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# New London Urban Forestry: Inventory and Analysis

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# New London Urban Forestry Inventory and Analysis 2018

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Class of 2019

Thank you to the Public Works Department for an engaging summer internship. Thank you to Connecticut College faculty, staff, and fellow students who helped me through this educational journey. Thank you to the friends who encouraged me through the ups and downs.

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# Table of Contents

Acknowledgements ........................................... 2
Table of Contents ............................................. 3
Introduction ..................................................... 4
Results ............................................................. 10
Suggestions ...................................................... 24
Apendex ........................................................... 27
Sources ............................................................ 29

## Purpose of Study

Connecticut has the third highest growing urban land-use development percentage between 1990-2000[1]. These rates have continued through the last 20 years. In New London the urban forest is well past its prime[2]. Dave Denoia, Tree Warden of New London, explains the challenges of overseeing a city's urban forest on a tight budget. The Public Works department is given $8million, but only $2,500 is allocated to trees. This is broken into planting, which is allotted $1,000, and tree maintenance. Required limb removal for safety, clearing and crown raising is standard maintenance work and is given the remaining $1,500. This does not go very far in municipal terms. As a result, the office relies heavily on Eversource Power for utility pruning, which is more focused on the power lines than the trees. The Parks Conservancy voluntarily plant municipal trees and the New London Beautification Committee plants occational ornamental trees in addition to perennial flowers[3].

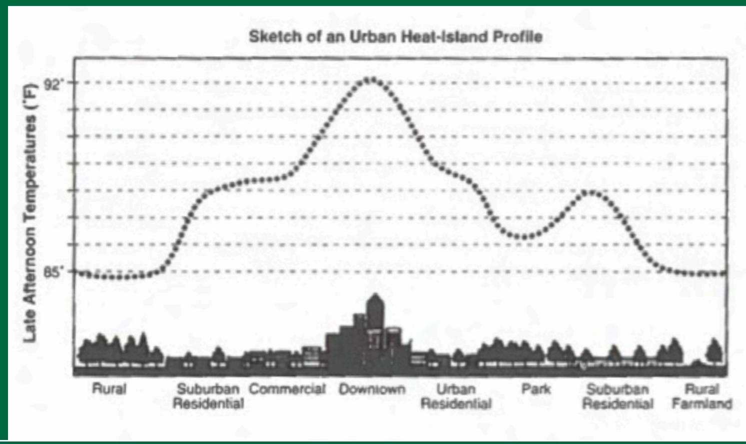


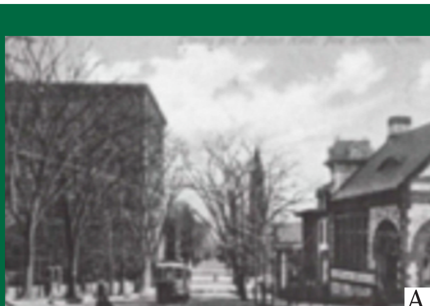

Figure 1: Image the temperature change from the "heat-island" effect in a hypothetical city. (From Akbari et al, 1992).[5]

A street tree inventory was completed in 1993, totalling 2,935 trees comprised of 55 species. There was also an incomplete inventory from 2011 listing 1,000 street trees, but becasue the information was incomplete, it is inconclusive for evaluation. In recent years, there has been a push to improve the urban forest of the city. Due to incomplete and outdated records, a new inventory was needed.

Because of the tight budget and aspirations to improve the city's tree canopy, in January 2017, New London Public Works applied for an America the Beautiful grant, which would match the city's financial contributions for rebuilding the urban canopy.

New London is a diverse community with varied necessities based on rich history and culture. Founded in 1646, the waterfront began New London's legacy as a port city, streets lined with unique shops, restaurants, and cultural attractions. New London was Connecticut's most-distressed city in 2017. The grant was to aid in improving the urban forest, estimated about 1200 municipal trees, based on the incomplete 2011 inventory, for the benefit of the diverse population of 27,615[4]. The grant was awarded in March 2017 and the inventory began in May 2018.

This document expresses the results of the summer 2018 tree inventory and analyses the significance of the information. The research will help inform future improvements on the current inventory as well as a new management plan set into action for the years to come.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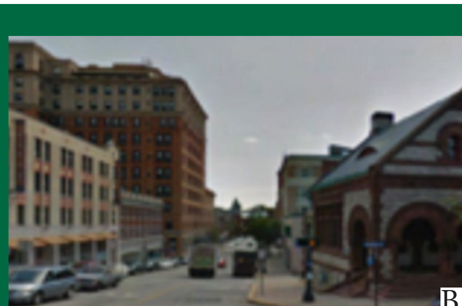
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Figure 2:
A) Corner of Huntington Street and State Street in 1900 (Courtesy of New London Historical Society).
B) Corner of Huntington Street and State Street in 2018. The William Williams estate previously lined with elm trees was replaced by the Garde Theater in 1926 (Photo by Phoebe Eckart).

# Tree Benefits

A city is an environment built for human convenience. It has dense living quarters for easier social engagement; it has roads and vehicles for effective transportation; it has stores to supply for resident's needs, wishes, wants, and desires. This environment of convenience quickly becomes full of brick, steel, stone, and asphalt. Unless the community is careful, this new environment becomes void of the essential ingredient in which humans first lived: plants. People have lived dependent on plants as long as humans have existed. We use them for food, medicine, fuel, building materials, and fabrics[6]. As transportation has become easier, some people have left the planted environment in favor of convenience, preferring the resources derived from the plants to be brought into their communities. The reality, though, is that humans need plants for more than their physical resources.

Trees maintain the natural environment that humans seem determined to change: they control temperature extremes, wind flows, and water runoff. They also benefit human health both physically and mentally. And seemingly most important for many people, trees save money. Results of tree growth research prove that savings resulting form the presence of trees and towns can be more than three times the cost of tree maintenance.[7] Environmental factors that trees control are numerous. Large urban centers are about 7 degrees Fahrenheit warmer than surrounding rural areas (Figure 1). This is because manmade materials like asphalt, concrete, glass, steel, and shingles, are poor insulators. When the sun beats down on a surface of the earth, all the heat is absorbed by these materials and quickly released into the surrounding air.[8] Trees have much higher

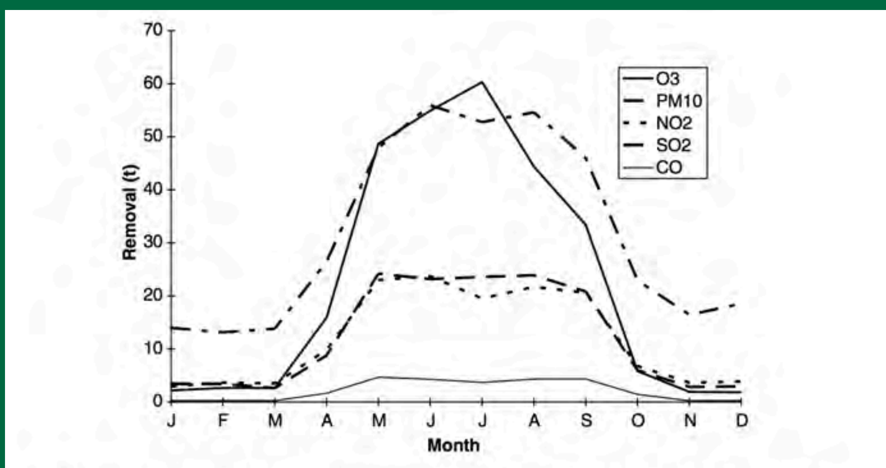



Figure 3: Above.
The image explains aerial cleaning in different months. Deciduous trees are more effective at air cleaning. They grow more quickly, so they filter more air through their leaves. (Nowak and Dwyer, 2010).[10]

Figure 4: Below.
This figure derives from an iTree study of tree benefits in New London. These figures are the benefits of urban canopy on a whole.[11]

| Abbr. | Benefit Description | Value (USD) | ±SE | Amount | ±SE |
|---|---|---|---|---|---|
| CO | Carbon Monoxide removed annually | 152.96 USD | ±21.44 | 1,097.04 lb | ±153.78 |
| NO2 | Nitrogen Dioxide removed annually | 42.51 USD | ±5.96 | 887.13 lb | ±124.35 |
| O3 | Ozone removed annually | 16,084.13 USD | ±2,254.60 | 21.13 T | ±2.96 |
| PM2.5 | Particulate Matter less than 2.5 microns removed annually | 26,802.09 USD | ±3,756.99 | 1,656.64 lb | ±232.22 |
| SO2 | Sulfur Dioxide removed annually | 18.34 USD | ±2.57 | 1,004.24 lb | ±140.77 |
| PM10* | Particulate Matter greater than 2.5 microns and less than 10 microns removed annually | 3,242.21 USD | ±454.48 | 2.49 T | ±0.35 |
| CO2seq | Carbon Dioxide sequestered annually in trees | 125,008.89 USD | ±17,523.16 | 3,545.81 T | ±497.04 |
| CO2stor | Carbon Dioxide stored in trees (Note: this benefit is not an annual rate) | 4,022,252.54 USD | ±563,820.57 | 114,089.06 T | ±15,992.47 |

ability to moderate air temperatures.[9] The leaves and trunk of the tree absorb the light from the sun and convert it into energy or transmit it through their leaves. Deciduous leaves can be particularly helpful in an urban environment because they provide shade in the warm months, protecting people and impervious surfaces below their canopy, while dropping their leaves in the cold months, allowing for the sun's warmth to heat up the microenvironment below their limbs.[12] One mature deciduous tree can also transpire up to 88 gallons of water a day, while covered with a healthy canopy, which is equivalent to operating five average-room air conditioners. Environmental cooling occurs when air intermingles with moisture. This cooling is very effective during the day, but at night trees provide a warming effect by slowing the rate by which the heat from the surfaces below is released back into the atmosphere.[13] This can change the microclimate up to 8 degrees C (15 degrees F).[14]

Figure 5:
People waiting for the bus huddled under a Pin Oak on Water Street, New London, the city's transportation hub. (Photo by Maggie Redfern).

Trees control wind flow too. Many people perceive wind to be a cooling agent because the convection effect causes warm air to rise and cool air to fall. Wind, while enabling convection, can blow away the moisture pockets below trees, which provide an actual cooling effect. Vegetation is filled with numerous small leaves and branches that deflect and reflect air flows. Along roadways, this can prevent toxic gases and particles produced by vehicles, to blow into pedestrian spaces.[15] Effective tree placement around a building can reduce heating and cooling costs up to 25%, by creating a surrounding insulation pocket.[16]

Trees can also change the clean up after big storms. In the warmer months, deciduous trees can catch up to 20% of rainfall in their branches, and conifers can catch up to 40%. This means there is not as much water sloshing around on the streets.[17] In winter months, trees reduce the depth of the snow and ice on the roads, which in turn reduces the time, energy, and road salts needed to remove it from the surfaces. Tree roots will also absorb the storm water and prevent runoff, which can lead to erosion. Unfortunately, if the trees are not well maintained, they can add additional stress to storm cleanup.

Plants also clean the air of pollutants. Trees catch the particle matter and gasses in their leaves, twigs and bark. Higher quantities of pollutants are caught in the tree canopy in the growing season because there is more mass to the trees (Figure 3). Rain washes the pollutants into the soil. This prevents people from breathing them in. Trees also absorb carbon dioxide from the atmosphere and turn it into water, carbon, and energy. The carbon is used to produce the wood in the trunk.

