Floristic change spanning 45 years of global change in the College Woods, Williamsburg, VA

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APPROVAL PAGE

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ABSTRACT PAGE

The College Woods, located in Williamsburg, VA, is a natural preserve of approximately 960 acres owned by the College of William & Mary. The Woods supports a relatively diverse flora in a mature coastal-plain forest which has been under long-term biological study by members of the College. This thesis contributes to the ongoing investigation of the Woods by documenting floristic and vegetation changes that have occurred over the last 45 years amidst a rising and uncontrolled white-tailed deer population. Three main research questions are addressed: (1) How has floristic diversity, composition, and species abundance changed since the last floristic survey in 1989? (2) Under the assumption of chronic browse by white-tailed deer, are there species-specific plant traits that associate with a suite of declining species? and (3) What is the estimated forest successional trajectory indicated by a 2015 quantitative analysis of the diversity, composition, importance, and browse rates in 19 long-term permanent plots?

For the floristic analysis, 297% more effort was required in 2015 to find 7% fewer species than in the last floristic survey of 1989, indicating a decline in the abundance of populations, making their rediscovery more difficult. Over the last 45 years, 745 vascular plant species have been documented in the Woods. One hundred and twenty-six species were newly reported in 2015, while 196 previously-reported species were not relocated. The turnover of species is consistent with the species-time relationship and was especially prominent in early successional open habitats. Assessments of changes in relative abundance showed that 46% of the species had declined in abundance. This appears to be driven by an overabundant white-tailed deer population, but no plant trait previously hypothesized to confer vulnerability to browse by white-tailed deer showed a signficant association with the set of declining species. It is hypothesized that because the deer population has been overabundant for 20 years, any trait-based associations that may have once existed would have become obscured over time as browse intolerant species were reduced and deer switched to less-preffered plant material. Deer-browse data on less preferred plants such as *Fagus grandifolia*, *Polystichum acrosticoides* and *Ilex americana* supports this hypothesis.

Nineteen permanent plots erected in 2003 were sampled for vegetation analysis immediately after Hurricane Isabel in 2004 and then resampled in 2015. Analysis showed little change in the large tree and small tree size classes, but there was significant change in the sapling size class. In the sapling size class, average stem density and species diversity significantly decreased between 2004 and 2015, or did not show the expected regeneration patterns in areas severely hit by the hurricane. An analysis of deer browse in these plots showed that nearly 60% of all vegetation was browsed. This is expected to slow down the rate of succession and alter forest composition, possibly resulting in a beech-dominated forest with very little understory. A management plan designed to allow the flora of the College Woods to recover from chronic deer browse was written and recommends controlling the white-tailed deer population through yearly managed hunts.

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Chapter 1

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INTRODUCTION

The College Woods, owned by the College of William and Mary in Williamsburg, Virginia, lies within an area of the United States that has been botanized since colonial settlement (Crouch, 1989). John Clayton, Mark Catesby, John Mitchell, and John Bannister all made collections within the vicinity of Williamsburg during colonial settlement. Interest in botanizing the area waned during the 19th century, but was revived in 1924 when Eileen Erlanson and biology professor E.J. Grimes published a flora of the Peninsula (1922), which was made from collections mostly taken from the Williamsburg area. A vascular flora focusing specifically on the College Woods was not created until 1968, when a graduate student (Allene Barans) documented 540 species (Barans, 1968). A second College Woods flora was created in 1989 by Virginia Crouch, an honors student. Her thesis verbally reports the status of the original species found by Barans and documents 120 additional species in the College Woods with herbarium voucher collections. It should be noted that Crouch also included an additional piece of woods owned by the College, the Papermill Creek area, and the results of that study are not reported here. Both theses are accessible at the William & Mary Swem Library and the voucher specimens are archived in the Herbarium of the College of William & Mary.

The College Woods has long been a focus of botanical research and conservation interest because of its size, maturity, species diversity, and proximity to the university. Because of these attributes, it was designated as a natural preserve by the College of William and Mary with the purpose of conserving the forest ecosystem and lake (Board of Visitors, 1994; General Assembly, 1995). The College Woods is composed of approximately 960 acres of forested land with many trees that are 160 or more years old, creating a dense, closed canopy. It is important to know that while some trees are over 160 years old, the majority of forest is approximately 90 years old. The largest contiguous area of the College Woods surrounds Lake Matoaka, the oldest manmade lake in Virginia (created in the early 18th century). The surface of the lake itself comprises an additional 40 acres, with an average depth of two meters and the deepest portion at five meters. The underlying geology is predominantly the Bacon's Castle, Sedley, and Yorktown soil formations which, in combination with the varying topography, lead to several different habitat types such as the lake, broad ravine bottoms, ravine slopes (some containing Pliocene shell deposits), sphagnous stream heads, ridges and level uplands, and open spaces. These habitats correspondingly lead to a rich diversity of vascular plant species. *Quercus* spp., *Fagus grandifolia* Ehrhart , and *Acer rubrum* L. dominate most wooded upland areas, but other species like *Ilex opaca* Aiton, *Liriodendron tulipifera* L., *Carya* spp., *Nyssa sylvatica* Marshall., and *Liquidambar styraciflua* L. are also common. As in most temperate forests, the herbaceous layer is where the vast majority of species diversity resides, and the College Woods contains higher species diversity than many surrounding areas. Accordingly, there are five species reported from the College Woods that are on the state and/or federal rare and endangered species lists. These include: *Crotalaria purshii* DC., *Desmodium cuspidatum* (Muhl. ex Willd.) Loudon, *Isotria medeoloides* (Pursh.) Raf., *Scutellaria incana* Biehler, and *Utricularia olivacea* C. Wright ex Griseb.. Only *I. medeoloides* is still recorded within the College Woods (this study) while the rest are now considered historical records. An additional ten species are on the state watch list. Current status of each of these can be viewed in Table 8 in the results section. Finally, the College Woods supports an unusual group of species in some ravine systems that are disjunct from the mountains (Crouch 1989). These are very rare locally and may harbor unique genetic variation because of their isolation and adaptation to calcareous habitats (McDonald, 2000).

Although the extent of the College Woods has not changed significantly since the last flora, observational evidence has suggested that the species composition of the forest has. Areas that were once cutover have matured, affecting populations of early colonizing, shade intolerant plant species. At the same time, Hurricane Isabel devastated some of the most mature areas of the College Woods in 2003, opening large canopy gaps where early colonizing species would thrive. Additionally, many embankments to streams have eroded as the areas surrounding the College Woods have been developed, increasing run-off into the woods and destroying sensitive habitats that had supported unique assemblages of plant species (Crouch, 1989). Several apparent population declines can be attributed to the number and abundance of invasive exotics, unapproved biking trails which have proliferated through sensitive-species populations, and the overabundance of white-tailed deer in the College Woods. A long-term study of permanent plots within the College Woods attributed significant declines in populations of tree species in the sapling layer between 1994 and 2003 to overabundant white-tailed deer populations (Kribel et al., 2011). Additionally, drastic declines in population sizes concomitant with evidence of deer browse have been noted in species that have been under long-term study in the woods, such as the yellow lady's slipper orchid (Case, personal communication). Although there has been no formal count of the deer population in the College Woods, there are likely more white-tailed deer in the College Woods than the ecosystem can sustainably support. Signs of white-tailed deer in the form of tracks, pellets, and scrapings have been pervasive and abundant in the woods since at least 2003 (Kribel et al., 2011). This is consistent with state and national trends as the numbers of white-tailed deer have increased exponentially throughout Virginia since the early 1990s (Virginia Department of Game and Inland Fisheries, 2007), and populations have increased exponentially nationwide in the last two decades, driven by the loss of top predators and habitat fragmentation (Horsley et al., 2003).

For the long-term goal of preserving the species integrity of the College Woods, my first objective of the research presented in this chapter was to document how the floristic diversity has changed since 1989, the last of the two vascular floras of the Woods. This was accomplished by targeted searches of original collecting sites of each species that Crouch and/or Barans reported in order to assess whether the populations are still extant. I also searched the College Woods broadly for new plant records and documented all species discovered with herbarium specimens (or photographs when populations were too small to support collection). Special care was taken to ensure that collecting effort greatly exceeded that of the previous studies, decreasing the chances of sampling error. This was accomplished by estimating the original effort and then increasing my effort by recruiting and training undergraduate students to assist in the searches. Additionally, because Crouch also included categorical assessments of relative abundance for each species, I also recorded population sizes of encountered species to estimate current relative abundance in order to compare to previous studies.

The second objective of this chapter tests whether specific plant traits that have been suggested to confer vulnerability under high deer browse are associated with species that are either declining in population size or were not relocated in the 2015 survey (i.e. those which are possibly extirpated). Too high of browse pressure by white-tailed deer affects survivability, fecundity, and the growth of plant species. The degree to which species are affected by too high browse pressure depends on their responses to herbivory and their detectability. Traits such as biogeography, flowering phenology, length of flowering period, habit, stem position, habitat, shade tolerance, height, presence of hidden meristems, pollination mode, and life history have the potential to influence a species' detection and response to herbivory. It is also possible that a combination of traits work together to confer browse tolerance, as opposed to the presence of any single trait. For example, slow-growing, shady understory plants may tolerate herbivory poorly (Coté et al., 2004). Therefore, understory species in mature, closed canopy portions of the College Woods (i.e. ridges and level uplands, ravine slopes, ravine bottoms, and sphagnous stream heads) that are also perennials would be most likely to experience population declines.

Timing of herbivory could affect populations of species if white-tailed deer prefer plants that are in flower versus a vegetative state. Browsing reproductive individuals can prevent them from flowering for several growing seasons, which when repeated can lead to population declines as individuals die without replacement (Coté et al., 2004). Flowering phenology and the length of the flowering period may therefore play important roles in determining browse tolerance. Species in the College Woods with short flowering periods would be most vulnerable because there is only a small window for plants to be able to reflower through compensatory growth. Flowering phenology may confer vulnerability (Coté et al., 2004) in part because species that reach maturity in early spring and early summer may be browsed more intensely as the abundance of food materials are relatively low compared to late summer when food materials are more abundant. Therefore, it is reasonable to expect that species that reach maturity in the early spring and summer and also have short flowering periods may be the most vulnerable to the effects of browse by white-tailed deer.

Browse tolerant plants are usually those that only lose partial foliage when browsed, have the ability to store material underground, hide their meristems, or grow quickly (Coté et al., 2003). These species are generally trees, graminoids, and herbs and shrubs that mature in the late summer. Herbaceous plants are particularly affected by herbivory because they remain low and vulnerable during their entire lifespan (Gilliam, 2007). Deer will browse on all palatable vegetation within reach (the browse line ends at approximately 1.8m, the height a deer could reach on its hind legs), which includes bushes and young saplings of forest trees as well as numerous species of herbaceous plants. Although trees as seedlings and saplings do suffer increased mortality under the presence of white-tailed deer (Russel et al., 2001), they also have the ability to grow above the browse line. Once above the browse line they can only be partially defoliated, increasing their chances of survival. Under the browse line, white-tailed deer preferentially choose larger species (Gilliam, 2007). In the College Woods, we would expect herbaceous species to be disproportionately negatively affected by white-tailed deer, especially those species that are taller and therefore more detectable.

Plants that hide their meristems generally have acauline leaves or are graminoids. Grasses, sedges, and ferns actually tend to benefit from browse by white-tailed deer because of their ability for compensatory growth (Coté et al., 2003). This usually results in an increase in relative abundance in areas with high white-tailed deer populations (Horsley et al., 2003). These species are also able to avoid detection to some extent because of their lack of showy flowers (abiotic pollination). We would expect grasses, sedges, and graminoids to remain stable in the College Woods while species without hidden meristems would be more likely to decline.

In general, plants that have low detectability are less likely to be browsed. In a study of the Great Lakes Region, the browsing zone is defined as between 0.2 and 1.8m (Freker et al., 2013). This suggests that species that grow below 0.2m are more likely to escape detection by white-tailed deer. Species that grow along the ground are therefore likely to escape high levels of browse by white-tailed deer, whereas erect stems would be preferentially targeted. Aquatic species also have the opportunity to escape detection away from the shoreline. Although white-tailed deer do browse on aquatic species (Pletscher, 1987; Wallace & Telfer, 1974), the size of Lake Matoaka provides a refugia near the middle of the lake, making them likely to persist in stable populations.

Native species can be disproportionately negatively affected by white-tailed deer, whereas introduced species may benefit. Introduced species experience decreased competition as deer preferentially browse native species, allowing introduced species to colonize in the open space (Williams & Ward, 2006). White-tailed deer can also aid in the dispersal of introduced seeds, again aiding in establishment (Williams & Ward, 2006). In the College Woods, we would expect introduced species to increase in abundance over time.

Native herbaceous species that are perennial, shade tolerant, in a closed-canopy habitat (uplands, ravine slopes or bottoms, and sphagnous stream heads), relatively tall, and that mature for only a short window of time in the early spring or early summer should in theory be the set of species most likely to experience declines in the College Woods. The herbaceous layer is where the vast majority of plant species reside in temperate forests. Therefore, the maintenance of this layer is critical in maintaining the structure and function of the entire community (Gilliam, 2007). The composition of the herbaceous layer plays many important roles in the ecosystem, as it influences soil chemistry and successional processes while also providing food, cover, and protection for an array of forest organisms including insects, birds, and mammals (Coté et al, 2004). High levels of herbivory by white-tailed deer can force the composition of this layer to shift rapidly (Rooney, 2009), moving the herbaceous layer towards certain functional and taxonomically similar families (termed biotic homogenization; Rooney, 2009). Biotic homogenization by deer is manifested as a shift towards non-nutritive and unpalatable species, leading to areas with high amount of exotics, ferns, grasses, and graminoids (deCalesta, 1994; Horsley et al., 2003; Rooney, 2003; Carson et al., 2005; reviewed by Royo & Carson, 2006; Duguay & Farfaras, 2011; Geotsch, 2011). This leads to homogenized understories dominated by just a few unpalatable species (Rooney & Dress, 1997; Hédl et al., 2010) and can also produce less ground cover and lower densities of herbaceous plants overall (Horsley et al., 2003; Rossell et al., 2007; Rooney, 2009; Abrams & Johnson, 2012). The formation of recalcitrant mats by quick-growing, unpalatable herbs that prevent the recovery and germination of other plant species is also possible. This prevents potential transitions that could have occurred through periodic disturbance (Webster et al., 2008). Ultimately, high levels of herbivory by white-tailed deer can lead to an alternate stable state: a stable condition in an ecological community that is different than what would normally be predicted (Stromayer & Warren, 1997).

To my knowledge, this objective of my thesis represents the first test of whether species decline under the assumption of heavy white-tailed deer browsing shows predicted patterns of plant trait associations. Such knowledge could be important in determining the best course of management for conserving plant populations in the College Woods and elsewhere under the influence of heavy browsing pressure from white-tailed deer.

MATERIALS & METHODS

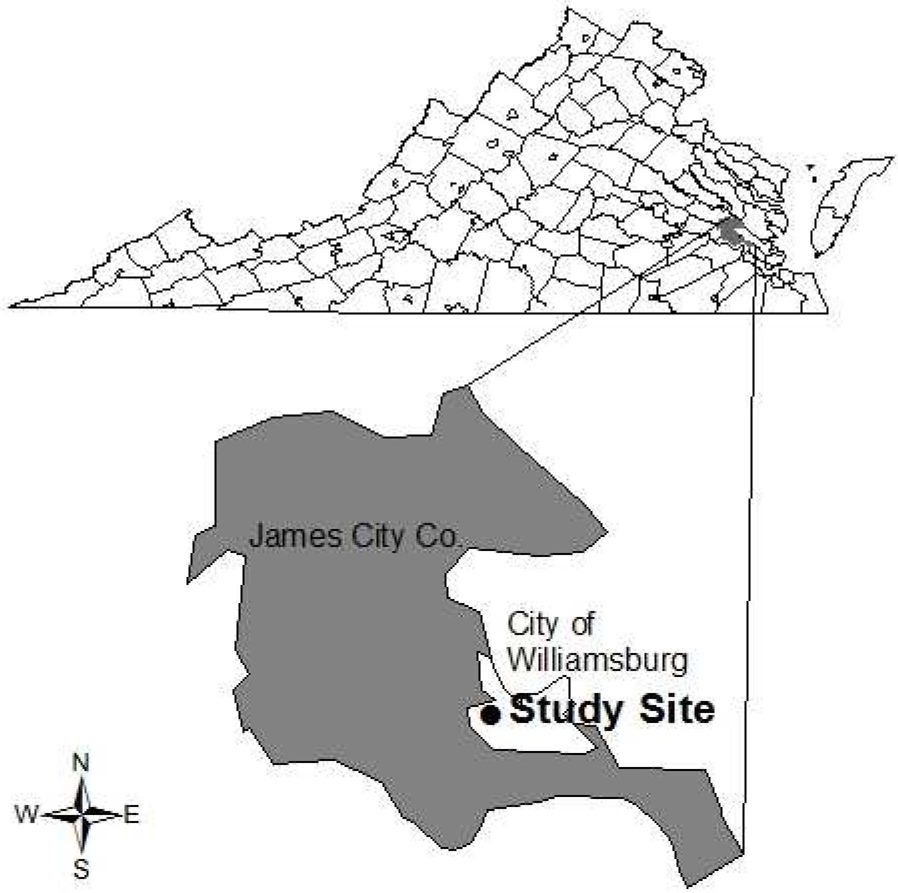


Figure 1. Top map: Virginia with James City County and the City of Williamsburg highlighted. Bottom map: location of study site within the City of Williamsburg.

Study Site

The College Woods lies in the inner coastal plain of the Virginia Peninsula between the York and James Rivers (Figure 1), adjacent to the College of William and Mary in Williamsburg, Virginia (37°16'13.9"N, 76°43'44.0"W). Precipitation averages about 48.26 inches annually and the climate is mild with an annual average low of 48.9 °F and average high of 68.3 °F. The woods are bounded to the east by the William & Mary campus, and to the south by Jamestown Road, Mill Neck Road, and Berkeley Road, with the exception of a small (approximately 1 acre) area of the College Creek floodplain directly south of the Jamestown Dam located on Jamestown Road. The western boundary consists of John Tyler Road and Strawberry Plains Road, with indentations where the Walnut Hills Shopping Center (formerly Walnut Hills Baptist Church), Strawberry Plains Neighborhood, and Berkeley Middle School are located. After Virginia Crouch's survey in 1989, a piece of land that spans from the north side of Aralia Ravine to the wood edge of Berkeley Middle School was acquired by the College, slightly expanding the extent of the College Woods (Appendix A shows current boundaries). The northern portion is dissected by Monticello and Compton Roads, creating a larger contiguous wooded area south of these roads and smaller portions north and east of them. These smaller areas are bounded by Ironbound Road, Chambrel Branch Retirement Home, and the William & Mary School of education. Collections for this thesis were made in the contiguous woods surrounding Lake Matoaka (including the newest addition to the woods near Aralia Ravine) as well as in the College-owned portions north of Monticello Rd, south of Jamestown Rd, and east of Compton Rd (See Appendix A for boundary lines).

Floristic Analysis

Plant Collection

The main objectives of the floristic analysis were to: (1) determine whether each species historically documented in the College Woods could still be located, (2) categorize relative abundance of all species documented, and (3) document any species newly reported to the College Woods. To locate previously collected species, Barans, Crouch and occasionally other historical -specimen collections were retrieved from the Herbarium of the College of William & Mary (WILLI), and data were obtained on the specific locality of each collection as well as the date it was collected. The location of at least one of the original collections was searched two weeks before and after its original collecting date to account for any annual differences in phenology and to facilitate locating the specimens with a comparable level of detectability. Most collections in all studies were historically and presently made in flower to facilitate identification. If a particular species could not be located in one previous location, a second known locality or other comparable habitats were searched across the woods. General collecting also occurred during these targeted searches as other species were encountered. For each given collection, a herbarium specimen was only made if the population was deemed large enough (>10 individuals) to support destructive sampling. Otherwise, partial collections or photographs were made. In addition to collector, collector number, and date, notes for each collection included a verbatim description of the plant, a GPS location using a handheld GPS, the number of individuals within the population, and relevant plant associates. Once a species was located and vouchered, further collection of that species generally ceased. However, running tallies of all herbaceous species encountered were made throughout the study in order to estimate relative abundance throughout the woods. During the course of the survey, all plants with evidence of white-tailed deer herbivory were also recorded. Deer browse was indicated when terminal buds were clearly removed and the point of removal was relatively parallel to the ground (a diagonal cut lower to the ground could be from a rodent).

Special effort was made to minimize sampling error by liberally estimating the number of hours that went into the original collections (we assumed 8 hour days during 112 collection trips for a total of 896 hours), and then exceeding that number. Increased effort was made possible by recruiting and training 9 undergraduate students who accompanied me in the field, with no more than four undergraduates searching at the same time. Taken together, effort consisted of three hundred and thirteen collecting trips comprising over 1,000 person hours. This generated 1,152 herbarium specimens from September 2013 through August 2015.

Specimens were primarily identified using the Flora of Virginia (Weakley et al., 2012), but occasionally The Manual of the Vascular Flora of the Carolinas (Radford et al., 2010) was used. The Manual of Cultivated Plants (Bailey, 1997) was used for ornamental species that could not be identified using the previously mentioned floras. Nomenclature follows the Flora of Virginia. This required a reassessment of all names and/or taxonomic identification of historical specimens to render all studies nomenclaturally compatible.

Collecting Effort

For the 2015 data, a collecting curve was produced that plotted effort against the accumulative number of new species added to the 2015 flora. Effort was measured by the number of days (i.e., collecting trips) that each person spent searching for plants. Therefore, if four researchers spent one day searching for plants, four consecutive collecting trips were recorded and the number of newly recorded species was split evenly across those four trips.

For the 1989 Crouch data, a collection curve was not possible because only species that were newly reported from the College Woods were vouchered with herbarium specimens. Thus, the species that Barans collected and were visually verified by Crouch are not associated with observation dates. However, Crouch does report the number of collecting trips in her study (125); of those, the number of collecting trips made from the College Woods (112) could be estimated from herbarium specimens. These trips, combined with the total number of species that Crouch reported in her flora, permitted a rough estimate of an average collecting rate at which specimens were discovered by Crouch.

Traits Analysis

In order to assess whether species were increasing or decreasing in abundance since the historical floras were conducted, I tallied individuals of each species observed during the 2013-2015 field seasons, and classified each as rare, occasional, common, or abundant. Species were considered rare if there were less than ten individuals found throughout the College Woods or if there was only one known population in the woods that contained less than fifty individuals. Species that were classified as occasional had 11 to 99 individuals present throughout the College Woods, or had just one population that contained 50 or more individuals. Common species had greater than 100 individuals throughout the College Woods, or were present in just a few populations but grew too densely to count. Species were considered abundant if individuals occurred in large clumps and were too dense to count in multiple areas of the College Woods (i.e., *Decodon verticillatus* (L.) Ell. or *Microstegium vimineum* (Trin.) A. Camus), or if they were encountered every few steps throughout the woods (i.e. *Ilex opaca* Aiton var. *opaca* or *Fagus grandifolia* Ehrhart). Crouch used the same four categories, but also recorded some in-between categories (i.e. "rare to occasional"). In these cases, the more rare category was used in order prevent overestimating the number of presently declining populations. Species that were not relocated between 1989 and 2015 are treated as rare in the comparative analyses. Although these species may be extirpated from the College Woods, it is also possible that they still persist in sparse numbers, in underground storage organs, or in the seed bank. I assessed changes in rarity by comparing Crouch's classifications with the present study. Because quantitative sampling was not used during either survey, it is important to note that abundance categories are relative.

Several species were excluded or treated differently in this analysis for the following reasons:

- *Dichanthelium acuminatum* and *D. dichotomum* have been split into varieties, of which there may be multiple taxa within the College Woods. These species were reported by Crouch but are missing their voucher specimens, which prevented their determination to variety. Therefore, these species were excluded from the analyses of rarity and the traits analyses.
- *Typha latifolia* L., *Rubus flagellaris* Willd., and *Scutellaria lateriflora* L. var. *lateriflora* were reported to the College Woods by Crouch, but their abundance was not assessed. As a result, these species were also removed.
- *Morella cerifera* (L.) Small was not reported from the College Woods by Crouch but was very likely present due to its ubiquitous, long-term presence in the tidewater area. *M. cerifera* was reported in the College Woods by both Barans (1968) and Ware (1970) but there are no known herbarium vouchers. In previous portions of this paper it has been included as a species held in common between years, however, because

there is no abundance information from 1989, it was removed for all comparative analyses.

- Ten species that were not reported by Crouch but were reported in 1968 and relocated in 2015 were assumed to be present but rare at the time of Crouch's survey and included in comparative analyses.
- The twenty-two other species recorded by Barans but not by Crouch or myself are not included because they have not been reported to the College Woods for nearly fifty years.
- Species that were newly reported to the College Woods as of 2015 were assessed for rarity, but not included in the assessments of changes in rarity and the analysis of traits, because we are only concerned with changes in abundance between 1989 and 2015 in this analysis.
- There were 23 instances (13.21% of unrecovered species) where new discoveries in 2015 were congeneric with unrecovered species. Because of the targeted nature of collecting, it is unclear whether previously reported species were actually replaced by congeneric species or whether they simply went undetected during the survey.

With the above list of exceptions, 591 species were investigated in total.

Each of the 591 species was categorized for each of the eleven traits that are predicted to influence herbivory (Table 1). Except where noted below, species traits were compiled using the descriptions contained in the Flora of

Virginia (Weakley et al., 2012). Three species found in the College Woods (*Philadelphus pubescens* Loisel., *Lagerstroemia indica* L., and *Rhododendron kaempferi* Planch.) were not treated by the Flora of Virginia because they are classified as waifs that have not become naturalized. For these species, trait characteristics were compiled from the Missouri Botanical Garden website (Missouri Botanical Garden, 2015). Habitat data were taken directly from Crouch (1989).

Habitat was given for each species by Crouch in her thesis (1989). Biogeography was listed for each species in the Flora of Virginia as was habit type (Weakley et al., 2012). When assessing life history, if a species had the ability to fall into multiple categories, it would be assigned the first life history stated in the Virginia Flora (for example, "annual or biennial" would be assigned "annual" status in the analysis). Pollination mode was determined based on family. A species was considered to have hidden meristems if it was a graminoid or had acauline leaves. The values used for plant height were the midpoint of the minimum and maximum heights listed in the Flora of Virginia. Two approaches were taken to evaluate height. I first tested the height variable using above 1.8m or below 1.8m as my two categories because 1.8m is considered the upper end of the browse line for white-tailed deer (Frerker et al., 2013). I also tested the height variable by binning species into every 0.2m (e.g. 0-0.2m, 0.2m-0.4m, etc.) up to 1.8m to see if there was a preference in height below the browse line. This analysis only involved 466 species (because the remaining

125 species grew over 1.8m), with 223 of those species declining. For the NMDS test, I used the binned data but included the data for all 591 species. Flowering phenology was classified by the first month of flowering listed in the Flora of Virginia (Weakley et al., 2012). The length of the flowering period was determined by the number of months between the first and last month listed for flowering in the Flora of Virginia (Weakley et al., 2012). Stem position was determined based on the description of the plant provided by the Flora of Virginia (Weakley et al., 2012).

For each trait, its frequency in the set of 591 species was compared to its frequency in the set of declining species identified by the present study. Chi-square goodness-of-fit tests (Vassarstats, 2015) were used to assess significance. If the expected values of a category were under five, p-values were calculated using a Monte-Carlo simulation in R (version 3.0.2) with 500 iterations. I used non-metric multidimensional scaling (NMDS) in order to see whether the combination of all eleven traits could define the set of declining species when compared to species with no change or an increase in abundance. An NMDS was chosen for this analysis because of its ability to handle both binary and continuous data.

Table 1. Traits and variables used to compare their frequency in the Crouch (1989) flora to their frequency in the set of species declining in abundance. Each trait was chosen based on its ability to influence survivability after browse by white-tailed deer according to Coté et al. (2004). Traits predicted to correspond with stable (“winner”) and declining (“loser”) populations are also included. Data was gathered from the Flora of Virginia (2012) and Missouri Botanical Garden (3 cultivated spp.) for all variables with the exception of Habitat. Habitat data came from Crouch (1989).

Trait	“Winner” Variable	“Loser” Variable
Biogeography	• Introduced	• Native
Flowering Period	• Late Flowering	• Early Flowering
Habit	• Tree • Shrubs • Woody Vines • Aquatic Forbs	• Herbaceous Forbs
Habitat	• Lake Matoaka • Open Spaces	• Broad Ravine Bottoms • Ravine Slopes • Ridges & Level Uplands • Sphagnous Stream Heads
Height	• Above 1.8m	• Below 1.8m • Tall spp. below 1.8m
Hidden Meristems	• Present	• Absent
Length of Flowering	• Longer Periods	• Shorter Periods
Life History	• Summer • Annual • Winter Annual • Biennial	• Perennial
Pollination Mode	• Abiotic	• Biotic
Shade Tolerance	• Full Tolerance • Shade Intolerant	• Shade Tolerant
Stem Position	• Along Ground • Acauline	• Climbing • Erect

RESULTS

Collecting Effort

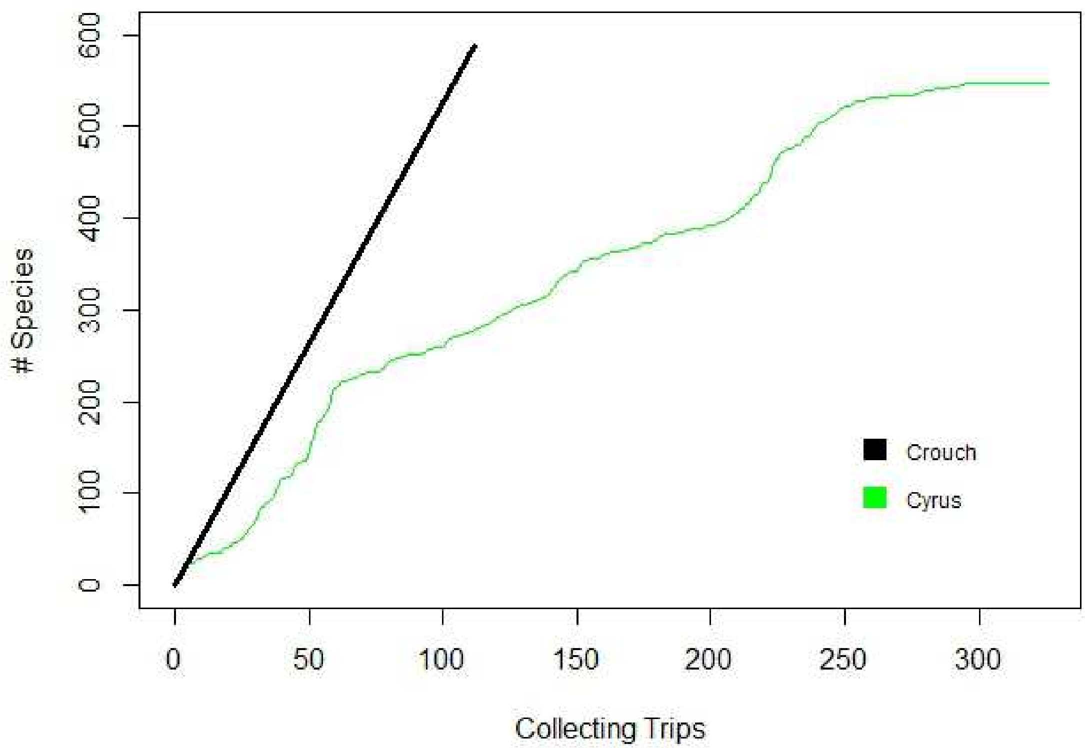


Figure 2. Species accumulation curve plotting collecting effort (trips) versus the cumulative number of new species added to the study. Only the number of estimated trips and total species can be derived from the Crouch data.

The species accumulation curve shows that 297% more effort was required in 2015 to find 7% fewer species than in the 1989 study (Figure 2). In 2015, the curve levels out around 540 species after approximately 225 collecting trips, but this levelling off may represent the end of a field season. It is likely that more species are present in the College Woods but are exceedingly rare to locate.

Floristic Summary

A total of 549 species were discovered from September 2013 through August 2015. One hundred and twenty six species are new records to the College Woods. Of the 587 species reported by Crouch, 174 species (29.64%) were not recovered in the present study. In comparison, 32 species from the Barans survey were not recovered by Crouch, and 83 new species were reported by Crouch but not Barans. Additionally, ten species that were reported by Barans (1968) and not found by Crouch (1989) were relocated in the present study. Because of this, and for ease of future comparison, the Crouch and Barans collections will be treated as one hereafter for a total of 619 species. When the Crouch, Barans, and present survey are combined, the total number of species reported from the College Woods is 745 (Table 2).

Table 2. Summary of floristic surveys in 1989 and 2015. Format after Standley (2015).

	# Species			% Species Introduced
	Native	Introduced	Total	
1968 + 1989	493	126	619	19.90
2015 Survey				
Relocated from 1989	339	74	413	17.92
Relocated from1968	5	5	10	50.00
Not prev. reported	68	58	126	46.03
Total	412	137	549	25.00
Not relocated	149	47	196	22.45
Total species recorded (1989 – 2015)	564	181	745	24.30

Table 3. The thirteen families in each survey possessing the highest number of species. Data for across Virginia state is included for comparison.

Family	Cyrus	Crouch (1989) + Barans (1968)	VA State
Asteraceae	68 (12.39%)	74 (11.96%)	427 (13.50%)
Poaceae	58 (10.56%)	56 (9.05%)	389 (12.29%)
Fabaceae	39 (7.10%)	41 (6.62%)	148 (4.68%)
Cyperaceae	32 (5.83%)	36 (5.82%)	357 (11.28%)
Orchidaceae	15 (2.73%)	15 (2.42%)	104 (3.29%)
Rosaceae	15 (2.73%)	15 (2.42%)	163 (5.15%)
Ericaceae	15 (2.73%)	17 (2.75%)	60 (1.90%)
Fagaceae	13 (2.37%)	14 (2.26%)	32 (1.01%)
Lamiaceae	13 (2.37%)	14 (2.26%)	122 (3.86%)
Rubiaceae	13 (2.37%)	11 (1.78%)	72 (2.28%)
Ranunculaceae	11 (2.00%)	12 (1.94%)	68 (2.15%)
Polygonaceae	10 (1.82%)	11 (1.78%)	42 (1.33%)
Brassicaceae	9 (1.64%)	13 (2.10%)	91 (2.87%)
Total	311 (56.65%)	329 (53.15%)	2075 (65.58%)
Total # Species in	549 (100%)	619 (100%)	3164 (100%)

There are 353 genera comprising 112 families in the most recent survey, compared to the 369 genera in 122 families found in the past two surveys combined. The thirteen most species-rich families comprise 56.75% of the 2015 flora. These reflect the same species-rich families in the 1989 survey as well as the Virginia Flora in general (Table 3). Thirty-nine families contained only one species in 2015 (7.10% of 2015 flora), while forty-one families contained only one species in 1989 (6.62% of 1989 flora). Sixty-two genera and 14 families were not recovered during the 2015 survey. All but two of these families contained only one species. Conversely, 49 genera and 9 families were added in 2015. Only one of these families contained more than one species.

Habitats of Newly Reported Species

A chi-square test showed there was no significant difference in the distribution of habitat types between newly reported species and those previously reported (χ^2 =5.32, df=NA, simulated p=0.39). In both cases, the majority of species were found in open spaces, and ridges and level uplands as categorized (Table 4). However, if the ravine environment is thought to comprise its ridges, stream heads, slopes and bottoms, then they too could be considered relatively species-rich.

Table 4. Distribution of habitat types in newly reported (2015) and previously reported (1968+1989) species.

Habitat Type	Newly Reported	% Total	Previously Reported	% Total
Lake Matoaka	3	2.38	37	5.98
Broad Ravine Bottoms	15	11.90	60	9.69
Ravine Slopes	9	7.14	64	10.34
Sphagnous Stream Heads	3	2.38	15	2.42
Ridges and Level Uplands	27	21.43	146	23.59
Open Spaces	69	54.76	297	47.98
Total	126	100.00	619	100.00

Congeneric Species that May Have Gone Undetected

Of the 196 species not relocated from the 1968 and 1989 surveys combined, forty-two of these species are visually similar and congeneric to one or more of 26 newly-reported species (Table 5). Because specimens were identified after the field season ended, differences went unnoticed until it was too late to relocate the previously recorded species. These visually similar species may or may not all exist in the woods, and they may have been overlooked in any of the College Woods floras. In the present flora, this problem could potentially affect up to 24.13% of the unrecovered flora (Figure 3).

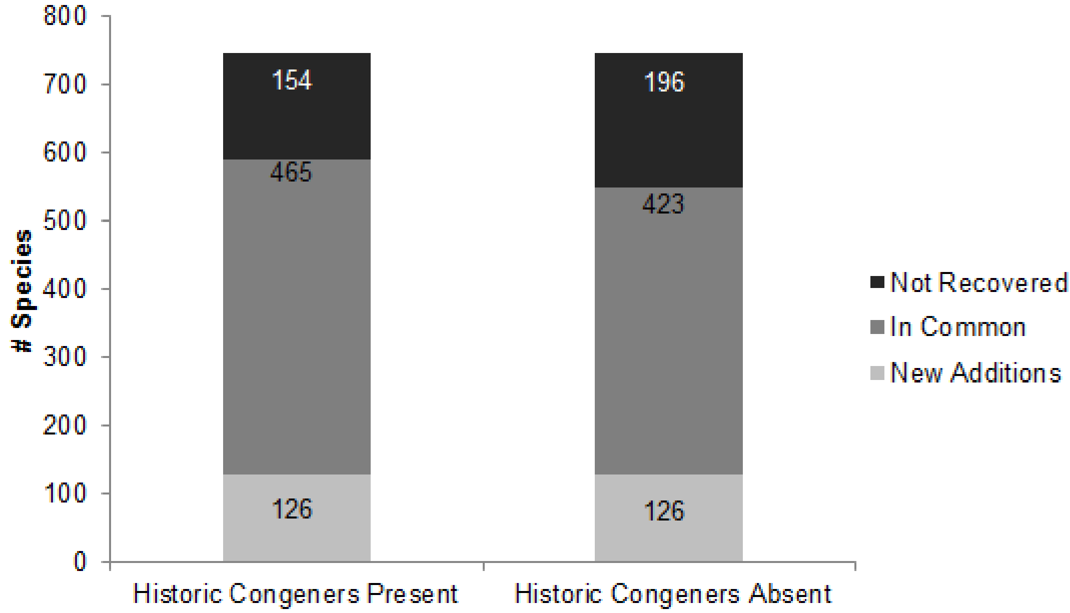


Figure 3. Histogram showing how the 2015 survey data would be affected if all visually-similar and historical congeneric species are present or absent in the College Woods. Forty-two more species would be held in common between the 1989 and 2015 survey. Sample sizes are written in the bins.

Table 5. A list of species previously reported to the College Woods but were not recovered during the 2015 survey that are visually similar to congeneric species that were newly reported to the College Woods in 2015. See Appendix C for authorities on names.

Species Not Relocated in 2015	Species Newly Reported in 2015
1. Bidens comosa	*B. connata*
2. Bromus japonicus	*B. latiglumus*
3. Bromus racemosus	*B. latiglumus*
4. Bromus pubescens	*B. latiglumus*
5. Carex atlantica	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
6. Carex debilis	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
7. Carex granularis	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
8. Carex grisea	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
9. Carex laxiculmis var. *laxiculmis*	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
10. Carex laxiflora	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
11. Carex leptalea	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
12. Carex striatula	*C. annectans, C. bushii, C. gracilescens, C. retroflexa*
13. Cirsium discolor	*C. vulgare* or *C. pumilum*
14. Cirsium horridulum ssp. *horridulum*	*C. vulgare* or *C. pumilum*
15. Conyza canadensis ssp. *canadensis*	*C. bonariensis*
16. Cyperus lancastriensis	*C. pseudovegetus*
17. Cyperus polystachyos	*C. odoratus* var. *odoratus*
18. Cyperus retrorsus	*C. pseudovegetus*
19. Dichanthelium depauperatum	*D. acuminatum* var. *acuminatum* or *D. meridionale*
20. Dichanthelium dichotomum var. *ramulosum*	*D. acuminatum* var. *acuminatum* or *D. meridionale*
21. Eupatorium pubescens	*E. hyssopifolium* or *E. serotinum*
22. Galactia regularis	*G. volubilis* var. *volubilis*
23. Galium pilosum	*G. tinctorum*
24. Ipomoea hederacea	*I. purpurea*
25. Lepidium campestre	*L. virginicum*
26. Lepidium didymum	*L. virginicum*

Table 5 Continued. A list of species previously reported to the College Woods but were not recovered during the 2015 survey that are visually similar to congeneric species that were newly reported to the College Woods in 2015. See Appendix C for naming authorities.

Species Not Relocated in 2015	Species Newly Reported in 2015
27. Oxalis stricta	*O. florida*
28. Paspalum pubiflorum	*P. floridanum* or *P. setaceum*
29. Persicaria maculosa	*P. hydropiper* or *P. glabra*
30. Persicaria pensylvanica	*P. hydropiper* or *P. glabra*
31. Rudbeckia laciniata var. *digitata*	*R. triloba* var. *triloba*
32. Rudbeckia laciniata var. *laciniata*	*R. triloba* var. *triloba*
33. Smilax glauca	*S. pseudochina*
34. Smilax herbacea	*S. pseudochina*
35. Smilax hispida	*S. pseudochina*
36. Smilax laurifolia	*S. pseudochina*
37. Solidago altissima ssp. *altissima*	*S. erecta*
38. Solidago nemoralis var. *nemoralis*	*S. erecta*
39. Solidago pinetorum	*S. erecta*
40. Veronica arvensis	*V. hederifolia*
41. Veronica peregrina var. *peregrina*	*V. hederifolia*
42. Vulpia octoflora	*V. myuros*

Plant Species With Browse By White-tailed Deer

Seventy-one species showed signs of browse by white-tailed deer on at least one individual (Appendix B). Four species that were browsed were non-native. Eleven species are considered unpalatable or have low food preference for white-tailed deer (USDA, 2014). There were no sedges or grasses with evidence of browsing by white-tailed deer.

Native and Introduced Species

Figure 4 shows the 2015 flora contained a higher percentage of introduced species (24.95%) than Crouch's flora (20.36%) or the Virginia flora in general (19.15%). However, three species from Crouch and Barans datasets, and 16 species from the present study are not treated by the Flora of Virginia because they are not naturalized in our flora. Removal of these species lowers the percentage of exotics in the woods to 22.70%, which is not significantly different from the state or the prior College Woods floras (χ^2=3.66, df=2, p=0.1604; Figure 4). Forty-two species reported from the College Woods are on the Virginia Invasive Species List (16 highly invasive, 15 moderately invasive level, 10 lowest invasive level), and two have alerts out from the National Park Service (Table 6). Two species (*Celastrus orbiculatus* Thunb. and *Dioscorea polystachos* Turczaniow) are historically reported from the woods but were not recovered in 2015. The area where these two species were located was clear cut after 1989, effectively destroying the habitat. Eleven introduced species are newly reported from the College Woods, including county records for *Euonymus alatus* (Thunb.) Sieb., *Ficaria verna* Hudson, and *Ampelopsis brevipedunculata* (Maxim.) Trautv..

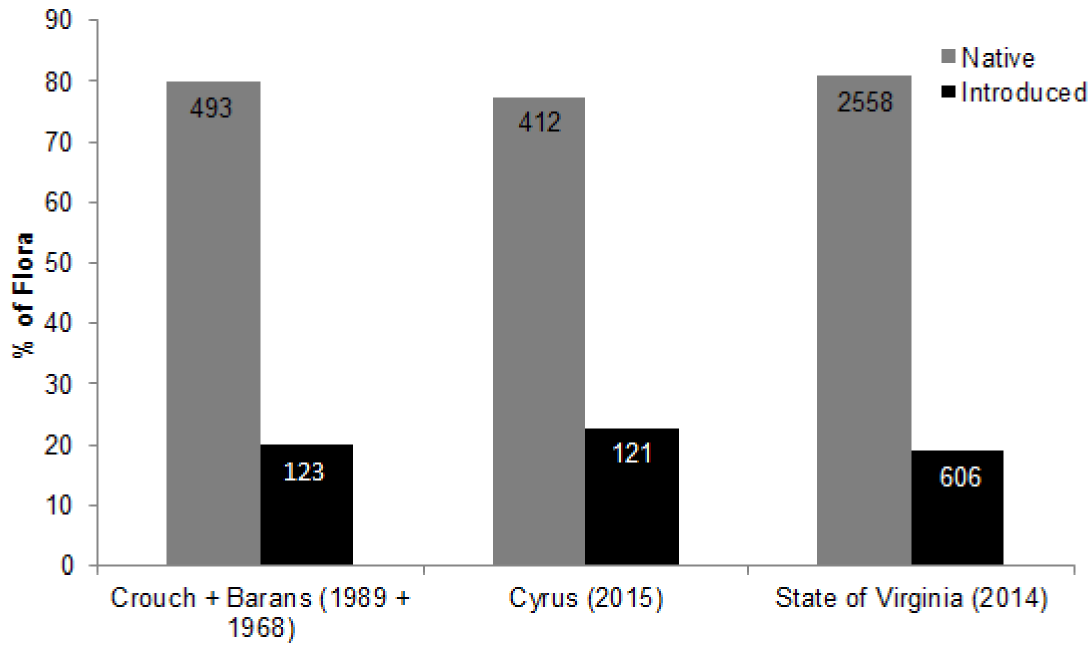


Figure 4. Percentage of native and introduced species in the Crouch and Barans College Woods floras combined, the Cyrus College Woods flora, and the state of Virginia overall (as of 2014). Exotic species in the College Woods that are not known to naturalize and are not treated by the Virginia Flora have been removed (three species from the Crouch and Barans dataset and sixteen from the Cyrus dataset). Sample sizes are written in each bin.

Table 6. Species on the Virginia Invasive Species List reported from the College Woods. Asterisks(*) are new records for the College Woods; double asterisks (**) are also county records. See Appendix C for authorities.

Highly Invasive	Moderately Invasive	Lowest Invasive Level
Ailanthus altissima	*Agrostis capillaris*	*Commelina communis*
* *Ampelopsis brevipedunculata*	*Albizia julibrissin*	*Lespedeza bicolor*
Celastrus orbiculatus	*Arthraxon hispidus* var. *hispidus*	*Morus alba*
Dioscorea polystachya	*Cirsium vulgare*	*Perilla frutescens*
Elaeagnus umbellata	* *Euonymus fortunei*	*Phleum pratense*
** *Ficaria verna*	*Glechoma hederacea*	*Populus alba*
* *Euonymus alatus*	*Hedera helix*	*Elaeagnus pungens*
Lespedeza cuneata	*Ligustrum obtusifolium* var. *obtusifolium*	*Rumex crispus* ssp. *crispus*
Ligustrum sinense	*Paulownia tomentosa*	*Securigera varia*
Lonicera japonica	*Persicaria longiseta*	*Vinca minor*
Microstegium vimineum	*Phyllostachys aurea*	**NPS Alert**
Murdannia keisak	*Poa trivialis*	* *Arum italicum*
Rosa multiflora	* *Pyrus calleryana*	* *Liriope spicata*
Rubus phoenicoliasus	*Stellaria media*	
Sorghum halepense	*Veronica hederifolia*	
Urtica dioica	*Wisteria sinensis*	

County Records, Rare Species, and Species of Distributional Significance

There are 36 county records from the 2015 survey, including one state record (*Cenchrus purpureus). Cenchrus purpureus* (Schumach.) Morrone is native to Africa and widely naturalized (and invasive) in many tropical areas throughout the world. In the United States, it is considered invasive in Florida and Hawaii. Twenty-two (61.11%) of the county records are introduced species, including *Ficaria verna, Euonymus alatus,* and *Ampelopsis brevipedunculata* which are all listed by the Virginia Department of Conservation and Recreation as invasive species. Additionally, *Cardiospermum halicacabum* L. is known to become "locally rampant". *Aesculus pavia* L., *Clereodendrum trichotomum* Thunb., *Tarenaya hassleriana* (Chodat) H. H. Iltis, and *Liriope spicata* Lour. are firmly established and spreading in the College Woods but are not previously known to be invasive.

Bouteloua curtipendula (Michx.) Torr. var. *curtipendula, Bromus latiglumus* (Shear) A.S. Hitchc., and *Helianthus microcephalus* Torr. & Gray all are documented throughout the western portion of Virginia, but have yet to be reported in the Coastal Plain. These are therefore newly reported instances of mountain-coastal plain disjuncts.

Comptonia peregrina (L.) Coult. and *Tilia americana* L. var. *americana* are mountain-coastal plain disjuncts newly reported to the College Woods, but are already known from the Coastal Plain. Twenty-two mountain-coastal plain disjuncts were previously reported from the College Woods, however, only ten were recovered during the 2015 survey (Table 7).

Fifteen species reported from the College Woods are on the state-threatened or state-watch list, including one species that is federally listed as threatened. Of these fifteen species, only eight were relocated, three of which are in declining in numbers (Table 8).

Table 7. Status of mountain-coastal plain disjunct species reported from the College Woods. Relocated species are present in a historically known location (when previously specified) except where indicated. See Appendix C for naming authorities.

Scientific Name	Previous Status (1989)	Current Status
Actaea pachypoda	Occasional; usually on steep slopes under fairly mature hardwoods.	Not relocated
Amianthium muscaetoxicum	Rare; one colony in open oak-hickory woods.	Not relocated
Aralia nudicaulis	Rare; in one narrow wooded ravine.	Not relocated
Aralia racemosa	Rare; in two narrow wooded ravines.	Not relocated
Aruncus dioicus	One substantial colony on steep slopes of narrow branched ravine on the East side of Squirrel Point.	Relocated: one individual in different location
Caltha palustris	Not relocated – reported 1968.	Not relocated
Comptonia peregrina	Not present.	Two individuals in one population
Cornus alternifolia	Occasional; open woods along trails, steep ravine slopes, stream bottoms.	Relocated: one individual
Desmodium cuspidatum	Common in cutover areas, along trails, woodland borders, occasionally in open woods.	Not relocated
Elodea canadensis	Common in shallow water of Matoaka Lake.	Not relocated
Euonymus atropurpureus	Rare; in shell-marl banks near streams in beech-oak woods.	Relocated: one individual
Galax urceolata	Rare; two large colonies on wooded slopes just above sphagnous stream heads.	Relocated: one population of 10 – 20 individuals

Table 7 Continued. Status of mountain-coastal plain disjunct species reported from the College Woods. Relocated species are present in a historically known location (when previously specified) except where indicated. See Appendix C for naming authorities.

