quercus coccinea	Year (centered): Fire	0.16	0.06	0.05	0.28	1.00
Quercus coccinea	Random Plot Intercept SD	2.11	0.38	1.48	2.99	1.00
Quercus falcata	Intercept	−4.52	0.62	−5.92	−3.51	1.00
Quercus falcata	Year (centered)	−0.09	0.05	−0.20	0.01	1.00
Quercus falcata	Fire	2.09	1.26	−0.45	4.54	1.00
Quercus falcata	Year (centered): Fire	0.12	0.09	−0.05	0.30	1.00
Quercus falcata	Random Plot Intercept SD	2.19	0.44	1.48	3.19	1.00
Quercus velutina	Intercept	−4.74	0.68	−6.28	−3.63	1.00
Quercus velutina	Year (centered)	−0.07	0.04	−0.15	0.00	1.00
Quercus velutina	Fire	3.29	1.33	0.81	6.10	1.00
Quercus velutina	Year (centered): Fire	0.14	0.10	−0.05	0.34	1.00
Quercus velutina	Random Plot Intercept SD	2.58	0.47	1.81	3.64	1.00
Sassafras albidum	Intercept	−3.72	0.45	−4.73	−2.96	1.00
Sassafras albidum	Year (centered)	−0.00	0.05	−0.10	0.09	1.00
Sassafras albidum	Fire	2.19	0.97	0.34	4.14	1.00
Sassafras albidum	Year (centered): Fire	−0.31	0.12	−0.57	−0.09	1.00
Sassafras albidum	Random Plot Intercept SD	1.73	0.33	1.18	2.47	1.00
Early Successional	Intercept	−3.79	0.47	−4.83	−2.98	1.00
Early Successional	Year (centered)	−0.04	0.03	−0.09	0.02	1.00
Early Successional	Fire	3.84	1.09	1.82	6.13	1.00
Early Successional	Year (centered): Fire	0.09	0.06	−0.04	0.21	1.00
Early Successional	Random Plot Intercept SD	2.29	0.35	1.71	3.07	1.00
Mesic	Intercept	0.37	0.09	0.18	0.55	1.00
Mesic	Year (centered)	−0.01	0.01	−0.03	0.01	1.00
Mesic	Fire	0.35	0.42	−0.47	1.17	1.00
Mesic	Year (centered): Fire	0.15	0.05	0.06	0.24	1.00
Mesic	Random Plot Intercept SD	0.90	0.08	0.75	1.07	1.00

Table B5a (continued). Tree seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	**Coefficient**	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Non-Canopy	Intercept	−1.62	0.22	−2.07	−1.23	1.00
Non-Canopy	Year (centered)	−0.02	0.02	−0.05	0.02	1.00
Non-Canopy	Fire	2.27	0.77	0.76	3.81	1.00
Non-Canopy	Year (centered): Fire	0.05	0.04	−0.02	0.12	1.00
Non-Canopy	Random Plot Intercept SD	1.72	0.18	1.40	2.12	1.00

Table B5b. Tree seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Negative Binomial distribution.

Species	**Coefficient**	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Acer rubrum	Intercept	−3.13	0.40	−3.99	−2.43	1.00
Acer rubrum	Year (centered)	−0.12	0.05	−0.22	−0.03	1.00
Acer rubrum	Fire	2.94	0.81	1.46	4.64	1.00
Acer rubrum	Year (centered): Fire	0.32	0.13	0.08	0.58	1.00
Acer rubrum	Shape	3.23	11.93	0.38	19.36	1.00
Acer rubrum	Random Plot Intercept SD	1.46	0.32	0.88	2.14	1.00
Cary alba	Intercept	−4.14	0.58	−5.43	−3.14	1.00
Cary alba	Year (centered)	−0.16	0.06	−0.29	−0.05	1.00
Cary alba	Fire	0.54	1.42	−2.36	3.24	1.00
Cary alba	Year (centered): Fire	0.12	0.27	−0.43	0.64	1.00
Cary alba	Shape	7.54	22.57	0.27	62.69	1.00
Cary alba	Random Plot Intercept SD	1.93	0.42	1.21	2.86	1.00
Nyssa sylvatica	Intercept	−3.14	0.38	−3.96	−2.46	1.00
Nyssa sylvatica	Year (centered)	0.06	0.05	−0.04	0.15	1.00
Nyssa sylvatica	Fire	0.95	0.97	−1.00	2.82	1.00
Nyssa sylvatica	Year (centered): Fire	−0.02	0.16	−0.34	0.31	1.00
Nyssa sylvatica	Shape	12.12	29.51	0.53	92.66	1.00
Nyssa sylvatica	Random Plot Intercept SD	1.56	0.31	1.01	2.23	1.00
Pinus virginiana	Intercept	−4.33	0.60	−5.66	−3.34	1.00
Pinus virginiana	Year (centered)	0.01	0.06	−0.10	0.12	1.00

