RUTGERS UNIVERSITY ECOLOGICAL PRESERVE

2020 Vegetation Inventory

and Survey of the Plant Community of the Rutgers University Ecological Preserve

Prepared by

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Abstract

An inventory of the canopy and understory vegetation communities was conducted of the Rutgers University Ecological Preserve and Natural Teaching Area (RUEP) during the summer of 2020 under the direction of RUEP faculty director, Dr. Richard G. Lathrop. The field measurements were undertaken by Rutgers Ecology & Evolution students Katarina Russell, Katharine Mattaliano, and Emelie Einhorn. The purpose of continuing this inventory is twofold: 1) to periodically maintain a quantitative record of the canopy, shrub, and herbaceous vegetation of the Ecological Preserve; and, 2) monitor and assess changes occurring over time due to invasive pests and other disturbances, as the result of management actions, and how the forest's maturity and successional stage affected its resilience. The inventory revisited field plots first established in 2008/2010 and expanded in number in 2015. Subsequent analysis of the 2020 data and was completed from Fall 2020 to Spring 2022. The 2020 survey found modest increases in understory plant diversity and a decline in tree biomass, most notably among mature oaks (*Quercus spp.*) in the old growth 'Kilmer Woods' section of the forest as well as a sharp decline in ash tree (*Fraxinus*) biomass due to the invasion of the Emerald Ash Borer.

Methods

Field Plot Design and Measurements

The vegetation survey plot was initiated in 2008 with 26 plots in which tree species and DBH were recorded. In 2010, 20 plots were revisited, and tree and herbaceous populations were recorded. In 2011, 4 additional plots were revisited and 12 new plots were established. Herbaceous populations, tree species, and DBH were recorded.

2020 Vegetation Inventory Plot Locations

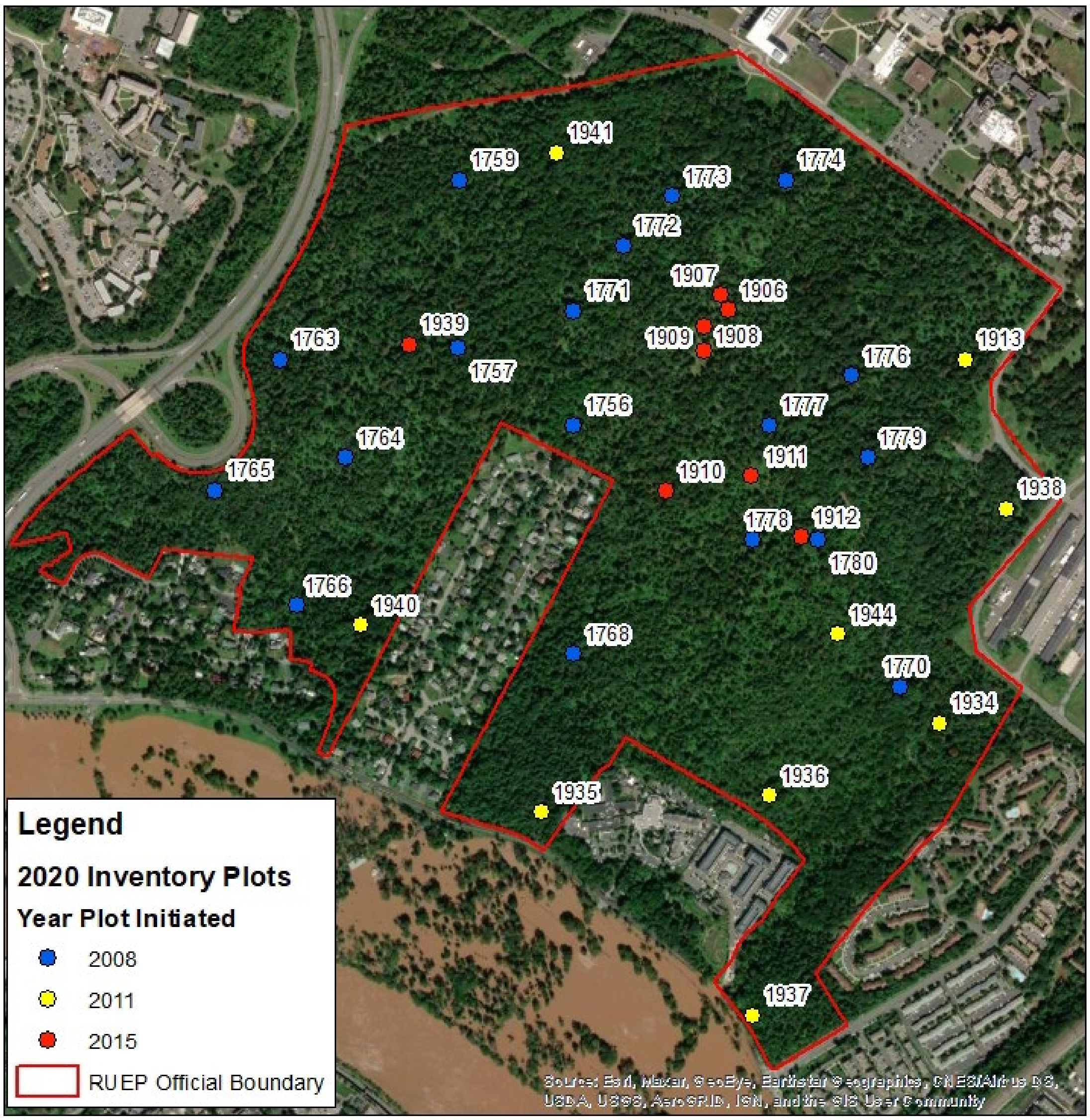

Figure 1: *Of the 40 plots created between 2008 to 2015, 35 were relocated and surveyed for the 2020 vegetation survey.*

In 2015, 27 plots were revisited and eight additional plots were added for a total of 35 plots surveyed. Tree and herbaceous populations were recorded for each plot, and DBH and biomass data was recorded for 34 of the 35 plots. The location for all plots was chosen using a stratified random plot sampling design using ESRI ArcMap software. While new plots were added in several years, plots were also lost over time, such that of the original 26 plots established in 2008, 14 were relocated and revisited as part of the 2020 survey (Figure 1). Of the 12 plots initiated in 2011, 9 were relocated and revisited in 2020. In 2020, the same 35 plots surveyed in 2015 were relocated and resurveyed.

Each plot was relocated and centered based on a central tree that was marked with an aluminum tag. Where there was only one aluminum tag in the tree, the center of the plot was located approximately 0.5 meters in front of the tag. Where there were 2 or more tags in the tree, the center of the plot was approximately 0.5 meters in front of the newest tag. From the plot center, a photograph was taken in each cardinal direction. The canopy plot was a circle with a radius 11.34m and area of 0.1 acres (Figure 2). The canopy layer was measured by recording the species and Diameter at Breast Height (DBH) of each woody stem taller than 2m and DBH > 2.5" within the circular plot.