Scientific Name	Previous Status (1989)	Current Status
Hexalectris spicata var. *spicata*	40 individuals in four colonies on three ravines; calcareous lake-banks under oaks and beeches.	Relocated: no change
Hylodesmum glutinosum	Common along trail and stream banks in oak and beech-oak woods.	Relocated: no change
Monotropsis odorata	Rare; heavy oak leaf litter in oak-beech-pine woods below William and Mary Cafeteria.	Not relocated
Myosotis laxa	Occasional in shallow water of Matoaka Lake, especially in the Main Ravine.	Relocation: no change
Panax quinquefolius	Two colonies of 12 individuals each, one colony possibly not on College property. Steep south-facing slopes in narrow ravines in beech-oak woods.	Relocated: two individuals in two distinct populations
Quercus muehlenbergii	Occasional on dry slopes, ridges and level uplands, especially in maturing hardwoods.	Relocated: no change
Sanicula marilandica	Common in open woods and stream bottoms.	Not relocated
Tilia americana var. *americana*	Not reported; likely present at time of study.	Occasional; found in areas of shell-marl deposit
Triosteum perfoliatum	Rare; a few individuals in wooded ravines.	Not relocated

Table 8. Status of species historically reported in the College Woods that are tracked (federally-listed, state-listed, or watch-listed) by the Virginia Natural Heritage Program. G = global ranking, S = state ranking, SH = known to state historically, LT = federally listed threatened. Relocated species are present in a historically known location (when previously specified) except where indicated. Authorities are listed in Appendix C.

Scientific Name	Previous Status (1989)	Current Status
Cenchrus incertus GNR, S3	Rare; along woodland border	Not relocated
Crotalaria purshii G5, SH	Occasional; observed in open cutovers	Not relocated
Desmodium cuspidatum G5T5, S2	Common; seen across multiple habitats	Not relocated
Hexalectris spicata var. *spicata* G5T4T5, S3	Rare; 40 individuals in four colonies	Relocated: No change
Ilex vomitoria G5, S3	Two small trees along trail	Not relocated
Isotria medeoloides G2?, S2, LT	3 stems comprising two populations	Relocated: 1 stem
Malaxis spicata G4?, S3	Two individuals in College Creek floodplain	Prev. population not relocated; new population of 9 individuals found
Monotropsis odorata var. *lehmaniae* G3, S3	One population just above College Creek floodplain	Not relocated
Panax quinquefolius G3G4, S3S4, LT	12 individuals across two populations	Relocated: two individuals in two populations; one population is new
Pedicularis lanceolata G5, S3	Occasional; found on shores of lake and open ravines	Relocated: two individuals in one population
Ponthieva racemosa G4G5, S3	Common; forming substantial colonies	Relocated: no change

Table 8 Continued. Status of species historically reported in the College Woods that are tracked (federally-listed, state-listed, or watch-listed) by the Virginia Natural Heritage Program. G = global ranking, S = state ranking, SH = known to state historically, LT = federally listed threatened. Relocated species are present in a historically known location (when previously specified) except where indicated. Authorities are listed in Appendix C.

Scientific Name	Previous Status (1989)	Current Status
Scirpus lineatus G4S3	Common; in wooded ravines and bottomlands	Relocated: no change
Scutellaria incana G5,S2	Rare; on sunny shell-marl banks	Not relocated
Utricularia olivacea G4,SH	Floating in mats in Lake Matoaka	Not relocated
Verbesina virginica G5? T5?, S3	Occasionally found in dry woods and cutovers	Relocated: no change

Habitats

The College Woods supports six distinct habitats, each with a characteristic flora (Crouch, 1989). The treatments below describe each habitat and makes note of common species, significant associations, and occurrences of note.

Lake Matoaka

Clusters of *Azolla caroliniana* Willd. are found floating along the lake surface. *Ceratophyllum demersum* L. is the most common species submerged near the center of the lake, however, it was consistently coated and entangled in large mats of algae, making it difficult to detect. *Potamogeton crispus* L. replaced *C. demersum* near lake edges.

Lycopodioides apodum (L.) Kuntze, *Pilea fontana* (Lunell) Rydb., *Boehmeria cylindrica* (L.) Sw.*, Cyperus polystachyos* Rottboell, *Morella cerifera*, *Bidens laevis* (L.) B.S.P., and multiple species of *Persicaria* are commonly encountered at the water's edge. Along the Jamestown Dam, *Kyllinga gracillima* Miquel*, Scutellaria lateriflora*, and *Cephalanthus occidentalis* L. also occur.

The delta to the north of the Lake supports the only population of *Ludwigia decurrens,* a newly reported species in 2015, in the College Woods. Notable populations of *Murdannia keisak* (Hasskarl) Handel-Mazzetti*, Myosotis laxa* Lehm.*, Symphyotrichum pilosum* (Willd.) Nesom var. *pilosum,* and *S. pilosum* (Willd) Nesom var. *pringlei* (Gray) Nesom are also found there*.* The area is dominated by *Carex* spp., *Juncus* sp., and *Leersia oryzoides* (L.) Sw.*.* A dense stand of *Acer rubrum* L. also exists at the tip of the delta.

Broad Ravine Bottoms

All ravines feeding into and out of Lake Matoaka have a broad bottom, especially in areas nearest to the lake. The east side of the Lake has a number of broad, shallow inlets that supports assemblages of *Saururus cernuus* L.*, Impatiens capensis* Meerburg*, Glyceria striata* (Lam.) A. S. Hitchc.*, Packera aurea* (L.) A. & D. Love*,* and *Bidens laevis*. These are overtopped by *Acer rubrum, Fraxinus americana* L.*, Ulmus rubra* Muhl. and *Ulmus americana* L.*.*

Occasionally, *Cornus stricta* Lam. is present. *Alnus serrulata* (Ait.) Willd. commonly forms dense thickets at the mouths of these systems. *Quercus phellos* L., *Pedicularis lanceolata* Michx., *Hydrocotyle ranunculoides* L.f., and *Hydrocotyle prolifera* Kellogg (a new addition to the flora) all occur in at least one of these inlets.

The southern portion of College Creek is the widest and most extensive ravine bottom owned by the College. *Saururus cernuus, Impatiens capensis,* and *Scirpus lineatus* Michx. dominate this area. *Sanicula canadensis* L. var. *canadensis, Asplenium platyneuron* (L.) B.S.P., *Dactylis glomerata* L. ssp. *glomerata, Sphenopholis nitida* (Biehler) Scribn., and *Sorghum halepense* (L.) Pers. grow scattered throughout. A mixture of *Acer rubrum, Fraxinus americana, Ulmus rubra, U. americana,* and rarely, *Pinus taeda* L. grow throughout the floodplain. *Bignonia capreolata* L. can be observed growing infrequently on these trees throughout.

The open edge at the base of Jamestown Road also supports populations of *Salix nigra* Marsh., *Elaeagnus umbellata* Thunb., *Scirpus atrovirens* Willd., and *Scirpus cyperinus* (L.) Kunth. An extensive colony of *Equisetum hyemale* L. ssp. *affine* is present in this area and runs along into the wooded area of the creek for at least 100 meters. *Heliopsis helianthoides* (L.) Sweet var. *helianthoides, Verbesina occidentalis* (L.) Walt., *Verbesina virginica* L., and *Ageratina aromatica* (L.) Spach grow in the wooded portion of the ravine bottom immediately adjacent to the open area, but disappear farther back into the floodplain. The only populations of *Peltandra virginica* (L.) Schott (a newly reported species) and *Carex alata* Torrey recorded in the woods grow in the College Creek floodplain.

The ravines on the west of the Lake start steep and narrow, but broaden out into wide floodplains as they feed into Lake Matoaka. Nearly all ravine systems on the west side of the lake are not wooded, with the exception of a scattering of *Cornus stricta* and *Lindera benzoin* (L.) Blume. There is very little vegetation in these areas, but *Scirpus lineatus, Glyceria striata, Carex* spp., *Juncus* spp., and *Bidens laevis* are predictably present. *Carex laevivaginata* (Kukenth.) Mackenzie, *C. lurida* Wahlenb., *C. crinita* Lam. var. *crinita, Typha latifolia* L., *Cicuta maculata* L. var. *maculata, Pilea fontana* and *Lobelia cardinalis* L. are found in at least one ravine system. *Rosa palustris* Marsh. is found at the mouth of each ravine growing on raised hummocks.

Ravine Slopes

Many of the ravine slopes in the College Woods contain fossilized shell-marl deposits, facilitating an assemblage of calciphiles. *Cercis canadensis* L. var. *canadensis, Brachyelytrum erectum* (Schreb. ex Spreng.), *Cypripedium parviflorum* Salisb. var. *pubescens* (Willd.) Knight, and *Hexalectris spicata* (Walter) Barnh. var. *spicata* only occur in the College Woods within this habitat. Regardless of soil type, *Microstegium vimineum* (Trin.) A. Camus, *Asimina triloba* (L.) Dunal, and *Polystichum acrostichoides* (Michx.) Schott are the most abundant species encountered on ravine slopes. *Smallanthus uvedalius* (L.) Mackenzie ex Small*, Verbesina virginica,* and *Verbesina occidentalis* are frequently found on open, sunny slopes. In small, steep ravines, *Luzula* spp. and *Adiantum pedatum* L. become very common. Additionally, *Matelea caroliniensis* (Jacq.) Woods. and *Ponthieva racemosa* (Walt.) C. Mohr can be found in nearly every ravine system. Three mountain-coastal plain disjuncts, *Aruncus dioicus* (Walt.) Fernald*, Panax quinquefolius* L., and *Euonymus atropurpureus* Jacq. var. *atropurpureus* were each found in only one location in the College Woods on ravine slopes.

Sphagnous Stream Heads

Sphagnum grows at the heads of College Creek, Blunt Point Ravine (Dead Dog Gulch), and the southern branch of Strawberry Plains Ravine. Each site supports populations of *Magnolia virginiana* L.*, Kalmia latifolia* L.*, Osmundastrum cinnamomea* (L.) C. Presl*,* and *Medeola virginiana* L.*. Platanthera clavellata* (Michx.) Luer (a newly reported species)*, Lyonia mariana* (L.) D. Dom*, Ilex verticillata* (L.) Gray*, Nyssa biflora* Walt.*, Eleocharis obtusata* (Willd.) Schultes*,* and *Carex seorsa* Howe in Gardinier & Howe were found only once in the College Woods, each in one of the three sphagnous stream heads.

Ridges and Level Uplands

The College Woods is mostly composed of level upland areas. *Fagus grandifolia, Ilex opaca* var. *opaca,* and *Quercus* spp. dominate with *Carya* spp.

also common. *Hexastylis virginica* (L.) Small*, Tipularia discolor* (Pursh) Nutt. var. *discolor, Polystichum acrostichoides,* and *Cynoglossum virginianum* L. var. *virginianum* are frequently in the herbaceous layer. In the spring, *Obolaria virginica* L.*, Hepatica americana* (DC.) Ker-Gawl.*, Houstonia caerula* L.*, Epigaea repens* L. and *Sanguinaria canadensis* L. occur along trail edges and in more open areas of the woods. Trail edges also support *Verbena urticifolia* L.*, Desmodium* spp., *Oxalis* spp., *Agrimonia rostellata* Wallr.*,* and *Lobelia inflata* L.*,* which flower later in the season. *Aplectrum hyemale* (Muhl. ex Willd.)*, Isotria medeoloides, Malaxis spicata* Swartz*,* and *Corallorhiza odontorhiza* (Willd.) Nuttall var. *odontorhiza* all occur in level uplands but in very small and scarce populations. Along the edge of the College Woods, *Smilax bona-nox* L. var. *bona-nox* is frequent.

The western and northwestern edges of the College Woods are drier, supporting a mixture of *Pinus taeda, P. virginiana* Miller*,* and occasionally *P. echinata* Miller*.* These are likely remnants of the clear cut that occurred in the mid 1960's. There is also a strong ericaceous quality to the western portion of the woods. *Oxydendrum arboreum* (L.) DC. and *Kalmia latifolia* are frequent. *Vaccinium* spp. and *Gaylussacia* spp., with the exception of one small population of *Lyonia mariana* were the only species encountered in the herbaceous or shrub layer. *Cornus florida* L. and *Nyssa sylvatica* are also scattered throughout.

A large pine stand occurs from Berkeley Middle School and down along Monticello Road. *Ilex opaca* var. *opaca* and *Kalmia latifolia* occur sporadically through this habitat. *Mitchella repens* L., *Chimaphila umbellata* (L.) Pursh, and *Polystichum acrostichoides* are common in this area. *Cypripedium acaule* Aiton and *Galium sherardia* E.H.L. Krause (a newly reported species) occur in large populations. Only one population of *Bartonia virginica* (L.) B.S.P. and *Malaxis unifolia* Michx. were observed in the pine habitat.

Open Spaces

There are few open areas within the College Woods, whereas open areas were more frequent in 1968 and 1989. Shade-intolerant plants can be found in disturbed areas where the canopy opens, but these are relatively small and mostly limited to areas where Hurricane Isabel hit in 2003. Shade-intolerant plants are more likely to be found along the edges of the woods, on either side of the Jamestown Dam (which is regularly mowed), or in an area that has long been used for grounds waste (the "refuse pile"). Within the College Woods, *Erechtites hieraciifolius* (L.) Raf. ex DC. and *Microstegium vimineum* are very common in these disturbed areas. In open areas nearer to the lake, *Callicarpa americana* L., saplings of *Pinus taeda,* saplings of *Juniperus virginiana* L. var. *virginiana,* and *Morella cerifera* are common. At the refuse pile, *Paulownia tomentosa* (Thunb.) Steud., *Tarenaya hassleriana,* and *M. vimineum* dominate. Large colonies of *Urtica dioica* L., *Datura stramonium* L., and *Rubus phoenicoliasus* Maxim. also occur along the edges. The Jamestown Dam supports *Rosa multiflora* Thunb. ex Murr., *Securigera varia* (L.) Lassen, *Verbascum blattaria* L., and *Verbascum thapsus* L. ssp. *thapsus*. *Lathyrus hirsutus* L., *Hypericum punctatum* Lam., *Hypericum hypericoides* (L.) Crantz, *Sabatia angularis* (L.) Pursh, *Melilotus alba* Medikus, and *M. officinalis* (L.) Lam. are common along wood edges.

Part 2: Changes in Declining Species

Changes in Rarity

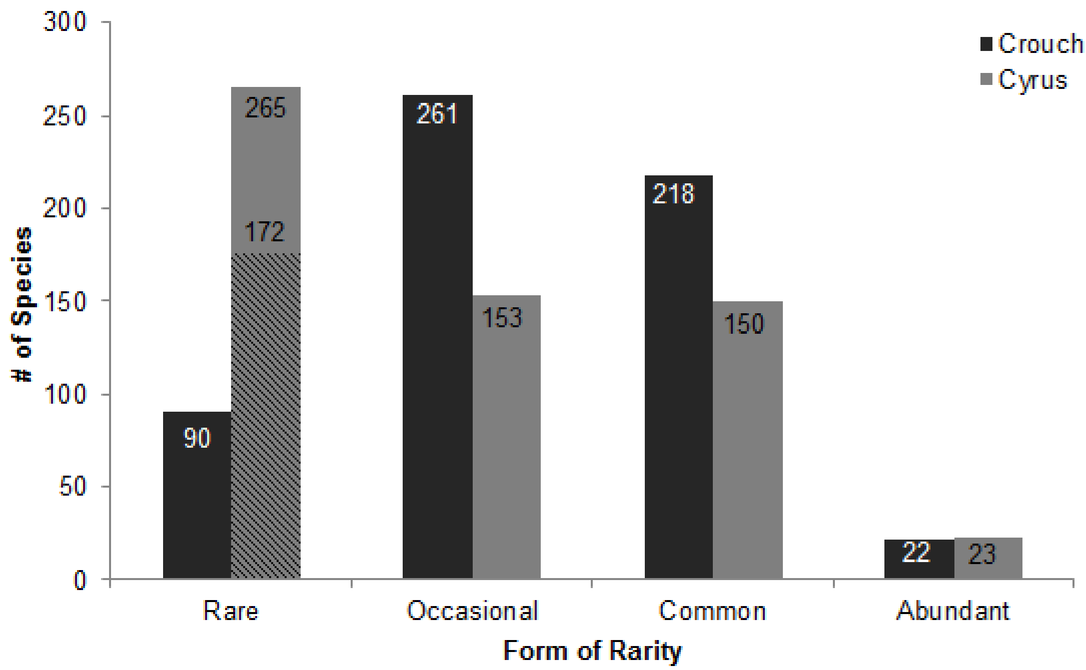


Figure 5. Number of species in each of four categories of rarity in 591 species that were located in 1989 compared to their status in 2015. Shaded portion of Cyrus rare category indicates species that were not relocated in 2015. Sample sizes are given at the top of each bin.

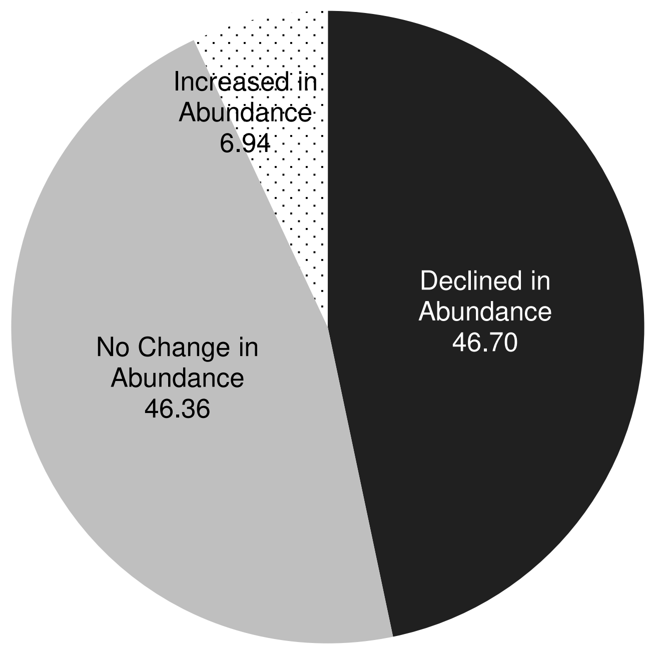


Figure 6. Change in relative abundance of 591 species between 1989 and 2015.

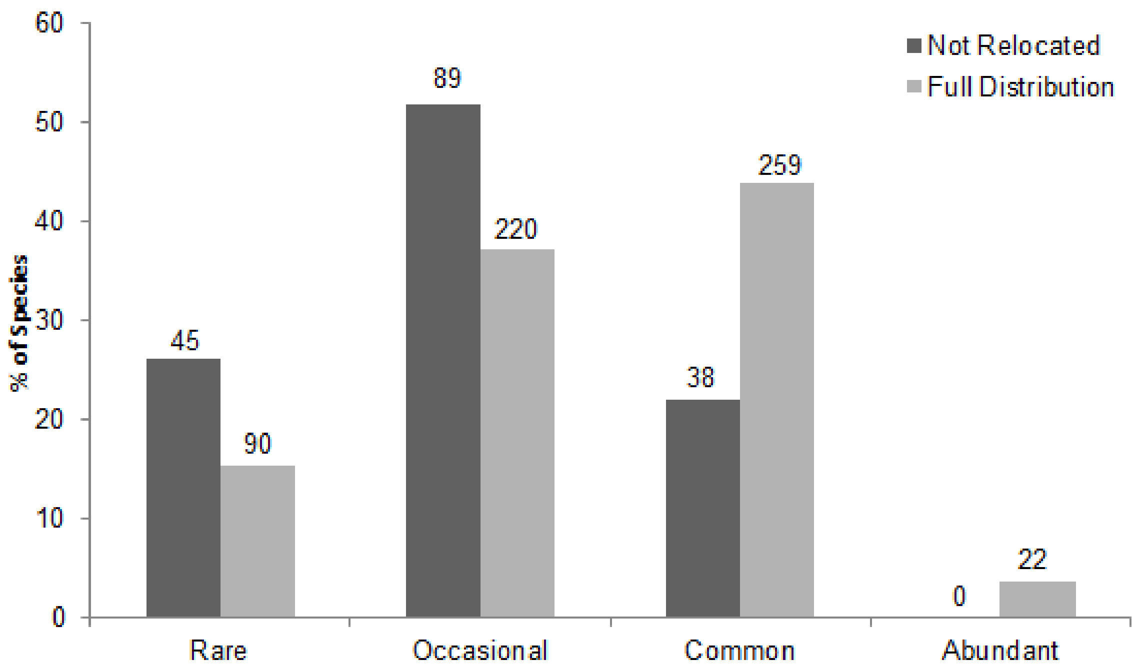


Figure 7. The distribution of rarity in species not relocated in 2015 compared to the distribution of rarity in all 591 species from 1989.

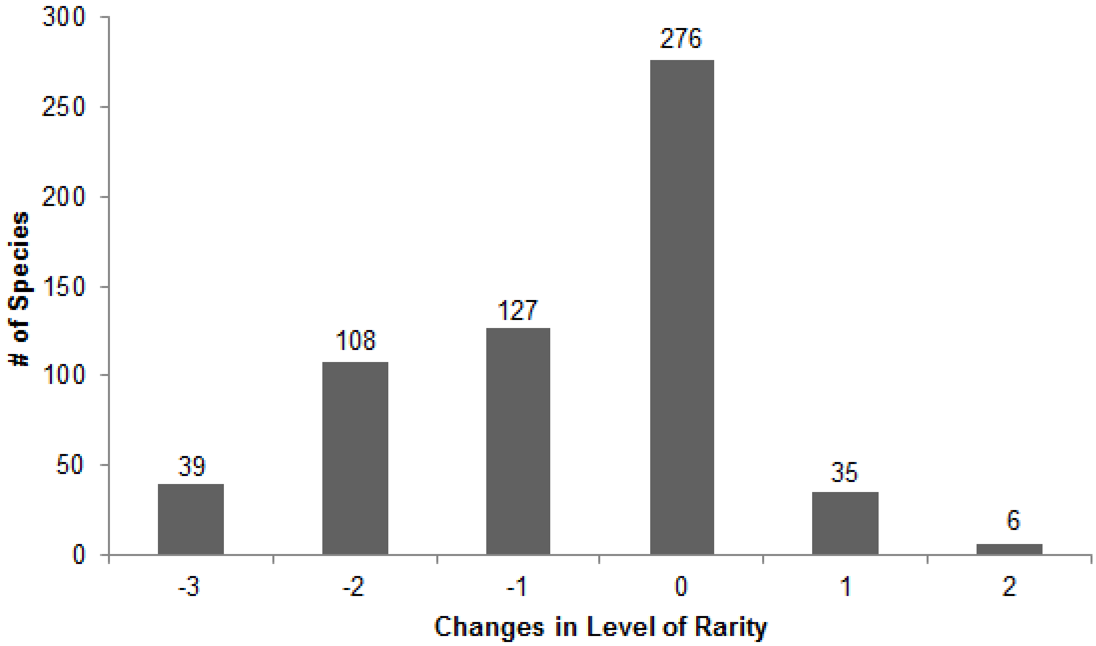


Figure 8. 2015 changes in rarity assessments of 591 species reported by Crouch in 1989. Assignment of values are based on species changes into five possible categories: not relocated, rare, occasional, common and abundant. A change of -3 represents common species that could not be relocated in 2015; a change of -2 represents common species becoming rare and occasional species that could not be relocated; a change of -1 represents common species becoming occasional, occasional species becoming rare, and rare species that could not be relocated; no change indicates relative abundance was the same between years; an increase of 1 represents common species becoming abundant, occasional species becoming common, and rare species becoming occasional; an increase of 2 represents a rare species becoming common or an occasional species becoming abundant.

Between 1989 and 2015 there was a shift towards more rare species (χ^2 = 127.03, df = 3, p = <0.0001). There are nearly three times more species considered rare in 2015 than there were in 1989 (Figure 5). 46.36% of plant species reported by Crouch increased in rarity by 2015 (Figure 6). 46.70% of plant species remained approximately as abundant as they were in 1989, and 6.94% of plant species became more common. There are proportionally more species considered rare and occasional in the set of species that were not relocated in 2015 when compared to the distribution of rarity in the full dataset of species reported by Crouch (Figure 7; χ^2= 127.03, df=3, p=<0.0001). One hundred and fifty three species (25.89%) changed in rarity by two categories or more (Figure 8).

Seven of the 41 species that became more common over time are on the Virginia DCR's invasive species list. *Microstegium vimineum, Murdannia keisak, Rubus phoenicoliasus, Lespedeza cuneata* (Dum.-Cours.) G. Don, *Ligustrum sinese* Louriere, and *Perilla frutescens* (L.) Britt.

Influence of visually similar congeners

Figure 9 shows the change in the number of species in each rarity category under the assumption that all 42 species identified by Crouch are still extant in the Woods. Although there are fewer species categorized as rare, the distribution of species into rarity categories in 2015 remains significantly different from 1989 (χ^2=87.99, df=3, p=<0.0001). Approximately 5% of the species in the College Woods switch from declining populations to stable populations if all 42 congeneric species were present in the woods in 2015 (Figure 10). In this scenario, slightly greater than half of the species reported by Crouch in 1989 have the same level of rarity in 2015.

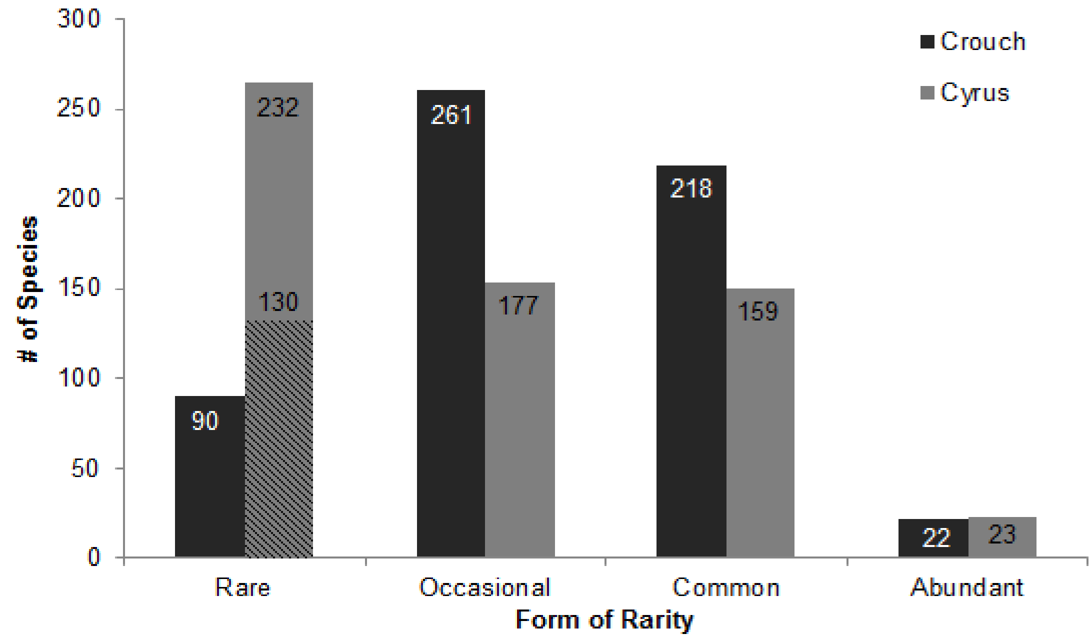


Figure 9. Changes in distribution of rarity under the assumption that all congeneric species were relocated and that the abundance of those species did not change between 1989 and 2015. The shaded area of the rare category bar for Cyrus indicates species that were not relocated in 2015. The skew towards rare species would be lesser, but is still larger than in 1989. Sample sizes are written in each bin.

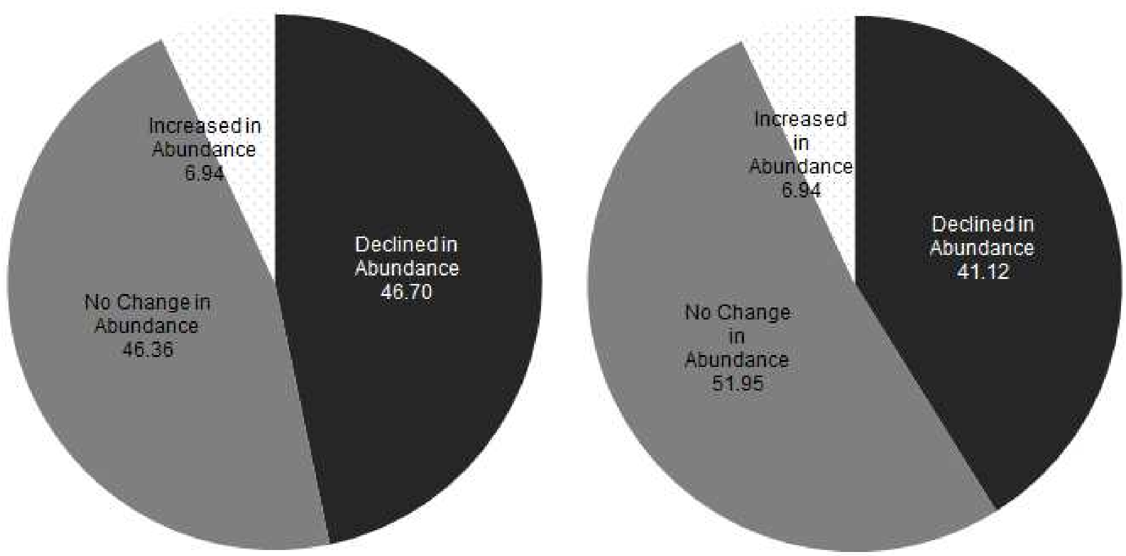


Figure 10. Distribution of changes in abundance categories between 1989 and 2015 if all visually similar congeneric species were relocated and had not changed in abundance between years. Slightly more than half of the recorded species would not have changed in abundance.

Traits Influencing Decline of Species

There were no significant differences in the frequency of any trait variable between the 1989 flora and the set of declining species from the 2015 flora (Table 9). There was a slightly higher proportion of species in decline in open areas when compared to the overall proportion of species in open areas (Figure 11). This trend, however, is not significant, with a difference of less than 5%. Declining species possess nearly the same proportion of native and introduced status when compared to the proportion of occurrences across the entire dataset (Figure 12). Declining species also have nearly the same proportion of habit types compared to the proportion of habit types across all species (Figure 13). There is no difference in the proportion of life history variables in declining species compared to the proportion of variables across all species (Figure 14). There is nearly no difference in the proportion of biotic and abiotically pollinated traits in the set of declining species when compared to the overall dataset (Figure 15). There is a slight trend towards declining species having a higher proportion of species without hidden meristems (Figure 16), however, the difference is only by 5%. There is no difference the proportion of height in declining species compared to the proportion of height in all reported species, even when binned by every 0.2m or when divided into above and below the browse line(Figures 17 and 18). The proportion of declining species found in April was about 5% smaller than the proportion of all species found in April (Figure 219). However, this trend was cancelled out by a higher proportion of declining species being found in nearly every other month. The distribution of length of flowering period is not different between declining species and all reported species (Figure 20). There is a higher proportion of shade intolerant declining species when compared to the proportion of shade intolerant species in the entire dataset, however, the difference is by only 5% (Figure 21). There is no difference in the proportions of stem position traits in declining species when compared to the proportions of all species (Figure 22). An NMDS shows considerable overlap of characteristics in species that are declining, increasing, and not changing in abundance (Figure 23).

Table 9. P-values for each test comparing the distribution of variables within eleven traits in declining species versus the distribution of variables in all reported species.

Trait	X^2	df	p-value
Habitat	4.85	5	0.4340
Biogeography	0.19	1	0.6629
Habit	4.49	4	0.3437
Life History	1.58	3	0.6639
Pollination Mode	1.08	1	0.2987
Hidden Meristems	2.36	1	0.1245
Height (above or below 1.8m)	0.6	1	0.4386
Height (binned every 0.2m)	6.0952	NA	0.6307
Flowering Phenology	11.51	NA	0.3353 (Simulated)
Length of Flowering Period	8.60	NA	0.5349 (Simulated)
Shade Tolerance	2.73	2	0.2254
Stem Position	2.08	NA	0.5888

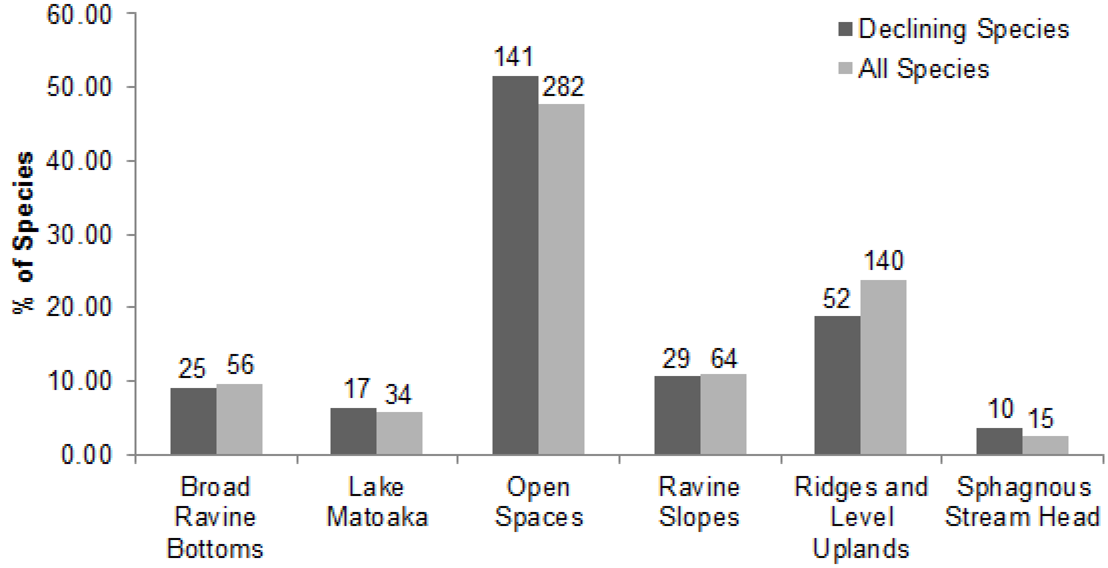


Figure 11. Proportion of habitat types of the 274 species declining in abundance between 1989 – 2015 compared to the overall proportion of habitat types in all 591 species reported by Crouch in 1989. Sample sizes are given above each bin.

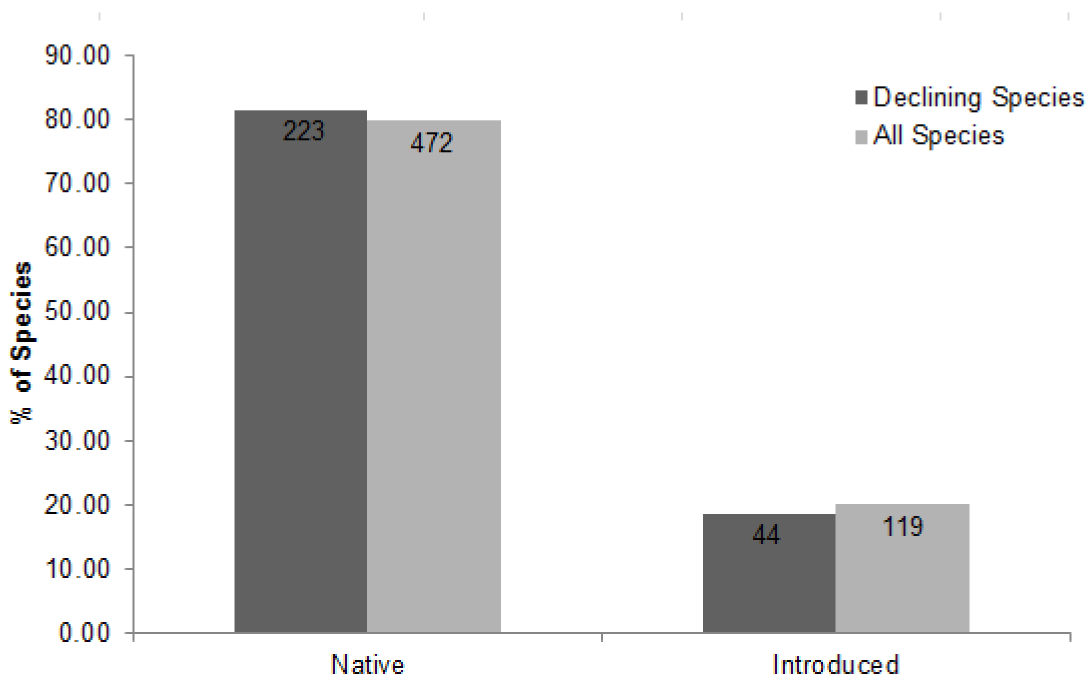


Figure 12. Proportion of native and introduced status in the 274 species declining in abundance between 1989-2015, compared to the overall proportions of the 591 species reported by Crouch in 1989. Sample sizes are given in each bin.

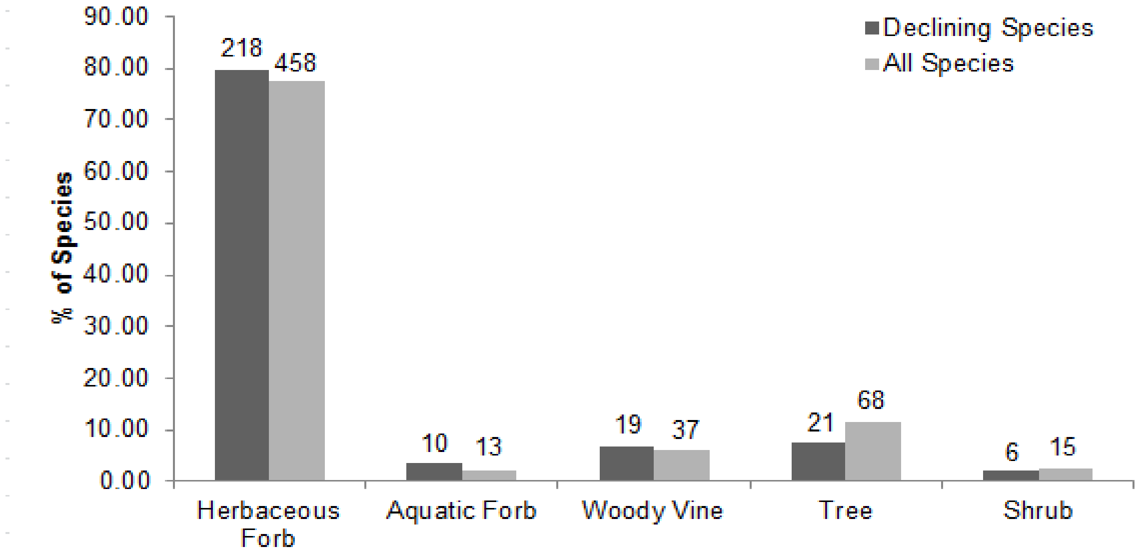


Figure 13. Proportions of habit types in the 274 species declining in abundance between 1989-2015 compared to the proportion of habit types in all 591 species reported by Crouch in 1989. Sample sizes are given above each bin.

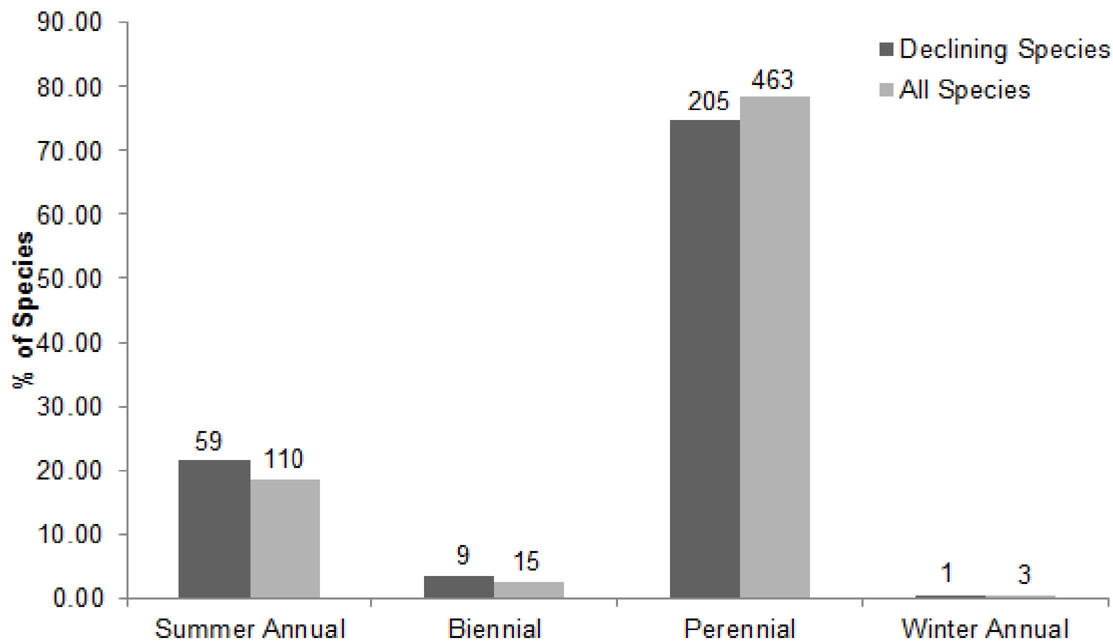


Figure 14. Proportion of life history traits in the 274 species declining in abundance between 1989-2015 compared to the proportion of traits in all 591 species reported by Crouch in 1989. The sample sizes are written above each bin.

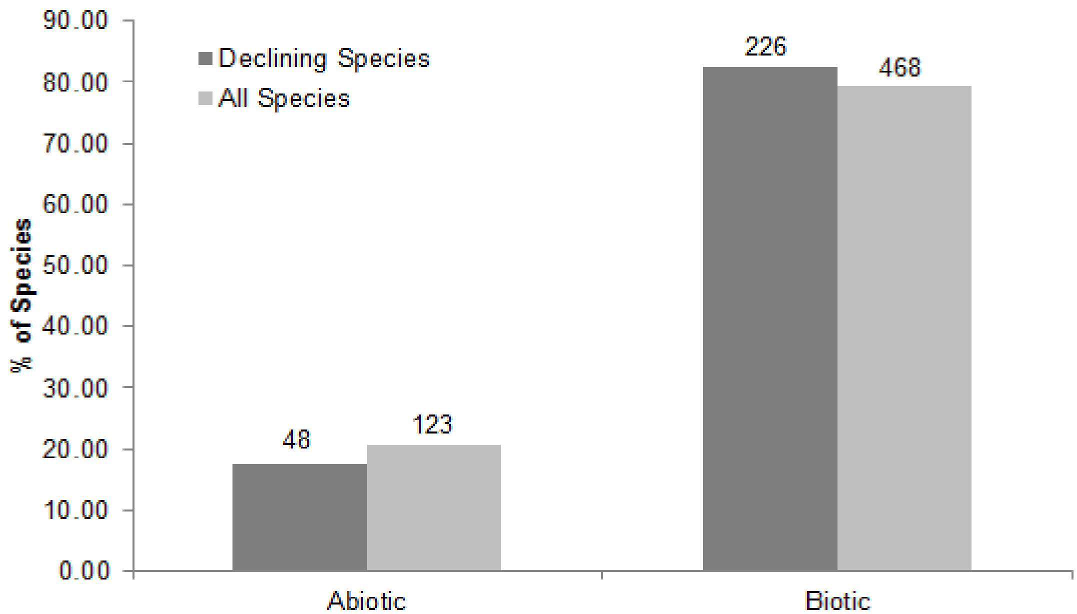


Figure 15. Proportion of abiotic and biotic pollination in the 274 species declining in abundance between 1989-2015 compared to the proportion of all 591 species reported by Crouch in 1989. Sample sizes are written above each bin.

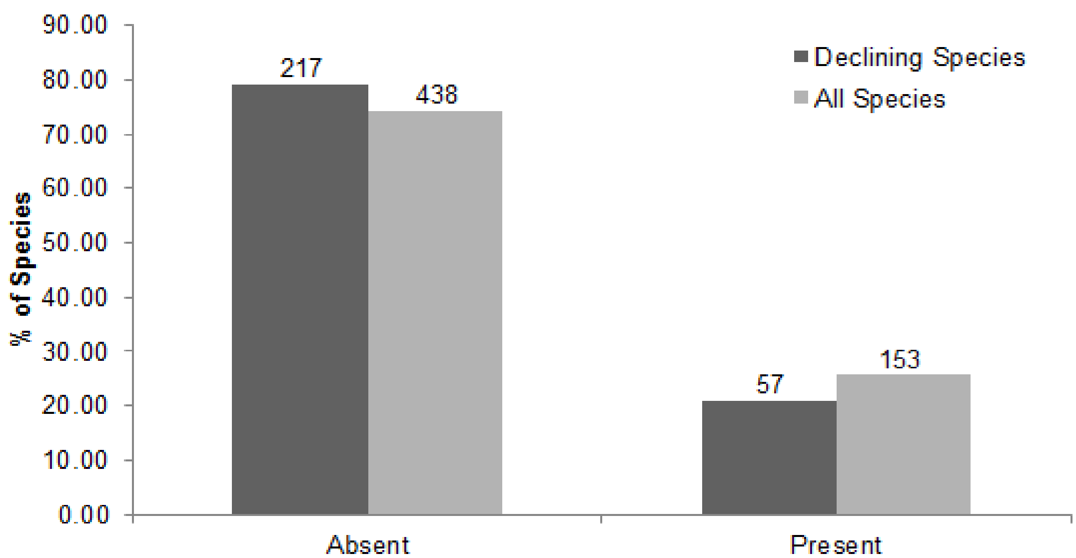


Figure 16. Proportion of hidden meristems in the 274 species declining in abundance between 1989-2015 compared to the proportion of hidden meristems in all 591 species reported by Crouch in 1989. Sample sizes are included above each bin.

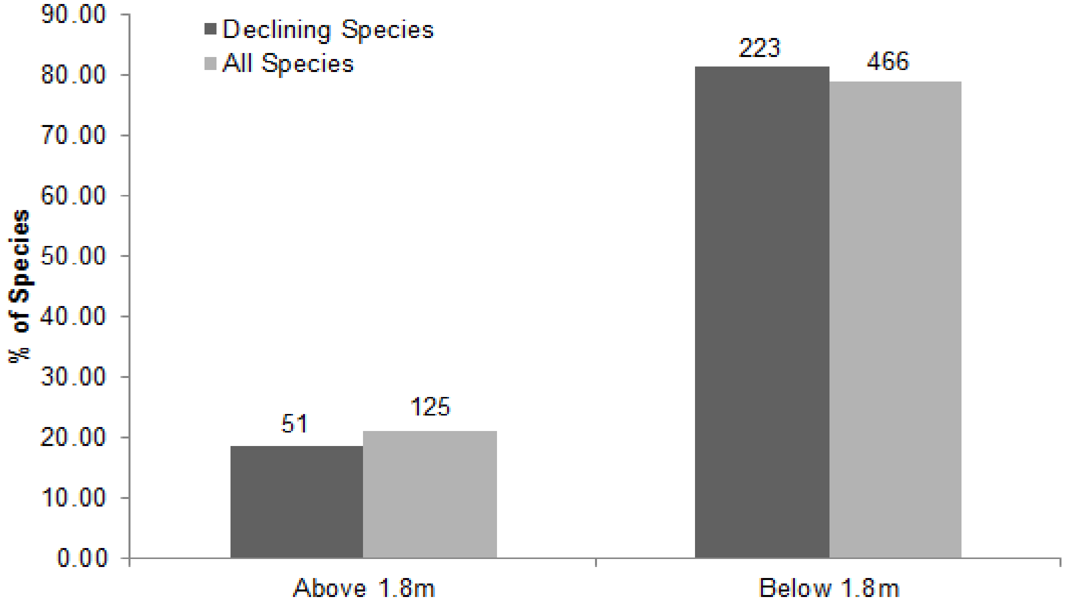


Figure 17. Proportion of species above and below the browse line in the 274 species declining in abundance between1989-2015 compared to the proportion of species above and below the browse line in all 591 species reported by Crouch in 1989. Sample sizes are included above each bin.

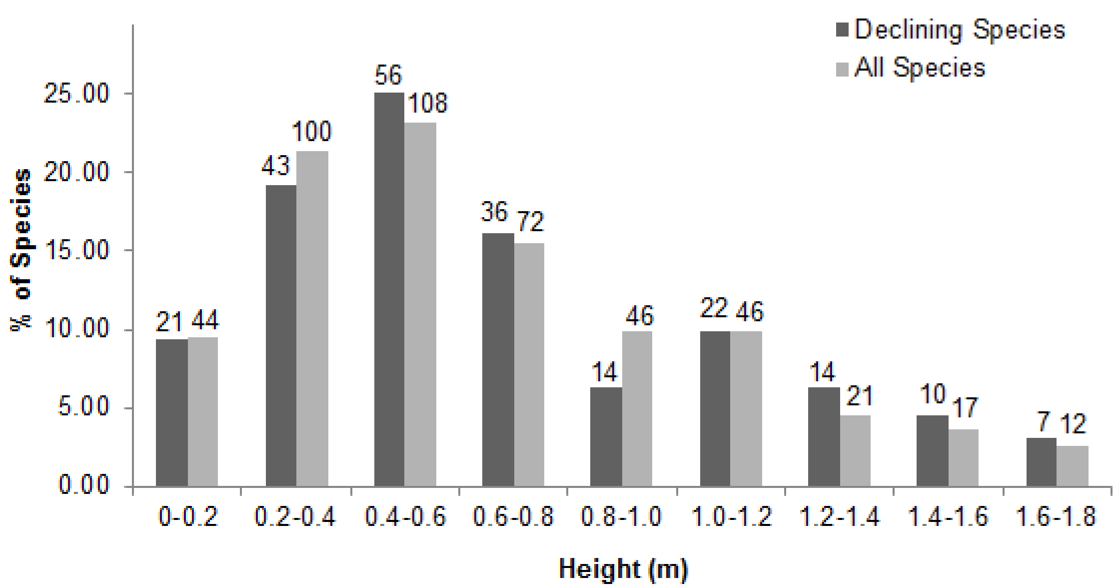


Figure 18. Proportion of species in 0.2m bins in height in 223 species declining in abundance between 1989-2015, compared to the proportion of species in height bins in all 466 species reported by Crouch in 1989 that are below 1.8m tall. Sample sizes are included above each bin.

