Training Tree Workers to Prune: How education impacts the health of the urban canopy in Massachusetts

A Thesis Presented

By

TERESA E. SIARNACKI

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements of the degree of

MASTER OF SCIENCE

August 2024

Environmental Conservation
Forest Resources and Arboriculture

Training Tree Workers to Prune: How education impacts the health of the u

A Thesis Presented

By

Teresa E. Siarnacki

Approved as to style and content by:

Signed by:
Brian Kane
508F89C7B0E94E2...
_____, Chair

Brian Kane

DocuSigned by:
Kristina Bezanson
973E964E085C48C...
_____, Member

Kristina Bezanson

_____, Outside Member

_____, Consulting Member

Signed by:
Paige Warren
A333949169224DA...
_____

Paige Warren, Department Head,
Environmental Conservation

ACKNOWLEDGMENTS

I would like to acknowledge and offer my gratitude to the following individuals and organizations: My committee members who provided invaluable guidance, support, and constructive feedback on my project; Heather Leff and the Massachusetts Tree Wardens and Foresters Association who helped distribute the survey to tree wardens and provided training information; Leslie Berckes and the Urban and Community Forestry Society who extended the survey's reach into the national urban forest management sphere; Julie Coop and the Massachusetts Department of Conservation and Recreation who funded and supported this research; and University of Massachusetts Amherst Department of Environmental Conservation.

ABSTRACT
TRAINING TREE WORKERS TO PRUNE: HOW EDUCATION IMPACTS THE HEALTH OF THE URBAN CANOPY IN MASSACHUSETTS

SEPTEMBER 2024

TERESA E. SIARNACKI, B.A., AMHERST COLLEGE

M.Ed., UNIVERSITY OF MASSACHUSETTS BOSTON

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Professor Brian Kane

As urban populations expand and climate change increases incidents of extreme weather, cities need sustainable ways to mitigate and adapt to these effects while supporting the health of their populations. Urban trees are a critical component of climate resilience and public health, but tree maintenance can be expensive and often beyond strained municipal budgets. Pruning trees in urban landscapes, especially early in a tree's life, can result in savings over the long term. To prune a young tree effectively, minimizing injury to the tree and maximizing structural and environmental benefits, requires a combination of knowledge and skills. Municipalities have different ways of meeting this demand for skilled labor, and these decisions affect the outcomes for the health and longevity of the urban forest. To define the population of municipal workers who are pruning trees and determine the qualities and quantity of the tree pruning training they receive, I surveyed tree wardens throughout Massachusetts for information about pruning cycles, the workers pruning trees, and training the workers receive. Using research-based best practices,

I developed a rubric that can be used to analyze training for essential instructional elements. The survey established that both Massachusetts tree wardens and pruning workers have a range of backgrounds. A large proportion of pruning workers are not arboricultural professionals, and this underscores the importance of effective training. Most training occurs on-the-job, led by a certified arborist. The fusion of the existing content-area expertise of the trainer with instructional techniques will result in more effective training with better outcomes for municipal trees. Successful training elements can be generalized and applied in other locations, resulting in a healthier, more mature urban canopy, a concomitant increase in environmental benefits, and cost savings that can be reinvested in urban forest management.

TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF FIGURES, continued

Figure **Page**

CHAPTER I

INTRODUCTION

New England is warming at a faster rate than the world average, making it particularly susceptible to the effects of climate change (Young and Young 2021). Despite the consensus that the urban canopy is a powerful deterrent to skyrocketing summer temperatures, many cities struggle to sustain their forests. This disconnect is produced in large part by the financial constraints of limited municipal budgets; yet such austere measures often result in more spending in the long term. When small problems are left to fester, it costs more to address them: the destruction caused by a large tree limb downed in a storm could have been prevented by proactive limb removal from a young tree. Given that the proportion of municipal budgets allocated for urban forest management is not likely to increase, creative solutions must make the expansion and maintenance of the urban canopy attainable and sustainable.

A. The role of trees in the urban landscape

The benefits that a healthy urban canopy can confer to a city are wide-ranging (Figure 1). These extend from economic impacts, like raising property values (McPherson et al. 2005, Escobedo et al. 2015, Widney et al. 2016) and reducing energy costs (McPherson et al. 2005, Donovan and Butry 2009, Nowak and Greenfield 2018), to reducing mortality from cardiac and respiratory disease (Donovan et al. 2013, Van Den Berg 2015). In addition, trees buffer the effects of extreme weather, which is increasing in frequency and severity. The leafy canopies of trees slow wind and provide shade, and their root systems hold soil in place and absorb excess stormwater, reducing erosion and flooding (Soares et al. 2011, Roy et al. 2012, Shetty 2023). The

leaves of trees are the main generators of many of these environmental benefits; as trees age and increase in size, the amount of benefits they provide also increases.

Trees also sequester and store carbon. Through photosynthesis, trees remove carbon dioxide from the atmosphere and accumulate it within their tissues as they grow. As carbon dioxide is a major greenhouse gas and driver of climate change, carbon sequestration and storage is an ecosystem service provided by trees with increasing importance. Street trees play this role in cities, offsetting some carbon emissions (Lv et al. 2016, McGovern and Pasher 2016). As trees grow, they amass ever-increasing quantities of carbon; more mature trees store more carbon (Lv et al. 2016).

These are a few of the many services that trees provide their environments, and these benefits increase as a tree ages and increases in size (Lv et al. 2016). Given that the average life expectancy for urban trees in the United States is far below their natural counterparts (Hilbert et al. 2019), maintenance is necessary to maximize these effects.

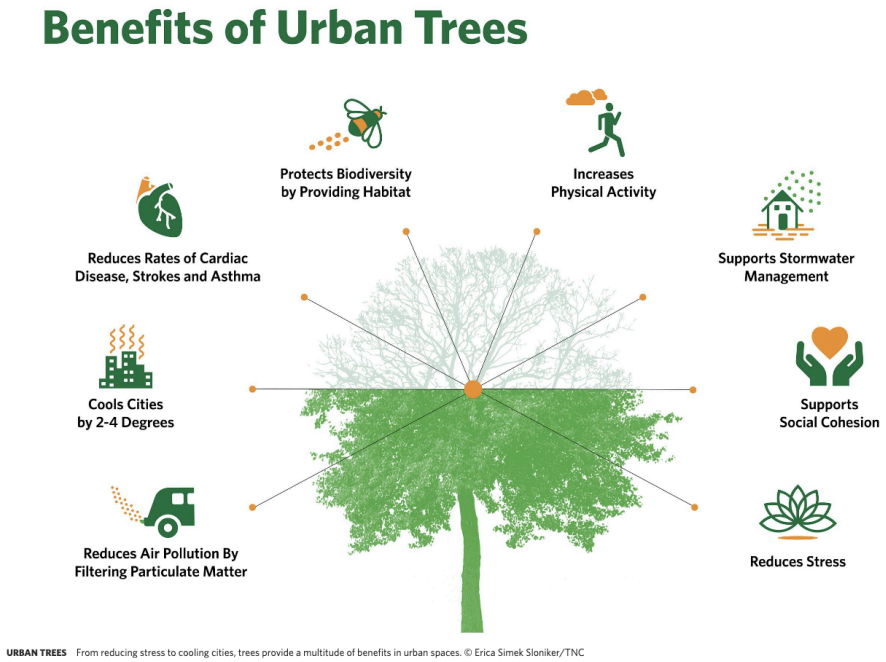


Figure 1: Trees provide a wide range of benefits. (Erica Simek Sloniker/The Nature Conservancy)

Maintenance of public trees is a major expense for municipal forest managers (Hauer and Peterson 2016), and it is essential to promote the longevity of trees (Lindenmayer et al. 2014, Mincey and Vogt 2014, Roman et al. 2015, Hilbert et al. 2019). A common attitude about trees in the built landscape is that their presence goes unnoticed until a problem arises. Problems include (1) tree and branch failures that cause injury, property damage, or disruption; (2) debris from storms that needs to be cleaned up; and (3) conflicts with utilities, views, and built infrastructure. Because these can be the primary experiences citizens have with trees in their communities, trees can be viewed as net negatives or even as general hazards.

Moreover, maintenance of urban trees is expensive, and pruning takes the largest share (McPherson et al. 2005, Hauer and Peterson 2016). In a study that analyzed municipal forestry expenditures in cities in the Southwestern and Western United States over two years, annual municipal pruning expenditures varied between $4 and $21 per tree (between $6 and $35, adjusted for inflation) (McPherson et al. 2005). However, neglecting routine pruning can be even more expensive. In one model, forgoing regular maintenance pruning resulted in an increased lifetime cost of $920 (Australian dollars) per tree ($607.51 U.S. dollars) (Moore 2022). With street tree populations numbering in the tens of thousands, pro-active pruning can save millions of dollars. The benefits of mature trees outweigh the costs, especially as anxieties arise around climate mitigation and adaptation (McPherson et al. 2005, Donovan and Butry 2009, Soares et al. 2011).

B. Municipal forestry practices

Urban forest managers use forest management plans to outline the objectives, action steps, and achievement metrics of the urban forest. Tree inventories involve the cataloging of trees that fall within the purview of urban forest managers, generally those that are

publicly-owned. These trees generally include street trees and those in public parks and spaces. Information such as species, location, size, and condition are included in tree inventories, which inform management decisions.Tree inventories provide critical information for management plans by creating a clear picture of the targets and scale of management actions. Together, urban forest management plans and tree inventories are indicators of a well-managed urban forest (Rines et al. 2011).

While there are many tangential costs connected to the urban forest, the primary costs pertaining to municipal budgets are tree planting, pruning, and removal (McPherson et al. 2005, Hauer and Peterson 2016). In the U.S. Census regions of the Midwest and Northeast, tree removal consumes the largest share of the budget (Hauer and Peterson 2016). This is likely in response to the emerald ash borer causing widespread mortality among ash trees, which were planted widely in the mid-20th Century to replace elm trees lost to Dutch elm disease. Conversely, nationally, pruning accounts for the largest fraction of spending, at 24.5% (Hauer and Peterson 2016). With urban forest management budgets remaining static, the increase in removal expenses in infested areas (primarily emerald ash borer) is resulting in a reduction in other tree maintenance areas, especially pruning (Hauer and Peterson 2016). Yet, despite the high costs associated with tree pruning, the importance of this element of urban forest management should not be overlooked.