Horizontal cover of herbaceous and shrubby vegetation was measured in a square subplot placed randomly within the larger canopy plot. One corner of the square subplot was placed at a random distance, 0 to 4m, and a random compass bearing, 1 to 360 degrees, from the plot center. The 4m maximum distance ensured that the subplot did not exceed the edges of a 1m buffer from the edge of the circular canopy plot. The subplot measured 5m by 5m, and was subdivided at intervals of .5m to create an internal grid system with 121 sample points (Figure 3). A dowel rod was touched to each sample point, and any species that touched the dowel rod was recorded. Where one large plant touched several sample points, it was recorded for each sample point. Where multiple individuals of a given species touched a single sample point, that species was recorded only once for that sample point.

To index the vertical cover of understory vegetation, forest secchi measurements were taken in each plot by the method described by Van Clef (Ecological Solutions). The secchi board was held at a height of 0.4m at a distance of 10m from the plot center in each of the four cardinal directions (Figure 2). An observer standing at the center of the plot recorded the number of fully or partially obstructed cells, with the total cover and cover of native and non-native species recorded separately.

An additional survey was performed in spring of 2021 between April 27 and May 12 to capture the diversity of spring ephemeral wildflowers. Each of the 35 plots was revisited. Each spring ephemeral species observed within the canopy plot was marked present. A 5m x 5m sub-plot was randomly placed in the same manner as the subplot of the summer survey. The sub-plot was divided into 12 sections of equal size. Within each section, the approximate percent cover of each species was scored, where a score of 1 indicated up to 5% cover, 2 indicated 5-25% cover, 3 indicated 25-50% cover, 4 indicated 50-75% cover, 5 indicated 75-95% cover, and 6 indicated 95-100% cover.

Analysis

All data was transferred from field notebooks to Microsoft Excel and stored on the Center for Remote Sensing & Spatial Analysis server at X:\projects\ruep\Data\PlantInventory\2020 Inventory Plots\Maps and Layers\Data Layers\Raw field data.xls. The status of a plant as native or non-native was determined by the USDA Plants Database at https://plants.usda.gov. Where the database indicates that a species is both native and introduced, it is counted as native. Tree density was calculated by multiplying the number of trees in a plot by 10, to give the number of trees per acre.

To repeat the indexing process performed in 2015, secchi scores were converted to percent cover by dividing the score by 16 for each of the four measurements taken at each plot. Percent cover was converted to an index from zero to five, such that zero indicated >5% cover, one indicated 6-15% cover, two indicated 16-25% cover, three indicated 26-50% cover, four indicated 50-75% cover, and five indicated 76-100% cover.

Aboveground biomass of trees was calculated based on the methods provided by Jenkins et al. (2003). Jenkins et al. provide a table of values to use for biomass estimation for different species of trees. For species in the RUEP that were not in the table, the value provided for the most similar species was used. Belowground biomass was calculated based on allometric equations derived from Chojnacky et al. (2014), an updated version of the work by Jenkins, et al. Allometric equations were not available to estimate shrub biomass. The amount of carbon sequestered was calculated as ½ the total biomass weight. Tree biomass was compared to 2008, 2011, and 2015, the years for which data is available.

Forest age was determined from the ArcGIS layer forest_age__6 available in the RUEP section of the CRSSA data bank under Maps>maps>20110801_Test_Trl>Map_Forest_Age. This layer was originally created in 2011, but while numerical forest ages may be out of date, successional stages are still largely correct. For the purposes of this report, meadow plots were separated from early successional plots, although they are not differentiated on the map layer.

Results

Species Richness

The summer vegetation survey found 108 plant species (Table 1), including 2 mosses, 8 vines, 30 graminoids, 26 herbaceous species, 15 shrubs, and 32 tree species. Of the species observed, 31 species – 4 vines, 3 graminoids, 10 herbaceous species, 10 shrubs, and 4 trees – are not native to New Jersey.

Table 1: *All species found in the tree canopy survey and vegetation sub-plots. Non-native species are in italics.*

Species				
Trees	**Shrubs**	**Herbs**	**Graminoids**	**Vines**
Acer rubrum	*Berberis thunbergii*	Achillea millefolium	*Arrhenatherum elatius*	*Celastrus orbiculatus*
Acer saccharum	*Elaeagnus umbellata*	Ageratina altissima	Calamagrostis canadensis	*Fallopia convulvulus*
Ailanthus altissima	*Euonymus alata*	*Ajuga reptans*	Carex appalachica	*Hedera helix*
Carya ovata	Euonymus americanus	*Alliaria petiolata*	Carex blanda	*Lonicera japonica*
Carya tomentosa	*Ligustrum lucidum*	Anntenaria plantaginifolia	Carex brevior	Parthenocissus quinquefolia
Celtis occidentalis	*Ligustrum sinense*	Apocynum cannabinum	Carex cephalophora	*Persicaria perfoliata*
Cornus florida	*Ligustrum vulgare*	Asteraceae sp.	Carex exilis	Toxicodendron radicans
Fagus grandifolia	*Lonicera mackii*	*Cardamine impatiens*	Carex pensylvanica	Vitis aestivalis
Fraxinus americana	*Lonicera morrowii*	Circaea lutetiana	Carex platyphylla	
Fraxinus pensylvanica	*Rosa multiflora*	*Dianthus armeria*	Carex radiata	**Mosses**
Ilex opaca	Rubus allegheniensis	*Duchesnea indica*	Carex sp.	Polytrichum commune
Juniperus virginiana	Rubus flagellaris	Euthamia graminifolia	Carex stricta	Sphagnum moss sp.
Malus pumila	Rubus occidentalis	Hackelia virginiana	Carex swanii	
Ostrya virginiana	*Rubus phoenicolasius*	Impatiens capensis	Carex virescens	
Prunus avium	Viburnum prunifolium	Lespedeza procumbens	Carex viridula	
Prunus pensylvanica		*Linaria vulgaris*	Cinna arundinicea	
Prunus serotina		Oxalis europaea	*Dactylis glomeratus*	
Prunus virginiana		*Polygonum cespitosa*	Danthonia spicata	
Quercus palustris		*Polygonum hydropiper*	Deschampsia cespitosa	
Quercus rubra		*Polygonum persicaria*	Deschampsia sp.	
Quercus sp.		Potentilla simplex	Dichanthelium acuminatum	
Quercus velutina		Solidago nemoralis	Dichanthelium clandestinum	
Rhus glabra		Solidago rugosa	Dichanthelium sphaerocarpon	
Sassafras albidum		Symphyotrichum novi-belgii	Festuca rubra	
Ulmus americana		*Vicia cracca*	Juncus tenuis	
Ulmus pumila		Viola sororia	Leersia virginica	
Unknown seedling			*Microstegium vimineum*	
			Poaceae sp.	
			Schizachyrium scoparium	
			Scirpus atrovirens	

During the spring ephemeral survey, 16 herbaceous species (Table 2) were recorded. Of these, 3 species were non-native, and 13 species had not been recorded in the summer vegetation survey.