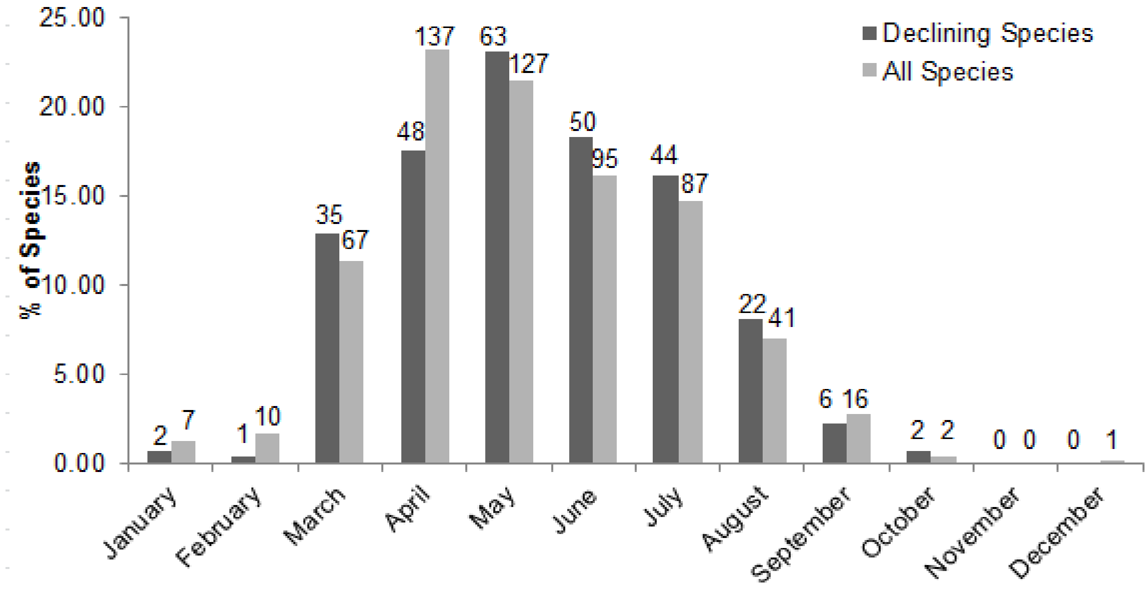


Figure 19. Proportions of the start of flowering in the 273 (one species removed; *Phyllostachys aurea* Carr. ex A. & C. Riviere never flowers in Virginia) species declining in abundance between 1989-2015, compared to the proportion of flowering start in all 590 species reported by Crouch in 1989. Sample sizes are given above each bin.

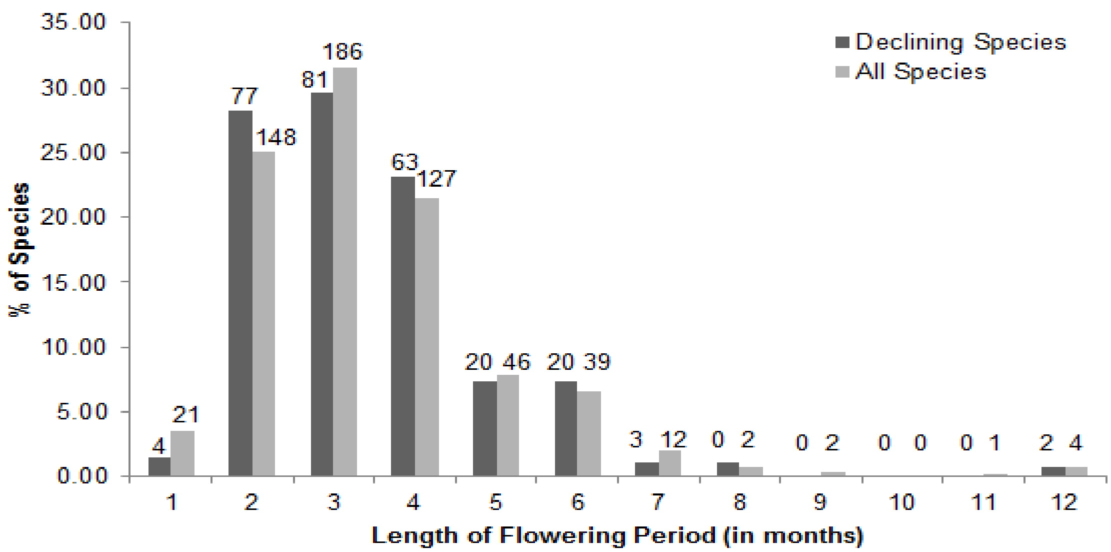


Figure 20. Proportion of length of flowering period in the 273 (one species removed; *Phyllostachys aurea* never flowers in Virginia) declining in abundance, compared to the proportion of flowering period length in all 590 species reported by Crouch in 1989. Sample sizes are given above each bin.

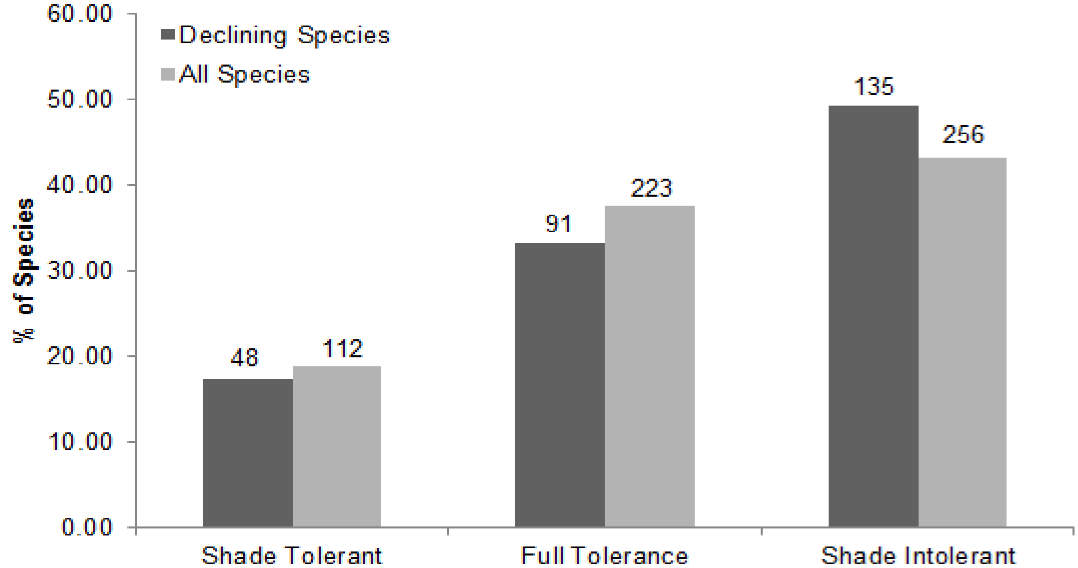


Figure 21. Proportion of shade tolerance traits in the 274 species declining in abundance between 1989-2015, compared to the proportion of shade tolerance traits in all 591 species reported by Crouch in 1989. The sample sizes are written above each bin.

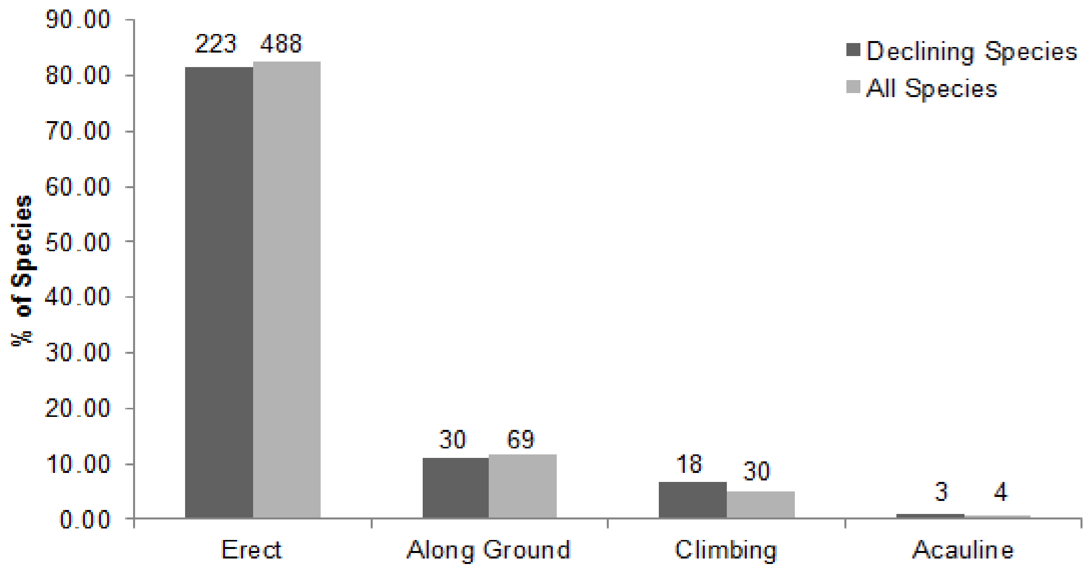


Figure 22. Proportion of stem position traits in the 274 species declining in abundance between 1989-2015, compared to the proportion of stem position traits in all 591 species reported by Crouch in 1989. Sample sizes are written above each bin.

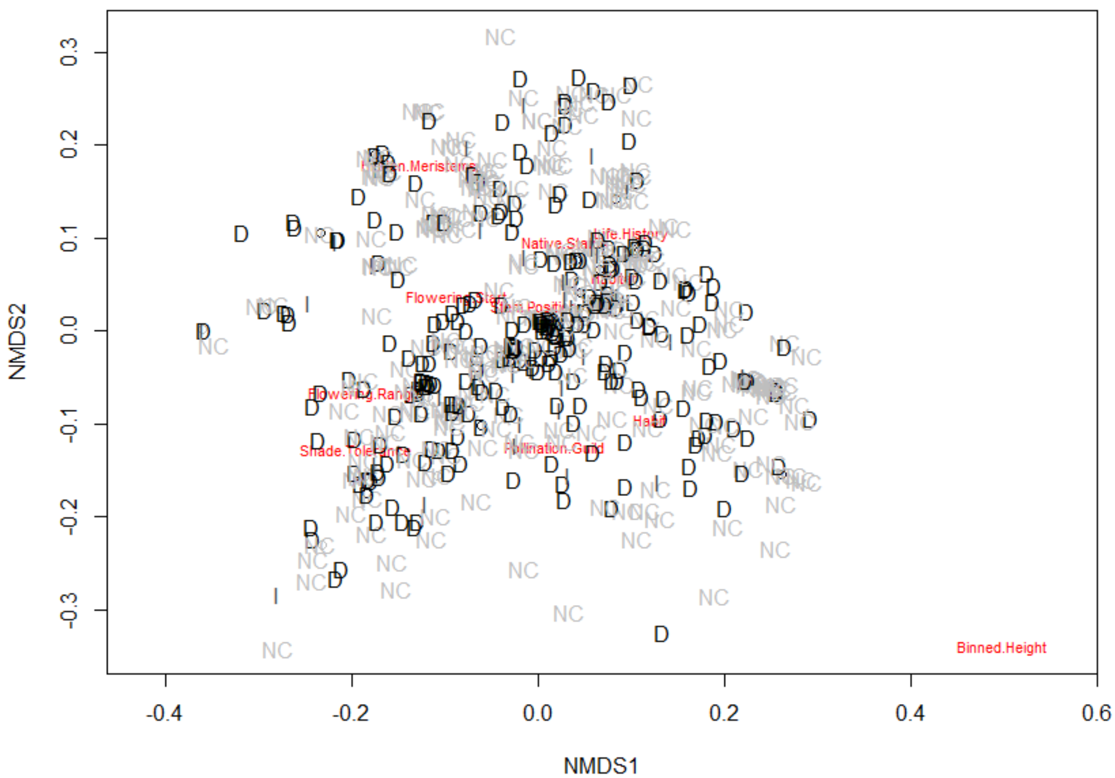


Figure 23. A NMDS based on traits within the eleven variables listed in Table 1. Variables used are plotted in red. D = declining species, NC = no change, and I = increasing species. There is considerable overlap between all groups.

DISCUSSION

Although species richness was relatively similar between the 1989 and 2015 surveys, the differences in species composition between the two floras of the College Woods are striking. 126 species (22.95% of 2015 flora) were newly reported in 2015, while 174 species (30%) of the previously reported flora were not recovered. Although the turnover appears drastic, these results are similar to a recently published flora of Broadmoor Wildlife Sanctuary, where 31% of the original flora was not found and the newly reported species composed 22% of the current flora (Standley, 2015). This suggests comparable trends may be occurring across the east coast, though there are no other recent studies that investigate floristic changes over less than a 100 year timespan (Standley, 2015).

The phenomenon of an increased total number of species observed in a sampling area with increasing time between observations is called the species-time relationship (White et al., 2006). This pattern may be driven by short-term and long-term factors that include differences in sampling processes, changes due to climatic variability, and succession affecting species turnover. It has been suggested to be as fundamental to ecology as the species-area curve and has been reported from a large number of studies (White et al., 2006). In the Standley (2015) study, most newly reported species were perennial and discovered due to increased search effort. In contrast, the College Woods flora had considerably greater search effort and the newly reported species do not represent a significant difference from the frequency of life histories found in the 1989 study. Additionally, the distribution of newly reported species among habitat types was not significantly different from the distribution of species among habitats from the entire Crouch flora, implying that new species additions were not due to a bias in collection from specific habitats between the two studies. This suggests that although some species were probably present at the time of the 1989 study and located in 2015 by increased search effort, other species are new colonizers of the College Woods.

The rediscovery of ten species located in 1968 but not reported in 1989 illustrates that some species (particularly the rare ones) were located due to increased search effort. Some of the visually-similar congeneric pairs (e.g., *Hydrocotyle ranunculoides* compared to *H. prolifera* and *Oxalis stricta* compared to *O. florida*) would be most affected by this possibility. In addition, perennial species that are found in mature, undisturbed habitats could also have been present during the 1989 floristic survey, but undetected. Such species include *Tilia americana* var. *americana, Phoradendron leucarpum* ssp. *leucarpum, Peltandra virginica, Listera australis,* and *Platanthera clavellata.*

Newly reported species that are probably recent colonizers of the College Woods are found in areas with regular environmental disturbances that could accelerate the rate of species turnover by influencing species extinction and immigration (Jackson & Sax, 2010). Over half of the species new to the 2015 flora were collected from edge or open- space habitats. The Jamestown Dam is one such habitat that is the sole known location of 18 of the newly reported species. Eight additional newly reported species are found on the Dam, but were also recorded in other areas of the woods as well. The newly reported species found on the Jamestown Dam account for 37.68% of the newly reported species found in open space habitats. At the time of the 1989 survey, the Jamestown Dam was wooded, but in 2005 it was logged and is now maintained by regular mowing. Species found solely on the dam, therefore, were most likely not present in past surveys. The remaining newly reported species that were found in open space habitats occur along wood edges which, like the Jamestown Dam, are regularly mowed. Mowing creates periodic disturbance that could lead to high species turnovers, which in part could explain the species-time relationship observed in the College Woods floras.

Thirteen newly reported species are considered waifs in Virginia, are not found in regularly mowed habitats, and have clearly colonized from nearby gardens. These species would not have been present at the time of Crouch's collections. Colonization could have been the result of repeated human introduction of discarded plant materials. Landscaping plants from the William & Mary campus are discarded at the refuse pile. Because the landscaping is changed seasonally, many plants are not dead when they are deposited and they occasionally take root or start by discarded seed. This is the most likely explanation for the introduction of *Tarenaya hassleriana* and *Vitex agnus-castus* to the College Woods, as well as many of the other non-native species found in that location. According to herbarium records, Virginia Crouch also visited the area where these plants are now established but because many of the new species are large and showy, they would have been difficult to overlook had they been present at the time of her survey. Likewise, introduced species that are found along Mill Neck road could have come from human introduction of discarded plant material from nearby gardens in the surrounding area. These waif species are establishing in a highly visible band in the woods along Mill Neck Road. Many of these species are also showy (e.g., *Aesculus pavia, Ficaria* *verna,* and *Arum italicum*) and in an area that Virginia Crouch would have travelled frequently. Therefore, as above, these species were probably not present at the time of her study.

The spread of some exotic species may have come from the pellets of white-tailed deer. As deer forage on material from cultivated gardens in nearby neighborhoods, they may ingest seeds incidentally. If these seeds are able to pass through the digestive tract of the deer and remain viable, they may establish in the interior of a forest (Williams & Ward, 2006). *Arum italicum, Liriope spicata, Euonymus alatus, Ficaria verna,* and *Clerodendrum trichotomum* were all observed in fruit during the 2015 floristic survey and could have possibly established in the College Woods this way. Again, because all of these species are large and showy, it is unlikely that they would have been missed by Crouch had they been present in 1989.

Species that could not be relocated in 2015 could have been overlooked during sampling or may no longer be present in the woods. The species reported by Crouch that were not relocated in the present study that are also visually similar and congeneric to a newly reported species are the most likely to still be found in the College Woods. During the 2015 floristic survey, we assumed that we had collected the species that were reported by Crouch and were unaware of the possibility of the presence of visually similar congeners. Because identification occurred after sampling, there was no opportunity to attempt to relocate these species when we realized this possibility. This situation applies to 42 species that were not relocated in 2015. However, even if we assume that all congeners were present in the woods, there are still over 100 species that could not be relocated.

Sufficient sampling effort decreased the chances of overlooking species in the College Woods. The much slower rate at which new species accumulated in the Cyrus study, despite over double the effort, strongly suggests drastic decreases in the overall abundance of plant populations, which greatly slowed their discovery. This suggests that any species that were not relocated in the present study are now exceedingly rare if they are still present in the woods, requiring substantial effort to relocate. Some species that could not be relocated may not be present in a vegetative form in the College Woods, but still present in the seed bank. Because of this, we have decided to treat species that could not be relocated as a special form of rarity instead of declaring them extirpated.

Species that could not be relocated in 2015 could be a symptom of a larger trend of declining population sizes throughout the College Woods. Consistent with the considerably slower collection rate of the 2015 study, nearly 50% of all species reported by Virginia Crouch declined in relative abundance categories between 1989 and 2015. One hundred and forty-seven species (53.65% of all declining species) declined in relative abundance by at least two rarity categories (e.g. changes “common” to “rare”, etc.), most likely reflecting true changes in abundance, as opposed to artificial changes due to differences in rarity assessment between the two studies Additionally, the assessment of declining populations is a conservative one since all species placed by Crouch in an intermediate category were re-categorized into the rarer category for this analysis.

Under the assumption of demographic stability, rare species ought to be more vulnerable to extinction (Gilliam, 2007). However, the species that declined were a broad swath across Crouch's rarity categories, suggesting that forces other than demographics contributed to the decline. Moreover, the analysis of traits associated with browse tolerance showed that no life history, biogeographical, or morphological trait, taken singly or in combination, can account for this decrease. Therefore, the declines appear widespread and untargeted.

In some habitats, reasonable hypotheses can account for declining populations.   For example, major erosion at the heads of nearly every stream in the College Woods as well as runoff from Jamestown and Compton Roads cause increased siltation in Lake Matoaka. The decreased water quality (evident by algal blooms that obscure vegetation that grows in the lake) may have contributed to the disappearance of some aquatic species reported in 1989. Moreover, erosion at the heads of streams in the College Woods has removed habitat where five species were solely recorded, resulting in their possible extirpation. Additionally, natural succession may explain the disappearance of eight other species that were solely located in cutover areas that have since matured. Although Hurricane Isabel was a source of large-scale disturbance in the College Woods, impacts were patchy on the landscape and the canopy openings are less extensive and diverse than the fields that were created by previous cutovers. As of 2015, the open habitat associated with cutover species only exists along wood edges and along the Jamestown Dam in considerably smaller patches than what was present in 1989. Still, the effects of specialized habitats and cutovers account for a relatively small percentage of declining species, pointing again to other factors contributing to major changes observed in the College Woods.

We expected associations amongst declining species with traits thought to be associated with decreased detectability and browse tolerance, but saw no such trends. Because there were no associations across the board, it could be that other stressors, such as climate change are affecting species in the College Woods directly and indirectly. Studies have shown that increased CO_2 differentially harms and benefits species in a species-specific manner, possibly explaining the declines and increases observed in the College Woods (Gilliam, 2007). A study by Willis et al. (2003) showed 63% of species reported 150 years ago in the Thoreau Woods had declined in abundance or been extirpated, and attributed this trend to climate change due to the differential loss of related taxa. In the College Woods, however, the occurrence of the ten most common families is relatively similar between 1989 and 2015, suggesting that this is not the case. Climate change may also induce phenological shifts due to longer growing seasons. These shifts can result in the loss of synchrony between plants and their pollinators (Fabina et al., 2010). As pollinators consistently emerge earlier or later than the plant's flowering period, the plant's population declines as individuals die without replacement. However, loss of plant-pollinator synchrony is a controversial topic, with some arguing that biodiversity buffers against such a phenomenon in the face of climate change (Bartomeus et al., 2013). Others argue that models need to include every species that can affect the fitness of a plant, including herbivores. When this is done, the outcome of the pollinator-plant-herbivore interaction is regionally and temporally variable and cannot be reliably predicted (Brody, 1997). It is therefore possible that in the College Woods, climate change is interacting with increased herbivory by white-tailed deer, making it impossible to characterize declining species based on plant traits.

Even though there were no associations with traits that may indicate vulnerability to overbrowsing by white-tailed deer, it is clear that white-tailed deer are affecting the College Woods. The next chapter of this thesis (Chapter 2) demonstrates that species diversity is decreasing in the smaller size classes of woody plants as well the density of stems throughout the College Woods. These declines are linked to high intensity herbivory by white-tailed deer by documenting browse rates in plots that are under long-term study. Because white-tailed deer appear to be the major drivers of change among seedlings, saplings, and small trees, it is also very likely that they are the major drivers of change in the rest of the flora of the College Woods as well.

Indirect effects of overabundant white-tailed deer populations may also obscure any trait-related associations. For example, increased soil compaction and trampling by white-tailed deer hinders plant germination and growth, possibly leading to declines in both unpalatable and palatable plant species (Heckel et al., 2010). Additionally, as deer browse in an herbaceous understory, the reduced density and cover of preferred browse species alters microclimates by reducing moisture and humidity while increasing temperature and light (Rooney & Waller, 2003). These could create unfavorable conditions for some unpalatable and browse tolerant species as well as any surviving palatable species, reducing their abundances in the College Woods. Nutrient cycling can also be altered by white-tailed deer, either increasing or decreasing mineralization rates based on the type of forage material deer are preferentially eating (Rooney & Waller, 2003). White-tailed deer may increase mineralization rates in areas dominated by evergreen trees if they favor those trees, shifting composition towards unbrowsed deciduous trees. Alternatively, they may decrease mineralization rates (and therefore increase the amount of leaf litter present in the understory) by preferring species with higher decomposition rates and leaving less palatable species with lower decomposition rates (Rooney & Waller, 2003). The effects of changes in nutrient cycling can be positive or negative depending on species identity, and they have the ability to affect all plant species present in the College

Woods. These effects could also be differential throughout the woods based on the overstory composition, since some areas are evergreen-dominated while others are not. Because indirect effects can lead to declines in species that you would expect to possess traits conferring browse tolerance or low detection in addition to species that would possess traits associated with browse intolerance and high detection, this could confound the results.

Direct effects from other stressors on other subsets of plants are very likely and could obscure any associations of plant traits that are attributed to browse intolerance. One particularly important one in the College Woods has been the increase of invasive species which can directly compete with native species and rapidly dominate the herbaceous layer (Gilliam, 2007) or negatively interact with deer to lower biodiversity. Five new invasive species were reported in the College Woods in 2015 while others that were reported in 1989 have increased in abundance. One such example is the highly invasive *Microstegium vimineum.* In 1989, Crouch listed this species as common while this study observed it as abundant. Observational evidence from researchers working in the College Woods over the last two decades also note a substantial increase (Case, personal communication). In studies utilizing deer exclosures, Knight et al. (2009) and Abrams & Johnson (2012) found that *M. vimineum* was not as aggressive in spreading within exclosures as it was in areas accessible to deer. The mechanism was that deer preferentially browsed on native plants, decreasing cover and creating barren areas in which *M. vimineum* could thrive

(Knight et al., 2009). Such interactive effects have also been implicated elsewhere (Williams & Ward, 2006; Schramm & Ehrenfeld, 2010). Compounding the problem is the observation that deer disperse *M. vimineum* seeds through their pellets (Williams & Ward, 2006). Therefore, increased competition of invasive species combined with the effects of white-tailed deer could be obscuring any expected trait-based associations in the College Woods.

The attempt to predict how or which groups of plants may react to environmental changes is common in the field of conservation, but it usually applies to climate change and disturbance scenarios (Lavorel & Garner, 2002). This is the first study attempting to apply this type of analysis to deer browse scenarios. However, most analyses identify groups of plants that possess common traits and react in common ways to the stressors. Plant traits used in such analyses are often similar to what was used in this analysis, including life history, growth form, height, and pollination mode (Liebergesell et al., 2016; Verheijen et al., 2015; Lavorel & Garner, 2002). There is an important distinction between "soft" traits—traits that are easily measurable but aren't directly linked with functionality (i.e. plant height)—and "hard" traits—traits that are directly linked with functionality (i.e. leaf chemical composition) but are difficult to measure. Most studies use a combination of the two, yet all of the traits used in this analysis are considered "soft" traits. Therefore, it is possible that with the future inclusion of "hard" traits, such as chemical compounds found in leaves or soil resource availability, trends may become clearer. At the same time, most studies only incorporate 1-6 traits in their analysis, while 11 were included in this study. The inclusion of so many traits should provide greater clarity in separation between declining and stable populations if such a trait-based separation exists.

There are some characteristics that influence browse tolerance that would be very difficult to include in a traits-based analysis. The history of past stressors, such as defoliation or nutrient limitations, can make a plant more vulnerable to browse by white-tailed deer. Individual plant genotype can influence the level of tolerance as well. Therefore, tolerance not only differs among species, but within species (Coté et al., 2004). The degree to which a plant is able to tolerate browse is also dependent on the timing, frequency, and intensity of browse (Russel et al., 2001). We attempted to address the timing of browse through the use of flowering phenology and the length of a flowering period in our analysis. However, we did not address how frequency and intensity could influence tolerance.

Perhaps the most likely explanation for a lack of trait association with declining species is the long time frame under which the College Woods has been subject to browse from an overabundant population of white-tailed deer. Because white-tailed deer have been overabundant in the College Woods for over 20 years, it is likely that deer quickly reduced the abundance of browse-intolerant species and moved on to more browse-tolerant species. This would eliminate all but the most robust plant-trait associations. The decline of preferred forage material is documented in the next chapter of my thesis (Chapter 2), where I show high rates of browse on species that are traditionally considered browse-tolerant or unpreferred forage material, such as *Fagus grandifolia* or *Ilex opaca.* The presence of regular browse on Christmas tree ferns (*Polystichum acrostichoides*), a species also generally considered browse-tolerant and not preferred forage material, points towards this trend as well. At high enough intensity and frequency, browse-tolerant species will show population declines as their resources are continually depleted (Coté et al., 2004). Therefore, there is probably only a small window where a trait-based approach could separate species that are declining in population size from species with stable populations based on the hypothesis of browse tolerance.

Conclusions & Future Directions

There has been significant turnover in species composition over the last 25 years in the College Woods. Although over 100 new species were reported to the area, species turnover in regularly disturbed, early successional areas explains the presence of many of these new additions. Over 30% of species previously reported in the College Woods were not relocated; in addition, nearly 50% of all species previously reported from the College Woods showed evidence of population declines. These declines appear to be due to heavy browse pressure from an overabundant white-tailed deer population over the course of 20 years, but no patterns emerged from an analysis of traits that were predicted to confer browse intolerance. Trait associations, if present, are probably only operative in a small temporal window before the effects of browse by white-tailed deer become too severe across all plant populations. Because the College Woods has supported overabundant white-tailed deer populations for over 20 years, it is likely past this point. In addition, other stressors, such as indirect effects from white-tailed deer, increased numbers of invasive species, and the effects of climate change may obscure important trait-based trends as well. Because of this, researchers should not rely on a trait-based approach to predict which species are at risk when there is prolonged overabundance of white-tailed deer in an area.

This floristic analysis shows significant changes over a span of 25 years and lays the ground work for future analyses to better understand long-term patterns of species compositional change. Importantly, abundance categories were defined in this thesis so that plant population sizes can be carefully monitored for changes. Finally, it is of urgent importance to understand how other forests are responding to chronic deer overabundance, and future efforts should be directed to understand the fate of our flora here and elsewhere. If the College Woods is a typical example (and there is no reason to think it is not) then we are facing an extinction crisis that may be far faster than the effects of climate change or other stressors. Because the College Woods is considered a natural preserve, immediate conservation action needs to be taken in order to allow plant populations to recover from the effects of chronic herbivory by white-tailed deer or extinctions beyond recovery are expected to continue. In the final chapter of this thesis (Chapter 3), I suggest a management plan for the future conservation of the area that focuses on population reduction of the white-tailed deer herds.

Chapter 2

Resampling Permanent Plots After 10 Years of Change

Introduction

Natural disturbances leave lasting impacts that affect forest trajectory and succession. The effects of small, frequent disturbances on forests have been heavily studied, but little is known about the effects of large-scale, infrequent disturbances (LIDs) due to the unexpectedness of such events and the lack of baseline data (Turner et al., 1998). Forests in the Southeastern U.S. are subject to hurricanes, a form of LID. While the immediate impacts of hurricanes on forest structure are easily assessed, long-term impacts on diversity and composition are more complex because they rely on the degree of change in both abiotic and biotic conditions, termed “legacies” (Xi et al., 2008). Abiotic legacies may refer to soil conditions or light levels, while biotic legacies refer to trees that remain standing, seed banks, or leaf litter (e.g., Turner et al., 1998). Understanding the impacts of such large-scale disturbances is becoming increasingly important in the face of climate change, as the frequency and intensity of storms are expected to increase (Mann & Emanuel, 2006).

The College Woods, located in Williamsburg, VA, is a potential model system to study LID impacts. In 2003, the College Woods was subjected to strong winds and microbursts from Hurricane Isabel, the most damaging storm in Virginia in at least 70 years (Kribel and Ware, 2014). While some areas of the forest were strongly affected, others were relatively untouched, providing an excellent opportunity to study the trajectory of succession in damaged and undamaged areas of the same forest stand.

The College Woods has long been used to study forest succession. There is no evidence of recent major human disturbance and some areas of the woods support trees approximately 160 years old (Kribel et al., 2011). There are many sets of permanent plots studying succession in the College Woods, including a set of twenty plots created in 2002 using the standard North Carolina Vegetation Survey protocols (NCVS; Peet et al., 1998). The plots lend themselves to a successional study because they were sampled during the initial set up in 2002 and immediately after Hurricane Isabel in 2004. This provided a way to analyze immediate changes in forest structure, such as identifying downed trees. The 2004 baseline data also provides a way to study the long-term effects of hurricanes on forest dynamics.

In the previous study of the impact of Hurricane Isabel, immediate structural changes were quantified for woody plants in the large tree (>10 cm DBH), small tree (10 cm > x > 2.5 cm DBH), and sapling (<2.5 cm DBH) size classes. Large canopy trees were most impacted by strong winds during Hurricane Isabel, which were mostly uprooted by strong winds (Kribel and Ware, 2014). Oaks in the large tree size class—specifically, *Quercus velutina* Lam., *Q. coccinea* Muenchhausen, and *Q. falcata* Michaux—suffered the highest mortality in the College Woods, while *Acer rubrum* L. and *Fagus grandifolia* Ehrhart suffered the least damage. Mortality in smaller size classes was all from secondary damage as a result of either broken limbs from larger trees or the crowns of uprooted trees. *Oxydendrum arboreum* (L.) D.C. had the highest mortality in the smaller size classes, while *A. rubrum* suffered the least damage. Because damage from the Hurricane varied greatly among plots, it is likely that the major effects of the Hurricane will be localized only to areas that experienced severe damage (Kribel and Ware, 2014). In those areas, it is likely that altered light levels and conditions as a result of the large canopy gaps generated from fallen trees may alter forest succession (Prengaman et al., 2008).

In addition to large scale catastrophic disturbances such as hurricanes, the College Woods, like much of the United States, supports an overabundant white-tailed deer population which may also alter forest composition trajectories. In the last two decades, the white-tailed deer population has risen to over 30 million individuals nationwide, driven by the loss of top predators and habitat fragmentation (Horsley et al., 2003). Much research has shown that deer forage selectively, altering the patterns of abundance and diversity for herbs, shrubs, and trees (Rooney, 2009; Coté et al., 2004; Augustine & Frelich, 1998). Overabundant populations can decrease diversity, cover, and even prevent forest regeneration. This can force an ecosystem into an alternate state that is usually depauperate and difficult to reverse (Coté et al., 2004). It is important to continue to study the effects of overabundant white-tailed deer populations on forest vegetation in order to inform future management decisions that allow forest recovery.

Evidence of overabundant deer populations in the College Woods arose sometime between 1994 and 2003. A separate set of permanent plots that were established in 1994 were resampled in 2003, revealing little change in the large tree (>10 cm DBH) and small tree (2.5-10cm DBH) size classes. However, there were drastic changes in sapling (<2.5 cm DBH) and tall seedling (0.4 m – 1.4 m height) layers. The density of plants decreased in these two layers, driven by the decline of *Viburnum acerifolium* L., *Cornus florida* L., *Acer rubrum,* and *Euonymus americanus* L. (Kribel et al., 2011). Because the preferential loss of species occurred only within layers that white-tailed deer can easily access, these drastic changes were attributed to the overabundance of white-tailed deer.

Potential interactions of white-tailed deer and large canopy gaps from Hurricane Isabel render forest trajectories more difficult to predict. While the overabundance of white-tailed deer are known to decrease species diversity and density over time (Runkle, 1982; Horsley et al., 2003), canopy gaps are known to increase diversity and stem density in forest stands. Increased vegetation in the gaps may be especially attractive forage for deer which could lead to substantially altered forest regeneration. The vegetation in the permanent plots established in 2002 was likely already heavily influenced by white-tailed deer before the initial measurements were made. However, since the deer population has likely remained high for twelve additional years based on abundant observations of deer, browsing and pellets, it is possible that the sapling layer has continued to change in composition. Because some plots were damaged more than others during Hurricane Isabel, the effects of white-tailed deer in both severely damaged and less damaged plots can be compared.

In this research, I used the permanent plots established in 2002 to quantify changes in woody plant diversity and composition using protocols established in the 2004 study. Additionally, in order to assess how the presence of abundant deer could potentially alter changes in forest succession, I used the same plots to quantify browse rates as well as what species were used and preferred. This allowed the following questions to be addressed: (1) What are the overall changes in woody species diversity and composition over the last ten years? (2) How strong is current browse pressure on woody plant vegetation; and (3) How might the observed changes impact forest succession?

Methods

Jake Kribel (Kribel, 2003) established 20 permanent plots in the College Woods during the spring and summer of 2002 using the NCVS method (Figure 24, Appendix D). To facilitate relocation, Kribel determined the linear direction of the centerline, numbered the subplots (i.e., modules) in a counterclockwise fashion with respect to the direction of the centerline, numbered and marked selected corners of the modules along the centerline and in sampled modules with rebar or plastic coated aluminum stakes, and then took the plot coordinates at the third stake. Additionally, photographs and aspect were taken from the 1^{st} and 3^{rd} stakes. Nineteen of the plots were in wooded uplands 160+ years old and the remaining plot was set up in a riparian forest which was not sampled in the current analysis. Plots were situated to minimize within-plot variation in composition, direction, and degree of slope. These plots had no evidence of recent human disturbance, which would be indicated by cut stumps or double-trunked oaks (Kribel et al., 2011). Kribel sampled all of the NCVS plots for woody vegetation after Hurricane Isabel in September 2003 but herbaceous vegetation was sampled only in 2002. A serendipitous result of the hurricane is that it caused significant damage to the College Woods in some but not all areas. This allows a natural experiment of forest regeneration with varying levels of recent disturbance. Eight of the 19 upland plots were severely damaged, nine were partially damaged, and the remaining were minimally damaged. Those that sustained the highest level of damage were those that were topographically vulnerable to winds from the east, or were located in microburst areas (Prengaman et al., 2008). These plots are 1, 2, 4, 8, 9, 12, 17, and 20 (Map in Appendix D).

In the winter of 2014, plots were relocated and sampled for woody vegetation. Plots were relocated using GPS coordinates, a map of the College Woods, and centerline headings. Relocating stakes was facilitated by matching landmarks with the previous photographs taken from the centerlines, by measuring the distance between existing stakes, and by inspecting the leaf litter for the marker, often with the aid of a metal detector. If missing stakes could not be relocated, a new plastic-coated aluminum stake was placed at the estimated original location (Table 10).

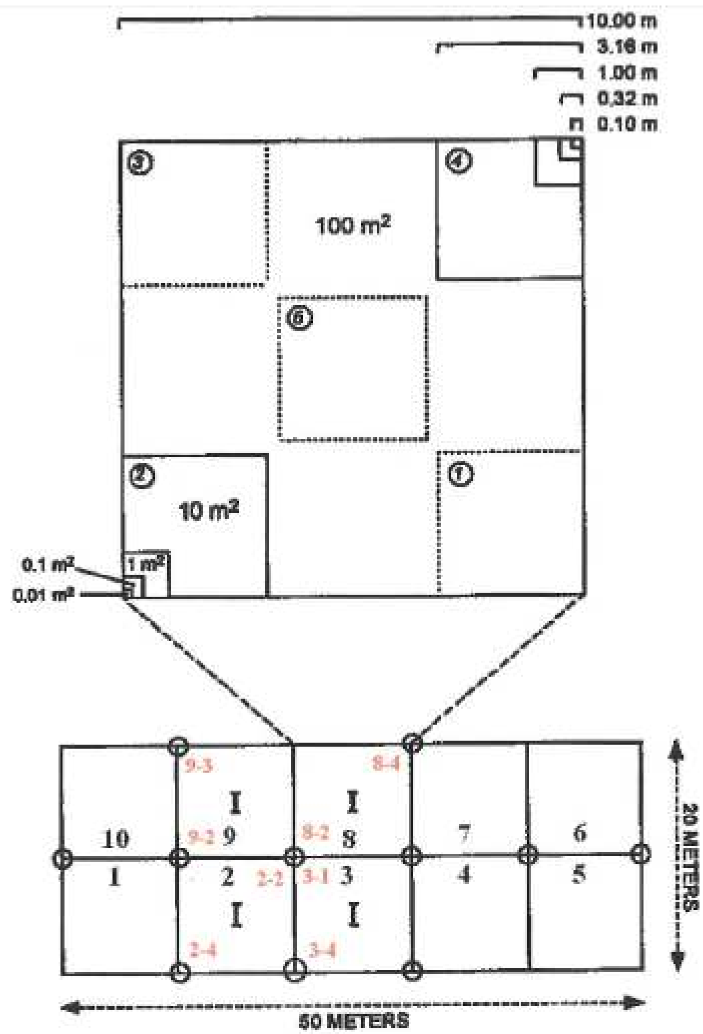


Figure 24. Reprinted from Kribel, 2003. Diagram of the standard plot layout of the NCVS method used to establish the plots. Open circles indicate points at which a stake was permanently placed. Numbers 1-10 indicate the number of the module. Modules marked with "I" are those where the ground layer was sampled in 2002 and 2015. The red numbers indicate the corners where subplots were placed to sample vegetation in 2002. The entire intensive module was sampled for vegetation in 2015 due to the sparse nature of the ground layer, and the subplots were not used.

Table 10. List of plot stakes not relocated and therefore replaced in the current study. All directions written use the centerline heading as the point of reference. For further description of plot layout see Kribel 2003.

Plot #	Replaced Stakes
5	Centerline: 2^{nd} stake
6	Centerline: 4^{th} stake
7	Centerline: 1^{st}, 3^{rd} stake
9	Centerline: 2^{nd}, 3^{rd}; Left of Centerline: 2^{nd}, 4^{th}, 5^{th}; Right of Centerline: 3^{rd}, 5^{th}
10	Centerline: 2^{nd}, 3^{rd}, 4^{th}; Left of Centerline: 2^{nd}; Right of Centerline: 2^{nd}, 3^{rd}
20	Centerline: 5^{th}

NCVS methods usually dictate measuring only four modules, but Kribel elected to sample six modules for the woody plant vegetation to account for the low density of trees in the mature College Woods. These were modules 2, 3, 4, 7, 8, and 9. Ground layer vegetation (all vegetation below 0.2m in height, including cotyledons), however, was measured in the standard four modules (2, 3, 8 and 9), but only in 2002. The 2004 resampling only included plants that reached breast height (1.2m) and did not include a ground layer component. Kribel sampled the ground layer using nested subplots $1m^2$, $10m^2$, and $100m^2$ in size. He used this nested subplot method to weight his abundance measurements for each species.

In 2014, the same six modules were resampled for woody plants per Kribel's (2003) methods (Figure 24). Within each module, all woody plants were identified to species except *Gaylussacia* spp. and *Vaccinium* spp. which were only determined to genus. Each stem diameter at breast height was binned into one of the following categories in the field: below 1cm, 1-2.5, 2.5-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, and 35-40 cm. In fallen plants, breast height was estimated and the midpoint values of the relevant bins in which the stems in question fell were used for calculations. Trees with DBH above 40cm were recorded to the nearest half centimeter. Trunks branching below 0.5m were recorded as two stems; if the trunks branched between 0.5m and 1.4m, they were measured as a single trunk just below the branching point. DBH values were used to calculate relative dominance, relative density, and importance values (I.V.) for each species in each of these size classes: sapling (0-2.5cm DBH), small tree (2.5-10cm DBH), and large tree (10cm+ DBH). Mixed-groups two-way ANOVAs (referred to as Mixed ANOVAs in text) were used to test the effects of time, degree of damage from Hurricane Isabel (severe or less damaged), and the interaction of both time and damage on stem density and species richness for each size class. These analyses assumed two fixed factors (time and damage class) using a repeated measures design. The assumption of equal variances was violated during the stem density test of the sapling size class. A constant of one was added to each number and then log-transformed, then the mixed two-way ANOVA was performed again. If there were significant main effects, a Fishers LSD test using alpha = 0.05 was performed for each group. The 2004 and the 2015 woody stem data were also compared by size class using Bray-Curtis cluster analyses (CA) and non-metric multi-dimensional scaling (NMDS). The I.V.s for each species in each plot was used for the CA and NMDS analyses. These tests were used to evaluate any change in plots over time. Groups were determined in the CA based on trends of high importance (I.V. >10) and species similarity among plots. Because of much dissimilarity among plots in the sapling data, it was analyzed by three separate CAs. First, a CA of the 2004 and 2015 data combined was performed to illustrate the degree of dissimilarity across time. Then, a separate CA was performed for the 2004 data and the 2015 data. These CAs were used to determine groups (and thus trends in importance and species composition) and were then compared to each other. Species nomenclature follows the Flora of Virginia (Weakley et al., 2012).

Ground layer vegetation was characterized in the four intensive modules of each plot by recording presence/absence data for the entire 100 m^2 area of each module. Although Kribel used a nested quadrat design and recorded cover as well as presence, the nested quadrat system is intended for dense ground layer vegetation, which the College Woods now lacks. In fact, most species existed in the ground layer only as scattered seedlings bearing cotyledons and first leaves, making it difficult to identify species. Because of the immaturity of species as well as low density and cover, only presence data was recorded, and for the entire modules. Species that could not be identified in the field were documented through photos and identified at a later time. In the case of one common but unknown species, two samples were taken and grown in the greenhouse until they grew large enough for identification.

For the deer browse analysis, all plants between 0.2m and 1.8m in height were examined and scored for the presence or absence of deer browse in each of the six modules per plot. The data were scored during the winter, which is the time when white-tailed deer are more heavily using woody trees as forage material (Gilliam, 2007). Deer browsing was indicated when terminal buds were clearly removed, and the point of removal was relatively parallel to the ground (a diagonal cut lower to the ground could be from a rodent). If a plant had been browsed, usually many buds had been removed and the plant exhibited a fractal pattern indicative of repeated removal of the terminal bud. In the case of two plots, *Gaylussacia* spp. were so dense that it was impossible to count by hand. Subquadrats of $10m^2$ were laid down in the left corner of each of the six sampled modules and the number of plants were counted (see Figure 24; labelled 2-4, 3-4, 8-2, and 9-2 and not labelled in plots 4 and 7). The number recorded from each subquadrat was then multiplied by an estimate of the area filled with *Gaylussacia* spp. plants within the module, and then the number in each module was added (i.e., a total of $600m^2$ was estimated, the same area covered by the woody sampling methods in each plot).

For each of the 19 plots, the proportion of browsed plants (PB) within each individual species (PBi) was calculated by dividing the total number of plants browsed for species i into the total number of plants comprising species i. Likewise, the proportion of all browsed plants across all species within a plot (PB_t) was calculated by dividing the total number of plants browsed across all species into the total number of plants comprising all species. For each species that was present in at least three plots, paired t-tests evaluated whether the plot PBi values differed significantly from the plot PBt values. A significant result indicates that white tailed deer prefer or less prefer the species relative to the total browse rate. Finally, for each species, all plots were pooled and PBi and PBt were calculated from the pooled data. A relative browse rate for each species is reported from the pooled data by Pbi/PBt.

Results

A total of 128 woody and ground layer species were recorded during the current survey (Appendix E) compared to 98 species recorded during the 2002 pre-hurricane survey. No tree species recorded with stems reaching breast height (29 total) were lost between the initial 2002 survey and the 2004 or 2015 re-surveys. Size classes and stem density within plots did change, however. Eight additional tree or bushy species were recorded at breast height during the 2015 survey, all only found in heavily hurricane-damaged plots. These species are *Paulownia tomentosa* (Thunb.) Steud., *Callicarpa americana* L., *Elaeagnus umbellata* Thunb., *Magnolia grandiflora* L., *Morella cerifera* (L.) Small, *Platanus occidentalis* L., *Celtis occidentalis* L., and *Rhus copallinum* L.

There were 58 species recorded below breast height in the ground layer that were present in both 2002 and 2015. Forty-two ground layer species were found only in hurricane-damaged plots (Appendix E). Because the ground layer was not resampled in 2004, a comparison cannot be made between that dataset and the 2015 data.

Large Tree Size Class (>10 cm stems)

Species diversity did not differ across years within groups (Mixed ANOVA, p=0.801, df=1) or between severely damaged and less damaged plot types (Mixed ANOVA, p=0.352, df=1). Additionally, there was no interaction between damage and time (Figure 25; Mixed ANOVA, p=0.390, df=1).

Stem density also did not differ significantly across years within groups (Mixed ANOVA, df=1, p=0.086) or between severely damaged and less damaged plots (Mixed ANOVA, df=1, p=0.606). However, there was a significant interaction of damage and time (Mixed ANOVA, df=1, p=0.039). Stem density increased over time in the severely damaged plots, but decreased in the less damaged plots (Figure 26).

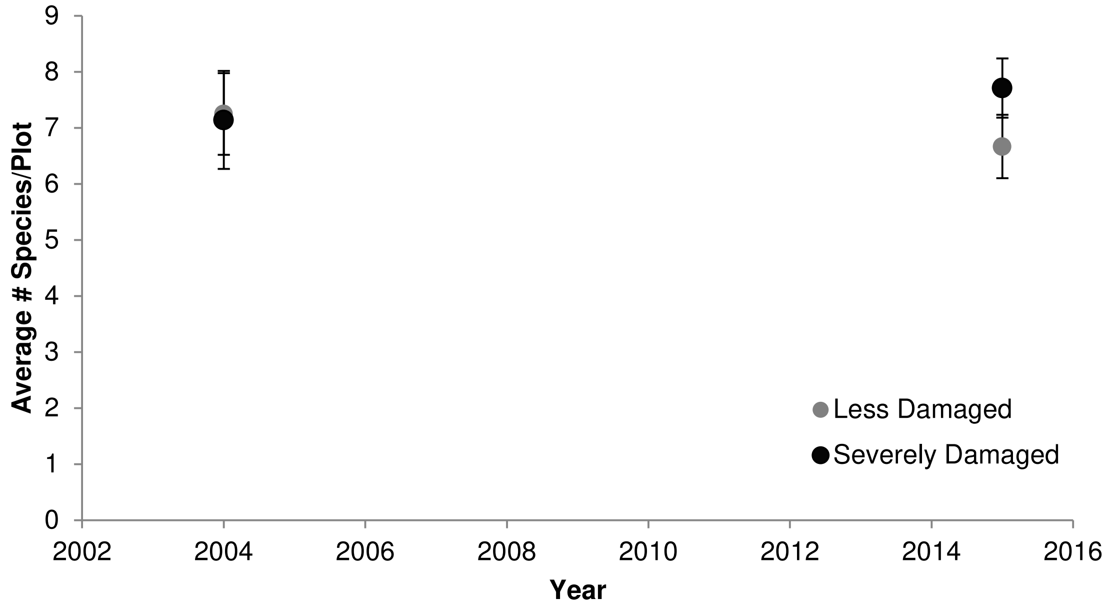


Figure 25. Mean species diversity per plot in the large tree size class in plots severely damaged and less damaged by Hurricane Isabel between 2004 and 2015. There are no significant differences across time within groups, between damage types, or as a result of interaction.

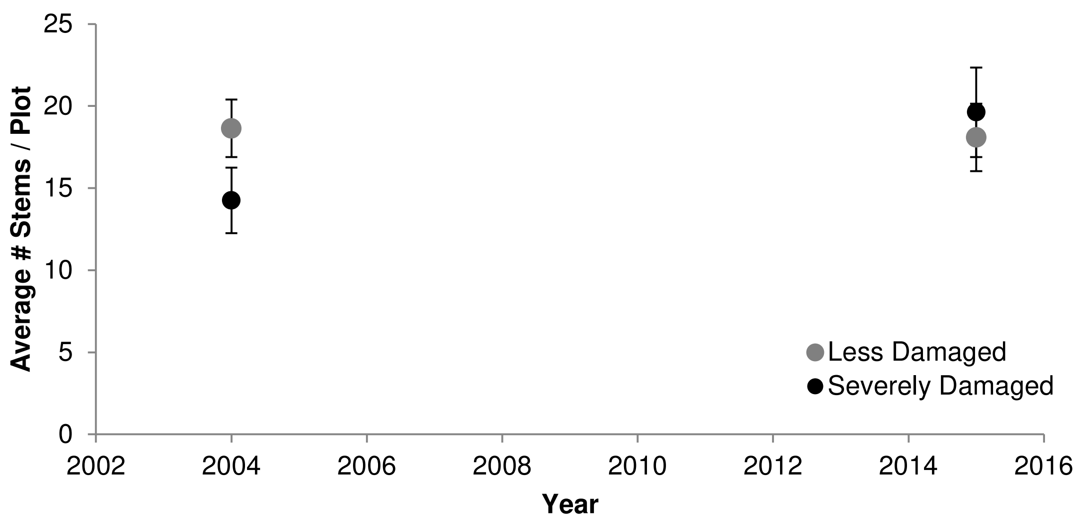


Figure 26. Mean stem density per plot in the large tree size class in plots severely damaged and less damaged by Hurricane Isabel between 2004 and 2015. The interaction between time and degree of damage is significant.

Table 11 summarizes the numbers and percentages of plots with importance values (I.V.) greater than 10 (considered high I.V.). Three species, all of which were important in the overstory in 2004, decreased to I.V. below 10 in at least two plots between 2004 and 2015 (*Quercus rubra* var. *rubra* L.*, Q. velutina,* and *Q. falcata*). Additionally, the total number of plots with *Carya* spp. with an IV > 10 decreased from 5 to 3 between 2004 and 2015. Three species that were well represented in the smaller size classes in 2004 increased notably in number of plots where they have IV > 10 (*Ilex opaca* Aiton var. *opaca, Fagus grandifolia,* and *Cornus florida*). *Pinus taeda* L.*,* a species not recorded in 2004, reached IV >10 in one plot in 2015.