Trees have great emotional benefits as well. People who see a tree from their office window have greater job satisfaction.[18] And those who see a tree from their hospital window heal sooner.[19] Contrarily, in communities where fewer trees are present, more antidepressants are prescribed, and more people smoke.[20] A study looking at communities before (1990) and after (2007) an invasive species, Emerald Ash Borer, drastically affected the urban forest suggests statistically significant increases in mortality rates related to cardiovascular and lower-respiratory tract illnesses.[21] People who live in neighborhoods with higher density of trees on their streets report significantly higher health perceptions.[22] It is also suggested that having 10 trees on a city block makes people feel similarly to people earning $10,000 more per year. Having 11 trees on a city block decreases cardio-metabolic conditions in ways comparable to an increase in annual income of $20,000.[23]

When individuals feel better, community benefits are also significant. A study shows than in inner city communities, people feel safer if there are trees in their neighborhood.[24] Children 14 years and younger constitute half of urban public housing, so having green spaces for them to play is important.[25] When children have the ability to play outside, their learning, behavior, and creativity are improve.[26] One study shows leisure activities occurring in urban forests and green spaces have the potential to facilitate positive interactions between citizens and immigrant people, stimulating social interactions across cultures.[27] There are also lower crime rates: domestic violence, property damage, violent crimes drop by nearly half.[28] On tree lined roads, people drive slower and there are consequently, fewer accidents.[29] Trees make the perceptions of a safer environment a reality.

## Process and Limitations

The City of New London hired another student and me, though the Connecticut College Arboretum to conduct a street tree inventory in New London. We underwent brief training

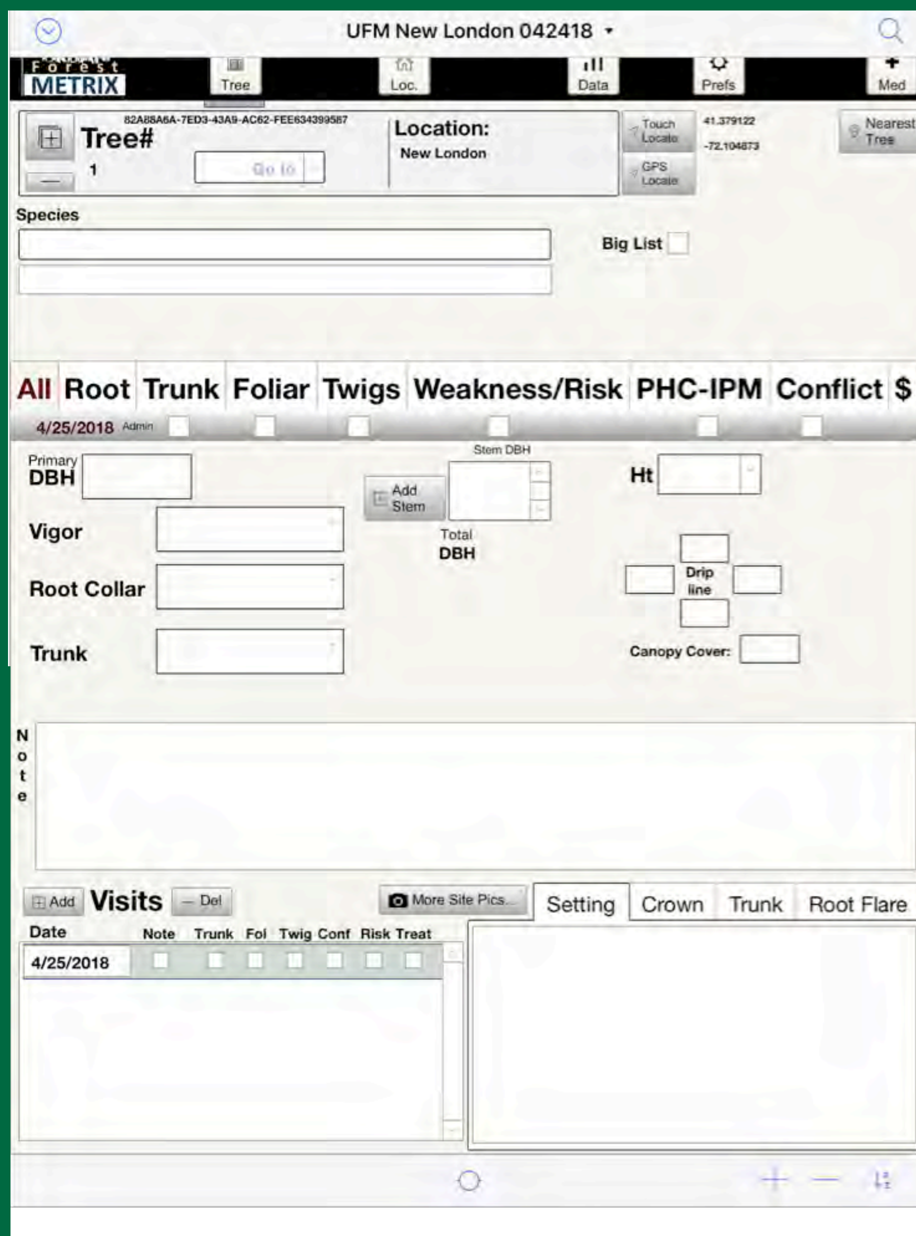



Figure 6: Left
Yellowwood on Hempstead Ave planted in the strip between the sidewalk and the road. (Photo by Maggie Redfern).

Figure 7: Above
The home screen on the Urban Forestry Matrix software, where all field data was stored.

with the Arboretum staff to refresh our tree identification and condition judgments.

The inventory looked at municipal street, school, and park trees. To record the necessary data, we used Urban Forestry Matrix software (UFM). This allowed for a systematic approach to organizing the tree data. Each tree was assigned a unique file number that stores the tree's information. Basic diagnostics were taken: GPS location, species, diameter at breast height (DBH), condition, height, canopy cover, and a picture.

Figure 7
The street map of New London with city and state managed roads.

City managed roads
State managed roads

DBH is measured at 4.5ft off the ground. If there were any complications, such as co-dominant stems or a canker, respectively, all breast-height branches would be recorded or the measurement would be taken below DBH. We commented on the condition assigning a rating five to one. Five equated "excellent," and one equated "dead/dying." To measure height, we used a hypsometer. This device works by calculating the horizontal distance, then capturing the points at the top of the canopy and the bottom of the trunk. Based on the heights of the points, it calculates the angles and shows the height of the tree on the screen. Next, the canopy was measured by measuring the drip line in the cardinal directions: North, South, East, and West. This included staking the measuring tape into the soil at the base of the trunk and walking to the furthest branch with growing leaves. Sometimes if a direction was inaccessible due to a busy road or there was a fence, the canopy for that direction was estimated. A picture was taken to evaluate the tree's condition from a remote location. The root collar, trunk, and canopy were all inspected and results recorded. The software allowed greater range of information for maintenance purposes, like proximity to power lines, or notes from previous visits. The data instantly uploaded to a server so that both fieldworkers and the office could view the data within moments.

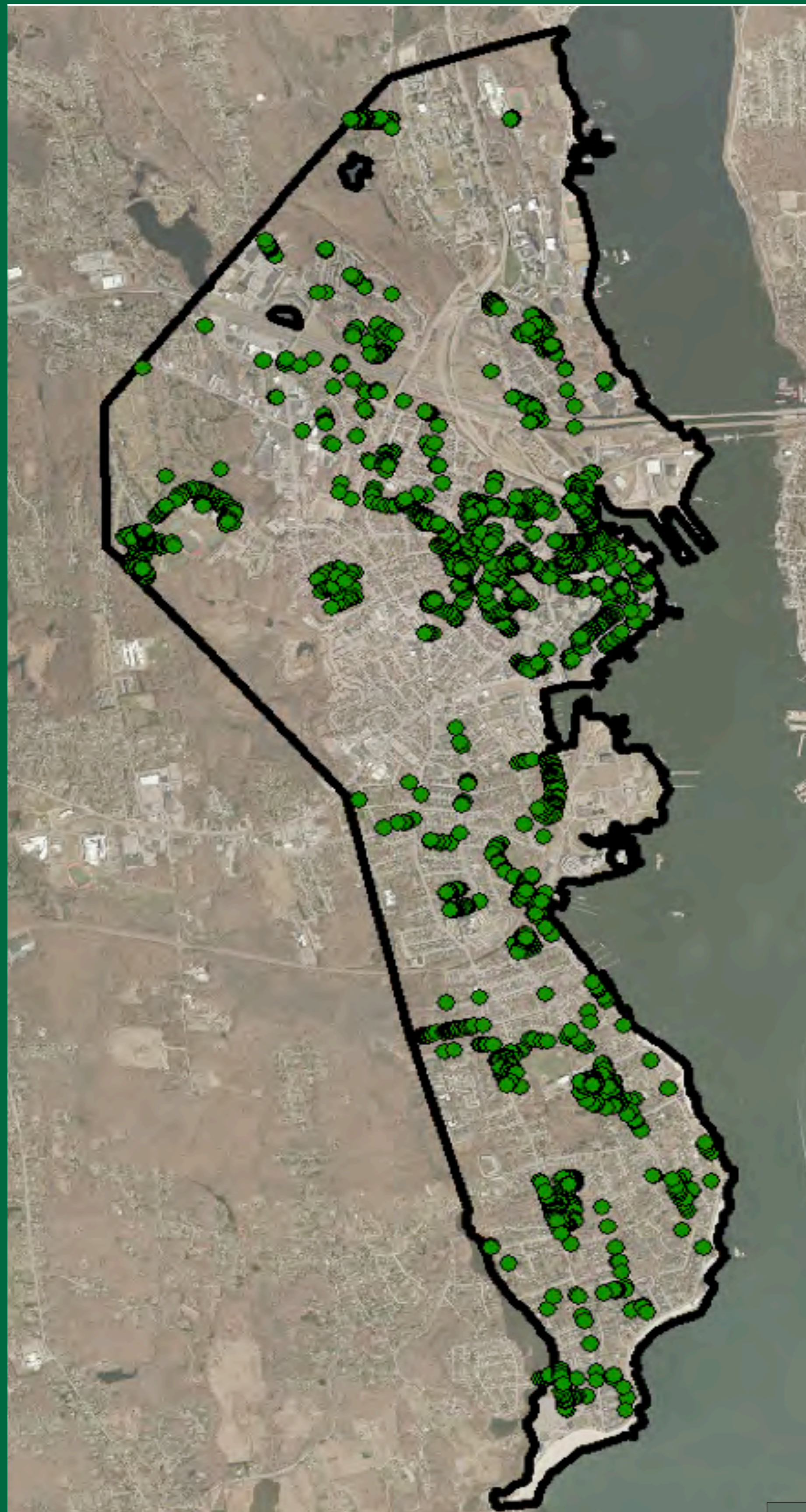
Once all the field work was complete, the data was uploaded into Graphic Information Systems (GIS). This is how all the maps and graphics were created for in depth analysis.

Figure 8: Picture of the field crew holding a hypsometer, iPad loaded with UFM software, and 100ft measuring tape (left to right). (Photo by Maggie Redfern).

# Tree Distribution

Figure 10
The points represent each tree that was documented during the inventory.

Trees inventoried
New London city boundary



# Results

The New London Summer 2018 inventory resulted in 1887 trees total. These trees were comprised of 80 taxa, 45 genera, and 25 families.