Table 2: *16 herbaceous species observed in flower during the Spring ephemeral survey, 13 of which had not been seen in the summer vegetation survey. Non-native species are italicized.*

Species	**Common name**
Alliaria petiolata	*Garlic mustard*
Arisaema triphyllum	Jack-in-the-Pulpit
Barbarea vulgaris	*Yellow Rocketcress*
Cardamine concatenata	Cutleaf toothwort
Claytonia virginica	Virginia spring beauty
Erythronium americanum	Trout Lily
Fragaria virginiana	Virginia Strawberry
Galium aparine	Cleavers
Maianthemum racemosum	False Solomon’s Seal
Oxalis dilenii	Southern Wood Sorrel
Podophyllum peltatum	Mayapple
Polygonatum biflorum	Solomon’s Seal
Potentilla simplex	Common cinquefoil
Stellaria media	*Chickweed*
Taraxacum officinale	Common Dandelion
Viola sororia	Common blue violet

Herbaceous Density & Diversity

Herbaceous species richness ranged from 3 to 24 species per plot, with an average of 12 species per plot. *Microstegium vimineum* was the most widespread species, appearing in 32 of 35 subplots. *Lonicera japonica* was similarly widespread, appearing in 31 subplots, but grew more densely, covering 36.9% of all subplot sample points in plots where it was found and 33.7% of all sampled points overall. This made *L. japonica* the dominant understory species by cover in 18 plots, an increase of 8 plots since 2015 (Figure 4). *M. vimineum* covered 33.4% of subplot sample points in plots where it appeared, and 29.7% of all sample points.

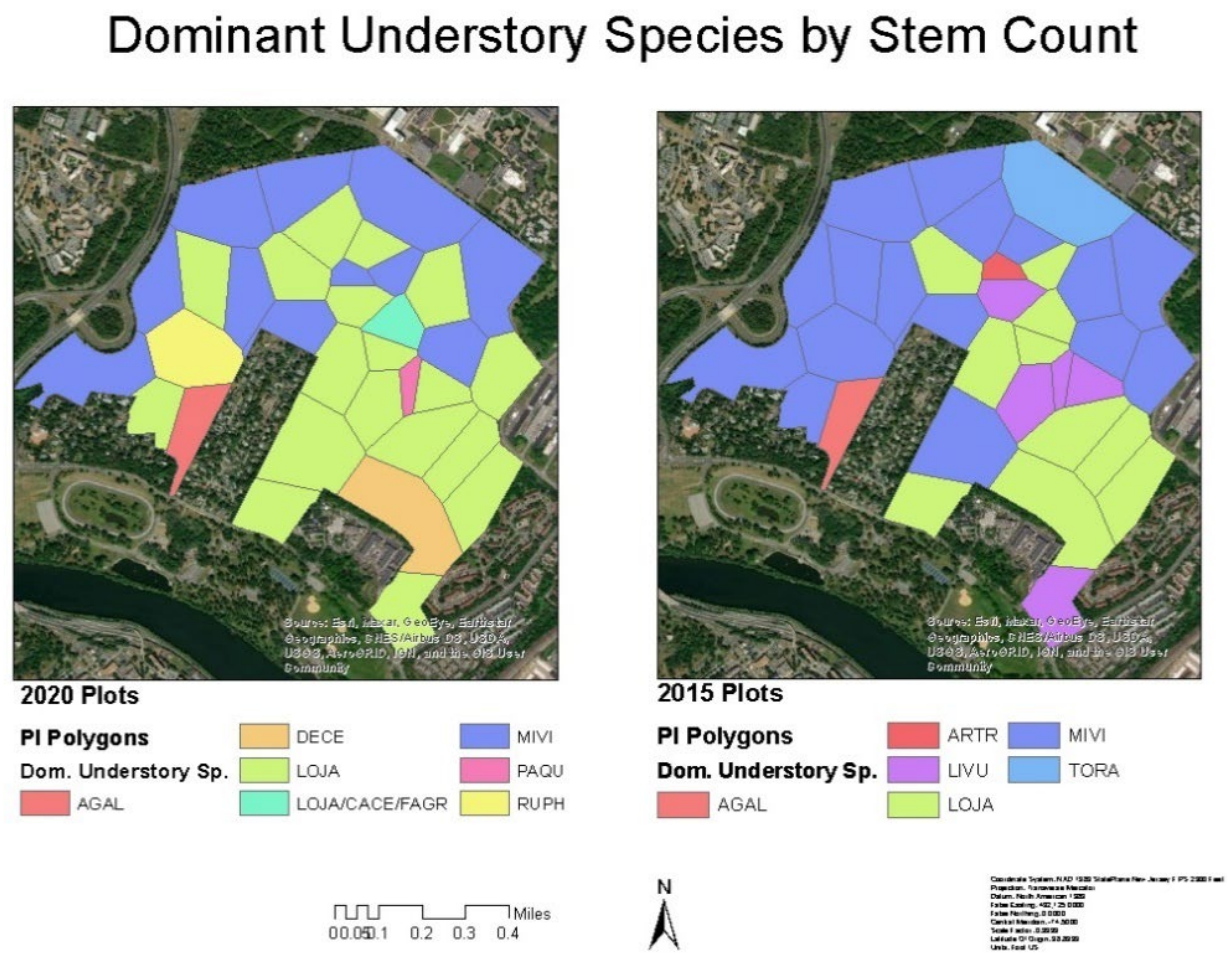

Figure 4: *The most abundant species in each vegetation sub-plot, 2015 and 2020. (AGAL = Ageratina altissima, ARTR = Arisaema triphyllum, CACE = Carex cephalophora, DECE = Deschampsia cespitosa, FAGR = Fagus grandifolia, LIVU = Ligustrum vulgare, LOJA = Lonicera japonica, MIVI = Microstegium vimineum, PAQU = Parthenocissus quinquefolia, RUPH = Rubus phoenicolasius, TORA = Toxicodendron radicans)*

Understory herbaceous diversity of each plot, measured by the Shannon-Weaver Diversity Index (SWDI), ranged from H = 0.40 to H = 2.53 (Figure 5), with an average of H = 1.61, representing an increase in average SWDI since 2010-2011 (H = 0.99) and 2015 (H = 0.68) (Table 3). The SWDI increased across 20 plots between the 2010-2011 and 2020 surveys, while 5 plots showed decreased diversity and 2 plots showed minimal change. Between 2015 and 2020, 5 plots showed a decrease in diversity and 2 showed almost no change. 8 plots showed a steady increase in diversity from 2010 to 2015 to 2020, 2 sites showed a steady decrease, and the other 25 sites showed no steady increase or decrease over time.