A cluster analysis of all plots over 2004 and 2015 data can be divided among four most-inclusive groups (Figure 27). Groups were created based on trends of high importance values and species similarity. Group 1 is composed of two plots situated near each other on the far western edge of the College Woods boundary. These plots contained high *Quercus alba* L. and *Nyssa sylvatica* Marshall*,* with relatively low *F. grandifolia.* Group 2 consisted broadly of plots containing high I.V.s for *F. grandifolia* (all but one plot with an I.V. over 25) and *Q. alba*. This was further subdivided into two subgroups: one with low presence of other oak species (2a), and the other with high presence of other oak species (2b). Subgroup 2a is composed of extremely high *F. grandifolia* (all I.V.s over 40) and mostly high *I. opaca* and *O. arboreum.* Plots in Subgroup 2b contained mixtures of *Q. falcata, Q. rubra, Q. velutina,* and *Q. michauxii.* A third group contains plots with very low *F. grandifolia* importance in comparison to other plots (three of five have an I.V. of 0; all other I.V.s less than 15). All plots in the third group also contained *A. rubrum, Carya tomentosa* (Poir) Nutt., and *C. florida* at various levels of importance. A fourth group contained plots with *F. grandifolia* present in all plots, but at low importance. Plots in this group tended to also have high importance for *A. rubrum, Liriodendron tulipifera* L., and *Q. alba.*

Despite the fact that all plots experienced some changes between sampling years, 10 plots clustered most similar to themselves across years in a cluster analysis (Figure 27). The exceptions were plots 1, 2, 3, 4, 8, 9, 12, 13, and 17, all except plots 3 and 13 were within areas severely damaged by Hurricane Isabel. Members of pairs generally fall within a single group identified above, except plot 17 which switched from group 4 to group 3. There are no consistent species-specific trends between sampling years. Likewise, the NMDS analysis reveals that there were no hard delineations between groups, suggesting that there is only minor variation in composition across the wooded upland area of the College Woods (Figure 28).

Table 11. Summary of the number and percentage of plots in 2004 and in 2015 containing stems >10 cm DBH with I.V. > 10, and the number of plots in which a given species had the greatest I.V. in that size class.

Species	#, % Plots with I.V. >10				#, % Plots with highest I.V.			
	2004		**2015**		**2004**		**2015**	
Acer rubrum	7	36.8	8	42.1	1	5.3	3	15.8
Carya cordiformis	0	0.0	1	5.3	0	0.0	0	0.0
Carya glabra	1	5.3	0	0.0	0	0.0	0	0.0
Carya pallida	2	10.5	0	0.0	0	0.0	0	0.0
Carya tomentosa	2	10.5	2	10.5	0	0.0	1	5.3
Cornus florida	0	0.0	3	15.8	0	0.0	1	5.3
Fagus grandifolia	11	57.9	15	78.9	7	36.8	9	47.4
Ilex opaca var. *opaca*	2	10.5	5	26.3	0	0.0	0	0.0
Liquidambar styraciflua	0	0.0	1	5.3	0	0.0	0	0.0
Liriodendron tulipifera	6	31.6	5	26.3	2	10.5	1	5.3
Nyssa sylvatica	2	10.5	3	15.8	0	0.0	1	5.3
Oxydendrum arboreum	3	15.8	2	10.5	1	5.3	0	0.0
Pinus taeda	0	0.0	1	5.3	0	0.0	0	0.0
Quercus alba	11	57.9	12	63.2	5	26.3	3	15.8
Quercus falcata	2	10.5	0	0.0	0	0.0	0	0.0
Quercus michauxii	1	5.3	0	0.0	0	0.0	0	0.0
Quercus rubra var. *rubra*	5	26.3	1	5.3	2	10.5	0	0.0
Quercus velutina	4	21.1	1	5.3	1	5.3	0	0.0

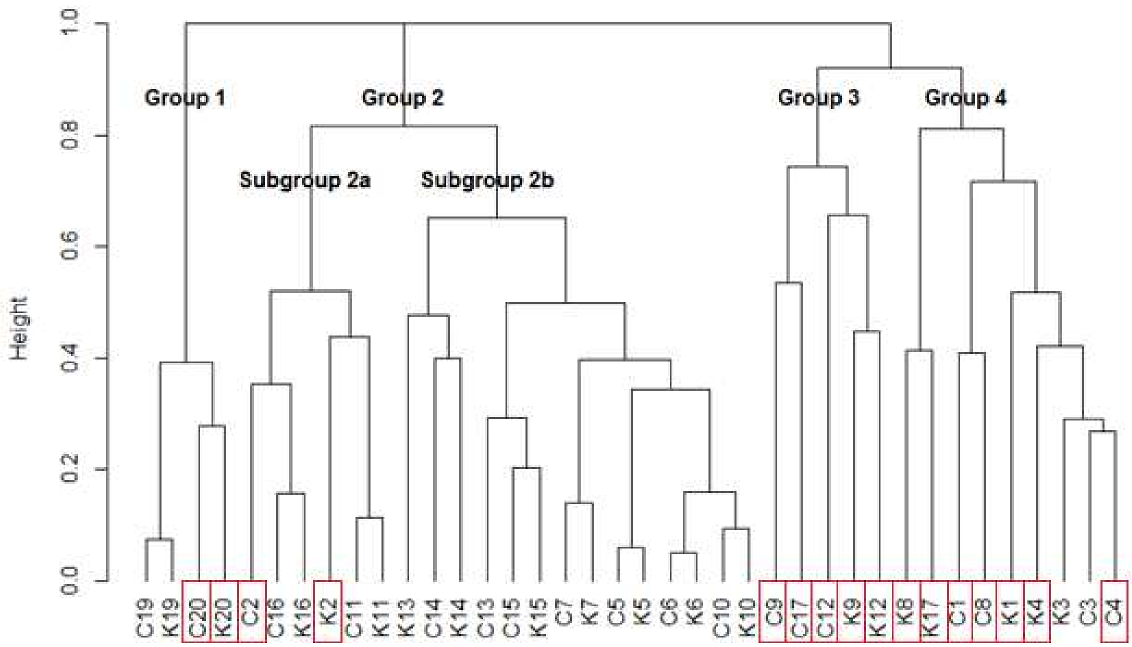


Figure 27. A cluster analysis of the permanent NCVS plots based on the I.V.s of tree species in the large tree size class. C and K are Cyrus vs. Kribel data, respectively, followed by the plot numbers. Red boxes indicate plots that were severely damaged by Hurricane Isabel.

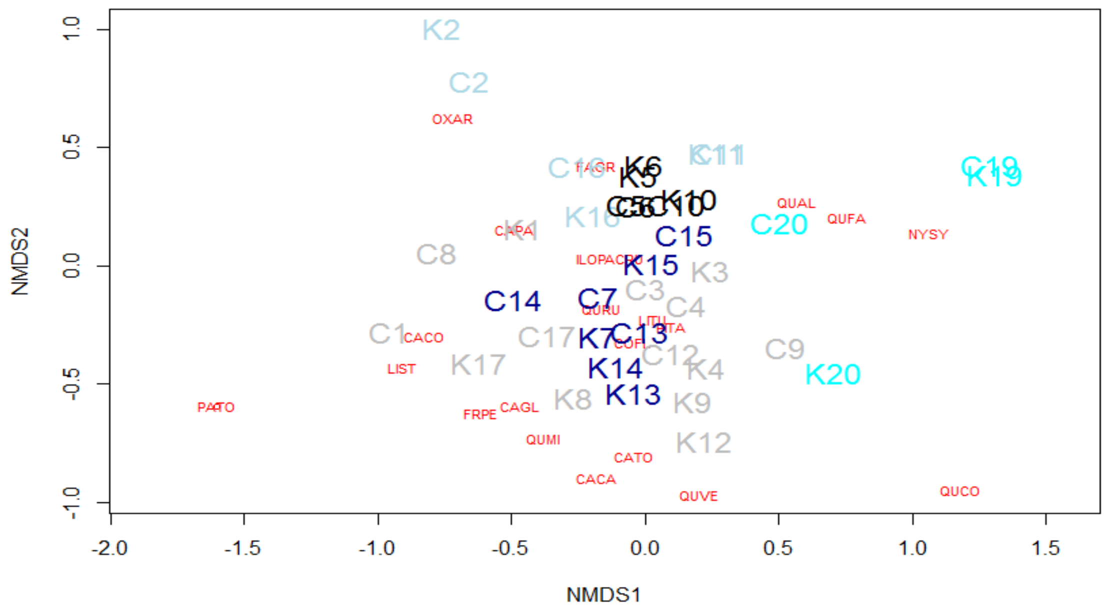


Figure 28. NMDS of 19 NCVS plots in 2004 and 2015 based on I.V.s of species in the large tree size class (>10cm DBH) size class. Species codes are colored red and represent the first two letters of the genus and specific epithets of the names, respectively. C# and K# indicate survey years and plot numbers (C = Cyrus, 2015; K = Kribel, 2004). Plots are color-coded based on the groups derived from the cluster analysis. Group 1 is colored cyan, Group 2a is light blue, Group 2b is dark blue, Group 3 is colored black, and Group 4 is colored grey.

Small Tree Size Class (10 cm > x > 2.5 cm stems)

Species diversity increased significantly over time within groups (Mixed ANOVA, $p<0.001$, df=1) in both the less damaged plot type (using $d_{LSD} = 0.7158$) and the severely damaged plot type (using $d_{LSD}=0.0838$). Species diversity did not differ significantly between severely damaged and less damaged plot types overall (Mixed ANOVA, $p=0.432$, df=1). There was an interaction between time and degree of damage (Mixed ANOVA, $p=0.010$, df=1). While species diversity was not initially different between less damaged and severely damaged plots, it became significantly higher in severely damaged plots by 2015 (using d_{LSD}=1.103). Although diversity increased over time in both damage types, the increase was much more pronounced in severely damaged plots (Figure 29). Stem density increased significantly over time within groups (Figure 30; Mixed ANOVA, p= 0.023, df=1), but only in severely damaged plot types (using d_{LSD} = 11.4381). There was no difference between severely damaged and less damaged plot types overall (Mixed ANOVA, p=0.464, df=1). There was no interaction between time and degree of damage (Mixed ANOVA, p=0.217, df=1).

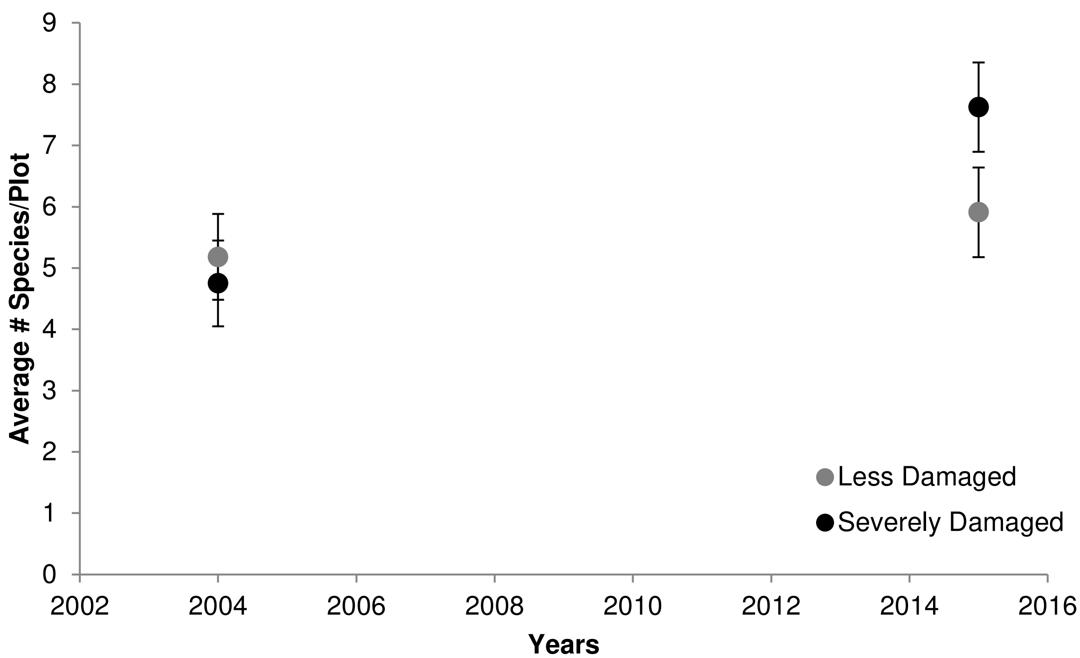


Figure 29. Mean species richness per plot across 2004 and 2015 and between plots severely damaged and less damaged by Hurricane Isabel. There was a significant increase over time in both damage types, a significant difference between damaged types in 2015, and a significant interaction between time and damage type.

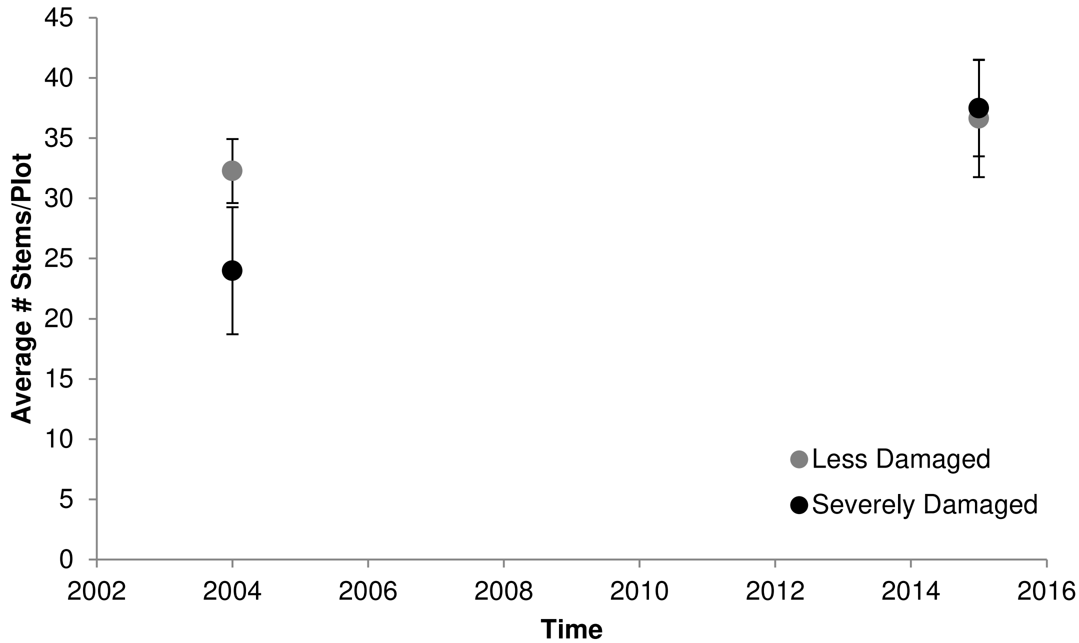


Figure 30. Mean stem density per plot across 2004 and 2015 and between plots severely damaged and less damaged by Hurricane Isabel. There was a significant increase over time in severely damaged plots.

Three species did not have I.V. >10 in any plot in this size class in 2004 but did so in 2015: *P. taeda* in two plots, *Liquidambar styraciflua* L. in two plots, and *M. cerifera* in one plot (Table 12). *Quercus alba* also first reached the threshold of I.V. > 10 in 2015, though the species was previously reported in the small tree size class in 2004. *Ilex opaca, F. grandifolia*, *A. rubrum*, and *C. florida* maintained the overwhelming dominance in this size class that they had held in 2004. *F. grandifolia* and *C. florida* decreased slightly in the number of plots where they reached I.V. >10. Despite declining in importance in a few plots, *F. grandifolia* had the highest I.V. in an additional three plots in 2015.

A cluster analysis based on the I.V.s of tree species in the small tree size class revealed four distinct groups with clustering values over 0.9 (Figure 31). Group 1 consists of a single plot located on the western edge of the College Woods where *N. sylvatica* had an I.V. of over 66. Group 2 is composed broadly of plots with low importance of *F. grandifolia.* Subgroup 2A contains the lowest values of *F. grandifolia* (1-10 I.V.), while also possessing the highest values of *A. rubrum* (up to I.V. of 71). Subgroup 2B is composed of plots with both low *F. grandifolia* and low *A. rubrum.* The third group consists of plots with high *F. grandifolia* (I.V.s over 40). Group 4 contains plots with high importance of *C. florida,* with most plots possessing I.V.s between 20 and 80 (the exception is one plot with an I.V. of 10).

Seven plots switched from one group to another between years; five of those were originally in Group 4 (plots with high *C. florida*) in 2004, and three of them had moved to Group 3 (high *F. grandifolia*) by 2015. Only one of these moved stands was severely damaged by Hurricane Isabel. Six plots were no longer most like themselves by 2015 but did not change enough to switch groups; only six plots were still most like themselves between 2002 and 2015. Figure 32 shows that the groups defined by the CA (color coded) separated out relatively well using an NMDS, suggesting there are identifiable group characteristics, despite many species having I.V.s >10 across the majority of plots.

Table 12. Summary of the number and percentage of plots in 2004 and in 2015 containing stems 2.5-10 cm DBH with I.V. > 10, and the number of plots in which a given species had the greatest I.V. in that size class.

Species	#, % Plots with I.V. >10				#, % Plots with highest I.V.			
	2004		**2015**		**2004**		**2015**	
Acer rubrum	8	42.1	8	42.1	4	21.1	3	15.8
Carpinus caroliniana	1	5.3	0	0.0	0	0.0	0	0.0
Carya tomentosa	1	5.3	1	5.3	0	0.0	0	0.0
Cornus florida	13	68.4	10	52.6	5	26.3	5	26.3
Fagus grandifolia	12	63.2	11	57.9	5	26.3	8	42.1
Ilex opaca var. *opaca*	10	52.6	12	63.2	3	15.8	1	5.3
Juniperus virginiana	1	5.3	0	0.0	0	0.0	0	0.0
Liquidambar styraciflua	0	0.0	2	10.5	0	0.0	0	0.0
Morella cerifera	0	0.0	1	5.3	0	0.0	0	0.0
Nyssa sylvatica	5	26.3	2	10.5	2	10.5	1	5.3
Oxydendrum arboreum	1	5.3	0	0.0	0	0.0	0	0.0
Pinus taeda	0	0.0	2	10.5	0	0.0	1	5.3
Quercus alba	0	0.0	1	5.3	0	0.0	0	0.0
Quercus rubra var. *rubra*	1	5.3	0	0.0	0	0.0	0	0.0
Sassafras albidum	1	5.3	0	0.0	0	0.0	0	0.0

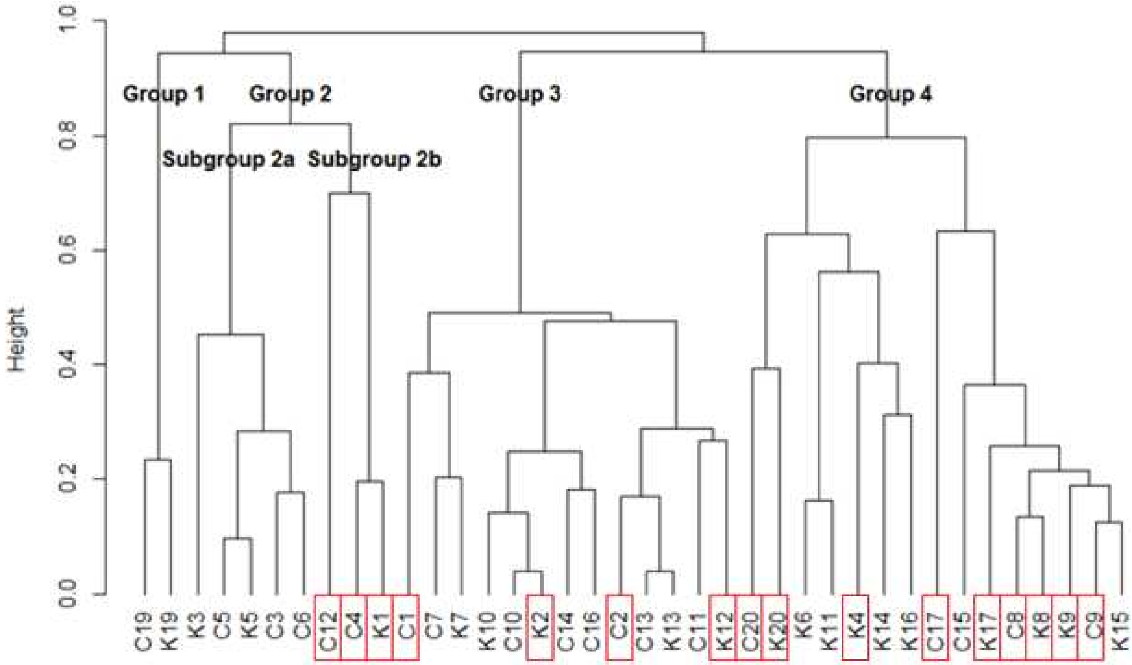


Figure 31. Cluster analysis of 19 NCVS plots in both 2004 and 2015, based on I.V.s of species in the small tree (10> x > 2.5 cm DBH) size class. Red boxes indicate plots that were severely damaged by Hurricane Isabel. The CA revealed 4 groups and two subgroups. Seven plots moved from one group to another, and only six plots remained most like themselves between 2004 and 2015.

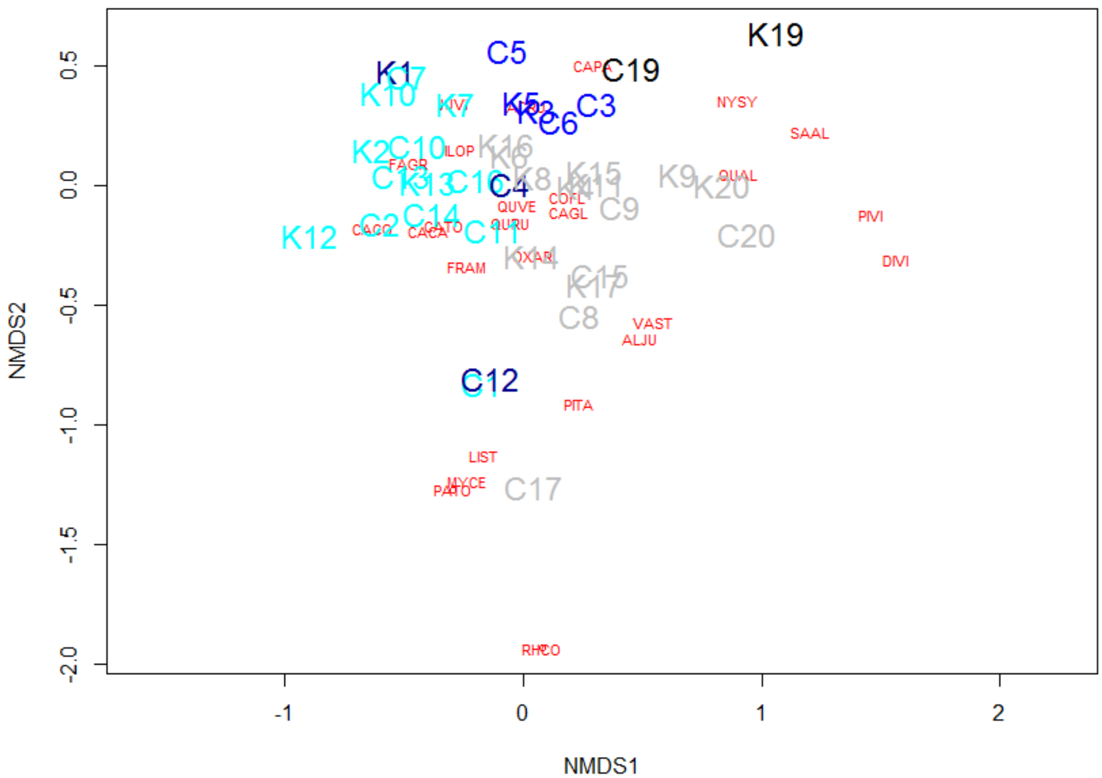


Figure 32. NMDS of 19 NCVS plots in 2004 and 2015 based on I.V.s of species in the small tree (10> x >2.5 cm DBH) size class. Species codes are colored red. C# and K# indicate survey years and plot numbers (C = Cyrus, 2015; K = Kribel, 2004). Plots are color-coded based on the groups derived from the cluster analysis. Black corresponds to group 1, blue to group 2a, dark blue to group 2b, cyan to group 3, and grey to group 4.

Sapling Size Class (<2.5 cm stems)

Species diversity per plot decreased over time within groups, but only significantly in the less damaged plots (Figure 33; Mixed ANOVA, p=0.001, df=1; using d_{LSD}= 1.912). There was no significant difference in species diversity per plot between severely damaged and less damaged plots overall (Mixed ANOVA, p=0.636, df=1) and no significant interaction between the two treatments (Mixed ANOVA, p=0.220, df=1). Stem density also decreased over time within the less damaged plot groups but not the severely damaged groups (using d_{LSD}=13.133; Figure 34; Mixed ANOVA on log-transformed data, p=0.010). However, there was no difference in stem density between severely damaged and less damaged plots (Mixed ANOVA on log-transformed data, p=0.748, df=1) or in the interaction between time and degree of damage (Mixed ANOVA on log-transformed data, p=0.211, df=1).

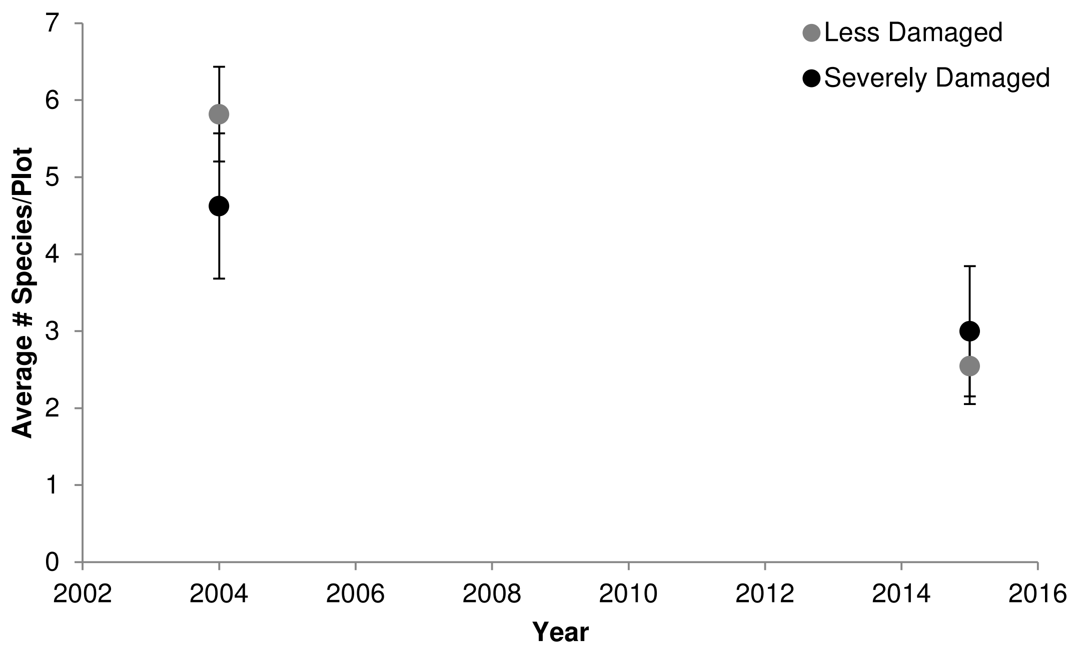


Figure 33. Mean species richness per plot across years and between severely damaged and less damaged plots. Species richness declined significantly over time.

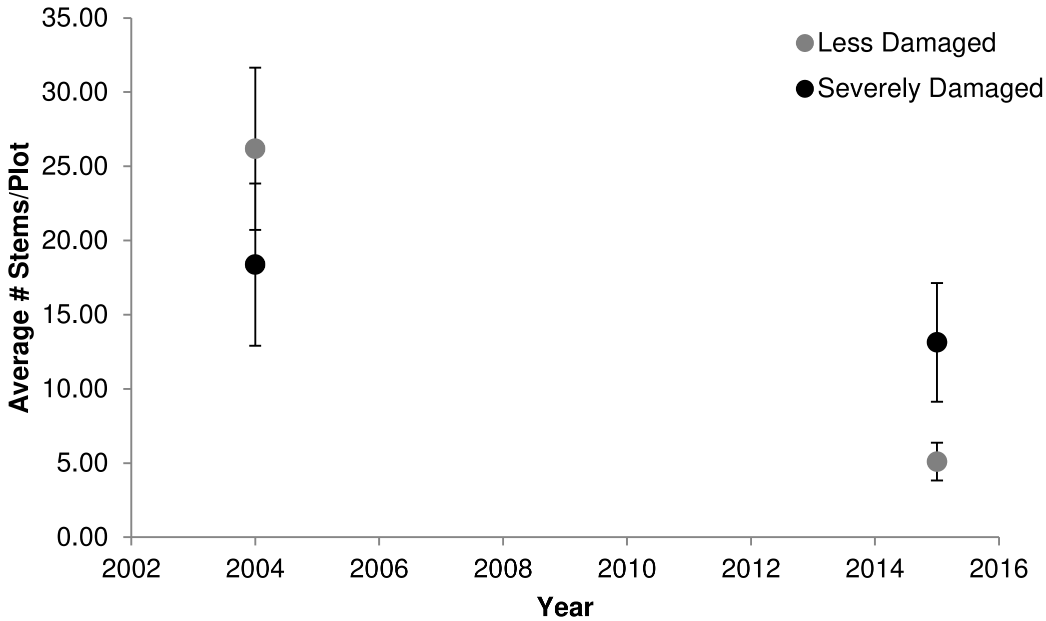


Figure 34. Mean stem density per plot across years and between severely damaged and less damaged plots. Stem density significant decreased over time.

Four species with IV >10 in seven or more plots in 2004 (*A. rubrum, F. grandifolia, C. florida,* and *I. opaca*) had all decreased greatly by 2015, especially *A. rubrum,* which was very important in 10 plots in 2004 but in only two plots in 2015 (Table 13). However, *Fagus grandifolia, C. florida,* and *I. opaca,* while each lower than in 2004*,* still had I.V.s > 10 in the highest number of plots in 2015. Five species that did not reach the IV>10 threshold in 2004, had reached it by 2015: *Pinus taeda* in three plots, *Morella cerifera* in two plots, and *Callicarpa americana*, *Liquidambar styraciflua*, and *Diospyros virginiana* L. each in one plot. The first three of these species reached this level only in plots severely damaged by Hurricane Isabel and were not recorded at all in any plot in 2004.

Figure 35 shows a cluster analysis of the 2004 and 2015 data that reveals approximately 8 groups clustering higher than 0.8, reflecting relatively high variance among plots. Only two plots were most similar to themselves between years. Figure 36 presents the NMDS analysis of 2004 and 2015 data, showing that most plots did not separate well. Because of the distinct shifts in composition in the sapling size class between sampling years, it was deemed best to treat each year separately. This will allow us to better compare changes in composition over time, allowing us to understand why so many plots are dissimilar to themselves between 2004 and 2015.

Table 13. Summary of the number and percentage of plots in 2004 and in 2015 containing stems <2.5 cm DBH with I.V. > 10, and the number of plots in which a given species had the greatest I.V. in that size class.

Species Code	#, % Plots with I.V. >10				#, % Plots with highest I.V.			
	2004		2015		2004		2015	
Acer rubrum	10	52.6	2	10.5	5	26.3	0	5.3
Amelanchier arborea	1	5.3	1	5.3	1	5.3	0	0.0
Callicarpa americana	0	0.0	1	5.3	0	0.0	1	5.3
Carya pallida	0	0.0	1	5.3	0	0.0	0	0.0
Carya tomentosa	1	5.3	1	5.3	0	0.0	0	0.0
Cornus florida	7	36.8	4	21.1	3	15.8	1	5.3
Diospyros virginiana	0	0.0	1	5.3	0	0.0	1	5.3
Fagus grandifolia	13	68.4	8	42.1	5	26.3	6	31.6
Fraxinus americana	0	0.0	1	5.3	0	0.0	0	0.0
Ilex opaca var. *opaca*	9	47.4	5	26.3	2	10.5	3	15.8
Liquidambar styraciflua	0	0.0	1	5.3	0	0.0	0	0.0
Morella cerifera	0	0.0	2	10.5	0	0.0	1	5.3
Nyssa sylvatica	4	21.0	3	15.8	1	5.3	0	0.0
Pinus taeda	0	0.0	3	15.8	0	0.0	2	10.5
Quercus velutina	1	5.3	0	0.0	1	5.3	0	0.0
Sassafras albidum	1	5.3	0	0.0	0	0.0	0	0.0
Vaccinium spp.	1	5.3	1	5.3	1	5.3	1	5.3

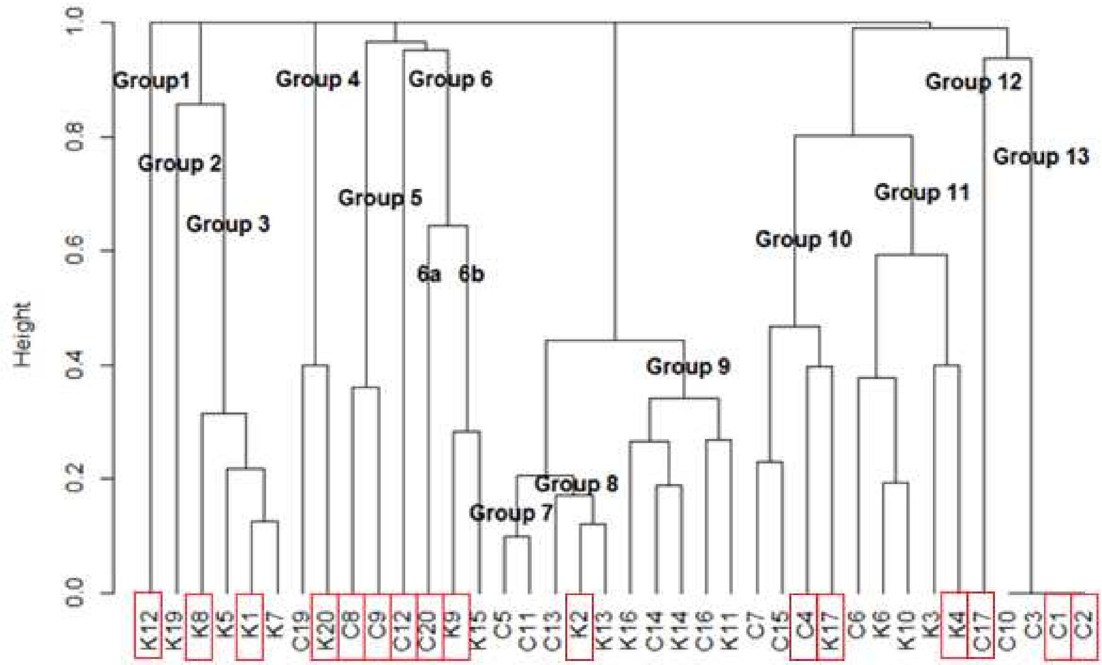


Figure 35. Cluster analysis of both 2004 and 2015 data based on I.V.s of species in the sapling (<2.5 cm DBH) size class. Red boxes indicate plots that were severely damaged by Hurricane Isabel. The CA revealed 13 groups which contained plots with similarities to each other. Only one plot was most like itself across the two studies.

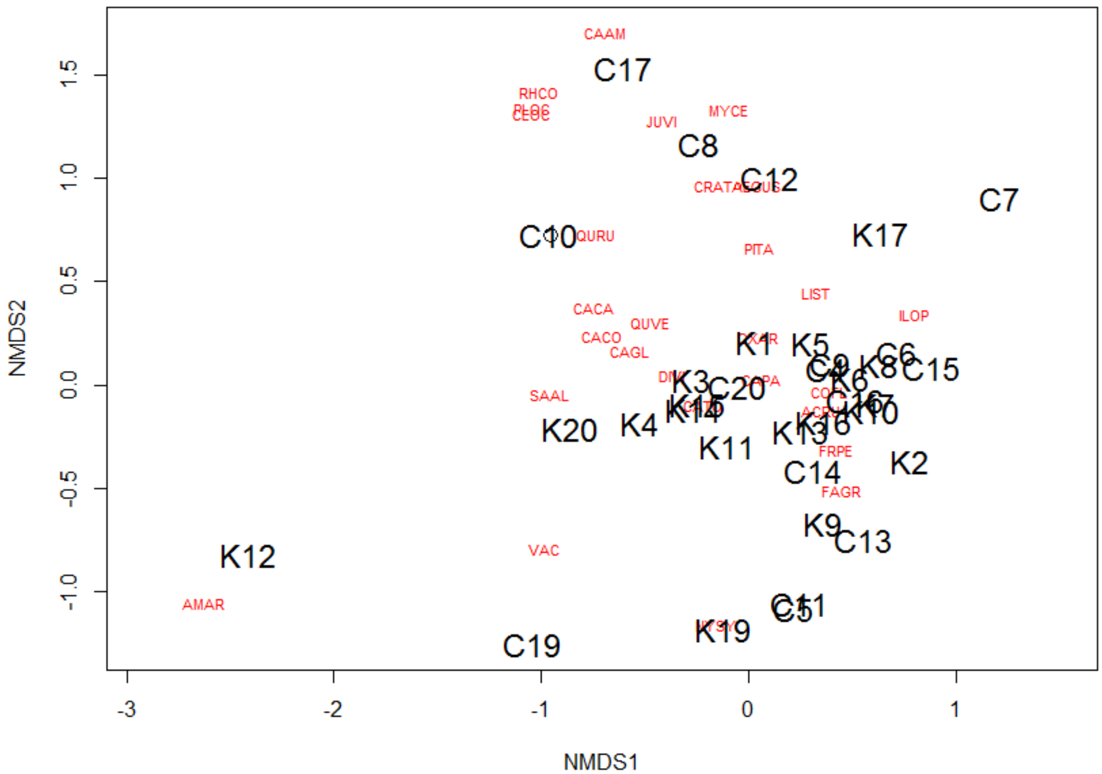


Figure 36. NMDS of 19 NCVS plots in 2004 and 2015 NCVS plot data based on I.V.s of species in the sapling (<2.5 cm DBH) size class. With the exception of six groups containing one or two plots each, all major groups plotted on top one another. Species codes are colored red. C# and K# refers to collection year and plot number (C = Cyrus 2015, K = Kribel 2004).

2004 Sapling Analysis

A cluster analysis of the 2004 survey revealed six major groups (Figure 37). Many species with high importance were spread across multiple groups (*A. rubrum, F. grandifolia, I. opaca, C. florida*); this suggests that the sapling layer of the upland wooded areas of the College Woods was relatively similar in composition, with some slight differences between plots, as is evidenced by how many groups overlapped each other on the NMDS (Figure 38).

In the CA (Figure 37), the first group consisted of a single plot located on the edge of Lake Matoaka at Blunt Point. The only species in this plot was *Amelanchier arborea* (Michx. f.) Fernald. The second group contained high I.V.s of *F. grandifolia* (>50 I.V.) with some plots also having high *C. florida* or *A. rubrum*. The third group also contained high *F. grandifolia,* but it was not nearly as dominant as in the second group. This third group also contained the majority of singular occurrences of species, with *Albizia julibrissin* Durazz., *Crataegus* sp., *L. styraciflua,* and *F. pensylvanica* each being present in a single plot. The fourth group contained a single plot located to the far western edge of the College Woods that had high I.V.s of *Sassafras albidum* (Nutt.) Nees and *Vaccinium* spp.. The fifth group contained a plot also on the far western edge of the College Woods with a high I.V. of *N. sylvatica.* The final group consisted of plots that all had high I.V. of *A. rubrum* and were mostly low in *F. grandifolia.*

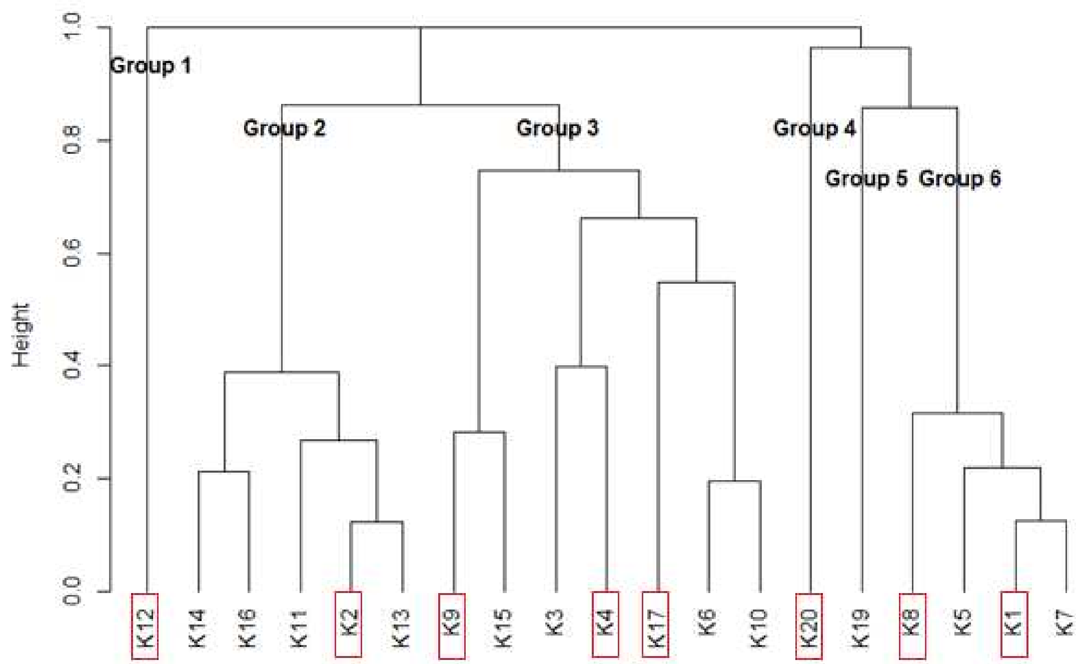


Figure 37. Cluster analysis of 19 NCVS plots sampled in 2004 revealed six groups in the sapling (<2.5 cm DBH) size class. Red boxes indicate plots that were severely damaged by Hurricane Isabel.

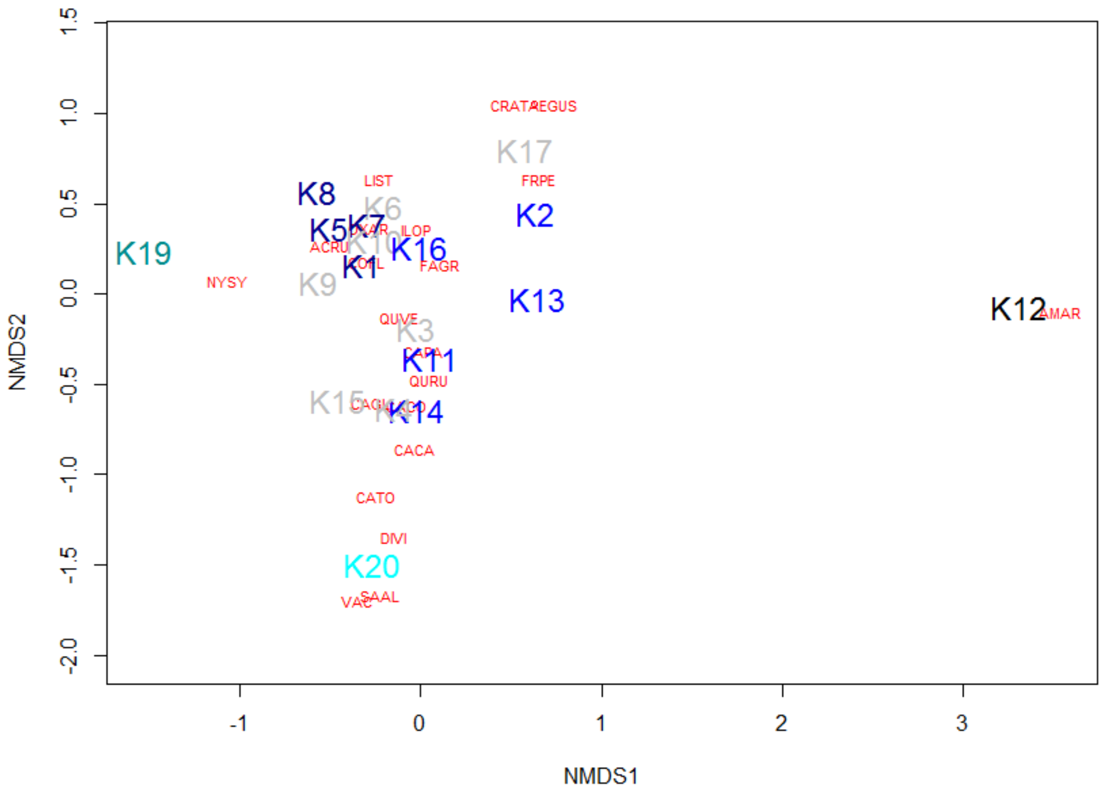


Figure 38. NMDS of 19 NCVS plots sampled in 2004 based on I.V.s of species in the sapling (<2.5 cm DBH) size class. Species codes are colored red. K# refers to sampler (Kribel in 2004) and plot number. Plots are Black corresponds to group 1, blue to group 2, grey to group 3, cyan to group 4, dark cyan to group 5, and dark blue to group 6.

2015 Sapling Analysis

A cluster analysis of the 2015 survey revealed seven major groups (Figure 39). The first group contained a single plot on the far west side of the College Woods that only contained three species, all of which had high I.V. These were *A. arborea, N. sylvatica,* and *Vaccinium* spp.. The second group contained a single plot that had been severely damaged by Hurricane Isabel, which contained high importance of *M. cerifera.* The third group contained plots where *Fagus grandifolia* was not present, and *Pinus taeda* had high importance*.* This group is most likely clustered together based on dissimilarity from other plots (most which contain *F. grandifolia*) rather than similarity between plots. The fourth group contains plots with *F. grandifolia* as the leading dominant (I.V. >60). The fifth group mostly possessed high *F. grandifolia,* but it was less dominant than the third group (I.V.s around 10-30). All plots in this group also contained high *I. opaca.* The sixth group contained a single plot located along Mill Neck Rd, where the only dominant species was *Callicarpa americana.* The final group consisted of plots that had no plants in the sapling layer. These groups separated out well in a NMDS (Figure 40).

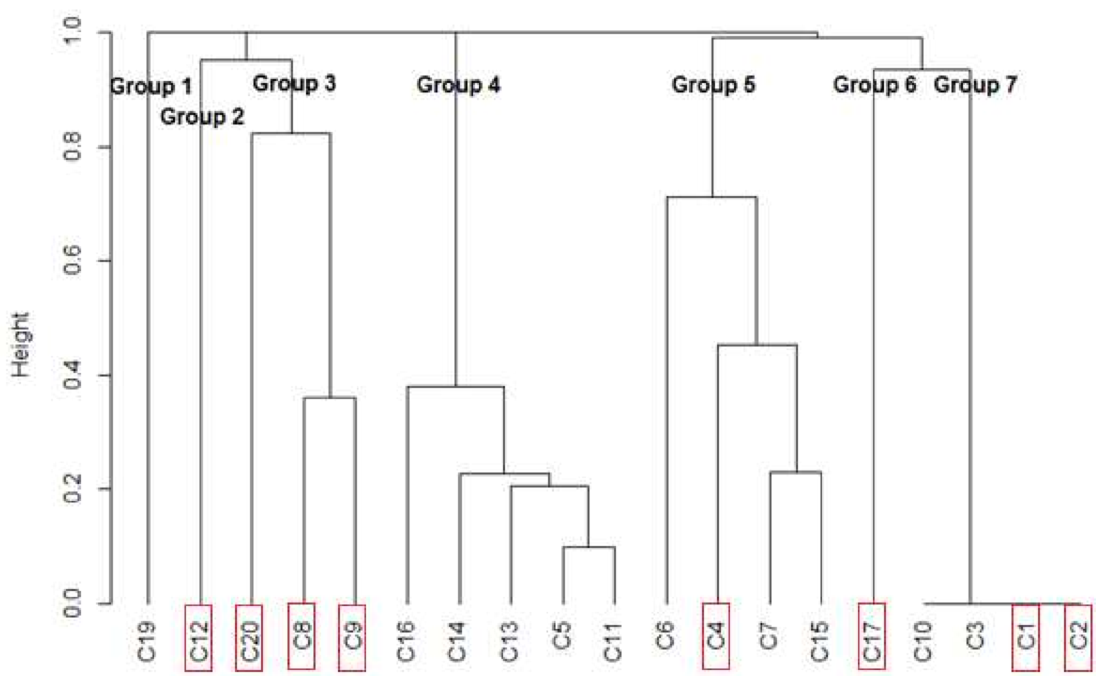


Figure 39. Cluster analysis of 19 NCVS plots sampled in 2015 based on I.V.s of species in the sapling size class (<2.5 cm DBH). Red boxes indicate plots severely damaged by Hurricane Isabel. The CA revealed seven groups.

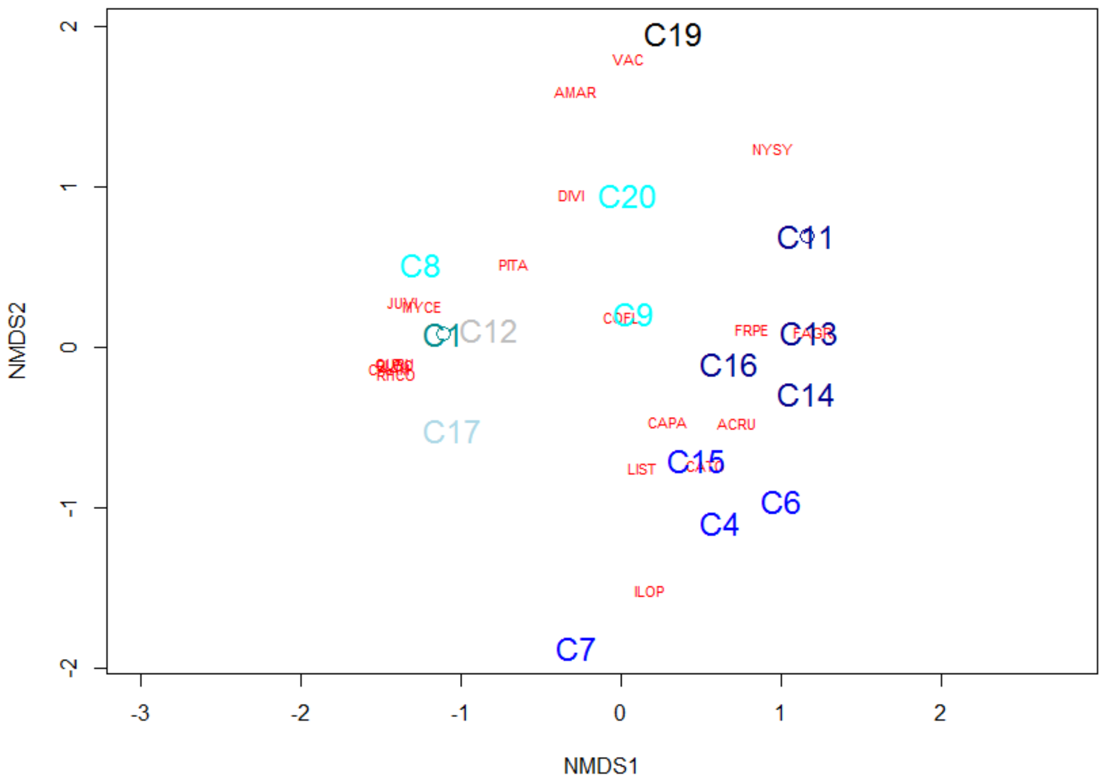


Figure 40. NMDS based on I.V. of trees found in sapling (<2.5 cm DBH) size class for 19 NCVS plots sampled in 2015. Black corresponds to group 1, grey to group 2, cyan to group 3, Dark Blue to group 4, blue to group 5, light blue to group 6, and dark cyan to group 7. Plots 2, 3, and 10 indicated by dark cyan circle, while Plot 5 is indicated by a dark blue circle.