Taxa are similar to a species, but sometimes species can be difficult to differentiate if they are not in bloom. For this reason some species or cultivars were grouped together. Crabapples, chokecherries, pears, hickories, yews, hawthorns were grouped as taxa rather than species.

1887 Trees
80 Taxa
45 Genera
25 Families

Figure 11
Graph showing top 20 taxa in the New London 2018 summer inventory.

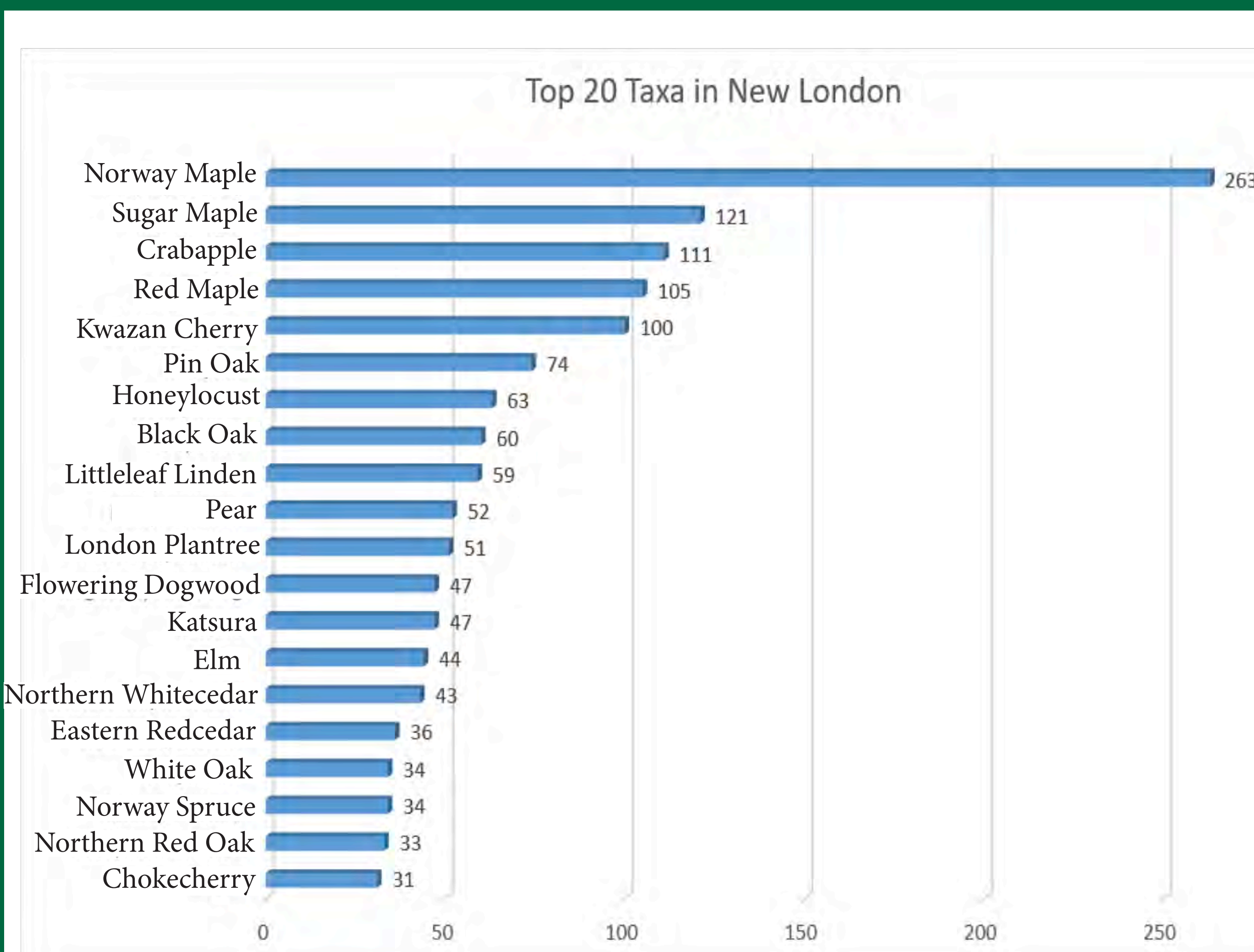


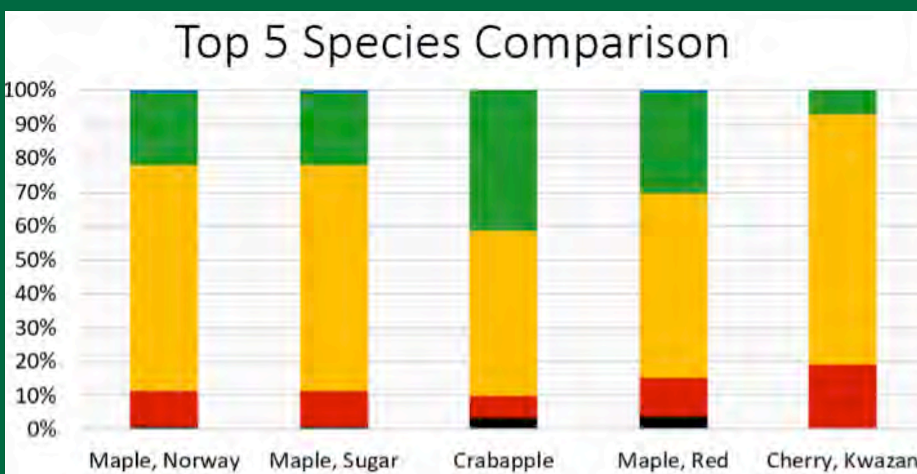
Figure 12: High visibility vests are reflective, not protective!
Field team measuring a Norway Maple along Jefferson Ave, New London.
(Photo by Maggie Redfern).

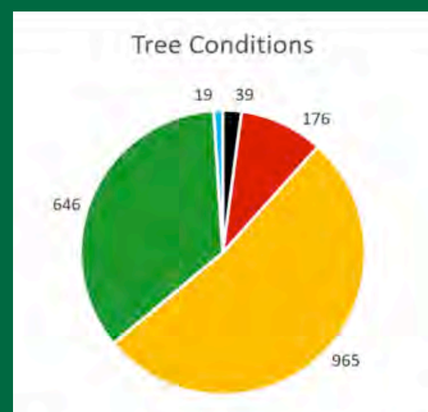
## Conditions

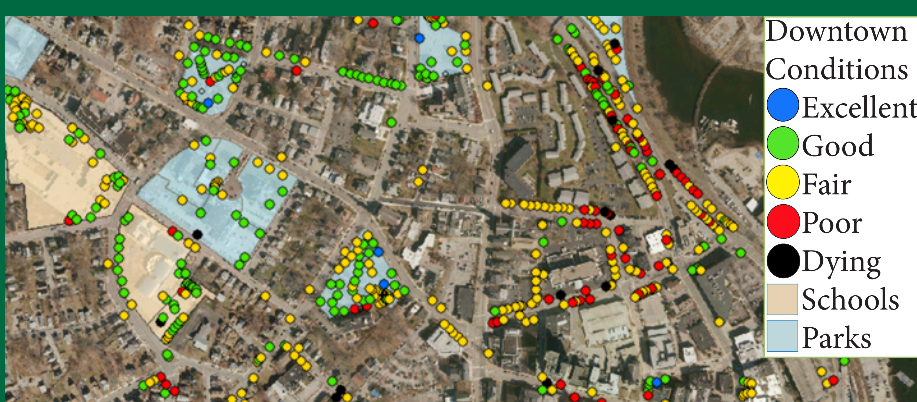
To an untrained eye, tree conditions are challenging to assess. When recording the data for each tree, we inspected from the roots to the crown to determine the condition code, ranging from dead/dying to excellent. Overall, most trees were “fair.” Each judgment – excellent, good, fair, poor, dead/dying – related to a percent of optimal health: 1, 0.7, 0.5, 0.3, 0.1.By averaging all the values for given species, it was easier to compare how the ten most numerous species perform as street trees (Figure 16). In addition to an average value, it is beneficial in understanding species heath to consider the percent of trees in each health category (Figure 13). Crabapples have higher “dying” ratings, but also have the most “good” trees of the top five species. The average rating for the top ten species is 3.21. Out of the top ten, Pin Oaks were the most successful at maintaining their health, while Kwazan Cherries are the least successful. This sort of evaluation allows for more successful future plantings.

There are many challenges in different municipal locations where trees grow.

Streets are a difficult environment for trees to grow. Most tree roots grow in the top 12 inches of soil because they need oxygen and organic matter, both which start on the surface and are mixed in with the help of soil microbes. In a healthy soil, there is 1:1 ratio of airspace to solid material. In an urban setting, the soil under a tree is stepped and driven on compressing its structure.




| Species | Mean Condition |
|---|---|
| Norway Maple | 2.99 |
| Sugar Maple | 3.24 |
| Crabapple | 3.27 |
| Red Maple | 3.09 |
| Kwazan Cherry | 2.88 |
| Pin Oak | 3.59 |
| Honeylocust | 3.22 |
| Black Oak | 3.30 |
| Littleleaf Linden | 3.22 |
| Common Pear | 3.30 |

Figure 13: Top Left. Graph of distribution of conditions for the top 5 species.
Figure 14: Bottom Left. Map of layout of trees in downtown New London. Notice trees in areas surrounded by roads and buildings are predominately “fair” or “poor,” while those on parks and schools are “good” and “fair.”
Figure 15: Top Right. Graph showing conditions for all trees in the summer 2018 inventory.
Figure 16: Bottom Right. Chart of the mean conditions for the top 10 species listed in frequency order.

This leaves little room for essential ingredients, air and water alike, to get to the roots. Additionally, streets are salted in the winter months to melt ice. This salt drains into tree beds, which creates a highly saline rooting environment. The atmosphere around trees is also polluted with gases and particle matter from vehicles. These pollutants are washed into the soil during rainfall. Once the soil environment is compressed and polluted with salts and particulates, healthy soil microbes die off and it leaves a wasteland. This makes it very difficult for roots to grow in the existing soil. On top of challenging soil environment, trees are generally given a small space to grow. Once the difficult root space is considered, add in all the damage that happens to the trunk from cars, dogs, or weed whackers. The crown of the tree also has to compete with utility lines for space.

Schools and parks are generally less challenging than streets because there is usually more open space. Sometimes soil compaction can be a problem, because of the children running around the roots of the tree, but usually this is minimal in comparison to an urban street. The problems of maintenance equipment are still prevalent. The crown usually has enough space to spread out, so even if the roots are struggling a bit, the tree can get enough light to compensate.

| Location | Trees |
|---|---|
| Street | 967 |
| School | 375 |
| Park | 544 |

Figure 17.
Chart of the locations of the trees in New London. Inventory only focused on municipal, cultivated areas.

