Developing a Nantucket Town Tree Inventory and Maps

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Abstract

Nantucket is proud of the town trees that grace its streets, especially its ancient elms. Unfortunately, disputes with property owners regularly arise due to the lack of clarity about the ownership of particular trees. The goal of this project was to create a comprehensive town tree inventory and online maps for use by property owners, developers, and the Town to minimize such disputes and facilitate tree maintenance. We collaborated with the Nantucket DPW to develop an inventory of 1,124 known town trees and consulted experts about community priorities. We recommend that the DPW updates the inventory and online maps periodically, adds new data fields as necessary, and uses them to develop tree maintenance and succession plans.

Executive Summary

Trees have been a ubiquitous presence in American cities for centuries and there are now some 5.5 billion urban trees in the U.S. contributing $18.3 billion annually in ecosystem services and other benefits (Nowak, et al, 2018, p. 164). The Nantucket Department of Public Works (DPW) and Tree Advisory Committee have primary responsibility for the management and care of town trees in Nantucket and have played a critical role in not only ensuring the wellbeing of Nantucket's trees, but also educating people about their significance and history. While urban trees provide substantial infrastructural, monetary, and health benefits for the cities in which they take root, they also bring with them heavy maintenance costs and occasional ownership disputes. In most cases, these disputes occur because a town tree is stationed on a private property whose owner wishes to remove it but does not have authorization from the Town. These disputes are exacerbated by a historical lack of clarity from the Town regarding which trees are town-owned, and which are not.

Project Goal & Objectives

The goal of our project was to develop a database and easily accessible online maps of Nantucket's town trees to aid the Department of Public Works (DPW), town officials, developers, property owners, and other members of the public in the identification and management of town trees. To complete this goal, we developed the following objectives:

(1) Evaluate current and best practices in developing tree inventories and maps in other Massachusetts communities.
(2) Review stakeholder opinions about current and previous efforts to inventory and manage town trees in Nantucket.
(3) Develop a system to collect and manage data on town trees for use by the Town.
(4) Develop easily accessible online maps to allow developers, homeowners, Town officials and others to access town tree data.

Findings

We reviewed existing town tree records, which included each tree's tag number, address, species, diameter at breast height (DBH), and condition. We designed a procedure to efficiently collect the tree data. We digitized the DPW's tree data, recorded each tree's coordinates with our phones, photographed each tree, and populated a Google Sheets database with this information. This Google Sheets database is shown in Figure A.

Tree Data

WKT	Tag#	Tree Species	Approximate Address	DBH	Condition
POINT (-70.0998002 41.2727828)	1068	Hybrid Elm	Front of High School	13	Good
POINT (-70.0997710 41.2728672)	1069	Hybrid Elm	Front of High School	13	Good
POINT (-70.0997341 41.2729456)	1070	Hybrid Elm	Front of High School	13	Good
POINT (-70.0996989 41.2730305)	1071	Hybrid Elm	Front of High School	12	Good
POINT (-70.0996660 41.2730991)	1072	Hybrid Elm	Front of High School	13	Good

Figure A. Screenshot of the Google Sheets tree inventory.

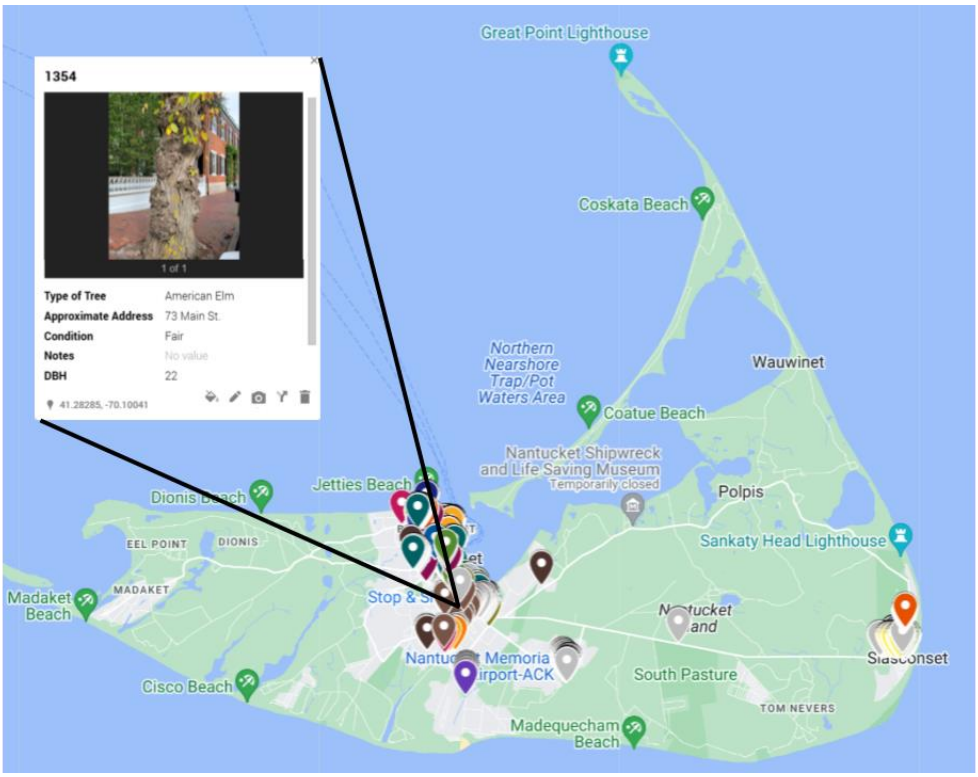

Figure B. The finalized Google Map organized by species.

The finalized inventory created in conjunction with the DPW contains 1,124 total town trees with fields for the location (WKT), tag number, approximate address, species, DBH, and condition of each tree. We chose to store the data in a Google Sheets spreadsheet due to its ease of use when entering, retrieving and updating data, as well as flexibility across different devices. To represent the data geographically, we used Google Maps. Clicking on a point will open a window containing information from each of the six data fields in the Google Sheets document as shown in Figure B. Additionally, the trees on the map can be color-coded according to their various data fields. Google Sheets and Google Maps provide a convenient and accurate inventory for no cost. In addition to Google Maps, we created a layer on the Town's GIS, showing only the positions of the trees acting as a resource for any developers and property owners who are looking to do any tree work. Prior to any unauthorized tree work or removal, the tree warden and DPW should still be contacted as the map still has some small gaps.

Figure C. Map and contemporary photograph of trees along Main Street.

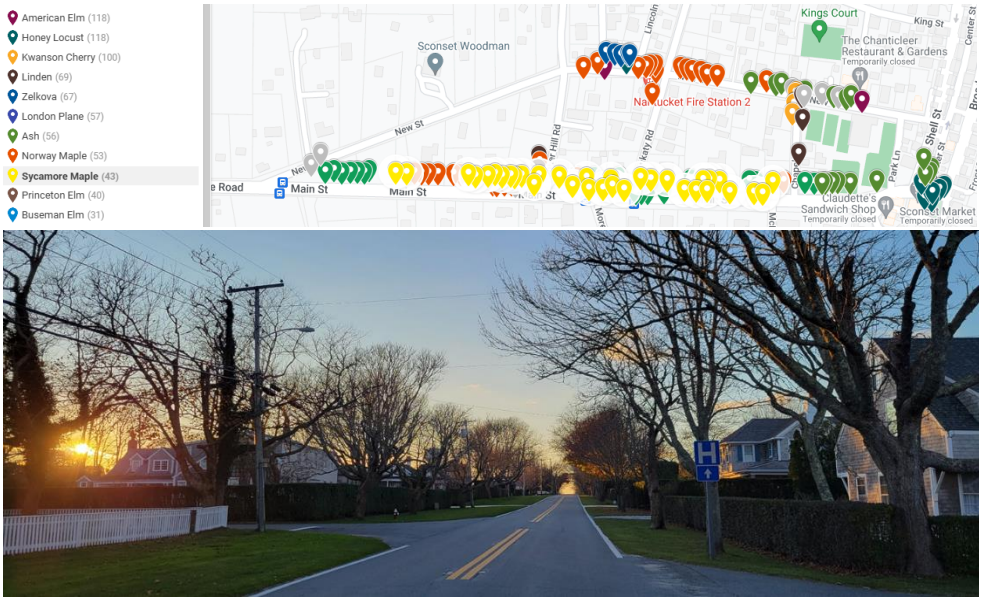

Figure D. Map and contemporary photograph of trees in Siasconset.

As shown in Figures C and D, we found that most of the town trees were located near the island's historic core and throughout Siasconset. Most of the trees lining Main Street in the town are elms which primarily include American elms, Buisman elms, and New Harmony elms. Most

of the trees lining in Siasconset consist of maples, with sycamore maples on Main Street and Norway maples lining New Street.

Recommendations

Based on the findings from our fieldwork, the inventory and mapping exercises, and our interviews with experts and stakeholders, we make several recommendations for the DPW and other organizations. These include valuable use cases for the inventory, as well as updates that should be made to the inventory to ensure continual use.

Recommendation 1: We recommend the DPW develop a plan to continually update the inventory.

We conducted remote interviews with the directors of town tree inventories in Natick, MA; Arlington, MA; Providence, RI; and Boston, MA. These experts informed us that since trees grow, change, and are trimmed, planted, and removed, the DPW should ensure that the inventory is regularly amended so it remains a useful planning tool. A comprehensive inventory should be conducted every 5–10 years. This comprehensive update can be conducted by trained volunteers. The DPW should also ensure that when new trees are planted, they are tagged and inventoried.

Recommendation 2: We recommend the DPW include additional data fields in the inventory.

We also interviewed a variety of stakeholders on the island – such as conservationist organizations, town management, and the town arborist and tree warden – regarding our inventory, its uses, and desired data fields. We determined that the DPW should consider expanding the number of fields in the existing inventory. These include:

(1) the year a tree was planted;
(2) the other trees, structures, and property surrounding a tree;
(3) whether a tree is native to Nantucket; and
(4) the maintenance history of the tree.

If collected, these fields would have utility for public education on trees, policy decisions, tree maintenance, and conservation efforts on Nantucket.

Recommendation 3: We recommend the DPW develop tree maintenance and succession plans.

This inventory is a crucial asset for the development of a systematic tree maintenance plan for use by the town arborist and DPW. The DPW can use additional data fields to schedule regular tree pruning, list fertilizers or treatments needed, or note special actions needed due to damage or problematic surroundings. The DPW should also use this inventory to develop a succession plan for when trees are removed.

Recommendation 4: We recommend that other organizations utilize the inventory for conservationism, tours, or educational materials.

As we learned in our stakeholder interviews, the inventory also benefits parties outside of property owners and the DPW. This inventory could be used to develop educational materials regarding trees, an informative tree tour like those hosted by the Land & Water Council, or for conservationist outreach materials regarding native trees and other environmental priorities regarding trees.

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Authorship

Section	Author	Editor
1. Introduction	A.S., B.G., J.G.	B.G., A.S.
2.1. Urban Trees	A.S., P.M.	A.S.
2.2. Legislation and Inventories in Massachusetts	A.S., P.M., B.G.	A.S., P.M.
2.3. Trees on Nantucket	J.G., B.G.	A.S., J.G., P.M.
2.4. New Tree Inventory	P.M.	B.G., J.G.
3.1. Objective 1	A.S.	P.M., A.S.
3.2. Objective 2	P.M.	A.S., P.M.
3.3. Objective 3	J.G.	A.S., P.M., B.G.
3.4. Objective 4	B.G.	A.S., B.G.
4.1.1. Tree Inventories in Other Towns	B.G., P.M.	A.S., P.M.
4.1.2. 2024 Tree Inventory Content and Functionality	J.G., B.G.	A.S., B.G., J.G.
4.2. Prospective Uses of the Inventory	P.M., A.S.	A.S.
4.2.1. Clarity on Tree Ownership	A.S.	A.S., B.G., J.G.
4.2.2. Public Outreach	P.M., A.S.	A.S., P.M.
4.2.3. Tree Management	P.M., A.S.	A.S., B.G.
4.3. Desired Data Fields	P.M., A.S.	A.S.
4.3.1. Year Planted	P.M., A.S.	A.S.
4.3.2. Surroundings	P.M., A.S.	A.S., B.G.
4.3.3. Native vs. Non-native Status	A.S.	A.S., J.G.
4.3.4. Maintenance History	P.M., A.S.	A.S.
5. Recommendations	P.M., A.S.	A.S., B.G., J.G.
5.1. Continually Update the Inventory	P.M., A.S.	A.S., B.G.
5.2. Continually Update the Maps	A.S.	P.M., J.G., B.G.
5.3. Include Additional Data Fields	P.M., A.S.	A.S., J.G., B.G.
5.4. Maintenance and Succession Plans	A.S.	A.S., B.G.
5.5. Other Organizations Should Utilize the Inventory	P.M., A.S.	A.S., J.G.
5.6. Conclusion	J.G., A.S.	P.M., B.G.
Appendix A	A.S.	P.M.
Appendix B	P.M.	A.S.
Appendix C	A.S., P.M.	A.S.