Deer Browse Analysis

Plants at or above 0.2m in height were surveyed in the 19 plots for a total of 22,822 plants. Two dense thickets of *Gaylussacia* spp. counted in two plots on the far western edge of the College Woods accounted for 21,100 plants out of a total of 21,135 *Gaylussacia* spp. plants. Of the 22,822 plants, 1,106 of these only had limbs that grew out of the reach of white-tailed deer, and were therefore excluded. These were mostly trees above 2.5cm DBH, although some plants in the sapling size class fell into this category, such as *Nyssa sylvatica* and *Cornus florida*. Of the 21,716 plants that possessed vegetation in the reach of deer, 2% possessed signs of deer browse. Because *Gaylussacia* spp. was never browsed and accounted for over 97% of plants, it significantly lowered the percentage of plants browsed. *Gaylussacia* spp. was present in four plots, but only dense in two plots. Because it disproportionately affects the browse data and only takes up a small amount of the overall sampling area, *Gaylussacia* spp. was removed from the remaining analyses. Once *Gaylussacia* spp. was excluded, 63% of all sampled plants showed signs of deer browse in the form of the removal of multiple terminal buds. The percentage of plants browsed in each plot ranged from 20 – 100%, with an average of 74.19±0.05 SE (Figure 41).

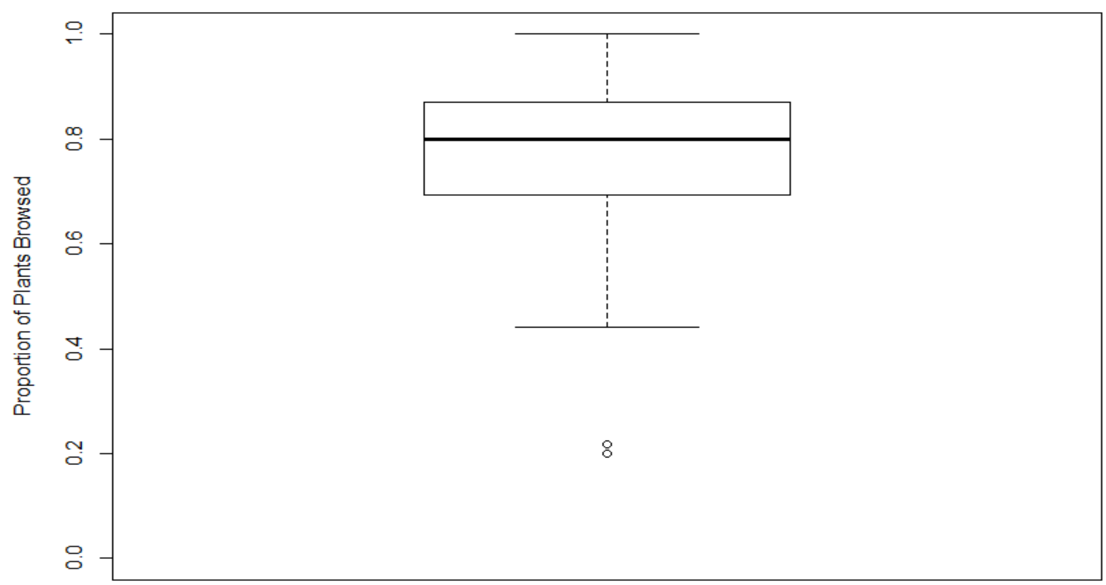


Figure 41. Boxplot of the overall proportion of plants browsed in each of 19 NCVS plots.

Across all plots combined, fifteen species had a higher proportion of browsed plants than the overall proportion of browsed plants, while thirteen had a lower proportion of browsed plants than the overall proportion of browsed plants (Figure 42).

Species that occurred in at least three plots and therefore could be tested for food preference were *Acer rubrum, Callicarpa americana, Cornus florida, Euonymus americana, Fagus grandifolia, Juniperus virginiana* var. *virginiana, Ilex opaca, Liquidambar styraciflua, Morella cerifera, Oxydendrum arboreum, Pinus taeda,* and *Vaccinium* spp. *Fagus grandifolia, I. opaca,* and *M. cerifera* were all browsed significantly more than the overall proportion of plants browsed in the plots where they occurred (Table 14).

Table 14. Total number of plants with available forage, number of plants browsed, percentage browsed, and relative browsing preference index for each species across all plots. Results of a paired t-test are included when a species was present in greater than 3 plots and could be tested against overall browse rates at the plot level. Significant results are bolded.

Species	# Plants	# Browsed	% Browsed Overall	# Plots	Two-way t-test
Acer rubrum	6	3	50%	5	df = 4, p = 0.6767
Amelanchier arborea	2	1	50%	1	NA
Asimina triloba	6	0	0%	2	NA
Callicarpa americana	39	36	92%	3	df = 3.2559, p = 0.0828
Carya glabra	1	1	100%	1	NA
Carya tomentosa	2	2	100%	2	NA
Celtis occidentalis	1	0	0%	1	NA
Cornus florida	6	4	67%	5	df = 2, p = 0.9428
Diospyros virginiana	1	1	100%	1	NA
Elaeagnus umbellata	1	1	100%	1	NA
Euonymus americanus	4	4	100%	3	df = 2, p = 0.0691
Fagus grandifolia	**208**	**184**	**88%**	**16**	**df = 15, p = 0.0374**
Fraxinus pensylvanica	1	1	100%	1	NA
Gaylussacia spp.	21135	1	0%	5	NA
Ilex opaca* var. *opaca	**57**	**48**	**84%**	**15**	**df = 14, p = 0.0464**
Juniperus virginiana var. *virginiana*	14	0	0%	3	df = 2, p = 0.3357
Liquidambar styraciflua	12	4	33%	3	df = 2; p = 0.2872
Magnolia grandiflora	*5*	*5*	*100%*	*1*	*NA*
Morella cerifera	***66***	***25***	***38%***	***5***	***df = 4; p = 0.0215***
Nyssa sylvatica	*3*	*2*	*67%*	*2*	*NA*
Oxydendrum arboreum	*3*	*1*	*33%*	*3*	*df = 2; p = 0.0832*
Paulownia tomentosa	*1*	*1*	*100%*	*1*	*NA*
Pinus taeda	*87*	*1*	*1%*	*4*	*df = 3, p = 0.07186*
Platanus occidentalis	*1*	*0*	*0%*	*1*	*NA*

Table 14 Continued. Total number of plants with available forage, number of plants browsed, percentage browsed, and relative browsing preference index for each species across all plots. Results of a paired t-test are included when a species was present in greater than 3 plots and could be tested against overall browse rates at the plot level. Significant results are bolded.

Species	# Plants	# Browsed	% Browsed Overall	# Plots	Two-way t-test
Quercus falcata	1	1	100%	1	NA
Quercus rubra var. *rubra*	1	0	0%	1	NA
Rhus copallinum	4	1	25%	2	NA
Vaccinium spp.	48	38	79%	6	df = 5, p = 0.6531
Total	21135	366	2%		NA
Removing *Gaylussacia*	581	365	63%		NA

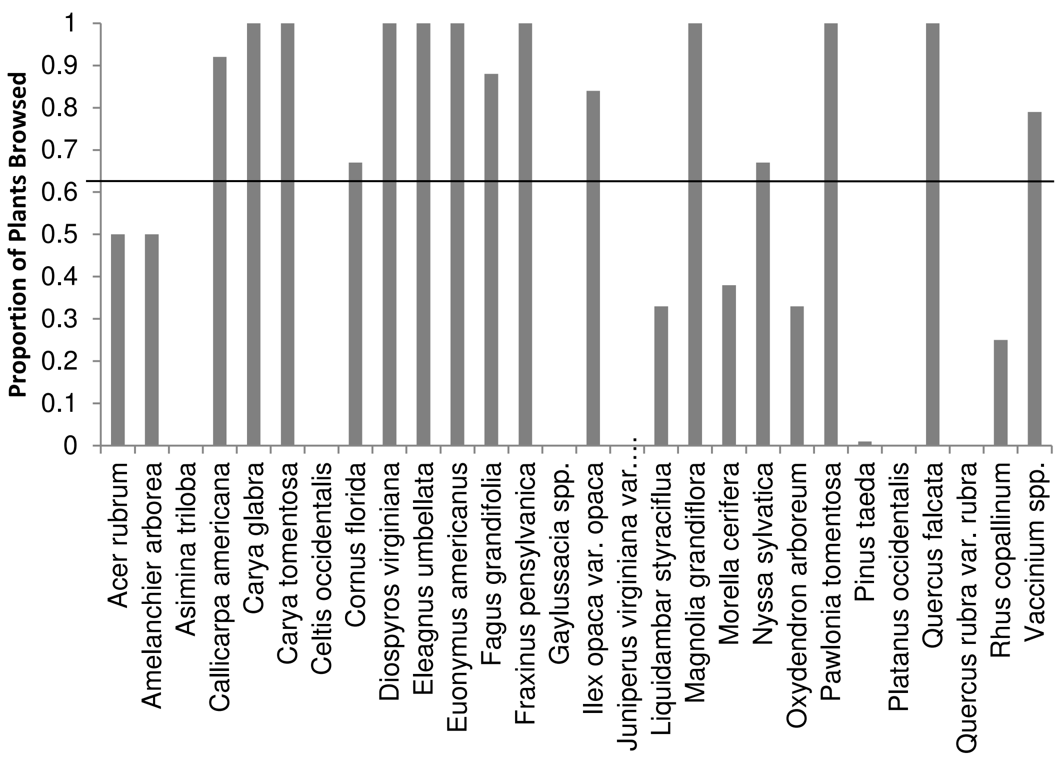


Figure 42. The proportion of plants browsed in each species across all plots. The line indicates the overall proportion of plants browsed with all species combined.

Discussion

Hurricane Isabel was the major driver of change between 2004 and 2015 in layers where white-tailed deer could not reach all potential forage material (i.e. the large and small size classes). These layers remained relatively similar over time and showed the expected patterns of succession, where clear recovery was shown in the severely damaged areas of the College Woods through increases in species diversity and stem density over time. The sapling layer, however, experienced dramatic changes that did not align with the expected trajectory of succession and is consistent with what would be expected with continual browse by white-tailed deer (i.e. no sign of recovery). Decreases in stem density and species diversity in less damaged plots and no change in the severely damaged plots show that this layer is not recovering from damage by Hurricane Isabel. Moreover, most plots were not most similar to themselves over time, suggesting rapid change in the composition of the sapling layer. The dramatic change to the sapling layer has the potential to alter future succession of the College Woods as the sapling class grows into the small and large tree size classes.

Species Richness, Stem Density, and Similarity Between Years

Hurricane Isabel continued to influence the large tree size class past the immediate changes that were observed in 2004, but only in areas that had been severely damaged. Plots that were severely damaged by Hurricane Isabel gradually recovered over time, as is evident by the increase in stem density in those areas between 2004 and 2015. However, severely damaged plots (with the exception of Plot 20, which has always had a different composition than the rest of the College Woods) did not recover to resemble their previous selves while less damaged plots were most similar to themselves in the cluster analysis. This is consistent with the predictions of Kribel and Ware (2014), who posited that compositional changes would only be observed in the areas most highly affected by Hurricane Isabel. The changes observed between 2004 and 2015 suggest that some large trees in the most heavily affected areas suffered secondary damage during the hurricane which was eventually fatal. Secondary damage was observed in many large trees in another set of permanent plots in the College Woods, but was not formally measured in the NCVS plots (Prengaman et al., 2008). Regardless, the changes that were observed between 2004 and 2015 were not significant enough for any plot to move to a different group in the cluster analysis, suggesting that although there were long-term effects in damaged plots, they were not great enough to significantly influence the large tree composition overall.

Changes in the small tree size class over time are greater than what was observed in the large tree size class, but the major driver of change still appears to be Hurricane Isabel. More change over time is expected in the small tree size class because of its restrictive nature (spanning less than 10cm DBH), which facilitates trees growing into and out of that size class quickly. Additionally, the diversity of the small tree and sapling size classes tends to have no relationship to stand age, making it difficult to make a prediction of how diverse the understory should be in the College Woods (Monette & Ware, 1983). The significant increase in species richness per plot, however, shows in part clear patterns of early succession. Thirteen new species were recorded in the small tree size class in 2015, four of which were present in the sapling layer of the same plot in 2004 (*Carya cordiformis, Diospyros virginiana, Pinus taeda,* and *Quercus velutina*), suggesting that these species entered the small tree size class as a result of natural succession. *Amelanchier arborea, Callicarpa americana, Liquidambar styraciflua, Liriodendron tulipifera, Morella cerifera, Paulownia tomentosa, Pinus taeda, Vaccinium* spp., *Platanus occidentalis,* and *Rhus copallinum* all grew through the sapling layer into the small tree layer between 2004 and 2015. With the exception of *A. arborea* and *Vaccinium* spp., all of these species are early successional (Weakley et al., 2012). All of them also only occurred in severely damaged plots, with the exception of *Vaccinium* spp. and *Pinus taeda,* which both occurred in a single less damaged plot (NCVS 15). Stem density also increased in the small tree layer over time, which is consistent with the effects of increased light levels after large scale canopy disturbances (Nuttle et al., 2013). Even though there was no significant effect of damage type on stem density, the observed increase is probably still from Hurricane Isabel because plots that were less damaged still experienced some decrease in canopy cover (and thus an increase in light availability) as an effect of the storm.

Changes in the sapling layer appear too drastic to be attributed to natural succession alone and are most likely from a combination of the effects of Hurricane Isabel and overbrowsing from white-tailed deer.   Changes would be expected to occur fairly quickly in the sapling size class since the range of DBHs it encompasses is fairly restrictive. Expected changes due to the Hurricane would include increased species diversity and stem density over time. The presence of *Pinus taeda, Callicarpa americana, Morella cerifera,* and *Rhus copallinum*—all species typical of early successional forests (Weakley et al., 2012) —illustrate that Hurricane Isabel effected the sapling layer. However, pervasive declines in species richness and sapling density, despite increased light and the presence of some early successional species, indicate another force working to drive changes in the College Woods. Decreases in a given tree species could be due to disease, but because many species are declining, this scenario is unlikely. Because 60% of woody vegetation between 0.2m and 1.8m showed signs of browse by white-tailed deer in the College Woods, overbrowsing is the most likely explanation for declining stem density and species diversity. A similar study performed in the Great Lakes Region considered 40% of all vegetation browsed to be high and 5% of all vegetation browsed to be low (Freker et al., 2013). A long term study in West Virginia showed that browsing by white-tailed deer decreased stem density and species diversity in non-disturbed mature forests (Nuttle et al., 2013). It also showed that large canopy gap openings increased species richness and diversity--however, when large canopy gaps were browsed by white-tailed deer, the positive effects of the canopy gap were cancelled out. This could help explain how even in the presence of large scale disturbance, the sapling layer did not increase in stem density and species diversity over time within severely damaged plots.

Large-scale disturbance in the presence of elevated white-tailed deer populations can quickly alter the path of succession. Changes to the understory caused by white-tailed deer alone could take centuries before it restructures the canopy due to low understory light without disturbance. However, when a canopy gap opens after a large-scale disturbance such as a hurricane, the trajectory of succession speeds up because resource availability is increased (i.e.; more light is available). This increases the chance of survival to maturity, potentially quickly changing canopy composition and altering the path of succession (Holm et al., 2013). In terms of species composition, it appears that successional processes in severely damaged areas are consistent with expectations. As indicated by the 2015 CA, *F. grandifolia* does not have an IV > 60 in any area severely damaged by Hurricane Isabel. *Pinus taeda, Morella cerifera,* and *Callicarpa americana* are leading dominants in at least one severely damaged plot and also dictate the formation of three of the six clustered groups. Leading dominants in other severely damaged plots are consistent with a mature

Virginia Coastal Plain understory (i.e. *Ilex opaca* and *Cornus florida),* suggesting that the seedling layer was released as light levels increased.

Species that are common in hurricane-damaged areas may establish themselves more permanently under high browse pressure of white-tailed deer, especially those that are avoided by them. This could lead to an alternate stable state (a path different than what would be expected from natural succession and resilient against change). Although alternate stable states would establish quicker in disturbed areas based on the combined effects of increased light availability and browse by white-tailed deer, undisturbed understories have also experienced alternate stable states under high browse pressure (Rooney, 2009). This could potentially occur in the College Woods, where declines in species richness and stem density are not influenced by the degree of damage from Hurricane Isabel. The extent to which an alternate stable state could occur is dependent on both the density of white-tailed deer and the abundance of species present, because plants that are rare are more likely to be extirpated whereas more abundant species may experience only slight declines in population size (Stromayer & Warren, 1997). This is of special concern in the College Woods because white-tailed deer populations are extremely high and there is very little regeneration occurring in the understory, effectively making every species rare as a juvenile. As of 2015, 21% of plots show total regeneration failure (i.e. no plants in the sapling size class). Additionally, no single species is found in greater than 50% of the 19 sampled plots as would be expected where a few dominants would largely comprise a regeneration layer. The average stem density across all plots decreased from 23±4 SE stems in 2004 to only 8±2SE stems in 2015. This makes the College Woods very susceptible to entering an alternate stable state in the future. It also makes predicting what that alternate state may look like very difficult because the chances of eventual extirpation are high for every tree species. However, a look at the browse preference of white-tailed deer and the abundance of each tree species in the larger size classes of the forest may lend some insights into the future composition of the College Woods.

Species Composition and Forest Trajectory

Mature forests in the Virginia Coastal Plain are characterized by dominant *Fagus grandifolia* and *Quercus alba* in the canopy (Monette & Ware, 1983) with a high diversity of understory herbaceous plants and bushes (see Chapter 1). The canopy of the College Woods is consistent with other regional forests, where *F. grandifolia* and *Q. alba* are consistently the leading dominants of the large size class. The short-term impacts of Hurricane Isabel were less severe on both species. *Fagus grandifolia* was damaged significantly less than the average rate, presumably because it had yet to reach the canopy layer (Prengaman et al., 2008). *Quercus alba* suffered approximately average damage, but it was still significantly less than the damage suffered by red oaks (*Q. falcata, Q. rubra* var. *rubra,* and *Q. velutina*). Because of this, neither species suffered enough damage to alter their status as leading dominants in the College Woods during the post-hurricane sampling of 2004.

Quercus alba and *Fagus grandifolia* both increased in dominance in the large tree size between 2004 and 2015. Because species richness and plant density stayed the same over time, this effect is most likely from trees in the large tree size class that increased in basal area, trees in the small tree size class that grew into the large tree size class over time, or a combination of both. *Quercus alba* was not well represented in the small tree size class in 2004 (present in one plot with an I.V. < 10) and was not present at all in the sapling size class, which means that the increased dominance over time is solely from increased basal area. It is typical for *Q. alba* to not be well-represented in the understory of a mature Virginia Coastal Plain forest, as it tends to disappear from the understory when forests reach 70-80 years old (Monette & Ware, 1983). In 2015, *Quercus alba* reached high importance in the small size class of one plot, which had been heavily damaged by Hurricane Isabel. Because this was reported from a plot that had no *Q. alba* recorded in the lower layers in 2004, it appears as if the light gap created by Hurricane Isabel allowed some seedlings to grow through the sapling size class into the small tree size class. Even though some *Q. alba* seedlings were released by canopy gaps, it still appears questionable whether *Q. alba* will replace itself in the future since the overwhelming majority of plots did not contain small trees or saplings.

Unlike *Q. alba, F. grandifolia* is well represented in the lower size classes. It has high importance in over half of the 19 plots in the small tree size class, making it a leading dominant. It is also the most dominant species in the sapling size class, but it is not a *leading* dominant because it does not occur in greater than half of the plots. *Fagus grandifolia* is usually well-represented in all layers of a mature Coastal Plain forest, making this result typical of the area (Monette & Ware, 1983). Because *F. grandifolia* is well represented in the small tree and sapling size classes, recruitment into the large tree size class accounts for some of the observed increase in dominance. Concurrently, *F. grandifolia* that was already present in the large tree size class continued to increase in basal area, also accounting for some increase in dominance over time. Because of its dominance, it would be expected to replace *Q. alba* in the College Woods; the fact that four additional plots gained high I.V. for *F. grandifolia* within 10 years points towards this trend.

However, *Fagus grandifolia* decreased in dominance in both the small tree and sapling layers, a result atypical of the expected trajectory of succession in the College. The factors leading to decreased dominance in *F. grandifolia* over time is different for each size class. In the small tree size class, there are a few factors that could have resulted in a decline. First, due to the restrictive nature of the size class, which encompasses a relatively small range of DBHs (2.5-10cm as opposed to >10cm), change is expected to happen quicker than it would in the large tree size class. Although *F. grandifolia* did decline over time, it is still a leading dominant in the small size class in 2015. Because of this, the observed changes could simply be due to normal fluctuations over time that are caused by a restrictive and relatively artificial size class. Secondly, 13 new species—mostly early colonizers of disturbed areas—entered the small tree size class between the 2004 and 2015. Three of these species (*Liquidambar styraciflua, Morella cerifera,* and *Pinus taeda*) even reached high I.V. in at least one plot in the small tree size class. The introduction of these new species spreads importance values out more across any plot where they are present, possibly enough to decrease the I.V.s of already present tree species so much so that they are no longer considered important (especially if that species is right on the cusp of the I.V. > 10 threshold). Finally, *F. grandifolia* increased in the number of plots in which it had high importance in the large tree size class, suggesting that some trees grew out of the small tree size class and into the large tree size class. If the recruitment from the sapling size class was low, these plants would not be replaced in the small tree size class and I.V.s would drop.

The decrease in dominance of *F. grandifolia* in the sapling size class is due to a combination of the effects of Hurricane Isabel and the influence of white-tailed deer. *Fagus grandifolia* is not an early successional species, as it generally appears in the understory after 60-70 years of forest maturity (Monette & Ware, 1983). Therefore, the absence of *F. grandifolia* in the eight severely damaged plots is to be expected. Declines in less damaged plots are likely driven by high browse pressure by white-tailed deer. This is supported by the preference white-tailed deer demonstrated for *F. grandifolia* in each plot in 2015 (deer browsed an average of 88%±0.03SE of available *F. grandifolia* trees compared to an average of 72%±0.06SE of all vegetation within the same plots). A study by Freker et al. (2013) of tree mortality in the presence of white-tailed deer shows that the chance of mortality in *F. grandifolia* decreased with increased size even in the presence of white-tailed deer, suggesting that it is browse tolerant. It is therefore possible that even in the presence of high white-tailed deer densities, *F. grandifolia* will continue to persist as an important tree species in the College Woods despite the declines observed in the sapling size class.

Prior to Hurricane Isabel, *Liriodendron tulipifera* was a leading dominant in the large tree size class, but it has slowly declined over time and shows few signs of regeneration. Losses from the hurricane (approximately 20%) were enough for this species to lose its leading dominant status by 2004 (Kribel & Ware, 2014). In fact, *Acer rubrum* became more dominant than *L. tulipifera* by 2004, as it was significantly less damaged when compared to other species (Kribel & Ware, 2014). The pattern of declining *L. tulipifera* and increasing *A. rubrum* continued in 2015, with *L. tulipifera* losing high importance in one plot and *A. rubrum* gaining high importance in one plot. Even though *A. rubrum* increased in dominance between 2004 and 2015, it is still not a leading dominant. The establishment and continual presence of *L. tulipifera* in Virginia Coastal Plain forests are unpredictable, making the persistence of this species unclear. In the

College Woods, *L. tulipifera* is not represented in any of the smaller size classes, suggesting that it will not persist as the woods mature.

Red oaks (*Quercus falcata, Q. rubra* var. *rubra,* and *Q. velutina*) are found in the canopy of Virginia Coastal Plain Forests, but are never a dominant component. All red oak species declined in importance in the large tree size class between 2004 and 2015. Because these oaks were disproportionally damaged by Hurricane Isabel, their continued to decline is likely a result of secondary damage from the storm (Kribel & Ware, 2014). Moreover, these species are sometimes important in the canopy, but never really dominate and disappear in importance from the understory once a stand matures past 40-60 years (Monette & Ware, 1983). While *Q. rubra* var. *rubra* and *Q. velutina* are still present in 2-3 of the small tree plots in 2015, they are not important, making it likely that red oaks will eventually disappear from the College Woods.

In general, *A. rubrum* becomes important in the understory (> 2.5cm DBH) of a forest by 40-50 years and remains important as stands mature, but never becomes a leading dominant in the upper layers. Because there was little change in *A. rubrum* in the large or small tree size classes over time, it will continue to be a major component of the large tree size class for some time as small trees are recruited into the large tree size class. *Acer rubrum* is generally a major component of the sapling size class, but it has declined dramatically over time in the sapling layer. It was dominant in 10 plots in 2004 but is now only dominant in two plots. Additionally, between 0.2 and 1.8m, only six trees were counted in all plots, 50% of which were browsed. The decline in *A. rubrum* is consistent with declines recorded between 1994 and 2003 in another set of plots in the College Woods (Kribel et al., 2011). At that time, deer browse was observed on *A. rubrum* trees. Therefore, the declines observed between 2004 and 2015 are likely a continuation of twenty year or older trend attributed to browsing by white-tailed deer. A study of tree mortality in the presence of white-tailed deer showed that mortality did not decrease with increased growth from seedling to small tree in red maple when white-tailed deer were present, making red maple browse intolerant and therefore more vulnerable to the effects of white-tailed deer (Long et al., 2007). Additionally, an exclosure experiment in the Virginia Piedmont, showed that *A. rubrum* was completely eliminated from the understory after only four years of high browse pressure (Rossell et al., 2005). Therefore, under current conditions, we would expect *A. rubrum* to eventually be extirpated from the College Woods as the forest continues to mature.

In addition to *A. rubrum, Ilex opaca* and *Cornus florida* are two major components of a mature Virginia Coastal Plain forest. These species become important after the stand matures 30-50 years and remain an integral part of the understory after that point. *Cornus florida* decreased in dominance in both the small tree and sapling size classes while it increased in dominance in the large size class. This suggests that *C. florida* grew out of the small tree size class into the large tree size class over time but was not replaced in the sapling layer. The decline observed in the sapling layer is consistent with declines observed in the College Woods between 1994 and 2003, suggesting that this is a continuation of a long-term pattern (Kribel et al., 2011). Some *C. florida* mortality could be due to arthracnose, though no signs of the disease were detected during sampling. Deer browse was recorded on *C. florida* in 2003; additionally, roughly 50% of trees with available forage material were browsed in 2014 (Kribel et al., 2011). This again points to long-term declines influenced by large populations of white-tailed deer. A study in Indiana showed that *C. florida* is negatively impacted by browse by white-tailed deer, but to a lesser degree than *A. rubrum* (Bresette et al., 2012). This suggests that while *C. florida* is declining in the College Woods, it may be able to persist for some time.

Ilex opaca is well represented in the large and small tree size classes, where it has increased in dominance over time. However, it should also be well-represented in the sapling size class but it has actually declined over time. This species was not reported to have changed between 1994 and 2003 in the College Woods, nor was browse reported on any trees (Kribel et al., 2011). However, as of 2015, white-tailed deer browse *I. opaca* significantly more often than the overall proportion of plants browsed in the College Woods. This suggests that forage on *I. opaca* by white-tailed deer is relatively new and the effects have yet to reach the small tree size class. American Holly is considered to have low palatability for white-tailed deer and is only browsed in the absence of preferred species as is observed in the sapling layer of the College Woods

(Lay, 1967). It has been hypothesized that *I. opaca* lacks compensatory growth, similar to other slow-growing evergreen trees, which makes saplings vulnerable to browse and increases mortality rates (Forester et al., 2006). Therefore, decreases in *I. opaca* may be expected in future samplings of the NCVS plots if white-tailed deer populations remain overabundant. However, because of its abundance in the upper layers of the woods and its very slow decline in the sapling layer, it is likely that any overall declines in this species will be very slow in the College Woods.

Quite a few early successional species were present in the College Woods in severely disturbed areas by 2015. These species include *Pinus taeda, Liquidambar styraciflua, Callicarpa americana, Morella cerifera, Rhus copallinum* and *Paulownia tomentosa.* All but *Paulownia tomentosa* would be expected in early successional pine forests and disturbed areas, suggesting that natural succession is occurring in severely damaged areas. The introduction of *Paulownia tomentosa* is especially troubling because it is invasive in Virginia and has taken over other disturbed areas within the College Woods.

Under the current browse scenario, it appears that the College Woods will have less species diversity of woody plants, becoming almost entirely *Fagus grandifolia*- dominant, as is consistent with other areas on the east coast (Rossell et al., 2007). Moreover, white-tailed deer appear to have offset the positive effects of recovery after a large-scale disturbance event, in some cases even halting regeneration in the sapling layer completely. Ultimately, alternate stable states may form in these hurricane-damaged areas as few species survive through the sapling stage. As suggested in Chapter 1, immediate conservation action needs to be taken in order to allow the woody plant population to recover. In the final chapter of this thesis (Chapter 3), I suggest a management plan for the future conservation of the College Woods, focusing on reduced white-tailed deer populations.

Chapter 3

Proposed Management Plan for the College Woods

I. State of the College Woods

The ecological value of forested land cannot be understated. Forests provide protection against water runoff, reduce pollution, and provide critical habitat for many mammals, songbirds, and reptiles. Unfortunately, the existence and health of forests are threatened by a myriad of factors, including deforestation, suburban development, erosion, invasion by exotic species, and overabundant white-tailed deer populations. In Virginia alone, over 68,000 acres of land are lost to deforestation every year. Because of the ecological importance of these forests, the need to preserve and protect native plants and their habitats is an urgent crisis in the face of unprecedented global change.

The College Woods, located in Williamsburg, VA is a unique forested area with a diverse flora comprised of 745 reported vascular plant species (i.e., mosses are not included in this figure, and their numbers are unknown in the College Woods). Encompassing approximately 960 acres, the College Woods is one of the largest contiguous forests in James City County, it is one of the oldest forest stands in the area (with trees over 160 years old), and it surrounds one of the oldest manmade lakes in Virginia (see Chapter 1, this thesis, for a detailed description of the study site). The forest itself is bisected by many streams feeding into the lake, some of which cut through fossil shell deposits. These calcium-rich areas support rare assemblages of plant species, including some species that are disconnected (i.e., disjunct) from their main ranges in the mountains, such as the alternate-leaved dogwood (*Cornus alternifolia*), American spikenard (*Aralia racemosa*), and the zigzag goldenrod (*Solidago flexicaulis*). Fifteen species are on the state-endangered or watch lists — including the small-whorled pogonia (*Isotria medeoloides*) and the spiked crested coral root orchid (*Hexalectris spicata*). As such, the diversity comprising the Woods has provided unparalleled opportunities for faculty-mentored student research from multiple departments; it has served as a unique opportunity for formal courses to study biology, geology, history, art, archeology and other disciplines; and it affords hundreds of students on a daily basis the solitude and peace of mind associated with wild places — all within minutes of developed campus. The uniqueness and importance of the College Woods to the mission of the university was recognized in the mid-1990's when it was designated a Natural Preserve by the Board of Visitors (Resolution #7, 1994), effectively conserving the land and requesting that the College make "*reasonable efforts to preserve and enhance the quality of Matoaka Lake and Woods*."

This thesis provides the first examination of the entire plant species composition of the College Woods in 25 years and serves as a proxy for the determination of forest health and ecological quality. Its findings (Chapter 1) show that, of approximately 600 species reported to the College Woods in 1989, about 50% have declined in abundance by 2015. Likewise, roughly 30% of the plant species recorded from the College Woods in 1989 could not be relocated in

2015.

Given that a forest is the sum of its parts and that there is existing legislation to manage it as a natural preserve, there necessarily must be effort put forth to protect the species in it in order to preserve the ecosystem, research, teaching, and health benefits that it provides. To be consistent with state guidelines for other natural preserves in Virginia, it is my recommendation that the all activities within the forest need to be measured against the major directive of protecting "*the long-term quality, condition, and viability of natural heritage resources within [its] boundaries* (Natural Heritage Technical Report, 2010)."

There are a number of known major factors contributing to the degradation of the health of the College Woods:

1. **Invasive species:** Approximately 25% of the present flora is composed of non-native species (Chapter 1, this thesis), a number that is higher than what was found in 1989 and what is found across the state of Virginia. Forty-two species found in the College Woods are on the Virginia Invasive Species List. Invasive species outcompete and eventually replace native species.
2. **Erosion**: The trail system as well as ravine heads are severely eroding, affecting water quality in Lake Matoaka and physically removing habitat that supports some populations of plant species that are rare to the

College Woods. This is driven by ineffective water containment from surrounding areas, loss of ground vegetation in the woods, unapproved trails, and lack of upkeep of the major historical trails.

3. **Unapproved trails:** Human impacts to the College Woods are increasing as a very high number of unapproved trails have been built. These trails inadvertently and frequently cut through rare plant populations or are built in such a way that they contribute to the erosion of stream heads. These trails also bring people into sensitive species areas on bike or foot which contributes to compaction and secondary damage from off-trail use. People also disperse invasive exotic species on foot or bike tires.
4. **Overabundance of white tailed deer:** While all of the above issues need to be addressed, the focus of this research has been the impacts of the overabundance of white tailed deer. Observations suggest that white-tailed deer are drastically changing the vegetation and biodiversity of the entire College Woods.

II. White-tailed deer overabundance

The observations

The numbers of white-tailed deer have increased exponentially throughout Virginia since the early nineties (Virginia Department of Game and Inland Fisheries, 2007). Likewise, evidence of the presence of deer within the College Woods was absent prior to 1994 (Kribel et al., 2011). Now, signs of deer are pervasive in the form of pellets, tracks, trails, and herbivory (Kribel et al., 2011). The idea of an overabundant deer population leading to degradation of the College Woods comes from several lines of evidence as a result of research conducted in the biology department:

1. There have been measurable alterations of understory vegetation which may impact the replacement of mature trees (Kribel et al., 2011).
2. Severe population declines of deer-palatable species such as the yellow lady's slipper orchid (*Cypripedium parviflorum var. pubescens*) have been observed concomitant with evidence of repeated deer browsing on those species. For example, one population of this species in the College Woods examined in the research publication of Case and Bradford (2009) was over ten times the size it is now. An entire line of research on pollination of this species can no longer occur because population sizes have become too small from the activities of deer (Case, pers. Comm.)
3. Many species are now being eaten which were previously not eaten. For example, until 2015, browse on low-palatable plant species such as Christmas fern (*Polystichum acrostichoides)*, Beech *(Fagus grandifolia)*, Holly *(Ilex opaca),* and Jack-in-the-pulpit (*Arisaema triphyllum)* in the College Woods was not observed (Chapters 1 & 2 of this thesis; Kribel et al., 2011). This implies that preferred forage material for white-tailed deer

is in short supply, leaving the population to feed on less preferred, low-palatable species.

4. Chapter 2 (this thesis) showed that approximately 60% of woody material below the browse line (1.8m) is browsed by white-tailed deer. This number is considered too high to support a healthy forest ecosystem. For example, Freker et al. (2013) considered 40% of woody material browsed high and 5% of woody material browsed low.

Mechanisms of forest decline

Chronic browsing by overabundant white-tailed deer populations has cascading effects on an ecosystem leading to major ecological losses. Deer can feed on anything within reach which includes plants that never become woody (i.e., the herbaceous layer) as well as small trees and bushes, and the young seedlings of all plants. The plants comprising the herbaceous layer are where the vast majority of diversity resides in temperate forests and is critical in maintaining the structure and function of the entire community since the composition of the herbaceous layer influences soil chemistry and successional processes while also providing food, cover, and protection for an array of forest organisms including insects, birds, and mammals (Gilliam, 2007). Because herbaceous plants remain low and vulnerable throughout their entire life span, high levels of herbivory by white-tailed deer force the composition of this layer to shift rapidly (Rooney, 2009).

Alterations in the palatable plant community influences nutrient cycling and microclimate (such as temperature, light availability, and moisture level) on the forest floor, negatively affecting plant growth in unpalatable and browse tolerant species, in addition to decreasing the ability for seeds to germinate (Rooney & Waller, 2003) and increasing erosion. This in turn affects invertebrate and gastropod communities, usually through corresponding changes in invertebrate species richness and composition. Additionally, decreased plant cover increases the predation rate of small mammals, and decreased vertical complexity of the forest decreases habitat availability for nesting songbirds (Rooney & Waller, 2003). All of these effects combine to decrease biodiversity in the forest overall while also feeding back into the susceptibility of the area to invasion by non-native plants, further imperiling the ecosystem (McGrady-Steed et al. 1997).

The benefits of controlling overabundant white-tailed deer populations are many-fold. Population reduction can also allow vegetation to recover from overbrowsing, providing a better habitat for songbirds, invertebrates, and even the deer themselves. Finally, reduction of white-tailed deer in the College Woods will allow us to achieve our management goals for the area. Studies have shown that recovery of the herbaceous layer is possible if the white-tailed deer population is controlled to a level that the forest can sustainably support.

Therefore, **the purpose of this management plan is to preserve and protect the College Woods flora by direct control of the white-tailed deer population.**

III. MANAGEMENT RECOMMENDATIONS

1. Organize a task force to include representative personnel from biology, facilities management, administrators, and local law enforcement that will plan and oversee an ongoing deer management program. Such a program should:
    a. Implement yearly managed hunts
    b. Implement a deer-monitoring program
    c. Implement a public education campaign on the ecological and public health hazards of an overabundant deer population.
2. Plant species recovery should be a visible goal for the effective reduction of the deer herd. Work with biology researchers who have initiated long-term ecological research in the College Woods and are accumulating data on the flora and fauna of the woods that can inform management practices.

IV. METHODS & RATIONALE

Managed Hunts

An organized hunt is recommended as the most efficient, effective, and least problematic control for the following reasons. Fencing and deer repellant sprays can help to alleviate the problem in small areas, but it is not a practical option for anything larger than small plots. Fertility control does not permit the consumption of deer that have received the treatment while the control itself is very expensive and work-intensive (DeNicola et al., 2000; Merrill et al., 2003). Because of the suburban nature of the City of Williamsburg, reintroducing top predators is also not practical (Coffey & Johnston, 1997). Therefore, the best way to control white-tailed deer in the College Woods is through compensatory mortality. This can be achieved through sharpshooting, sport hunting, or controlled hunts.

Because of the suburban nature of James City County, safety concerns, firearm ordinances, and social attitudes must be taken into account (DeNicola et al., 2000). In the City of Williamsburg, there are ordinances against firearm discharge and therefore bow hunting must be used instead. There is precedent for bow hunting as a form of controlling white-tailed deer populations in the area (VA DGIF, 2014). York River State Park offers managed hunts that form a wait list. Therefore, there are available hunters and high demand locally for hunting space (Connoly, 2012). Because there is public support in Williamsburg for bow hunting, this is a viable option to pursue.

These hunts can occur during urban archery season, regular archery season, and general firearms season, which currently run from September 6th to October 3rd, the first Saturday in October to the first Saturday in January, and from January 4th to March 29th (subject to change with VGDIF). I suggest that one, two-day hunt occurs during the season. This hunt should occur during the early

January portion of urban archery season (January 4th to March 29th) in order to coincide with the winter break for William & Mary students. The winter temperatures combined with the absence of most students from campus will reduce the effort required to close the woods to foot traffic.

Only antlerless deer can be taken during urban archery season, ensuring that there is no bias towards hunting trophy bucks. Additionally, the age and sex of all deer killed in the College Woods should be recorded by whomever is leading the managed hunts. Managed hunts can generally support 14 archers/km^2 (Hansen and Beringer, 1997); the College Woods can therefore hold a maximum of 42 hunters at a time. However, I recommend 32 archers to allow a buffer around trails, roadsides, and developments. Archers should carry archery and big game licenses as well as a hunter education certificate. In order to curb costs to the College, I suggest a $15 registration fee, which appears standard for public lands across Virginia.

For at least two weeks prior to the hunt, signs should be posted at all entrances, including small foot trails to the woods. A notice should be placed in the local newspapers and in William & Mary electronic media. Finally, communities that border the woods directly should be notified through their communities. The College Woods would be closed to the public during the days of the hunts.

Table 15. Summary of proposed managed hunt requirements and restrictions.

Dates	# Hunters	Max. # Deer Taken	Hunter Requirements	Fee
Two days between 01/04 – 01/15	32	64	• Archery License • Big Game Permit • Hunter Education Certificate	$15

Monitoring Program

There are several methods to monitor the density of the white-tailed deer population. These include camera traps, Hahn lines, spotlight counts, aerial surveys, pellet counts, or mark-recapture methods (Hansen & Beringer, 1997; Killmaster et al., 2007). Spotlight counts are not feasible for the College Woods because they require vehicular access to the land while aerial surveys and mark-recapture methods are too time consuming and costly. Camera traps, pellet counts, and Hahn lines are the most economically feasible and least time intensive, however, camera traps do not account for detection probability and a Hahn line is less reliable at low densities of deer (Shult & Armstrong, 1999; Rowclife et al., 2008).

In areas like the College Woods where ecosystem integrity is important, maintaining 8 deer/km^2 is recommended (Hansen & Beringer, 1997). The density of white-tailed deer in the College Woods should be censused annually in late September using the Hahn transect and camera trap methods in combination. If it is determined that the white-tailed deer are at the desired 8/km^2 level, then no managed hunt needs to occur for the following year. However, if vegetation recovery goals are not met while deer are at 8 individuals/km^2, the deer density objective should be lowered to 5 deer/km^2 because many plants are at the brink of extinction in the College Woods and may require a lower-than-average density of deer to bring their numbers up.

<u>Plant Species Recovery</u>

a. **Deer exclosures** provide an excellent way of measuring deer impacts on herbaceous and woody understory plants. Deer exclosures are fenced-in areas tall enough and small enough to prevent deer from jumping over the fence and into the exclosed area. Nearby, a paired control plot is set up where the vegetation is compared to the vegetation in the deer-excluded area. These areas offer a unique opportunity for monitoring because the exclosed areas can act as references to determine if the culling of deer is having the expected effect on the vegetation, which would be indicated if the exclosed and control areas become less disparate over time and correlate with a lowered deer population. A number of metrics can be gathered and compared from each plot such as species richness, evenness, diversity, and % cover. In areas with high levels of deer populations, reports of woody plant stem densities in exclosures range from 4-16 times greater than control plots within the first ten years (Rooney 2009; McGarvey 2013). Therefore, exclosures provide a fairly quick way to assess directly the impacts of deer. Fortunately, a major collaborative research and teaching project in the biology department has already established 20 exclosures and control plots in the summer of 2015. Their long-term studies and findings should greatly facilitate understanding of plant species recovery.

The College Woods supports several habitat types (Crouch, 1990), but only mature upland wooded areas are represented by the deer exclosures. The majority of diversity in the woods can be found in nearby ravine systems, which support local occurrences for rare populations of plant species, some of which are regularly browsed by white-tailed deer (Stromayer & Warren, 1997). In conjunction with the biology department, additional deer fences in areas with unique diversity could be targeted to allow recovery and protection of these areas until they can support a "normal" level of deer browse that will not decimate their populations.

b. **Proxy species.** While an entire survey of the abundances of uncommon species in the College Woods is ideal, it is not possible due to the high number of species, shortages of time, funds and expertise. However, monitoring select species that would be indicative of the deer population could be very helpful in gauging the success of the deer management program. These species should include those typically not eaten by deer but are eaten when other forage is in short supply, as well as species that are commonly chosen by deer as a forage food. Multiple species may be used as proxy species, including some combination of species that flower in the early, mid, and late growing seasons, are preferred and not preferred forage foods for white-tailed deer, and vary from rare to abundant (Table 16). The success criteria for species surveys should be a demonstrated reduction in browse by white-tailed deer and/or an overall increase in population size over time.

Surveys would need to occur in the same populations and at the same time each year, be replicated across at least 10 areas in the woods to capture the variance in the randomness of deer browse, and include the following data: number of individuals in each population, number of individuals flowering or in

Table 16. Possible proxy species to use for recovery surveys. Scientific name, month of flowering and rarity in College Woods, as well as whether it is preferred forage material for white-tailed deer is included.

	Species	Searching Season	Rarity	Deer Preference
1.	*Packera aurea*	Early Season (April)	Abundant	Not Preferred
2.	*Rhododendron periclymenoides*	Early Season (April)	Rare	Preferred
3.	*Polygonatum biflorum*	Mid-Season (May)	Occasional	Preferred
4.	*Saururus cernuus*	Mid- Season (June)	Abundant	Not Preferred
5.	*Arnoglossum atriplicifolium*	Mid-Season (June)	Occasional	???
6.	*Endodeca serpentaria*	Mid-Late Season (Find Sterile)	Rare	Preferred
7.	*Euonymus atropurpureus*	Late Season (Aug.)	Rare	Preferred
8.	*Prenanthes serpentaria*	Late Season (Oct.)	Occasional	Preferred
9.	*Impatiens capensis*	Late Season (Sept.)	Common	Preferred
10.	*Polystichum acrostichoides*	Year Round	Abundant	Not Preferred
11.	*Smilax bona-nox*	Year Round	Common	Preferred

fruit (for herbaceous taxa), and number of individuals that have been browsed. Representative photographs of each population would be also especially helpful.

Public Education

A public education program should aim to convey the ecological and human health benefits of controlling the white-tailed deer population in the College Woods. This program could provide excellent opportunities to involve student environmental organizations at the college. The outreach program should raise awareness not only on campus but within local communities, emphasizing bow hunting as the most humane and practical method of control. The public education program should also emphasize the following benefits that are gained from controlling the white-tailed deer population:

- Human Health Benefits
  - Reduced instances of tick-borne illnesses (Kilpatrick et al., 2007)
  - Reduced deer-vehicle collisions (DeNicola & Williams, 2008)
  - Reduced browsing in gardens by white-tailed deer (Kilpatrick et al., 2007)
- Ecological Benefits
  - Increased plant diversity and abundance (Coté et al., 2004)
  - Increased habitat for fauna and songbirds (Coté et al., 2004)
  - Increased forest resilience and recovery (Coté et al., 2004)

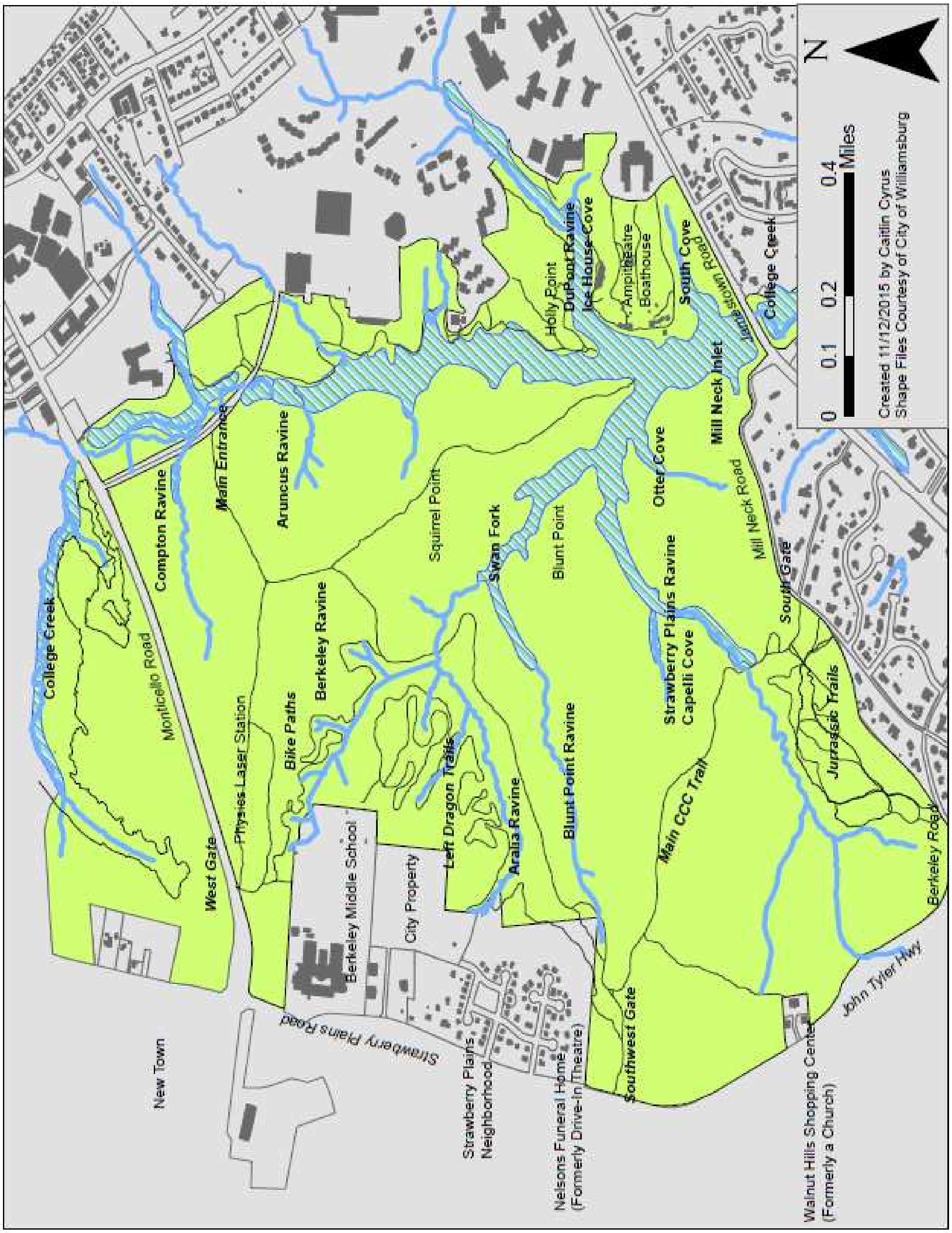
V. SUMMARY

Human impacts, erosion of trails and streams, and the increase in invasive exotics all also contribute to the currently degraded health of the College Woods but have not been addressed in this management plan. These factors should not be ignored, but they are likely to not affect the College Woods as ubiquitously or swiftly as the present overabundance of white-tailed deer. I propose that future management plans incorporate: invasive species removal, increased signage of College Woods rules and regulations, trail restoration and regular maintenance, and investigation into ways to mitigate impacts of eroded stream heads.