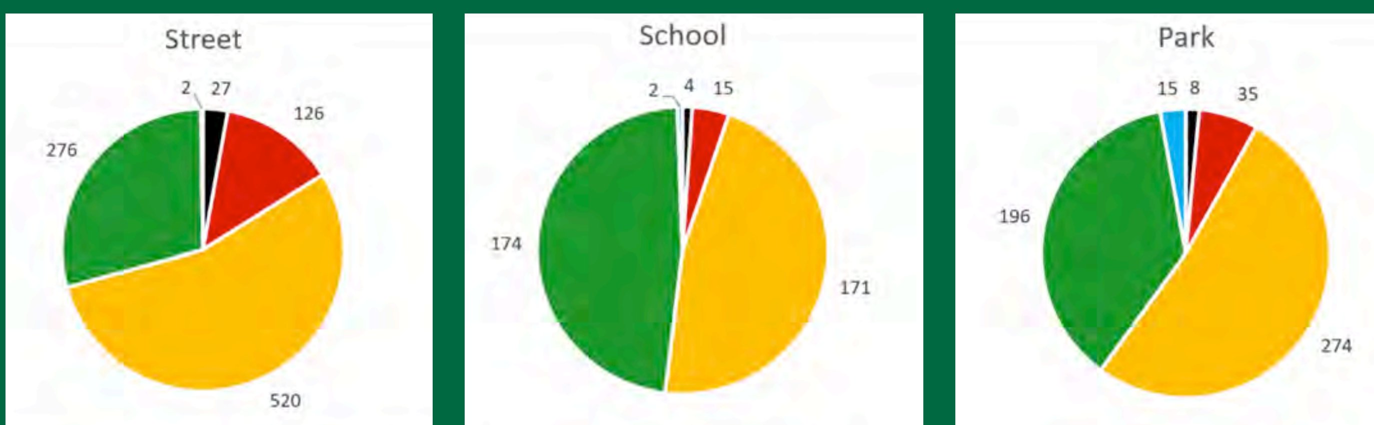



Figure 18: Above. Conditions of trees in different municipal locations.

Excellent
Good
Fair
Poor
Dead/ Dying

Figure 19: Below. Conditions in different urban environments. (By Maggie Redfern).
A) Oak on Prospect Street with decay and fungal growth in roots.
B) Sugar Maple on Montauk Ave with excessive utility pruning.
C) Beech on Harbor St in a spacious school grounds, but affected by utility pruning.
D) Williams Park is a perfect place for a tree to grow, with fewer stresses.

## Tree Heights

Heights are challenging to use as a model for growth because every species is so different. A Flowering Dogwood may be full grown at 20 feet, while a Pin Oak planted in the same year may be 75 feet tall. This being said, a Pin Oak in a park may be taller than a Pin Oak on a street corner because its possible root growth area and access to resources is greatly improved. Another scenario is, again, two Pin Oaks are planted right next to one another. One might be expending a lot of energy to add height so it can reach more sunlight, leaving the shadowed one in a more stunted position.

Because all these growth factors are at play, a simple height display would not suffice in showing true health of the trees in New London. Figures 23 and 24 illustrate tree heights. The top image is the percent of the tree's growth based on expected height at maturity. The expected heights were taken from Michael Dirr's *Manual of Woody Landscape Plants*. The one below is the pure heights. It is apparent that the tallest trees in New London tend to grow in the parks. Between these two images, it is possible to see, unsurprisingly, that healthier and older trees grow in parks, but there are still some mature trees along roads. These roadside mature trees, while in the top height category, are not at their expected species height. This suggests that they are affected by the roadside conditions.

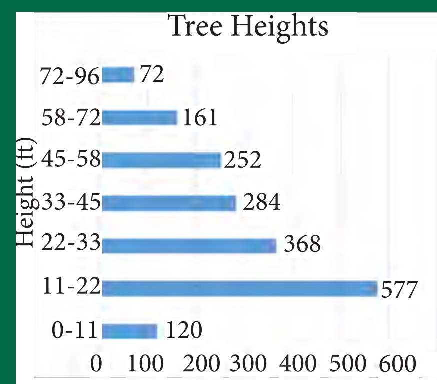


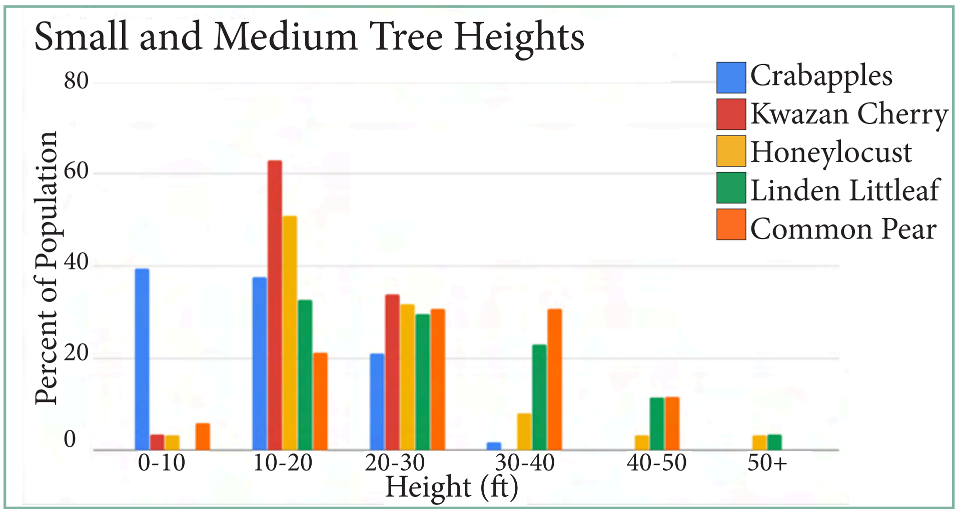

Figure 20.
Graph of trees height distribution of inventory results in New London.

**Height Shoutouts:**

**Tulip Tree**
**100ft**
**Toby May Park**

**Cottonwood**
**95ft**
**Cove View Road**

**Eastern White Pine**
**95ft**
**Mitchell Woods Park**



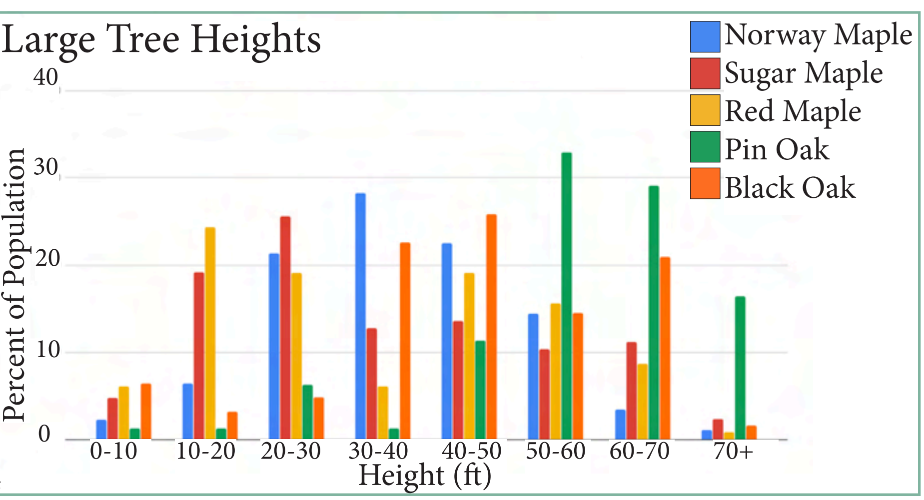




Figure 21: Top Left.
Chart of small and medium trees catergorized by heights in New London.

Figure 22: Bottom Left.
Chart of small and medium trees catergorized by heights in New London.

These figures express the different nature in which different species grow. When considering new plantings, it is important to understand a tree's potential height.

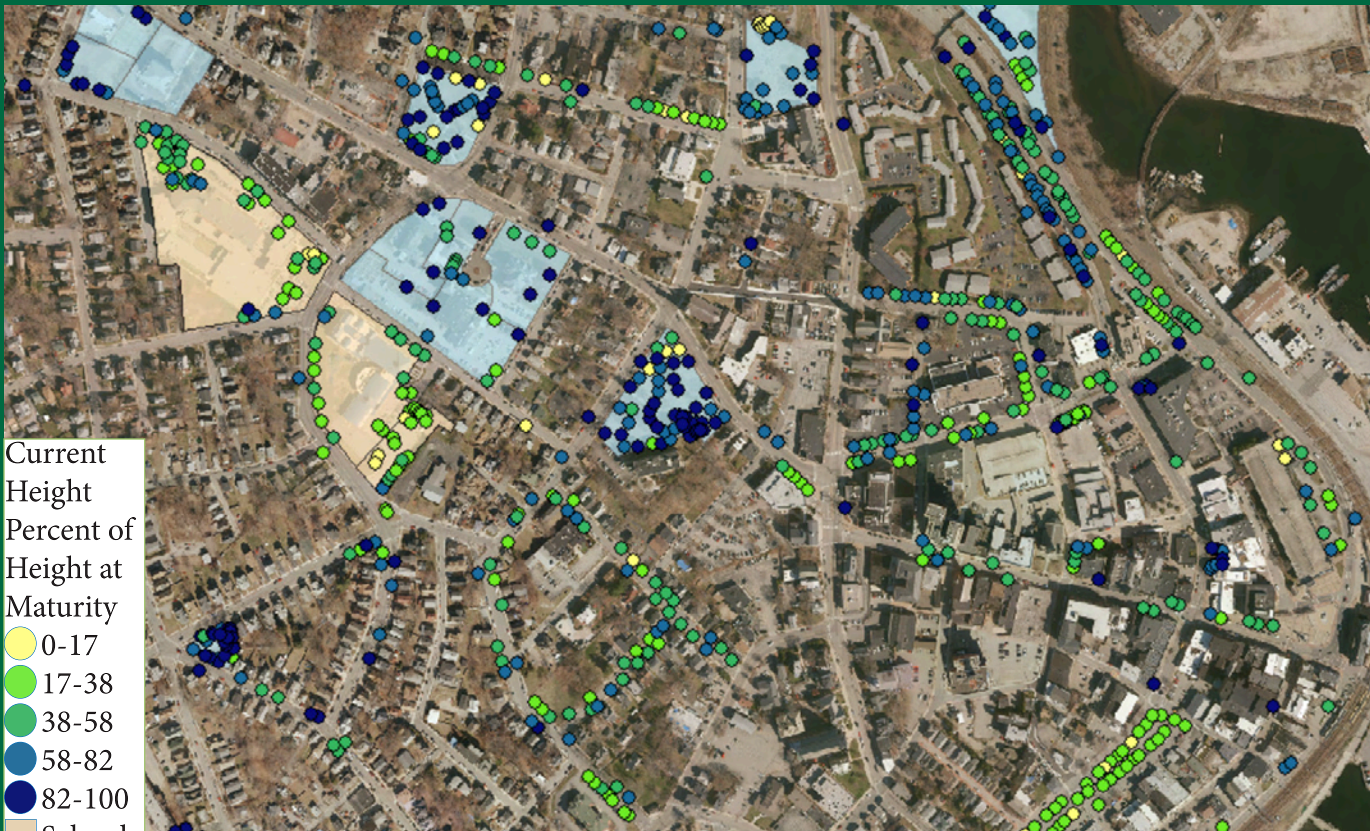



Figure 23: Map of percent of potential tree height in New Lonon. The maximum tree heights came from Dirr's *Manual of Woody Landscape Plants*.