Trees that grow in the built landscape are often limited in their growth by the built environment. Their branches and roots can obstruct (and are obstructed by) utilities, roads, driveways, and views (McPherson et al. 2005). Urban forest managers work to eliminate these issues and harmonize the trees with the human landscape.

In addition to these site-specific pruning objectives, structurally pruning a tree can also improve its resilience by stabilizing crown structure, which increases its load-bearing capacity (Gilman et al. 2015, Lilly et al. 2019). Structural or formative pruning can address issues like codominant stems and rubbing or crossing branches (Figure 2), thereby contributing to a tree's long-term success (Clark and Matheny 2010, Ryder and Moore 2013, Vogt et al. 2015). As smaller cuts create less damaging wounds, it is better to prune trees when they are younger, with small-diameter branches and a lower height (Ryder and Moore 2013). Structural pruning cuts often can be done from the ground, with no need for climbing, chainsaws, chippers, or aerial lifts. Pruning young street trees to improve structure and eliminate conflicts with human infrastructure results in cost savings and improves the resilience of street trees.

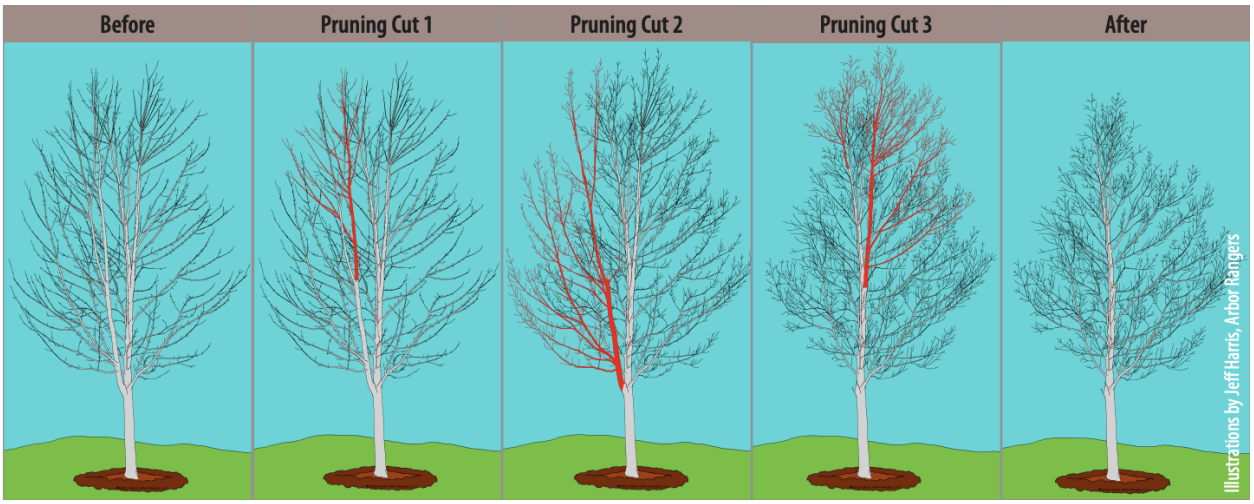


Figure 2: Structural pruning cuts (shown in red) improve long term outcomes for trees by eliminating weak branch attachments and competitive codominant leaders, which are established causes of tree failure. (Harris 2018)

Finding the resources to prune young trees effectively can be difficult for many municipalities (Stobbart and Johnston 2012, Grado et al. 2013, Hargrave et al. 2022). As a result, structural issues like codominant stems grow larger and lead to subsequent mechanical failure. Therefore, the benefits of pruning early in a tree's life are potentially significant, particularly for

the health of the tree. Recovering from the large wound created when a large branch is removed requires considerable resources from the tree, and the opening is a pathway for disease and rot. On a young tree, in contrast, pruning cuts are smaller and much more readily occluded. It is also much less expensive: according to Ryder and Moore (2013), two pruning cycles (year 3 and year 6) cost between $6.00 and $7.00 per tree, whereas waiting 20 years is estimated to cost between $78.00 and $112.00 per tree. Effective pruning can increase a tree's mechanical stability and reduce conflicts with its environment, supporting its likelihood of reaching maximum size. Furthermore, proactively pruning shade trees as part of a pruning cycle can reduce safety-related pruning requests after weather events, a potential cost-savings opportunity for municipalities (Luley et al. 2002).

However, the cost of employing a large team of city arborists to complete this work is not economically viable; thus the work of caring for American urban trees is shared between volunteers (5%), contractors (41%), and city employees (54%) (Hauer and Peterson 2016). Spreading the workload in this way can result in a range of outcomes. For example, nationally, an average of 60% of outside contracts stipulate adherence to the ANSI A300 standards (American National Standards Institute 2014), the tree care industry standards that outline accepted tree care practices (Hauer and Peterson 2016). Perhaps even more remarkable, compliance with the ANSI Z133.1 safety standards (American National Standards Institute 2017) in these contracts is required in only 51% of contracts, putting workers at potential risk (Hauer and Peterson 2016). Without a standard of care to guide tree maintenance decisions and actions, the type and quality of tree care becomes unmoored from science and best practices.

Another strategy is for cities and towns to train non-tree-care professionals (such as workers from their public works or parks departments) to complete pruning cycles within the

urban forest. These workers are paid an average of $17.05 per hour, compared to $30.82 per hour for urban foresters (United States Bureau of Labor Statistics 2023), resulting in significant cost savings. It is likely that municipalities provide some training to their employees who are pruning street trees, but the extent and format of this training is not clear—and may vary widely.

The efficacy of trained volunteers carrying out assessments in the natural resources field has been well documented (Fore et al. 2001, Foster-Smith and Evans 2003, Gillett et al. 2012, Roman et al. 2015, Bancks 2018, Wattenhoffer and Johnson 2021, Fawcett et al. 2024). Previous research has shown that the variation among professional opinions and errors when performing data collection tasks mimics the ranges seen in volunteer assessments in inventories and measurements (Foster-Smith and Evans 2003, Gillett et al. 2012, Kosmala et al. 2016, Bancks 2018). This suggests that trained community scientists can contribute practicable data for use in research.

Nationally, volunteers complete 5% of municipal tree care activities, with 80% of municipalities providing training for their volunteers (Hauer et al. 2018). In the field of urban forestry, volunteer effectiveness has been demonstrated in tree inventories (Bloniarz and Ryan 1996, Roman et al. 2016, Bancks 2018), and, to a lesser degree, tree health assessments and measurements (Roman et al. 2016, Bancks 2018), and pruning of small street trees (Fawcett et al. 2024). The competency level of volunteers and effectiveness of training is a proxy for training effectiveness of non-tree-care professionals with similar low levels of arboricultural experience. The type (or modality) of training volunteers receive has an impact on the quality of outcomes, with hands-on or in-the-field training most effective (Ratnieks et al. 2016, Fawcett et al. 2024). These studies can be extrapolated to apply to the efficacy of urban forestry tree workers and suggest best practices for training to ensure optimal outcomes. When taken in sum, research

demonstrating the competency of volunteers and the effectiveness of training indicate that with proper training, municipal tree care workers can be trained to prune trees according to industry standards.

While pruning trees in an urban setting can increase their longevity, pruning is also an action that damages tree tissue, disrupts growth, and creates avenues for insects and disease to invade. Furthermore, pruning actions like flush cuts (parallel to the stem) and topping, once (and still) fairly common, exacerbate these effects by increasing wound sizes, destabilizing the structure of the tree, or both (Grabosky and Gilman 2007, Fini et al. 2015). Poor pruning techniques like these can increase a tree's likelihood of failure (Suchocka et al. 2021, Cavalari et al. 2024). Thus, while it is important that trees are pruned, it is crucial that they are pruned according to the professional standards outlined in the ANSI A300 (American National Standards Institute 2014) to ensure that resources are not wasted and that trees receive care that supports their health and growth. To achieve this, workers that are pruning trees should receive training that follows the ANSI A300 standards (American National Standards Institute 2014).

C. Training and Adult Education

Based on best practices in adult learning, effective training should incorporate several features to maximize learner engagement and knowledge outcomes. An overview of these elements is illustrated by the answers to the following questions: What content is included? Where does instruction take place? How does the learner engage with new information?

The training content should connect with and build on learners' background knowledge and skills, and explicitly support the needs and work within the constraints of their jobs (Knowles et al. 2005). Whenever possible, trainees should be granted autonomy (Knowles et al. 2005, Kolb 2015). For example, they should be able to choose the topics covered, or vote on

when the training is held. In addition to basic information, instructional content needs to include instances that run counter to what is being taught, often referred to as "non-examples" (Bandura 1986). These introduce failure and mistake-making into the educational environment, which are critical for knowledge retention and skill generalization (Bandura 1986, Mezirow 1997). When the topics covered in a training are directly relevant to the trainees and there is a clear pathway for applying new knowledge within the scope of trainees' jobs, adult learning is optimized (Sticht 1999, Knowles et al. 2005).

The instructional format should include demonstrations and, whenever possible, be structured as a series of problems that need to be solved (Bandura 1986, Knowles et al. 2005). Context is also very influential in educational outcomes, and this relates directly to the instructional setting: skills should be taught in the environment where they are going to be applied (Sticht 1999). The optimal learning environment for adult learners has a strong growth climate—one that celebrates mistakes and questions as opportunities for understanding the concepts with more depth (Mezirow 1997, Knowles et al. 2005, Hammond 2015, Kolb 2015). Given these components, the instructional setting will ensure that the learner is comfortable, invested, and engaged.

It is also important to consider the learner—connecting the new information to their previous knowledge and experiences, engineering ways for them to be involved in the learning process and providing opportunities for practice that include failure and feedback (Guthrie 1960, Bandura 1986, Mezirow 1997, Knowles et al. 2005, Linsey et al. 2009, Brown et al. 2014, Deksissa et al. 2014, Kolb 2015). Part of this is making sure that the objectives are clear; this way, the learner can formatively self-assess and request clarification when needed. Furthermore, the experience of making a mistake can have a profound positive effect on the retention of

knowledge and the depth of conceptual understanding, and this effect is amplified when coupled with feedback and opportunities for correction (Mezirow 1997, Metcalfe 2017). However, for this to occur, the culture of the learning group needs to feel safe and supportive; otherwise, the learner disengages (Hammond 2015). Supportive environments such as these also form a natural foundation for collaborative learning, where students exchange ideas and ask and answer questions of each other, and this further reinforces the learning process (Knowles et al. 2005).