The overabundant white-tailed deer population in the College Woods is directly conflicting with the BOV request to enhance the quality of the lake and woods and is greatly reducing biodiversity, available habitat for fauna, and preventing some lines of scientific research. Reducing the population to 8 individuals/km^2 will allow woody understory and herbaceous vegetation to recover, allowing a healthy population of white-tailed deer to sustainably exist in the area. Population reduction will have other cascading benefits, including: reduced damage by deer to gardens and landscaping in neighboring areas, reduction of deer-vehicle collisions nearby, lowering the incidence of tick-borne disease, and allowing hunting heritage to continue in the community. Managed hunts will also provide the opportunity for many lines of student research that involve collaborative efforts with the biology department to monitor plant populations for their anticipated recovery.

Appendix A

Map showing the current boundaries, trails, and key areas of the College Woods.



N
0 0.1 0.2 0.4 Miles
Created 11/12/2015 by Caitlin Cyrus
Shape Files Courtesy of City of Williamsburg
College Creek
Compton Ravine
Main Entrance
Aruncus Ravine
Squirrel Point
Swan Fork
Blunt Point
Otter Cove
Mill Neck Inlet
Mill Neck Road
South Gate
Strawberry Plains Ravine
Capelli Cove
Jurassic Trails
Berkeley Road
Main CCC Trail
Blunt Point Ravine
Aralia Ravine
Left Dragon Trails
Berkeley Ravine
Bike Paths
Physics Laser Station
Monticello Road
West Gate
Berkeley Middle School
City Property
Strawberry Plains Road
New Town
Strawberry Plains Neighborhood
Nelsons Funeral Home (Formerly Drive-In Theatre)
Southwest Gate
John Tyler Hwy
Walnut Hills Shopping Center (Formerly a Church)
Holly Point
DuPont Ravine
Ice House Cove
Ampitheatre
Boathouse
South Cove
Jamestown Road
College Creek

Appendix B

List of species where deer browse was observed on at least one individual throughout the field season. Asterisks indicate non-native species while underlined species indicates species that they are considered unpalatable or low-preference for white-tailed deer (USDA, 2014). There are a total of 71 species.

FERNS AND FERN ALLIES
Blechnaceae
Woodwardia areolata

Dryopteridaceae
Polystichum acrostichoides

Equisetaceae
Equisetum hyemale ssp. *affine*

Ophioglossaceae
Botrypus virginiana

Osmundaceae
Osmundastrum cinnamomeum var. *cinnamomeum*

GYMNOSPERMS
Pinaceae
Pinus taeda

MONOCOTS
Araceae
Arisaema triphyllum

Orchidaceae
Cypripedium parviflorum var. *pubescens*
Hexalectris spicata var. *spicata*
Liparis lillifolia
Tipularia discolor

Smilaceae
Smilax bona-nox
Smilax spp.

REMAINING ANGIOSPERMS (*Ceratophyllum*, Magnoliids and Eudicots)

Altingiaceae
Liquidambar styraciflua

Anacardiaceae
Rhus copallinum

Apiaceae
Cicuta maculata var. *maculata*
Sanicula canadensis

Aquifoliaceae
Ilex opaca var. *opaca*
Ilex verticillata

Asteraceae
Arnoglossum atriplicifolium
Bidens laevis
Conoclinium coelestinum
Helianthus microcephalus
Symphyotrichum cordifolium
Solidago caesia var. *caesia*
Smallanthus uvedalia
Prenanthes altissima
Packera aurea

Balsaminaceae
Impatiens capensis

Berberidaceae
Podophyllum peltatum

Betulaceae
Carpinus caroliniana

Boraginaceae
Mertensia virginica

Campanulaceae
Lobelia inflata
Lobelia siphilitica var. *siphilitica*

Caprifoliaceae
Lonicera sempervirens

Celastraceae
Euonymus americanus

Cornaceae
Cornus florida

Ebanaceae
Diospyros virginiana

Elaeagnaceae
* *Elaeagnus umbellata*

Ericaceae
Kalmia latifolia
Oxydendrum arboreum
Vaccinium spp.

Fabaceae
Hylodesmum nudiflorum
* *Trifolium repens*

Fagaceae
Castanea pumila
Fagus grandifolia
Quercus rubra var. *rubra*
Quercus falcata
Quercus alba

Hypericaceae
Hypericum hypericoides

Juglandaceae
Carya cordiformis
Carya glabra
Carya tomentosa

Lamiaceae
Callicarpa americana
Lycopus virginicus

Lauraceae
Lindera benzoin

Magnoliaceae
Liriodendron tulipifera
Magnolia grandiflora

Myricaceae
Morella cerifera

Nyssaceae
Nyssa sylvatica

Orobanchaceae
Aureolaria virginica
Pedicularis lanceolata

Rosaceae
Agrimonia rostellata
Amelanchier arborea
* *Rubus phoenicolasius*

Sapinidaceae
Acer rubrum

Saururaceae
Saururus cernuus

Simaroubaceae
* *Ailanthus altissima*

Urticaceae
Pilea fontana

Verbenaceae
Verbena urticifolia

Appendix C

List of all plant species reported from the College Woods in 2015, 1989, and 1968. A list containing detailed verbal descriptions of locations can be found in the College of William & Mary Herbarium (WILLI), Williamsburg, VA.

Species recorded in the College Woods during the 2014/2015 collecting seasons. All collections from this study and indicated below will be housed at WILLI. ‡ indicates species newly reported to the College Woods; + indicates possible county records; * indicates non-native species. Herbarium specimens are indicated first by collector (Ak = Akbarali, Ba = Barans, Cr= Crouch, Ci= Ciarlone, Cy = Cyrus, Ha = Hall, Hu = Hunter, Na = Nakahata, Ph = Phung, Sl = Sleight), then by collection number. Rarity as reported by Cyrus (this study), Barans (1968) or Crouch (1989) is given by collector followed by R = rare, O = occasional, C = common, or A = abundant. Habitat information is reproduced verbatim from Crouch (1989) and is underlined. Unless otherwise noted, habitats observed in the present study are consistent with Crouch (1989). Changes to habitats or additional notes on species' distribution from the present study follow the Crouch description.

FERNS AND FERN ALLIES
ASPLENIACEAE

Asplenium platyneuron (L.) B. S. P.; BaO, CrO, CyC. Slopes in beech-oak woods. Also observed in floodplains; the largest populations observed in a floodplain and in a post-successional field. Ba4, Ba202, Cr725, Cy58, Cy272, Cy281, Sl70

BLECHNACEAE

Woodwardia areolata (L.) T. Moore; BaC, CrC, CyO. Moist ravines and draws in open woods. Notable populations in a lowland area and in an open area near a trail. Ba448, Ba554, Cy1, Ha8, Ha12

DENNSTAEDTIACEAE

Dennstaedtia punctilobula (Michx.) T. Moore; BaR, CrR, CyO. One colony, dry open woods. Also observed on a ravine slope. Ba436, Cy415, Cy595

DRYOPTERIDACEAE

‡ *Dryopteris celsa* (Wm. Palmer) Knowlt., Palmer & Pollard ex Small; CyO. Growing in large clumps scattered throughout woods. Notable populations found in wooded uplands, trailside, and at the head of a ravine. Cy416, Cy597, Na28, Sl99

Polystichum acrostichoides (Michx.) Schott; BaA, CrA, CyA. Mixed deciduous woods. Also found in disturbed areas. Ba186, Cy255

EQUISETACEAE
Equisetum hyemale L. ssp. *affine;* BaR, CrO, CyO. <u>Broad wooded floodplain.</u> One large population growing in same location as 1989. Ba734, Cr332, Cy57

ONOCLEACEAE
Onoclea sensibilis L.; BaO, CrO, CyO. <u>Moist slopes in open woods.</u> No change. Ba738, Sl53

OPHIOGLOSSACEAE
Botrypus virginianus (L.) Holub; BaC, CrC, CyO. <u>Open woods, wooded slopes.</u> Two large populations observed; scattered throughout woods otherwise. Ba203, Cr174, Cy282

Sceptridium dissectum (Sprengel) Lyon; BaO, CrO, CyO. <u>Open woods, wooded slopes, shaded, damp areas.</u> No change. Ba654, Ba689, Cr548, Cy560

OSMUNDACEAE
Osmunda spectabilis Willd; BaO, CrO, CyR. <u>Damp wooded areas, especially in peaty soil.</u> Only one population observed on water's edge. Ba616, Cy303

Osmundastrum cinnamomeum (L.) C. Presl var. *cinnamomeum*; BaC, CrC, CyC. <u>Along streams, especially in openings in sphagnous areas.</u> A notable population of 33 clumps observed at sphagnous head of a ravine. Ba173, Cy235

PTERIDACEAE
Adiantum pedatum L.; BaO, CrO, CyC. <u>Moist wooded slopes, stream banks.</u> 123 clumps counted; found in every single ravine system. Ba436, Cr199, Cy417

SALVINIDACEAE
Azolla caroliniana Willd; CrC, CyC. <u>Floating on lake surface near sunny shores.</u> No change. Cr577, Sl34

SELAGINELLACEAE
Lycopodioides apodum (L.) Kuntze; BaR, CrO, CyC. <u>Damp exposed soil shore of Lake Matoaka; rotten logs and hummocks in swampy ravines.</u> Also found out in lake on fallen logs and mud hummocks. Ba11A, Cr426, Cr717, Cy145, Cy316

THELYPTERIDACEAE
Parathelypteris noveboracensis (L.) Ching; BaO, CrO, CyO. <u>Dry ravines, open woods</u>. A notable population of 11 individuals observed at head of a ravine. Ba612, Sl97

Phegopteris hexagonoptera (Michx.) Fee; BaA, CrC, CyC. Under maturing hardwoods, especially in moist areas. No change. Ba716, Ha20, Na32, Sl101

GYMNOSPERMS

CUPRESSACEAE

Juniperus virginiana L. var. *virginiana;* BaC, CrC, CyC. Occasional in seedling layer of mixed oak woods, common on edges of woods. Also found as saplings and >10cm DBH trees in hurricane-disturbed and other open areas. Ba170, Cy41

PINACEAE

Pinus echinata Miller; BaC, CrO, CyR. Mixed pine-deciduous woods, especially in the western sections. Only a few adult individuals observed. Ba737, Ba739, Cy625, Cy627

Pinus taeda L.; BaA, CrA, CyA. Dominant species in large sections of the woods, an important tree in the mixed pine-deciduous woods. No change. Ba741, Cy40

Pinus virginiana Miller; BaC, CrC, CyC. Pine- and mixed pine-deciduous woods, edges of woods. No change. Ba487, Ci3, Cy34, Cy64, Cy317

MONOCOTS

AGAVACEAE

‡ *Yucca filamentosa* L.; CyR. Two populations; one individual in wooded area along a road, and a few individuals growing on slopes of open, sunny area. Ph21

AMARYLLIDACEAE

* *Allium vineale* L.; BaC, CrC, CyC. Sunny waste places. Mostly concentrated on slopes of open, sunny area. Ba320, B4a51, Cy354, Sl56

* *Narcissus* sp.; CrR, CyO. Persisting from cultivation, old house site near head of Aralia ravine. Scattered along wood edges. Not found at old home site. Cr685, Cy52

‡* *Narcissus pseudonarcissus* L.; CyR. Two clumps spreading from cultivation behind a dorm and down into a wooded ravine. Cy43

ARACEAE

‡* *Arum italicum*; CyR. At the time of collection, one individual growing along wood edge. However, has rapidly expanded since collection into >20 individuals along entire span of road. Cy286

Arisaema triphyllum (L.) Schott; BaC, CyC, CrC. Damp wooded ravines. Especially concentrated in moist woods along roads. Ba82, Cy32, Cy114

‡ *Peltandra virginica* (L.) Schott; CyO. Common in a single floodplain; over 100 individuals. Sl71

Symplocarpus foetidus (L.) Salisb. ex W. P. C. Barton; CrR, CyR. Seven rosettes in and near Aralia ravine near its head. Four rosettes in same location as 1989. Cy402

COMMELINACEAE

* *Commelina communis* L.; BaC, CrC, CyC. Disturbed areas, roadsides, wood edges. No change. Ba249, Ba504, Ak3, Ci21

* *Murdannia keisak* (Hasskarl) Handel-Mazzetti; CrO, CyC. Broad wooded ravine bottoms. Found in broad floodplain and delta, in ravine bottoms, and along edges of Lake Matoaka. Cr634, Cr675, Cy568, Na5

‡+ *Tradescantia virginiana* L. ; CyR. Two populations; each composed of one individual along a wood edge. Cy203, Cy339

CYPERACEAE

Carex alata Torr.; CrR, CyR. Sunny south-facing slope of Swan Fork, about 4dm above water, in oak-beech woods. Only observed growing in a single floodplain in a ravine system distinct from Swan Fork. Cy353, Ak43, Na73

Carex albicans complex; BaO, CrO, CyO. Open cutover areas, steep moist bank of small narrow ravine in beech-oak-pine woods. Two clumps growing near overturned log on a ravine slope, and five clumps growing trailside. Ba52, Cr272, Cr275, Cy129A, Cy129B

Carex albolutescens Schweinitz; BaO, CrO, CyO. Open woods. No change. Ba228, Ph17

‡ *Carex annectans* (Bickn.) Bickn.; CyR. Two individuals found trailside. Ci103

Carex blanda Dewey; CrC, CyC. Stream banks in maturing woods. Also found trailside. Cr200, Cr273, Ci89, Cy198, Cy347, Cy355, Na61

‡+ *Carex bushii* Mackenzie; CyR. One individual in open disturbed area trailside. Cy439

Carex cephalophora Muhl. ex Willd.; BaO, CrO, CyO. Open woods, sunny ravine slopes and along trails. No change. Cr328, Cr440, Cr606, Ak32, Ak34, Ci96, Cy365

Carex comosa Boott; BaC, CrC, CyC. Shallow water, shores of Matoaka Lake, open bottomlands. No change. Ba726, Cy242B

Carex crinita Lam. var. *crinita;* CrO, CyO. Small open stream bottom in maturing forest, and wet sphagnous depression in mixed oak woods. Also observed along banks of two ravines. Ba498, Cr346, Ha17, Ci84, Cy353

Carex frankii Kunth; BaR, CrR, CyR. Open woods. Also growing in a floodplain and along a wood edge. Ba834, Ci58, Ci110, Na70

‡ *Carex gracilescens* Steudel; CyR. One individual on wood edge of Compton Drive. Cy323

Carex laevivaginata (Kukenth.) Mackenzie; BaO, CrO, CyO. Wet ravine bottoms, edges of lake and marsh. Also observed on bank of a ravine. Ba804, Cr352, Cy214

Carex lurida Wahlenb.; BaC, CrC, CyC. Damp open ravine bottomlands. No change. Ba812, Cr171, Cr344, Ak40, Cy193, Cy346, Cy357, Na30, Na64

Carex nigromarginata Schweinitz; BaO, CrO, CyO. Dry wooded slopes, open woods. Especially concentrated along a trail. Ba17, Cy131

‡+ *Carex radiata* (Wahlenb.) Small; CyR. One individual on mossy mound in floodplain of a ravine. Ci97.

‡ *Carex retroflexa* Muhl. ex Willd. var. *retroflexa*; CyO. 50 clumps scattered along a single floodplain. Cr213.

Carex rosea Schk. ex Willd.; BaO, CrC, CyC. Open woods, dry wooded slopes, along trails. No change. Ba256, Ba821, Cr257, Cr284, Cr291, Cr319, Cr321, Cr327, Cr367, Ha52, Ak39, Ci38, Ci108, Na59

Carex seorsa Howe in Gordinier & Howe; CrR, CyR. Sphagnous upper portion of Strawberry Plains Ravine. 18 clumps counted in same location as stated in 1989. Cr296, Cr299, Cy170

Carex swanii (Fern.) Mackenzie; BaC, CrC, CyR. Open cutover areas, sometimes in damp soil. Only one individual in moist woods near head of a ravine. Ba804, Ba814, Na63

Carex vulpinoidea Michx.; BaC, CrC, CyC. Open disturbed areas. No change. Ba229, Ba808, Ba814, Ak35, Cy306, Cy362, Na77

Cyperus echinatus (L.) Wood; BaC, CrC, CyC. Wet soil, open bottomlands and ditches. No change. Ba281, Ak20, Cy24, Cy29, Na74, Ph49

Cyperus esculentus L. var. *leptostachys* Böckler; BaO, CrO, CyO. Roadside ditches, weedy disturbed areas. No change. Ba569, Cr600, Cy390, Na20

* *Cyperus iria* L.; BaO, CrO, CyO. Open cutover areas, typically in dry soil. Only observed along wood and trail edges. Ba542, Cy391, Cy559

ǂ *Cyperus odoratus* L. var. *odoratus*; CyR. Three individuals growing at water's edge.   Na3

ǂ *Cyperus pseudovegetus* Steudel; CyR. One individual on wood edge. Ph42

Cyperus retrofractus (L.) Torrey; BaO, CrO, CyO. Cutover areas, typically in dry soil. Only observed growing on along wood edges and on the slopes of sunny, open area. Ba396, Ph38

Eleocharis obtusata (Willd.) Schultes; BaO, CrO, CyR. Wet soil, open areas along shore of Matoaka Lake. One clump observed in sphagnous head of a ravine. Ba491, Cr576, Cy436

ǂ *Kyllinga graccilima* Miquel; CyO. Three individuals at water's edge and five clumps on wood edge. Cy541, Cy557

Scirpus atrovirens Willd.; BaC, CrC, CyC. Wet soil, open ravines, wet ditches. Only found in broad, open floodplains of two ravines. Ba275, Ph3, Sl77

Scirpus cyperinus (L.) Kunth; BaC, CrC, CyR. Typically in damp soil, depressions in cutover areas. Only two populations observed, one of five individuals in a floodplain and one of two individuals in open area along a trail. Ba594, Cy407, Cy461, Cy617

Scirpus lineatus Michx.; BaC, CrC, CyC. Wet soil in wooded ravines and bottomlands. Notably large populations observed in two different floodplains. Ba194, Ba282B, Ba628, Ba820, Cr170, Cr250, Ak8, Ak23, Cy345, Cy356, Na69, Ph33

Scleria olignantha Michx.; CrO, CyO. High on lake banks and slopes under maturing forest. Notably observed on slopes of two ravines west of the Main CCC trail. Cr355, Cy358, Na78

DIOSCOREACEAE

Dioscorea villosa L.; BaO, CrO, CyO. Deciduous woods, especially ravine slopes. Most individuals depauperate; notably large population in sphagnous head of a ravine. Ba268, Ba317, Ba357, Cy400, Sl107

HYACINTHACEAE

* *Ornithogalum umbellatum* L.; BaO, CrE, CyR. Formerly in cutover areas. Currently, one individual growing at entrance to a trail. Ba164, Ba437, Cy204

HYPOXIDACEAE

Hypoxis hirsuta (L.) Coville; BaC, CrC, CyO. Dry uplands in deciduous woods. Only found scattered trailside. Ba108, Ba476, Cr201, Cr577, Cy224

IRIDACEAE

ǂ+* *Iris domestica* (L.) Goldblatt & Mabberly; CyR. One individual growing on wood edge. CY364

Sisyrinchium angustifolium P. Mill.; BaO, CrO, CyO. Open woods, shaded meadow, edge of woods. Observed only along wood edges. Ba148, Ba172, Ba238, Cy229

ǂ+* *Sisyrinchium rosulatum* Bickn.; CyR. Two populations; each containing one in individual in a sunny, open area. Ci31, Sl41B

JUNCACEAE

Juncus coriaceous Mackenzie; BaO, CrO, CyO. Wooded ravine bottoms. Particularly concentrated in a single ravine. Ba731, Ha54, Cr297, Cr339, Cy184

Juncus dichotomus Ell.; BaO, CrO, CyO. Grassy swales and open woods. No change. Ba347, Ph28, Sl41A

Juncus effusus L.; BaO, CrO, CyO. Shores of Matoaka Lake, roadside ditches. Also found in floodplains and in a low-land trailside. Ba733, Na67, Ph6

Juncus tenuis Willd.; BaC, CrC, CyC. Dry woods, trailsides, open areas. No change. Ba225, Ba323, Ba383, Ba400, Ba818, Ak13

Luzula acuminata Raf.; BaC, CrC, CyC. Deciduous woods, weedy areas, ravine bottom. No change. Ba6, Ba47, Cr322, Cy44, Cy45, Cy49, Cy91, Na54

Luzula bulbosa (Wood) Smyth & Smyth; BaC, CrC, CyC. Relatively dry slopes in open mixed deciduous woods. No change. Ba30, Ba130, Ba244, Cr281, Cr298, Cy86, Cy119

LILIACEAE

Medeola virginiana L.; BaR, CrO, CyC. Every sphagnous stream head and rarely on uplands. No change in distribution, relatively more common now by virtue of other species' populations declining. Ba237, Cy236

ORCHIDACEAE

Aplectrum hyemale (Muhl. ex Willd.); BaR, CrR, CyR. Three small colonies, dry draw and ravine slopes under beech-oak woods near lake. Only observed three populations; four individuals total. Cr155, Ha3767, Ci2, Cy16A, Cy327

Corallorhiza odontorhiza (Willd.) Nutt. var. *odontorhiza;* BaO, CrO, CyR. Dry woods, especially under pines. Only one colony observed growing trailside. Ba657, Cy33

Cypripedium acaule Aiton; BaC, CrC, CyC. Pine and mixed pine-deciduous woods. Notably large population in open piney area. Ba55, Ba128, Cy142

Cypripedium parviflorum Salisb. var. *pubescens;* BaR, CrO, CyC. 75-85 stems in colonies of up to 12 on several steep, calcareous wooded ravine slopes. 204 stems counted throughout. Ba71, Cy137

Goodyera pubescens (Willd.) R. Br. ex Ait. f., BaC, CrC, CyC. Mixed or deciduous woods, dry upland areas. Also found trailside. Ba421, Ci1, Cy396

Hexalectris spicata (Walter) Barnh. var. *spicata*; CrO, CyO. 40 individuals in four colonies on three ravines; calcareous lake-banks under oaks and beeches.

A total of 78 stems counted; one population reported from 1989 not observed, but new population found. Cy450, Apparently no recent collection

Isotria medeoloides (Pursh) Raf.; CrR, CyR. Three stems at two discrete sites in beech-oak woods. One fruiting stem observed. CPhoto, Na47 (Photo)

Liparis lilifolia (L.) L. C. Rich ex Ker-Gawl; BaR, CrR, CyO. Sandy soil, mixed woods. Large colony of 100+ individuals observed. Ha3694, Cy275, Cy278

ǂ *Listera australis* Lindl.; CyR. Two individuals in sandy bank of floodplain near head of a ravine. Cy236

Malaxis spicata Swartz; CrR, CyR. Two sites in wooded stream bottomlands, found only in College Creek floodplain near the southern border of the College Property. Only one population of nine individuals observed in a dry draw. Ba598, Cr425, Cy399

Malaxis unifolia Michx.; BaO, CrO, CyR. Pine and mixed pine-deciduous woods. Only two individuals observed in open pine woods. Ba573, Cr256, Cy321

ǂ *Platanthera clavellata* (Michx.) Luer; CyR. At least twenty individuals growing throughout a single wooded floodplain. Ph22

Ponthieva racemosa (Walt.) C. Mohr; BaO, CrC, CyC. Stream banks and bottomlands in mixed deciduous woods, marsh edge; forming substantial colonies in almost every wooded ravine on College property. No change. Ba584, Cy7

Spiranthes tuberosa Raf.; BaR, CE, CyR. Formerly one population located on slope of Holly Point. Two populations; two individuals located trailside, and five individuals located on wooded slope near Lake Matoaka. Ba621, Cy508

Tipularia discolor (Pursh) Nutt; BaC, CrC, CyC. Deciduous woods, especially upland areas. No change. Ba433, Cy27, Cy398

POACEAE

* *Agrostis gigantea* Roth; BaC, CrC, CyC. Weedy situations, rarely in open woods. Notable population of five individuals at trail entrance, otherwise scattered. Ba277, Cy350

Agrostis perennans (Walt).; BaO, CrO, CyO. <u>Moist woods, especially along trails</u>. Concentrated trailside, but also observed in woods. Ba539, Cy367, Cy458A, Cy571

ǂ+* *Agrostis stolonifera* L.; CyC. Spread throughout woods, along trails, and in floodplains. Ph27, Ci66, Cy295, Cy325, Sl88

ǂ+* *Alopecurus pratensis* L.; CyR. One population of 15 individuals growing along wood edge. Cy200

ǂ+ *Andropogon gerardii* Vitman; CyR. A few scattered individuals on either side of open, sunny slopes. Cy465, Cy607

Andropogon virginicus L. var. *virginicus;* BaC, CrC, CyC. <u>Dry, open situations; disturbed areas</u>. Wood edges, disturbed areas including hurricane-affected areas, and old Physics Laser Station field. Ba595, Ba696, Ci146, Cy478, Cy561, Cy599

* *Anthoxanthum odoratum* L. ssp. *odoratum;* BaC, CrC, CyC. <u>Dry soil, open areas along trails and edges of woods</u>. Notable population of 100+ clumps located along a bike trail. Ba63, Ba183, Ak36, Cy118, Cy146, Cy487, Sl48, Sl60

* *Arthraxon hispidus* (Thunb.) Makion var. *hispidus*; CrO, CyO. <u>Roadsides adjacent to woods</u>. No change. Ha16, Cr591, Cy567

ǂ+ *Bouteloua curtipendula* (Michx.) Torr. var. *curtipendula*; CyR. One clump on slope of sunny, open area. First record in the coastal plain and extreme mountain disjunct. Cy466

Brachyelytrum erectum (Schreb. ex Spreng.) Beauv.; BaO, CrO, CyO. <u>Mixed deciduous woods, usually dry situations.</u> Notably large population of 50+ clumps observed on slope into ravine; also found on multiple ravine slopes. Ba557, Cr393, Cr505, Ak24, Ak30, Ci63, Ci67, Ci71, Ci83 Ci93, Ci109, Cy371, Ph44, Sl114

ǂ+ *Bromus latiglumus* (Shear) A.S. Hitchc.; CyR. One individual growing trailside. This is potentially an extreme mountain disjunct. Ph43

ǂ+* *Cenchrus purpureus* (Schumach.) Morrone; CyR. One clump growing in open area. Likely a state record. Cy482

Chasmanthium laxum (L.) Yates; BaC, CrC, CyC. <u>Moist deciduous woods, especially on slopes</u>. No change. Ba402, Ba446, Ci102, Cy343

Chasmanthium sessiliflorum (Poir.) Yates; CrC, CyC. <u>Stream banks in maturing woods</u>. No change. Cy590, Ci92, Ci111

Cinna arundinacea L.; BaO, CrO, CyC. <u>Shores of lake, especially the upper Main ravine.</u> Also observed in two different ravine bottoms. Ba484, Cy429, Cy525

Coleataenia anceps (Michx.) Soreng ssp. *anceps;* BaC, CrC, CyC. <u>Moist sandy soil, woodland borders</u>. Also observed growing on either side of sunny, open slope area.   Ba457, Ba458, Cr492, Ak68, Ci129, Cy563

* *Cynodon dactylon* (L.) Pers. var. *dactylon*; BaC, CrC, CyC. <u>Roadsides; overgrown disturbed areas</u>. No change. Ba230, Ci105, Cy331, Ph8

* *Dactylis glomerata* L. ssp. *glomerata;* BaO, CrO, CyO. <u>Roadsides, woodland borders.</u> Also observed in a floodplain. Ba736, Na75

Danthonia spicata (L.) Beauv. Ex Roemer & J.A. Schultes;   BaO, CrO, CyO. <u>Dry upland deciduous woods</u>. No change. Ba303, Cr274, Cr279, Na53

Dichanthelium aciculare (Desv. ex Poir.) Gould & C.A. Clark; CrO, CyO. <u>Ridges in mixed oak woods.</u> Notably large population observed in woods between a road and the lake. Cr280, Ci18

ǂ *Dichanthelium acuminatum* (Sw.) Gould & C. A. Clark *var. acuminatum*; CyR. One population of 10-15 individuals growing along wood edge. Na62

Dichanthelium boscii (Poir.) Gould & C.A. Clark; BaC, CrC, CyC. <u>Open woods, cutover areas, woodland borders</u>. Also observed trailside. Ba200, Ba535, Ba809, Cr351, Cy342, Ph20

ǂ *Dichanthelium clandestinum* (L.) Gould; CyR. One individual along stream edge. Ph43

Dichanthelium commutatum (J.A. Schultes) Gould var*. commutatum;* BaO, CrC, CyC. <u>Ridges and slopes in open woods</u>. Also observed trailside. Ba200, Cr278, Cr565, Cr616, Ci90, Cy267

‡ *Dichanthelium dichotomum* (L.) Gould var. *dichotomum* ; CyO. 50-100 individuals scattered along wood edge. Ci73

‡ *Dichanthelium meridionale* (Ashe) Freckman; CyR. One population of twenty individuals along wood edge. Cy392

Dichanthelium polyanthes (Schultes) Mohlenbrock; BaC, CrC, CyC. Moist open woods and clearings, small ravine bottoms. Also found trailside. Ba297, Ba688, Cr623, Na81

Dichanthelium scoparium (Lam.) Gould; BaC, CrC, CyC. Sandy soils, open cutover areas. Also found along shaded wood edge. Ba669, Ph30

‡+* *Dichanthelium tenue* (Muhl.) Freckmann & Lelong; CyO. At least 21 individuals growing with *Microstegium vimineum* near Physics Laser Station. Ci154

* *Digitaria sanguinalis* (L.) Scop.; BaO, CrO, CyC. Grassy areas, woodland borders. No change. Ba513, Cy423, Cy464, Sl74

* *Echinochloa crus-galli* (L.) Beauv. var. *crus-galli;* BaO, CrO, CyO. Edges of woods, cutover areas, roadsides. No change. Ba674, Ba730, Cr702, Ak49, Cy336, Cy470

Elymus virginicus L.; BaR, CrO, CyC. Sunny calcareous banks in open woods, disturbed areas. Also observed on ravine slopes. Ba380, Ba666, Cr479, Cy388, Cy441, Sl96, Sl108

Eragrostis spectabilis (Pursh) Steud.; BaC, CrC, CyC. Dry sandy soil in cutover areas, along woodland borders. Only observed along woodland borders. Ba509, Ba606A, Hu51

Glyceria striata (Lam.) A. S. Hitchc; BaC, CrC, CyC. Wet soil, wooded ravine bottoms. No change. Ba134, Ba276, Cr283, Cr288, Cr337, Cy366, Na52, Ph18

Hordeum pusillum Nutt.; BaC, CrC, CyC. Dry open areas. Notably large population of 15 clumps observed roadside. Ba226, Sl27

Leersia oryzoides (L.) Sw.; BaC, CrC, CyC. Wet areas, locally abundant on deltas in Lake Matoaka. Particularly concentrated along lake edges. Ba626, Cy581, Hu10

Leersia virginica Willd.; BaO, CrO, CyO. Wooded areas, including one recently disturbed. Also found along wood edge. Ba516, Cr606A, Cy505

* *Lolium arundiceum* (Schreb.) Darbysh.; BaO, CrE, CyO. Scattered in open, sunny areas and wood edges. Ba353, Ci75, Ci86, Cy383, Na55, Na56, Na65

ǂ+* *Lolium perenne* L. *var. aristatum* Willd.; CyR. One population of 11 individuals on crest of ravine. Cy266

* *Lolium perenne* L. var. *perenne;* BaO, CrO, CyO. Exposed soil, woodland borders. Also found growing in a floodplain. Ba278, Ak58, Cy305, Cy326, Cy332, Cy361

Melica mutica Walt.; BaO, CrO, CyO. Rich wooded ravine slopes. No change. Ba106, Ba137, Cr188, Cr277, Cy243

* *Microstegium vimineum* (Trin.) A. Camus; CrC, CyA. Open disturbed areas, but invading woods in several places. In every disturbed area and along trail edges. Especially large patch at Physics Laser Station Field. Cr624, Cr625, Cr696, Cy594

ǂ *Panicum virgatum* L. var. *virgatum;* CyO. Over 100 individuals spread across open, sunny area. Ci91, Ph23

* *Paspalum dilatatum* Poir.; BaO, CrO, CyR. Dry situations, woodland borders. Only a few individuals found along wood edge. Ba282A, Ba839, Cr594, Cr602, Cy307, Na22

ǂ *Paspalum floridanum* Michx.; CyR. Four individuals growing on slope of open, sunny area. Cy468

ǂ *Paspalum setaceum* Michx.; CyR. One population of 5 individuals trailside. Cy502

* *Phyllostachys aurea* Carr. A. & C. Riviere; BaA, CrA, CyA. Locally abundant along edge of pine woods by Berkeley School, forming extensive thickets. No change. Ha4038, Cy501

Piptochaetium avenaceum (L.) Parodi; BaO, CrO, CyO. Dry woods, especially on the eastern side of the lake. Also found on a ravine slope. Ba184, Cr734, Cy244

ǂ* *Poa annua* L.; CyO. Two populations; one at a trail entrance and the other trailside within the woods. Cy71, Cy195

* *Poa pratensis* L. ssp. *pratensis;* BaO, CrO, CyC. Open woods, especially along paths. Also found along trail edges and in a floodplain. Ba181, Cy163, Cy194, Cy217

ǂ* *Setaria faberi* Hermm; CyR. Growing on either side of sunny, open sloped area. Ak57, Cy384, Cy469

Setaria parviflora (Poir.) Kerguelen; CrO, CyO. Sunny roadside near xeric woods. Also observed trailside. Cy566, Ak55

* *Setaria pumila* (Poir.) Roemer & Schultes ssp. *pumila;* BaC, CrC, CyC. Sunny disturbed areas. Also observed trailside. Ba419, Ba511, Ba512, Ba560, Cr649, Cy438, Ph55

Sorghastrum elliottii (C. Mohr) Nash; BaO, CrO, CyO. Dry open woods. No change. Ba596, Ba636, Ba646, Ci141, Hu6

* *Sorghum halepense* (L.) Pers.; BaO, CrO, CyO. Occasional on woodland borders. Also observed in a floodplain. Ba528, Ak29, Ak37, Ci61, Ci62, Cy374, Na66, Ph11, Ph25

Sphenopholis nitida (Biehler) Scribn.; BaO, CrO, CyO. Woods, moist shaded situations. Notable population in a broad floodplain. Ba208, Ci37, Cy294

Sphenopholis pensylvanica (L.) A. S. Hitchc.; BaO, CrO, CyO. Moist soil, in wooded ravines and more open bottomlands. No change. Ba133, Cy218

Tridens flavus (L.) A. S. Hitchc.; BaC, CrC, CyC. Dry soil; cutovers woodland borders. Also found trailside. Ba418, Cy463, Cy516

ǂ* *Vulpia myuros* (L.) K.C. Gmel ; CyR. One population of 10 clumps located in open, sunny, sloped area. Na58

POTAMOGETONACEAE

* *Potamogeton crispus* L.; BaO, CrC, CyC. Forming extensive mats in shallow water of Matoaka Lake. No change. Ba727, Cr661, Na44

RUSCACEAE

ǂ+* *Liriope spicata* Lour.; CyO. >200 individuals growing trailside. Cy472

Maianthemum racemosum (L.) Link ssp. *racemosum;* BaC, CrC, CyC. Ravine slopes and level uplands, maturing hardwoods. Only located on steep ravine slopes. Ba439, Cr153, Cy153, Cy397

Polygonatum biflorum (Walt.) Ell. var. *biflorum;* BaC, CrC, CyO. Trail sides and ravine slopes in mixed deciduous woods. Not observed along trails sides; mostly observed as small sterile plants. Ba127, Ba422, Sl1

SMILACACEAE
Smilax bona-nox L.; BaA, CrA, CyC. Edges of woods. Also growing on ravine slopes and in hurricane-disturbed areas. Ba588, Cy418

ǂ *Smilax pseudochina* L.; CyR. Open area on slope of Lake Matoaka. Cy427

Smilax rotundifolia L.; BaA, CrA, CyO. Edges of woods and open areas. Not observed in open areas. Ba695, Ak78, Cy434, Cy437, Ph74

TYPHACEAE
Typha latifolia L.; Ba & Cr no rating; CyR. No entry. Two populations; one of five individuals growing in an open, relatively dry area, and another small population growing in a broad ravine mouth. Ba682, Ba833, Cy377

TRILLIACEAE
ǂ+* *Trillium cuneatum* Raf.; CyR. Two populations; one individual in woods along a road, and two sterile individuals in a wooded floodplain. Likely a state record. Cy106, Cy117

REMAINING ANGIOSPERMS (*Ceratophyllum*, Magnoliids and Eudicots)
ACANTHACEAE
Ruellia caroliniensis (Gmelin) Steudel; BaC, CrC, CyO. Roadsides. Also observed in a floodplain, along wood edges, and trailside. Ba369, Cr331, Cr445, Ak21, Ak56, Ci76

ADOXACEAE
Viburnum acerifolium L.; BaC, CrC, CyR. Open woods along trails, important in seedling layer in maturing hardwoods. Only one individual observed, in woods along road. Ba155, Ba251, Sl2

ǂ* *Viburnum plicatum* Thunb.; CyR. Single mature tree growing in middle of floodplain. Cy128

Viburnum prunifolium L.; BaO, CrO, CyO. Mixed woods. Substantial colony growing roadside. Not observed below 1.4cm DBH. Ba67

Viburnum rufidulum Raf.; BaO, CrO, CyR. Deciduous woods, especially on Squirrel Point. Only two individuals observed; both growing on ravine slopes. Ba534, Ba606

ALTINGACEAE
Liquidambar styraciflua L.; BaO, CrC, CyO. Oak-, pine-, and mixed pine-deciduous woods. No change. Ba576, Cy544

ANACARDIACEAE
Rhus copallinum L.; BaC, CrC, CyO. Open cutover areas, borders of woods. Especially concentrated in hurricane-disturbed areas. Ba452, Ci124

Rhus glabra L.; BaC, CrC, CyO. Open cutover areas, borders of woods, typically in dry, weedy areas. Found most frequently in hurricane-disturbed areas. Ba308, Cy401, Cy582, Ph36

Toxicodendron radicans (L.) Kuntze var. *radicans*; BaC, CrC, CyC. Ravines, trailsides, edges of woods. No change. Ba480, Ba700, Cr435, Cy283

ANONNACEAE
Asimina triloba (L.) Dunal; BaO, CrO, CyA. Mixed deciduous woods. Forming dense colonies throughout wooded uplands and along sides of ravines. Ba634, Cy103

APIACEAE
Cicuta maculata L. var. *maculata;* BaO, CrO, CyO. Wet stream bottoms. Notably large population growing at mouth of a ravine. Ba829, Cr407, Cr484, Cy451B, Cy500

Cryptotaenia canadensis (L.) DC.; BaC, CrC, CyO. Damp, shaded ravine bottoms and slopes. Also observed in damp areas trailside. Ba315, Ba631, Cr391, Cr439, Cy360, Cy375, Sl120

ǂ * *Cyclospermum leptophyllum* (Pers.) Sprague ex Britt. & Wilson; CyO. Spread along wood edges and in open areas. Ak45, Cy409

* *Daucus carota* L.; BaC, CrC, CyC. Open, weedy areas, along trails and edges of woods. Not observed along trails, but observed frequently growing on either side of open, sunny slopes area. Ba291, Ci22

Osmorhiza longistylis (Torr.) DC.; BaC, CrC, CyC. Woods, shaded slopes and damp areas. Also found in floodplain. Ba123, Cy196

Sanicula canadensis L. var. *canadensis;* BaC, CrC, CyO. Open woods, wooded slopes and along trails. Mostly concentrated in a floodplain.   Ba135, Ba252, Cr439, Na68

Sanicula odorata (Raf.) K.M. Pryer & L. R. Phillippe; BaO, CrO, CyO. Open woods and stream bottoms. Also along trail edges. Ba819, Cr185, Cr226, Cy247, Cy248, Cy289, Cy379, Cy431

Thaspium barbinode (Michx.) Nutt.; BaC, CrC, CyC. Open woods, especially on stream banks and along trails. Also found in a floodplain. Ba77, Ba105, Ba312, Cr395, Cr443, Cy288, Cy290, Sl35

APOCYNACEAE

Apocynum cannabinum L.; BaO, CrO, CyO. Woodland borders, especially near campus; roadsides. Concentrated on wood edges. Ba288, Ba840, Cr682, Ci60, Ph4

Asclepias tuberosa L. var. *tuberosa;* BaO, CrO, CyR. Woodland borders, cutover areas. Only one individual observed growing in small canopy gap on wooded slope of Lake Matoaka. Ba322, Ph54

‡ *Matalea carolinensis* (Jacq.) Woodson; CyO. Scattered throughout woods, especially on ravine banks and in floodplains. Cy297, Cy299

* *Vinca minor* L.; BaR, CrO, CyR. Several large colonies in deciduous woods, persisting from cultivation. Only one population, growing roadside. Ba49, Ba735, Cy60B, Cy61B

AQUIFOLIACEAE

Ilex opaca Ait. var. *opaca;* BaA, CrA, CyA. Important tree in sapling and seedling layers, mixed woods. No change. Ba10, Ba57, Ba157, Cy22, Sl81, Sl89

Ilex verticillata (L.) Gray; CrR, CyR.   A number of seedlings in sandy sphagnous stream bottom where Swan Fork crosses the CCC trail. Only one large adult found in same location as 1989. Cr681, Na43

ARALIACEAE

Aralia spinosa L.; BaC, CrC, CyO. Open cutover areas, woodland borders. Only observed along woodland borders. Ba477, Cy406

* *Hedera helix* L.; BaO, CrO, CyO. Open woods, near trails and property boundaries. Also found growing in disturbed area trailside. Ba572, Ph67

‡ *Hydrocotyle prolifera* Kellog; CyR. One population in inlet of Lake Matoaka. Ph41

Hydrocotyle ranunculoides L. f.; BaC, CrC, CyO. Shallow water of Matoaka Lake, especially in Main Ravine. One particularly large population observed in inlet of Lake Matoaka. Ba214, Ci4, Ci5, Sl68

Panax quinquefolius L.; CrR, CyR. Two colonies of 12 individuals each, one colony possibly not on College property. Steep south-facing slopes in narrow ravines in beech-oak woods. Only two populations of one individual each observed, one on a steep ravine slope and the other on a gentle ravine slope. CPhoto, Sl73 Photo

ARISTOLOCHIACEAE

Asarum canadense L.; BaR, CrC, CyC. Deep wooded ravines. Notably observed on extremely steep slopes of two ravines. Ba83, Cr276, Cy152

Endodeca serpentaria (L.) Raf.; CrC, CyR. Maturing hardwoods ridges and ravines. Only two populations observed; one on wood ridge near trail and the other on ravine slope. Cr324, Cr326, Cy498

Hexastylis virginica (L.) Small; BaC, CrC, CyC. Level uplands and ravine slopes in mixed deciduous woods. No change. Ba4, Cy69

ASTERACEAE

Achillea millefolium L.; BaO, CrO, CyO. Dry weedy situations. Twenty-one individuals tallied, concentrated across open, sunny slopes area. Ba285, Ci20, Cy273, Sl8, Sl49

Ageratina aromatica (L.) Spach; BaO, CrO, CyO. Open mixed woods and clearings. Also scattered throughout a floodplain. Ba678, Cy484, Cy596

Ambrosia artemisiifolia L.; BaO, CrO, CyC. Weedy and disturbed areas. Scattered along wood edges and growing densely across sunny, open, shaded area. Ba503, Cy504

Antennaria parlinii Fern. ssp. *parlinii;* BaC, CrC, CyC. Slopes under beeches and oaks and along trails. Also observed on wooded slopes along roadsides. Ba81, Ba810, Cr454, Cy124

Antennaria solitaria Rydb.; BaR, CrR, CyR. A few small colonies on maturing hardwood slopes. Only one individual observed. Ba74, Cr158

* *Anthemis arvensis* L.; BaO, CrO, CyO. Dry weedy situations, edges of woods. Growing mostly on either side of open, sunny sloped area. Ba190, Cy219

Arnoglossum atriplicifolium (L.) H.E. Robins.; BaR, CrO, CyO. Shell-marl slopes throughout College Woods. Only observed in two different ravine systems. Ba301, Cr394, Na80

Baccharis halimifolia L.; BaO, CrO, CyR. Along edge of Lake. Only two populations observed, both growing in open places, one away from lake edge. Ba711, Cy553, Cy608

Bidens *bipinnata* L.; BaC, CrC, CyR. Weedy places, broad trails and cut overs. Only observed growing on wood edge. Ba555, Cy490

ǂ *Bidens connata* Muhl. ex Willd.; CyR. Two individuals at water's edge. Cy542

Bidens laevis (L.) B.S.P.; BaC, CrC, CyC. Wet soil, open ravines, bottomlands. Largest population growing at mouth of a ravine, but scattered across lake edge. Ba650, Cr581, Cy5, Cy555, Cy572, Cy574, Cy619, Na33

Chrysopsis mariana (L.) Ell.; BaC, CrC, CyC. Open woods, cutover areas, woodland borders. Most concentrated trailside. Ba538, Ba667, Ci139, Cy18, Cy507, Cy509, Hu5, Hu9

ǂ *Cirsium pumilum* (Nutt.) Spreng.; CyR. One individual growing roadside. Cy494

ǂ* *Cirsium vulgare* (Savi) Ten.; CyR. Two populations; ten individuals total. Both populations occurring on slopes near roads. Sl43, Sl102

Conoclinum coelestinium (L.) DC.; BaC, CrC, CyC. Weedy areas and edges of woods. No change. Ba498, Ci138, Cy483, Cy493

ǂ+ *Conyza bonariensis* (L.) Cronq.; CyR. Two populations; 11 individuals total. Both populations occur along wood edges. Ci131, Cy453

ǂ* *Coreopsis lanceolata* L.; CyR. One individual growing on north side of Jamestown Dam. Ak4

ǂ+* *Coreopsis tinctoria* Nutt. var. *tinctoria*; CyR. One population of 2 individuals growing in open area. Ph61

Doellingeria infirma (Michx.) Greene; BaO, CrO, CyR. <u>Open woods, usually in dry situations</u>. Only one individual found on south side of a wooded point into Lake. Ba460, Cy545

Eclipta prostrata (L.) L.; BaO, CrO, CyO. <u>Stream banks and bottomlands</u>. One notably large population observed along Compton Rd just past entrance to Main CCC trail. Ba627, Cy503

Elephantopus tomentosus L.; BaO, CrO, CyC. <u>Dry open woods, especially near trails</u>. Also found in hurricane-disturbed areas and highly concentrated along trails. Ba463, Ba529, Cy11, Cy421

Erechtites hieraciifolius (L.) Raf. ex DC.; BaC, CrC. <u>Recently exposed soil in woods, cutovers and woodland borders.</u> In every open, disturbed area in woods. Ba348, Ba541, Ba586, Cr603, Cy456A, Ph72

Erigeron annuus (L.) Pers.; BaC, CrC, CyC. <u>Disturbed areas.</u> Also observed along wood edges and on either side of sunny, open, sloped area. Ba341, Ak6A, Ci23, Ci51, Cy335, Cy403, Na6, Na36, Sl31

Erigeron pulchellus Michx. var. *pulchellus*; BaC, CrC, CyC. <u>Maturing deciduous woods, frequent on banks near trails</u>. Also observed along wood edges. Ba41, Ba75, Ba156, Ba176, Cy123, Cy138, Cy241

Erigeron strigosus Muhl. ex Willd. var. *strigosus;* BaC, CrC, CyC. <u>Dry disturbed areas</u>. Also observed along wood edges. Ba287, Cy330

ǂ *Eupatorium album* L. var. *album*; CyR. One individual growing along wood edge. Cy517

Eupatorium capillifolium (Lam.) Small; BaC, CrO, CyC. <u>A few on edges of woods</u>. Dense populations formed along nearly every open wood edge. Ba670, Cy28, Cy564

‡ *Eupatorium hyssopifolium* L.; CyO. Scattered in open areas; four individuals on one side of a sunny, open, sloped area, and few individuals scattered along a wood edge. Cy30, Cy527, Na14

‡ *Eupatorium serotinum* Michx.; CyR. One individual growing along wood edge. Na16

Eutrochium purpureum (L.) E.E. Lamont; CrO, CyR. <u>Calcareous slopes and bottomlands in deciduous woods</u>. Only one individual growing on a ravine slope. Ba473, Cr421, Cr504, Ph32

Gamochaeta purpurea (L.) Cabrera; CrC, CyC. <u>Edges of woods, cleared areas</u>. Only observed growing along trail edges. Ba146, Ci53, Cy268

‡+ *Helianthus laetiflorus* Pers.; CyR. One individual growing on log in Lake Matoaka. Ci113

‡+ *Helianthus microcephalus* Torr. & Gray; CyC. Two populations; >200 individuals scattered along a wood edge, and one individual trailside. Has potential to be an extreme mountain disjunct. Cy171, Cy522

Helianthus strumosus L.; BaO, CrO, CyO. <u>Dry open areas</u>. Found mostly along a wood edge. Ba664, Na15

Heliopsis helianthoides (L.) Sweet var. *helianthoides;* CrC, CyC. <u>Sunny slopes and trailsides in mixed deciduous woods.</u> No change. Cr475, Ak26, Ci87, Cy433, Cy386, Cy459A, Cy495, Hu2, Hu3, Ph64

Hieracium gronovii L.; CrO, CyO. <u>Dry open situations</u>. Also found trail side and on dry ravine slopes. Ba507, Ba676, Ci44, Ci85, Cy475, Cy586

Hieracium venosum L.; BaO, CrO, CyC. <u>Deciduous and mixed pine-deciduous woods, especially on banks along trails</u>. Also found on open ravine slopes. Ba126, Ba156, Ba355, Cy208

Krigia virginica (L.) Willd.; BaO, CrO, CyO. <u>Dry sterile soil, cutover areas.</u> Found along wood edges. Ba231, Co25, CY109

Lactuca canadensis L.; BaC, CrC, CyO. <u>Dry soil, woodland borders</u>. Mostly concentrated on either side of open, sunny, sloped area. Ba438, Ak80, Ci80, Cy471

Liatris pilosa (Ait.) Willd.; BaR, CrR, CyR. One colony in dry soil, pine-oak woods, along Strawberry Plains Road. Two individuals located in same location as 1989. Ba707, Cr607, Cy587

Mikania scandens (L.) Willd.; BaC, CrC, CyC. Open bottomlands and along banks; occasionally forming dense tangles. Also found twining on trees in open ravine bottoms. Ba522, Cr414, Cr456, Cr662, Ci134, Cy8, Cy444, Ph52

Packera aurea (L.) A. & D. Love; BaA, CrA, CyA. Typically in ravines and bottomlands but also common in drier woods. No change. Ba178, Ba207, Ci10

Pluchea camphorata (L.) DC.; BaR, CrE, CyR. Formerly, a few plants in damp soil along shore of Matoaka Lake. Two individuals growing on a wood edge. Ba488, Cy552

Prenanthes altissima L.; BaO, CrO, CyO. Dry wooded slopes, occasionally in cutover areas. Only found on ravine slopes. Ba658, Ba703, Ak74, Cy372, Cy598, Na40

Pseudognaphalium obtusifolium (L.) Hilliard & Burtt; BaO, CrO, CyO. Dry sterile soil of disturbed areas. Also found in a floodplain. Ba453, Cy565

ǂ *Rudbeckia fulgida* Ait. var. *fulgida;* Cy R. Two individuals growing in open area. Cy408

Rudbeckia hirta L.; BaC, CrC, CyO. Dry open areas, along trails and edges of the woods. No change. Ba264, Ba293, Ak31

ǂ *Rudbeckia triloba* L. var. *triloba;* CyR. One population of 44 individuals growing in a small inlet of Lake Matoaka. Cy536

ǂ* *Senecio vulgaris* L.; CyO. Found along wood edges. Cy104

Sericocarpus asteroides (L.) B.S.P.; BaO, CrO, CyR. Dry woods, wooded slopes. Only two individuals observed trailside. Ba260, Ba405, Ph40

Smallanthus uvedalia (L.) Mackenzie ex Small; CrO, CyO. Sunny slopes and trail sides in oak- and beech-oak woods. Large population of over 200 individuals growing on a ravine slope. Otherwise scattered throughout, not observed on trailsides. Ba372, Ba471, Cy402, Sl111

Solidago bicolor L.; BaO, CrO, CyR. Dry open woods, especially along trails. Only one population observed trailside. Ba677, Ba714, Ba715, Hu22

Solidago caesia L. var. *caesia;* BaC, CrC, CyC. Woods and woodland borders. Also frequent along trails. Ba523, Ba660, Ba709, Cy479, Cy573, Cy590, Cy611, Cy620, Cy623, Hu23

* *Solidago erecta* Pursh.; BaO, CrO, CyR. Dry woods, woodland borders. Two populations; four individuals total. Both growing trailside. Ba690, Ba710, Cy3, Cy548A

Solidago odora Ait.; BaC, CrC, CyR. Dry exposed soil, disturbed areas. Only one population of seventeen individuals observed, growing trailside. Ba533, Ba680, Cy456A

Solidago rugosa P. Mill.; BaO, CrO, CyR. Moist situations near streams in mixed woods. Only two populations observed, twenty-two individuals total. One occurs along a road edge, and the other population on a sunny, open, sloped area. Ba691, Ci147, Cy556, Cy588

* *Sonchus asper* (L.) Hill; BaC, CrC, CyO. Dry situations, cutover areas and edges of woods. Observed along wood edges and on sunny, open, sloped area. Ba304, Ba344, Cy308, Sl50

Symphyotrichum cordifolium (L.) Nesom; BaC, CrC, CyO. Mixed woods, along trails and near ravine floodplains. No change. Ba701, Cr672, Cy17, Cy585, Cy592

‡ *Symphyotrichum lanceolatum* (Willd.) Nesom; CyO. Growing trailside, along wood edges, and on a ravine slope. Cy589, Cy591, Cy615, Cy618

Symphyotrichum lateriflorum (L.) A. & D. Love; BaR, CrR, CyR. Dry wooded slopes. Only one population of five individuals observed, on slope of a ravine. Ba675, Na34

‡ *Symphyotrichum novi-belgii* (L.) Nesoml; CyR. Locality data are missing for both collections. Ci140, Hu18

Symphyotrichum pilosum (Willd.) Nesom var. *pilosum;* BaC, CrC, CyC. Sunny, weedy areas. Observed along wood edges, trail edges, and on delta. Ba618, Ba708, Cr660, Cy12, Cy562, Cy569

ǂ *Symphyotrichum pilosum* (Willd.) Nesom var. *pringlei* (Gray) Nesom; CyR. One population of 2 individuals growing on delta. Cy569

Symphyotrichum undulatum (L.) Nesom; BaC, CrC, CyR. Dry wooded slopes. Only two individuals observed trail side. Ba693, Ba704, Ba705, Ba721, Cr669, Cy402

* *Taraxacum officinale* G. H. Weber ex Wiggers; BaC, CrC, CyO. Weedy areas near trails and in disturbed areas. Only observed along wood edges, trail side, and across an open, sunny, sloped area. Ba305, Cy87, Sl12

Verbesina occidentalis (L.) Walt.; BaR, CrC, CyC. Along trails, woodland borders and slopes. Also observed in a floodplain. Ba567, Cy15, Cy531, Cy534, Cy546, Ph60

Verbesina virginica L.; BaO, CrO, CyC. Dry woods and cutover areas. More than 100 individuals scattered throughout a floodplain, and another large population scattered along slopes of a ravine. Ba556, Ci136, Cy530

Vernonia glauca (L.) Willd.; BaO, CrO, CyR. Open wooded calcareous slopes. Only one population observed, occurring in an inlet of a ravine system. Cr473, Cr474, Ak75

ǂ* *Youngia japonica* (L.) DC.; CyO. Many sporadic populations; both trailside and along wood edges. Ci19, Ci27, Ci36, Ci159, Sl92

BALSAMINACEAE

Impatiens capensis Meerburg; BaC, CrC, CyC. Wet ravines and open bottomlands. No change. Ba464, Ak77, Cy6

BERBERIDACEAE

* *Berberis bealei* Fortune; CrO, CyO. Occasional escape into College Woods, most frequently encountered near Jamestown Road. Found growing in woods near road edges. Cr618, Cr619, Cy46

Podophyllum peltatum L.; BaC, CrC, CyC. Moist deciduous woods. One large colony growing on wood edge, and also found growing on ravine slopes. Ba72, Ba75, Ba85, Cy180

BETULACEAE

*Alnus serrulata (*Ait). Willd.; BaA, CrA, CyA. On shores of Matoaka Lake, ravine bottomlands and College Creek floodplain. Not observed in ravine bottomlands.