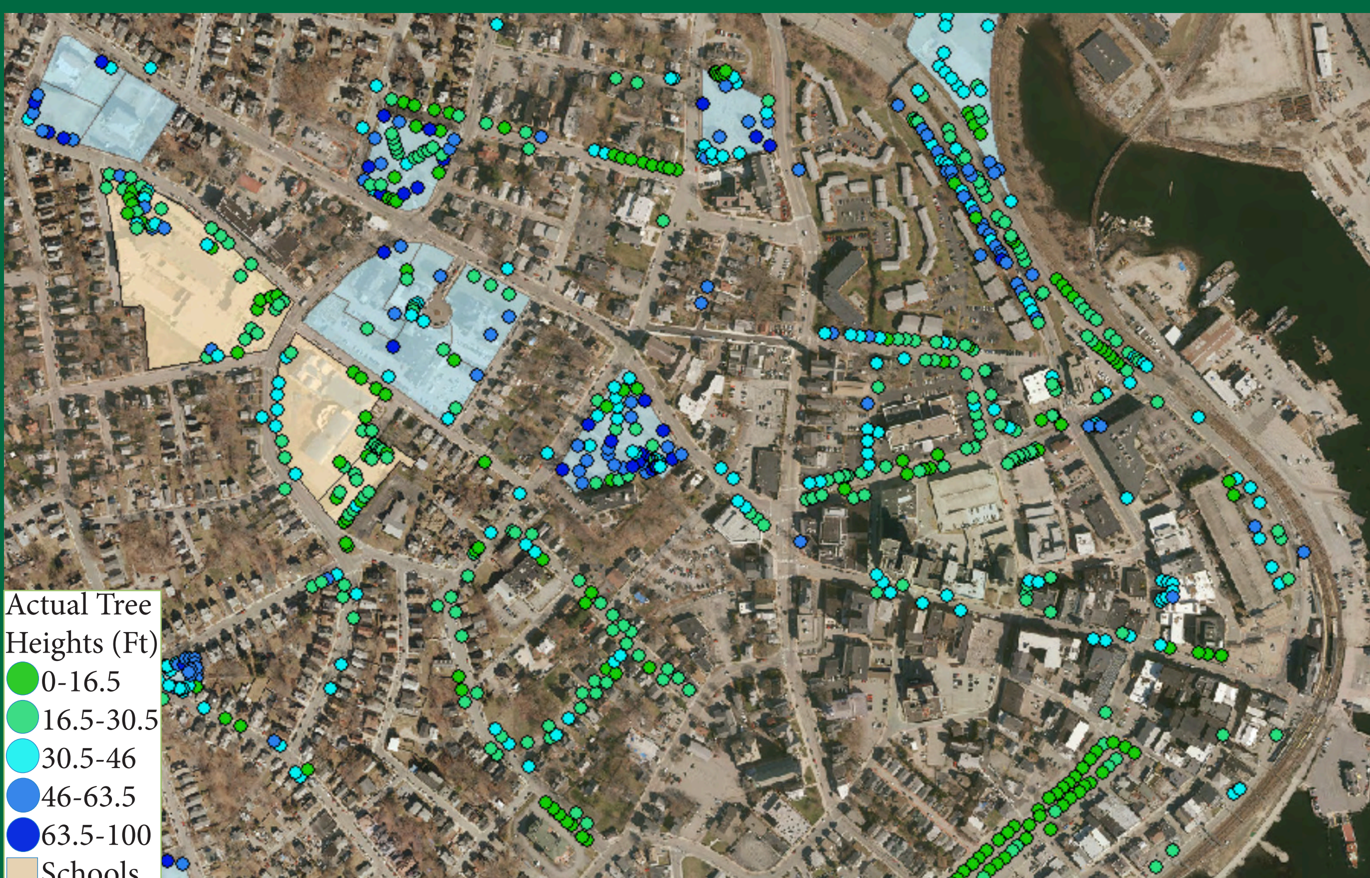



Figure 24: Map of actual tree heights in New London based on inventory results.

# Diameter at Breast Height

A frequently asked question is "How old is that tree?" Unfortunately, there is not a good way to figure out the age of the tree without cutting down the tree and counting the growth rings near the base. Obviously, for conservation purposes, this is completely contrary to the intention. There have been many methods to estimate the age of a tree. Some include boring samples, but this can be an invasive method as it involves drilling a hole in the wood to count the rings.[30]

A much less invasive method, but not nearly as accurate, is called Growth Modeling.[31] There have been a number of studies that identify how quickly a tree grows. This method takes a measure and multiplies the measurement by the growth rate. The standard place to measure a tree is at 4.5 feet. This is called Breast Height. It is most common that the diameter is measured because the diameter shows growth more lineally than the circumference. Measuring the diameter at breast height is commonly referred to as "DBH."

Knowing the estimated age of a tree is important for the city becasue an urban canopy needs to be replanted for continuous health. New London does not currently keep accurate records for individual trees, so an estimation method is essential.

We will use DBH growth modeling to estimate the ages of the trees. It is important to use a species specific the growth model, because the multiplier changes even within the same genus.

There are some limitations to this model, however, because not every species has had significant enough testing to reveal its growth rate. There are also problems with the growth rate itself. A tree growing between a sidewalk and a road with road salts being dumped into their root wells every other week for half the year is not going to grow as successfully as a tree in a managed forest setting, where is gets all the light and nutrients it could possibly need. This means that there is a species average growth rate, but trees in either setting extreme cannot be held to the calculated age. For more accurate growth modeling, one can use regression modeling. This comes within a 15% error range. Simple multiplication is less accurate because trees grow much more quickly at the beginning of their lives and slow down as they get older.

In this study, only a few of the most commonly growing New London trees are looked at, due to the limitations in growth rate data. These average ages are only estimates, because the environment in New London is not the same as the environment of the previous study on street trees.

Many times, if construction is in process, it is less expensive to cut a tree down on the building site than to work around the tree. This is terrible for all those who live in the area, however, because a tree with a 30in (77 cm) diameter delivers seventy times the environmental benefits of a tree with a 3in (8 cm) diameter.[32] As New London develops its urban canopy, finding building solutions that accommodate trees is essential. Without these efforts, the question, "How old is that tree?" will be far less frequent, and the answer far less impressive.

| **Species** | **Growth Factor** |
|---|---|
| Norway Maple | **4.5** |
| Sugar Maple | **5.5** |
| Red Maple | **4.5** |
| Pin Oak | **3.0** |
| Black Oak | **4.5** |
| Littleleaf Linden | **3.0** |
| Pear | **3.0** |
| Flowering Dogwood | **7.0** |
| Elm | **4.0** |
| White Oak | **5.0** |
| Norway Spruce | **5.0** |
| Northern Red Oak | **4.0** |

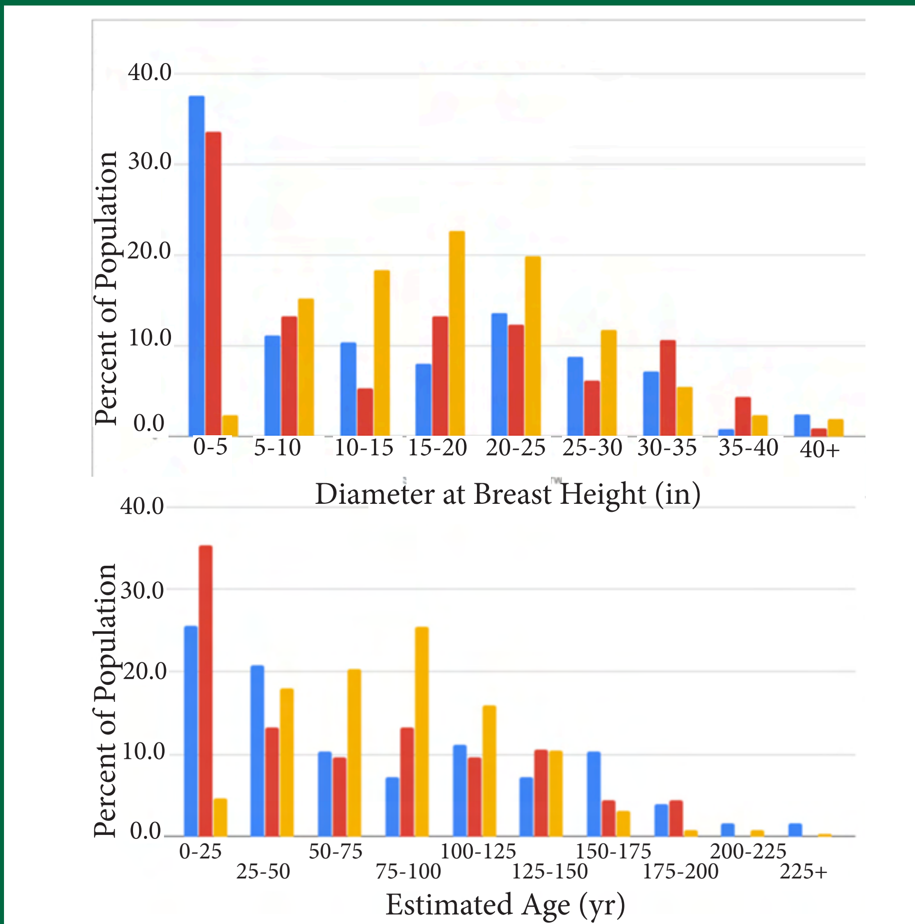
Figure 25: Left.
The growth factor can be multiplied by a tree's DBH to estimate the tree's age. It is only acurate enough for informal purposes.

**DBH Shoutouts:**

**Euopean Beech**
**63.2in**
**Williams Memorial Park**

**White Ash**
**58.2in**
**Williams Park**

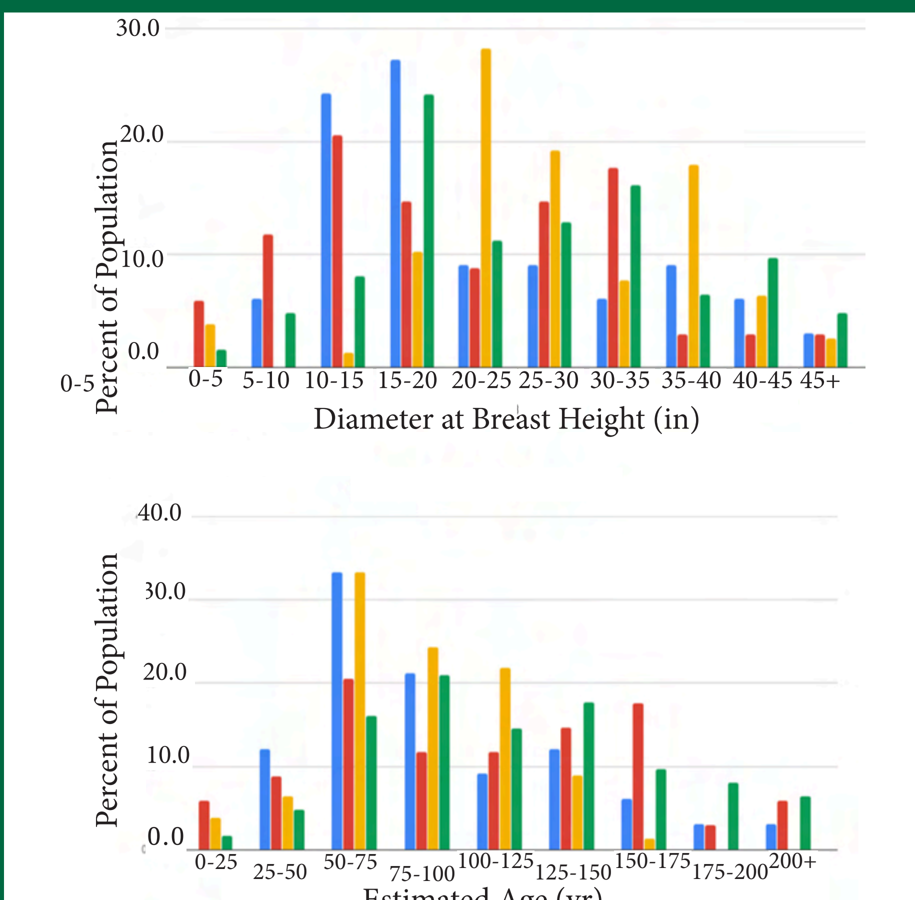
**Euopean Beech**
**56.5in**
**Ye Ancestral Burial Ground**




# MAPLES

Figure 26:
Based on these models, Red Maples have been a more commonly planted tree within the last 25 years. It seems as if Sugar Maples outlive Norway Maples. This may be because Norway Maples are not native to New England, so in their old age, they are more affected by pests and diseases. It also seems as if far fewer Norway Maples have been planted within the last 25years because awareness of their invasive tendencies has increased.