Table of Contents

List of Figures

List of Tables

1. Introduction

Trees have been a ubiquitous presence in American cities for centuries and there are now some 5.5 billion urban trees in the U.S. producing $18.3 billion annually in ecosystem services and other benefits (Nowak, et al, 2018, p. 164). While urban trees provide substantial infrastructural, monetary, and health benefits for the cities in which they take root, they also bring with them substantial maintenance costs and occasional ownership disputes. Urban tree inventories, or records of city-owned trees, allow homeowners and developers to know the ownership status of trees before engaging in tree work, and provide the authorities with information to better manage the trees in their care (Gaydos, n.d.). Maintaining an accurate and up-to-date tree inventory helps to lower maintenance costs, improve tree health, and mitigate ownership disputes. A comprehensive tree inventory is a vital element of any cost-effective and successful urban tree management program.

Since the Great Fire of 1846, the people of Nantucket have taken great care to maintain and cultivate their town trees. The Department of Public Works' (DPW) and Tree Advisory Committee have primary responsibility for the management and care of town trees. Other organizations, such as the Nantucket Land and Water Council (NLWC), have played a critical role in not only ensuring the wellbeing of Nantucket's trees, but also educating people about their significance and history. The Town of Nantucket has implemented bylaws and policies pertaining to tree maintenance, planting, and the demarcation of town trees. Unfortunately, the lack of information on the precise locations and ownership status of town trees has led to numerous disputes between property owners and the Tree Advisory Committee regarding the maintenance or removal of town trees on private and public property.

The goal of our project was to develop a database and easily accessible online maps of Nantucket's town trees to aid the DPW, town officials, developers, property owners, and other members of the public in the identification and management of town trees. To achieve this goal, we laid out four objectives to guide us:

(1) Evaluate current and best practices in developing tree inventories and maps in other Massachusetts communities.
(2) Review stakeholder opinions about current and previous efforts to inventory and manage town trees in Nantucket.
(3) Develop a system to collect and manage data on town trees for use by the Town.
(4) Develop easily accessible online maps to allow developers, homeowners, Town officials and others to access town tree data.

In this report, the background section reviews our research into the various benefits and disservices of town trees, as well as town tree inventory efforts made by other towns in Massachusetts. We then discuss a brief history of Nantucket's trees and tree bylaws, followed by previous attempts to create a functional tree inventory for the island. The methods section outlines our core objectives and methods used to complete our project. Finally, we discuss our findings, deliverables, and recommendations for improved town tree management in the future.

2. Background

2.1. Urban Trees

Urban trees are a vital piece of green infrastructure in cities worldwide. In the United States alone, an estimated 5.5 billion trees exist in urban areas. While city-owned trees do require maintenance (i.e., planting, pruning, and extraction), the benefits they provide for their cities are substantial. For example, Nowak & Greenfield (2018) estimate that urban trees in the US contribute $18.3 billion in various services annually (Nowak et al, 2018).

Urban trees offer a variety of infrastructural, aesthetic, and health benefits (as illustrated in Figure 2.1) that researchers have tried to estimate in various ways, including imputed dollar values. Urban trees retain stormwater, lightening the load on other water infrastructure (American Rivers, 2023); they increase the sequestration (capture) and storage of carbon emissions by up to 6.2% (Speak, et al., 2020); they increase the monetary value of surrounding property by tens of thousands of dollars (Wells, 2010); they provide shade and cool the air by up to 45°F in urban heat islands (Environmental Protection Agency, 2017); they provide habitat for animals, allowing residents to connect with local fauna (Sundberg, 2019); they add aesthetic value, with a majority of individuals feeling "touched" by the beauty of public trees (O'Brien, 2024); and they provide health benefits such as stress relief, restored attention span, increased immune function, lower prevalence of obesity, and increased cardiovascular function (Wolf, et al., 2020). In short, the presence of town trees provides extensive environmental, infrastructural, aesthetic, and human health benefits.

Figure 2.1. Infographic detailing the benefits of street trees (The Nature Conservancy).

2.1.1. Infrastructural Services

Wu (2014) estimated that the 415,000 urban trees in Providence, Rhode Island, removed 91 tons of air pollutants (carbon monoxide, nitrogen dioxide, and ozone) annually and intercepted 4,213,000 cubic feet of stormwater runoff. Trees moderate the temperature of nearby buildings significantly, either by cooling (through shading and evapotranspiration) or blocking harsh winter winds (Energy Saver, n.d.). She also estimated that residents save $591,000 annually in energy costs as a result, and that the trees in Providence sequestered 4,030 tons and stored 124,000 tons of carbon annually, resulting in significantly cleaner air and delivering the equivalent of more than $9 million of total carbon sequestration and storage. Carbon storage is one of the most valuable of the infrastructural services offered by street trees; Nowak, et al. (2013), estimate the total carbon storage of urban trees in the U.S. at 643 million tons (equivalent to a value of $50.5 billion in 2013). Other infrastructural benefits of trees (i.e., carbon sequestration, air pollution removal, avoided energy use, and avoided emissions) are listed in Table 2.1 below.

Table 2.1. Tree value totals in 2018 (Nowak, D. J., Greenfield, E. J., 2018, p. 174.)

Service	**Value (billions USD/year)**
Carbon sequestration	4.8
Air pollutant removal	5.4
Avoided energy use	5.4
Avoided emissions	2.7
Total	18.3

Aside from infrastructural benefits, trees also increase property values. For example, economists Donovan and Butry (2010) found street trees in Portland, Oregon enhanced sales price of homes by $8,870 on average ($12,886 today) and enhanced the net value of homes in surrounding area by $12,828 ($18,636 today). Extended to the entire city, Donovan and Butry found that street trees add $45 million a year to the property value of Portland, Oregon (Wells, 2010). A study by the University of Nebraska reports that trees have a positive impact of $31.5 billion dollars on the net property value of the United States (University of Nebraska-Lincoln, n.d.).

2.1.2. Health Services

In addition to the infrastructural and financial services performed by urban trees, there are many social and health benefits to the presence of urban trees and green infrastructure in general. In an extensive review of literature on the subject, Wolf, et al., found in 2020 that the wide spread of positive social and health outcomes of urban trees could be divided into three categories: harm reduction, restorative, and facilitative. Harm reduction outcomes pertain to the mitigation of social and health concerns: the interception of air pollutants by trees in green spaces (Wolf, et al., 2020, p. 6), crime reduction (p. 9), and shade, which decreases risk of

excessive ultraviolet radiation and heat (p. 8-9); shade cast by park trees is depicted in Figure 2.2a below. Restorative outcomes pertain to psychological or physiological function: it was found, for instance, that the presence of trees correlates with better focus; more effective life management; reduced tension, fatigue and anxiety (p. 10); reduced stress and depression (p. 11); and increased social behavior (p. 14). Finally, facilitative outcomes describe improvements to physical wellness: these include lower blood pressure, shorter recovery times for gallbladder surgeries (p. 12), better birth outcomes, improvements to the immune system, increased proclivity towards physical activity (p. 13), lower rates of obesity, and increased cardiovascular function (p. 14). O'Brien, et al. (2024) have also reported high rates of agreement with positive sentiments towards the presence of trees, such as "they are good for my wellbeing," "I feel touched by their beauty," and "they provide a peaceful refuge for me" (O'Brien, et al., 2024, p. 1341); an urban trees' aesthetic contributions are shown in Figure 2.2b. In general, the medical, psychological, physiological, aesthetic, and emotional benefits of trees are numerous and significant and must be taken into consideration alongside the other factors of tree value.

Figure 2.2a. Walkway trees provide beauty and shade.

Figure 2.2b. Street trees provide aesthetic value.

Figure 2.2c. A fallen tree causes property damage.

Figure 2.2d. A tree causes nuisance via fruit litter.

Figure 2.2. A collage of four images of urban trees (Roman, et al., 2020, p. 617).

2.1.3. Disservices

This is not to say, though, that urban trees are solely advantageous; the oversimplification that "trees are good" omits a much more nuanced evaluation of benefits and costs. Tan, et al., (2001, p. 15) found that trees' ecological benefits in Kyoto did not, in fact, outweigh the expenditures of planting and maintenance. Roman, et al. (2020), identified five disadvantages

("disservices") of town trees: damage to existing grey infrastructure, such as sidewalks and systems for water, transportation, and energy (with powerlines being a notorious target of fallen trees; tree failure and overgrowth are the most common cause of power interruptions according to Simpson and Van Bossuyt, 1996); injuries and fatalities (due to collisions between trees or branches and individuals, vehicles, or buildings, as well as arboriculture incidents such as falls or chainsaw incidents); nuisances such as leaf, branch, and fruit litter; increased housing prices which lead to the displacement of vulnerable residents, known as green gentrification); and the thirty-year duration needed for the slow carbon benefits of trees to outweigh the carbon deficits from planting and maintaining a new tree (Roman, et al., 2020). Damage to structures and fruit litter are depicted in Figures 2.2c and 2.2d above. Some trees also emit volatile organic compounds or pollen, which can aggravate allergies (Wolf, et al., 2020, p. 8). The many deficits of town trees provide a layer of complexity to the question of evaluation; the myriad ecological gains must be considered in proportion to the losses to calculate the true value of a tree.

2.2. Legislation and Inventories in Massachusetts

2.2.1. Massachusetts Town Tree Legislation

Trees in urban areas are variously defined as town trees, urban trees, shade trees, urban forests, and the like. There is a distinction, however, between trees owned and maintained by state and town government and private trees. However, often disputes arise about details in ownership and responsibilities. The definitions of town trees vary by state and local laws; however, they can be generally defined as any tree that is owned and/or maintained by the town government. Massachusetts state law classifies any tree situated in a public way or its boundaries as a 'public shade tree' (Public shade trees § 1). Citizens are forbidden from unauthorized trimming or removal of public shade trees (Public shade trees § 3) and unpermitted signage or marking (Public shade trees § 9). Violations to this law can result in fines up to $500 or a prison sentence up to six months (Public shade trees § 11). As such, when ambiguity arises regarding the ownership of a tree, large disputes between individuals and cities often result, such as those described in section 2.3 below. It becomes significantly easier for individuals and organizations to avoid these disputes when equipped with the knowledge of who owns each tree in an area. Therefore, tree inventories, which catalogue this information, prove extremely useful to individuals, organizations, and local governments alike.

Local government protection of trees in Massachusetts dates back to the late 19th century, when Chapter 190 of the Acts of 1896 protected shade trees from unpermitted removal or relocation and enumerated the powers of Tree Wardens, such as authorizing removal and creating regulations to protect trees (Massachusetts Department of Conservation and Recreation, 2021, p. 4). Many towns in Massachusetts also implement different types of tree ordinances to protect the trees as thoroughly as possible. Street tree ordinances, for instance, regulate the planting and removal of trees on public sidewalks. Tree protection ordinances are used by towns to protect trees that either have historical importance to the town, are native to the area, or are endangered. To prevent disputes over trees blocking views or sunlight, towns implement view

ordinances. Towns also use landscape ordinances which determine how many and which types of trees need to be placed on certain types of properties such as parking lots (Massachusetts Department of Conservation and Recreation, 2021, p. 6). Massachusetts residents have historically cared deeply for their trees, reflected in the state's regulations and bylaws closely protecting trees from harm.

2.2.2. Town Tree Inventory Management

The Massachusetts state government defines a tree inventory as a "record of location and characteristics of individual trees and, sometimes, characteristics of their environs, within a defined geographic area" (Commonwealth of Massachusetts, n.d.). The government also describes three different types of inventories that most towns will create: a small random sample of trees along a street called a 'sample inventory;' a 'partial inventory' which is a more 'systematic' although incomplete sample; and a 'complete inventory' of all the trees in a town or designated area. The Massachusetts Department of Conservation and Recreation has funds available for towns to put towards creating a complete inventory.