Ba1, Cy35B, Cy59, Sl75

Carpinus caroliniana Walt.; BaC, CrC, CyC. Wooded bottomlands, ravines, bordering Matoaka Lake. Rare below 1.4cm DBH. Ba352, Ci7, Sl80

Corylus americana Walt.; BaO, CrO, CyR. Level uplands and ravine slopes, maturing hardwoods, especially on Squirrel Point. One individual observed trailside, browsed below 0.2m tall. Ba602, Ba661, Cy613

BIGNONIACEAE

Bignonia capreolata L.; BaO, CrO, CyO. Typically climbing tall trees, found in College Creek floodplain and among the Berkeley Pines. No change. Ba637, Cr426, Cr516, Cy239, Cy242A, Cy621

Campsis radicans (L.) Seem. ex Bureau; BaC, CrC, CyC. Open woods and disturbed areas. Also growing on wood edges. Ba377, Cy313, Na60

BORAGINACEAE

Cynoglossum virginianum L. var. *virginianum;* BaO, CrO, CyA. Dry draws and stream banks under maturing hardwoods. Also in hurricane-disturbed areas and open woods. Ba107, Ba192, Cr157, Cr175, Ci11, Ci50

Hackelia virginiana (L.) I.M. Johnston; CrO, CyO. College Creek Woods. Also found in ravine bottom. Cr515, Cy458B

ǂ *Mertensia virginica* (L.) Pers ex. Link; CyR. One population of 2 individuals along wood edge; spreading from cultivation. Cy172

Myosotis laxa Lehm.; BaO, CrO, CyR. Shallow water of Matoaka Lake, especially in the Main Ravine. Found in two locations; in a floodplain and on a delta. Ba212, Sl36

ǂ* *Myosotis stricta* Link ex Roemer & J.A. Schultes; CyR. Four individuals growing on one side of open, sunny, sloped area. Cy100

ǂ *Myosotis verna* Nutt.; CyR. One population of six individuals in a floodplain. Cy209

BRASSICACEAE

* *Arabadopsis thaliana* (L.) Heynhold; BaC, CrC, CyC. Most concentrated along either side of sunny, open, sloped area. Woodland borders, open cutover areas. Ba28, Ba35, Ba150, Cy98, Cy99

* *Barbarea verna* (Miller) Ascherson; BaO, CrO, CyR. Only one population growing on one side of sunny, open, sloped area – not present on dam in 2014. Laser Station field, woodland borders. Ba61, Ba168, Cy629

*Cardamine bulbosa (*Schreber ex. Muhlenberg) Britton, Sterns, & Poggenberg; BaC, CrC, CyR. Open bottomlands, in wet soil. Only one individual growing in a floodplain. Ba70, Cy167

* *Cardamine flexuosa* Withering; BaR, CrR, CyR. One small colony in disturbed area at the tip of Squirrel Point. Only two populations observed; five individuals total. One occurs roadside and the other population in a ravine bottom. Ba151, Cy21, Cy292

* *Cardamine hirsuta* L.; BaC, CrC, CyC. In open grassy areas and along roads. Also observed growing on either side of open, sunny, sloped area. Ba27, Cy42, Cy54, Cy78, Cy151, Cy293, Cy446

Cardamine pensylvanica Muhl. ex Willd.; BaO, CrO, CyO. Wet open areas in ravines near the lake. Growing in floodplain of nearly every ravine.   Ba801, Cy182, Cy298

ǂ* *Draba verna* L.; CyR. One population of >100 individuals growing on open, sunny, sloped area. Cy95

ǂ *Lepidium virginicum* L.; CyO. Three populations; ten individuals total. Two occur on wood edges, and the other on an open, sunny, sloped area. Ci106, Cy481, Sl19

* *Raphanus raphanistrum* L.; BaC, CrC, CyR. Woodland borders, disturbed areas. Only two populations observed; two individuals total. One occurs along a roadside and the other on an open, sunny, sloped area. Ba217, Cy94, Sl94

BUXACEAE

ǂ* *Buxus sempervirens* L.; CyR. One individual growing in disturbed area near old Physics Laser Station. Cy77

CAMPANULACEAE

Lobelia cardinalis L.; BaR, CrR, CyO. Lake shores, wooded floodplain. Observed in sunny open ravine bottoms of two ravines, also growing on lake shore. Ba490, Cr540, Cr670, Ci127, Cy404

Lobelia inflata L.; BaC, CrC, CyO. Woodland borders, along trails, in open areas. Only found along trail edges. Cr514, Ba406, Ak60, Cy393

Lobelia puberula Michx.; BaO, CrO, CyR. Open woods, along paths. Only four individuals counted trailside. Ba474, Ba587, Cr547, Cy4, Cy535

Lobelia siphilitica L. var. *siphilitica;* BaO, CrO, CyO. Moist soil, wooded ravines, cleared ravine, occasionally in drier situations. Found mostly in steep ravine systems. Ba581, Ba615, Ba683, Ci137, Hu15

ǂ *Triodanis perfoliata* (L.) Nieuwl. var. *biflora* (Ruiz & Pavon) Bradley; CyR. One individual on sunny, open, sloped area. Due to visual similarity with *T. perfoliata* var. *perfoliata,* there are likely more individuals in College Woods than documented here. Sl9

Triodanis perfoliata (L.) Nieuwl. var. *perfoliata* (Ruiz & Pavon) Bradley; BaO, CrO, CyO. Dry exposed soil in cutover areas. Many individuals observed only on either side of open, sunny, sloped area. Ba219, Ba232, Ci24, Cy250, Cy304

CAPRIFOLIACEAE

* *Lonicera japonica* Thunb.; BaA, CrA, CyA. Open woods, especially in the vicinity of pine; along trails and property borders, disturbed areas. Also found growing along either side of sunny, open, sloped area. Ba122, Ba363, Sl3

Lonicera sempervirens L.; BaO, CrO, CyR. Open woods, along trails, woodland borders. Only two populations observed in woods just off of a road. Ba195, Cy221, Cy389

* *Symphoricarpos orbiculatus* Moench; BaR, CrR, CyR. Persisting from cultivation near old Physics Laser Station. One individual observed near Physics Laser Station. Ha4046, Cy148

* *Valerianella locusta* (L.) Latterade; BaC, CrC, CyC. Woodland borders, in open weedy areas. More than 300 individuals scattered on either side of open, sunny, sloped area. Ba91, Cy185, Cy212

CARYOPHYLLACEAE

* *Dianthus armeria* L. ssp. *armeria;* BaO, CrO, CyR. Roadsides at edge of woods, along trails. One population observed in open area along wood edge. Ba313, Ba366, Sl72

Silene stellata (L.) Ait. f.; BaR, CrR, CyR. One small colony at edge of woods north of Mill Neck Road entrance. Only two populations observed, two individuals total. One occurs trailside, the other on the slope of a ravine. Ba499

* *Stellaria media* (L.) Vill.; BaC, CrC, CyC.   Open cutover areas, edge of woods, along trails. Many individuals observed on either side of sunny, open, sloped area. Ba26, Cy55, Cy56, Cy97

CELASTRACEAE

ǂ+* *Euonymus alatus* (Thunb.) Sieb.; CyR. One individual growing along wood edge. Cy606

Euonymus americanus L.; BaC, CrC, CyO. Open woods, slopes, important in seedling layer under maturing hardwoods. Observed frequently in seedling layer, rarely above 0.5m. Ba188, Cr198

Euonymus atropurpureus Jacq. var. *atropurpureus;* CrR, CyR. Shell-marl banks near streams in beech-oak woods. Only one individual observed on shell-marl slope of a ravine. Cy265

* *Euonymus fortunei* (Turcz.) Hand.- Maz.; CrR, CyR. Edge of woods along Compton Drive near new intramural gym. Only one individual growing on dead tree in floodplain. Cy723, Ak65

CERATOPHYLLACEAE

Ceratophyllum demersum L.; BaC, CrC, CyC. Shallow and deeper water of Matoaka Lake. No change. Ba359, Cr583, Ci114

CLEOMACEAE

ǂ+* *Tarenaya hassleriana* (Chodat) H.H. Iltis*;* CyR. One large population of >100 individuals growing in open, sunny area. Cy338, Cy340

CONVOLVULACEAE

Cuscuta compacta Jussieu ex Choisy; CrC, CyC. On a variety of plants, shores of Matoaka Lake, open bottomlands. No change. Ba574, Cy528, Cy549, Ph69

Ipomoea lacunosa L.; CrO, CyO. Edges of woods. Also found on open, sunny, sloped area. Ba559, Cy526

‡+* *Ipomoea purpurea* (L.) Roth; CyR. Two populations; two individuals total. One occurs along a roadside and the other in a disturbed area along a trail. Cy489, Na10

CORNACEAE
Cornus alternifolia L. f.; BaO, CrO, CyR. <u>Open woods along trails, steep ravine slopes, stream bottoms</u>. One individual observed growing trailside. Ba164, Ba641, Cr167, Cy604

Cornus florida L.; BaA, CrA, CyA. <u>Very important understory tree throughout woods</u>. Not observed below 1.4cm DBH. Ba80, Ba545, Apparently no recent collection made

Cornus stricta Lam.; BaO, CrC, CyO. <u>Ravine bottoms and floodplain forests</u>. No change. Ba580, Ba611, Cr249, Cr254, Ak67, Cy310, Cy312, Cy318, Ph5, Sl47, Sl83, Sl86

CUCURBITACEAE
‡ *Melothria pendula* L.; CyR. Two individuals growing on slope of sunny, open area. Ak79, Cy413

DIAPENSACEAE
Galax urceolata (Poir.) Brummitt; BaR, CrR, CyR. <u>Two large colonies on wooded slopes just above sphagnous stream heads</u>. Only one large colony growing on slope at sphagnous head of a ravine. Ba407, Cr237, Cy309

EBENACEAE
Diospyros virginiana L.; BaO, CrO, CyO. <u>Mixed woods.</u> Concentrated especially along open wood edges. Cr248, Cr255, Sl24

ELAEAGANACEAE
‡* *Elaeagnus umbellata* Thunb.; CyO. Scattered in disturbed areas throughout the woods; one notable example occurs trailside. Cy 147, Cy474

ERICACEAE
Chimaphila maculata (L.) Pursh; BaC, CrC, CyC. <u>Pine- and mixed pine-deciduous woods</u>. No change. Ba258A, Ba259, Cr300, Ci49, Sl66

Epigaea repens L.; BaR, CrC, CyC. <u>Steep moist banks in old deciduous woods</u>. Also observed growing trailside. Ba12, Cy111

Gaylussacia baccata (Wangenh.) K. Koch; BaA, CrA, CyA. Mixed oak woods; pine- and mixed pine-deciduous woods. No change. Ba88, Ba95, Ba141, Ci17, Ci43, Cy141, Cy188, Cy234

Gaylussacia frondosa (L.) Torr. & Gray ex Torr.; BaA, CrA, CyA. Mixed oak woods; common in mixed pine-deciduous woods. No change. Ba142, Ba825, Cr182, Ci47, Cy207, Cy225, Cy226, Cy279

Hypopitys monotropa Crantz; CrO, CyR. Particularly large colony occurs on slope of Strawberry Plains ravine just above its trail crossing. One small colony observed trailside. Cr342, Sl121

Kalmia latifolia L.; BaR, CrC, CyC. On several steep slopes, forming thickets across sphagnous stream heads, along trails in mixed oak woods. No change. Ba175, Sl5

Lyonia ligustrina (L.) DC. var. *ligustrina;* BaO, CrO, CyR. Forming thick shrub layer in mixed pine-deciduous woods behind Berkeley School. Approximately five individuals found at sphagnous head of a ravine. Ba331, Ba445, Cr259, Cy395

Lyonia mariana (L.) D. Don; BaO, CrO, CyR. Found in pine border of mixed oak woods along Strawberry Plain Road*.* Only one individual found in same location as 1989. Ba138, Ba240, Cr202, Cy233

Monotropa uniflora L.; BaC, CrC, CyC. Leaf litter of deciduous woods. No change. Ba411, Cr366, Cy23, Sl46

Oxydendrum arboreum (L.) DC.; BaC, CrC, CyC. Important part of sapling layer in pine woods. Observed frequently as adults along a trail. Some saplings observed, but encountered rarely. B310, Apparently no recent collection made

* *Rhododendron x obtusum;* BaO, CrR, CyR. Squirrel Point, other isolated areas. Only one large population observed; at tip of Squirrel Point. Ba40, Cr261, Cy626, Na45

Rhododendron periclymenoides (Michx.) Shinners; BaC, CrC, CyR. Dry woods, especially along slopes and trails. Only two populations observed; two individuals total. Both occur trail side. Ba43, Cr184

ǂ* *Rhododendron* x *pulchrum;* CyR. Two populations; three individuals total. One population in dry upland woods, the other occurs trailside. Cy133, Cy190

Vaccinium pallidum Ait.; BaA, CrA, CyA. Dry woods, woodland borders. No change. Ba16, Ba94, Ba96, Ba100, Cy231, Cy232

Vaccinium stamineum L.; BaA, CrA, CyA. Dry oak and pine woods, wooded slopes, along trails in maturing hardwoods. No change. Ba87, Ba93, Ba97, Ba99, Cy204, Cy222, Cy227, Cy228, Cy230

EUPHORBIACEAE

Acalypha rhomboidea Raf.; BaO, CrO, CyC. Woodland borders, roadsides. Greater than 100 individuals counted, with largest concentration road side. Ba424, Ba619, Cy491, Cy558

ǂ* *Euphorbia cyparissias* L.; CyR. One population of >100 stems growing in open area along wood edge. Cy67

Euphorbia maculata L.; BaC, CrC, CyR. Open areas, woodland borders. Only one individual observed at water's edge. Ba481, Ci128

Euphorbia pubentissima Michx.; BaC, CrC, CyO. Dry open soil, along trails and in disturbed areas. Observed on an open upper ravine slope. Ba328, Ba423, Ba836, Cr429, Cy405

FABACEAE

* *Albizia julibrissin* Durazz.; BaR, CrR, CyO. A few trees and many saplings north and east of Berkeley School, near Monticello Avenue. Persisting and spreading from cultivation. Sixteen trees scattered along wood edge, a few scattered on another wood edge, and a single large tree persisting from cultivation near old Physics Laser Station. Ba361, Cy319, Sl78

Amphicarpa bracteata (L.) Fern.; BaO, CrO, CyO. Open woods, along trails. Most concentrated trailside. Ba552, Ba649, Cy513, Na25, Ph63

ǂ *Apios americana* Medik.; CyR. One individual growing on *Morella cerifera* at water's edge. Cy529

Baptisia tinctoria (L.) R. Br. Ex Ait. f.; BaC, CrC, CyR. Open cutover areas. Only one population of seven individuals growing trailside. Ba306, Ba401, Cy333

Cercis canadensis L. var. *canadensis;* BaC, CrC, CyC. Shrub-sapling layer in mixed deciduous woods. Especially frequent on shell-marl banks in maturing hardwoods. Not observed below 1.4cm DBH, especially concentrated along a roadside. Ba36, Cy101

Clitoria mariana L. var. *mariana;* BaC, CrC, CyC. Open woods, along trails, disturbed areas. No change. Ba385, Cr384, Ak19

Desmodium canescens (L.) DC.; BaC, CrC, CyC. Dry woods, woodland borders. Also observed in floodplain. Ba374, Ak71

Desmodium paniculatum (L.) DC. var. *paniculatum;* CrC, CyO. Sunny ravine slopes, trail sides. Mostly observed along trails. Cr543, Cr586, Cy473, Cy510

Desmodium rotundifolium DC.; BaO, CrO, CyO. Dry open woods, especially along ridges and trails. Mostly observed along trails. Ba635, Cr545, Ci135, Cy514, Cy538

ǂ *Galactia volubilis* (L.) Britt. var. *volubilis*; CyR. One population of 5 individuals growing on open slope to Lake Matoaka. Cy426

Hylodesmum glutinosum (Muhl. ex Willd.) H. Ohashi & R. R. Mill; CrC, CyO. Trail and stream banks in oak and beech-oak woods. No change. Cr287, Ak50, Ci132, Cy476, Na39

Hylodesmum nudiflorum (L.) H. Ohashi & R. R. Mill; BaO, CrO, CyO. Steep ravine slopes and along trails in mixed woods. No change. Ba371, Ci95, Sl106

Hylodesmum pauciflorum (Nutt.) H. Ohashi & R. R. Mill; BaC, CrC, CyC. Deciduous woods, especially damp shaded ravines. No change. Ba414, Ba435, Ba659, Cr388, Ak47, Ak51, Ak59, Ci65, Cy448, Ph47

* *Kummerowia striata* (Thunb.) Schindl.; CrO, CyO. Sporadically mowed roadside along Compton Drive. Also found growing along wood edge. Cr596, Na17

* *Lathyrus hirsutus* L.; CrO, CyO. Weedy areas, edges of woods, roadsides. Also found growing on either side of sunny, open, sloped area.

* *Lespedeza bicolor* Turcz.; BaO, CrO, CyO. Disturbed areas, especially on trail near old Physics Laser Station. Also observed along either side of a road. Ba367, Ba570, Cr488, Ph50

* *Lespedeza cuneata* (Dum.-Cours.) G. Don; BaO, CrO, CyA. Disturbed areas, especially on trail near old Physics Laser Station.   Also found in dense colonies along wood edges. Ba639, Cr607A, Ci35, Cy14, Cy410

Lespedeza procumbens Michx.; BaO, CrO, CyR. Dry exposed soil in cutover areas. One population of three individuals observed in disturbed area. Ba585, Cy524

Lespedeza repens (L.) W. Bart.; BaC, CrC, CyC. Open woods, along trail, woodland borders. Also found growing on either side of sunny, open, sloped area. Ba426, Ba506, Cr657, Cy412, Cy424B, Cy488, Cy518

ǂ *Lespedeza violacea* (L.) Pers.; CyR. One individual in woods near a trail. 457A

Lespedeza virginica (L.) Britt.; BaO, CrO, CyR. Dry open woods, especially borders of pine woods. Only one individual observed growing in woods. Ba550, Cy457A

ǂ* *Lotus corniculatus* L.; CyR. Two populations; 37 individuals total. Both populations occur on wood edges. Ak7, Ph48

ǂ+* *Maackia amuriensis* Rupr. & Maxim.; CyR. One individual growing along wood edge. Likely a state record. Ak54

* *Medicago lupulina* L.; BaO, CrO, CyO. Cutover areas, along trails, woodland borders, shaded roadsides. Only observed along woodland borders and roadsides. Ba356, Ba385, Ba450, Cr246, Ph37, Sl95

* *Melilotus albus* Medikus; BaO, CrO, CyO. Roadsides adjacent to woods, along trails, edges of woods. Only found along roadsides and wood edges. Ba263, Cr203, Cr389, Ak27, Na38, Sl117

* *Melilotus officinalis* (L.) Lam.; BaO, CrO, CyO. Roadsides and trails. Only observed along roadsides. Ba292, Ci69, Sl57

Robinia pseudoacacia L.; BaO, CrO, CyO. Few trees in cutover south of Monticello Avenue, other disturbed areas. Particularly concentrated along a roadside. Ba92, Cy202

* *Securigera varia* (L.) Lassen ; CrO, CyO. Weedy roadside ditches. Also observed trailside. Cr398, Ci48, Ci98, Cy363, Sl11

Strophostyles umbellata (Muhl. ex Willd.) Britt.; CrR, CyR. <u>A few small plants found, trailside near Compton Drive in deciduous woods</u>. Two individuals growing on wood edge. Cr585, Cy454B

Tephrosia virginiana (L.) Pers.; BaO, CrO, CyR. <u>Woodland border, predominantly pine woods, Strawberry Plains Road</u>. Only one population of two individuals observed, on wood edge. Ba239, Ak14

* *Trifolium arvense* L.; BaO, CrO, CyO. <u>Cutovers, forming large colonies</u>. Found only along wood edges. Ba295, Sl29

* *Trifolium campestre* Schreb.; BaC, CrC, CyC. <u>Woodland borders</u>. Also observed substantial numbers growing on either side of open, sunny, sloped area. Ba145, Ba234, Ci29, Sl17

ǂ+* *Trifolium dubium* Sibthorp; CyR. One population of a few individuals along wood edge. Cy16

* *Trifolium hybridum* L.; BaO, CrO, CyO. <u>Edges of woods.</u> No change. Ba431, Ak83

* *Trifolium pratense* L.; BaO, CrO, CyO. <u>Woodland borders and trails</u>. Only observed along woodland borders. Ba189, Sl28

* *Trifolium repens* L.; BaC, CrC, CyC. <u>Trails, edges of woods</u>. No change. Ba90, Ci32, Cy178

ǂ* *Vicia sativa* L.; CyR. Two populations; 12 individuals total. One population occurring along a wood edge, and the other growing trail side. Cy132, Cy216

ǂ* *Vicia tetrasperma* (L.) Schreb.; CyR. One population of >100 individuals growing in disturbed area. Cy155

Wisteria sinensis (Sims) Sweet; CrO, CyR. <u>In trees along Compton Drive and Monticello Avenue, old house site in mixed woods</u>. Not relocated at old home site. Cr444, Cr683, Cy199

FAGACEAE

Castanea dentata (Marshall) Borkhausen; BaO, CrO, CyR. <u>Sterile root-sprouts in oak and beech-oak woods</u>. Only one individual observed; growing trailside. Ba412, Cr233, Cy300

Castanea pumila (L.) P. Miller; BaC, CrC, CyO. Oak and beech-oak woods. Observed most frequently along lake and wood edges. Ba204, Ba309, Cr232, Cr432, Cr567, Ak10, Ph10

Fagus grandifolia Ehrhart; BaA, CrA, CyA. Major canopy tree in several areas, present in sapling or seedling layer in most other deciduous woods. No change. Ba614, Na27

Quercus alba L.; BaA, CrA, CyA. Major canopy tree in most areas of woods. No change in large class, though little regeneration—present in seedling layer, but not sapling layer. Ba593, Cy521

Quercus coccinea Muenchhausen; BaR, CrO, CyO. Many large trees in several section of the woods, with other oaks. Not observed below 1.4cm DBH. Ba686, Cy622

Quercus falcata Michx.; BaC, CrC, CyC. An important canopy species. Observed mainly in upland woods; not observed below 1.4cm DBH. Ba33, Ba553, Ci57, Cy435, Na41

Quercus michauxii Nutt.; BaO, CrO, CyO. Lower ravine slopes in mixed oak woods. Not observed below 1.4 cm DBH. Cr436, Cy359, Cy411, Cy523

Quercus muehlenbergii Engelmann; BaO, CrO, CyO. Dry slopes, ridges and level uplands, especially in maturing hardwoods. Not observed below 1.4 cm DBH. Ba579, Ba610, Ba656, Ba702, Cr269, Cy271, Cy601

Quercus nigra L.; CrR, CyR. Few seedlings in mixed pine-deciduous woods. Only two adults observed; one located on wood edge, the other in a deer exclosure. Cr330, Cr699, Ci57

Quercus phellos L.; CrR, CyR. Few seedlings in mixed deciduous woods. Two large individuals growing on lake edge in inlet off lake Matoaka. Cr329, Ph34

Quercus rubra L. var. *rubra;* BaC, CrC, CyC. Dry upland woods, an important canopy species. Not observed below 1.4cm DBH. Ba479, Ba600, Ak53, Na42

Quercus stellata Wangenheim; BaO, CrO, CyO. Dry upland woods, an important canopy species. Not observed below 1.4cm DBH. Ba655, Ba699

Quercus velutina Lam.; BaC, CrC, CyC. Many large trees in mixed oak woods, especially on Blunt Point. Not observed under 1.4cm DBH. Ba685, Cr495, Cy520, Hu14, Na8

GENTIANACEAE

Bartonia virginica (L.) B.S.P. ; CrO, CyR. Small colony dry oak woods near Strawberry Plains Professional Center. Only two populations; one growing at head of a ravine, and one growing in dry wooded uplands. Cr500, Cy381, Cy381

Obolaria virginica L.; BaO, CrO, CyO. Stream banks and trail sides in maturing hardwoods. Also growing in broad dry draw at head of a ravine. Ba7, Cr152, Cy83, Cy84

Sabatia angularis (L.) Pursh; BaC, CrC, CyO. Roadsides and edges of woods. A few individuals in each population; observed along wood edges, trailside, and in hurricane-disturbed areas. Ba420, Cr447, Ci120, Cy453A, Ph45, Ph58

GERANIACEAE

Geranium carolinianum L.; BaC, CrC, CyC. Disturbed areas, edges of woods. No change. Ba110, CrY9, Cy191, Ph7

ǂ* *Geranium molle* L.; CyR. One population of 5 individuals along wooded edge. Sl44

HAMAMELIDACEAE

Hamamelis virginiana L.; BaO, CrO, CyR. A few colonies of shrubs in the College Woods. One population of two trees observed, on slope at sphagnous head of a ravine. Ba408, Cy450A

HYDRANGACEAE

Decumaria barbara L.; BaC, CrC, CyO. Climbing pines or deciduous trees, especially near lake shores and in stream bottomlands. No change. Ba216, Ba224, Ak1, Ci149

HYPERICACEAE

Hypericum hypericoides (L.) Crantz; BaO, CrO, CyC. Roadsides adjacent to xeric pine-oak woods. Also found along trails and in hurricane-disturbed areas. Ba349, Cr399, Ak44, Ci74, Cy2, Cy296, Cy345, Sl112, Sl115, Sl119

Hypericum mutilum L.; BaO, CrO, CyR. Dry, open woods, especially along trails and at small clearings. Only found along wood edge. Ba403, Ba443, Ba620, Ak15, Ak62, Ak66, Sl79, Sl103

Hypericum punctatum Lam.; BaC, CrC, CyO. Roadsides, edges of woods, disturbed areas. Particularly concentrated along wood edge. Ba351, Cr368, Ci81, Ci104, Cy380, Sl98

JUGLANDACEAE

Carya cordiformis (Wangenh.) K. Koch; BaO, CrC, CyC. Throughout deciduous woods, especially beech-oak woods. No change. Ba640, Cr455

Carya glabra (P. Miller) Sweet; BaO, CrO, CyO. Throughout mixed woods, especially on Squirrel Point. No change. Ba601, Ba613, Cr263

Carya tomentosa (Poir.) Nutt.; BaC, CrC, CyC. Throughout deciduous and mixed woods. No change. B413, Ba489, Ci59, Cy577, Hu11

Juglans nigra L.; BaR, CrO, CyO. Some mature trees scattered in mixed hardwoods, a few saplings on ravine slopes. No change; some saplings observed along a ravine system. Ba638, Cr405, Na2, Na11

LAMIACEAE

ǂ* *Ajuga reptans* L.; CyR. One population in wooded area paralleling road. Cy630

Callicarpa americana L.; BaO, CrE, CyC. In nearly every open or disturbed area in the College Woods. Cy376

ǂ+* *Clerodendrum trichotomum* Thunb.; CyO. Thirty-six individuals spread throughout open disturbed area along a trail. Likely a state record. Cy452A

* *Glechoma hederacea* L.; BaO, CrO, CyR. Woodland borders, shaded roadsides. Only three individuals observed on east-facing slope of a ravine. Ba79, Cy115

* *Lamium amplexicaule* L.; BaC, CrC, CyC. Roadsides, disturbed areas. Also found growing on either side of sunny, open, sloped area. Ba468, Ci8, Ci9, Cy53, Cy61A

Lycopus virginicus L.; BaC, CrC, CyR. <u>Trail sides, damp ravine slopes, edge of lake</u>. Only three individuals observed, found along edge of lake. Ba500, Cr562, Cr579, Cy532, Cy548B

* *Perilla frutescens* (L.) Britt.; BaO, CrO, CyC. <u>Paths and small disturbed areas in mixed woods</u>. Also found frequently along wood edges. Ba575, Cr604, Cy486, Hu4

Prunella vulgaris L.; BaC, CrC, CyC. <u>Edges of woods, roadside ditches</u>. Also observed along trail edges. Ba266, Ba326, Cr326, Cr520, Ak42, Ci52, Cy419, Ph1, Ph9, Ph12

Salvia lyrata L.; BaC, CrC, CyO. <u>Along trails in mixed woods, at edges of clearings and disturbed areas</u>. Found only along trails. Ba129, Ba159, Cr178, Cy223

Scutellaria elliptica Muhl. ex Spreng. var. *elliptica;* BaC, CrC, CyR. <u>Deciduous woods, especially along trails</u>. Only one individual observed on ravine slope. Ba261, Cy301

Scutellaria lateriflora L. var. *lateriflora;* CrC, CyO. <u>No entry</u>. Found in wet, open, situations. Cr482, Cr611, Cy445, Na4, Na7, Ph15, Ph65

ǂ *Teucrim canadense* L.; CyO. 11 individuals scattered along wood edge. Na11

ǂ* *Vitex agnus-castus* L.; CyR. One large individual growing on wood edge. Ak28

LAURACEAE

Lindera benzoin (L.) Blume; BaC, CrC, CyO. <u>Wet wooded ravines</u>. One or two individuals found in four different ravine systems. Ba3, Cr140 , Cy68, Cy120, Cy134

Sassafras albidum (Nutt.) Nees; BaC, CrC, CyO. <u>Open woods, borders of woods</u>. No change. Ba59, Ba740, Cr433, Cy85, Cy172, Sl122

LYTHRACEAE

Decodon verticillatus (L.) Ell.; BaC, CrC, CyA. <u>Shallow water around shores of Matoaka Lake</u>. Forming dense colonies around entirety of lake. Ba482, Cr573, Cr574, Cy443

* *Lagerstroemia indica* L.; BaR, CrE, CyO. Formerly, a few trees persisting in area west of the Physics Laser Station which was formerly a nursery. A few individuals scattered in disturbed places. Ba417, Ci130, Cy616, Ph73

MAGNOLICACEAE

Liriodendron tulipifera L.; BaA, CrA, CyA. Important canopy tree throughout much of the woods. Not observed in seedling or sapling layers. Ba154, Cy246

Magnolia grandiflora L.; BaO, CrO, CyO. Spreading from cultivation into many areas of the woods. Large trees observed only along Monticello Avenue. Mature trees also found along another roadside. Ba318, Ak2

Magnolia virginiana L.; BaO, CrO, CyO. Mature fertile trees in almost every sphagnous stream head, with seedlings in many areas of the woods. No seedlings observed. Ba332, Cr360, Sl54

MALVACEAE

ǂ+* *Firmiana simplex* (L.) W. Wight; CyR. One population of two individuals growing in open disturbed area. Cy462

ǂ+ *Tilia americana* L. var. *americana;* CyO. Found trailside and in woods paralleling a road. Cy512, Cy600

MOLLUGINACEAE

ǂ* *Mollugo verticillata* L.; CyR. Two populations; 12 individuals total. Both populations occurring roadside. Cy480, Sl93

MORACEAE

ǂ* *Fatoua villosa;* CyR. One individual growing along wood edge. Cy485

ǂ* *Maclura pomifera* (Raf.) Schneid.; CyR. One individual growing along roadside. Ci145

* *Morus alba* L.; BaR, CrE, CyR. Formerly one tree near edge of field at Physics Laser Station. One individual growing on wood edge. Ba116, Sl32

Morus rubra L.; BaC, CrC, CyO. Occasional to common as a sapling in deciduous and mixed woods. Especially concentrated trailside. Ba478, Ba502, Cr477, Ak17, Cy614

MYRICACEAE

‡ *Comptonia peregrina* (L.) Coult. ; CyR. Three individuals growing on upper ravine slope. Na29

*Morella cerifera (*L.) Small; CyC. Along edges of Lake Matoaka and commonly along wood edge on east side of Lake; also appearing in some hurricane-disturbed areas. Although not documented by Crouch, it is extremely likely this species was present. Cy286

NYSSACEAE

‡ *Nyssa biflora* Walt.; CyR. Twenty-two individuals growing in small stagnant pond. Cy610

Nyssa sylvatica Marshall; BaO, CrC, CyC. <u>Seedling and sapling layers of all upland forest types, occasionally reaching canopy</u>. Rarely observed below 1.4cm DBH, but present throughout woods in midstory. Ba324, Cr350, Cr424, Cy519

OLEACEAE

Chionanthus virginicus L.; BaR, CrR, CyR. <u>One small tree in a ravine NW of the Rt. 5 entrance.</u> One tree in same location as 1989. Ba174, Sl4

+ Forsythia suspensa* (Thunb.) Vahl; BaR, CrE, CyR. One population of four individuals growing trailside*.* Ha4044, Cy76

Fraxinus americana L.; BaC, CrC, CyC. <u>Relatively common in ravine bottoms; more a lowland than an upland tree here</u>. No change. Ba577, Ba648, Cy533, Cy579, Na1

* *Ligustrum sinense* Louriere; BaR, CrR, CyC. <u>Rare escape from cultivation.</u> Found along every wood edge, sometimes forming thickets. Rarely observed in interior of College Woods. Ba824, Ak22, Cy334, Sl23, Sl51

‡* *Osmanthus heterophyllus* (G. Don) P.S. Green; CyR. One individual just off trail. Ci55

‡* *Osmanthus* x *fortunei;* CyR. One individual just off trail. Ci56

ONAGRACEAE

Circaea canadensis (L.) Hill ssp. *canadensis;* BaO, CrO, CyO. <u>Damp shaded wooded areas, open ravines</u>. Also observed trail side. Ba257, Cr333, Ak48, Ci68, Ci82, Cy322, Cy368, Cy387

Ludwigia alternifolia L.; BaO, CrO, CyO. Open cutover areas. Found only along wood edges. Ba350, Cy394, Cy492

‡ *Ludwigia decurrens* Walter; CyO. Scattered throughout floodplain and delta of Main Cove. Ci143, Cy551, Hu9, Na21

Ludwigia palustris (L.) Elliott; CrA, CyC. Locally abundant in several wet wooded ravine bottoms. Largest population found in ravine bottom. Cr406, Cy432

OROBANCHACEAE

Aureolaria virginica (L.) Pennell; BaO, CrO, CyC. Dry open woods, sunny wooded lake banks. Only found trailside, but found frequently throughout that trail. Ba269, Cr253, Cr563, Ci112, Ph13

Epifagus virginiana (L.) W. Barton; BaC, CrC, CyC. Common under beeches. No change. Ba597, Hu13

Pedicularis lanceolata Michx.; BaC, CrO, CyR. Shores of lake, open ravines. Only two individuals growing on shore of lake in inlet of Lake Matoaka; heavily browsed. Ba625, Cr578, Cy580

OXALIDACEAE

Oxalis dillenii Jacquin; BaC, CrC, CyC. Dry sunny areas, edges of woods. No change. Ba144, Ba233, Ak73, Ak82, Cy187

‡ *Oxalis florida* Salisbury; CyO. Spread sporadically trailside. Ph56, Ci49, Ci99, Cy270, Cy424A, Ph56

PAPVERACEAE

Sanguinaria canadensis L.; BaC, CrC, CyC. Common on ravine slopes in deciduous forest. No change. Ba21, Cr138, Cy72, Cy81, Cy105

PASSIFLORACEAE

‡ *Passiflora incarnata* L.; CyR. One population of five individuals growing at wood edge near old home site. Cy454A

Passiflora lutea L.; BaO, CrO, CyR. Along trails in woods. Only one individual found growing in inlet of Lake Matoaka, and one individual found twining along wood edge. Ba456B, Cy428

PAULOWNIACEAE

* *Paulownia tomentosa* (Thunb.) Steud.; BaO, CrO, CyO. A few mature trees near Berkeley School; saplings scattered elsewhere in more disturbed portions of woods. Also in disturbed area along a trail, and dominating in a sunny, open area. Ba111, Ba390, Cy176

PHRYMACEAE

ǂ* *Mazus pumilus* (Burm. f.) Steenis; CyO. Over twenty individuals scattered in wet depression along wood edge. Ci 116, Ci119, Cy385, Cy447, Sl52, Sl118

Mimulus alatus Ait.; BaO, CrO, CyO. Open swampy ravines, wet waste places. Mostly concentrated in two different floodplains. Ba524, Cr481, Ci121, Na23

Phryma leptostachya L. var. *leptostachya;* BaC, CrC, CyC. Along trails in mixed woods, borders of woods. No change. Ba375, Cr390, Cr44, Ci118, Cy116, Cy460

PHYLLANTHACEAE

ǂ+* *Phyllanthus urinaria* L. ssp. *urinaria;* CyR. One population of 10 individuals growing along wooded edge. Na12

PHYTOLACCACEAE

ǂ *Phytolacca americana* L. var. *americana;* CyO. 29 individuals counted scattered throughout woods in canopy gaps and other open, disturbed areas; found often growing on overturned logs. Cy414, Cy422

PLANTAGINACEAE

ǂ *Gratiola neglecta* Torr.; CyO. Greater than 100 individuals spread across a single ravine bottom. Ph66

* *Plantago lanceolata* L.; BaC, CrC, CyO. Grassy areas along trails, edges of woods. Also found on either side of sunny, open, sloped area. Ba119, Ba149, Ci46, Sl10

Plantago rugelli Dcne.; BaC, CrC, CyO. Grassy areas, woodland borders. No change. Ba376, Sl91

Plantago virginica L.; BaC, CrC, CyC. Dry exposed soil, cutover areas. Also found trail side. B65, Ba70, Cy160

* *Veronica agrestis* L.; BaO, CrO, CyO. <u>Dry open soil at the tip of Squirrel Point</u>. Observed scattered throughout sunny, open, sloped area; not relocated at Squirrel Point. Ba467, Cy192

‡* *Veronica hederifolia* L.; CyR. One individual growing on one side of sunny, open, sloped area. Cy47

PLATANACEAE

Platanus occidentalis L.; BaC, CrC, CyO. <u>Bottomlands, occasionally along shores of lake</u>. Also saplings found growing on one side of sunny, open, sloped area. Ba486, Cy459B

POLYGALACEAE

Polygala mariana P. Mill.; BaR, CrR, CyR. <u>One small colony of plants in open cutover areas.</u> One individual growing in open area near wood edge at entrance to bike trail. Ba444, Cy451A

POLYGONACEAE

‡ *Persicaria glabra* (Willd.) M. Gomez; CyR. One individual growing in a drainage ditch along a wood edge. Na19

‡ <u>*Persicaria hydropiper* (L.) Spach</u>; CyR. Six individuals in a single floodplain. Ci125.

