# Quinnipiac Meadows Nature Preserve: A Rapid Ecological Assessment

Performed by Dr. Marlyse Duguid's Graduate Course: Ecosystem Measurements for Conservation and Restoration at the Yale School of Forestry & Environmental Studies

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*Photo by Michael Storace*

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# INTRODUCTION

The Quinnipiac Meadows Preserve consists of nine parcels in the City of New Haven currently owned by the New Haven Land Trust (NHLT) and managed for passive recreation. The Preserve lies east of the Quinnipiac River, north of Hemingway Creek, and south of the Little River along New Haven's eastern shoreline. The property currently provides valuable habitat for a variety of sensitive wildlife, along with an open natural space for recreational activities and community members.

To better understand this property's present and future value, as well as its vulnerabilities, student researchers from the Yale School of Forestry and Environmental Studies conducted a multi-pronged, rapid ecological assessment of Quinnipiac Meadows. Through original fieldwork and archival research, the group described and quantified vegetative composition, wildlife presence, and historical use of the land.

Future invasive species management will present an ongoing challenge that may require more financial resources and organizational capacity than NHLT determines feasible, given the current use and management goals of the property. The potential conservation benefits to establishing a tidal salt marsh and upland coastal forest with native vegetation are high; however, the current functions of the Preserve may outweigh the potential efforts required to establish effective restoration.

# LAND USE HISTORY

Prior literature and historical maps of the New Haven area show that the salt marsh lowlands along the Quinnipiac River have long been impacted by anthropocentric uses. Scholars have previously described Native American life around the Quinnipiac Meadows Preserve and the Grannis Island region (see Sargent, 1952; and Menta, 1996, among others). Traces of this indigenous legacy exist throughout the salt marshes of New England in the form of oyster middens and the lasting way these deposits impact soils.

However, the most fundamentally transformative impacts on this site, and the most well documented, have been driven by modern industry and urban development. The lands and waters at the mouth of the Quinnipiac River have been exploited, developed, and degraded continually since New Haven's founding, according to historical reports. In this rapid assessment, student researchers focused their investigation on land use history from 1900 onwards, due to the most dramatic shifts in site usage, hydrology, and topography happening in the past 100 years. Here, the implications of this land use history are explored for the present and future of the Quinnipiac Meadows ecosystem.

## Deed Search

Student researchers from Yale attempted to investigate ownership of Quinnipiac Meadows parcels to find and evaluate site-specific land use and large-scale modifications. However, the organization of New Haven land record documents do not allow one to easily trace ownership beyond one prior owner. Additionally, the ownership of the areas surrounding Quinnipiac Meadows is complex; the region is broken up into so many different parcels that thoroughly tracing all parcels by transactions through time would be a significant, albeit interesting and informative, research project. For instance, the parcels donated to NHLT by Roger Chapman of Blakeslee Arpaia Incorporated were previously purchased from Percy Wheeler Grannis, Blakeslee & Sons Inc. and the City of New Haven. Other evidence from our visit to the New Haven Clerk's Office indicates that Ruel S. Thompson, John C. Bradley, and William E. Grannis also had previous ownership of parcels in Quinnipiac Meadows. Further research into how these landholders used and modified the land could complete the in-depth narrative of recent Quinnipiac Meadows land use.

When, how, and why direct construction and filling activities occurred on the landscape have important implications for the current ecological state of Quinnipiac Meadows. Other records indicate a complicated land use past between railroad companies, the City of New Haven, and the New Haven Water Company. An easement between the New Haven Water Company and the Hartford Railroad Company from 1930 indicates that the railroad company had an ownership stake in the property in the early 20th century. It is possible that the railroad company filled the marsh during the construction of the line to protect its investment.

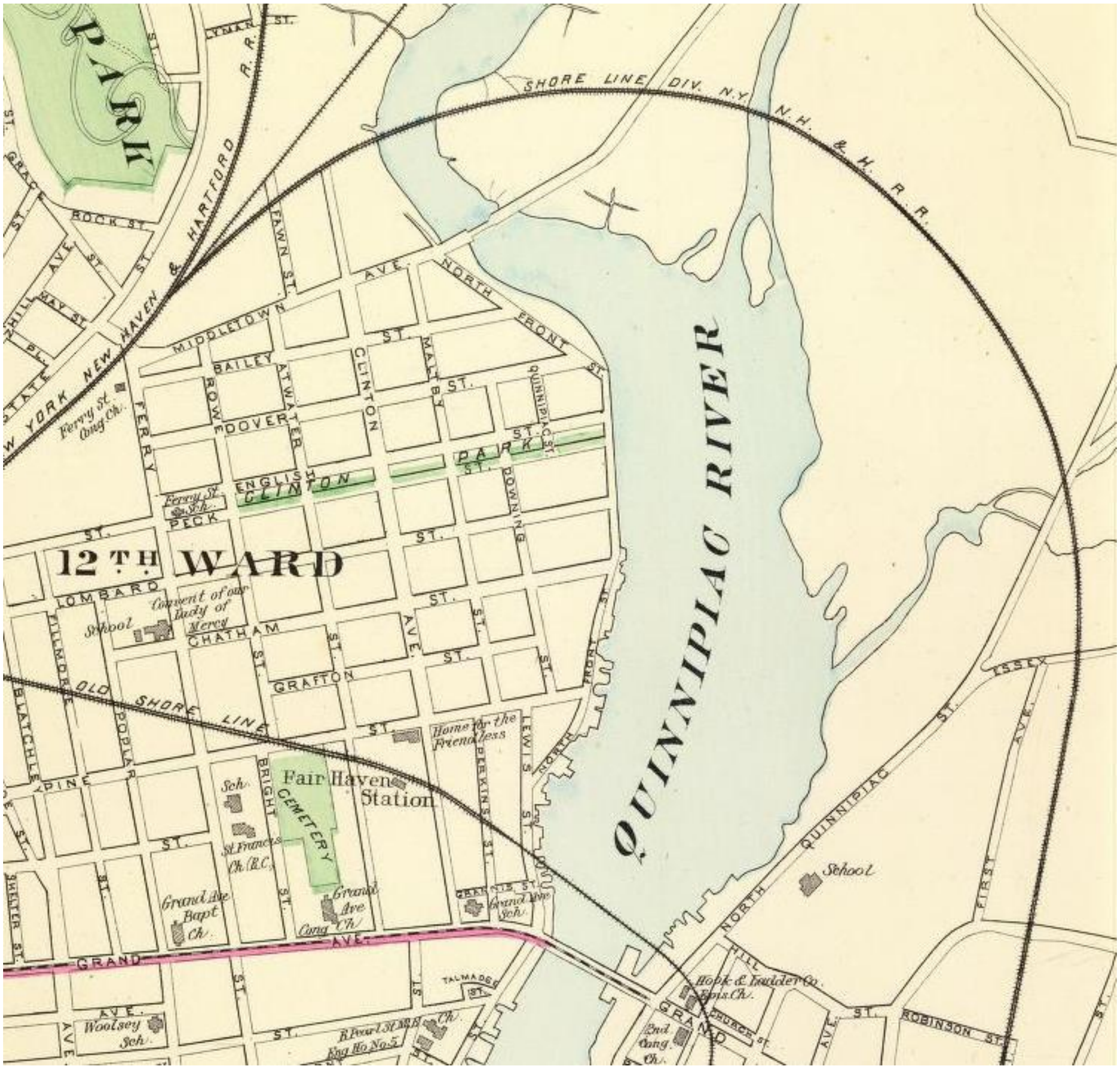


***Figure 1.*** *The undeveloped Quinnipiac Meadows region, east of the Quinnipiac River, from an 1895 map. (Source: David Rumsey Map Collection)*

## Industrialization of the Region and Mosquito Mitigation (1900-1940s)

Prior to 1900, New Haven officials made numerous attempts to convert the city's salt marshes into agricultural land with varied success. However, as the city grew more industrial in the 20th century, and space grew more limited, marsh parcels became more valuable as dumping grounds than as farmland. A former New Haven superintendent of parks was quoted in one instance that reclaiming a particular swamp would "at least afford a good dumping place of which the city is sadly in need" (Casagrande, 1997). This was a common viewpoint of the time. Wetlands were seen, at their most useful, as little more than a dump. Yet throughout this initial wave of urban development and industrialization, Quinnipiac Meadows remained relatively untouched. (Evidence of modern and historic dumping is visible on the site today, including car remnants, several mattresses, a shopping cart, bricks, rebar, and other uncategorized debris.) Prior to 1934 aerial photos show a strip of bright sediment laid atop what is today the River Walk trail on the Preserve (Fig. 2), though the photograph alone does not provide enough information to confirm what the material is.

The early 1900s brought with it new public health concerns, and in turn a new threat to Connecticut's salt marshes. New England citizens worried deeply about mosquito-borne diseases and launched public campaigns to eradicate the insects. Among other techniques, like spraying insecticide, citizens vocally advocated for digging ditch systems in marshland. These ditches lower the marsh water level and deplete mosquito breeding ground (Casagrande, 1997). However, shallow water levels also severely degrade oyster and fish habitat (Quinnipiac River Fund, 2019). About 750 acres of marsh in New Haven were ditched by 1921 (Casagrande, 1997).