2.2.3. Tree Inventories in Other New England Towns

There have been many cities in New England which have recently conducted complete tree inventories and created databases that record species, size, canopy size, and the environmental impact of trees. Several lawmakers found that such inventories could be used to help mitigate climate change by anticipating when trees will need to be replaced and identifying places where there is a lack of trees (Carley, 2024). In Providence, RI, city officials intend to collect data on canopy size every ten years to assess changes in the tree canopy and calculate the monetary values associated with benefits such as providing shade, lowering surface temperatures, and removing airborne pollutants as seen in Table 2.2 (Wu, 2014). City officials believe these data would help maintain tree canopy size and ensure that any diseases can be caught early to prevent major tree losses (Wu, 2014). City officials in both cities believe the inventories will allow them to better maintain the trees and maximize the environmental, aesthetic, and monetary benefits associated with them.

Table 2.2. An example monetary database from Providence showing the value of all 415,000 trees based on their contributions to the city. Adapted from Wu, 2014.

Total Annual Benefits of Street Trees, City of Providence			
Benefit	**Amount**	**Sub-Value**	**Total Value**
Energy			
Electricity Saved	1684 MWh	$202,132	
Natural Gas Saved	633,812 therms	$1,026,528	$1,228,660
CO2			
CO2 Stored	2,180 tons	$14,564	
CO2 avoided	2,527 tons	$16,945	

CO2 released	504 tons	-$3,367	$28,143
Air Quality			
Pollution Intercepted	29 tons	$101,096	
Pollution Avoided	12 tons	$101,863	
BVOC pollution emitted	2 tons	-$8,627	$194,334
Stormwater			
Stormwater Intercepted	30.6 m. gallons		$244,945
Aesthetic/Other			
Increased Property Values			$1,236,649
		Total	$2,932,731

Smaller towns such as Bedford, MA and Amherst, NY have taken different approaches to inventorying their trees. Bedford used community volunteers to collect data (see Table 2.3) rather than employing professional arborists or tree analysts (Bedford Urban and Community Forestry, n.d.). This approach saves money but limits the accuracy and consistency of the data collected. The Bedford and Amherst inventories were less sophisticated than those conducted in Boston and Providence. For example, Amherst did not conduct cost analysis or calculate canopy size (Town of Amherst, n.d.). Bedford and Amherst focused largely on data that affected the health of their trees such as wood and foliage condition because the goal of both towns was to protect the health of the trees and not calculate the monetary value of the services the trees provide.

Table 2.3. Sample tree inventory sheet from Bedford, MA (Town of Amherst, n.d.).

TREE INVENTORY FORM

Address	Tree #	Site Type	GPS Latitude(N)	GPS Long.(W)	Species or "stump"	Inches Around	Wood Condition	Foliage Condition	Notes	Pavement Conflict > 1"	Potential Wire Conflict	Evidence of Pests	Tree Stress (if any)	Foliage Stress (if any)
		Roadside Median Bike Path Trailside Other					Good Fair Attn	Good Fair Attn		Sidewalk Road Both Neither	Conflict Not yet No wire No conflict	EAB ALHB Other None	Dieback Roots Rot Crack	Defoliat. Mining ALHB Discolor
		Roadside Median Bike Path Trailside Other					Good Fair Attn	Good Fair Attn		Sidewalk Road Both Neither	Conflict Not yet No wire No conflict	EAB ALHB Other None	Dieback Roots Rot Crack	Defoliat. Mining ALHB Discolor
		Roadside Median Bike Path Trailside Other					Good Fair Attn	Good Fair Attn		Sidewalk Road Both Neither	Conflict Not yet No wire No conflict	EAB ALHB Other None	Dieback Roots Rot Crack	Defoliat. Mining ALHB Discolor
		Roadside Median Bike Path Trailside Other					Good Fair Attn	Good Fair Attn		Sidewalk Road Both Neither	Conflict Not yet No wire No conflict	EAB ALHB Other None	Dieback Roots Rot Crack	Defoliat. Mining ALHB Discolor
		Roadside Median Bike Path Trailside Other					Good Fair Attn	Good Fair Attn		Sidewalk Road Both Neither	Conflict Not yet No wire No conflict	EAB ALHB Other None	Dieback Roots Rot Crack	Defoliat. Mining ALHB Discolor
		Roadside Median Bike Path Trailside Other					Good Fair Attn	Good Fair Attn		Sidewalk Road Both Neither	Conflict Not yet No wire No conflict	EAB ALHB Other None	Dieback Roots Rot Crack	Defoliat. Mining ALHB Discolor

2.3. Trees on Nantucket

2.3.1. History

When Nantucket was connected to the mainland 7,000 years ago, jack pine and spruce were the prevalent tree species (Dunwiddie, 1989). Due to rising temperatures, by 1500 AD, the island consisted primarily of oak, along with some pine, beech, maple, hickory, and bayberry (Amaral, et al, 2018).

During the European settlement, most of Nantucket's oak population, along with other woody vegetation, was cut down. Within the first few years, the settlers were dependent on firewood from the mainland, which was scarce due to the American Revolution. Desperate for fuel, they harvested a majority of available trees, exhausting much of the island's wood supply by 1780 (Dunwiddie, 1989). Sixty-six years later, the great fire of 1846 burned down most of the remaining trees in the downtown area, leaving the town of Nantucket barren. From the ashes of the fire, however, there sprouted a new life that quickly took root and flourished with the help of the islanders. Two of these people were Josiah Sturgis and Henry Coffin. (Dunwiddie, 1989; Lang, et al, 1992).

In 1847, Josiah Sturgis planted pitch pine seeds around the island. Unfortunately, the resurgence of pitch pines also introduced the Nantucket pine tip moth to the island, which caused severe damage to the island's pitch pines. The moth was initially contained within Nantucket but found its way to the mainland where it is still a problem today (Dunwiddie, 1989).

In 1851, Henry Coffin reintroduced the American elms along Main Street. Following Coffin's replanting efforts, Nantucket's American elms became a beloved staple of the island's culture and are still recognized today for their distinctive appearance (Lang, et al, 1992; Nantucket Land and Water Council, n.d.).

Dutch elm disease (DED) was first discovered in 1918 in France and spread throughout Europe. By 1979, the disease had wreaked havoc throughout North America, killing off 50 to 100 million elms (Karnosky, 1979). Fortunately, separation from the mainland has its advantages. Since the island only had a limited exposure to the disease, only a few of the island's trees caught the disease. As a result, Nantucket is now home to most of the world's American elm trees, and they remain a quintessential part of Nantucket's culture and history (Nantucket Land and Water Council, n.d.).

Figure 2.3. Two pictures showing the Town of Nantucket in 1895 (left) and present day (right) (Nantucket Historical Association, 1890.; Gee, 2024). Courtesy of the Nantucket Historical Association, GPN4219.

2.3.2. Bylaws and Tree Management

In order to preserve the island's cherished trees, the town of Nantucket implemented bylaws in 1998 (Chapter 132; bylaws 132-1 – 132-8). According to bylaw 132-2, a tree will be designated as a "town tree" if one of the following criteria is met:

- The town purchased the tree or paid to have it planted.
- The tree is fully or partially on town property.
- The tree was given to the town.
- The town serviced the tree more than once within the last twenty years, with the visits separated by at least a year.
- The tree has a medallion to signify its status.

Citizens are prohibited from cutting or removing town trees except with a written permit from the tree warden. Additionally, the tree warden must hold a public hearing where they identify the size, type, and location of the tree. If any part of the chapter is violated, the Department of Public Works (DPW) will inform the offender via mail. Moreover, the DPW will be allowed to rectify the issue if the individual has not responded or solved the problem within fifteen days (132-1B) (Town of Nantucket, n.d.).

All efforts to maintain the trees are managed by several organizations including the Department of Public Works (DPW), the Tree Advisory Committee, the Tree Warden, and the Town Arborist. The Parks and Recreation sub-division of the DPW oversees the island's parks and recreational facilities including beaches, playgrounds, and various parks and open spaces (Town and County of Nantucket Massachusetts, n.d. -b). The Tree Advisory Committee oversees the enhancement, well-being, and overall management of the town trees (Nantucket Tree Advisory Committee, 2024a-e). The Nantucket Tree Warden is primarily tasked with enforcing the tree bylaws, settling disputes and serving as head of the Tree Advisory Committee (Nantucket Tree Advisory Committee, 2024a; Town of Nantucket, n.d.). The Town Arborist is responsible for keeping a record of and maintaining the island's trees, helping to settle tree related disputes, and provide solutions that aim to preserve trees around the island (Nantucket Tree Advisory Committee, 2024e; Graziadei, 2022b).

There have been several accounts of tree disputes across the island. Two of these had very similar outcomes. One case involved a 70-year-old catalpa tree on York Street. The tree was planted on empty private property whose owner wanted the tree removed to build a house (Graziadei, 2022a). The other featured two 25-year-old elms on Pleasant Street. These were planted on a property owned by the Reinemo family who wanted the trees removed to build a commercial building (Graziadei, 2022c).

The Nantucket Tree Advisory Committee opposed the notion of the trees being removed. In the first case, the property owner and his lawyer insisted that there was no proof that the catalpa was a town tree. However, the catalpa was ultimately considered a town tree since it had been maintained by the town on multiple occasions (Graziadei, 2022a). In the second case, the trees were planted by the town, but the Reinemo family argued that the town did not have authority to plant the trees on their property (Graziadei, 2022c).

The officials on the island deal with many other cases very similar to these. People approach the Tree Advisory Committee with questions about maintaining nearby trees (Nantucket Tree Advisory Committee, 2024a; Nantucket Tree Advisory Committee, 2024e). Ultimately, however, the underlying issue was that transparency from the Town on tree ownership status has been limited. In both cases, the owners had town trees planted on their private property but could not remove them due to the bylaws in place. The criteria for town tree designation were based on information unknown to the property owners, making it feel as though they were "[b]asically walking into a trap" (Graziadei, 2022a). The lack of accurate and accessible records on town trees has resulted in many similar cases where the citizens and officials spend time and effort trying to resolve disputes. The Tree Advisory Committee is extremely protective of trees around the island, believing that the trees in both cases symbolize Nantucket's rich history (Graziadei, 2022c). While the property owners did not disagree with the Committee's perspective, they both felt that clarification was needed regarding town ownership of trees. By documenting only town-owned trees, public, accessible town tree inventories provide this much-needed clarification.

2.3.3. Previous Inventory Efforts & Shortcomings

One of the earliest documented tree inventories of Nantucket was completed around 1986 by the DPW. This inventory featured the first iteration of the ID number system created for mapping trees (Amaral et al., 2018). Each tree was tagged with a medallion, showing its ID number (see Figure 2.4). Unfortunately, the inventory was never completed due to competing demands for staff time and resources, and the information collected is now largely dated. In 2017 the DPW attempted a partial town tree inventory, including data such as location, species, tag number, size, condition, if they are sprayed or fertilized, the date planted and an additional column for comments. In 2018, WPI students conducted a project in collaboration with the Nantucket Land Council (now known as the Nantucket Land and Water Council). The project entailed inventorying a selection of trees (both private and Town-owned) and Main Street with the intent to create a GIS map (Figure 2.4) and educational resources for the public. To this end, the team created a prototype of a website called 'ACKnowledge the Trees' which could showcase the data in a fun and educational way. The data collected was used to create a data layer that was the basis for the ArcMap (Figure 2.4).

Figure 2.4. A map of downtown Nantucket showing the previously mapped trees along Main Street in green and blue, from the 2018 WPI team.

The 2018 inventory included data on the tree species, the ID number, the location, damage or disease, the diameter at breast height (DBH), and the overall height. The ID number system was revised, and new medallions were attached to the trees, as shown in Figure 2.5.

Figure 2.5. Original tree medallion (left) and 2018 Medallion (right).

Amaral et al. (2018) analyzed changes in the trees on Main Street since 1986. They found the greatest change was a dramatic shift from American elms to Buisman elms that are more resistant to DED. In 1986 there were 94 American elms on Main Street. By 2018, only 45 American elms survived while 67 Buisman elms had been planted. Not unexpectedly, the trees on Main Street increased substantially in size during this period as indicated by measurements of diameter at breast height, and overall height. In 2019, after the previous inventory attempts, the

DPW tried to create another one for town trees. They inventoried 652 trees, and recorded the position, DBH, genus, species, address, type, approximate height and condition.