- Norway Maple
- Sugar Maple
- Red Maple




# OAKS

Figure 27:
All the oaks on this list are native to Connecticut. It appears there are few young oaks in gneral, and more specifically, very few Pin Oaks (less than 50 years). Black Oaks also seem to be an older population, but they don't seem to die off. White Oaks have a similar pattern. There are no Northern Red Oaks under the age of 25. This is a shame because they seem to be successful in the urban environment and live for a long time.

- Pin Oak
- Northern Red Oak
- White Oak
- Black Oak

# Land Use

For a general understanding of the city's current overall canopy, municipal and private alike, iTree software was used to measure the city's surfaces. The categories were broken into Trees, Grass, Pavement and Building. One hundred and fifty randomly generated points on aerial photographs revealed that 25.3% of the city's surface is covered by trees. Interestingly 37.3% of the city's surfaces are covered with grass, 24.7% is paved, and 12.7% is built. The national average for canopy cover is 27.1%. This means that New London is below the average, but not by much. This is encouraging.

Most canopy cover lives on private lands, including private residences, Connecticut College, the United States Coast Gaurd Academy and Mitchell College. An iTree study was also conducted for municipal school trees and park trees. Schools make up 1.4% of the city's area. Trees cover only 14.9% of school properties. Considering many public school properties have a high proportion of playing fields – 37.8% grass – and school buildings – 23.0% buildings – it is not surprising that the schools have lower percentage coverage. There could be greater improvements by planting trees in parking lot islands, because nearly a quarter of school properties are parking lots.

ITree park results were surprising. Parks cover 6% of New London. Only 36.5% of parks are covered with tree canopy. Just below half are covered with grass. Close to 20% is paved, and less than 3% is built. If New London wants to improve it's urban canopy, it seems like parks would be a great place to start. Even if playing fields need to remain as a significant portion of the city's real estate, by having more trees surrounding the properties, the fields would have better drainage and be more user friendly on windy or sunny days.[33] They would also prevent erosion of play fields.[34]

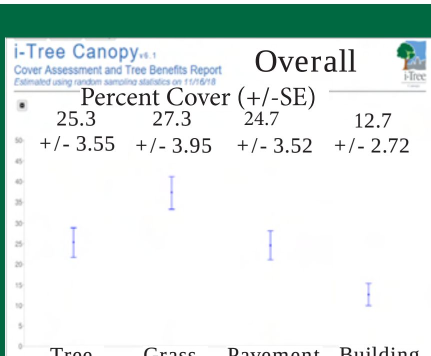



Figure 28:
Graph of Land use in New London according to an iTree study.

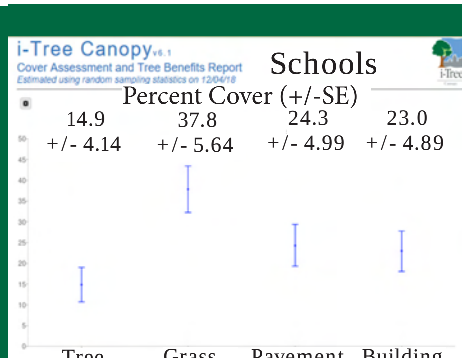



Figure 29:
Graph of Land use in New London schools according to an iTree study.

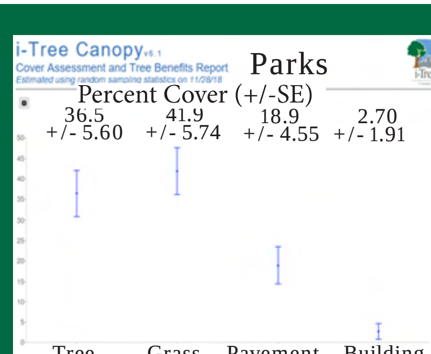



Figure 30:
Graph of Land use in New London parks according to an iTree study.

The national average city canopy cover is 27.1%. New London's overall canopy is about 25%. This is not too far off. The New London canopy includes so much more than was studied in this inventory. This study only looked at the municipally managed, cultivated areas, which totals about 2.4% of New London's canopy. During the inventory, measurements for the drip line were recorded based on the cardinal directions. The amount of canopy surface coverage is measured in a two dimensional figure, but the canopy mass is measured in a three dimensional figure.

Humans feel canopy benefits more than any other tree feature. While the roots may help with drainage and erosion control, the canopy is what makes people feel safe, calm, and included.

| Species | Percent Canopy | Percent Tree Count |
|---|---|---|
| Norway Maple | 15.6 | 13.9 |
| Sugar Maple | 6.2 | 6.4 |
| Crabapple | 1.0 | 5.9 |
| Red Maple | 5.7 | 5.6 |
| Kwazan Cherry | 2.7 | 5.3 |
| Pin Oak | 13.1 | 3.9 |
| Honey Locust | 1.9 | 3.3 |
| Black Oak | 10.2 | 3.2 |
| Linden Littleleaf | 1.6 | 3.1 |
| Common Pear | 0.9 | 2.8 |
| London Plantree | 5.1 | 2.7 |

Figure 31: Above.
Chart lists top 11 species in frequency order.

The "canopy percent" column shows how much of the canopy that taxa encompasses.

The "percent tree count" collumn expresses the percentage of the species in the city. If each tree were the same size, this colum shows how much of the canopy the species would cover. The is the "expected" value.

The intention of the chart is to clarify the canopy coverage differences in different taxa groups.

Figure 32:
A massive weeping European Beech in Ye Ancestral Burial Ground.
(Photo by Isabelle Smith).

**Canopy Shoutouts:**

**American Sycamore**
**6865ft³**
**Mitchell Woods Park**

**Euopean Beech**
**6220ft³**
**Nathan Hale Magnet School**

**Scarlet Oak**
**5026ft³**
**Stuart Ave**

**White Ash**
**5026ft³**
**Williams Park**

**Tupelo**
**4300ft³**
**Mitchell Woods Park**

Impervious surfaces were considered in two different ways. The first was in regards to the total of impervious surfaces in New London, using information provided by the Center for Land Use Education and Research. Buildings, Roads, and Other Impervious allowed study of canopy over impervious surfaces. Overall, 36.3% of New London is covered with impervious materials. The city's managed canopy covers 3% of these surfaces.

The second approach was measuring the absorbent areas in which trees were planted. This area is formally called the planting strip. To measure the planting strip size, ArcGIS layering allowed the GPS points of the trees to be placed over a high-definition aerial photograph. The shape of the planting strip was traced to make polygons with calculatable areas. This study is limited to the area directly around the base of the tree. If a tree's canopy extended over the sidewalk into a lawn area, the additional absorbent area was not included in the planting strip area. If a tree did not share the planting strip with any other tree, the planted area would continue until there was a division in the absorbent area. It is commonly suggested that an 8 ft wide planting strip will support a large tree ($64ft^2$).[35] In New London, many planting strips were only measured $5.5ft^2$ wide. After sizes were reviewed, conditions in relation to planting strip sizes were analyzed. Unsurprisingly, on average, the greater the planting strip size, the better the tree condition. The minimum planting strip size of trees with a condition, "Excellent," was $712ft^2$. This area frequently supported multiple trees. This is because the trees have enough room to spread their roots and crown to take advantage of all the surrounding resources: water and sunlight. Additionally, growing many trees in a shared area allows root grafting so the trees can share nutrients.[36] Most planting strips in New London were about 5.5ft wide, but were very long, compensating for the lack of width.

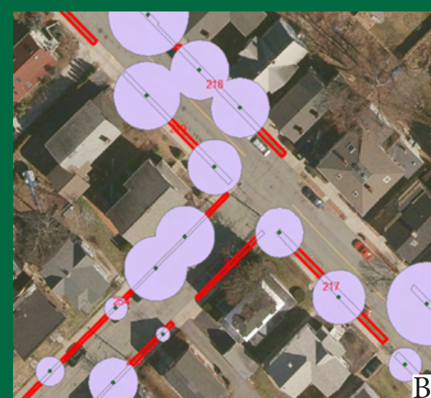




Figure 33: Top Right.
Overall city impervious surface coverage.
Tree Canopy
Buildings
Roads
Other Impervious

Figure 34: Bottom Right.
Pits of trees.
Tree Canopy
Planting Strips

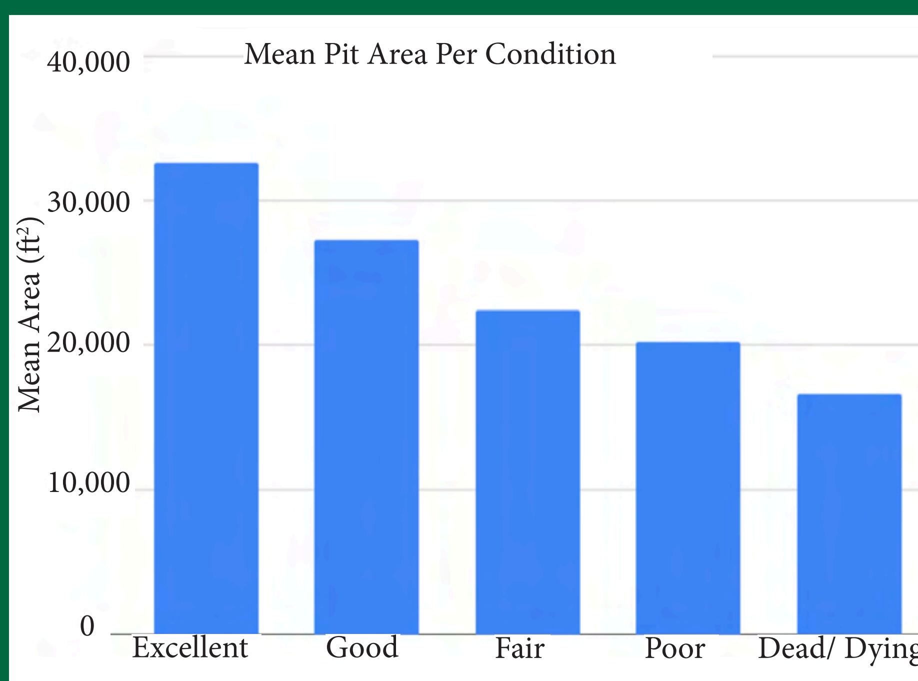



Figure 35: Relationship between condition and mean pit size.