Table B5b (continued). Tree seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Negative Binomial distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Pinus virginiana	Fire	3.91	1.09	1.94	6.24	1.00
Pinus virginiana	Year (centered): Fire	0.16	0.12	−0.06	0.42	1.00
Pinus virginiana	Shape	10.34	26.03	0.63	0.42	1.00
Pinus virginiana	Random Plot Intercept SD	2.10	0.41	1.41	3.03	1.00
Quercus alba	Intercept	−2.79	0.44	−3.74	−2.00	1.00
Quercus alba	Year (centered)	−0.06	0.02	−0.09	−0.03	1.00
Quercus alba	Fire	3.11	1.48	0.22	6.06	1.00
Quercus alba	Year (centered): Fire	0.07	0.04	−0.00	0.16	1.00
Quercus alba	Shape	19.11	18.80	5.52	65.39	1.00
Quercus alba	Random Plot Intercept SD	3.29	0.38	2.63	4.13	1.00
Quercus prinus	Intercept	−7.10	1.45	−10.49	−4.87	1.00
Quercus prinus	Year (centered)	−0.08	0.06	−0.21	0.03	1.00
Quercus prinus	Fire	−289.77	649.60	−1347.26	−14.89	1.00
Quercus prinus	Year (centered): Fire	2.32	72.89	−88.28	91.79	1.00
Quercus prinus	Shape	2.67	4.50	0.61	9.03	1.00
Quercus prinus	Random Plot Intercept SD	4.06	0.94	2.63	6.28	1.00
All Trees	Intercept	1.28	0.10	1.09	1.47	1.00
All Trees	Year (centered)	−0.04	0.01	−0.05	−0.02	1.00
All Trees	Fire	1.78	0.45	0.92	2.67	1.00
All Trees	Year (centered): Fire	0.07	0.02	0.03	0.11	1.00
All Trees	Shape	39.97	25.57	15.79	106.56	1.00
All Trees	Random Plot Intercept SD	1.05	0.08	0.92	1.21	1.00
Oak Hickory	Intercept	−0.90	0.24	−1.39	−0.45	1.00
Oak Hickory	Year (centered)	−0.08	0.01	−0.11	−0.05	1.00
Oak Hickory	Fire	3.40	0.95	1.57	5.32	1.00
Oak Hickory	Year (centered): Fire	0.09	0.03	0.02	0.16	1.00
Oak Hickory	Shape	10.92	4.89	5.08	23.13	1.00
Oak Hickory	Random Plot Intercept SD	2.24	0.21	1.86	2.70	1.00

Table B6. Tree seedling browse model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Acer rubrum	Intercept	−1.31	0.67	−2.75	−0.11	1.00
Acer rubrum	Fire	−7.93	9.77	−30.96	−0.27	1.00
Amelanchier arborea	Intercept	−0.63	0.44	−1.51	−0.21	1.00
Amelanchier arborea	Fire	−0.82	1.48	−4.12	1.74	1.00
Asimina triloba	Intercept	−7.50	5.09	−19.7	−3.34	1.00
Asimina triloba	Fire	i.d.	i.d.	i.d.	i.d.	i.d.
Carpinus caroliniana	Intercept	−0.35	0.61	−1.59	0.83	1.00
Carpinus caroliniana	Fire	0.08	0.72	−1.31	1.52	1.00
Cary alba	Intercept	−6.69	8.22	−24.77	−1.27	1.00
Cary alba	Fire	−30.87	62.90	−172.45	−8.05	1.00
Cary glabra	Intercept	−3.00	1.04	−5.40	−1.35	1.00
Cary glabra	Fire	2.13	1.81	−1.53	5.68	1.00
Fagus grandifolia	Intercept	−0.48	0.25	−0.98	0.01	1.00
Fagus grandifolia	Fire	100.22	112.37	4.79	327.53	1.00
Ilex opaca	Intercept	−1.18	0.18	−1.55	−0.84	1.00
Ilex opaca	Fire	−52.73	59.12	−207.79	−2.65	1.00
Liquidambar styraciflua	Intercept	−1.62	0.77	−3.29	−0.27	1.00
Liquidambar styraciflua	Fire	i.d.	i.d.	i.d.	i.d.	i.d.
Nyssa sylvatica	Intercept	0.11	0.38	−0.62	0.86	1.00
Nyssa sylvatica	Fire	−44.66	53.42	−167.56	−2.22	1.00
Pinus virginiana	Intercept	−1.69	0.81	−3.50	−0.29	1.00
Pinus virginiana	Fire	−0.65	1.47	−3.82	2.03	1.00
Quercus alba	Intercept	−1.48	0.17	−1.82	−1.16	1.00
Quercus alba	Fire	−15.26	34.27	−53.52	−2.86	1.00
Quercus coccinea	Intercept	−20.47	25.65	−83.84	−1.96	1.00
Quercus coccinea	Fire	16.99	25.61	−1.83	80.35	1.00
Quercus falcata	Intercept	−1.55	1.27	−4.46	0.57	1.00
Quercus falcata	Fire	−5.53	7.80	−22.57	1.30	1.00
Quercus prinus	Intercept	−0.86	0.50	−1.88	0.07	1.00
Quercus prinus	Fire	i.d.	i.d.	i.d.	i.d.	i.d.
Quercus velutina	Intercept	−1.46	0.66	−2.88	−0.29	1.00
Quercus velutina	Fire	−14.20	17.89	−60.67	0.32	1.00
Sassafras albidum	Intercept	−1.88	0.78	−3.61	−0.54	1.00
Sassafras albidum	Fire	−22.20	31.11	−103.75	1.26	1.00