According to the earliest airborne photography in the state, the marsh at Quinnipiac Meadows has been ditched since at least 1934. It is possible that the site was ditched around 1913 as part of a major contract deal between the New Haven Anti-Mosquito Committee and the United States Draining and Irrigation Company (Casagrande, 1997). Historic ditches at Quinnipiac Meadows impact the property today by severely altering hydrology, biogeochemistry of soils, and predator-prey dynamics. These manipulated conditions often favor the establishment and dominance of *Phragmites australis,* or the European reed, which is a common invasive (Lashey, 2013).

## Major Filling of the Marshland (1960-1970s)

After World War II, mosquito ditches faded out of fashion in favor of something even more ecologically damaging: filling marshland entirely. In the 1960s, many of New Haven's marshes were filled for parking lots, buildings, and other structures made of predominantly impervious surfaces like concrete and asphalt (Casagrande, 1997). By 1970, New Haven had lost over 60% of its tidal wetlands (Rozsa, 1995). The Quinnipiac Meadows property was not spared: aerial photographs reveal that between March 1966 and September 1969, a major portion of Quinnipiac Meadows's marshland was filled with some type of bright sediment (Fig. 3). It is unclear whether Quinnipiac Meadows marsh was used as a dumping ground for these materials or whether someone intended to fill the marsh in order to build upon the property later and the development, for whatever reason, never happened.

Soil analysis (not undertaken in this field assessment) is necessary to verify what this dumped material may have been. However, historical land use in nearby areas suggest a few possibilities. During this era, other New Haven marshes were used to temporarily or permanently store sediment dredged from the bottom of Connecticut's rivers or the Long Island Sound (Darling, 1961). It is possible that the 1960s deposit on Quinnipiac Meadows was dredged silt from a nearby river or lake bottom. Another hypothesis is that the property was storing material that had been dug up in the construction of Route 91. Although this is less likely, since the highway appeared operational in 1966, before the dumping. Considering the gravel and sand industry in the region, it is plausible that landowners at the time used the Meadows properties for outdoor storage of extra construction materials. (Parcels north of the preserve serve this function to this day.)

***Figure 2.*** *Aerial image of the Quinnipiac Meadows region in 1934. The swath of bright sediment covering the modern-day location of the River Walk trail may be evidence of filling by the Hartford Railroad Company, the New Haven Water Company, or the City of New Haven. (Source: University of Connecticut Library Map and Geographic Information Center)*

***Figure 3.*** *Aerial image of the Quinnipiac Meadows region in 1969. Note that the mosquito ditching is still clear in this photo as the geometric patterns throughout the marshland right of center. There is also clear land filling in the form of the tannish sediment that seems to have been spread around the railroad and into the site's northern half. It is unknown who put this material on the site and what their purpose was, but the effect is undeniable: it turned a marshland into forest. (Source: U.S. Geological Survey [USGS] Earth Resources Observation and Science [EROS] Center)*

This major marsh filling in the 1960s, and the ecological succession of flora and fauna that took place afterwards, is perhaps the biggest disturbance the Quinnipiac Meadows property has undergone on historical record. Historical photography shows an almost immediate vegetative and hydrologic shift after the 1960's land filling, and over time the filled portion of the site developed into upland forest, an ecosystem that likely had not existed on this plot in recent history (Fig. 4).

## Current Land Use

The area surrounding the Preserve is zoned with the City of New Haven as light industrial (LI), planned development unit (PDU), and general business (BA). The parcels immediately surrounding the nine parcels owned by NHLT are all zoned as light industrial and are currently owned by the Grannis Island Company, Inc. The company, owned and operated by Roger Chapman, has historically stored construction materials on 4.6 acres of land that was previously owned by the South Central Regional Water Company. When the South Central Regional Water Company conveyed the land to NHLT, the land trust requested that Grannis Island Company, Inc. remove the stored materials from the property (Grannis Island Company, Inc. v. City of New Haven Planning Commission, 2002).

The Preserve parcels and the immediately adjacent properties are located within the Special Flood Hazard Area (SFHA) Zone AE as defined by the Federal Emergency Management Agency (FEMA) as areas that have a one percent chance of flooding annually. The Quinnipiac Meadows Preserve and the adjacent parcels that are currently located within the SFHA are vulnerable to future flooding and are unsuitable for future development. The area is also vulnerable to future sea level rise driven by climate change. However, the largely developed surrounding land inhibits the ability of the marsh ecosystem to migrate inland, so the marsh will likely succumb to more frequent inundation by 2080 (New Haven Land Trust “You’ll be Under Water!”, n.d.).


***Figure 4.*** *Aerial image of the Quinnipiac Meadows region in 1986. Note the clear outline left by the land fill in the 1969 image. The height of this portion of the site was artificially raised through the process, and by changing its hydrology the filled marshland slowly turned to a patch of land that could support large trees. This segment of the site is now the forested portion of the Quinnipiac Meadows Nature Reserve. This land use evidence helps us understand why there is such a sharp and regular delineation on the site between forest and wetland.*
*(Source: University of Connecticut Library Map and Geographic Information Center)*

# VEGETATION

The entire Quinnipiac Meadows Preserve consists mainly of four vegetation cover classes or “community types”: salt marsh, shrubland ecotone, early successional/wetland forest, and upland forest (Green, 2017). This assessment focuses on the upland forest zone of the Preserve to investigate the community type with the greatest vegetative diversity. The following sections present the results of this evaluation, providing a baseline understanding of the Preserve’s upland forest characteristics to inform future management plans. The work of this assessment also sought to build on an earlier assessment of the site (Green, 2017).

## Field Methods

Guided by the interests of NHLT, student researchers sought to describe and quantify species abundance and diversity across forest strata within the upland forest zone or forest stand, assess invasive species occupation and potential competition with native species, and estimate tree infestation by lianas (woody vines) as a proxy for tree health.

The total upland forest stand comprises 5.97 hectares (14.74 acres), which accounts for 42.13% of the entire Quinnipiac Meadows Preserve area, which is approximately 14.17 hectares (35 acres). To sample vegetation in the forest stand, a systematic sampling approach was employed, and evenly-distributed sample plots were established across the stand. Systematic sampling rather than random sampling was employed to better capture the heterogeneity of vegetation cover observed through aerial photographs and site visits. A random approach may have increased chances of oversampling in areas with similar vegetation character and undersampling in others, thus increasing sampling bias.

Sample plots were established based on the placement of a 50 m x 50 m grid onto aerial imagery of the Preserve using Geographic Information Systems (GIS) software (ArcMap 10.6). The 24 intersection points of the grid falling within the upland forest stand were used as center points for the sample plots (Fig. A-1). At each plot, vegetation was measured within a 10 m, 3 m, and 1 m radius from the plot center (Figure A-2), surveying vegetation types as described in Table 1.

| Plot Details | Data Collected | Rationale |
|---|---|---|
| **Macro plot:**<br>● Ten-meter radius from the plot center<br>● Total area: 0.75 ha (1.86 acres)<br>● Focus: All large trees within radius | **Canopy Trees:**<br>● Tree species<br>● Diameter at Breast Height (DBH), where DBH > 10 cm<br>● Current tree health (visual assessment)<br><br>**Vines (when found present on a given tree):**<br>● Species<br>● Degree of vine infestation (whether vines reach below DBH, between DBH and canopy, or within canopy) | ● To quantify canopy-level species composition, volume and growth.<br><br>● To describe vine infestation as a potential indicator of current or future tree health. |
| **Meso-plot (nested)**<br>● Three-meter radius from the plot center<br>● Total area: 0.067 ha (0.168 acres)<br>● Focus: Shrubs, woody vines and midstory trees within radius | **Shrubs and woody vines:**<br>● Shrub species<br>● Estimated extent of plot cover (%)<br><br>**Midstory trees:**<br>● Tree species, where DBH ranged between 2 - 10 cm<br>● Number of individuals present per species observed | ● To describe the extent of invasive species occupation in this strata (where they appear to be most evident).<br><br>● To describe current midstory occupation, and infer potential future canopy composition. |
| **Micro plot (nested)**<br>● One-meter radius from the plot center<br>● Total area: 0.0075 ha (0.019 acres)<br>● Focus: Tree seedlings, invasive herbs within radius | **Tree seedlings:**<br>● Tree species<br>● Number of individuals present per species observed<br><br>**Invasive herbs:**<br>● Herb species<br>● Estimated extent of plot cover (%) | ● To describe the extent of invasive species occupation in this strata.<br><br>● To assess regeneration activity. |

***Table 1.*** *Summary of vegetative sampling methods. Species cover was estimated using the Daubenmire classification scheme, comprised of six percentage ranges used to guide visual estimations. More information can be found at* [https://www.webpages.uidaho.edu/veg_measure/](https://www.webpages.uidaho.edu/veg_measure/)

## Vegetation Measurements and Data Analysis

Quantitative vegetation measurements were extrapolated from sample plot area to the total forest stand area, to provide an estimate of vegetation characteristics over the entire stand. Specifically, the number of trees present in sample plots and the measure of tree diameter at breast height (DBH) were collected to inform two vegetation indicators: basal area and trees per area.

Basal area is a commonly used indicator in forest management to understand stand density, volume, canopy cover, and tree growth (Elledge and Barlow, 2010). Basal area describes the cross-sectional area ($m^2$) of a single tree at breast height (4.5 feet). To estimate tree density across the entire stand, basal area measurements of individual trees were scaled up using the ratio of the total sample area to the total stand area ($m^2$/ha).