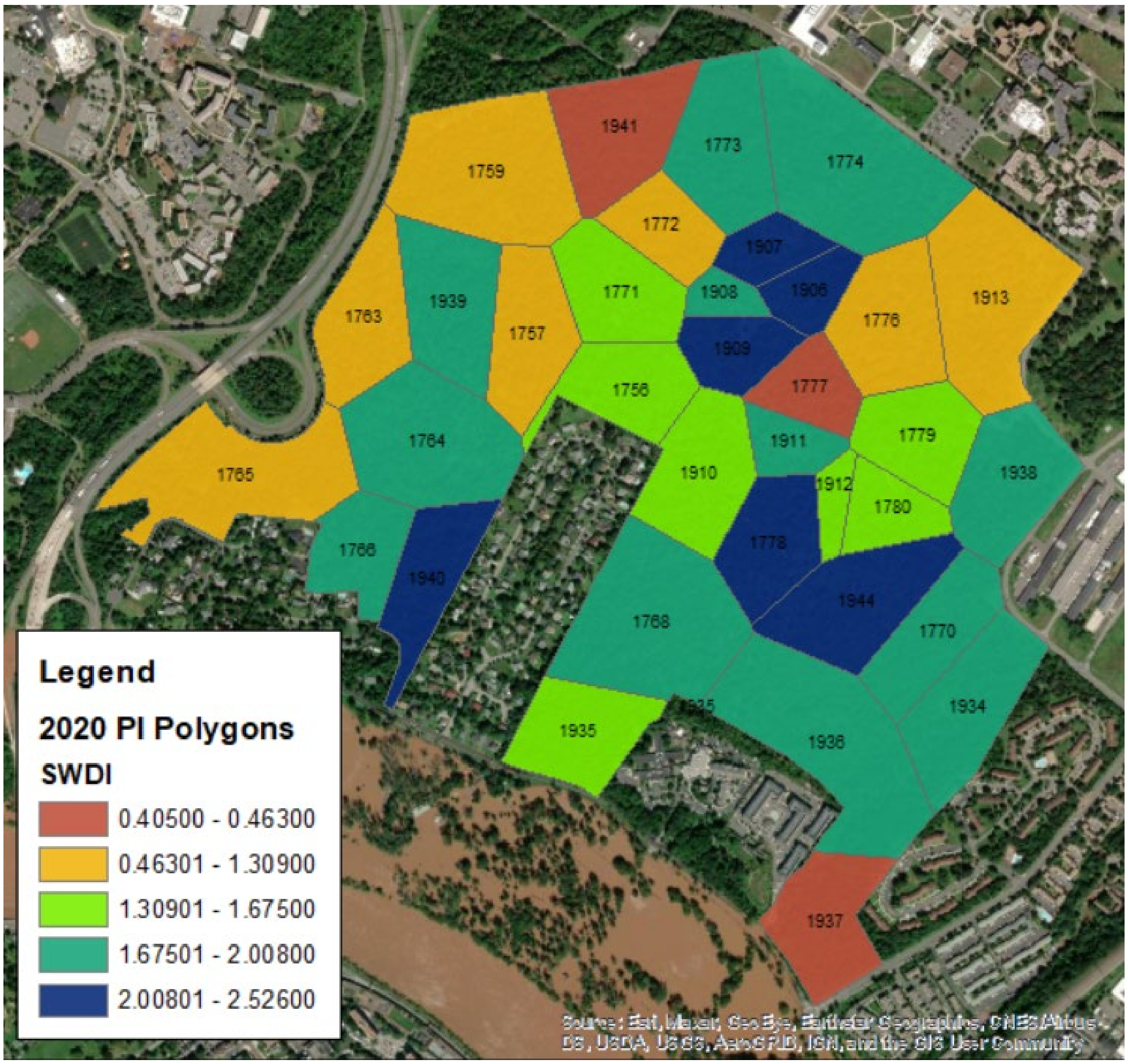

Figure 5*: Shannon-Weiner Diversity Index of understory vegetation measured in sub-plots for each plot*

Understory Vertical Cover

Vertical understory cover, as measured by the secchi methodology, generally increased between 2015 and 2020. The average secchi index of non-native vegetation cover increased from 1.26 to 1.78, and the average secchi index of native vegetation increased from 0.32 to 1.63. In plots in early successional forest, the secchi index of non-native vegetation increased from 1.65 to 1.88, and the secchi index of native vegetation increased from 0.25 to 1.83. For plots in mid-successional forest, the secchi index of non-native vegetation increased from 0.95 to 1.73 and the secchi index of native vegetation increased from 0.31 to 1.86. For plots in mature forest, the secchi index of non-native vegetation increased from 1.38 to 1.75, and the secchi index of native vegetation increased from 0.41 to 0.91.

Tree Density and Diversity

In non-meadow plots, tree stem density ranged from 80 trees per acre to 370 trees per acre, and tree species richness ranged from 1 to 9 species per plot, with an average of 4.8 species per plot. *Quercus palustris* was the most widespread species, occurring in 22 of the 35 plots, and the most dominant by basal area in 15 plots (Figure 6). It is also the most dominant tree by basal area of all plots combined (Table 4).

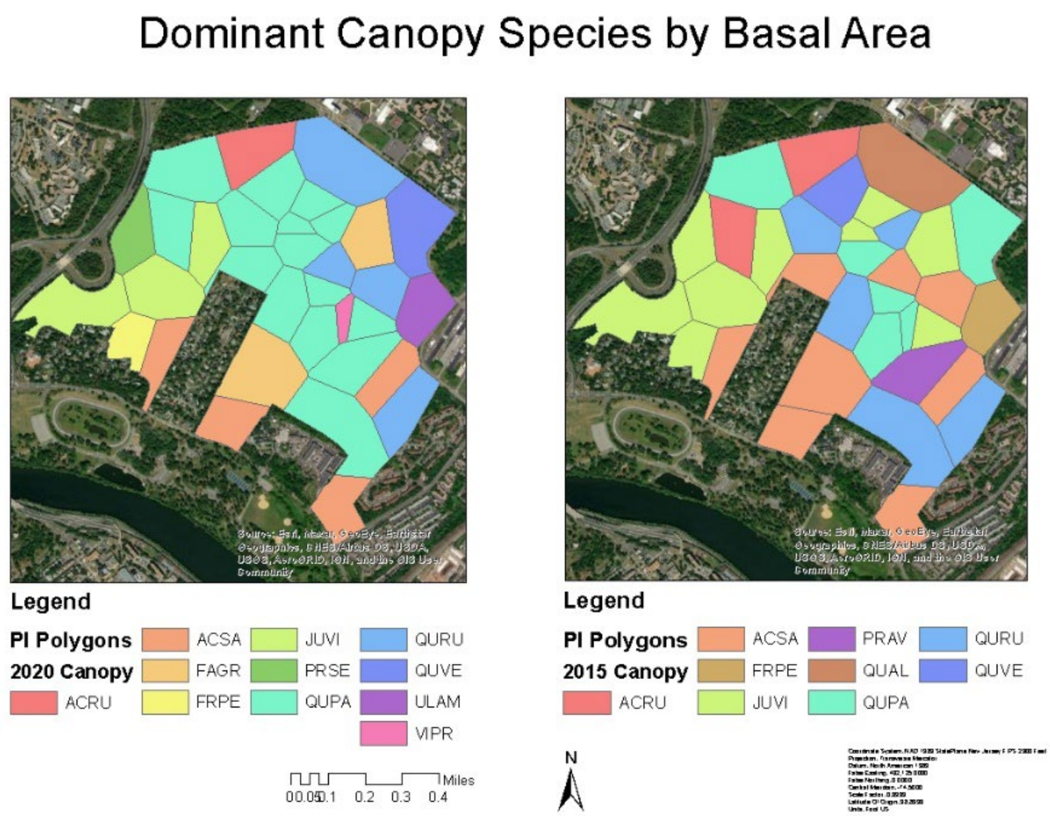

***Figure 6**: Maps show the dominant canopy tree species by basal area in each plot for 2015 and 2020.*

Table 4: *Tree species are listed with the total basal area of those species present in all canopy plots combined, as well as the percent of total tree basal area represented by that species. 13 additional species each constitute less than 1% of tree basal area.*