It follows, then, that educational programming that incorporates all of these elements would be maximally effective. Yet, little is known about the types and formats of training that non-professional tree care workers receive, and there is no consensus within the industry that establishes or provides guidance on training. Given effective training, urban trees can be pruned to maximize returns: more urban trees will reach full maturity, when their ecosystem services are at their peak.

Objectives:

The objectives of this project were to:

1. Determine the levels of participation in urban forest management practices like forest management plans and tree inventories of Massachusetts municipalities.
2. Determine the characteristics of pruning cycles of public street trees in Massachusetts.
3. Define the professional background of the workforce carrying out pruning in municipalities in Massachusetts.
4. Define the features of pruning training in Massachusetts municipalities, including content, trainer qualifications, assessment, and modality.
5. Create guidelines for effective training based on the research-based best practices of adult learning.

CHAPTER II

METHODS

To address objectives 1– 4, I developed an online survey using Qualtrics software (Qualtrics 2020) and distributed it to tree wardens in Massachusetts (Appendix A).

- To determine the levels of participation in urban forest management practices, I included questions about active municipal forest management plans and tree inventories.
- To determine the characteristics of pruning cycles of public street trees, I asked whether forest management plans included specifications for pruning, as well as whether public shade trees were pruned on a cycle, and other details related to the timing of tree pruning in municipalities.
- To define the demographic characteristics of the workforce carrying out pruning, I sought to delineate demographic groups based on arboricultural education and experience background by asking questions about how and by whom pruning decisions are made, who completes the work, and whether municipalities require pruning workers to follow professional standards.
- To define the features of pruning training in Massachusetts municipalities, I included questions that covered major topics of training, trainer identification and arboricultural background, training structure, and assessment.
- To create guidelines for effective training, I conducted a literature review of adult education theorists. Using the principles outlined in those texts, I developed a framework that highlighted the major recommendations for effective andragogy, and used contemporary studies to underpin the concepts in the framework. I summarized the

framework into a rubric that makes the guidelines more accessible by breaking them down into categories like objectives, environment, content, and modality (Appendix B).

The survey was developed in the Spring of 2023, and was active from June 2023 to the end of November 2023. The last response was recorded on November 17, 2023. The items of the survey were constructed to address 5 main research targets: demographics, general urban forestry practices, municipal pruning practices, pruning workforce, and pruning training. Together, these topics provide a picture of urban forestry practices specific to pruning.

A. Study Design

The Pruning and Training Survey was largely descriptive, with some analytical elements that allowed for the exploration of relationships between demographic features and urban forest management practices, or relationships within the urban forest management sphere. For example, the data from the survey were used to assess whether there was a relationship between municipality population and the existence of an urban forest management plan, or whether the existence of an active tree inventory increased the likelihood of urban trees being pruned in a cycle.

After considering the options of phone and paper surveys, I determined that the online survey was the best fit for this project. I did not utilize paper-mailed surveys due to resource and expense considerations, as well as a lack of mailing addresses for potential respondents. The internet-based survey ensured a maximum distribution, efficiency of communication, and a lower environmental and economic footprint. Respondents were able to access the survey through a QR code or a link, and responses were recorded anonymously. The target population was employees of municipalities, the majority of whom have email addresses linked to their workplace (Ricard

and Bloniarz 2006). There are also trade groups, like the Massachusetts Tree Wardens and Foresters Association (MTWFA) and the Society of Municipal Arborists (now Urban and Community Forestry Society, UCFS), that maintain email mailing lists that assisted with distribution.

The intended survey recipients were Massachusetts tree wardens. The tree warden title is unique to New England states, and has its roots in the 19th century. In Massachusetts, all municipalities are required to have tree wardens by law (Massachusetts General Law 2022); they are responsible for the care and protection of public shade trees. Because of their ubiquity, tree wardens are well positioned to report on municipal forestry practices in Massachusetts. Survey respondents opted into participation after being contacted by their government-affiliated email as noted on municipal web pages or by their industry association (UCFS or MTWFA). Because the respondents chose to complete the survey independently, the sampling type was convenience-based. This could lead to some bias in the results, which will be discussed later.

B. Survey Instrument

I developed the survey structure in consultation with the Institute for Social Science Research at the University of Massachusetts Amherst, with feedback from Dr. Brian Kane, and according to recommendations outlined in Dillman et al. (2014). I presented the survey instrument to the Institutional Review Board at the University of Massachusetts Amherst via the Kuali platform to make a determination of approval requirements and was found not to require approval. While the survey does involve human subjects, the information elicited is neither private nor personal in nature and no identifying information was collected.

I used several strategies to construct questions to limit measurement error. A “Yes/No” forced-choice format replaced “mark all that apply” in one instance, where more detailed

information was needed and where many options were listed. I did not include open-ended questions, which are associated with high non-response rates for users who respond on mobile phones (Dillman et al. 2014), a likelihood in this study. I wrote questions simply, asking for one piece of information per question, using succinct, straightforward, and commonly used language. I organized the survey items by category, beginning with broad demographic inquiries, and progressing using logic within the question behavior. The categorical structure ensured that questions were clearly presented and elicited the required information.

I also considered the visual presentation of the survey. To optimize user experience, respondents were able to (1) move back and forth between survey items and (2) hold their place in the survey and finish at a later time. The layout of each page of the survey was consistent, using familiar fonts at legible sizes: questions were bold, instructions were italicized, and answer options had no emphasis and were indented. The survey (included in its entirety in Appendix A) was also a manageable length that encouraged high response rates. At full length, it covered 28 questions over 10 pages (or screens), including the greeting and thank you screens. Twelve of the 28 questions were outside of the main body of the survey; respondents saw them only if their previous answers triggered the display logic contained within the survey. The survey was designed to take 10 - 15 minutes. Finally, the survey cultivated a positive social experience for respondents: a greeting to begin, contact information for questions and feedback, and a statement of gratitude at the end. These elements contributed to a positive user experience, which can elevate survey response rates (Dillman et al. 2014).

C. Survey Content

The survey contained 8 sections on 10 pages (or screens) (Appendix A). The first section asked respondents for demographic measures, including job title, state of employment, population of municipality, and arboricultural education and experience background. The second section asked respondents for details of urban forest management in their community; it included questions on tree inventories and urban forest management plans. The third section asked respondents for information about municipal pruning cycles, encompassing initiation, timing, and frequency of pruning within the cycle. The fourth section asked respondents to elaborate on pruning practices; it contained questions about pruning motivations, objectives, and techniques. Pruning questions were included regardless of the presence of an urban forest management plan, as it is likely that pruning occurs both with and without such formal plans.

The fifth section asked respondents for demographic information about the workforce completing different aspects of pruning work to understand how pruning decisions are made and what issues and outcomes are prioritized. It included questions about decision making, work completion, and professional standards. In this area, survey items pursued details about the professional knowledge and experience of the workers completing pruning cuts, as well as the type of worker (i.e. city employee, contractor, or volunteer). Since it is possible that pruning work is done by a variety of workers, I asked about portions of workload and how the work is divided (e.g., pruning of young trees, pruning of large trees). If workers were not credentialed in arboricultural practices (Massachusetts Arborist Association or International Society of Arboriculture certified arborists), I asked whether they receive training specific to pruning, shifting to the training section of the survey.

The sixth section of the survey asked respondents whether municipal workers and private contractors receive training to prune trees properly. Based on positive responses from the sixth section, the seventh section asked respondents for details about training format, trainer (e.g. training company, certified arborist), and training frequency. The trainer identity question sought to establish whether the trainer has an arboricultural educational background, and whether training is conducted by municipal employees or by outside training companies. Understanding the frequency of training is also important, as retention of information can wane over time; thus, survey items sought information on whether and how often employees received refresher training. The final section asked respondents about training content; it included questions about assessment and training topics. Together, these factors provided insight into the character of training occurring in municipalities across Massachusetts.

D. Data Collection

I activated the Massachusetts Pruning and Training Survey on Qualtrics in June 2023 (Qualtrics 2020). The first distribution was through the paper mailer "Bark" publication circulated by the MTWFA, which introduced the survey and included a QR code linked to the online survey. In mid-July, the MTWFA listserv sent an introductory email to Massachusetts tree wardens.

Following these initial distributions, I compiled an email list of Massachusetts tree wardens independently, by researching individual municipalities. Through this work, I was able to find the email addresses of 106 tree wardens (out of 351 municipalities). I contacted these individuals following the Dillman method (Dillman et al. 2014), with follow-up emails after

three and seven weeks. These emails continued from August to November, and the survey was closed November 15, 2023.

The independent email list was one of many strategies employed to maximize response rates. Using Mail Merge (Qualtir L.L.C. 2023), I sent personalized emails to each recipient that included their names and the names of their city or town. I highlighted the connection to the University of Massachusetts Amherst, a respected research institution to establish trust and legitimacy. By describing how their contributions would be useful, I fostered a connection between the survey and the respondents; many became stakeholders in the results and success of the survey. Respondents were encouraged to provide feedback and ask questions, and contact information was clearly displayed in multiple locations.

E. Data Analysis

The key variables of interest for this project were urban forest management practices, tree worker demographics, and training modes. I conducted qualitative and quantitative data analyses using the R suite (R Core Team 2022). I compiled responses and analyzed them as proportions of the sample size for each question on the survey. I conducted univariate analyses of the responses to each question on the survey. I analyzed the percentages or mean for each question, depending on the response type. I used logistic regression to analyze the relationship between arboricultural education background of tree wardens and whether the municipality had an active urban forest management plan and tree inventory, and whether municipal trees were pruned as part of a pruning cycle. I also used logistic regression to analyze the relationship between population and the arboricultural education background of tree wardens, urban forest management plans, and active tree inventories.

To simplify analyses, I re-coded the educational backgrounds into four bins: professional arboriculture certification, some arboricultural education (characterized by post-secondary coursework or MA Qualified Tree Warden credential), significant work experience (5 or more years), and no specific arboricultural education or experience. This positioned tree wardens along a spectrum of arboricultural knowledge. With this information and the binary nature of the forest management plan data, I explored the relationship between education background and active forest management plans through binary logistic regression.