2.4. New Tree Inventory

Nantucket is very proud of the graceful elms and other large shade trees that line many of the streets downtown and elsewhere on the island. Residents appreciate the trees for their historic and aesthetic value despite the problems trees create by disturbing sidewalks and utilities. The Town has passed bylaws to protect town trees that are managed by members of the Tree Advisory Committee and DPW staff. Unfortunately, there are no accurate or complete inventories and maps of town trees, which can lead to disputes with private property owners regarding tree maintenance or removal. The lack of data also prevents the DPW and others from analyzing how the trees are changing each year which makes it significantly more difficult to anticipate and manage problems. The goal of our project was to develop an up-to-date inventory and online maps of town trees to enhance the Tree Advisory Committee and DPW's abilities to manage the trees and would help the town adjudicate disputes with homeowners, developers, and others about the management of trees.

3. Methods

The goal of this project is to evaluate Nantucket's town trees and to create a database and accessible online maps of Nantucket's town trees to aid town officials, property owners, and developers in the identification and management of town trees. This project had four main objectives:

(1) Evaluate current and best practices in developing tree inventories and maps in other New England communities,

(2) Review stakeholder opinions about current and previous efforts to inventory and manage town trees in Nantucket,

(3) Develop a system to collect and manage data on town trees for use by the town,

(4) Develop accessible online maps to allow developers, homeowners, town officials and others to access and map town tree data.

Figure 3.1 shows the tasks associated with each objective that are discussed in more detail. We also compiled our deliverables and a final presentation during this time.

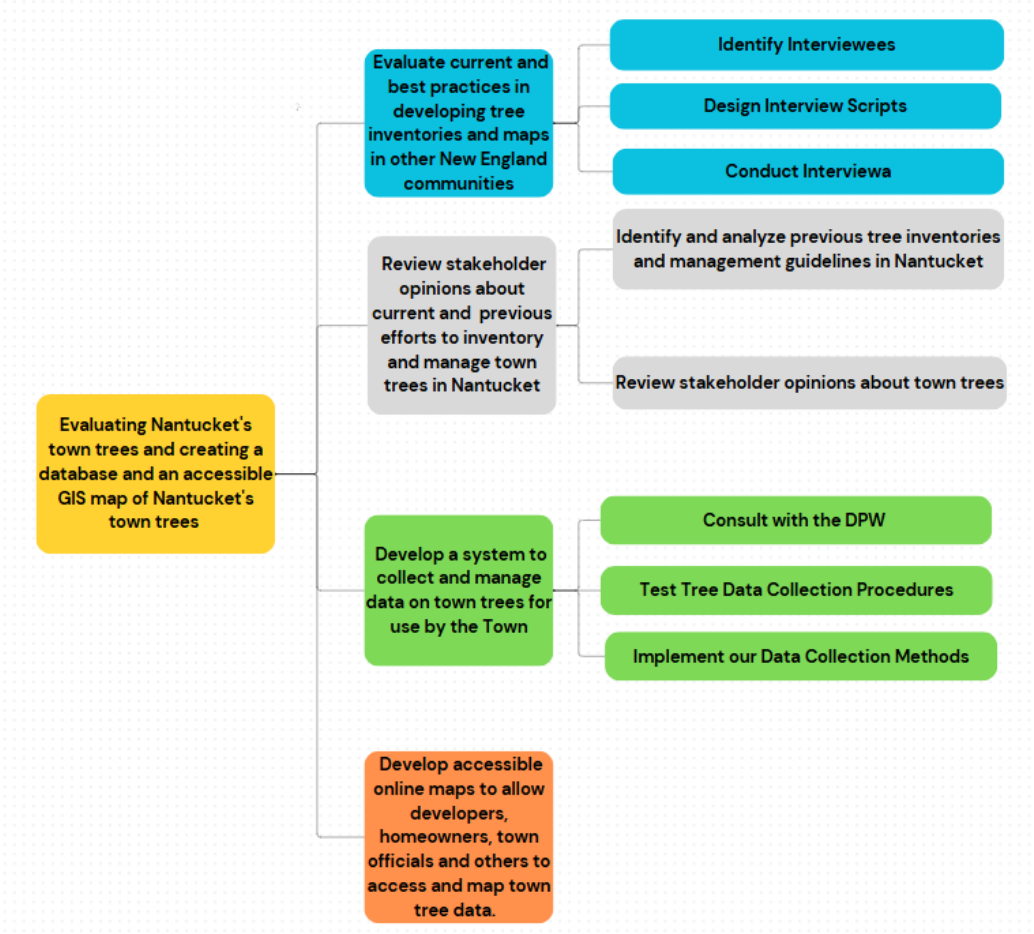

Figure 3.1. Project goal, objectives, and tasks.

3.1. Objective 1: Evaluate current and best practices in developing tree inventories and maps in Nantucket and other New England communities.

In our background research, we identified several towns other than Nantucket that have developed inventories and GIS maps of town trees, such as Natick, MA; Arlington, NY; Providence, RI; and Boston, MA. We supplemented our initial background research through interviews with representatives of those towns to learn more about how and why they developed their inventories and maps, what problems they encountered, and how they overcame them. Conducting these interviews involved three steps described below: identifying relevant figures from these towns, designing interview scripts, and conducting interviews with these individuals.

We reviewed the websites of the cities listed above to identify the staff responsible for tree inventories and maps, such as DPW officials and town arborists, and volunteer workers. To identify other towns that have conducted state-of-the-art inventories, we asked each interviewee to suggest representatives from other towns with exemplary tree management programs. These interviewees were compiled in our interviewee spreadsheet in Table 3.1. below.

We conducted 15–30-minute interviews over Zoom, Google Meet, or by phone with interested town officials using the prepared scripts. Each interview began with a consent preamble informing the interviewee about our intentions and that they may stop at any time. We then asked questions focusing on the purposes of the inventory, the development choices made, and the data collection strategies employed. An example preamble and interview script, which was modified for each town based on our background research, is provided in Appendix A. Since this primarily informed our own future design decisions and recommendations, we relied on notes taken during the meeting rather than a recording.

Table 3.1. Other towns' tree inventory directors and interview status as of December 2, 2024.

Type	On island?	Organization	Contact Name (if any)	Reached out?	Heard back?	Scheduled?	Date/time	Interviewed?
Other Town	☐	Amherst	Davey Resource Group	☐	☐	☐		☐
Other Town	☐	Bedford	Nick Pouliot	☑	☐	☐		☐
Other Town	☐	Arlington	Tim Lecuivre	☑	☑	☑	Tues 12/3 10:00 AM	☐
Other Town	☐	Franklin Regional Council of Governments	Kimberly Macphee	☑	☐	☐		☐
Other Town	☐	Cambridge		☑	☑	☐		☐
Other Town	☐	Providence	Douglas Still	☑	☑	☑	Friday 10/25 11:00 AM	☑
Other Town	☐	Natick	Art Goodhind	☑	☑	☑	Tues 11/26 10:00 AM	☑
Other Town	☐	Boston	Todd Mistor	☑	☑	☑	Wed 11/6 11:00 AM	☑

3.2. Objective 2: Review stakeholder opinions about the current and past attempts to inventory and manage trees in Nantucket.

This objective was important to our project since having information about tree inventories in other towns and in Nantucket would inform us as to how to conduct our inventory optimally. To accomplish this objective, we (1) identified and analyzed other tree inventories and management guidelines in Nantucket and (2) reviewed stakeholders' opinions on town tree inventories.

3.2.1. Identify and analyze current and previous tree inventories and management guidelines in Nantucket.

After arriving on Nantucket, we located as much existing data as we could (previous inventories from 2017 and 2019, and the current paper copies of data) on the town trees from the DPW in our first sponsor meeting. We analyzed this data for relevant information to our project such as the data fields and data collection methods. By looking at these previous attempts and speaking with the town arborist we adjusted our data collection protocols for the trees to ensure we created a useful inventory. The DPW also had tagged most of the town trees and made paper copies of the address, tag number, and diameter at breast height (DBH) of the town trees which we converted into a spreadsheet and updated as we collected data as described in objective 3. The tags used by the DPW include a tree number matching the finalized database information, as well as a QR code which leads to the town website including the Google Map of the trees. A photograph of a tree tag is shown in Figure 3.2.

Figure 3.2. A tree tag currently used by the DPW.

3.2.2. Review stakeholder opinions on town tree inventories.

With the information we gathered about the previous tree inventories and management efforts we identified key informants on tree management and tree inventory use cases. These included: the town arborist, the town tree warden, the Tree Advisory Committee, the Land and Water Council, Planning and Land Usage Services (PLUS), the Historic District Commission, and the town GIS coordinator. We also identified several key stakeholders who were not directly related to town tree management but would be impacted by a street tree inventory, such as realtors, environmental groups, staff at the Visitor Center, and representatives of other organizations. A full list of interviewed stakeholders is presented in table 3.2.

Table 3.2. Stakeholders and interview status as of December 2, 2024.

Type	On island?	Organization	Contact Name (if any)	Reached out?	Heard back?	Scheduled	Date/time	Interviewed?
Town	☑	Visitor Center	Shantaw Bloise-Murphy	☑	☐	☐		☑
Town	☑	Tree Advisory Committee	Mary Longacre	☑	☑	☑	Thurs 11/14 11:30 AM	☑
Town	☑	Chamber of Commerce	Peter Burke	☑	☑	☑	Thurs 11/7 3:00 PM	☑
Town	☑	Town management	Gregg Tivnan	☑	☑	☑	Wed 11/6 1:00 PM	☑
Town	☑	Town Arborer	Dale Gary	☑	☑	☑	Mon 11/25 10:00 AM	☑
Town	☑	DPW	Drew Patnode	☑	☑	☑	Mon 10/21 2:00 PM	☑
Town	☑	PLUS & NHC	Holly Backus	☑	☑	☑	Wed 10/30 1:00 PM	☑
Town	☑	Select Board	Brooke Mohr	☑	☑	☑	Wed 10/30 11:00 AM	☑
Town	☑	Maria Mitchell Association	Joanna Roche	☑	☑	☑	Tues 11/19 10:00 AM	☑
Environment	☑	Tree Advisory Committee	Dave Champoux	☑	☑	☑	Thurs 10/31 2:00 PM	☑
Environment	☑	Nantucket Conservation Foundation	Kelly Omand	☑	☑	☑	Tues 11/19 3:30 PM	☑
Environment	☑	Land and Water Council	Emily Molden	☑	☑	☑	Thurs 11/21 11:00 AM	☑
Environment	☑	Nantucket Land Bank	Emily Goldstein Murphy	☑	☑	☑	Tues 10/29 11:00 AM	☑
Residential	☑	Town association	Lee Saperstein	☑	☑	☑	Fri 11/22 1:00 PM	☑
Residential	☑	Real Estate Agency	Realtor	☑	☑	☑	Thurs 10/31 12:00 PM	☑
Other	☐	GIS Coordinator	Nathan Porter	☑	☑	☑	Tues 11/5 11:00 AM	☑

We developed interview scripts based on our background research and in consultation with our sponsors which included questions on how town trees are managed on Nantucket, the causes of tree disputes and other tree issues, the significance of town trees to citizens and tourists, and how an inventory of trees might help improve tree management. We also asked the people who were a part of previous tree inventory efforts about some of the problems they ran into as well as what methods they used so we were better prepared for our data collection. When interviewing the GIS coordinator, we focused our questions on topics relating to which of the data we collected should be publicly accessible, what data we should include in the GIS map, and other factors that could make our GIS map more useful. We also asked him and the DPW about the current tree layer on the town's GIS which we found was not specific to town trees and was not a complete inventory. We developed a script, seen in Appendix B, for people involved with town tree management and Appendix C for stakeholders that are not directly involved with developing tree inventories or management.

The protocols for these interviews were very similar to the ones done in Objective 1, however the questions were more focused on the specific organization the individual was a part of and how the inventory could be used to accomplish tree maintenance and other objectives on Nantucket. The scripts were assessed and amended if the interviews gave us new ideas or topics to ask future interviewees or if some questions did not yield useful answers.

3.3. Objective 3: Develop and Implement Methodology for Tree Data Collection

On arrival in Nantucket, we learned that DPW staff were actively engaged in replacing the old tags on town trees with new tags and compiling an inventory of trees at the same time. Unfortunately, the inventory was available only in paper form, so we transferred the data into a Google spreadsheet. The data collected by the DPW included DBH, species, approximate address, and current condition (generally: poor, fair, or good).

Through observations in the field, we added latitude and longitude coordinates, verified the DBH measurements, and took a photo of each tree. We determined the approximate lat/long coordinates using our mobile phones followed by desk-based verification and correction using satellite imagery.