Similar to basal area is trees per unit area (usually expressed as trees per hectare or acre), another common and simple measure of stand density. Because trees per hectare does not consider the size of the individual trees, the measurement is often used to describe density of young stands or midstory trees, but is less relevant in a developed forest.

In this assessment, the basal area of trees larger than 10 cm DBH was calculated, and these individuals were denoted as canopy trees. Trees per hectare was used to describe trees between 2-10 cm DBH, denoted as midstory trees.

## Canopy Trees

The sampling plots contain 14 unique species of native (nine) and invasive (five) canopy trees with a DBH over ten centimeters. Of the plots sampled, 75% contain canopy trees. Based on trees sampled, the average basal area in our 24 plots is 6.07 $m^2$/ha (Fig. 6). Of this, 60% of the plot basal area consists of native tree species and 40% of invasive tree species. Extrapolating these values, the total basal area ($m^2$) of all canopy trees in the upland forest stand is 36.25 $m^2$. The species with the largest basal area across the entire stand is white mulberry (*Morus alba*) with a total basal area of 9.17 $m^2$. A number of other canopy tree species were observed in the Preserve (Table 2).

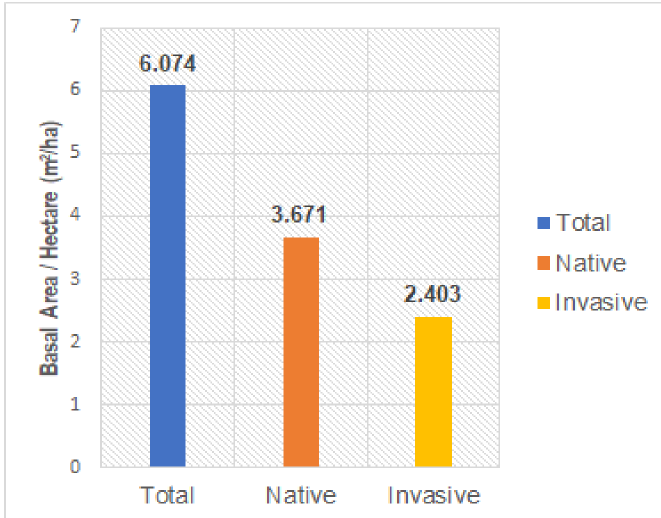


***Figure 5.*** *Estimated basal area per hectare ($m^2$/ha).*

| Common Name | Scientific Name | Native/Invasive | Basal Area ($m^2$) |
|---|---|---|---|
| White mulberry | *Morus alba* | Invasive | **9.17** |
| Black Oak | *Quercus velutina* | Native | **7.18** |
| Eastern Red-Cedar | *Juniperus virginiana* | Native | **4.60** |
| Black locust | *Robinia pseudoacacia* | Invasive | **3.90** |
| Scarlet Oak | *Quercus coccinea* | Native | **2.93** |
| Cottonwood | *Populus deltoides* | Native | **2.89** |
| Paper birch | *Betula papyrifera* | Native | **1.70** |
| Black cherry | *Prunus serotina* | Native | **1.65** |
| Tree of heaven | *Ailanthus altissima* | Invasive | **0.99** |
| Black Birch | *Betula lenta* | Native | **0.53** |
| Yellow Birch | *Betula allegeniensis* | Native | **0.35** |
| Callery Pear | *Pyrus calleryana* | Native | **0.21** |
| Northern Red Oak | *Quercus rubra* | Native | **0.08** |
| Apple | *Malus spp.* | Invasive* | **0.07** |
| | | **TOTAL** | **36.25** |

***Table 2.*** *Basal area by species. * The apple tree is not a native species, but is not considered to be ecologically threatening or compromising due to its agricultural benefits and its acceptance in American culture.*

Fig. 6 shows the distribution of native and invasive canopy tree species using basal area as a percentage of the area occupied by that species across the stand. Of the 40% basal area consisting of invasive species, white mulberry (*Morus alba*) accounts for 25% of the total. The top eight species account for 93% of the entire basal area of the upland forest stand. Six of the top eight species are actually native species, despite the most common tree species being invasive.

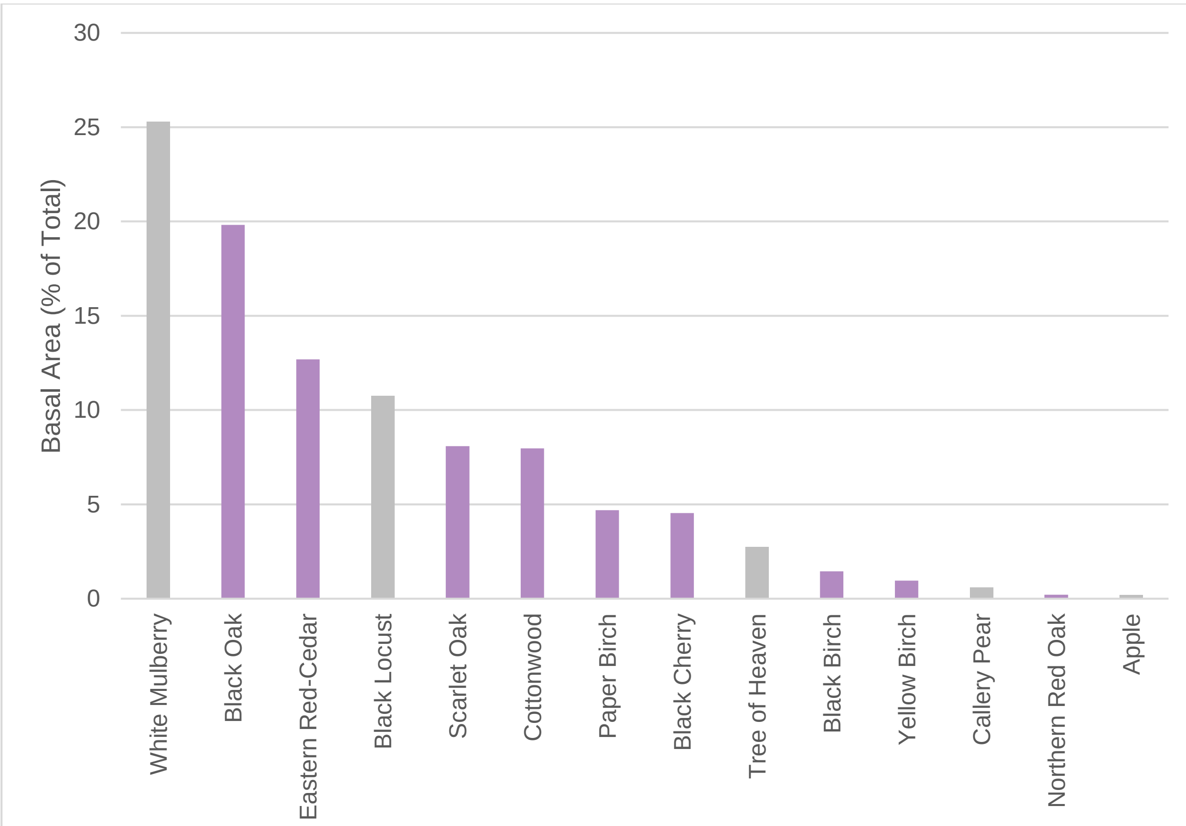


***Figure 6.*** *Native and invasive canopy tree species as a percentage of the total basal area. [Purple – Native; Gray – Invasive]*

Of the 24 plots measured for canopy trees, six did not contain a single canopy tree, revealing several large clearings in the forest. Plot 11 - located within the northeastern corner of the preserve - contains the highest amount of basal area, largely due to the presence of two black oaks measured with larger than 70 cm at DBH. These were the two largest trees measured across the entire stand. The average basal area of an individual plot containing canopy trees is 0.25 $m^2$.