The identities of pruning workers also required simplified re-coding to highlight workers that lack specific arboricultural certification or training. I narrowed these from 9 to 3 categories: municipalities that solely utilized certified arborists to complete pruning, municipalities that solely used non-professional arborist tree workers to complete pruning, and municipalities that employed a combination of the two.

CHAPTER III

RESULTS

A. Tree Warden Demographics

Ninety-nine tree wardens responded to the survey. Tree wardens in Massachusetts come from a range of backgrounds and often have additional professional responsibilities within their municipalities. Respondents identified themselves as urban foresters/municipal arborists or as directors of public works, parks and recreation, or engineering, building, and construction in nearly equal numbers (Figure 3). A small minority of respondents indicated that they were utility arborists or private contractors, and there was 1 respondent who worked in custom soils sales (Figure 3).

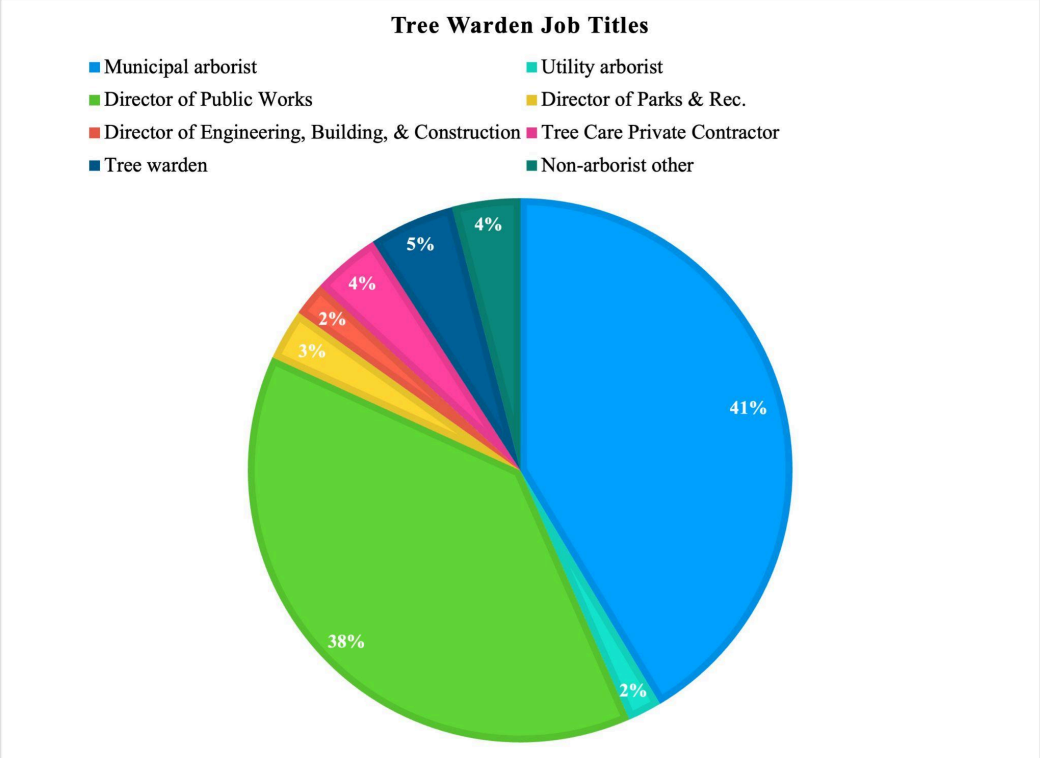


Figure 3: Massachusetts tree warden job titles.

More than half of respondents represented municipalities with populations between 10,000 and 49,999 (Figure 4). There was also significant representation from smaller towns and villages, with more than a quarter of respondents hailing from municipalities with fewer than 10,000 residents. Few of the respondents identified their municipality as having a population greater than 50,000.

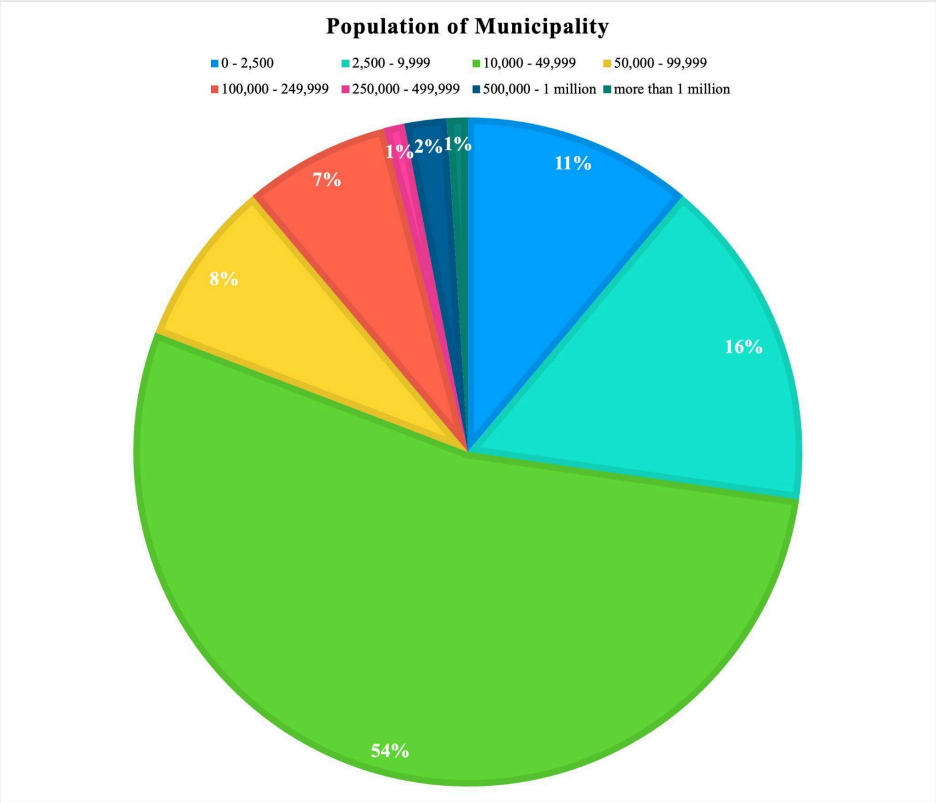


Figure 4: Populations of the municipalities of responding tree wardens.

A majority of respondents had 5 or more years of experience working in tree care (Figure 5). Massachusetts (MCA) and International Society of Arboriculture (ISA) certified arborists represented around one-third of responses each.

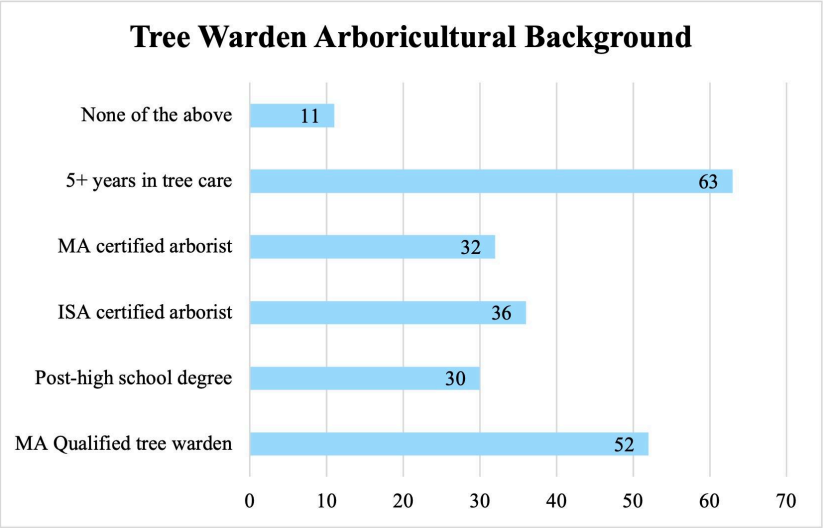


Figure 5: Tree warden arboricultural background, based on responses from a "check all that apply" prompt.

Filtered by certification and education, over half of responding tree wardens had MCA and/or ISA certification (Figure 6) and another quarter were Massachusetts Qualified tree wardens. A small but significant proportion of tree wardens had no education or certification specific to arboriculture.

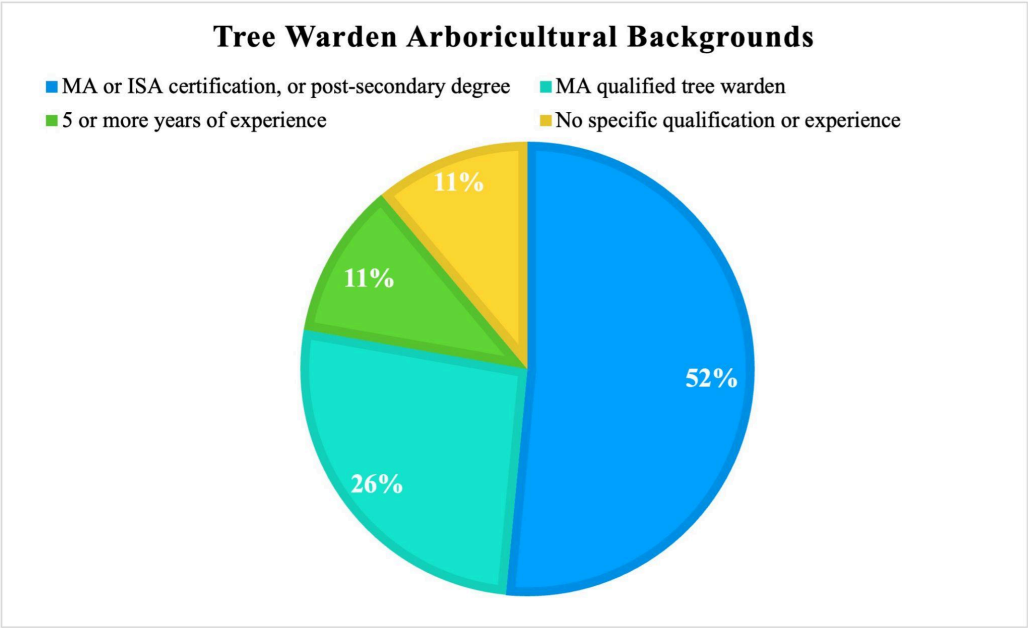
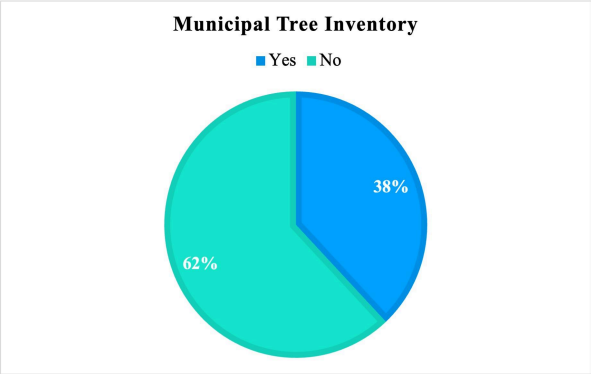
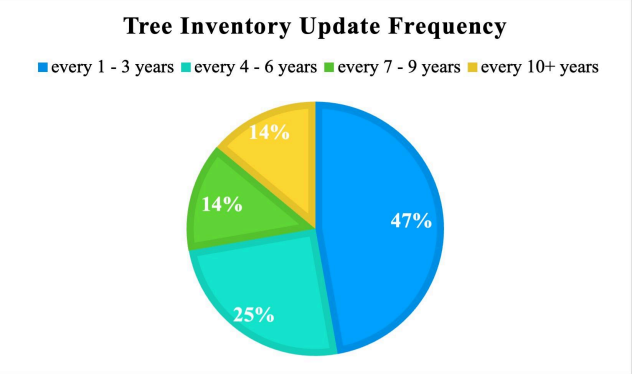