Originally, we believed we would borrow a Trimble unit from the Land and Water Council to record the coordinates and other attributes, such as height, species, etc. We decided against using the Trimble unit because neither the DPW nor Land and Water Council had subscriptions to the Trimble GPS Pathfinder software, and the Trimble unit would be superfluous for collecting only lat/long coordinates. Instead, we experimented with different GPS software and found that Google and Apple Maps both proved to be reasonably accurate. With manual corrections against satellite maps, our coordinates were reasonable to at least five decimal digits. As the difference between two degrees of latitude is about 111 kilometers, five decimal digits narrow the space down to 1.11 meters, or about four feet of inaccuracy – a very reasonable scope for surveying individual trees (U.S. Geographic Survey). After recording the coordinates for each tree based on phone data in the field, we adjusted the precise location based on the software's satellite view.

Initially, we believed our research would be confined to the downtown area, but we discovered that the DPW had already inventoried and tagged around 600 trees in all parts of the island by mid-October. DPW staff continued to tag and inventory the remaining town trees while we verified the lat/long and DBH data on trees that had already been tagged. Ultimately, the database and maps included 1,124 trees across the entire island.

3.4. Objective 4: Develop accessible online maps to allow developers, homeowners, town officials and others to access and map town tree data.

Our fourth and final objective focused on designing and publishing the online Google and GIS maps. We created an easily accessible Google Map for internal use at the DPW and to act as a backbone for the GIS layer. This Google Map will be updated in the future as the DPW sees fit and based on the Google Sheet inventory. In addition, we consulted with the town's GIS coordinator about creating a layer on the official towns GIS map, displaying the trees based on the Google Map layer.

The Town's GIS is managed by GIS coordinator, Nathan Porter. The GIS includes a data layer specifically for street trees, but this layer is of limited use in determining the location or ownership status of town trees. The data layer on trees in the Town GIS was derived by interpolation from satellite imagery and does not distinguish between private and town trees. We consulted with Nathan Porter to determine how the data from the town tree inventory (in Google Sheets) and the Google Map might best be transferred to him for inclusion in the Town GIS as a new, more authoritative map of known town trees. Going forward, the plan is that the Google Sheets inventory and Google Map will be managed and updated by DPW staff. Periodically (i.e., once or twice per year), DPW staff will transfer the data into a .kml file for Nathan Porter to use in updating the town tree data layer in the Town GIS. This data layer of town trees on the

GIS only displays the locations of the town trees. This map is not definite, however as it does not include all of the town owned trees on Nantucket so property owners and developers should still check with the DPW or tree warden before any tree work is done. We ran a test trial of the map using Google Maps and got feedback from the DPW regarding the placement of the trees, data fields collected, and pictures taken of trees. The test trial encompassed a single street of data. To mitigate any integration issues between the spreadsheet of data, the Google Map iteration and the GIS layer we sent this single street of data to Nathan Porter to confirm all the systems will talk to each other well. The final iteration of the Google Map once completed was sent to the GIS coordinator to upload to the Town's GIS as a data layer and published with a disclaimer stating the above for any future developers.

4. Findings

In recent years, multiple efforts have been made to inventory street trees on Nantucket. The DPW began a town tree inventory in 2017, but data collection was interrupted by the COVID-19 pandemic, and the inventory was never finalized. In 2018, a team of WPI students collaborated with the Land & Water Council to inventory the trees along Main Street and developed a fun and informative prototype app for public outreach and education. In 2019, the DPW conducted a partial town tree inventory which featured similar but fewer data fields than the 2017 inventory. This included the location, the species, the address, the height, and the condition of each tree recorded. We built on these previous inventories to develop a more comprehensive inventory of all known town trees on the island and a set of interactive, online maps.

In this chapter, we discuss the structure and content of the inventory and explain the different ways data can be extracted from the database and displayed in maps and graphs. Following this section, we highlight the potential uses for such a database for the DPW and the town of Nantucket as described in stakeholder interviews. Our final section highlights additional data fields that stakeholders recommended for inclusion in future updates to the inventory.

4.1. Approaches to Tree Inventories

4.1.1 Tree Inventories in Other Towns

There are several different approaches that towns take when inventorying trees. These include relying on their own staff and interns to collect the data, contracting companies to do the inventorying and analysis for them, or training volunteers to record information. To learn more about the benefits of each of these methods, we interviewed different town officials who were involved with conducting their tree inventories. In these interviews, we learned that Boston, MA and Providence, RI did not complete the inventories in-house but rather hired a company called Davey Tree to inventory and evaluate their town trees. Based on our discussions, the most basic data Davey Tree collects are GPS location, species, DBH, and condition. Using this set of data, Davey Tree derives monetary benefits and maintenance plans. Officials from Boston, MA and Providence, RI said that the Davey TreeKeeper software suite was more suited for larger datasets (e.g., more than 5,000 trees) and would therefore not be very cost effective for Nantucket to implement. Arlington, MA hired interns and volunteers to collect species, DBH, GPS location, and condition data on their town trees, which they stated was significantly cheaper than hiring a company like Davey Tree but was also more prone to inconsistencies in data collection. All four of these towns' tree inventories included plans for either repeating the inventory every 3-5 years or continuously updating the inventory with every tree removal or planting to ensure it stays up to date.

4.1.2. 2024 Tree Inventory Content and Functionality

Our final data collection process, as described in the Methods, involved utilizing a cell phone to take GPS coordinates and record tree data. This process proved to be accurate within reason. We decided to store data in a Google Sheet and Google Map as these are simple, free, and efficient enough to be used in the field without any setbacks. Utilizing cell phones also makes the process much more accessible for use while in the field and cuts costs significantly; this requires no software subscription or special hardware such as a Trimble unit. To work with this inventory, the DPW workers just need a phone or tablet with cellular data.

The town tree inventory created in conjunction with the DPW has data (including photographs) on 1,124 town trees, which can be displayed in a tabular or geographical format. The inventory is maintained in Google Sheets because this enables easy data entry, retrieval, and updating by DPW staff from any location using a variety of devices, assuming Internet access. Using Google Sheets obviates the need for specialized software and licensing fees. The screenshot in Figure 4.1 shows that currently the inventory comprises six data fields (location (lat/long) or WKT, tag number, tree species, approximate address, DBH, and condition).

The database in Google Sheets can be portrayed geographically using Google Maps. In addition to Google Maps some of the data can be displayed on the Town's GIS tree layer. As with our decision to use Google Sheets, we used Google Maps to allow the DPW to easily access the data in map form without the need for specialized software and licensing fees. The Google Map in Figure 4.2 shows all of Nantucket with the trees marked and labelled by species (each map pin is colored to portray a particular species). If a user clicks on one of the pins on the map, a window will pop-up that displays a photograph of the tree and a summary of the data drawn from the inventory database (including the coordinates or WKT, species, DBH, address, condition). The current inventory does not include all the town trees on Nantucket, there are still some trees left to be tagged as part of the inventorying efforts by the town, so it is important that when referencing the map to still consult the DPW before any tree work or removals are done.

Tree Data

WKT	Tag#	Tree Species	Approximate Address	DBH	Condition
POINT (-70.0998002 41.2727828)	1068	Hybrid Elm	Front of High School	13	Good
POINT (-70.0997710 41.2728672)	1069	Hybrid Elm	Front of High School	13	Good
POINT (-70.0997341 41.2729456)	1070	Hybrid Elm	Front of High School	13	Good
POINT (-70.0996989 41.2730305)	1071	Hybrid Elm	Front of High School	12	Good
POINT (-70.0996660 41.2730991)	1072	Hybrid Elm	Front of High School	13	Good
POINT (-70.0996436 41.2731852)	1073	Hybrid Elm	Front of High School	13	Good
POINT (-70.0996436 41.2731852)	1074	Hybrid Elm	Front of High School	13	Good
POINT (-70.0993660 41.2731054)	1075	Prinstin Elm	Front of High School	11	Fair
POINT (-70.0984704 41.2725936)	1076	Locust	Court Yard Behind High School	23	Good

Figure 4.1. Screenshot of the Google Sheets database.

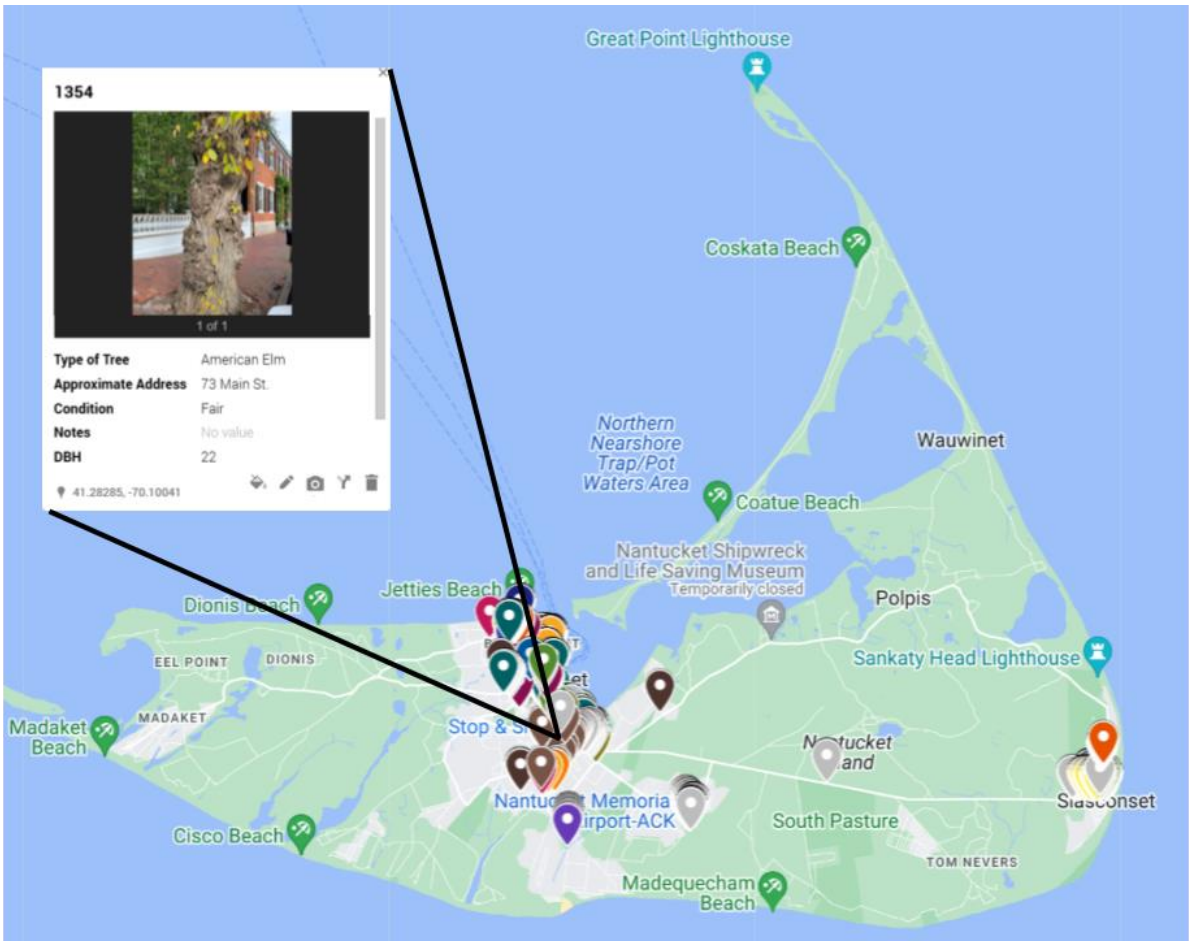

Figure 4.2. Google Map showing the distribution of town trees across the island by species.

Figure 4.2 shows that most of the town trees are in the historic cores of downtown or Siasconset, with a few others at the airport and along Surfside Road. As the user zooms in on the map, the pins on the map will spread out to reveal the locations of individual trees more clearly. For example, Figure 4.3 shows that most of the trees lining Main Street are elms, including American elms, Buisman elms, and New Harmony elms. The American elms can be traced back to Henry Coffin, who reintroduced the species to the town in the 1850s (Lang, et al, 1992). The other elm species have been planted since because they are resistant to Dutch elm disease. Similarly, Figure 4.4 shows that the town trees in Siasconset comprise primarily sycamore maples on Main Street and Norway maples along New Street. Other prominent species include ash trees and red maples.