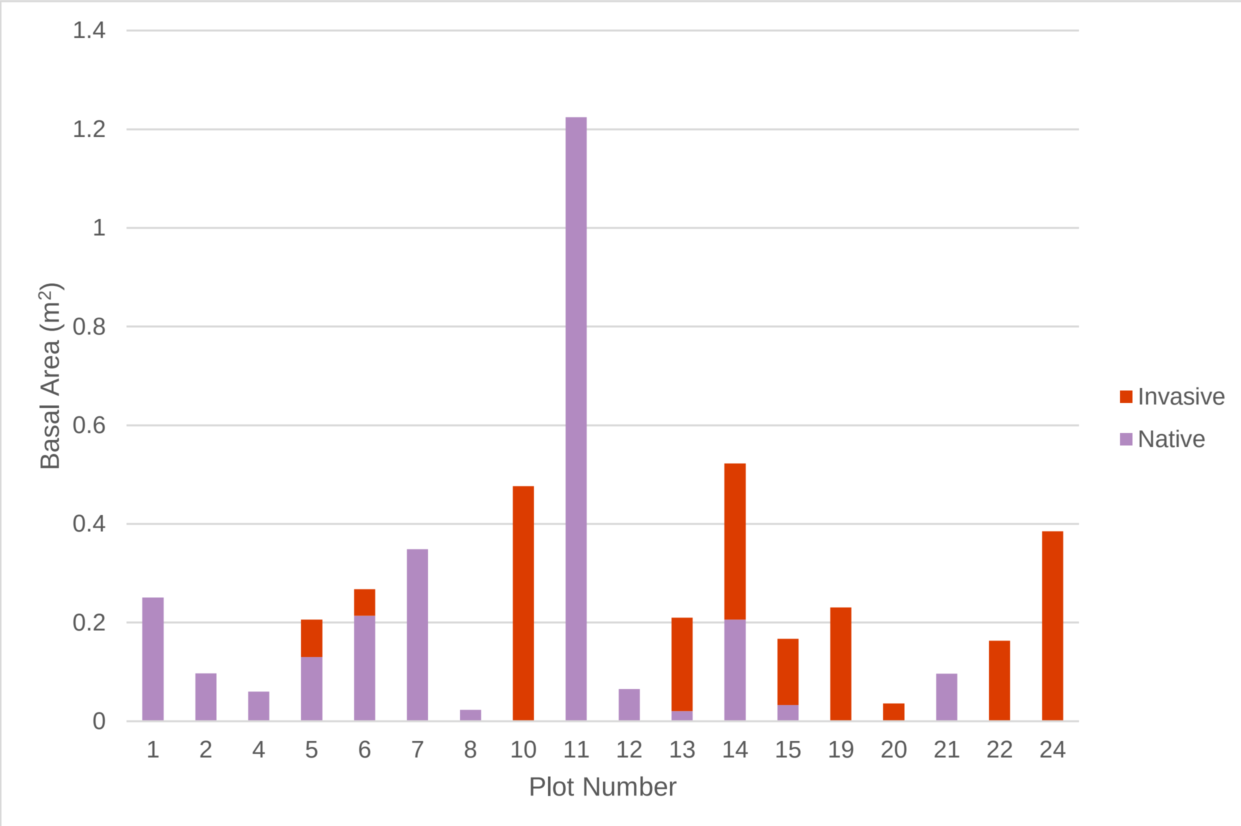


***Figure 7.*** *Basal area ($m^2$) by plot.*

Fig. 7 depicts the basal area of native and invasive canopy tree species by plot. On average, plots on the northern half of the preserve (Plot 1 - 12) contain a higher proportion of native trees by basal area, while the southern plots (Plot 13 - 24) contain slightly higher amounts of invasive species.

Species richness is a measure of the number of unique species within an individual plot. Figure 8 shows that of the 18 plots that contain a tree, there is an average of two species per plot (average marked by a dot). Plot 14 contains the highest amount of unique species, with five species. Eight of the 24 plots contain only one species.

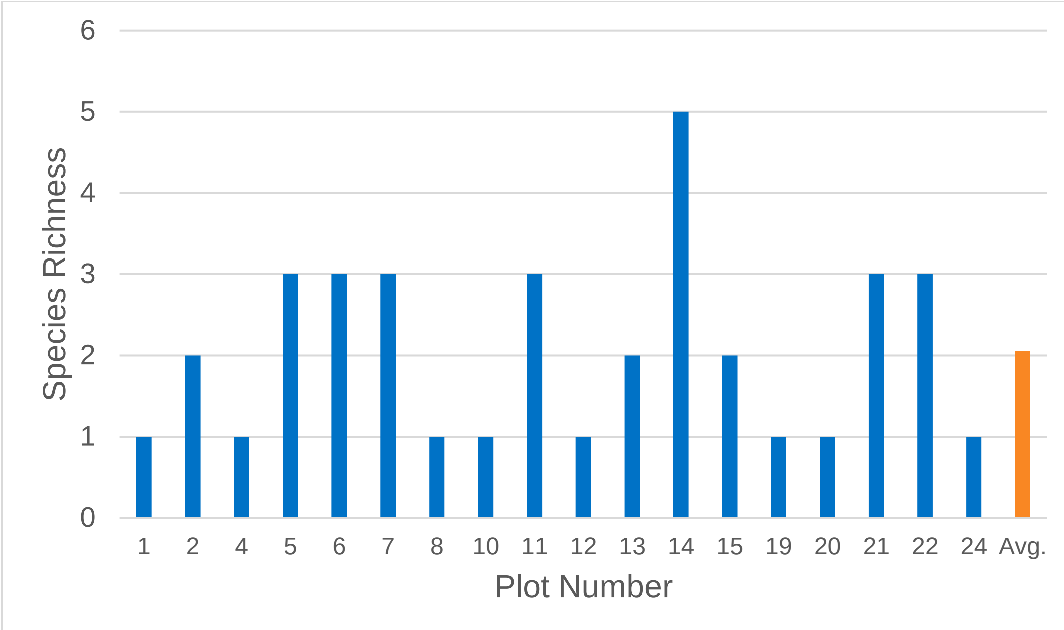


***Figure 8.*** *Species richness (aka species count) by plot, and average species richness.*

The presence of invasive vines in a tree can significantly damage or kill individual trees. Two of the most common invasive vine species in the eastern U.S. are found in the Quinnipiac Meadows Preserve; Japanese honeysuckle (*Lonicera japonica*) and oriental bittersweet (*Celastrus orbiculatus*) (Webster et al., 2006). Though native vine species were not included in the following calculations, two native species were recorded; Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (*Toxicodendron radicans*). Invasive vine species are found in 48.2% of all surveyed trees. Invasive tree species exhibit a slightly higher frequency of invasive vines on average, with 55.7% of invasive trees compared to 42.3% of native trees containing an invasive vine species.

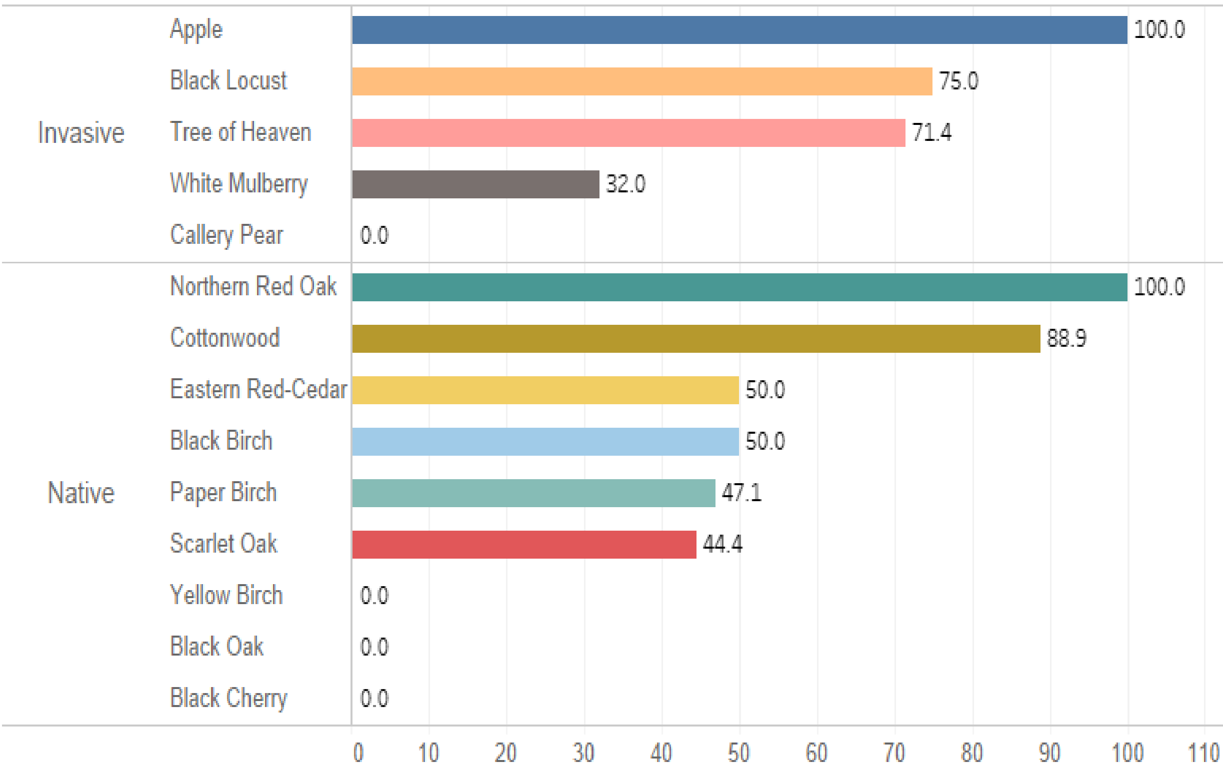


***Figure 9:*** *Percent species with vines present*

## Midstory Trees

Nine species of both native (six) and non-native (three) midstory trees are present in 46% of the sample plots. Eastern red cedar (*Juniperus virginiana*) is the most frequently observed (i.e. captured by the most sample plots) and most abundant (the highest number of individuals), with a total of 12 individuals present in five of the 11 plots; followed by pin cherry (*Prunus pensylvanica*; ten individuals observed in two plots). Based on all plot observations, data suggests an average midstory tree density of 214 (±76) trees per acre, or 529 trees per hectare (Table 3, Fig. 10).