Persicaria hydropiperoides (Michx.) Small; CrO, CyO. Also found in sphagnous head of a ravine. <u>Stream bottoms in maturing hardwood forest.</u> Cr589, Ak12, Sl64

* *Persicaria longiseta* (Bruijn) Kitagawa; CrO, CyO. <u>Consistently wet roadside ditch</u>. Also located along moist trailsides and at the top of a single ravine. Cr593, Ak5, Ci26, Ci72, Cy13

Persicaria sagittata (L.) H. Gross ex Nakai; BaO, CrO, CyO. <u>Open bottomlands, shores of lake</u>. Large population growing densely at water's edge. Ba651, Cr609, Cy540

Persicaria setacea (Baldw.) Small; BaC, CrC, CyC. <u>Shores of lake, bottomlands, roadside ditches</u>. Also found in sunny, open area. Ba483, Cr601, Ci64, Ci123, Cy337, Na37

Persicaria virginiana (L.) Gaertn.; BaO, CrO, CyO. Moist woods, slopes and ravines. Also found along wood edge. Ba459, Cy420

ǂ* *Polygonum aviculare* L.; CyR. One population of many individuals growing along water's edge of Lake Matoaka. Cy543

* *Rumex conglomeratus* Murr.; BaC, CrC, CyR. Disturbed areas with damp exposed soil. Only one population of two individuals observed in a single floodplain. Ba280, Ci77, Ph39

* *Rumex crispus* L. ssp. *crispus*; BaC, CrC, CyR. Open cutover areas. Only observed in two locations; one population along the water's edge, and the other along a wood edge. Ba191, Ba220, Ba327, Cy329, Cy269, Sl58

PRIMULACEAE

Samolus valerandi L. ssp. *parviflorus* (Raf.) Hulten; CrO, CyR. Broad sunny ravines near lake and marsh. Also found in a broad floodplain. Cr287, Cy370, Na72, Sl84, Sl104

RANUNCULACEAE

Actaea racemosa L.; CrO, CyO. Deciduous woods, especially on ravine slopes. Approximately 100 individuals counted, most notable population consists of 25 stems on ravine slope paralleling trail. Ba311, Ba603, Ph19

Anemone virginiana L. var. *virginiana;* CrC, CyC. Dry wooded slopes and along trails. No change. Ba265, Ba290, Ba373, Cr437, Ak76, Ci126, Ph31

Aruncus dioicus (Walt.) Fernald; CrR, CyR. One substantial colony on steep slopes of narrow branched ravine on the East side of Squirrel Point. Only observed four individuals growing out of steep slope of a ravine; not relocated in Aruncus ravine. Cr506, Sl45

* *Clematis terniflora* DC.; BaR, CrR, CyR. Sunny overturn in floodplain forest along College Creek below Jamestown Road. One individual observed growing on edge of open, sunny, sloped area. Ba471, Cr517, Cy19A, Cy430

ǂ+* *Ficaria verna* Hudson; CyR. One population of six individuals growing in woods along a road. Cy108

Hepatica americana (DC.) Ker-Gawl.; BaC, CrC, CyC. On slopes of damp wooded ravines and on drier slopes in upland maturing hardwood stands. No change. Ba5, Ba19, Cr136, Cy50, Cy51

Ranunculus abortivus; CrO, CyO. Broad ravine bottoms. No change. Cr168, Cy121, Cy287

* *Ranunculus bulbosus* L.; BaO, CrO, CyO. Open woods, typically in dry habitats. Only found along wood edges. Ba180, Cy166

Ranunculus hispidus Michx. ; BaO, CrO, CyO. Rich wooded ravines, typically in damp shaded areas. No change. Ba76, Ba102, Ci15, Cy139, Cy197, Cy285, Sl33, Sl40, Sl87

Ranunculus recurvatus Poir var. *recurvatus;* BaC, CrC, CyC. Damp soil in wooded ravines. No change. Cy181, Cy215

* *Ranunculus sardous* Crantz; BaO, CrO, CyO. Woodland borders, along trails. Also found in moist areas, including in a single floodplain and in depressions along a road. Ba193, Cr252, Cy144, Cy169, Cy457B

ROSACEAE

Agrimonia rostellata Wallr.; BaO, CrC, CyC. Deciduous woods, along trails and on sunny lake-banks. Greater than a hundred individuals, concentrated along trails—not observed in deciduous woods or lake banks. Ba398, Ba831, Cr442, Ci117, Cy302, Ph46, Ph57

Amelanchier arborea (Michx. f.) Fernald; BaO, CrO, CyO. Woods near Matoaka Lake. Not observed under 1.4cm DBH. Also observed along wood edge and trailside. Ba22, Ba211, Cy66, Cy90, Cy112, Cy113

‡ *Crataegus* sp.; CyR. Two populations; two individuals total. One growing trailside, and the other along a wood edge. Cy612, Sl20

Fragaria virginiana Duchesne; BaC, CrC, CyC. Along trails, edges of woods, small clearings. No change. Ba37, Ba50, Cy136

Geum canadense Jacquin; BaC, CrC, CyC. Moist ravine bottoms, slopes and trailsides under maturing hardwoods. No change. Ba289, Cr364, Ak38, Ak52, Ci94, Ci101, Cy324, Sl113

Geum virginianum L.; BaC, CrC, CyO. Wooded slopes and ravine bottoms. Mostly concentrated in a single floodplain. Ba382, Ak41

* *Potentilla indica* (Andr.) T. Wolf; BaC, CrC, CyC.   Along trails, borders of woods, disturbed areas. No change. Ba62, Ba223, Ci33, Ci100, Cy179, Cy211, Sl6, Sl7

Potentilla simplex Michx.; CrC, CyC. Sunny trailsides throughout woods, edges of woods. No change. Cr217, Ak11, Cy149, Cy253

Prunus serotina Ehrhardt ssp. *serotina;* BaC, CrC, CyO. Seedling and sapling layers in pine and mixed oak woods, some large trees among pines and along woodland borders. Observed in seedling layer, but not observed in sapling layer. Ba109, Ba117, Ba604, Cy177, Cy328, Cy550

ǂ * *Pyrus calleryana* Dcne.; CyR. One individual growing behind guard rail road side. Cl144

* *Rosa multiflora* Thunb. ex Murr.; BaC, CrC, CyC. Spreading from cultivation near property borders and disturbed areas. Also spread along road edges. Ba171, Ak63, Cy201, Sl67

Rosa palustris Marsh. ; BaC, CrC, CyO. Scattered near mouths of ravines feeding lake and in College Creek floodplain. Not observed in College Creek floodplain. Ba270, Ba485, Cr349, Cy36, Sl69

Rubus flagellaris Willd.; Ba & Cr no rarity recorded, CyO. Open cutover areas. Two thickets of greater than fifty stems observed, both on wood edges. Ba66, Ba136, Ba325, Ba386, Ba387, Ba632, Cy220, Na76

Rubus pensylvanicus Poir.; BaC, CrC, CyC. Open cutover areas, thickets along woodland borders. Observed along borders, in a disturbed area at the head of a ravine, and trailside. Ba206, Ba325, Cy254, Cy276, Hu21, Sl61

* *Rubus phoenicolasius* Maxim.; BaO, CrO, CyC. Woodland borders, occasionally forming thickets in open areas. Concentrated at a trail entrance. Ba632, Sl26, Sl38

RUBIACEAE

Cephalanthus occidentalis L.; BaO, CrO, CyO. Shores of Matoaka Lake. Also observed growing on one side of open, sunny, sloped area. Ba272, Ba274, Ak25, Ci25

Diodia teres Walt.; BaC, CrC, CyR. Dry soil, woodland borders. Only seven individuals found along wood edge. Ba549, Cy351, Cy452B

Galium aparine L.; BaC, CrC, CyR. Deciduous woods, especially in damp soil of wooded ravines. Only a few individuals growing on sunny, open sloped area and on one ravine slope. Ba118, Cy158, Cy186, Cy210

‡ *Galium asprellum* Michx.; CyO. Too many individuals to count spread across a floodplain. This is potentially an extreme mountain disjunct. Ph2

Galium circaezens Michx.; BaC, CrC, CyC. Open woods, especially along slopes and trails. No change. Ba252, Ba253, Ba392, Cr292, Ba388, Ak18, Ci39, Ci42, Cy156, Cy322, Cy449, Na57, Na79, Sl37

‡* *Galium sherardia* E. H. L. Krause; CyO. Four populations; 18 individuals total. One population growing trailside, one along a wood edge, one on open, sunny sloped area, and one in woods at the Physics Laser Station. Cy130, Cy173, Sl16

‡ *Galium tinctorum* (L.) Scop.; CyO. Scattered in wet, open places. Seen along water edge and growing on roots in Lake Matoaka. Ci122, Cy311A, Ph71

Galium triflorum Michx.; BaO, CrO, CyC. Mixed pine-deciduous woods, both uplands and College Creek floodplain. Also found growing on ravine slopes. Ba422, Cr169, Cr487, Ci88, Cy354, Cy378, Na31, Sl85

Galium uniflorum Michx.; BaO, CrO, CyR. Scattered small colonies in pine- and mixed pine-deciduous woods. Two individuals growing in pine woods near Physics Laser Station. Ba661, Cr260, Cy348

Houstonia caerulea L.; BaA, CrA, CyA. Also found along wood edges. Deciduous woods, along trails and ravine slopes. B24, B236, C137, CY60A, CY73, CY110

Houstonia purpurea L. var. *purpurea;* BaO, CrO, CyC. Also found along shaded wood edges. Ravine slopes under maturing hardwoods. B199, B434, C215, C285, CI28, CI34, CI41, S21

‡ *Houstonia pusilla* Schopf.; CyR. Two populations; 49 individuals total. Both populations occur on wood edges. Cy80, Cy148

Mitchella repens L.; BaC, CrC, CyC. Throughout woods, especially mixed pine-deciduous woods. No change. Ba23, Cr230, Cy277

SALICACEAE
ǂ* *Populus alba* L.; CyR. One individual reproducing clonally; 20 stems at wood edge. Cy65

Populus deltoides Bartram ex Marshall ssp. *deltoides;* BaC, CrO, CyO. Bottomlands, College Creek and shores of Matoaka Lake. Also seen along wood edges. Ba591, Cy547

Salix nigra Marsh.; BaC, CrC, CyO. Shores of Matoaka Lake, occasionally on woodland borders. Also found at edge of ravine. Ba38, Ba196, Ba210, Ba590, Ba713, Ba725, Cr718, Cy566

SANTALACEAE
ǂ *Phoradendron leucarpum* (Raf.) Reveal & M.C. Johnston ssp. *leucarpum;* Cy O. Growing normally on trees in moist areas, like along ravine banks. Cluster of four or five seen on large oaks along ridge of a single ravine. Observed sporadically elsewhere. Cy628

SAPINIDACEAE
Acer rubrum L.; BaA, CrA, CyA. Stream bottomlands and in understory of deciduous woods. Stems below 1.4 DBH extremely rare. Ba2, Ba13, Ba592, Cr451, Ci6A, Hu1

ǂ+* *Aesculus pavia* L.; CyO. At least fifteen individuals of different ages scattered throughout woods paralleling road. Cy62, Cy161

ǂ+* *Cardiospermum halicacabum* L.; Cy R. Four individuals growing in open area along wood edge. Na18

SAURURACEAE
Saururus cernuus L.; BaA, CrA, CyA. Shallow streams and College Creek. Also in broad inlets of Lake Matoaka. Ba271, Sl55

SCROPHULARIACEAE
* *Verbascum blattaria* L.; BaO, CrO, CyR. Relatively rare at Physics Laser Station. Only one population of two individuals observed, on one side of sunny, open sloped area. Ba335

* *Verbascum thapsus* L. ssp. *thapsus;*   BaO, CrO, CyO. Disturbed areas, edges of woods. Also observed a population of eight individuals on one side of sunny, open sloped area. Ba384, Cy382

SIMAROUBIACEAE
* *Ailanthus altissima* (P. Miller) Swingle; BaO, CrO, CyO. Disturbed areas near Monticello Avenue; occasional where woods border on developed areas. Twenty-four individuals counted throughout the woods. Ba672, Cy440, Cy584

SOLANACEAE
* *Datura stramonium* L. ; BaR, CrE, CyO. Formerly only at cleared tip of Squirrel Point. One population of 40 individuals growing in sunny, open area. Ba246, Sl65

* *Solanum carolinense* L. var*. carolinense*; BaC, CrC, CyC. Dry exposed soil, disturbed areas and woodland borders. Also observed in two sunny, open areas. Ba543, Ci30, Sl15, Sl63

* *Solanum ptycanthum* Dunal; BaO, CrO, CyO. Sunny waste places on exposed, disturbed soil. Many individuals observed across open, sunny sloped area. Ba429, Cy467, Sl13, Sl116

TETRACHONDRACEAE
Polypremum procumbens L.; BaC, CrC, CyC. Dry sandy areas, woodland borders, cutover areas. No change. Ba409, Ba442, Ba599, Ak64, Cy373

ULMACEAE
Celtis occidentalis L.; CrR, CyR. Very rare in the College Woods, along trail in mixed woods just east of old Physics Laser Station. Only two individuals; one on wood edge and the other trailside. Ha4043, Cy583, Cy605

Ulmus americana L.; BaO, CrO, CyO. Open bottomlands, especially along College Creek. Not observed below 1.4cm DBH. Ba647, Cy602

Ulmus rubra Muhl.; BaC, CrC, CyC. Bottomlands and upland deciduous woods. Not observed below 1.4cm DBH. Ba578, Cr102, Cr497, Cy537

URTICACEAE
Boehmeria cylindrica (L.) Sw.; BaC, CrC, CyC. Ravines, tributary to lake, shores of lake, College Creek floodplain. No change. Ba391, Ak70, Cy442, Cy593, Ph53, Ph59, Ph70

‡ *Pilea fontana* (Lunell) Rydb.; CyC. Over 200 stems counted throughout woods in sunny open areas near water. *Pilea* sp. was previously reported in the College Woods. Cy570

+* *Urtica dioica* L.; BaR, CrE, CyO. Formerly, located at old Physics Laser Station field. Over 100 stems spread throughout open, sunny area. Sl25

VERBENACEAE

‡+* *Verbena brasiliensis* Vell.; CyR. Two populations; 12 individuals growing at wood edge at West Gate Entrance, and 6 individuals growing along wood edge at Campus Dump. Cy31, Ph51, Sl62

Verbena urticifolia L.; BaC, CrC, CyC. Open woods, along trails, woodland borders. No change. Ba383, Cr362, Cr531, Ci79B, Ci115, Ph24, Ph29

VIOLACEAE

Viola bicolor Pursh; BaR, CrC, CyC. Roadsides, sunny edges of woods, grassy disturbed areas. Large population growing on one side of open, sunny sloped area. Ba735, Cr727, Cy93

‡ *Viola blanda* Willd.; CyO. 42 individuals spread around stagnant pond. A potential mountain disjunct. Cy206

Viola cucullata Ait.; CrC, CyR. Woods, typically wet ravine bottoms. Only three populations observed; six individuals total. One population occurs on a ravine slope while the other two occur in floodplains. Cr189, Ci12, Ci13, Ci14, Cy143, Cy150, Cy162

‡ *Viola incognita* Brainerd; CyR. Two individuals, a floodplain. Potentially an extreme mountain disjunct. Cy122, Na46

Viola palmata L. var. *palmata;* BaO, CrO, CyR. Moist wooded ravine slopes. Only one population of twenty individuals observed, in dry draw. Ba48, Ba86, Ba143, Cr222, Cr423, Cr438, Cy320

Viola primulifolia L.; BaR, CrO, CyR. In every sphagnous stream head and occasionally along trails in dense woods. Only one population of three individuals observed. Ba58, Cr181, Cr220, Cy237

Viola sororia Willd.; BaA, CrA, CyA. Woods, especially along trails. Also observed on tops of ravine banks. Ba18, Cr139, Cr141, Cy107, Cy164, Cy165

VITACEAE

‡* <u>*Ampelopsis brevipedunculata* (Maxim.) Trautv.;</u> CyR. Two individuals growing along wood edge. Ph16

Parthenocissus quinquefolia (L.) Planch.; BaC, CrC, CyC. <u>Scattered throughout woods.</u> No change. Ba518, Ak6B

Vitis aestivalis Michx.; BaC, CrC, CyO. <u>Along trails, edges of woods</u>. Not observed along trails. Ba609, Cy315

‡ *Vitis cinerea* (Engelm.) Engelm. var. *floridana* Munson; CyR. One individual growing at edge of woods. Cy575

‡ *Vitis palmata* L. var. *palmata;* CyR. One individual growing at edge of woods. Cy554

Vitis rotundifolia Michx. var. *rotundifolia;* BaC, CrC, CyC. <u>Edges of woods, disturbed areas</u>. No change. Ba517, Ba608, Cy506

Vitis vulpina L.; BaC, CrC, CyC. <u>Trees bordering lake, occasionally around ravines.</u> Also found along wood edges. Seen commonly in seedling layer throughout woods. Ba197, Sl22

Species reported from the woods in 1989, but were not recovered during the 2015 survey. Asterisks indicate non-native species. Collections are indicated as B = Barans, C = Crouch, D = Davis, and H = Hall followed by collector number. All collections are stored at WILLI. Rarity as given in 1989 survey is written in parentheses CR = rare, CO = occasional, CC = common, CA = abundant. Habitat is reprinted from 1989 floristic survey.

FERNS AND FERN ALLIES

EQUISETACEAE

Equisetum arvense L.; CrR. Swampy wooded area along College Creek north of Matoaka Lake. Ba743

LYCOPODIACEAE

Dendrolycopodium obscurum (L.) A. Haines; CrR. Sphagnous upper portion of stream tributary to Main Ravine, north of Monticello Rd. Cr228

Diphasiastrum digitatum (Dill. Ex A. Braun) Holub; BaR, CrR. Open woods east of Common Glory grounds, one on west side of Squirrel Point. Ba595, Cr651

POLYPODIACEAE

Pleopeltis polypodioides (L.) Andrews & Windham ssp. *michauxiana* (Weatherby) And; CrR. One clump epiphytic on white oak. Cr722

MONOCOTS

ARACEAE

Lemna minor L.; BaC, CrC. Floats on Matoaka Lake in larges (3x2 m) mats with *Wolffia brasiliensis* and *Spirodela polyrrhiza*. Ba493, Cr81

Orontium aquaticum L.; BaR, CrR. One colony of fifty plants in shallow water, wooded floodplain of Main Ravine east of lake, just behind parking lot of Williamsburg Community Hospital. Ba73

Spirodela polyrrhiza (L.) Schleid.; BaC, CrC. Floats on Matoaka Lake in large (3x2 m) mats with *Lemna minor* and *Wolffia brasiliensis.* Ba492

Wolffia brasiliensis Weddell; BaC, CrC. Floats on Matoaka Lake in large (3x2 m) mats with *Lemna minor* and *Spirodela polyrhiza.* Cr82, Ba495

CYPERACEAE

Bulbostylis capillaris (L.) Clarke in Hook.; BaO, CrO. Dry open soil; cutover areas, edge of woods. Ba399, Ba718

Carex debilis Michaux.; CrO. Sphagnous branches of Strawberry Plains Ravine. Cr295, Cr358, Cr359

Carex granularis Muhl. ex Willd.; CrO. Stream banks and floodplains, moist meadows. Cr336, Cr340, Cr343, Cr354

Carex grisea Wahlenb.; BaO, CrO. Damp wooded ravines. Ba803

Carex laxiculmis Schweinitz var. *laxiculmis;* CrO. Steep moist banks of deep ravines. Cr401

Carex laxiflora Lam.; CrO. Calcareous banks of large and small ravines in maturing hardwoods. Cr271

Carex leptalea Wahlenb.; CrC. Hummocks in broad, sunny, wet ravines. Cr223, Cr282, Cr320, Cr404

Carex striatula Michaux.; BaO, CrO. Dry woods, ravine slopes. Ba131, Cr286

Cyperus lancastriensis Porter ex. Gray; CrO. Wet roadside ditches, sunny disturbed areas. Cr446

Cyperus polystachyos Rottboell; CrR. Sunny lake shore by Jamestown Road. Cr612

Cyperus retrorsus Chapman; CrO. Cutover areas, edge of woods. Ba623

Scleria triglomerata Michx.; CrO. Slope of dry draw in mixed oak woods. Cr496

DIOSCOREACEAE
* *Dioscorea polystachya* Turczaninow; BaO, CrO. Edge of woods along Mill Neck road, College Creek below Jamestown Road. Ba520

HYDROCHARITACEAE
Elodea canadensis Michx.; BaC, CrC. Shallow water of Matoaka Lake. Ba93, Ba360, Cr580

JUNCACEAE
Luzula echinata (Small) F.J. Hermann; CrR. Sphagnous stream head in mixed oak woods. Cr298

LILIACEAE

Lilium superbum L.; CrR. One colony in sphagnous stream near northern border of College property. Cr728

NAJADACEAE

Najas flexilis (Willd.) Rostk. & Schmidt; BaC, CrC. Matoaka Lake. Ba497

ORCHIDACEAE

Isotria verticillata (Muhl. ex Willd.) Raf.; CrO. About 20 stems at three sites; mixed oak woods. Cr735

POACEAE

* *Bromus japonicus* Thunb. ex. Murr.; BaO, CrO. Dry open areas, field, edges of woods. Ba340

Cenchrus longispinus(Hack.) Fern.; BaR, CrR. Dry exposed soil, woodland border. Ba548.

Dichanthelium depauperatum (Muhl.) Gould & C.A. Clark; BaO, CrO. Open cutover areas. Ba817

Dichanthelium dichotomum var*. ramulosum* (Torr.) LeBlond; CrC. Dry exposed soil in open woods. Cr511

* *Digitaria ischaemum* (Schreb.) Muhl.; CrO. Roadsides. Cr592

* *Eleusine indica* (L.) Gaertn.; BaC, CrC. Weedy areas, roadsides and paths. Ba514

Festuca subverticillata (Pers.) Alexeev; CrC. Small streams under beech-oak canopy. Cr270, Cr338, Cr375

* *Lolium temulentum* L.; BaC, CrC. Open disturbed areas, edges of woods. Ba227, Ba277

Muhlenbergia schreberi J.F. Gmel.; CrO. Trailsides. Cr595, Cr709

Paspalum pubiflorum Rupr. ex Fourn.; CrO. Roadside adjacent to woods and edge of woods elsewhere. Cr594, Cr602

* *Phleum pratense* L.; BaO, CrO. Weedy situations exposed soil edges of woods. Ba339

Poa autumnalis Muhl. ex Ell.; BaO, CrO. Moist deciduous woods. Ba182

* *Poa trivialis* L.; CrC. Scattered stream bottomlands in maturing woods. Cr266, Cr347

Schizachyrium scoparium (Michx.) Nash var. *scoparium;* CrO. Dry slopes and ridges in beech-oak woods. Cr671

Sphenopholis obtusata (Michx.) Scribn.; BaC, CrC. Dry situations, trails in woods. Ba245

Vulpia octoflora (Walt.) Rydb.; BaO, CrO. Woodland borders. Ba814

PONTERIDACEAE
Heteranthera reniformis Ruiz & Pavon; CrR. One small colony in mud, Main Ravine. Cr584

SMILACACEAE
Smilax glauca Walt.; CrC. Pine and mixed pine-deciduous woods. Cr197, Cr396

Smilax herbacea L.; BaO, CrO. Sphagnous heads of streams, slopes in deciduous woods. Ba605, Cr497, Cr512

Smilax hispida Raf.; CrO. Beech-oak woods, especially near streams. Cr400

Smilax laurifolia L.; CrR. One colony in Kalmia thickets spanning sphagnous stream. Cr494

XANTHORRACEAE
* *Hemerocallis fulva* (L.) L.; BaR, CrR. Escaping cultivation along Mill Neck Road; formerly in cutover area. Ba319, Ba433

REMAINING ANGIOSPERMS (*Ceratophyllum*, Magnoliids and Eudicots)
ADOXACEAE
Sambucus canadensis L. var. *canadensis*; CR. Several shrubs in beech-oak woods near old Common Glory amphitheater; formerly found only in an open cutover area. Ba835

Viburnum nudum L.; BaO, CrO. Damp soil, wooded slopes of ravines, sphagnous stream heads. Ba329, Cr218

AMARANTHACEAE

Amaranthus hybridus L.; BaO, CrO. Open cutover areas and edge of woods. Ba624, Ba717

* *Chenopodium album* L. ; BaO, CrO. Open cutover areas, edge of woods. Ba594, Ba722

* *Dysphania ambrosioides* (L.) Mosyakin & Clemants; BaO, CrO. Edge of woods, open weedy areas. Ba595, Cr723, Cr651

APIACEAE

Angelica venenosa (Greenway) Fern.; BaO, CrO. Dry open woods, cutover areas. Ba368

Oxypolis rigidor (L.) Raf.; CrR. One colony on bank of sphagnous stream in mixed deciduous woods, near northern border of College property. Cr510

Sanicula marilandica L.; BaC, CrC. Open woods and stream bottoms. Ba135, Ba163

APOCYNACEAE

Asclepias variegata L.; BaO, CrO. Open woods and woodland borders. Ba243, Ba283

Cynanchum laeve (Michx.) Pers.; BaO, CrO. Several small colonies in open weedy areas near Jamestown Road. Cr397, Ba698

AQUIFOLIACEAE

* *Ilex crenata* Thunberg; CrR. Persisting near remains of building near tip of Squirrel Point. Ha4040

* *Ilex vomitoria* Aiton; CrR. Two small trees along trail in beech-oak woods on Squirrel Point. Possibly persisting from cultivation. Ha4041

ARALIACEAE

Aralia nudicaulis L.; BaR, CrR. One narrow wooded ravine. Ba415

Aralia racemosa L.; BaO, CrO. In two narrow wooded ravines. Ba583

ASTERACEAE

Ageratina altissima (L.) King & H.E. Robins. var. *altissima;* BaO, CrO. Open mixed woods and clearings. Ba672

Bidens comosa (Gray) Wiegand; CrR. A few tall plants in upper reaches of Main Ravine floodplain north of Monticello Avenue. Cr483

Bidens frondosa L.; BaO, CrO. Dry open areas, woodland borders. Ba558

Cirsium discolor (Muhl. ex Willd.) Spreng.; BaR, CrR. A few plants at Physics Laser Station. Ba568

Cirsium horridulum Michx. var. *horridulum;* BaR, CrR. Roadsides and waste places. Ba820A

Conyza canadensis (L.) var. *canadensis;* BaC, CrC. Cutover areas, edges of woods. Ba454, Ba617

Eupatorium pubescens Muhl. ex Willd.; BaO, CrO. Dry, open woods, especially with pine. Ba473

Eurybia compacta Nesom; BaR, CrR. One colony, edge of pine-oak woods. Ba561

Helianthus atrorubens L. ; BaO, CrO. Open woods. Ba508

Helianthus divaricatus L.; BaC, CrC. Woods along trails and roads and near cutover areas. Ba307, Ba441, Ba664

* *Hypochaeris radicata* L. ; BaO, CrO. Dry exposed soil, cutover areas and woodland borders. Ba147, Ba221

*Lactuca floridana (*L.) Gaertn.; BaO, CrO. Dry woods, edges of woods. Ba525

Parthenium integrifolium L.; BaO, CrO. Dry open woods, disturbed areas, edges of woods. Ba242, Ba300

Pityopsis aspera (Shuttlw ex Small) var. *adenolepis* (Fern.) Semple & Bowers; BaO, CrO. Dry open pine-oak woods. Ba562

Rudbeckia laciniata L. var. *humilis* Gray; BaR, CrR. Two colonies of plants , moist wooded ravines, one a small ravine on Squirrel Point and the other the broad floodplain of the Main Ravine. Ba644

Rudbeckia laciniata L. var. *laciniata;* BaR, CrR. Two colonies of plants , moist wooded ravines, one a small ravine on Squirrel Point and the other the broad floodplain of the Main Ravine. Cr588, Cr677

Silphium asteriscus L.; BaO, CrO. Dry woods, especially along trails and slopes of broad ravines. Ba381

Solidago altissima L. var. *altissima;* BaC, CrC. Open weedy places. Ba671

Solidago nemoralis Ait. var. *nemoralis;* BaO, CrO. Dry woods near trails. Ba630, Ba681

Solidago pinetorum Small; BaO, CrO. Dry sunny disturbed areas. Ba451

Symphyotrichum grandiflorum (L.) Nesom; BaR, CrR. Dry soil, edges of woods. Ba706

Symphyotrichum patens (Ait.) Nesom var. *patens;* BaO, CrO. Dry open woods, edges of woods. Ba668, Ba692

Vernonia noveboracensis (L.) Michx.; CrO. Low on sunny bank of marsh and in floodplain of main ravine in College Woods proper. Cr485

BRASSICACEAE

* *Capsella bursa-pastoris* (L.) Medicus; BaO, CrO. Rt. 5 entrance to woods. Ba466

* *Lepidium campestre* (L.) R. Brown; BaC, CrC. Cutover areas, other clearings. Ba166, Ba224, Ba345

* *Lepidium didymum* L.; BaO, CrO. A small colony of plants in disturbed area on Squirrel Point. Ba152

* *Nasturtium officinale* R. Brown; BaC, CrC. Shores of Matoaka Lake, occasionally in streams and College Creek. Ba177, Ba215

* *Sisymbrium officinale* (L.) Scopoli; BaR, CrR. One specimen collected from field near Physics Laser Station. Ba221

CAPRIFOLIACEAE

Triosteum perfoliatum L.; BaR, CrR. A few individuals in wooded ravines. Ba358, Cr668.

CARYOPHYLLACEAE
* *Cerastium glomeratum* Thuill; BaC, CrC. Open cutover areas, edge of woods. Likely species still in woods and just overlooked. Ba25

CELASTRACEAE
* *Celastrus orbiculatus* Thunb.; CrR. One colony escaped from cultivation, floodplain of College Creek near Jamestown Road. Cr617

CISTACEAE
Lechea racemulosa Michx.; BaC, CrC. Sunny disturbed areas. Ba397

COLCHICACEAE
Uvularia perfoliata L.; BaR, CrR. Two or three limited occurrences, slopes in deciduous woods. Cr258, Cr293, Cr732

CONVOLVULACEAE
Cuscuta gronovii Willd. Ex Roem. & Schult.; BaC, CrC. On a variety of plants, shores of Matoaka Lake. Ba652

Ipomoea hederacea Jacq.; BaC, CrO. Woodland borders, open disturbed areas, old Laser Station Field. Ba521

ELAEAGANACEAE
* *Elaeagnus pungens* Thunb.; BaO, CrO. Escape from cultivation in College Woods. Ba526, Ba633

ERICACEAE
Eubotrys racemosus (L.) Nutt.; CrO. Forming thickets in and around sphagnous streams in mixed deciduous forest. Cr227

Monotropsis odorata Schwein. ex Ell. var. *odorata;* BaR, CrR. Heavy oak leaf litter in oak-beech-pine woods below William and Mary Cafeteria. Cr620, Ha3761

EUPHORBIACEAE
Acalypha gracilens Gray; BaO, CrO. Disturbed exposed soil. Ba424

* *Croton glandulosus* L. var. *septentrionalis* Muell.-Arg.; BaO, CrO. Disturbed areas, borders of woods. Ba563

FABACEAE

Crotalaria purshii DC.; BaO, CrO. Open cutover areas. Ba394

Crotalaria sagittalis L.; BaO, CrO. Open cutover areas. Ba395

Desmodium cuspidatum (Muhl. ex Willd.) Loudon; BaC, CrC. Cutover areas, along trails, woodland borders, occasionally in open woods. Ba472

Desmodium glabellum (Michx.) DC.; CrC. Sunny ravine slopes, trail sides. Ba354

Desmodium laevigatum (Nutt.) DC.; CrO. Sunny trail sides in maturing hardwoods. Cr503, Cr546

Desmodium virdiflorum (L.) DC.; BaO, CrO. One colony in College Woods. Ba832

Galactia regularis (L.) B.S.P.; BaO, CrO. Dry open places, woodland borders and cutover areas. Ba440

* *Kummerowia stipulacea* (Maxim.) Makino; CrO. Woodland borders, especially in the vicinity of pines. Ba565

Phaseolus polystachios (L.) B.S.P.; BaO, CrO. Dry woods and calcareous slopes; twining on shrubs. Ba531, Cr472

Strophostyles helvola (L.) Ell.; BaO, CrO. Edge of woods and edge of marsh. Ba416, Cr658

FAGACEAE

Quercus marilandica Muenchhausen var. *marilandica;* BaO, CrO. Edge of College Woods. Ba697

GELSEMIACEAE

Gelsemium sempervirens (L.) St.-Hilaire; BaR, CrR. Several steep slopes, forming thickets across sphagnous stream heads, along trails in mixed oak woods. Ba84, Cr703

GERANIACEAE

* *Erodium cicutarium* (L.) L'Her. ex Ait. ssp. *cicutarium*; BaR, CrR. A few small plants, sandy soil at edge of woods. Ba744

Geranium maculatum L.; BaO, CrO. Damp wooded ravines. Ba160, Cr177

JUGLANDACEAE
Carya pallida (Ashe) Engl. & Graebn.; BaO, CrO. Sandy soil, often near borders of maturing hardwoods. Highly likely species still in woods and just overlooked. Ba334, Cr263

HYDRANGEACEAE
Hydrangea arborescens L.; BaO, CrO. Wooded slopes, especially along broader and more open ravines. Ba284

* *Philadelphus pubescens* Loisel.; CrR. Persisting from cultivation along trail in mixed oak woods. Cr225

HYPERICACEAE
Hypericum gentianoides (L.) B.S.P.; BaO, CrO. Woodland borders, cutover areas. Ba530

* *Hypericum perforatum* L.; BaC, CrO. Dry soil, cutover areas. Ba342, Cr399

LAMIACEAE
Cunila origanoides (L.) Britt.; CrR. On bare soil in heavy shade, beech-oak woods, near tip of Squirrel Point. Ha4039

Pycnanthemum tenuifolium Schreb.; BaO, CrO. Dry soil, cut over areas and edges of woods. Ba362

Scutellaria incana Biehler; CrO. Sunny shell-marl banks in mixed oak woods. Ba370, Cr480

Scutellaria integrifolia L.; CrC. Open areas, borders of woods, along trails. Ba250

Trichostema dichotomum L.; BaO, CrO. Along trails in mixed woods. Ba537

LENTIBULARIACEAE
Utricularia olivaceae C. Wright ex Griseb.; CrR. Floating in Lake Matoaka. Ba496

MELASTOMACEAE
Rhexia mariana L. var. *mariana;* BaC, CrC. Open areas in woods and woodland borders, typically in sandy soil. Ba447

Rhexia virginica L.; CrR. A few plants found in damp sphagnous depression in mixed oak woods. Cr499

OLEACEAE
* *Ligustrum obtusifolium* Sieb. & Zucc. var. *obtusifolium*; CrR. Persisting from cultivation near old Physics Laser Station. Ha4045

ONAGRACEAE
Oenothera biennis L.; BaC, CrC. Open disturbed areas, along trails. Ba544, Ba566, Ba727

Oenothera laciniata Hill; BaO, CrO. Roadside weed. Ba828

OROBANCHACEAE
Pedicularis canadensis L.; BaC, CrO. Slopes and small draws in maturing hardwoods. Ba44, Cr348

OXALIDACEAE
Oxalis stricta L.; BaO, CrO. Along wooded trails in rich soils. Ba428

PLANTAGINACEAE
Chelone glabra L.; BaO, CrO. Ravine bottomlands. Ba115

Nuttallanthus canadensis (L.) D.A. Sutton; BaO, CrO. Dry soil, cutover areas. Ba115

* *Plantago aristata* Michx.; BaC, CrC. Dry exposed soil, waste places. Ba346

* *Veronica arvensis* L.; BaC, CrC. Borders of woods, roadsides, old pasture and other disturbed areas. Ba42, Ba89

Veronica peregrina L. var. *peregrina;* BaO, CrO. Disturbed soil, and old house site at tip of Squirrel Point. Ba153

POLYGALACEAE
Polygala incarnata L.; BaR, CrR. A few plants in open cutover area. Ba838

POLYGONACEAE
Fallopia cristata (Engelm. & A. Gary) Holub; CrR. One colony on large overturn, open floodplain forest along College Creek. Cr615

* *Persicaria maculosa* Gray; CrC. Open disturbed areas, edges of woods, roadside ditches. Ba343, Ba427, Ba673, Cr656

Persicaria pensylvanica (L.) M. Gomez; BaO, CrO. Grassy disturbed areas, edges of woods. Ba663, Cr598, Cr654, Cr656A

* *Rumex obtusifolius* L.; BaC, CrC. Open cutover areas, edges of woods. Ba336

PRIMULACEAE

* *Anagallis arvensis* L.; BaO, CrO. Cutover areas and disturbed area at the tip of Squirrel Point. Ba254

RANUNCULACEAE

Actaea pachypoda Ell.; BaO, CrO. Usually on steep slopes under fairly mature hardwoods. Ba311, Cr502

* *Aquilegia canadensis* L.; CrR. Persisting from cultivation at old home site. Cr682, Cr729

RHAMNACEAE

Ceanothus americanus L.; BaO, CrO. Dry open woods, typically on sunny banks of lake. Ba302, Ba316, Cr289.

ROSACEAE

Agrimonia parviflora Ait.; CrR. A few individuals found in small tributary to Berkeley Branch near Deer Run Crossing, under beech-oak canopy. Cr267

Aronia arbutifolia (L.) Pers. ; CrO. Open woods, usually in areas with pine. Ba57, Ba720, Cr720

RUBIACEAE

Diodia virginiana L.; CrO. Grassy areas along woodland borders. Ba505

Galium pilosum Ait.; BaO, CrO. Dry wooded areas. Ba519, Cr385

SAXIFRAGACEAE

Heuchera americana L. var. *americana;* BaO, CrO. Damp shaded slopes. Ba201

SOLANACEAE

Physalis heterophylla Nees; CrR. Several individuals established on large overturn in open floodplain woods along College Creek below Jamestown Road. Cr334

Physalis virginiana P. Miller; BaO, CrO. Dry open soil, cutover areas, woodland borders. Ba393

Species historically reported in the College Woods, but not relocated in 1989 or 2015 survey. Asterisks indicate non-native species. Collections are indicated as B = Barans, followed by collector number. All collections are stored at WILLI. Rarity as given in 1968 survey and reported in 1989 survey is written in parentheses BR = rare, BO = occasional. Habitat is reprinted verbatim as reported from 1989 survey.

MONOCOTS
CYPERACEAE
Kyllinga pumila Michaux; BaR. A few in short grass near Mill Neck Road entrance. Ba515

Scleria ciliata var. *elliottii* (Chapman) Fernald; BaR. One colony near wet depression in cutover area. Ba816

HYACINTHACEAE
* *Muscari comosum* (L.) P. Mill.; BaR. Persisting from cultivation, open wooded ravine. Ba173, Ba273

MELANTHIACEAE
Amianthium muscitoxicum (Walt.) Gray; BaR. One colony in open oak-hickory woods. Ba330, Ba425

ORCHIDACEAE
Platanthera cristata (Michx.) Lindl.; BaR. One colony in cutover area. Ba826

POACEAE
Andropogon ternarius Michx. var. *ternarius;* BaR. One colony, woodland border under pines, junction of Rt. 5 and Berkeley Lane. Ba719

Avena sativa L.; BaR. One colony along roadside, probably escaping cultivation. Ba822

Elymus villosus Muhl. ex Willd.; BaR. One population along Mill Neck Rd. Ba510

Triticum aestivum L.; BaR. Roadside, probably escaping cultivation. Ba827

DICOTS
ASTERACEAE

Bidens aristosa (Michx.) Britt.; BaR. One colony along Ironbound Road, low woods. Ba665

BORAGINACEAE
Myosotis arvensis (L.) Hill; BaR. Along trail in damp soil. Ba800

FABACEAE
Lupinus perennis L.; BaO. Open cutover area which are overgrown with herbaceous vegetation. Ba56

Rhynchosia tomentosa (L.) Hook. & Arnott; BaO. Dry woods, along trails or in sunny areas. Ba457

LINACEAE
Linum striatum Walt.; BaO. Dry, open cutover areas. Ba470

MORACEAE
Broussonetia papyrifera (L.) L'Her ex. Vent; BaR. One small plant at edge of woods. Ba729

NYMPHACEAE
Nuphar advena (Ait.) Ait.f. ; BaR. One small colony in College Creek. Ba176

PLANTAGINACEAE
Mecardonia acuminata (Walter) Small. var. *acuminata;* BaR. Cutover area west of old Physics Laser Station.   Ba455

RANUNCULACEAE
Caltha palustris L.; BaO. Colony of plants in swampy area in Main Ravine. Ba69

Ranunculus sceleratus L. var. *sceleratus;* BaR. Open swampy bottomlands, in wet soil or shallow water. Ba213

ROSACEAE
Gillenia trifoliata (L.) Moench; BaR. Open slope adjacent to a cutover area. Ba205

SOLANACEAE
Solanum tuberosum L.; BaR. Woodland dump. Ba432

VIOLACEAE

Viola pedata L.; BaR. Two small colonies, one along a woodland border, one in cutover area. Ba114

Species historically reported in the College Woods for which herbarium voucher specimens could not be located in WILLI. Collections are indicated as B = Barans, C = Crouch, and D = Davis followed by collector number. ◊ indicates species that were not reported as being seen in Crouch (1989). Rarity is reported from Crouch (1989) as C and Barans (1968) as B, followed by R = rare, O = occasional, C = common, A = abundant. Habitat is reprinted verbatim from Crouch (1989).

FERNS AND FERN-ALLIES

PTERIDACEAE
Pteridium aquilinum L.; BaC, CrC. Dry woods, occasionally in dry draws. Ba248

GYMNOSPERMS

PINACEAE
Pinus strobus L.; CrR. One colony spreading from cultivation just south of Monticello Avenue. Seedlings and trees with dbh > 30 cm. found. Cr730

MONOCOTS

CYPERACEAE
Carex atlantica Bailey; BaR, CrR. A few tussocks in deeply shaded sphagnous upper portion of Strawberry Plains Ravine. Cr294, Cr301

JUNCACEAE
Juncus acuminatus Michx.; BaO, CrO. Ravine bottoms. Ba279

POACEAE
Bromus pubescens Sprengel; BaR, CrR. Dry ravine slope under maturing hardwoods. Cr637

Bromus racemosus L.; BaO, CrO. Dry open areas, field, edges of woods. Ba546

Dichanthelium acuminatum complex; CrA. Locally common in young deciduous woods by the old Physics Laser Station field. Cr605.

Dichanthelium dichotomum complex; BaC, CrC. Dry exposed soil in open woods. Ba425

Muhlenbergia tenuiflora (Willd.) B.S.P.; BaA, CrA. Dry woods, paths, and woodland borders. Ba645

Panicum dichotomiflorum Michx. var. *dichotomiflorum*; CrO. Weedy area behind new soccer field. Cr595

MAGNOLIIDS AND EUDICOTS

ASTERACEAE
Prenanthes serpentaria Pursh.; BaO, CrO. Dry soil, woodland borders. Ba679, Ba712

Symphyotrichum prenanthoides (Muhl. Ex Willd.) Nesom; CrO. Mixed woods, moist ravines. Ba582, Ba589

BRASSICACEAE
Barbarea vulgaris R. Brown; BaO, CrO. Woodland borders. Ba113

CALYCANTHACEAE
Calycanthus floridus var. *glaucus* (Willd.) Torr & A. Gray; BaR, CrR. One substantial colony spreading from cultivation on Squirrel Point. Cr264

EUPHORBIACEAE
Euphorbia corollata L.; BaC, CrC. Dry woods. Ba235, Ba262

Euphorbia nutans Lagasca y Segura; BaC, CrC. Open areas, woodland borders. Ba564

ERICACEAE
Vaccinium corymbosum L.; BaO, CrO. Moist woods, ravine slopes. Ba60

FABACEAE
Desmodium perplexum Schub.; CrR. West facing slope in the Aruncus ravine system, maturing hardwoods. Cr542

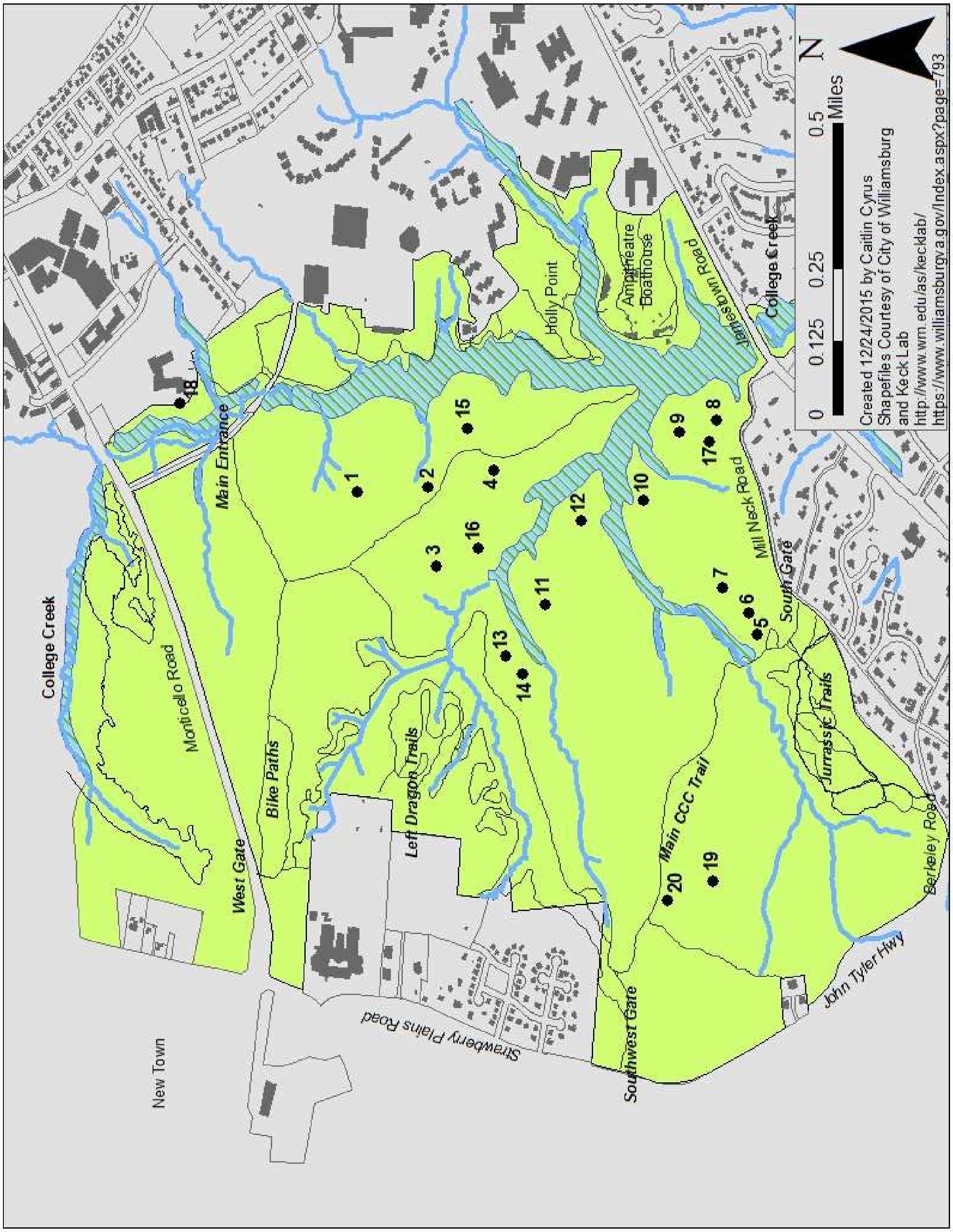
PLANTAGANACEAE
◊ *Mecardonia acuminata* (Walter) Small var. *acuminata*; BaR. Cutover area west of old Physics Laser Station. Ba455

ROSACEAE
Potentilla canadensis L.; CrC. Open disturbed areas, along trails, edges of woods. Ba14, Ba31, Ba51
Rubus occidentalis L.; CrA. Woodland borders, cutover areas. Ba247, Ba386

SOLANACEAE
◊ *Solanum tuberosum* L.; BaR. Woodland dump. Ba432

Appendix D

Map detailing locations of 20 NCVS plots established in the College Woods in 2002 and a table of coordinates.


College Creek
Monticello Road
Bike Paths
West Gate
Main Entrance
Left Dragon Trails
Holly Point
Amphitheatre
Boathouse
Jamestown Road
College Creek
Mill Neck Road
South Gate
Jurrassic Trails
Main CCC Trail
Berkeley Road
John Tyler Hwy
Southwest Gate
Strawberry Plains Road
New Town
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
0 0.125 0.25 0.5 Miles
N
Created 12/24/2015 by Caitlin Cyrus
Shapefiles Courtesy of City of Williamsburg
and Keck Lab
http://www.wm.edu/as/kecklab/
https://www.williamsburgva.gov/Index.aspx?page=793

Supplementary Table 1. Location and status of permanent plots giving plot number used in this research (with the exception of #18) and cross-reference plot tag #, GPS coordinates, compass headings of photographs taken at two stakes and the centerline, and an estimate of hurricane damage from 2003. Compass headings are in the direction of the photographic view. Centerline headings are in the direction of stake 3 when standing at stake 1. Photographs from 2002 may be obtained by contacting either Dr. S. Ware or J. Kribel while 2015 photographs may be obtained by contacting Dr. S. Ware or C. Cyrus. Table and caption modified from Kribel, 2002.

NCVS Plot #	Tag #	GPS Coordinates	Stake 1 Heading	Stake 3 Heading	Centerline Heading	Hurricane Damage?
1	28	N 37 16.399 W 76 43.578	200	10	70	Moderate
2	29	N 37 16.292 W 76 43.571	210	295	165	Severe
3	30	N 37 16.280 W 76 43.689	225	South	100	Moderate
4	31	N 37 16.195 W 76 43.545	West	315	North	Moderate
5	32	N 37 15.802 W 76 43.791	285	West	130	Moderate
6	33	N 37 15.815 W 76 43.759	225	40	150	None
7	34	N 37 15.854 W 76 43.721	190	0	40	None
8	35	N 37 15.863 W 76 43.470	250	120	North	Severe
9	36	N 37 15.917 W 76 43.489	170	30	185	Severe
10	37	N 37 15.971 W 76 43.590	300	300	East	Moderate
11	38	N 37 16.118 W 76 43.746	225	105	45	None
12	39	N 37 16.065 W 76 43.620	80	110	250	Severe
13	40	N 37 16.119 W 76 43.791	135	West	315	None
14	41	N 37 16.241 W 76 43.854	300	195	135	Moderate
15	42	N 37 16.234 W 76 43.483	South	230	290	Moderate
16	43	N 37 16.218 W 76 43.662	230	345	North	Moderate
17	44	N 37 15.873 W 76 43.503	200	East	30	Severe
18	45	N 37 16.662 W 76 43.445	55	275	South	Moderate
19	46	N 37 15.867 W 76 44.158	120	N/A	10	Moderate
20	47	N 37 15.935 W 76 44.187	30	North	West	Moderate

Appendix E

List of species recorded from at least one of 19 NCVS plots in 2015. Asterisks (*) indicates species that were recorded at 0.2m height or above; ◊ highlights woody trees and shrubs found only in the ground layer. + Indicates species unique to the 2015 survey. × indicates species reported in 2002 but not relocated in the 2015 survey. ǂ Indicates species found only in hurricane-damaged plots.

Trees

* _Acer rubrum_ L.
+◊‡ _Ailanthus altissima_ (P. Miller) Swingle
‡* _Albizia julibrissin_ Durazz.
×◊ _Alnus serrulata_ (Ait.) Willd.
‡* _Amelanchier arborea_ (Michx. f.) Fernald
* _Asimina triloba_ (L.) Dunal
* _Carpinus caroliniana_ Walt.
* _Carya glabra_ (P. Miller) Sweet
* _Carya cordiformis_ (Wangenh.) K. Koch
* _Carya pallida_ (Ashe) Engl. & Graebn.
* _Carya tomentosa_ (Poir.) Nutt.
* _Carya_ spp.
‡* _Celtis occidentalis_ L.
‡ _Cercis canadensis_ L. var. _canadensis_
* _Cornus florida_ L.
× _Crataegus_ sp.
* _Diospyros virginiana_ L.
* _Fagus grandifolia_ Erhart
* _Fraxinus americana_ L.
* _Ilex opaca_ Aiton var. _opaca_
×◊ _Ilex cornuta_ Lindley
* _Juniperus virginiana_ L. var. _virginiana_
◊ _Kalmia latifolia_ L.
×◊ _Koelreuteria paniculata_ Laxmann
* _Liquidambar styraciflua_ L.
* _Liriodendron tulipifera_ L.
‡*_Magnolia grandiflora_ L.
×◊ _Morus rubra_ L.
* _Nyssa sylvatica_ Marshall
* _Oxydendrum arboreum_ (L.) DC.
+‡ _Paulownia tomentosa_ (Thunb.) Steud.
‡* _Pinus taeda_ L.
* _Pinus virginiana_ Miller
+‡* _Platanus occidentalis_ L.
◊ _Prunus serotina_ Ehrhart ssp. _serotina_
\+ _Pyrus calleryana_ Dcne.
* _Quercus alba_ L.
* _Quercus falcata_ Michaux.
Quercus nigra L.
◊ _Quercus phellos_ L.
* _Quercus rubra_ L. var. _rubra_
* _Quercus velutina_ Lamarck
+* _Rhus copallinum_ L.
+◊ _Rhus glabra_ L.
* _Sassafras albidum_ (Nutt.) Nees
◊ _Ulmus_ sp.

Woody Shrubs and Vines

+◊‡ _Berberis bealei_ Fortune
‡* _Callicarpa americana_ L.
× _Campsis radicans_ (L.) Seem. ex Bureau
+‡◊ _Citrus trifoliata_ L.
× _Decumaria barbara_ L.
+‡ _Elaeagnus umbellata_ Thunb.
* _Gaylussacia baccata_ (Wangenh.) K. Koch
* _Gaylussacia dumosa_ (Andr.) Torr. & Gray
* _Gaylussacia frondosa_ (L.) Torr. & Gray ex Torr.
Hedera helix L.
‡* _Morella cerifera_ (L.) Small
Parthenocissus quinquefolia (L.) Planch.
+‡ _Rosa multiflora_ Thunb. ex Murr.
+‡ _Rubus phoenicoliasus_ Maxim.
\+ _Rubus_ spp.
Smilax bona-nox L. var. _bona-nox_
Smilax glauca Walt.
Smilax rotundifolia L.
Toxicodendron radicans (L.) Kuntze var. _radicans_
\+ Unknown Sp. 1 (possibly _Viburnum nudum_)
* _Vaccinium_ spp.
\+ _Viburnum prunifolium_ L.
Vitis rotundifolia Michx. var. _rotundifolia_

Ferns

\+ _Asplenium platyneuron_ (L.) B. S. P.
× _Athyrium asplenoides_ (Michx.) A.A. Eaton
\+ _Botrychium_ sp.
\+ _Dennstaedtia punctilobula_ (Michx.) T. Moore
+‡ _Dryopteris celsa_ (Wm. Palmer) Knowlt., Palmer & Pollard ex Small
\+ _Onoclea sensibilis_ L.
× _Phegopteris hexagonoptera_ (Michx.) Fee
Polystichum acrostichoides (Michx.) Schott
Parathelypteris noveboracensis (L.) Ching
+‡ _Woodwardia areolata_ (L.) T. Moore

Other Angiosperms
+‡ *Ageratina altissima* (L.) King & H.E. Robins. var. *altissima*
+‡ *Agrimonia rostellata* Wallr.
+‡ *Ambrosia artemisiifolia* L.
Arisaema triphyllum (L.) Schott
+ *Asarum canadense* L.
Carex spp.
Chasmanthium sp.
Chimaphila maculata (L.) Pursh
+‡ *Cynodon dactylon* (L.) Pers. var. *dactylon*
+ *Cynoglossum virginianum* L. var. *virginianum*
× *Cypripedium acaule* Aiton
+ *Daucus carota* L.
‡ *Desmodium rotundifolium* DC.
Desmodium sp.
Dichanthelium commutatum (J.A. Schultes) Gould var. *commutatum*
Dichanthelium spp.
‡ *Dioscorea villosa* L.
‡ *Elephantopus tomentosus* L.
Endodeca serpentaria (L.) Raf.
Epifagus virginiana (L.) W. Barton
+ *Erechtites hieraciifolius* (L.) Raf. ex DC.
+ *Erigeron* sp.
Euonymus americanus L.
+ *Eupatorium capillifolium* (Lam.) Small
+‡ *Eupatorium* sp.
+‡ *Fragaria virginiana* Duchesne
Galium circaezans Michx.
+ *Galium uniflorum* Michx.
‡ *Hieracium gronovii* L.
+ *Hexastylis virginica* (L.) Small
Houstonia caerula L.
Hylodesmum glutinosum (Muhl. ex Willd.) H. Ohashi & R. R. Mill
× *Geum* sp.1
× *Geum* sp. 2
× *Goodyera pubescens* (Willd.) R. Br. ex Aiton
× *Houstonia* sp.
× *Hexastylis virginica* (L.) Small
Hypericum hypericoides (L.) Crantz
+‡ *Juncus* sp.
+ *Kyllinga* sp.
+ *Lespedeza* sp.
+‡ *Lonicera japonica* Thunb.
+‡ *Liparis liliifolia* (L.) L.C. Rich. ex Ker-Gawl.
× *Maianthemum racemosum* (L.) Link ssp. *racemosum*
‡ *Malaxis unifolia* Michaux
Microstegium vimineum (Trin.) A. Camus
Mitchella repens L.
+ *Monotropa uniflora* L.
× *Galearis spectabilis* (L.) Raf.
+‡ *Oxalis stricta* L.
+‡ *Phytolacca americana* L. var. *americana*
+ Poaceae sp. 1
+ Poaceae sp. 2
Polygonatum biflorum (Walt.) El..
+‡ *Potentilla canadensis* L.
+‡ *Potentilla indica* (Andr.) T. Wolf
Prenanthes sp.
+‡ *Ranunculus* sp.
‡ *Sabatia angularis* (L.) Pursh
+‡ *Sanguinaria canadensis* L.
‡ *Taraxacum officinale* G.H. Weber ex Wiggers
+ *Tipularia discolor* (Pursh) Nutt.
× *Trifolium pratense* L.
× *Trifolium* sp.
+ Unknown Sp. 2
× *Uvularia perfoliata* L.
‡ *Viola* sp.
+ *Youngia japonica* (L.) D.C.

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