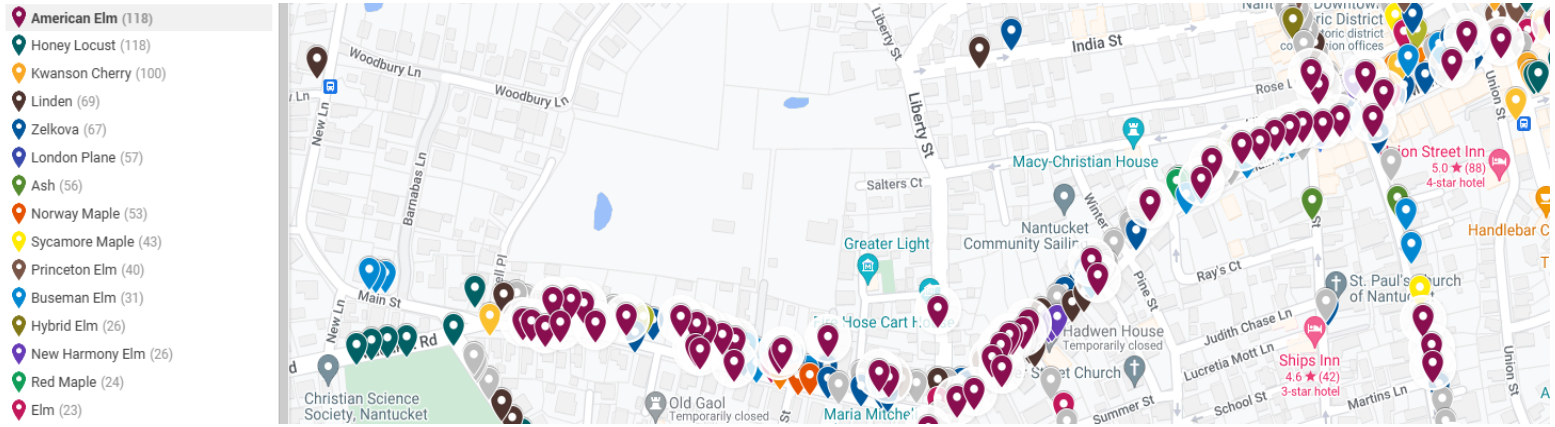

Figure 4.3. Map and Historic and Contemporary Photographs of Town Trees on Main Street (Nantucket Historical Association, n.d.; Gee, 2024). American Elms are highlighted. Courtesy of the Nantucket Historical Association, GPN4143.

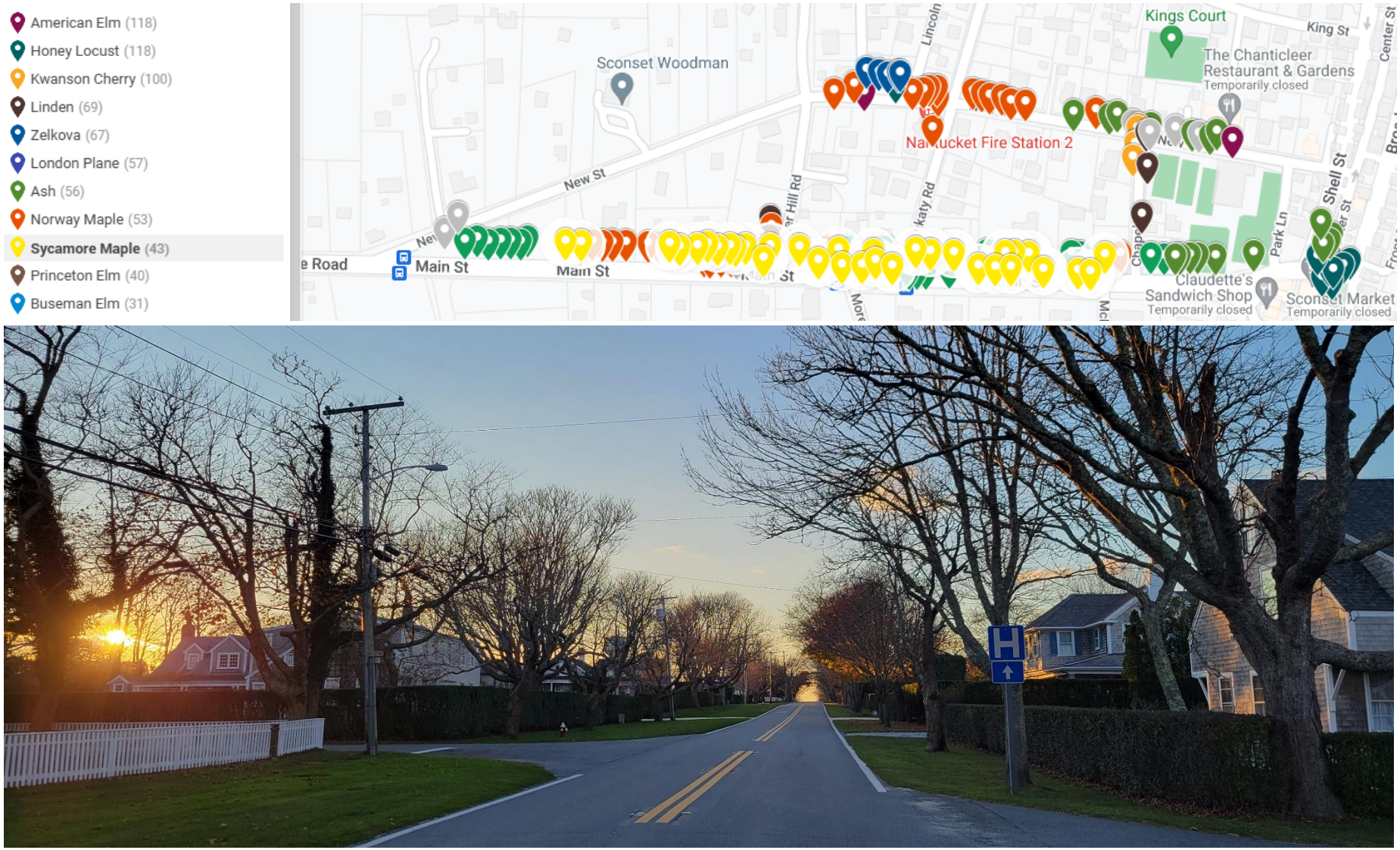

Figure 4.4. Map and Contemporary Photograph of Town Trees on Main Street in Siasconset (bottom) (Gee, 2024). Sycamore maples are highlighted.

Using the chart function in Google Sheets, users can create graphics based on specific data fields. In addition to the location and tree ID, the current tree inventory has three other data fields for the species, condition, and DBH of trees. The inventory includes 70 different species of tree from more than 10 different genera. The most prominent of these include elms with 321 trees, of which 114 are American elms, maples with 149 trees, and locusts with 121 trees. (Figure 4.5). Reviewing the condition of the trees, we can see that roughly 76% of the recorded trees are in good condition, while only 2% are in either poor or worse condition.

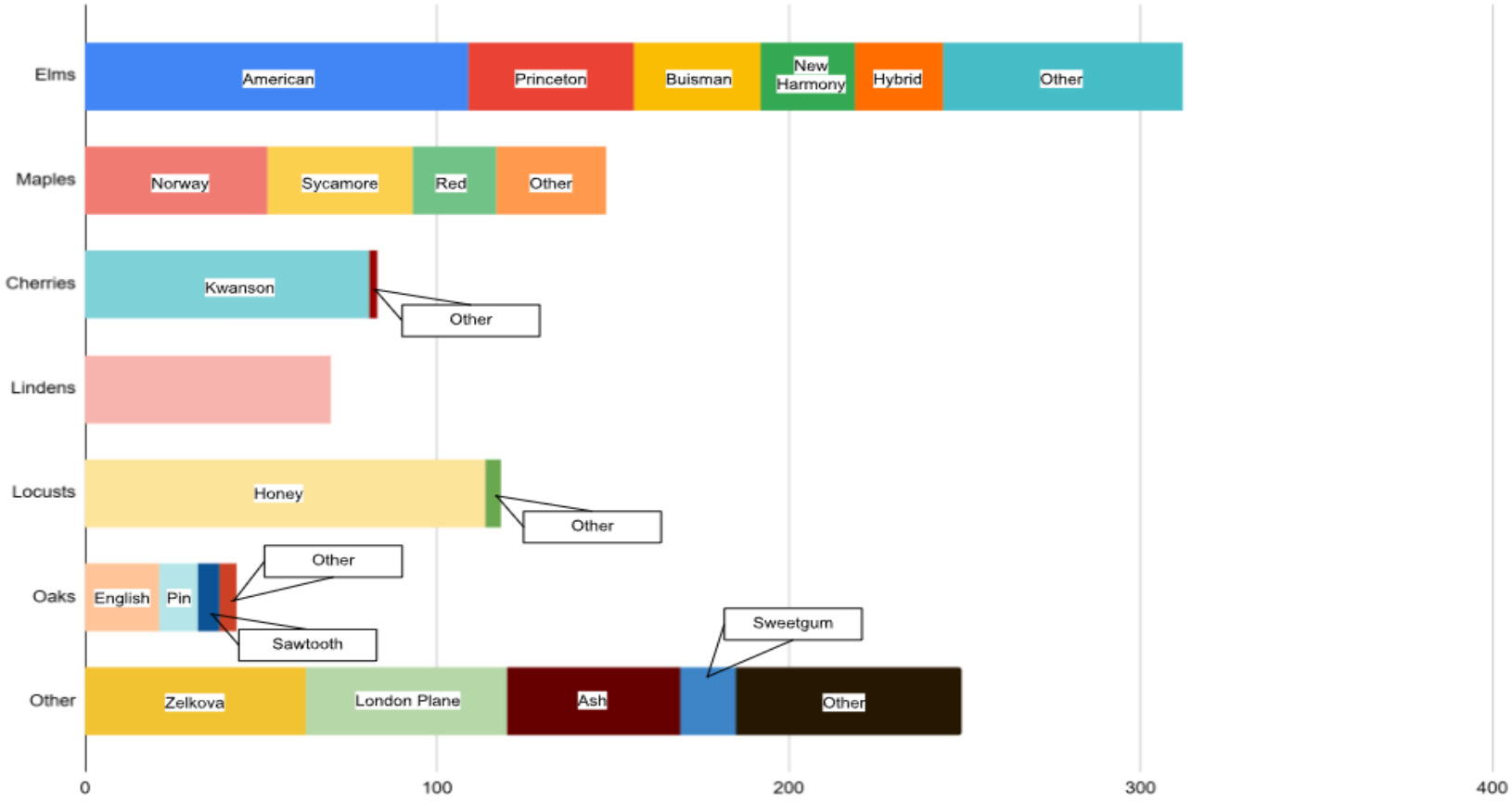

Figure 4.5. The distribution of town trees by species.

In reviewing the DBH shown in Figure 4.6, we see that the vast majority of town trees measure within the range of 5-20 inches, with 62 trees having a modal DBH of 12 inches. This suggests that many of the island's trees belong to species that do not grow very wide. The average DBH for the entire inventory is 16.44 inches, while the standard deviation is 10.27 inches. The overall distribution of the graph takes on a bell curve but is skewed towards the right, with few trees wider than 30 inches at breast height.

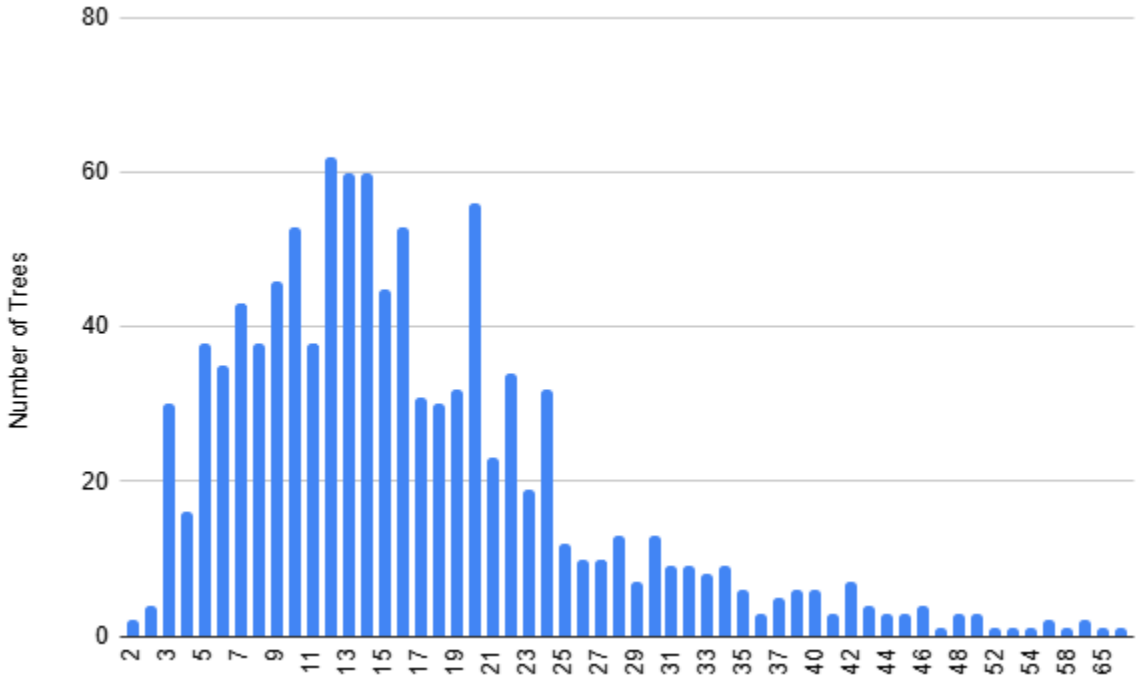

Figure 4.6. Distribution of the diameter at breast height (inches) of the town trees.