| Common Name | Scientific Name | Native or Invasive | Found in this number of plots | Total number of trees |
|---|---|---|---|---|
| Eastern red-cedar | *Juniperus virginiana* | Native | 5 | 12 |
| Pin cherry | *Prunus pensylvanica* | Native | 2 | 10 |
| Black locust | *Robinia pseudoacacia* | Invasive | 2 | 2 |
| Paper birch | *Betula papyrifera* | Native | 1 | 5 |
| Tree of heaven | *Ailanthus altissima* | Invasive | 1 | 2 |
| White mulberry | *Morus alba* | Invasive | 1 | 2 |
| Apple | *Malus spp.* | Invasive* | 1 | 1 |
| Black cherry | *Prunus serotina* | Native | 1 | 1 |
| Sassafras | *Sassafras albidum* | Native | 1 | 1 |

***Table 3.*** *Summary of observed midstory trees in sample area. * Apple is not a native species, but is also not considered to be ecologically threatening.*

The invasive species observed included black locust (*Robinia pseudoacacia*), tree of heaven (*Ailanthus altissima*) and white mulberry (*Morus alba*). There were only two individuals per invasive species observed across the sample area, although one plot consisted entirely of invasive trees (plot 21, with three trees). Interestingly, all of the invasive observations are limited to southern-most plots, and no midstory trees are captured by the centrally located plots (plots 8-15) which are overrun by the common reed (*Phragmites australis).*

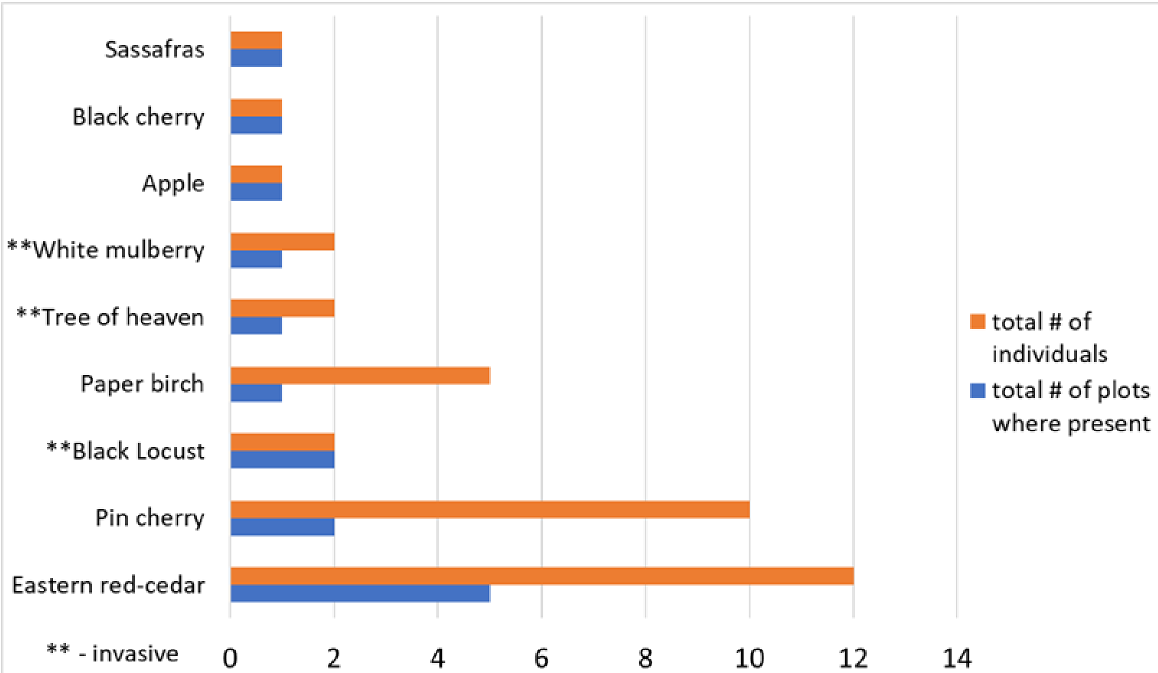


***Figure 10.*** *Summary of observed midstory trees in sample area.*

## Shrubs and Woody Vines

Shrubs and woody vines are present in almost all plots with the exception of one, ranging in cover (based on the median values of the Daubenmire classes) from 5 to 100%. On average, shrubs and woody vines cover at least 30% of the area sampled (at the meso plot scale), amounting to approximately 200.74 $m^2$ (0.05 acres) of the sample area. The data assume that the highest cover class value for any given species in a plot can be equated to the minimum overall plot cover (cover values of different species are not summed, to account for possible species overlap). Extrapolated to stand level, this amounts to 1.77 hectares (4.36 acres) of land cover.

Species composition is found to be mostly invasive. Of the nine species identified, only three species are native: grapevine (*Vitis vinifera*); virginia creeper (*Parthenocissus quinquefolia*); and baccharis (*Baccharis halimifolia*). On average, 2.54 shrub and/or woody vine species are observed per plot. For any given plot there is an extremely strong likelihood that all species present are invasive; a high number of plots (n=18) with shrubs and woody vines present consist of mainly invasive species (at least 94% of the shrub/vine cover present within the plot). The most frequently captured species includes honeysuckle shrub (*Lonicera spp.*), observed in 17 of the 24 sample plots; whereas autumn-olive (*Elaeagnus umbellata)* is the most abundant species, with an average plot cover of 16.35% of plot area.

| Common Name | Scientific Name | Observations (n=24) | Average Plot Cover (%) | Total Area (acres) |
|---|---|---|---|---|
| Honeysuckle shrub** | *Lonicera japonica* | 17 | 12.19 | 1.80 |
| Honeysuckle vine** | *Lonicera spp.* | 12 | 5.73 | 0.84 |
| Autumn-olive** | *Elaeagnus umbellata* | 10 | 16.35 | 2.41 |
| Baccharis | *Baccharis halimifolia* | 5 | 3.54 | 0.52 |
| Multiflora rose** | *Rosa multiflora* | 5 | 1.46 | 0.21 |
| Oriental bittersweet** | *Celastrus orbiculatus* | 4 | 0.52 | 0.08 |
| Buckthorn** | *Frangula alnus* | 3 | 0.31 | 0.05 |
| *Unidentified vine* | *Unidentified vine* | 3 | 0.31 | 0.05 |
| Grapevine | *Vitis vinifera* | 2 | 0.21 | 0.03 |
| Virginia creeper | *Parthenocissus quinquefolia* | 1 | 0.10 | 0.02 |

***Table 4.*** *Summary of observed shrubs and woody vines in sample area. Total Area values are extrapolated, stand-level values based on average plot cover by that species. Average Plot Cover Values are not summed because there may be spatial overlap of species. Common names with two asterisks (**) are known invasive species.*

## Invasive Herbs

Five invasive herb species are observed in 18 of the 24 sample plots, with a wide range of area cover estimates. Of the 18 plots, 39% (seven) exhibit minimal herb presence (between zero and five percent cover), and another 33% (six) are entirely or almost entirely covered by invasive herbs. On average, the minimum cover value is approximately 34%. The most frequently captured species are the common reed (*Phragmites australis*) and mugwort (*Artemesia vulgaris*), observed in ten and nine of the sample plots, respectively. Similarly, these species are the most abundant species across the sample space. Additionally, of the 18 plots, the common reed is the only invasive herb present in 44% (eight) of these; three of which are totally covered. Table 5 provides a summary of sample data.

| Common Name | Scientific Name | Observations (n=24) | Average Plot Cover (%) | Total area (acres) |
|---|---|---|---|---|
| Common reed | *Phragmites australis* | 10 | 14.90 | 2.20 |
| Mugwort | *Artemesia vulgaris* | 9 | 12.40 | 1.83 |
| Garlic mustard | *Alliaria petiolata* | 5 | 8.44 | 1.24 |
| Japanese knotweed | *Fallopia japonica* | 1 | 0.10 | 0.02 |

***Table 5.*** *Summary of observed invasive herbs in sample area. Total Area values are extrapolated, stand-level values based on average plot cover by that species. Average Plot Cover Values are not summed because there may be spatial overlap of species.*

## Regeneration: Tree Seedlings

Within the sample plots, evidence of natural tree regeneration is extremely limited. Four of the 24 plots contain only five seedlings (Eastern red cedar = four; cottonwood = one). One additional planted seedling of the northern red oak species was also captured, but was excluded from data analysis as it is not a product of natural regeneration. Sample data suggest that the average number of seedlings per acre is approximately 322 (±177; a significant degree of spread). There appears to be no distinct association between seedlings and trees of the same species within the same plot. Visual assessment of the site might suggest that regeneration is stifled by the dominance of shrubs and herbs in the understory, which may be out-competing seedlings for resources. Other potential drivers, such as predation or soil conditions, may also be at play.

## Comparison with Undisturbed Upland Coastal Forest

Student researchers had the opportunity to collect data in a healthy, mature mixed-hardwood coastal forest ecosystem at the Yale Peabody Museum's "Richards Property" located in Branford, Connecticut. Coastal development in Connecticut has all but eliminated most of the coastal forest habitat in the state. As a result, this is a fairly novel ecosystem with little comparable data in the literature. This property provides a hypothetical baseline of a mature coastal forest, which the Quinnipiac Meadows upland forest area could *potentially* look like with intensive and consistent treatment of invasive species and intervention efforts to establish dominant native forest tree species. The Richards Property forest is primarily stocked with older native hickory and oak, with some healthy advanced regeneration of sugar maple persisting in the subcanopy. There is also a significant presence of understory trees such as hop hornbeam. In total, 12 tree species were found across the experimental plots.