Species	Symbol	Common Name	Basal Area (ft^2)	% of Total
Quercus palustris	QUPA	Pin Oak	93.92	32.75
Acer saccharum	ACSA	Sugar Maple	33.05	11.52
Quercus rubra	QURU	Northern Red Oak	29.54	10.3
Juniperus virginiana	JUVI	Eastern Red Cedar	28.04	9.78
Quercus velutina	QUVE	Black Oak	21.69	7.56
Fagus grandifolia	FAGR	American Beech	15.08	5.26
Fraxinus pennsylvanica	FRPE	Green Ash	13.9	4.85
Acer rubrum	ACRU	Red Maple	12.11	4.22
Prunus serotina	PRSE	Black Cherry	11.9	4.15
Ulmus americana	ULAM	American Elm	8.34	2.91
Quercus alba	QUAL	White Oak	6.97	2.43

Quercus palustris is the dominant tree species by basal area through central regions of the preserve, while *Juniperus virginiana* and *Prunus serotina* dominate in the western portion and *Acer spp.* tend to dominate in the southeast (Figure 6). *Q. palustris* is the dominant canopy species in more plots than in 2015, in some places replacing the early successional *Acer rubrum* or *Juniperus virginiana* that dominated in 2015. In some plots, the 2020 vegetation inventory identified several trees as *Quercus palustris* where the 2015 inventory misidentified these same trees as *Quercus rubra*. These oaks appear somewhat similar and can hybridize.

Tree Biomass & Carbon Sequestration

The aboveground biomass of all measured trees with DBH > 2.5” is 208.65 Megagrams (Mg), and the belowground biomass is approximately 44.86 Mg, for a total of 253.51 Mg of measured tree biomass. However, tree biomass is not evenly distributed throughout the preserve. Tracts of forests that contain canopy plots range in age from open meadow, to early- and late-successional, to mature forests (Table 7). In old growth sections of the preserve, a total of 42.337 Mg of tree biomass were observed per observed hectare (Table 5). In the western section of the preserve, 28.718 Mg of biomass were observed per hectare, and 19.901 Mg of biomass were observed per surveyed hectare. When adjusted for the relative sizes of these sections, the Old Growth sections may contain 2148.602 ± 742.929 Mg of biomass. The western portion of the preserve may contain 1875.343 ±435.107 Mg, and the younger, eastern section may contain 1114.973 ±465.352 Mg of tree biomass (Table 5).

__Table 5__: Recorded biomass and confidence intervals for forest stands in an early successional stage (Southeast), mid-successional stage (Western), and mature stage (Old Growth).

Section	Recorded biomass (Mg/ha)	CI (Mg/ha)	Lower Bound (Mg)	Upper Bound (Mg)	Area (ha)	Area adjusted Lower Bound (Mg)	Area adjusted Upper Bound (Mg)
Old Growth	42.337	14.639	27.699	56.976	50.75	1405.738	2891.548
Western	28.718	6.663	22.055	35.381	65.302	1440.219	2310.477
Southeast	19.901	8.306	11.595	28.207	56.026	649.630	1580.298

Tree biomass decreased by approximately 13% in the preserve since 2015 (Table 6). Based on comparable plots, tree biomass decreased 37% between 2008 and 2015, then increased by approximately 7% from 2015 to 2020. In the 8 plots measured in 2011, tree biomass increased by 20% from 2011 to 2015, then fell from 2015 to 2020. However, tree biomass did not change uniformly in all plots or plots across all successional stages (Figure 7).

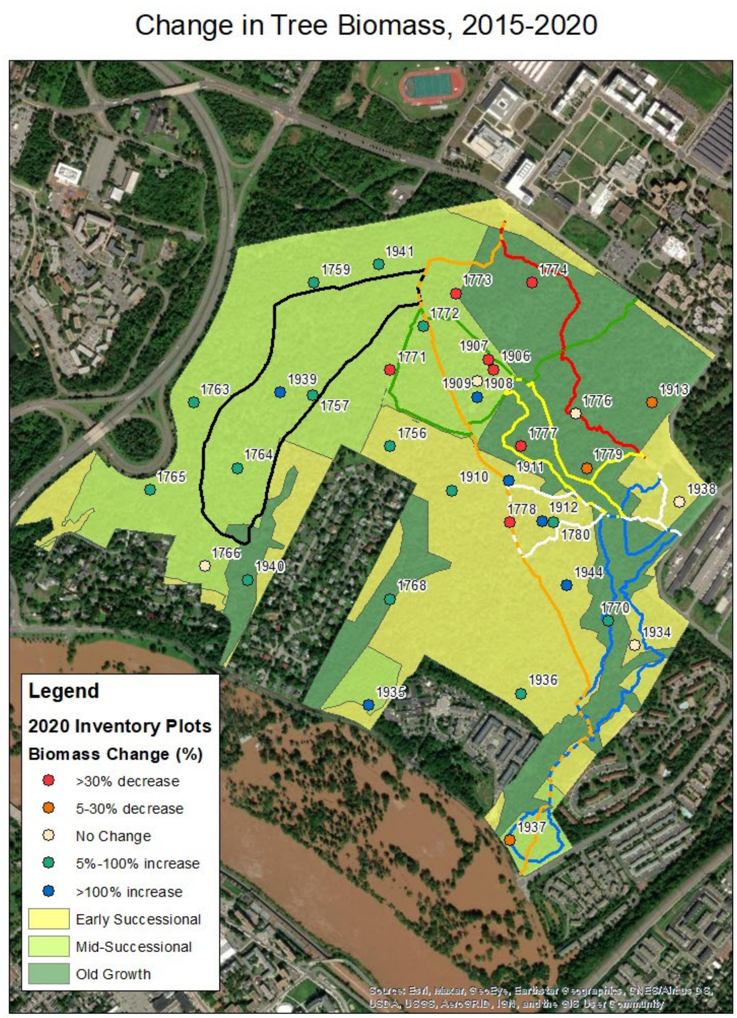

__Figure 7__: Canopy plots, placed in forest stands of varying ages, showed varying loss and gain of tree biomass.

Table 6: Biomass (in Megagrams) for all trees measured in a given year for which DBH data is available.

	2008	2011	2015	2020
14 Plots surveyed in 2008, 2015, and 2020	242.19		152.41	162.91
8 plots surveyed in 2011, 2015, and 2020		51.11	61.61	47.90
34 plots surveyed in 2015 and 2020			285.06	246.66

Tree biomass declined in early-successional and late-successional plots between 2008 and 2020 as well as on the shorter timescale between 2015 and 2020 (Table 7). Tree biomass in mature forest tracts decreased overall between 2008 and 2020, despite a slight increase between 2015 and 2020 (Table 7).