Figure 6: Tree warden arboricultural background, filtered by minimum certification/education level.

B. Urban Forestry Practices

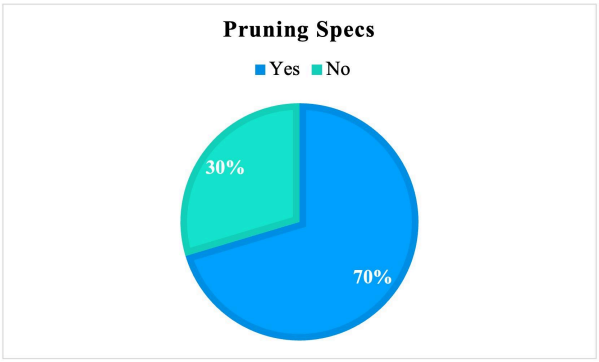
A minority of respondents reported that they have an active tree inventory (Figure 7). The frequency with which inventories were updated ranged from annually to every decade or more, with a plurality updated every 1-3 years (n = 36)(Figure 8).





Figures 7 & 8: Active tree inventories and tree inventory update frequency.

Urban forest management plans include tree inventories and the analysis of tree inventory data, and can extend to include tree risk assessment and reduction, public outreach and involvement, governance, and cost/benefit analyses for the urban forest. The majority of respondents did not have an urban forest management plan in place (Figure 9). Of the municipalities that had urban forest management plans (n = 26), about two-thirds of those plans included specifications for tree pruning (Figure 10).



Figures 9 & 10: Urban forest management plans and urban forest management plans including specifications for pruning.

C. Pruning Practices

While some tree pruning occurs as a part of a pruning cycle, a range of factors push municipalities to prune their trees. The survey presented 4 possible motivations for pruning: "as part of the pruning cycle", "in response to citizen/business requests", "to address city-identified hazards", and "other". Based on the "other" responses, I added "Utility line clearing" as an additional response column prior to data analysis. The majority of municipal pruning reported was evenly split between "in response to citizen/business requests" and "to address city-identified hazards" (Figure 11). A small but substantial amount of pruning was done as a part of the pruning cycle. One municipality reported that 85% of pruning occurs as "tree work/removal on nearby trees to finish the day." Thus, the motivations for pruning extended well beyond the pruning cycle, and are governed by trees' interactions with their environment.

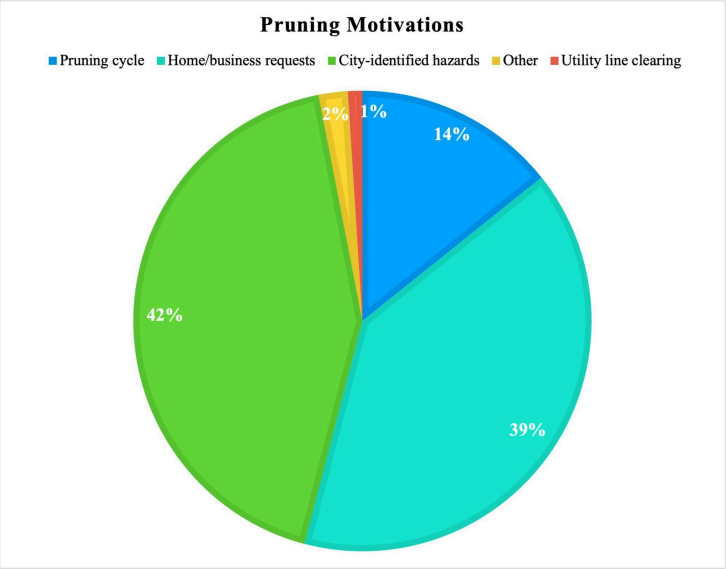


Figure 11: Average share of pruning done for each motivating factor.

There was a wide range of timing for the first pruning of urban trees, from pruning within the first 2 years after planting to initial pruning after 10 or more years (n = 90) (Figure 12). The 2 most common responses were after 10 or more years and after 3 to 4 years.

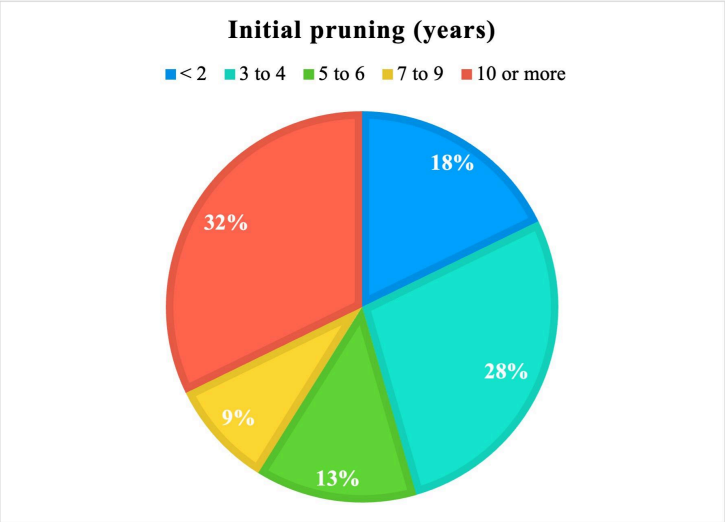
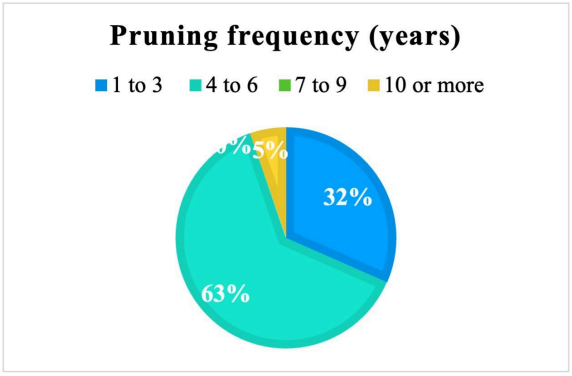
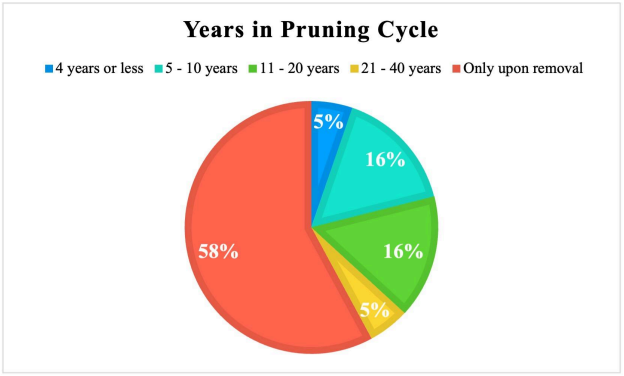


Figure 12: The number of years after planting before a transplanted tree is pruned.

Of all those surveyed, very few pruned trees on a pruning cycle. Within pruning cycles, trees were most commonly pruned every 4 - 6 years, with about one-third pruning trees every 1 - 3 years, and one reporting every 10+ years (n = 19) (Figure 13). Most municipalities retained trees within the pruning cycle for their lifespan (56%), though responses ranged from 4 or fewer years to 21 - 40 years (n = 18) (Figure 14).





Figures 13 & 14: The frequency of street tree pruning within pruning cycles and the period of time trees remained in pruning cycles.

The objectives for pruning uncovered by the survey extend beyond the pruning cycle into the ways trees interact with their environments. While a small proportion of pruning objectives

were to improve the structure of the tree, more significant objectives were to remove conflicts with trees' environment and address damaged, dead, or diseased branches (Figure 15).

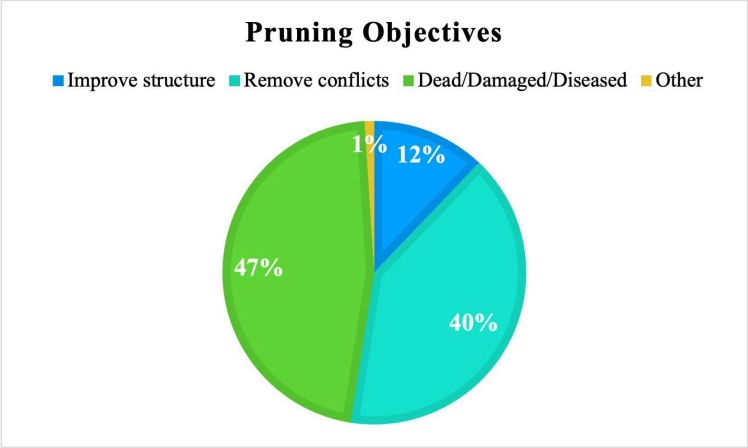


Figure 15: Average share of pruning done with each objective.