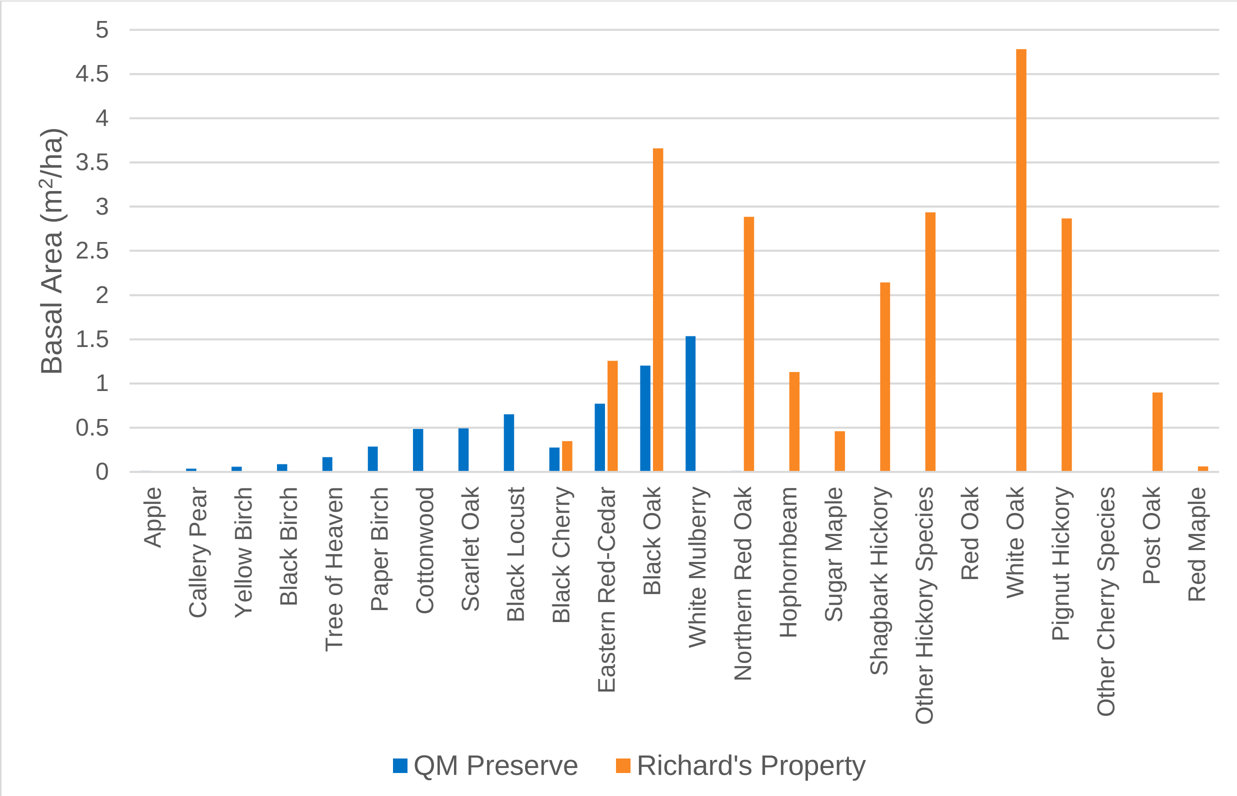


***Figure 11:*** *Basal area of tree species on an undisturbed upland forest in Branford, Connecticut.*

The basal area of the canopy trees in the Richards forest is 25.2 $m^2$/ha -- significantly higher than the 6.07 $m^2$/ha found at Quinnipiac Meadows. The majority of this basal area comes from native oak and hickory species, which is exceptionally different from the coastal forest on the Quinnipiac Meadows Nature Preserve.

# Discussion

The current canopy of the upland forest in the Quinnipiac Meadows Preserve is dominated by white mulberry, black oak, and Eastern red cedar, though there exists substantial heterogeneity across the stand. According to USDA's *The Forests of Southern New England, 2012*, most upland forests are dominated by oak and hickory. In Connecticut upland forests, basal areas range widely from 1.15 to 75.04 $m^2$/ha, with a more representative mean of 27.08 $m^2$/ha (Butler et al., 2012). Compared to other upland forest types in Connecticut, the Quinnipiac Meadows preserve has a very low basal area (6.07 $m^2$/ha) and thus a relatively low stand density. Still, the Quinnipiac Meadows Preserve contains a majority of native species of trees and is relatively diverse for a small parcel of forest.

Within the midstory, sample data suggests a prevalence of native over invasive species. Midstory species primarily consists of eastern red cedar, which parallels canopy tree observations, as well as early successional pioneer species, both short-lived (cherry species) and long-lived (birches). However, given that half of the plots surveyed were devoid of midstory trees, they are evidently concentrated within certain areas, but absent in others. Pioneering species typically expend resources to reproduce quickly as a tradeoff for shorter lifespans, but require sufficient resource access (space, light, water, quality environment) to employ this strategy effectively.

Shrubs and woody vines are found to comprise at least 30% of the sample area, which can be extrapolated to 4.36 acres of total land cover in the upland forest zone. The presence of several invasive species across the majority of the sample plots suggests ample shrub and vine cover in the forest zone that would present challenges for other functional groups to enter and establish themselves within the site. There is a possibility that, given the ratio of invasive to native species, the latter will eventually be overtaken by the former if no management interventions take place.

The current threats to the upland forest include invasive vine species, which are present in nearly half of all canopy trees; very small amounts of regeneration; and the ubiquitous presence of invasive species, particularly *Phragmites australis*. Invasive species are particularly efficient at recruitment and regeneration, and have great tolerance for a wide range of site conditions that allow them to establish and proliferate much faster than many of the native species. The worry with such high levels of vines and such low levels of regeneration is that trees will blow over in storms and be replaced by the more productive invasive species since there is so little regeneration of native species.

# WILDLIFE

## Overview

Quinnipiac Meadows is a small protected area in a much larger urban setting. As such, it was theorized the preserve might constitute important wildlife habitat. The preserve is already acknowledged as an important ecosystem for many birds, in addition to the northern diamondback terrapin (*Malaclemys t. terrapin*). Motivated to learn more about what animals frequent the property, approximately two weeks of photographs from motion-activated wildlife cameras - also known as camera traps - were collected. Over this time, the cameras captured images of numerous bird species, including osprey, great egrets, robins, and tree swallows. The cameras also captured images of various mammals that included muskrat, fox, raccoons, opossums, deer, rabbits, groundhogs, and squirrels. The following sections include the methods and results of the data collection, as well as a brief description of the majority of the animals that were sighted (including a few others known to be present on the preserve).

This survey does not include an exhaustive list of all of the bird species that are found on the property. For a more complete list of these bird species, it would be advisable to contact the Connecticut Audubon Society.

## Methods

In order to assess the wildlife diversity on this site, five wildlife cameras were set up on the property (Bushnell Trophy Cam HD Essential E3 12MP Trail). In order to capture a variety of different habitats, two cameras were placed along the Meadow Walk and three cameras along the River Walk. Cameras were placed two to three feet off the ground and most were secured around tree trunks. Each camera was set to take a burst of three photographs when triggered by its motion sensor.

Cameras collected data for a twelve-day time period in late April. After twelve days, the cameras were retrieved and the images examined. In total, there were 33,725 pictures. Each picture was analyzed by at least one student, but for those with unclear visuals, a second student also viewed them to assist with species identification.

## Results

In total, four bird species were counted (osprey, great egret, robin, and tree swallow) and eight mammals (muskrat, fox, raccoon, opossum, deer, rabbit, groundhog, and squirrel) – a total of 12 species. A house cat was also observed, but was not counted among the wildlife (although a high number of outdoor cats could pose a threat to bird populations). While the student researchers were confident about at least ten of these identifications, the image of the fox was not completely clear and the muskrat images may have indeed been a woodchuck (as such these two species were not included in the descriptions below).

## Discussion

There were a fairly high number of wildlife viewings considering the short time frame of the survey. In order to gain a more comprehensive understanding of the wildlife present at Quinnipiac Meadows, it would be advisable to conduct a camera trap survey over all four seasons. This may be particularly relevant for evaluating avian diversity, especially during bird migration seasons. At these times, one might expect to see an even wider array of species and a greater abundance of individuals per species.

Even with the short survey, the data collected indicates that the Quinnipiac Meadows Preserve is an important wildlife habitat - especially in light of the surrounding development, and the likelihood of increased urbanization in New Haven.

## Species Descriptions and Photos

*Photo by Hagerty Ryan USFWS* https://pixnio.com/fauna-animals/reptiles-and-amphibians/turtles-pictures/diamondback-terrapin-turtle/diamond-terrapin-turtle-reptile-malaclemys-terrapin

**Northern Diamondback Terrapin (*Malaclemys t. terrapin*) – KNOWN TO BE ONSITE**
**IUCN Status:** Vulnerable
**CT ESA:** Species of Special Concern
**Habitat:** Brackish water in salt marshes, tidal creeks and estuaries
**Diet:** Fish, molluscs, crabs, worms, and carrion
**Range:** Cape Cod, Massachusetts to Cape Hatteras, North Carolina
**Threats:** Habitat destruction, illegal collection, oil spills, motor boats, pollution, crab and lobster traps, cars and roads (DEEP, 2015a).