As the tree inventory develops and expands further, the DPW will be able to represent and visualize specific data for use in tree maintenance and management projects. This might have uses in applications for grants and the creation of public presentations and reports.

4.2. Prospective Uses of the Inventory

Town tree inventories are particularly important assets for town governments and organizations in their many prospective uses. From interviews with other towns' tree inventory directors and stakeholders on Nantucket, we uncovered several significant use cases for the tree inventory. In particular, the inventory might be used to:

(1) limit disputes between town officials, property owners, developers, and others by improving clarity on the location and ownership status of town trees;
(2) promote public education and outreach about town trees; and
(3) enhance town tree management and planning.

We explain each benefit in more detail below.

4.2.1. Improve Clarity about Town Tree Ownership

As previously illustrated, town tree disputes are relatively frequent on Nantucket due to the lack of information and clarity about the location and designation of town trees. However, with a comprehensive town tree inventory in place, town officials, property owners, developers, and tree workers can easily determine whether a particular tree is town-owned and avoid such disputes in the future.

Stakeholders have had many overlapping insights on this. Drew Patnode, director of the Nantucket Department of Public Works, emphasized the utility of this inventory to facilitate communications between town officials and property owners regarding tree ownership status. In our further discussions with Mr. Patnode, we determined that the best method to display the ownership status would be in a layer of the town GIS. This layer will serve as an official record of town trees and can be contrasted with other layers to see the interactions of town trees with parcels, sidewalks, and other planimetric features.

The Town GIS data layer will be drawn from data on the tree inventory spreadsheet as well as the linked Google Map. The user will be able to export the data from the map as a KMZ file to upload to the GIS layer, which will only contain the coordinates for each tree as well as the associated tag number. To update the data on the GIS layer, the user will need to reimport and merge the Google Sheet with the Google Map and then re-export the data from the map. Seeing as our inventory is not representative of all town trees on the island, the published GIS layer will include a disclaimer warning users against removing trees prior to contacting the town arborist and/or town tree warden.

Brooke Mohr, chair of the Select Board, and Peter Burke, director of the Chamber of Commerce, indicated this inventory could also inform planners, architects, permitters, and potential buyers in their decision-making. Holly Backus, preservation planner with Planning and Land Use Services (PLUS), said an inventory would also make it easier for PLUS to gauge the arboreal feasibility of a proposed development. Dave Champoux, Nantucket's tree warden, stated that an inventory would make it much easier to come to a decision on a tree ownership dispute. A local realtor also indicated that greater clarity on tree ownership would make communications with clients more straightforward, as realtors could use this inventory to confidently indicate a tree's ownership status with a potential buyer. In general, the clarity introduced by this inventory will dramatically simplify the work of all parties dealing with property ownership issues related to town trees.

4.2.2. Promoting Public Education and Outreach

Both our interviews with other towns and stakeholders on Nantucket have emphasized the possibility of using the tree inventory and maps in public education and outreach regarding trees. The inventory and maps could be used to generate support for conservation efforts or tree work conducted by DPW and others, and to educate the public on the history of Nantucket's trees. Todd Mistor, Boston's director of urban forestry, mentioned that the inventory could be used to make maps of trees based on several factors such as species, age, or health, which could

be used for making tours of the trees for tourists or outreach materials. The idea of a tree tour proved popular among stakeholders: Emily Molden, executive director of the Land & Water Council, described how the inventory could be used to craft a self-guided tree tour for tourists, while Peter Burke proposed that the map be displayed at the Visitor Center so that tourists can locate trees of interest by species, location, and tag number.

Beyond tourists, this inventory could also be used for educational efforts targeting concerned or curious residents. Drew Patnode described how the inventory could be used to explain to the public that tree work, especially controversial tree removal, is not an effort to disrupt the historic image of Nantucket's trees but a key element of a larger systematic plan to improve town trees' health and appearance. Joanna Roche, director of the Maria Mitchell Association, described a program in Nantucket schools where students could choose the species and location for new town trees, which taught children about the significance of native species and the nuance of tree planting decisions. She indicated the tree inventory could be useful for designing similar projects in the future, cultivating children's interest in trees. Gregg Tivnan, assistant town manager of Nantucket, and Nathan Porter, GIS coordinator for Nantucket, indicated that the tool could be useful to quickly gather and report data for public education – Nantucket's distinctive tree species distribution could be used to craft materials on the threats to elms, for instance.

In discussing public outreach, many interviewees also noted the immense historical value of Nantucket's trees, which could be chronicled in a tree tour or other educational experience. Gregg Tivnan and Mary Longacre noted that the trees contribute to Nantucket's character, which helps to draw in tourists. Perhaps most eloquently, Peter Burke stated that these trees are a key element of the "Nantucket magic" tourists experience alongside other historic features like the classical architecture and cobblestone streets. As trees are central to Nantucket's historic image, this inventory has immense use both for tourism and as an educational asset.

4.2.3. Enhancing Town Tree Management

In our research and interviews, we observed that tree management, succession planning, and planting efforts will be improved by a continually updated tree inventory. The directors of tree inventories in Providence, Boston, Natick, and Arlington stated that inventories are often used to develop or enhance tree management procedures. This is done by recording when the trees were last maintained, and which trees need more upkeep. Since trees do not last forever, it is important to know when trees are starting to decline in health so that a succession plan can be developed to replace them with newer trees. Using the existing data on tree condition and species, an arborist could assess which trees are in urgent need of replacement and with which species they should be replaced. This inventory can also be used to gauge areas that are more susceptible to certain diseases and pests based on lack of species diversity and use this to inform protection efforts; representing more diverse tree species on Nantucket could slow down the spread of disease or pests, for instance. Mary Longacre also described how this inventory could be used to inform new tree planting efforts. The Tree Advisory Committee could use the inventory to target areas with few trees for future planting efforts. Generally, stakeholders and

officials from other towns agree that this inventory will simplify the organization of tree work and management as well as succession planning.

4.3. Desired Data Fields

The inventory features five data fields: the GPS location, approximate address, species DBH, and condition of each tree recorded. However, in addition to these, officials from other towns and stakeholders from Nantucket have suggested other data fields that might have some utility. The data fields most frequently mentioned include:

(1) the year a tree was planted;
(2) the other trees, structures, and property surrounding a tree;
(3) whether a tree is native to Nantucket; and
(4) the maintenance history of the tree.

We describe each of these data fields more thoroughly and some of the motivations for their suggested inclusion.

4.3.1. Year Planted

The year a tree was planted – and, as derived, its age – was by far the most popular data field requested by stakeholders with nine of fourteen interviewed stakeholders indicating this would be appealing to them. Holly Backus indicated that the age of a tree could be useful for tree management as older trees might need more imminent replacement, which could be prepared further in advance. Brooke Mohr, discussing the Select Board's involvement in tree removal disputes, described how an older tree's age is pivotal in deciding whether to preserve or remove a tree. Recalling such a dispute, she asked incredulously: "you're really asking to take down an 80-year-old tree, 100-year-old tree?"

Others brought up closely related information: Dr. Emily Goldstein-Murphy, research ecologist with the Nantucket Land Bank, indicated that the history of a tree (such as its cultivator and associated history) would be valuable for outreach efforts, while Peter Burke suggested that the inventory indicates whether a tree was originally planted as a gift (and if so, by whom.) If inventoried alongside the year a tree was planted, these would both serve to elevate public interest in town trees and their history. In general, the year of planting and associated history of each town tree is of interest to a majority of interviewed stakeholders for a variety of reasons.

4.3.2. Surrounding Impacts and Encumbrances

A description or photograph of the tree's surroundings – including sidewalks, drainage grates, buildings, and power lines – was another frequently requested data field. Several inventory directors and stakeholders, especially those with expertise regarding the complex interactions of these systems, explained that this information could be useful for planning tree work in problematic areas or restoring disrupted structures. Todd Mistor, director of Boston's street tree inventory, noted that information about the area immediately around the tree, such as if it is near power lines or breaking up the surrounding sidewalk, would be beneficial for tree maintenance. Gregg Tivnan and Nathan Porter also suggested adding data fields indicating

interference with adjacent power lines, sidewalks, or sewer systems. In our meetings with the Nantucket DPW, we have discussed the possibility of including pictures of any disrupted surroundings. Six interviewed stakeholders mentioned disruption to nearby structures as a significant drawback to Nantucket's town trees. Since many town-owned trees are stationed on private property, Mary Longacre indicated that it might be of use to also record the contact information of the property owner, if applicable.

Dr. Goldstein-Murphy also suggested we indicate whether a tree is closely surrounded by many trees of the same species, as this would make them much more susceptible to certain diseases and pests such as the Southern Pine Beetle and Dutch elm disease. Since these can quickly spread and can lead to substantial tree death, it is important to be able to know this information ahead of time so efforts can be focused on regions that need help urgently. This can also be used to plan diverse planning efforts so that the spread of disease is impeded. While this can be assessed by comparing the species of neighboring points on the map, an additional data field nonetheless could help to identify problematic regions.

In general, knowledge of the surroundings of a tree, which includes both nearby infrastructure and other trees, can be very important for tree workers, the Tree Advisory Committee, and others, as it allows them to plan tree work around neighboring structures and plan more diverse and resilient tree populations.

4.3.3. Native vs. Non-native Species

Several stakeholders from conservation organizations such as the Land and Water Council and the Nantucket Conservation Foundation emphasized the need to know if a tree is a native species. This was described as a crucial data field for planning future planting efforts; many of Nantucket's trees, including town trees, are non-native, and some are even invasive, such as the Norway Maple (*acer platanoides)*. It should be noted that "invasive" designation does not mean the tree necessarily poses a significant ecological threat, but merely that it can repopulate prolifically and potentially problematically.

Joanna Roche noted that this information could provide insight into the ecological role of a tree, as many birds and insects prefer native trees as habitats. Kelly Omand, a research ecologist with the Nantucket Conservation Foundation, described how in urban areas, many native tree species have planting requirements that are more involved than those of non-native species, such as specific soil or more allocated space. She also explained that many invasive tree species such as the tree of Heaven (*ailanthus altissima*) are very common on the island and some residents have grown attached to them. Despite these challenges, both indicated that protecting and promoting native trees is a high priority for conservationists on Nantucket. If native/non-native status were included in this inventory, it would be substantially easier to gauge areas in need of native trees and craft outreach materials to educate the public on their significance.

4.3.4. Maintenance History

Finally, several interviewees indicated that 'internal fields' (i.e., not for general public access) regarding tree maintenance history could be useful for scheduling regular tree work. The

officials from Boston, MA; Providence, RI; Natick, MA; and Arlington, MA recommended incorporating a data field showing when a tree was last maintained in order to mitigate the scheduling of regular maintenance of the town trees. Dale Gary, Nantucket town arborist, and Drew Patnode indicated interest in a data field displaying when a tree was last pruned, with Mr. Gary suggesting that this field be used to ensure each tree is pruned at least once every three to five years. They had also discussed adding another data field representing whether a tree required special maintenance due to compromising surroundings or health concerns. Brooke Mohr also suggested a field indicating whether the tree has died. These fields, if present, would make scheduling regular tree work – alongside the development of a tree management plan – significantly simpler.

5. Recommendations

From our findings, we have identified several recommendations for the DPW and other organizations. These include valuable use cases for the inventory, as well as updates that should be made to the inventory to ensure continual use. We recommend that:

(1) the DPW develop a plan to continually update the inventory,
(2) the DPW develop a plan to continually update the GIS layer,
(3) the DPW include additional data fields in the inventory,
(4) the DPW utilize the inventory for the development of systematic tree maintenance and succession plans,
(5) other organizations utilize the inventory for conservationism, tours, or educational materials.