Table 7: Average change in tree biomass in Megagrams per plot for plots in each succession class.

	2008-2015	2015-2020	2008-2020
Mature	-5.08	1.69	-2.20
Late successional	-5.70	-0.94	-6.70
Early successional	-3.22	-3.75	-4.25
Meadow		0.17	

Different species showed varying patterns of change over the 12-year span (Table 8). *Quercus* and *Carya* species lost 30.1% and 88.1% of their basal area over this time period, respectively. Other species did not demonstrate a clear pattern of change, such as *Acer spp.*, which increased in basal area overall but decreased in recent years or *Ulmus spp.*, which decreased in basal area overall, but increased between 2015 and 2020. A few species, such as *Ostrya virginiana* and *Sassafras albidum* showed clear patterns of increase.

Table 8: The amount and percent change of basal area of each species in all canopy plots in mature forest stands

Change in Basal Area (ft^2) and Percent Change, Mature Forest Plots				
	2008 - 2015	2015 - 2020	Overall Change 2008 - 2020	Direction of Change
Acer	7.17	-10.27	1.24	Not Clear
	53.9%	-34.9%	9.3%	
Carya	-2.44	-4.55	-3.06	Decrease
	-70.2%	-85.3%	-88.1%	
	0.04	-0.33	-0.28	Decrease

COFL	11.7%	-82.1%	-80.1%	
FAGR	-3.84	7.61	1.38	Increase
	-35.3%	101.8%	12.7%	
FRPE	2.49	-9.07	-6.59	Decrease
	33.6%	-91.7%	-89.0%	
OSVI	-0.67	1.10	0.43	Increase
			64.8%	
Prunus	-0.01	-0.15	0.07	Not clear
	-1.1%	-10.3%	6.0%	
Quercus	-2.74	-3.99	-11.42	Decrease
	-7.2%	-8.9%	-30.1%	
RHCA	0.00	0.10	0.10	Increase
	Not Recorded 2008 or 2015			
SAAL	0.04	0.05	0.09	Increase
	30.0%	26.1%	63.8%	
ULAM	-1.36	0.65	-0.71	Not clear
	-80.9%	202.6%	-42.3%	
VIPR	-0.41	0.29	-0.12	Not clear
			-28.8%	

Fraxinus

Among the 14 plots for which data is available beginning in 2008, the basal area of living ash trees fell from 26.08 ft^2 in 2008 to 19.02 ft^2 in 2015 to 10.04 ft^2 in 2020 (Table 9). Across all 35 sites with data from 2015 and 2020, the number of ash trees fell from 30 to 27 and the combined basal area of ash fell from 33.4 ft^2 to 11.4 ft^2. 17 out of 35 plots had at least one ash tree in 2015, while only 12 out of 35 plots had at least one ash tree in 2020. Despite the general declining trend, basal area did not uniformly decline in all plots with ash. Six plots saw an increase in ash basal area from 2015 to 2020 as new trees were recruited into the canopy size class of 2.5+ inches DBH.

Spring Ephemerals

The most widespread native spring ephemeral species was *Claytonia virginica*, which appeared in 30 of 35 plots. *Viola sororia* and *Taraxacum officinale* were also somewhat widespread, appearing in 11 and 7 plots respectively. Each of the remaining species were observed in five or fewer plots. *Claytonia virginica* is the most abundant spring ephemeral species, covering on average 2.44% of each plot, with cover ranging from 0 to 19.38%. Most plots contained one or two species. Four plots contained five species each while one plot contained no spring ephemerals at all.

Discussion

The RUEP vegetation inventory is repeated every few years to track changes in vegetation in response to major climatological and ecological events, as well as the slow and regular process of succession. The 2020 vegetation survey recorded more species than any previous vegetation inventory and included the first rendition of the spring ephemeral survey. Changes were noted in the herbaceous, shrub, and tree communities that reflect management decisions made over the past decade.

More species were recorded in the 2020 vegetation survey than in any previous survey. The 2011 survey recorded 58 species and the 2015 survey recorded 87 species. The increased species diversity may reflect use of different subplots in 2020 than in previous years and varying level of familiarity with local flora. The increased number of species is also reflected in the higher Shannon-Weiner Diversity Index.

The results of the understory survey reflect the trend noted in the 2015 Plant Inventory report of increasing coverage of invasive species. The 2010 report indicated that *Carex pensylvanica* was the second most common understory species, but it has now been overtaken by *Microstegium vimineum*. Changes in the relative frequency of *Microstegium vimineum* and *Lonicera japonica*, as well as differences in SWDI values, may reflect genuine differences in population numbers or differences in sampling techniques used in 2015 compared to other years. The 2015 Plant Inventory Report noted that the Shannon-Weaver Diversity Index in the southwestern section of the preserve was considerably higher than other areas, but this is no longer the case. Instead, the central and eastern portions of the preserve are most diverse in the understory.

The increase in vertical understory cover between 2015 and 2020, especially in native cover, reflects reduced damage from deer browse, brought about by deer management programs that are in effect.

Differences in forest maturity appear related to the uneven change in biomass across plots in the preserve. Despite the overall loss of biomass since 2008, mature forests were least effected, losing only 2.2 Mg of biomass per plot compared to a loss of 6.7 Mg in late successional plots and 4.25 Mg in early successional plots (Table 7). There has also been an overall loss of biomass since 2015, but mature forest plots gained 1.69 Mg of biomass while early successional plots performed the worst, losing an average 3.75 Mg of biomass per plot. This may be due to a greater loss of ash biomass in early successional plots.

Mature forest plots saw reduced basal area of oaks and hickories, which number among the oldest trees in the preserve and may be reaching the ends of their natural lifespan. There was also a decline in *Cornus florida*, which tends to be a short-lived species. Ash basal area also declined, though this is a result not of natural aging, but of Emerald Ash Borer. The species that showed the greatest increase in basal area were *Sassafras albidum* and *Ostrya virginiana*, both of which tend to remain relatively small and grow well in existing understories.

Certain species showed no particular pattern of change, as they may not have been included in the canopy measurements of each year. For example, the 2020 survey did not include the sub-canopy layer that was separately analyzed in 2015. This increased the importance of *Viburnum prunifolium* in the canopy category, but not in tree biomass measurements. Future surveyors may wish to re-introduce the separate sub-canopy category.

Practical Implications

Hurricane Sandy, which made landfall in late October 2012, was a major cause of the loss of tree biomass between the 2008 and 2015 surveys. This loss was not reflected in the difference between 2011 and 2015, because the 2011 survey measured only 8 plots. However, among the 14 plots measured in 2008 and repeated in 2015, there was a 37% reduction in tree biomass. It was observed at the time that many downed trees were mature oaks. Mature trees continue to fall in storms, especially in the ravines along Buell Brook.