**Osprey (*Pandion haliaetus*) – IMAGE CAPTURED ONSITE**
**IUCN Status:** Least Concern (IUCN, 2016b)
**Connecticut General Statutes Section 26-92:** Prohibit disturbance of ospreys (DEEP, 1997)
**US Migratory Bird Act**: Protected (Kirschbaum and Watkins, 2000)
**Habitat:** Coastal marshes, shoreline, larkes, and river
**Diet:** Mostly fish
**Range:** Expands almost worldwide. They spend the winter in South and Central America, West Indies, Mexico, and Florida before returning to Connecticut in late March
**Threats:** Decrease in nesting habitat due to recreational development, exposure to pesticides in wintering habitat, human presence that leads to increases in predation of young birds and eggs, litter, and human disturbance (DEEP, 1997)
**Ecosystem Services:** Their nests may provide shelter for other, smaller birds. They also may serve as an indicator species for estuaries, rivers, etc. (Kirschbaum and Watkins, 2000)

*Photo by Russ 2018*
https://www.flickr.com/photos/russ-w/44464488862

**Atlantic Marsh Fiddler Crab (*Uca pugnax*) – SPECIES SEEN ONSITE**
**IUCN Status:** No Special Status
**CT ESA:** No Special Status
**Habitat:** Salt marshes
**Diet:.** Particulate organic matter in mud
**Range:** Mostly along Mid-Atlantic coast of the United States (Patterson, 2001)
**Threats:** Land uses that decrease available habitat (South Carolina Department of Natural Resources, 2015)
**Ecosystem Services:** Burrowing in soil helps to increase nutrient availability in soil (Patterson, 2001)


**White-tailed Deer (*Odocoileus virginianus*) – IMAGE CAPTURED ONSITE**
**IUCN Status:** Least Concern (IUCN, 2015b)
**CT ESA:** No Special Status
**Habitat:** Woodlands with herbaceous understory vegetation, as well as fields
**Diet:** Changes based on the season but includes acorns, grasses, twigs, conifer leaves, and hardwood tree buds
**Range:** Found in most of the United States - except for most of California, Utah, and Nevada - and stretches down to Panama and up to southern Canada
**Threats:** Populations had reduced starting in 1700 due to hunting for their meat and deerskin, but have increased dramatically since then. They have few natural predators, and because of their growing populations and their ability to alter habitat, the state now has hunting regulations meant to control the population (DEEP, 1999b)


**Raccoon (*Procyon lotor)* – IMAGE CAPTURED ONSITE**
**IUCN Status**: Least Concern (IUCN, 2015a)
**CT ESA**: No Special Status
**Habitat**: Prefer wooded areas near water bodies like streams or ponds, but can also be found close to human development and agricultural areas
**Diet**: Omnivorous - consumes fruits, assorted nuts, grains, eggs, invertebrates, small rodents, birds, fish, etc. Will also take advantage of trash and pet food
**Range:** Stretch from Canada, throughout most of the United States, to Central America
**Threats**: No major threats to population
**Nuisance Species**: Have been found within human structures, across the urban-nature matrix, and will search for food in garbage cans. Can also carry rabies, canine distemper, and roundworm, among others (DEEP, 2011)


**Virginia Opossum** (***Didelphis virginianus)*** **– IMAGE CAPTURED ONSITE**
**IUCN Status**: No Special Status
**CT ESA**: No Special Status
**Habitat**: Very adaptable: can be found in wooded areas near bodies of water like ponds or lakes, but will also live in woodlots, agricultural areas, and near residential areas
**Diet**: Omnivorous - consumes such things as reptiles, worms, amphibians, and fruit
**Range**: Live in the eastern United States (they arrived in Connecticut in the early 1900s), up to southeastern Canada, and down to Central America
**Threats**: Largest threats include humans and automobiles, but are also subjected to predation from such species as coyotes, foxes, and bobcats (DEEP, 2008)


**Woodchuck (*Marmota monax*) – IMAGE CAPTURED ONSITE**
**IUCN Status:** Least Concern (IUCN, 2016a)
**CT ESA**: No Special Status
**Habitat**: Found in wooded areas along bodies of water like ponds or lakes, but will also live in farmlands, woodlots, and residential areas
**Diet**: Variety of vegetation including clovers, herbs, grasses, along with fruits and twigs
**Ranges**: Found in eastern Alaska, most of Canada, eastern United States, to Georgia
**Threats**: No major threats to population
**Nuisance Species**: Impacts include damage to fruit trees and crops. Their burrows can also cause damage to pastures and lawns (DEEP, 2015b)


**Great Egret (*Ardea albus)* – IMAGE CAPTURED ONSITE**
**IUCN Status**: No Special Status
**CT ESA**: Threatened
**Habitat**: Freshwater bodies of water like ponds or lakes, as well as saltwater marshes. In Connecticut, they often make nests on uninhabited islands in Long Island Sound
**Diet**: Includes fish, amphibians, snakes, mice, crayfish, and insects
**Ranges**: Live in Maine, southern Canada, Great Lakes region, Texas, and states along the Gulf and Atlantic Coasts
**Threats**: Species declined in the twentieth century due to hunting for their feathers. Loss of habitat to development, along with disturbance to their nests from humans and predators, have inhibited increases to their population (DEEP, 1999a)


**Tree Swallow (*Tachycineta bicolor*) – IMAGE CAPTURED ONSITE**
**IUCN Status**: Least Concern (IUCN, 2016c)
**CT ESA**: No Special Status
**Habitat**: Lakes, ponds, marshes, swamps, shorelines, and fields
**Diet**: Assorted insects, as well as occasionally plants and other small animals
**Ranges**: Live throughout the United States and Canada, into Central America for the winter. Connecticut overlaps with their breeding ground
**Threats**: Decline in natural tree cavities for nesting, possible exposure to pesticides through their diet and biomagnification, and increased temperatures due to climate change (Cornell Lab of Ornithology, 2017)

# RECOMMENDATIONS

NHLT's *Preserve Management Plan* for Quinnipiac Meadows states that the ten-year vision for the ecology of the Preserve is to "improve wildlife habitat by eradicating exotic invasive plants and replace them with a diversity of native plants common to Connecticut coastal zones." The plan asserts that aggressive invasive species removal will be conducted using sustainable methods, with physical removal preferable to herbicide application (New Haven Land Trust, n.d.).

The lack of native tree species regeneration found in this study presents a serious concern given the land trust's goal to encourage the current and future ecological health of the Preserve's native vegetation. As previously stated, only five seedlings were found in the 24 plots of this study, with one additional planted seedling. Extrapolated, this represents 260 total (likely red cedar) seedlings in Quinnipiac Meadows. These seedlings were found in open plots that featured less cover by invasive species. The low regeneration is likely a result of (a) exotic invasive species outcompeting native plants and (b) intensive browsing by mammals like deer and woodchucks with little open habitat for forage in the immediate vicinity. Without significant intervention such as regular mechanical removal, intensive herbicide application, or prescribed fires, the density of understory invasives will likely continue to prevent native regeneration from establishing in the Preserve's forested areas.

Considering the extent of highly productive invasive species within the Preserve, any sitewide treatment will be onerous and expensive. Even assuming that NHLT successfully treats and removes the existing exotic invasive species, it would have to continuously follow up with treatments to actively prevent re-establishment of exotic species from buried seed banks or wind dispersal. The Preserve's wetlands have not been a healthy, native ecological community likely since colonial times.

According to aerial photo analysis, significant shrub and tree coverage may not have established on the site until the 1960s after it existed in a severely degraded state for generations due to extensive pollution, ditching, hydrologic manipulation, and filling. Vegetation at the Quinnipiac Meadows Preserve is relatively young and in a stagnant (potentially arrested from lack of seed source or disturbance) successional state compared to other upland forest areas such as those described at the Richards property.

Without a coordinated supra-site plan and significant investment, treatments without continued management could result in a similar or even worse invasion of exotic invasive species like *Phragmites australis* which currently covers nearly the entire lowland marsh areas and much of the clearing in the forest. Considering the surrounding development, transportation corridors, and riverine location--each important vectors for the continued spread of non-native vegetation--non-native vegetation is likely to remain the dominant feature of the Preserve. This is especially the case with the lack of native regeneration and native seed sources in the area. Upstream wetlands on the Quinnipiac River along 1-91 demonstrate the establishment of a pervasive and dominant *Phragmites* monoculture population. In the case of *Phragmites*, successful long-term treatments are associated with the return of brackish or saltwater inundation, which is an unlikely intentional treatment given the surrounding development and location directly on the mouth of the Quinnipiac River (Wolfe, 2018). Additionally, NHLT's own interpretive signage indicates that the entire Quinnipiac Meadows area is likely to be inundated as a result of sea level rise by 2080 (New Haven Land Trust "You'll be Under Water!", n.d.). The land trust may want to focus its restoration efforts on resilient salt-water marsh species that will continue to serve as a defensive, habitat buffer for coastal areas.

In fact, aggressive short-term treatment may have unintended implications for wildlife, which can cause loss of protective cover from predation, or increased stress from human disturbance. This sort of treatment can also impact the performance of the preserve with regard to ecosystem services. For instance, according to recent research, *Phragmites australis* may serve an ecological role in carbon storage and sequestration (Moran, 2018).