5.1. The DPW should develop a plan to continually update the inventory.

Since conditions change and trees are regularly planted, trimmed, and even felled, we recommend that the DPW create a system for continually updating the inventory. When new trees are to be planted, those trees should be tagged and inventoried immediately. Per suggestions from other towns' tree inventory directors, we also believe that a complete town tree inventory should be conducted again once every 5–10 years to measure which trees have grown, what species have become more or less prevalent, and how the condition of certain trees has changed. By observing the change in health or condition over time, the DPW could identify which areas and trees are more or less resilient to disease or pests. This information could be used to inform new planting efforts as well as to protect existing trees. As their time is very limited, the DPW could train a team of volunteers to conduct the inventory; no professional experience is necessary to conduct such an inventory, so this could be an element of a similar school program to that described by Joanna Roche in section 4.2.2., or a Scouts program. Since plantings and felling are common and trees consistently grow, this would ensure that all data in the inventory is relatively up to date at all times.

5.2. The DPW should develop a plan to continually update the GIS layer.

As the inventory continues to grow, it is critical that the DPW regularly consults with the GIS coordinator to update the official Nantucket GIS database to minimize confusion and disputes. This can be done by exporting the shapefile from the Google Map and transferring it to the GIS coordinator. With periodic updates to maintain its reliability, the GIS layer representing town trees will be able to act as an official information source for use by property owners, developers, and other parties. As discussed, this layer is not complete and it is likely that as tree work continues on the island, new town trees may be noticed and inventoried. Therefore, the layer, though it contains all known town trees as of writing, is not guaranteed to be comprehensive and users are still encouraged to consult with the town tree warden and/or town arborist prior to tree removal. In order to maintain that the GIS layer is accurate, the DPW should continually update it alongside the inventory.

Figure 5.1. Side-by-side comparison of the Town GIS layer (left) and the Google Map (right) displaying town trees by Children's Beach.

5.3. The DPW should include additional data fields in the inventory.

From our stakeholder interviews and interviews with directors of other towns' tree inventories, we concluded that there are several data fields not currently represented in the inventory that would nonetheless have utility to some users. Of these, the most popular is the year a tree was planted, which would have utility for public interest and policy decisions as described in section 4.3.1. While this data cannot be reliably collected unlike DBH or species, it should be viable to collect for at least some town trees; the incomplete 2017 inventory partially lists the date a tree was planted alongside other notes, and the age of relatively recent trees may

be inferred by reviewing satellite imagery year-by-year. This process can be conducted by volunteers; as many interviewees indicated interest in the trees' ages and history, it should not be difficult to find interested parties to volunteer. Some trees' ages can also be recorded by the town arborist, including those planted during his term; if the DPW is interested in collecting this information, sufficient time should be allotted into the arborist's schedule. New plantings should also be dated when inventoried.

Other suggested data fields are simpler to record. The condition of the surroundings of the tree and any encumbrances can be assessed visually or via comparison with other GIS layers. Determining if the species is native or non-native could be determined by reviewing the existing species listing. We recommend that age, surroundings, and native/non-native designation be inventoried alongside the existing data where possible, as this would benefit the DPW, the public, and organizations interested in outreach and conservation.

5.4. The DPW should utilize the inventory for the development of systematic tree maintenance and succession plans.

This inventory is a crucial asset for the development of a systematic tree maintenance plan for use by the town arborist. The DPW can add an internal data field to the inventory that shows when a tree was last maintained so all trees are pruned at least once every 3–5 years. Tree management plans should focus in particular on trees that are in poor condition, or that could pose a danger to the public or property. Additional data fields can also be used to indicate the status of the tree's tag, the fertilizers or treatments needed by a tree, and any corrective action needed for damage to the tree's surroundings. These should facilitate tree tag replacement, fertilization and treatment, and maintenance on trees that compromise their surroundings.

To this end, the DPW can also use this inventory to develop a succession plan for trees nearing the end of their lives. New plantings, including succession plantings, can emphasize trees that are more disease-resistant, trees that are native to Nantucket, or trees that preserve the historic essence of Nantucket. By reviewing the map, the DPW can quickly gauge which areas have fewer trees so future planting efforts can be focused more on those areas. This inventory can also help the DPW gauge which regions are more homogeneous in their tree population so that future planting efforts can increase biodiversity, which blocks disease transmission and facilitates treatment. We recommend that the DPW use the inventory to develop and later implement these plans.

5.5. Other organizations should utilize the inventory for conservation, tours, or other educational programs.

As we learned in our stakeholder interviews, the inventory also benefits parties outside of property owners and the DPW, such as educators, tourists, and conservationists. This inventory could be used in the development of educational materials on the diverse tree population of Nantucket or the many factors of tree planting and maintenance decisions. Efforts to develop newer versions of the inventory could be conducted by student volunteers as described above.

These experiences would foster passion for and curiosity regarding trees in Nantucket's youth. A tree tour hosted by the visitor center or a conservation organization could highlight the distinctive elms of Nantucket and their scarcity after Dutch Elm Disease devastated most of the elms in the contiguous United States. Displaying the Google map outside of the Visitor Center could allow interested visitors to quickly locate significant trees. Research organizations on Nantucket like the Maria Mitchell Association and the Nantucket Conservation Foundation could develop materials to encourage the DPW to make ecologically friendly tree planting decisions, such as prioritizing native populations. We recommend that other organizations employ these data to craft outreach and education materials, design informative tree tours, or further conservation efforts on the island.

5.6. Conclusion

Ultimately, Nantucket's trees serve as vital pieces of the island's history and are beloved by thousands of residents and visitors today. The sense of "Nantucket magic" observed by islanders is reliant upon the presence of these graceful street trees. However, the historical lack of clarity from the Town regarding town tree designation has led to several disputes between property owners and the Town. These disputes cost time and effort and could largely be avoided with more clarity from the Town on which trees are town-owned and which are not.

This town tree inventory will be a crucial asset in preventing and resolving future tree disputes and will also greatly facilitate future tree maintenance on the island. The town tree GIS layer we developed will enable property owners, developers, architects, planners, and town officials to quickly gauge whether a tree is town-owned or not. Internally, the Google Map we designed will revolutionize the organization and scheduling of tree work and maintenance. The DPW should plan to continually update this inventory and consider implementing new data fields based on the needs of stakeholders. This will ensure that the inventory remains accurate and useful for all users. In general, this inventory will improve clarity about town tree designation and streamline tree work on Nantucket, ensuring that the island's trees remain protected, maintained, and appreciated.

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Appendix A: Town Official Interview Script Template

Preamble

We are a group of students from Worcester Polytechnic Institute designing a town tree inventory for Nantucket in collaboration with Nantucket's Department of Public Works. We are exploring how other towns have developed similar inventories.

We would be very grateful if you would answer some of our questions regarding the design and data collection strategies employed in [your town]'s tree inventory. Your participation in this interview is voluntary, and you may choose to stop or not to answer a question at any time. The interview will take less than 20 minutes of your time. We will be taking notes during the interview and will save a recording of the conversation. We may wish to quote you in our final report. Would you mind if we quote you by name or would you prefer us to anonymize your responses? We will give you an opportunity to review any quotations prior to publication, and we would be happy to provide you with a copy of the report when it is completed, if you would like. Thank you for supporting our research. Do you have any questions for us before we begin?

If you have any questions or concerns regarding this interview or our project, please contact us at gr-ACK24-Trees@wpi.edu or contact our advisors Dominic Golding (golding@wpi.edu) and Melissa Belz (mbelz@wpi.edu).

Questions

1. Can you please describe your role in the creation or maintenance of [your town]'s tree inventory?
2. What are the primary motivations [your organization] had for designing and maintaining a town tree inventory?
3. Have you encountered any legal or political problems related to your town tree inventory?
4. Why did [your organization] choose to measure [these data fields]?
    a. How does this information help [your organization] further its motivations?
5. *For each data field:* What strategies does [your organization] use to collect data on [this data field]?
    a. *If applicable:* What hardware or software does [your organization] use to collect data on [this data field]?
    b. Why did [your organization] choose this technology?
    c. Are you satisfied with this technology?
    d. Have you had any issues with this technology?
6. What software does [your organization] use to store, display, or host [your town]'s tree inventory?
    a. Why did [your organization] choose this technology?
    b. Are you satisfied with this technology?
    c. Have you had any issues with this technology?

Appendix B: Tree Inventory and Management on Nantucket Interview Script Template

Preamble

We are a group of students from Worcester Polytechnic Institute working to develop a system for valuing the town trees for Nantucket with Nantucket's Department of Public Works. To design an effective, well-made inventory, we are looking to find information on current and past tree inventory and management guidelines.

We would be very grateful if you would answer some of our questions regarding the tree inventory collection strategies employed in [your organization]'s tree inventory. Your participation in this interview is voluntary, and you may choose to stop or not to answer a question at any time. The interview will take less than 20 minutes of your time. We will be taking notes during the interview and will save a recording of the conversation. We may wish to quote you in our final report. Would you mind if we quote you by name or would you prefer us to anonymize your responses? We will give you an opportunity to review any quotations prior to publication, and we would be happy to provide you with a copy of the report when it is completed, if you would like. Thank you for supporting our research. Do you have any questions for us before we begin?

If you have any questions or concerns regarding this interview or our project, please contact us at gr-ACK24-Trees@wpi.edu or contact our advisors Dominic Golding (golding@wpi.edu) and Melissa Belz (mbelz@wpi.edu).

Questions

1. Can you describe how your organization what aspects of town trees are the most important to your organization?
    a. What are the most important positive features of town trees?
    b. What are the most important negative features of town trees?
2. Can you describe your involvement with creating or using the current tree inventory or tree management system?
3. Can you describe what aspects of trees were collected during your inventory?
    a. Why was this data collected and why not others?
4. Do you have any issues with the current system of tree management and inventory collection
    a. Why do you think so, and do you have any possible solutions?
5. What changes would you most like to see implemented to the current system?
    a. Why do you think this would be beneficial?
    b. Why do you think that this has not been changed previously?
    c. How long would it take to implement these changes?
    d. Are you happy with the current system in place? Why?
6. How can this information best be presented to the public and other officials?
    a. What are the benefits for making a tree GIS map and database?

b. What has your organization done with the previous incomplete inventories, if anything?
c. What information should be made available to the public on the GIS map and what should be kept for use by town organizations alone?
d. What do you think your town could do with this system in the future?

7. Do you know any other people or organizations that might have more information on any of these concerns regarding town tree inventories and management?

Appendix C: Stakeholder Interview Script Template

Preamble

We are a group of students from Worcester Polytechnic Institute working to develop a system for valuing the town trees for Nantucket with Nantucket's Department of Public Works. To design an effective, well-made inventory, we are looking for insight from [your organization] on the impacts of street trees and the benefits of a street tree inventory.

We would be very grateful if you would answer some of our questions regarding these impacts. Your participation in this interview is voluntary, and you may choose to stop or not to answer a question at any time. The interview will take less than 20 minutes of your time. We will be taking notes during the interview and will save a recording of the conversation. We may wish to quote you in our final report. Would you mind if we quote you by name or would you prefer us to anonymize your responses? We will give you an opportunity to review any quotations prior to publication, and we would be happy to provide you with a copy of the report when it is completed, if you would like. Thank you for supporting our research. Do you have any questions for us before we begin?

If you have any questions or concerns regarding this interview or our project, please contact us at gr-ACK24-Trees@wpi.edu or contact our advisors Dominic Golding (golding@wpi.edu) and Melissa Belz (mbelz@wpi.edu).

Questions *(to be tailored to organization)*:

1. How do Nantucket's street trees bring value to the town?
    a. What are the most significant positive attributes or contributions of Nantucket's street trees?
    b. What are the most significant negative attributes of Nantucket's street trees?
2. How is [your organization] impacted by Nantucket's street trees?
    a. In what capacity does [your organization] work with (or around) street trees?
3. *(If applicable)* How is [your organization] impacted by the lack of transparency from the Town on tree ownership status?
    a. What are some of the effects of this lack of transparency?
4. How would a database of town-owned trees benefit [your organization] / mitigate achieving [your organization's] objectives?
    a. What would be the most useful way to display this data?
    b. We are planning to collect: lat/long coordinates, address, DBH, species, and condition. What other data fields, if any, would you like to see in a town tree inventory? / would be of use to [your organization]?
        i. Why?
5. Are there any other on-island organizations you think would be impacted by the presence of a tree inventory?