Finally, respondents described the typical technique used for a pruning cut in their municipality. More than half of the respondents characterized pruning cuts as "just outside the branch collar", while nearly one quarter reported cuts that were either "flush to the stem", "through the branch collar", or "outside the branch collar, leaving a stub" (Figure 16). This outcome underscores how workforce training can have an impact on outcomes for urban trees.

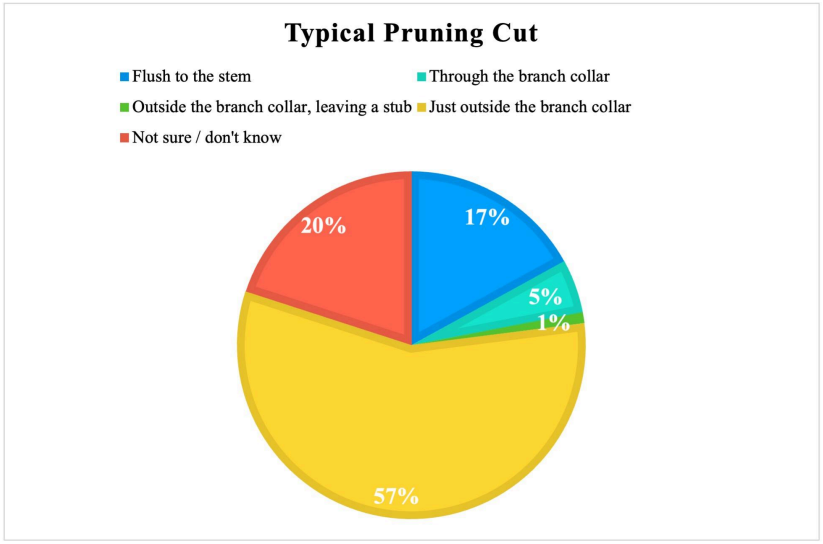


Figure 16: Typical technique for pruning cuts.

D. Pruning Workforce

The survey responses shed light on the pruning workforce: for example, whether they are municipal employees or private contractors, are required to adhere to the standards outlined in the A300 and the Z133, and whether they receive training.

The majority of respondents indicated that their municipalities require tree workers to follow the ANSI A300 standards (American National Standards Institute 2014) (Figure 17).

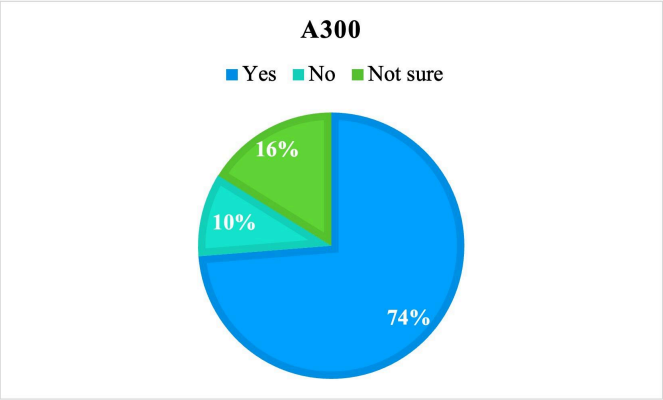


Figure 17: Requirement for tree workers to follow the ANSI A300 guidelines for pruning.

Two thirds of respondents' municipalities required tree workers to follow the ANSI Z133 Safety Standards (American National Standards Institute 2017), while almost one quarter did not (Figure 18).

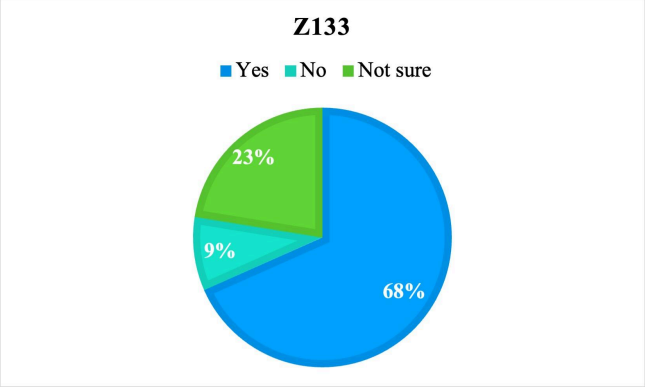


Figure 18: Requirement for tree workers to follow the ANSI Z133 guidelines for tree worker safety.

A few different agents made pruning decisions, and in nearly one-third of respondents there was more than one mechanism for decision making (Figure 19). Approximately equal proportions of decisions were made by the leader of the tree crew, private contractors, and a certified arborist. Taken together, half of respondents indicated that a certified arborist made pruning recommendations in their municipality.

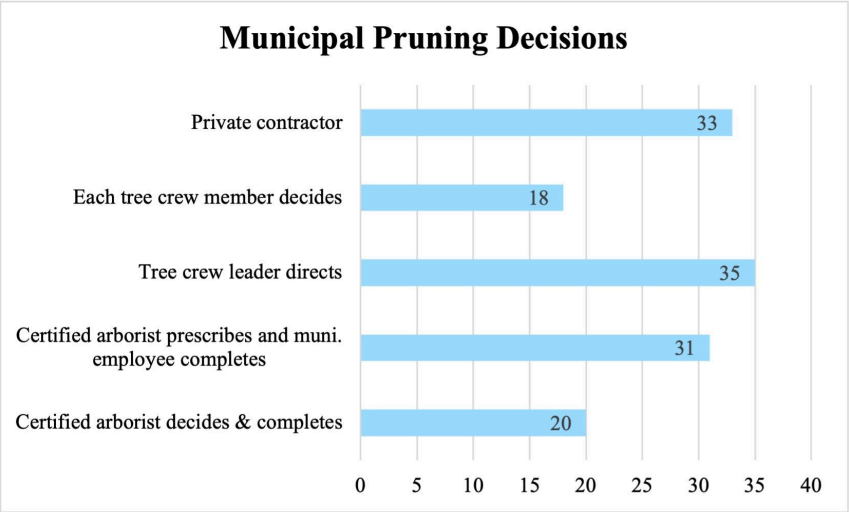


Figure 19: Municipal pruning decision makers, based on responses from a "check all that apply" prompt.

Once the pruning prescription has been outlined, workers prune the specified trees. As shown in Figure 20, many different workers contributed to tree pruning, even within a single municipality. Generally, work is divided between tree wardens, private contractors, utilities, and municipal employees. The majority of respondents reported that municipal employees, such as those from the parks, highway, or public works departments, completed pruning work.

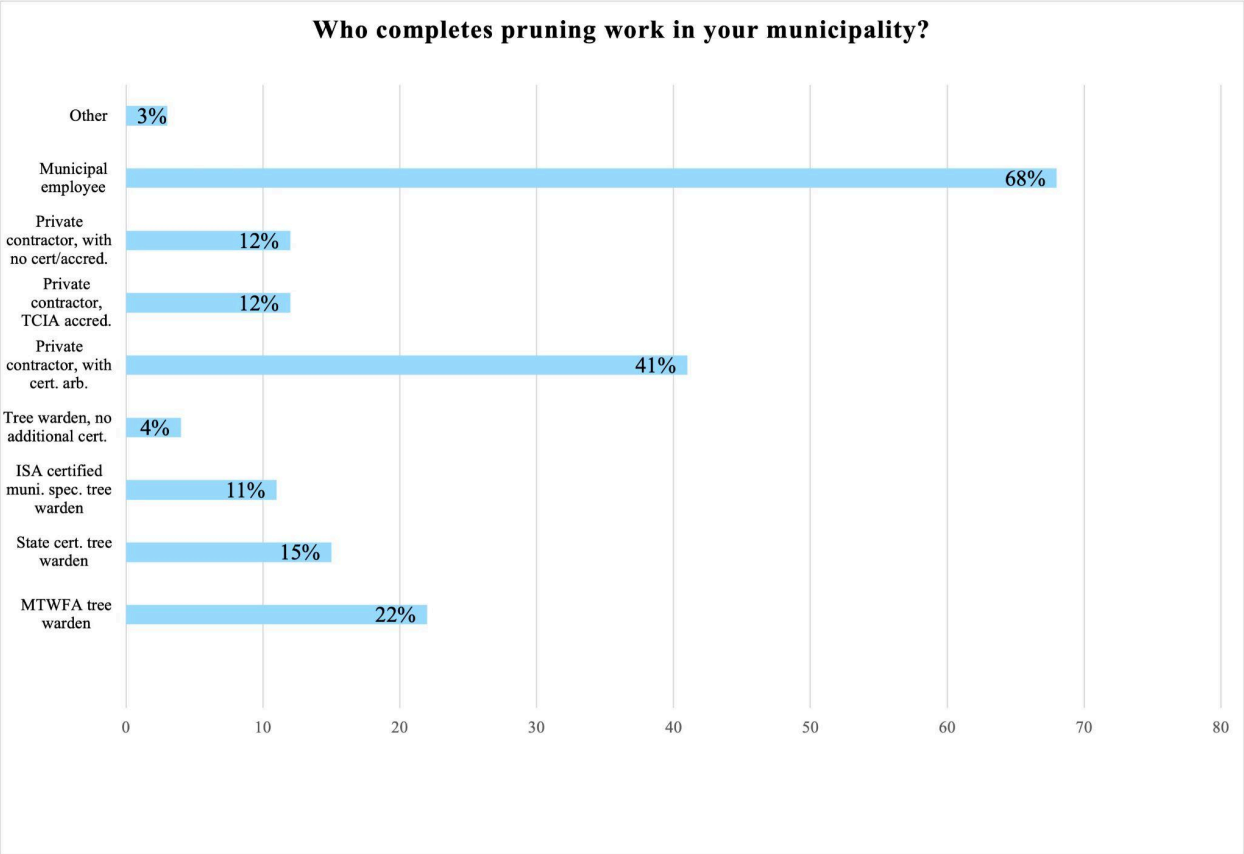


Figure 20: Percentage of respondents that chose each pruning worker type, based on responses from a "check all that apply" prompt.