General care should be taken to stop *Phragmites* initial establishment; however the invasive species is a challenging competitor whose rapid growth pattern can translate into high biomass content. It typically features relatively tall vegetation, dense thickets of vegetation, deep roots, and rapid growth rates (Moran, 2018). *Phragmites* can also store carbon in the soil when it dies and decomposes into peat. The presence of dense stands of *Phragmites* can play an additional role in building up marshes against sea level rise. So although it is an invasive and lowers biodiversity on the site, it offers benefits which will only become more important in the face of climate change. Exotic invasive species like *Phragmites* can have unexpected boons and their removal can have unintended consequences especially in an interconnected and fragile ecosystem.

This is not to say that successful restoration is not possible. Save the Sound and the Connecticut Fund for the Environment note that the Sunken Meadow State Park saw the return of native smooth cordgrass in place previously inhabited by *Phragmites* once natural tidal flow returned to the area following the breach of a dirt dike by Superstorm Sandy (Connecticut Fund for the Environment and Save the Sound, n.d.).

In short, before investing significant resources in the restoration of a small plot within a much larger area dominated by invasive species, NHLT should consider its financial and managerial capacity for ongoing intensive management that would be required. The state of the Quinnipiac River calls for larger coordination beyond any individual site for restoration. If it has not already, NHLT should consider coordinating resources with neighboring and regional authorities for the overall management of the Quinnipiac River, lest it risks losing significant invasive species removal and restoration investments when new invasive seed stock is carried downstream and onto the Quinnipiac Meadows site.

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# APPENDIX

## Soils

While soil sampling was not conducted as part of this rapid assessment, some soil properties may be determined using state-wide surveys and publicly available information. The marsh portion of the Preserve is classified as part of Connecticut's *Westbrook mucky peat* soil unit, similar to much of the marshland along the southern Quinnipiac River. The forest that has developed on the filled marsh is trickier to classify. The Connecticut Soil Survey dubs this zone a *smoothed Udorthent* (Table A-1).

| **Unit Name** | **Westbrook mucky peat** | **Udorthent, smoothed** |
|---|---|---|
| *Parent material* [1] | Herbaceous organic material over loamy drift and/or marine deposits | Varies |
| *Natural drainage class* [1] | Very poorly drained | Moderately well-drained |
| *Soil Order* [2] | **Histosol**. Forms in organic materials. Half or more of upper 80cm is organic. | **Entisol**. No diagnostic soil horizons due to very young soil, unaltered from parent material. |
| *Soil Suborder* [2] | **Hemist**. Wet, organic materials. Ground water at/near surface. | **Orthent**. Loamy, very fine sand, 35% by volume or more rock fragments. |
| *Soil Group* [2] | **Sulfihemist**. Sulfidic materials within 100 cm of the soil surface. Ultra-acidic. | **Udorthent**. Generally acid to neutral. Often result of earth-moving activities. |
| *Moisture Regime* [3,1] | **Mesic**. Moist, well-balanced moisture supply year-round. | **Udic**. Well-distributed rainfall. Amount of rainfall + stored moisture exceeds evaporation. |
| *Acidity* [3] | **Euic.** Soil pH 4.5 or higher | Unknown |

***Table A-1.*** *Soil properties of Quinnipiac Meadows. Data sources as follows: 1 = Soil Survey Staff, n.d.; 2 = Soil Survey Staff, 2014a; 3 = Soil Survey Staff, 2014b.*

## Sampling Method

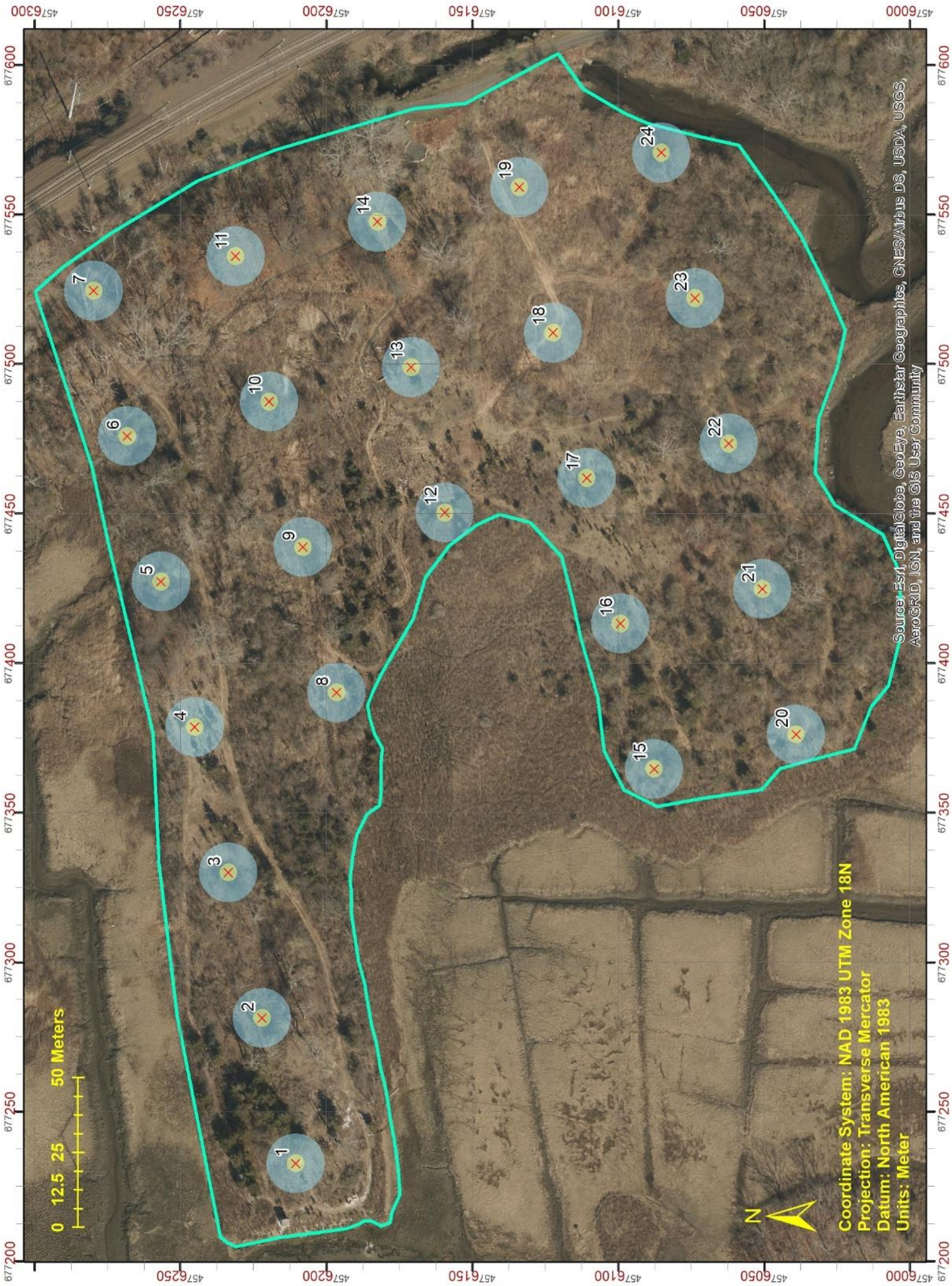


***Figure A-1.*** *Upland forest zone (outlined in green) and vegetation survey sites.*

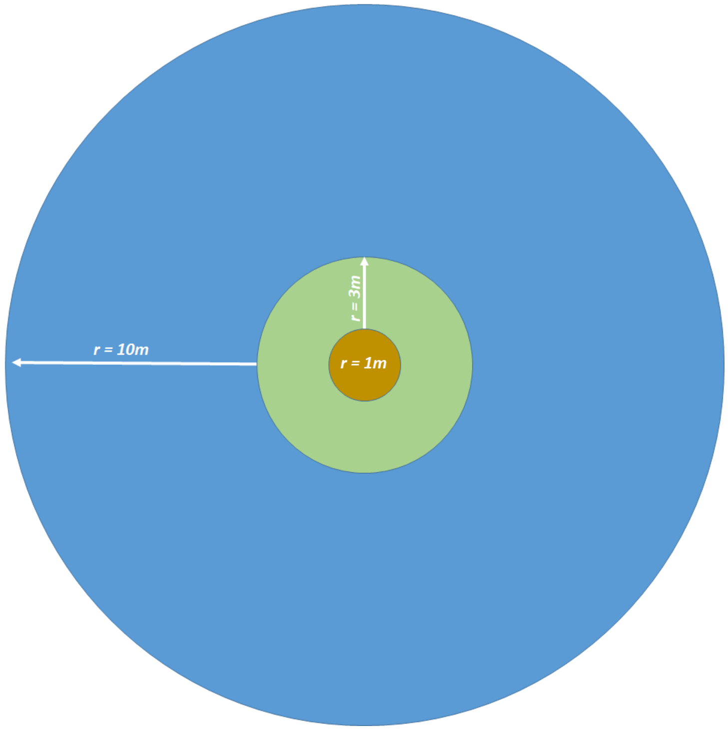


***Figure A-2.*** *Sample plot diagram with 10 m (blue), 3 m (green) and 1 m (orange) radii.*