Before completing the field data, an introductory study looked at canopy vegetation in the City of New London over a thirty-year period. LandSAT images were taken for every year between 1985-2014 between late spring to early fall. There was some variation in the time of year because of the access and clarity of the images. High definition images do not go back to the 1980's, so some of the photographs were fuzzier than ideal. After the images were selected, using Graphic Information System (GIS), a spatial analysis was conducted. Areas with canopy vegetation were selected based on dark green colors (grass usually came across as a light green to brown shade). This is because a cluster of trees limits light reflecting off other surfaces, so they are darker. All the years were layered on top of each other. If selected areas overlapped, they were considered significant areas. This method looks at clusters of trees, not just individual trees. This study came back showing that only 13.2% of New London is covered by significant canopy. Because only clusters of trees were measured, street trees would very rarely show up in this study. This exposes that while there are street trees, unless they are in communities of trees they do not make a significant difference in the canopy. One study revealed dense tree crowns have a significant impact on wind, but for isolated trees, their influence nearly disappears within a few crown diameters downwind.[37] This reveals that some of the benefits of street trees are limited if there are only sporadically planted trees, as opposed to consistent street linings.

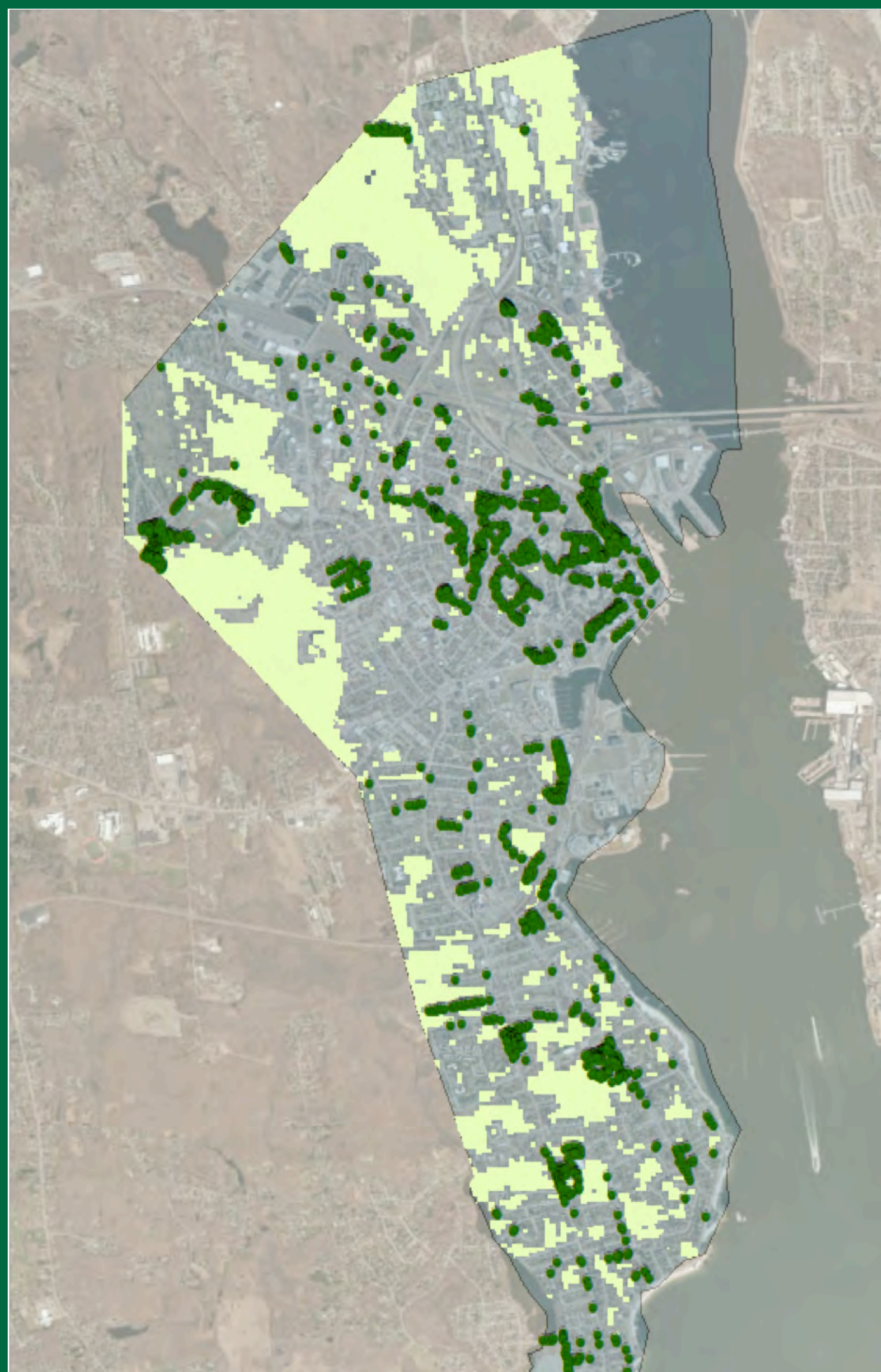


Figure 36:
The inventory trees overlayed on results from a 30 year study between 1975-2014 of tree clumpings in aerial.

Summer 2018 Inventory Results
30 year tree cluster results

The species origin breakdown allows us to see where city trees are indigeneous to. The four major categories are Connecticut Native, Eastern United States Native, Non-Invasive Exotic, and Invasive. Because invasive species are from other regions of the world it is important to note all these categories are mutually exclusive. The Invasive plants were selected based on the *Invasive Plant List* by the Connecticut Invasive Plant Working Group, funded by University of Connecticut.[38] The the Department of Energy and Environmental Protection Invasive Species page provided the link.[39] Connecticut statute only bans the planting of Tree-of-Heaven. Invasive species do not have nearly the same beneficial effects on a community or the ecosystem.[40] Fortunately, according to the growth rate model (Figure 26), Norway maples are not being planted nearly as frequently any more, even though they still naturalize.

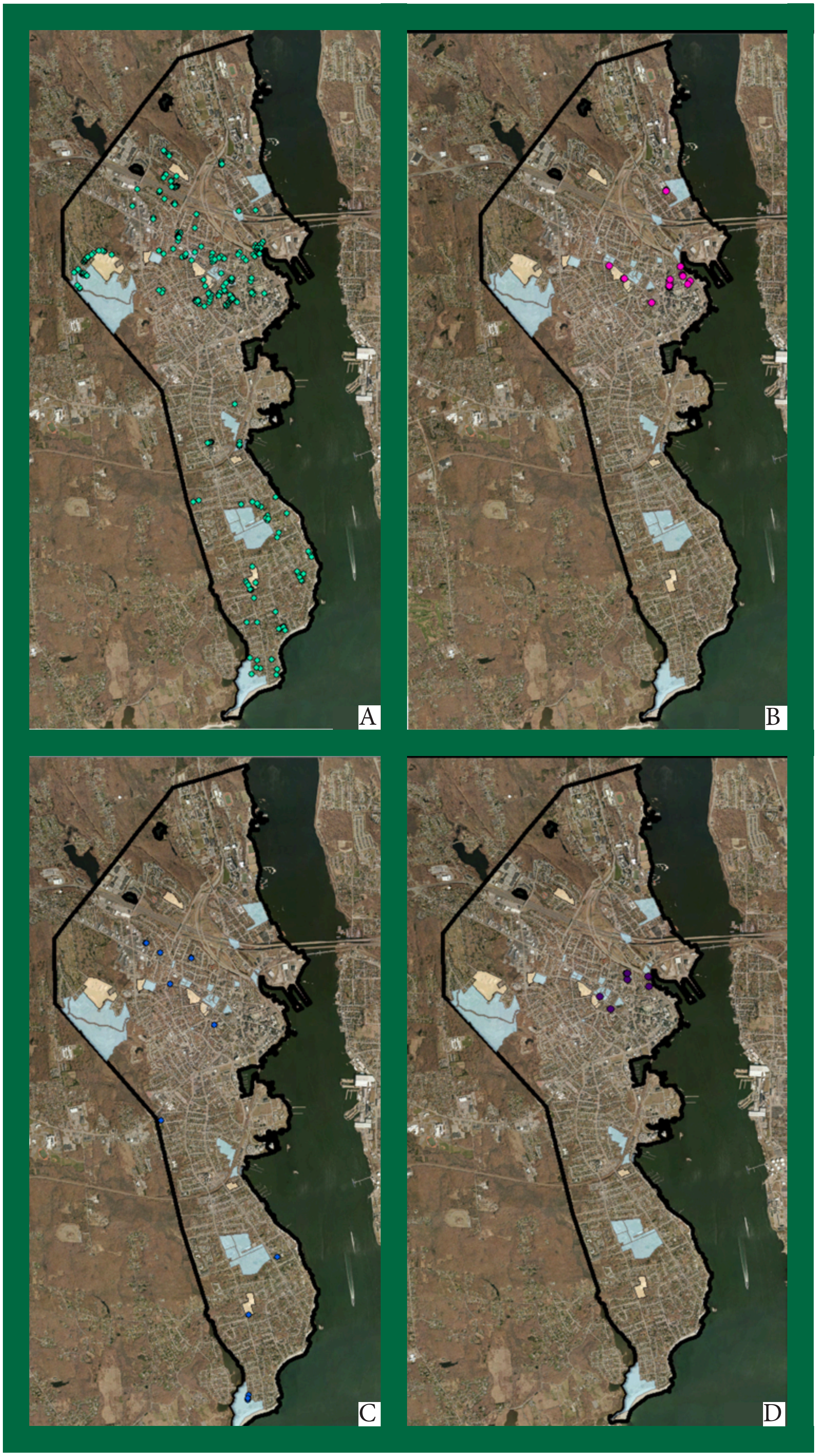
Invasive species naturalize and aggressively sprout in places where native trees should be growing. Removed from their native environment, they are much more competitive because they do not have predators to restrict their growth.[41] In an urban context, neglected, uncultivated areas between properties tend to be overgrown. The invasive species sprout and spread. These areas are not included in the study because they are uncultivated areas, but they still contribute to the urban canopy. The invasive species do not provide the same ecological benefits.

Figure 37: Above.
Photograph of an uncultivated area in New London. Even though it is not neat and organiazed, it still adds to the urban canopy. This is a prime location for invasives to sprout. (Photo by Maggie Redfern).

Figure 38:
Photograph of Tree-of-Heaven sprouting through a fencepost along the traintracks near Union Station, New London. Trees like this were not included in the inventory, but they still make up the urban canopy. They need removing otherwise they spread. (Photo by Maggie Redfern).

Figure 39: Chart of catagories of origin and percent of inventory.

| **Catagory** | **Number** | **Percent of City** |
|---|---|---|
| CT Native | 803 | 42% |
| Eastern US Native | 124 | 6.5% |
| Non-Invasive Exotic | 667 | 35.3% |
| Invasive | 293 | 15.5% |




# Invasive Species Maps

Figure 40:

A) Noraway Maples (263 trees)
B) Black Locust (23 trees)
C) Sycamore Maples (13 trees)
D) Tree-of-Heaven (9 trees)

Traditionally, Norway Maple, Black Locust, and occassionally Sycamore Maple were planted as street trees because they do not have natural predators, like insects or fungi.

All four species sprout without planting. They are very aggressive becasue their seeds spread profusly and they lack the natural controls (OO).

In New London, there are a number of exsisting Norway Maple and Black Locust street trees remaining.

Sycamore Maple and Tree-of-Heaven primarily sprout in uncultivated area on property borders without assistance.