Table B6 (continued). Tree seedling browse model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
All Trees	Intercept	−1.31	0.09	−1.48	−1.13	1.00
All Trees	Fire	−0.93	0.26	−1.46	−0.45	1.00
Early Successional	Intercept	−1.69	0.55	−2.87	−0.68	1.00
Early Successional	Fire	−0.87	1.37	−3.96	1.44	1.00
Mesic	Intercept	−0.86	0.13	−1.12	−0.61	1.00
Mesic	Fire	−1.82	0.84	−3.67	−0.41	1.00
Non-Canopy	Intercept	−1.93	0.28	−2.50	−1.41	1.00
Non-Canopy	Fire	1.42	0.45	0.55	2.30	1.00
Oak Hickory	Intercept	−1.58	0.15	−1.88	−1.30	1.00
Oak Hickory	Fire	−2.72	0.80	−4.53	−1.41	1.00

Table B7a. Shrub density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Vaccinium spp.	Intercept	−3.51	0.50	−4.58	−2.64	1.00
Vaccinium spp.	Year (centered)	0.00	0.02	−0.03	0.04	1.00
Vaccinium spp.	Fire	3.85	1.36	1.25	6.63	1.00
Vaccinium spp.	Year (centered): Fire	0.05	0.04	−0.03	0.13	1.00
Vaccinium spp.	Random Plot Intercept SD	3.00	0.40	2.32	3.89	1.00

Table B7b. Shrub density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Negative Binomial distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Lyonia ligustrina	Intercept	−8.70	2.02	−13.55	−5.80	1.00
Lyonia ligustrina	Year (centered)	0.18	0.12	−0.04	0.44	1.00
Lyonia ligustrina	Fire	7.41	2.30	3.76	12.69	1.00
Lyonia ligustrina	Year (centered): Fire	0.06	0.16	−0.27	0.37	1.00
Lyonia ligustrina	Shape	5.16	14.45	0.44	28.90	1.00
Lyonia ligustrina	Random Plot Intercept SD	3.47	1.01	2.00	5.88	1.00

Table B8. Shrub percent model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Gaylussacia spp.	Intercept	−2.25	0.11	−2.47	−2.03	1.00
Gaylussacia spp.	zi-Intercept	0.26	0.17	−0.08	0.60	1.00
Gaylussacia spp.	Fire	0.34	0.32	−0.33	0.91	1.00
Gaylussacia spp.	zi_Fire	−37.22	29.17	−109.68	−3.74	1.00
Gaylussacia spp.	phi	13.87	2.52	9.41	19.28	1.00
Kalmia latifolia	Intercept	−1.03	0.17	−1.37	−0.69	1.00
Kalmia latifolia	zi-Intercept	1.02	0.22	0.59	1.45	1.00
Kalmia latifolia	Fire	0.75	0.67	−0.63	2.04	1.00
Kalmia latifolia	zi_Fire	−1.03	1.16	−3.33	1.26	1.00
Kalmia latifolia	phi	5.33	1.33	3.07	8.25	1.00
Lonicera japonica	Intercept	−3.90	0.13	−4.15	−3.63	1.00
Lonicera japonica	zi-Intercept	1.88	0.25	1.41	2.39	1.00
Lonicera japonica	Fire	93.15	101.94	−100.04	282.85	1.00
Lonicera japonica	zi_Fire	26.63	25.65	0.69	94.94	1.00
Lonicera japonica	phi	188.79	65.18	82.69	336.20	1.00
Smilax glauca	Intercept	−4.47	0.03	−4.53	−4.41	1.00
Smilax glauca	zi-Intercept	0.63	0.18	−0.99	−0.29	1.00
Smilax glauca	Fire	0.10	0.12	−0.14	0.32	1.00
Smilax glauca	zi_Fire	−1.41	1.34	−4.53	0.76	1.00
Smilax glauca	phi	1251.70	183.81	916.73	1636.62	1.00