The emerald ash borer has been present in central New Jersey since 2014 (Department of Agriculture), but may have arrived in the RUEP as late as 2016. Emerald Ash Borers may not be evenly distributed throughout the preserve, as some areas have seen a complete loss of ash while other areas still have mature trees with diameter over 15 inches. Ash trees that displayed symptoms of emerald ash borer infestation, but which had not died, were measured. We expect these and more trees to die in coming years, removing most remaining mature ash trees. Numerous small ash trees were found alive and in good condition, so the species is not extirpated from the preserve. The continued survival of small ash trees is consistent with a study in Michigan, which found that the majority of surviving ash trees in an EAB-infested forest were between 1-2in DBH (Herms et al., 2009).

At 89.49 Mg of carbon per hectare, the RUEP falls below US Forest Service estimations and the IntCarb model. However, the result is in line with carbon stock estimations from Woodall 2013 (Rutgers Task Force). There has been a general decline in tree biomass in the preserve over the last 12 years. In comparable plots, there has been a 13.5% decline in sequestered carbon in only the 5 years from 2015 to 2020. Senescence, storm damage, and the invasion of pests such as the Emerald Ash Borer and, in coming years, the Spotted Lanternfly, pose a serious risk to mature trees in the RUEP. While deer herbivory has been somewhat curbed in recent years by deer management program as evidenced by increasing shrub cover, continued herbivory combined with pressures of invasive plants may in some areas pose a risk to regeneration. This may cause the continued decline in the ability of the RUEP to sequester carbon in the future.

Limitations

Due to temporal and spatial limitations, only about 1% of the RUEP is surveyed. A species-accumulation curve (Figure 8) indicates that this may be nearly the minimum area required to capture most of the vegetative biodiversity in the preserve. The survey failed to capture some species that have been observed only in small or isolated patches, including *Tradescantia virginiana, Scutellaria elliptica, Dennstaedtia punctiloba, Onoclea sensibilis*, *Pycnanthemum tenuifolium*, *Asclepias tuberosa,* and *Asclepias variegata*.

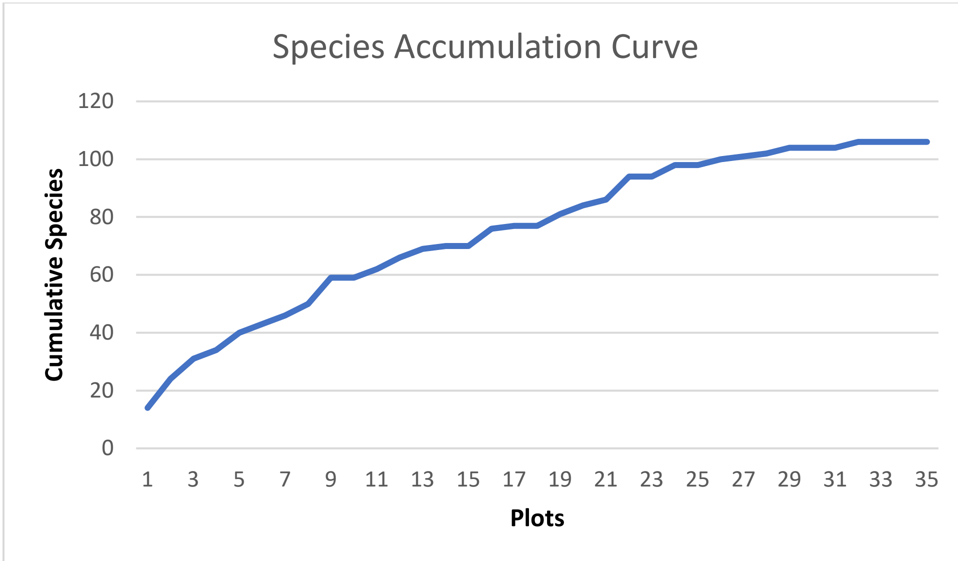

Figure 8: *A Species-Accumulation Curve begins to level off at 108 species at approximately 32 plots, showing that 35 plots is sufficient to capture most of the vegetative biodiversity of the RUEP.*

Recommendations

The 2020 survey discontinued the practice of re-using the precise location of the sub-plot as used in previous years. Using a sub-plot in the same plot is sufficient to show changes and trends over time. However, if future surveyors wish to continue re-using the precise locations of sub-plots, the bearings and distances can be found in the 2015 Plant Inventory report. Future surveyors may also wish to count the number of points in the sub-plot that are 'empty', touching no vegetation at all, to allow the surveyor to assess how much ground space is not covered by vegetation.

The analysis for this survey discontinued the use of the Plant Stewardship Index, which is no longer available online. This survey used equations from Jenkins et al. (2003) to calculate aboveground and belowground tree biomass. Future surveyors should use the updated equations available in Chojnacky et al. (2014), which are slightly changed.

Future surveys should also continue to consider the effects of pests. It may be beneficial to note the health condition of surviving ash trees and factor that into future calculations. Additionally, the spotted lanternfly, which was first spotted in the EcoPreserve in 2020, may begin to influence the mortality of *Ailanthus altissima*, *Acer spp.*, or other woody vegetation in coming years, and this should be explored in future vegetation surveys.

Sources

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Appendix

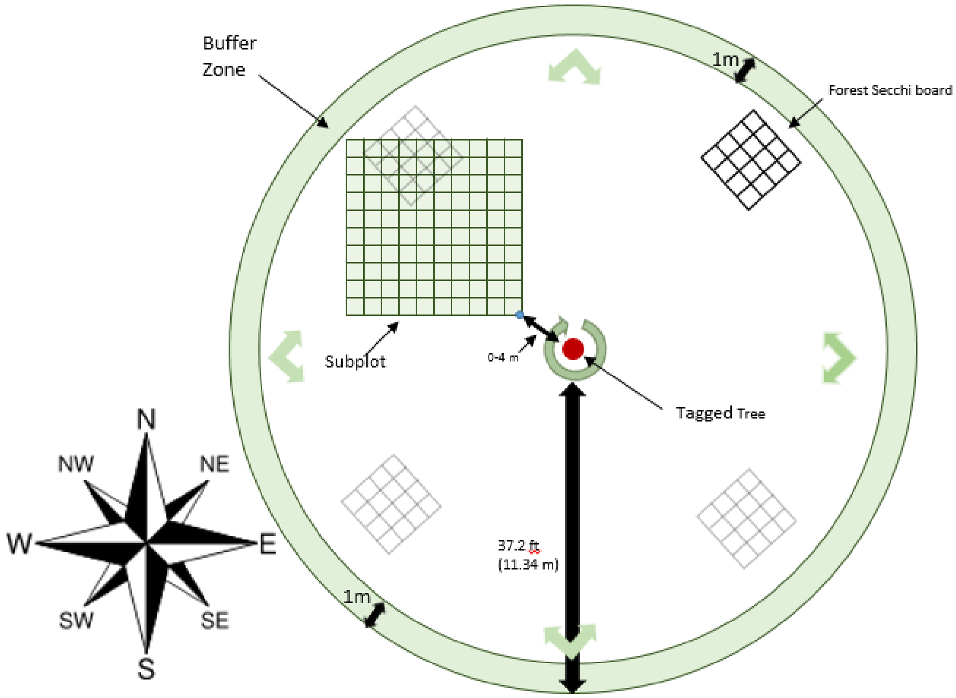

Figure 2*: A bird's eye diagram of the Vegetation Inventory plot with canopy, subplot, and secchi components.*