Some would call these trees weeds. All invasive species should be removed to prevent them from spreading and taking over natural areas.

| Street Trees: | Park Trees: |
|---|---|
| Pin oak | Carolina Silverbell |
| Red oak | Northern Catalpa |
| Elm Hybrids | Flowering Dogwood |
| London Planetree | American Basswood |
| Sweetgum | Tupelo |
| Hackberry | Hickory |
| Yellowwood | Sweetbay Magnolia |
| Ironwood | American Holly |
| Eastern Redcedar | Sourwood |
| Witchazel | Yellow Buckeye |

Figure 43: Above.
Street trees were suggested based on their durability.
Park trees were suggested based on environmental benefits.

In order to maintain a healthy urban forest, new trees need to be planted regularly. New London currently uses the theory of "Right Tree, Right Place." This considers the environment and the requirements for the tree to live. When planting, the rule of no greater than 5% of one species, 10% of one genus, and 20% of one family, should be considered.

Because different environments face different restrictions, a wide variety of trees are offered as potential candidates. Two categories of trees are offered here: street and park trees. Street trees need to be durable against environmental and physical abuse. Park trees can be less hardy and offer greater atmospheric, ecological, and aesthetic benefits. The offered selections originate from Connecticut or the Eastern United States because native trees have greater beneficial impacts on the present ecosystem.

In the selection of street trees, Pin Oaks and Red Oaks are recommended. These species include greater than 5% of the city's canopy, but the population is aging (Figure 27). All the Oaks are very successful as street trees (Figure 16), so planting some young trees will maintain the population as the older trees being to decline with age. London Planetree, a half naive hybrid, is in a similar situation to the Oaks. They are successful, but there is an aging population and their population is lower. Witchazel is offered as a tree for around or under power lines because of its short stature.[42] Some suggested species are new to New London, but are successful street trees in other cities in the area. Red maples are successful street trees, but they have been planted in great quantity in the past 25 years so it would be ill advised to plant more (Figure 26).

The park trees, rather than focusing on durability, focused on canopy coverage, atmospheric cleansing, and ecological benefits. Holies and Magnolias are effective at removing particle matter from the air.[43] Most of the suggested trees are produce nuts or small fruit for wildlife, offer flowers for insects, or tasty leaves for lepidoptera larvae.

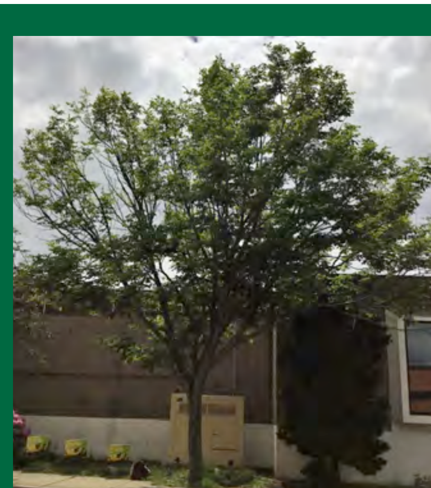


Figure 44:
Yellowwood planted on Eugene O'Neil Drive, New London. Photo from inventory results.

# Monitoring

Figure 41:
Map of Ashes in New London. There are only Ash trees in the Northern part of the city. There are 20 along streets, 17 in Bates Woods Park, 2 in Williams Park, and 1 in Williams Memorial Park.

With an increased planting plan, it is important to include the cost of monitoring trees in the planting budget. Newly planted trees need time to establish their roots system. For many young trees grown in ideal conditions in a nursery, being thrown into an urban environment is torturous. To prevent loosing the investment, newly planted trees need to be watered, even if there is not a drought. To prevent the excess cost for the city later, it is also recommended that young trees are pruned to prevent weak branch joins, or suckering growth, which may later become hazardous. These two steps may be expensive upfront, but if they are working into the budget, it can be very successful for healthier trees and less expensive in the long run.[44]

It is also important to save money in the budget for natural emergencies. Sometimes this looks like bad storm damage. Sometimes it is much bigger. Currently, in the state of Connecticut, the Emerald Ash Borer is spreading like wildfire, affecting true ash trees. (Mountain Ash is not a true ash). The insect larva eat the phloem layer of trunk, which means they eat all the tunnels transporting sugars from the leaves to the roots. This consumption of the tree's resources prevents the tree from repairing itself, and makes them very difficult to treat after the tree has become infected. The adults emerge from under the bark in the spring, leaving D-shaped exit holes. The insects are metallic green. An excess of woodpecker damage may also be a sign of an infestation. It is important for the city to have the financial reserves to either treat the major street trees, or have the money to have them removed once they are a problem. It is also a safely hazard to leave Ash trees standing once dead. Unlike most trees, Ashes can be burned for firewood as soon as it is cut. The wood is brittle, so it doesn't need drying time. This can be beneficial if one looking for last minute wood, but very dangerous if a dead tree is standing over a home or a main road. If infested, the wood must be burned within the quarantine zone.

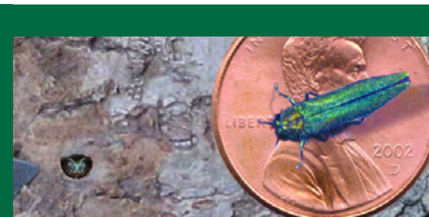


Figure 42
Above: Close up of an Emerald Ash Borer. On the left is an image of the 'D' shaped exit holes from which the adults emerge. A hole on an ash tree is a sign of infestation.

# Change in the City

Naturally, there have been drastic changes in New London since it's founding in 1646. While people's motivations and wants have changed with time, our basic needs have not. People need to be immersed in the natural environment. It is much more convenient to live in an urban setting, so it is important for people's wellbeing to bring the natural environment into the city. The 2018 inventory allows the city to critically analyze their tree stock and make beneficial changes in planting and management in the future. As New London moves into this more environmentally minded time in the city's history, it is important consider the benefits of trees. Bigger trees have exponentially more benefits for the citizens than small trees. As new development continues, engaging building plans with the existing environment will be important for the maintaining an extensive canopy.

Road improvements or new sidewalks have taken priority in the recent past (Figure 45 and 46). The 1993 inventory included 2,935 trees, but now there are only 1,887 trees. Sometimes, trees livelihood is not considered when new parking lots are built (Figure 47). New tree management considerations could change this. Awareness of the New London tree benefits, current tree stock, new plantings, monitoring, and maintenance pruning will allow for a healthier tree canopy. If trees were planted in clumps on school grounds, parks, and green patches, they are better able to support each other, leading to fewer maintenance costs. The groupings also contribute more the the city's canopy. If more shade trees are planted around fields and new tall canopy trees line the streets, New London will seem like a whole new place, or like it was 100 years ago!

Figure 45: London Planetrees on Plant Street
Summer 2018 & Fall 2018
Phtos by Maggie Redfern.

Figure 46: Cherries on Huntington Street
Spring 2015 & Fall 2018.
Phtos by Maggie Redfern.

Figure 47:
Baldcypress on Broad Street
Circa 1950 & Summer 2017.
Photos from New London Historical Socielty Maggie Redfern.

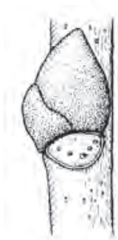
| | |
|---|---|
| **Ash** | **Fraxinus** |
| Green | americana |
| White | pennsylvanica |
| **Bald Cypress** | **Taxodium** distichum |
| **Beech** | **Fagus** |
| American | grandifolia |
| European | sylvatica |
| **Birch** | **Betula** |
| Black | lenta |
| Grey | populifolia |
| Paper | papyrifera |
| River | nigra |
| Yellow | alleghaniensis |
| **Buckeye**, Yellow | **Aesculus** flava |
| **Catalpa**, Northern | **Catalpa** speciosa |
| **Cedar**, Japanese | **Crypomeria** japonica |
| **Cherry** | **Prunus** |
| Black | serotina |
| Chokecherry | - |
| Higan | subhirella |
| Kwazan | serrulata 'Kwazan' |
| **Cottonwood**, Eastern | **Populus** deltoides |
| **Crabapple** | **Malus** |
| **Dogwood** | **Cornus** |
| Flowering | florida |
| Kousa | kousa |
| **Elm** hybrid | **Ulmus** |
| **Falsecypress**, Japanese | **Chamaecyparis** obtusa |
| **Ginkgo** | **Gingko** biloba |
| **Hackberry**, Northern | **Celtis** occidentalis |
| **Hawthorn** | **Crataegus** |
| **Hickory** | **Carya** |
| **Holly** | **Ilex** |
| **Honeylocust** | **Gleditsia** triacanthos |
| **Hornbeam**, American | **Carpinus** caroliana |
| **Katsura** | **Cercidphyllum** japonicum |
| **Larch**, European | **Larix** decidua |
| **Lilac**, Japanese Tree | **Syringa** rticulata |
| **Linden** | **Tilia** |
| American | americana |
| Bigleaf | platyphyllos |
| Littleleaf | cordata |
| **Locust**, Black | **Robinia** pseudoacacia |
| **Maple** | **Acer** |
| Hedge | campestre |
| Japanese | palmatum |

White Ash leaf

Elm leaf

Ginkgo leaf

Larch twig



American Basswood bud

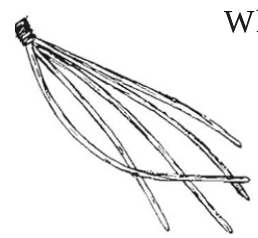
* According to Michael Dirr's Manual of Woody Lanscape Plants

| | |
|---|---|
| Norway | platanoides |
| Red | rubrum |
| Silver | saccharinum |
| Sugar | saccharum |
| Sycamore | pseudoplatanus |
| Trident | buergerianum |
| **Mimosa**.............................. | **Albzia,** julibrissin |
| **Mulberry**............................ | **Morus** |
| Red | rubra |
| White | alba |
| **Oak**.................................... | **Quercus** |
| Black | velutina |
| Northern Red | rubra |
| Pin | palusris |
| Scarlet | coccinea |
| Swamp White | bicolor |
| White | alba |
| **Peach**................................. | **Prunus**, persica |
| **Pear**................................... | **Pryus** |
| Callery | calleryana |
| Common | communis |
| **Pine**................................... | **Pinus** |
| Eastern White | strobus |
| Pitch | thunbergii |
| Scots | rigda |
| **Planetree**, London................ | **Plantus**, x acerifolia |
| **Redbud**, Eastern.................. | **Cercis**, canadensis |
| **Redcedar**, Eastern................ | **Juniperus**, virginiana |
| **Rose-of-Sharon**................... | **Hibiscus,** syriacus |
| **Sassafrass**.......................... | **Sassafrass,** albidum |
| **Serviceberry**...................... | **Amelanchier** |
| **Spruce**............................... | **Picea** |
| Blue | pungens |
| Norway | abies |
| White | glauca |
| **Sycamore**, American............. | **Platanus**, occidentalis |
| **Tree-of-Heaven**................... | **Ailanthus** altissima |
| **Tuliptree**............................ | **Liriodendron** tulipifera |
| **Tupelo**............................... | **Nyssa** sylvatica |
| **Walnut,** Black...................... | **Juglans**, nigra |
| **Whitecedar**........................ | **Chamaecypris** |
| Atlantic | thyoides |
| Northern | occidentallis |
| **Yellowwood**........................ | **Cladrastis** ketukea |
| **Yew**................................... | **Taxus** |
| **Zelkova**.............................. | **Zelkova** serrata |


Norway Maple leaf


Red Maple bud


White Oak leaf


Eastern White Pine needles


Black Walnut leaf

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