Table B8 (continued). Shrub percent model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Smilax rotundifolia	Intercept	−3.82	0.07	−3.96	−3.69	1.00
Smilax rotundifolia	zi-Intercept	−1.27	0.21	−1.68	−0.88	1.00
Smilax rotundifolia	Fire	1.10	0.19	0.71	1.44	1.00
Smilax rotundifolia	zi_Fire	−28.71	26.44	−99.78	−1.41	1.00
Smilax rotundifolia	phi	92.06	12.79	68.68	118.90	1.00
Toxicodendron radicans	Intercept	−4.40	0.12	−4.63	−4.16	1.00
Toxicodendron radicans	zi-Intercept	1.94	0.26	1.46	2.46	1.00
Toxicodendron radicans	Fire	106.36	96.01	−86.65	302.24	1.00
Toxicodendron radicans	zi_Fire	25.98	24.68	0.65	91.26	1.00
Toxicodendron radicans	phi	409.19	145.39	174.36	747.32	1.00
Vaccinium spp.	Intercept	−3.16	0.07	−3.30	−3.01	1.00
Vaccinium spp.	zi-Intercept	−1.07	0.20	−1.46	−0.69	1.00
Vaccinium spp.	Fire	0.72	0.23	0.23	1.13	1.00
Vaccinium spp.	zi_Fire	−29.08	26.00	−97.92	−1.63	1.00
Vaccinium spp.	phi	43.61	26.00	32.34	56.47	1.00

Table B9. Shrub seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Negative Binomial distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Euonymus americanus	Intercept	−3.47	−0.49	−4.53	−2.61	1.00
Euonymus americanus	Year (centered)	0.25	0.06	0.14	0.38	1.00
Euonymus americanus	Fire	−169.56	216.47	−750.39	−13.81	1.00
Euonymus americanus	Year (centered): Fire	1.23	29.64	−49.54	56.92	1.00
Euonymus americanus	Shape	0.87	0.56	0.31	2.14	1.00
Euonymus americanus	Random Plot Intercept SD	2.07	0.39	1.40	2.91	1.00
Kalmia latifolia	Intercept	−4.29	0.66	−5.75	−3.16	1.00
Kalmia latifolia	Year (centered)	−0.03	0.03	−0.09	0.03	1.00
Kalmia latifolia	Fire	0.28	1.95	−3.63	4.08	1.00
Kalmia latifolia	Year (centered): Fire	−0.60	0.18	−0.98	−0.29	1.00
Kalmia latifolia	Shape	2.86	2.54	1.07	7.11	1.00

Table B9 (continued). Shrub seedling density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin’s (1992) potential scale reduction factor. All models used a Negative Binomial distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Kalmia latifolia	Random Plot Intercept SD	3.54	0.53	2.64	4.73	1.00
Lyonia ligustrina	Intercept	−4.69	0.71	−6.25	−3.48	1.00
Lyonia ligustrina	Year (centered)	0.27	0.06	0.16	0.40	1.00
Lyonia ligustrina	Fire	3.54	1.65	0.40	6.92	1.00
Lyonia ligustrina	Year (centered): Fire	0.09	0.17	−0.22	0.46	1.00
Lyonia ligustrina	Shape	1.00	0.54	0.37	2.38	1.00
Lyonia ligustrina	Random Plot Intercept SD	3.30	0.53	2.41	4.50	1.00
Vaccinium spp.	Intercept	−4.16	0.62	−5.52	−3.10	1.00
Vaccinium spp.	Year (centered)	0.24	0.08	0.08	0.41	1.00
Vaccinium spp.	Fire	3.31	1.31	0.84	6.01	1.00
Vaccinium spp.	Year (centered): Fire	0.24	0.25	−0.21	0.79	1.00
Vaccinium spp.	Shape	0.43	0.20	0.17	0.92	1.00
Vaccinium spp.	Random Plot Intercept SD	2.22	0.44	1.46	3.21	1.00
All species	Intercept	−0.69	0.20	−1.10	−0.31	1.00
All species	Year (centered)	0.10	0.03	0.05	0.16	1.00
All species	Fire	1.97	0.82	0.38	3.60	1.00
All species	Year (centered): Fire	−0.06	0.09	−0.23	0.12	1.00
All species	Shape	1.03	0.21	1.69	1.50	1.00
All species	Random Plot Intercept SD	1.75	0.18	1.43	2.14	1.00