While the survey results suggested that workers with many different backgrounds complete pruning work across Massachusetts municipalities, the percentage of that work within each municipality varied. Private contractors and municipal employees did roughly the same share of pruning and completed the vast majority of pruning work (Figure 21). Arborists and urban foresters contributed a relatively small portion; utilities also added a modest amount.

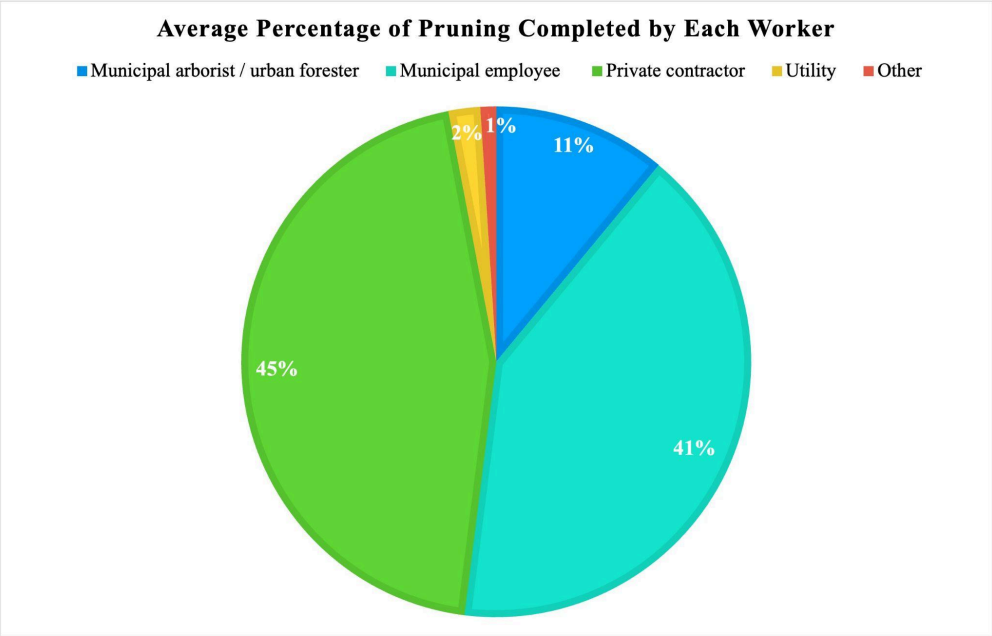
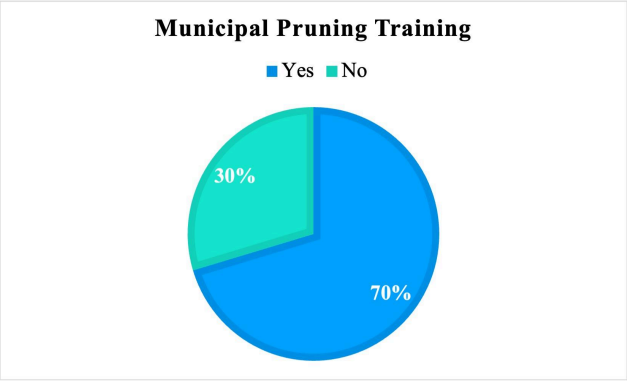


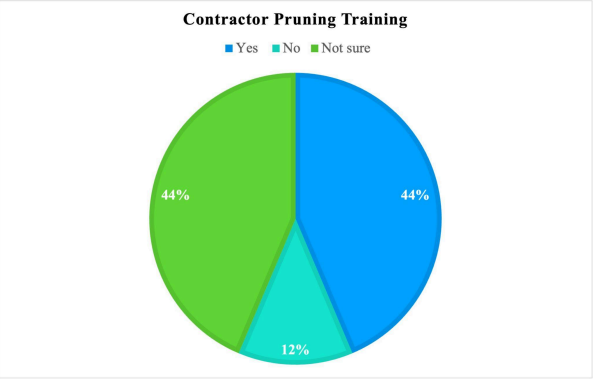
Figure 21: Average percentage of pruning done by each worker type.

E. Pruning Training

The survey showed whether municipal tree workers receive training to prune trees, who provides it, how it is conducted, and what content is included.

The majority of municipalities trained their employees or volunteers on proper tree pruning techniques (n = 80) (Figure 22), and almost half of respondents reported that private contractors provided training to their tree workers (n = 55). However, the same proportion of respondents chose “Not sure” when asked about private contractor training (Figure 23), so potentially the true incidence of training within private contractor organizations is higher. Overall, these responses suggest that tree workers receive training in their area of work.





Figures 22 & 23: Shares of respondents and their private contractors that offer pruning training to workers.

The format and context of a training can impact its effectiveness in terms of the retention of key concepts and skills. Training modes included online (asynchronous or live), in-person lecture, and on the job (n = 65). The majority of respondents for this item included on the job training. On the job training was most commonly paired with lecture-style, although almost one-third of respondents indicated that on the job training was the sole mode (Figure 24).

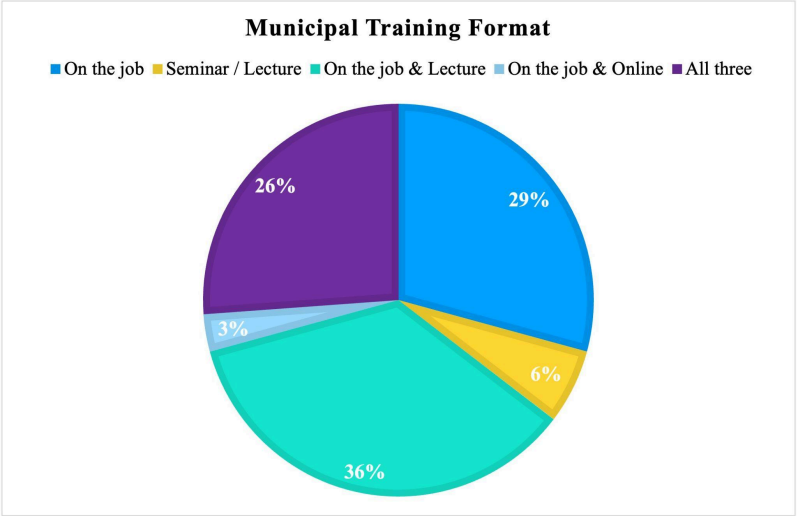


Figure 24: Average share of training formats.

Training most commonly involved a certified arborist. This was most frequently as the singular trainer, though also in combination with the tree crew supervisor and/or an outside training company (n = 55) (Figure 25).

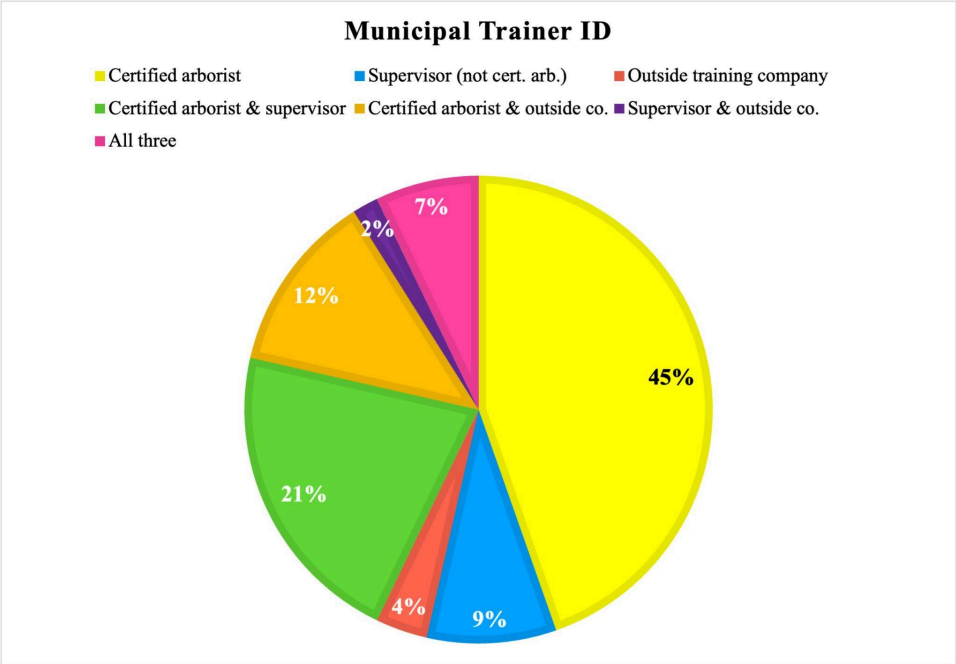


Figure 25: Average share of pruning trainer types.

Many tree wardens provided refresher training for their employees (n = 56), and typically these refreshers occurred every 1 - 2 years (Figures 26 & 27).

Figures 26 & 27: Share of respondents that offer refresher training to workers and the frequency of refresher training in municipalities.

Training assessment used a combination of written, verbal, and skills demonstration; one of the above; or not at all (n = 56). Almost half of respondents assessed the learning of the trainees solely through an observation of a skills demonstration (Figure 28). Over a third of

respondents utilized no assessment. The remaining portion employed a combination of assessment types, though all included a skills demonstration.

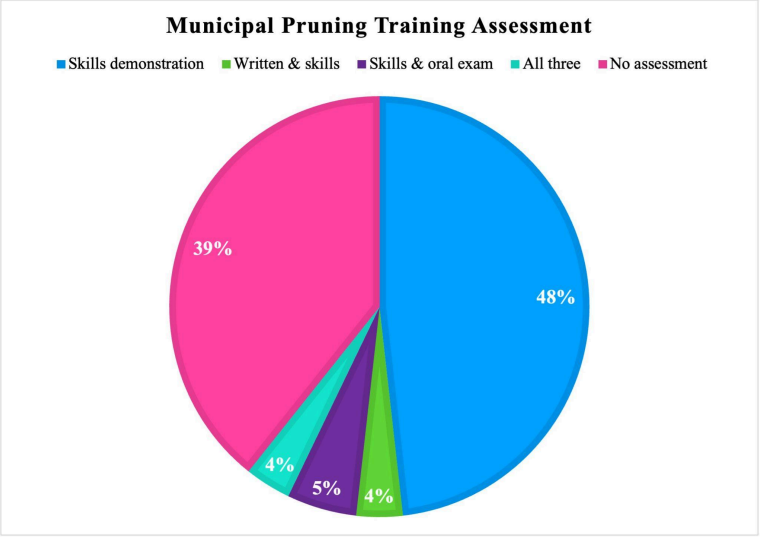


Figure 28: Average share of pruning training assessment types.