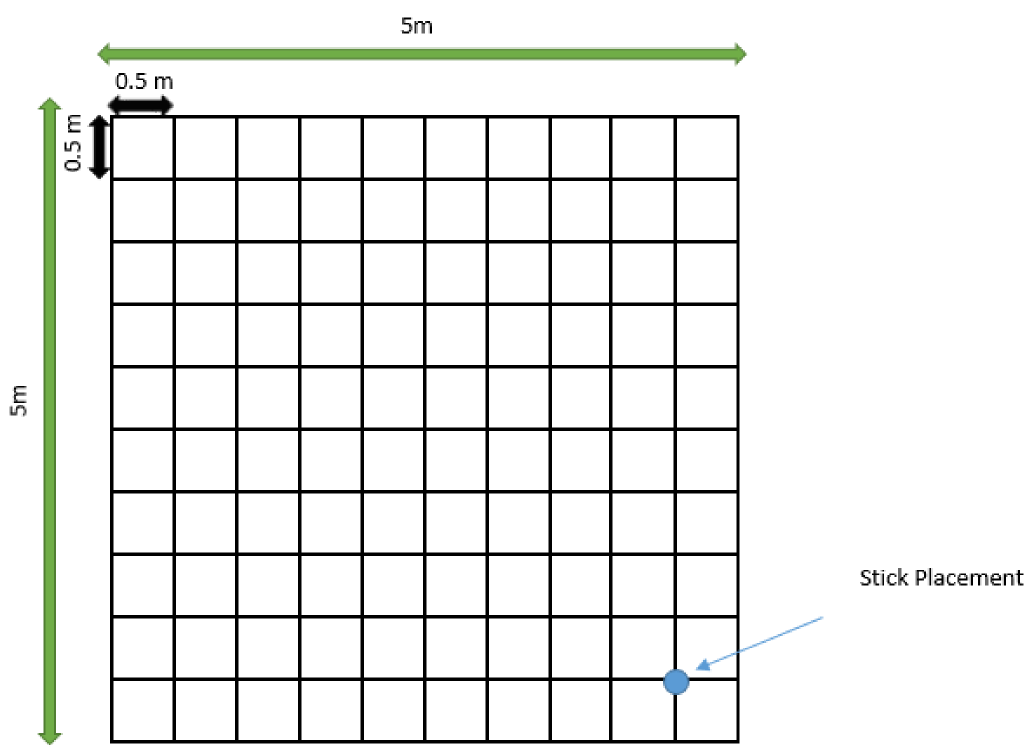

Figure 3: *A bird's eye diagram of the subplot, illustrating the size and sampling locations.*

Table 3: *Shannon Weaver Diversity scores for understory subplots in 2010-2011, 2015, and 2020. Blank cells are present for plots that did not yet exist in 2010-2011 surveys. Cells with zeroes have diversity indices of 0.*

Plot	SW Diversity Index 2020 Understory	SW Diversity Index 2015 Understory	SW Diversity Index 2010-2011 Understory
1756	1.43	0.67	1.88
1757	1.31	0	1.15
1759	1.16	0.92	0.72
1763	1.26	0	0.43
1764	1.95	0	0.87
1765	1.12	0	1.13
1766	1.94	0.93	1.68
1768	1.79	1.03	0.88
1770	1.71	0.56	1.14
1771	1.57	1.67	2.31
1772	1.03	0.66	0.27
1773	1.85	0.68	1.45
1774	1.83	0.82	0.75
1776	1.22	1.04	1.22
1777	0.46	0.45	1.51
1778	2.39	1.55	1.33
1779	1.53	0	0
1780	1.64	1.09	0.64
1906	2.14	1.24	
1907	2.27	0.56	
1908	2.01	0.68	
1909	2.53	0	
1910	1.46	1.55	
1911	1.85	0	
1912	1.50	1.12	
1913	0.94	1.06	1.50
1934	1.91	0	1.12
1935	1.67	0	0.96
1936	1.74	1.31	1.05
1937	0.43	0.60	0.30
1938	1.82	0.86	0.76
1939	1.93	0.69	
1940	2.37	0.53	
1941	0.40	0.90	0.58
1944	2.12	0.60	1.11

Table 5: Tree biomass for each plot for each year of measurement.

Plot	2020 - Total Biomass (Mg)	2015 - Total Biomass (Mg)	2011 - Total Biomass (Mg)	2008 - Total biomass (Mg)
1756	5.53	9.78		16.23
1757	8.21	12.09		
1759	10.52	15.57		17.31
1763	7.23	7.89		9.31
1764	5.22	8.79		7.28
1765	6.67	9.49		9.43
1766	6.84			11.73
1768	12.64	13.17		11.94
1770	5.89	7.07		8.82
1771	16.26	10.76		16.03
1772	7.67	14.49		37.32
1773	9.39	6.57		11.02
1774	11.79	5.87		22.46
1776	4.27	4.21		6.92
1777	11.72	6.48		11.21
1778	5.86	2.66		2.68
1779	14.15	10.81		16.73
1780	1.46	1.71		8.18
1906	6.72	3.33		
1907	7.51	3.50		
1908	2.25	2.33		
1909	0.43	1.71		
1910	9.39	13.81		
1911	2.16	7.33		
1912	2.19	15.34		
1913	19.81	17.07		17.60
1934	11.13	11.24	11.09	
1935	3.78	11.81	9.74	
1936	7.39	8.85	6.61	
1937	9.18	8.03	7.13	
1938	2.30	2.25	1.60	
1939	3.85	11.61		
1940	3.42	5.42	4.95	
1941	8.94	9.70	6.87	
1944	1.77	4.32	3.12	

Table 6: Successional stage and approximate forest age for each plot

Mature (100+)	Mid-successional (60-90)	Early successional (10-35)	Meadow
1768	1757	1756	1906
1770	1759	1765	1907
1774	1763	1778	1908
1776	1764	1780	1909
1777	1766	1910	1911
1779	1771	1912	
1913	1772	1935	
1940	1773	1936	
	1934	1944	
	1937		
	1938		
	1939		
	1941		

Table 9: *Basal areas of ash trees (Fraxinus spp.) in plots with ash for 2008, 2015, and 2020. Blank cells represent plots that did not exist yet in 2008.*

Plot	Ash BA 2008	Ash BA 2015	Ash BA 2020
1756	0	0	0.352
1757	4.426	1.329	0
1763	1.486	1.645	1.47
1764	0.636	0	0
1765	2.417	2.936	3.376
1766	6.571	2.936	3.855
1768	2.431	1.448	0
1770	4.372	2.474	0.684
1771	3.139	0	0
1772	0	0.581	0.092
1774	0	0	0.132
1776	0.601	4.052	0
1777	0	1.807	0
1780	0	0	0.074
1908		0.457	0
1910		0.21	0
1912		0.472	0.492
1935		4.976	0
1936		0.223	0.306
1937		5.372	0
1938		2.143	0
1939		0	0.545
1944		0.332	0.043
Total BA (1756-1780)	26.079	19.207	10.036
Total BA (All plots)		33.392	11.422