Table B10. Shrub seedling browse model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Euonymus americanus	Intercept	−0.21	0.21	−0.63	0.19	1.00
Euonymus americanus	Fire	i.d.	i.d.	i.d.	i.d.	i.d.
Kalmia latifolia	Intercept	−2.73	0.25	−3.24	−2.26	1.00
Kalmia latifolia	Fire	−23.46	30.83	−104.61	−1.43	1.00
Lyonia ligustrina	Intercept	−0.82	0.13	−1.07	−0.57	1.00
Lyonia ligustrina	Fire	−1.94	0.83	−3.83	−0.56	1.00
Vaccinium spp.	Intercept	0.08	0.23	−0.37	0.52	1.00
Vaccinium spp.	Fire	0.85	0.51	−0.12	1.89	1.00
All species	Intercept	−1.11	0.08	−1.27	−0.95	1.00
All species	Fire	−0.44	0.27	−0.98	0.07	1.00

Table B11a. Vine density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Poisson distribution.

Species	Coefficient	Estimate	Estimate Error	Lower 95% CI	Upper 95% CI	R-hat
Smilax spp.	Intercept	−5.46	0.34	−6.18	−4.86	1.00
Smilax spp.	Year (centered)	−0.02	0.01	−0.04	0.01	1.00
Smilax spp.	Fire	1.62	1.21	−0.75	4.04	1.00
Smilax spp.	Year (centered): Fire	0.38	0.09	0.21	0.58	1.00
Smilax spp.	Random Plot Intercept SD	2.64	0.30	2.13	3.28	1.00
All species	Intercept	−5.19	0.34	−6.18	−4.86	1.00
All species	Year (centered)	−0.02	0.01	−0.04	0.01	1.00
All species	Fire	1.36	1.21	−1.00	3.76	1.00
All species	Year (centered): Fire	0.38	0.09	0.22	0.58	1.00
All species	Random Plot Intercept SD	2.64	0.28	2.15	3.24	1.00

Table B11b. Vine density model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. All models used a Negative Binomial distribution.

Species	**Coefficient**	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Lonicera japonica	Intercept	−10.77	1.55	−14.47	−8.46	1.00
Lonicera japonica	Year (centered)	−0.05	0.06	−0.16	0.06	1.00
Lonicera japonica	Fire	−384.83	536.40	−1857.47	−19.98	1.00
Lonicera japonica	Year (centered): Fire	1.45	67.00	−122.53	131.31	1.00
Lonicera japonica	shape	30.97	48.12	0.91	167.36	1.00
Lonicera japonica	Random Plot Intercept SD	3.65	0.93	2.27	5.85	1.00
Vitis spp.	Intercept	−10.81	1.53	−14.44	8.51	1.00
Vitis spp.	Year (centered)	−0.03	0.05	−0.12	0.06	1.00
Vitis spp.	Fire	−422.83	789.76	−2230.88	−20.55	1.00
Vitis spp.	Year (centered): Fire	0.50	92.61	−145.02	150.97	1.00
Vitis spp.	shape	38.08	51.05	2.03	182.35	1.00
Vitis spp.	Random Plot Intercept SD	3.85	0.94	2.43	6.09	1.00

Table B12. Coarse woody debris model coefficients from generalized linear mixed model analysis. Coefficient indicates the model coefficients, Estimate is the estimate of the coefficient, Estimate Error, Lower 95% Credible Interval (CI) and upper 95% Credible Interval (CI) indicate the precision of the estimate, R-hat is Gelman and Rubin's (1992) potential scale reduction factor. Models for All species used a constant occupancy distribution.

Coefficient	**Estimate**	**Estimate Error**	**Lower 95% CI**	**Upper 95% CI**	**R-hat**
Intercept	3.95	0.08	3.80	4.11	1.00
Year (centered)	−0.00	0.01	−0.02	0.01	1.00
Fire	0.62	0.38	−0.14	1.37	1.00
Year (centered): Fire	0.01	0.04	−0.06	0.08	1.00
shape	4.39	0.35	3.73	5.12	1.00
hu	0.02	0.01	0.01	0.03	1.00
Random Plot Intercept SD	0.88	0.06	0.77	1.00	1.00

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