Finally, respondents provided information about the topics covered in training for municipal workers (n = 56). The most common topics were "Personal Protective Equipment/Safety," "Proper cut angle and location," and "Tools / maintenance," with the vast majority of training including those topics (Figure 29). Most municipal training also included "Types of pruning cuts", "Structural pruning", and "Setting up a work site/site inspection". "Pruning prescriptions" and "Tree physiology" were less common. There were also individual reports including "Tree Identification" and "Public Outreach" as training topics.

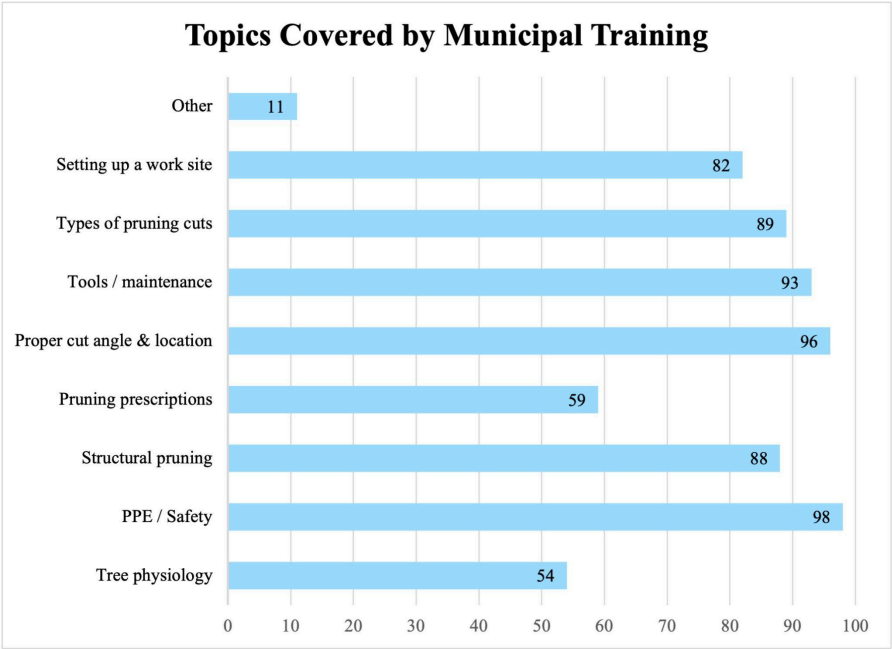


Figure 29: Count of municipal trainings that chose each pruning training topic, based on responses from a "check all that apply" prompt.

F. Correlations

Some relationships emerged through statistical analysis. Statistical testing indicated that the population of a municipality was associated with many survey variables.

Based on binomial logistic regression analysis, the population of a municipality had a positive relationship with both urban forest management plans and tree inventories (Table 1). Municipalities with populations over 100,000 were much more likely than municipalities with populations below 10,000 to have urban forest management plans in place. The same was true for tree inventories.

Chi-squared testing indicated that population is also an influencing factor in the arboricultural background of the tree warden. Communities with populations between 50,000 and 249,999 were more likely than those with populations below 2,500 to have Massachusetts Qualified tree wardens. Tree wardens in municipalities with populations between 250,000 and 499,999 were more likely than municipalities with populations between 2,500 and 9,999 to have

a post-secondary degree in forestry or arboriculture. Similarly, communities with populations between 100,000 and 249,999 were more likely than any community with a population less than 50,000 to have tree wardens who possessed ISA certification. Finally, the smallest Massachusetts municipalities (population < 2,500) emerged as more likely than communities with populations between 10,000 and 49,999 to have tree wardens with no additional education or certification.

The arboricultural background of tree wardens also had a positive relationship with multiple response variables (Table 1). Tree wardens with higher levels of professional certification and/or education specific to arboriculture were more likely to have urban forest management plans, active tree inventories, and prune municipal street trees in pruning cycles. They were also more likely to provide pruning training to municipal tree workers.

Independent Variable	**Dependent Variable**	**Estimate**	**Standard Error**	**z-value**	**Pr(>|z|)**
Population	Urban forest management plan	0.72	0.22	3.23	0.0013
Population	Tree inventory	1.14	0.30	3.78	0.0002
Arboricultural background	Urban forest management plan	1.69	0.52	3.23	0.001
Arboricultural background	Tree inventory	0.53	0.24	2.23	0.03
Arboricultural background	Pruning in a cycle	0.96	0.41	2.36	0.02
Arboricultural background	Municipal training	0.64	0.23	2.80	0.005

Table 1: Coefficients of binary logistic regression analysis with independent variables “Population” and “Arboricultural background”.

G. Error

Three respondents inaccurately reported the population of their municipality. One reported the population between 250,000 and 499,999, but there are no municipalities in Massachusetts that fit that population range. Similarly, 2 respondents reported populations between 500,000 and 1 million, but only Boston is in that category. Lastly, 1 respondent reported the population as greater than 1 million, which is incorrect.

CHAPTER IV

DISCUSSION

This study investigated the urban forest management practices of municipalities in Massachusetts and consolidated information about the workforce completing tree pruning through an online survey distributed to Massachusetts tree wardens. This information, combined with the guidance of research-based best practices in adult education, can be used to provide a framework for optimal pruning training practices. Effectively trained workers will have a good understanding of industry standards (both in pruning techniques and safe work practices), and will apply those skills to their work. This will have positive health and safety outcomes for both workers and trees.

A. Limitations & Challenges

An initial challenge for this project was dispersal of the survey according to the Dillman method (Dillman 2014). Because the first few rounds of survey advertisement were through Massachusetts Tree Warden and Foresters Association publications with somewhat prescribed pacing, the gaps between contacts were wider than recommended. This was rectified in part by compiling an independent list of email addresses that were available online and contacting tree wardens through that pathway as well.

A significant limitation of this study was a moderate response rate resulting in a smaller sample size. The 99 respondents represent 28% of the 351 municipalities in Massachusetts. This is relatively consistent with the response rate reported by Ricard and Bloniarz (2006) at 29%, but less than what was achieved by Rines et al. in 2010 (41%). One of the primary points of contact for tree wardens was through their work email, found through an online search. Only 106 tree

warden emails were available in this way, and thus only 30% of the survey population was contacted directly in this way. Other points of contact were through a voluntary list-serv and a QR code circulated in an organizational newsletter. Both of these avenues have unclear levels of engagement and may not have meaningfully improved survey circulation.

Census data provides a way to explore the question of the extent to which the respondents reflect the demographics of Massachusetts. The mean population of Massachusetts municipalities in 2020 was 20,028 (The 193rd General Court of the Commonwealth of Massachusetts 2024), while the median population of the municipalities represented by survey respondents is between 10,000 and 49,999. This indicates that response distribution in terms of population is roughly in line with statewide parameters.

The proportional response from municipalities within population classes was somewhat representative of municipal populations throughout Massachusetts according to the 2020 US Census (Figure 30). According to the 2020 United States Census, 19% of Massachusetts municipalities have populations of less than 2,500; these made up 11% of survey responses. Sixteen percent of survey respondents have populations between 2,500 and 9,999, while these make up 29% of Massachusetts municipalities as a whole. Forty-five percent of Massachusetts municipalities have populations between 10,0000 and 49,999; these made up 54% of survey respondents. Five percent of Massachusetts municipalities have populations between 50,000 and 99,999, and these made up 8% of respondents. Two percent of Massachusetts municipalities have populations between 100,000 and 249,999, and these made up 7% of respondents. Overall, a larger percentage of higher-population municipalities responded to the survey, consistent with Rines et al. (2010). While these numbers were not sufficient to make statistical inferences about the municipal forestry practices across Massachusetts, the information provided by survey

respondents nonetheless gave insight into the urban forest management practices followed by the wide range of respondents.

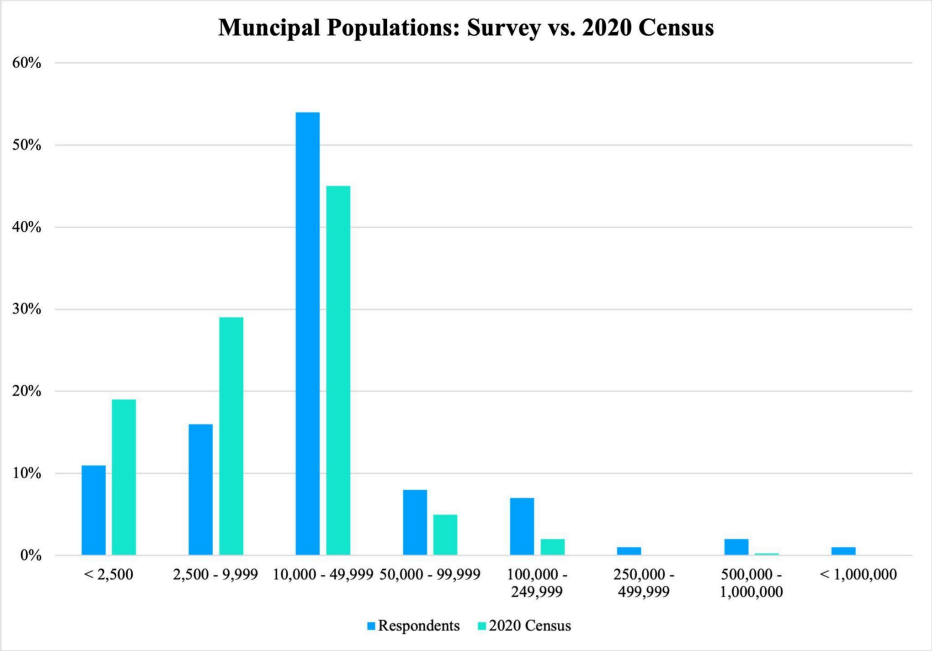


Figure 30: Comparison of survey respondents' municipality populations with 2020 Census Data, data source 2020 U.S. Census (The 193rd General Court of the Commonwealth of Massachusetts 2024).

The small sample size and the voluntary nature of responses were both limitations of the study. Given that there are 351 municipalities in Massachusetts and each is required to have a tree warden by law, the 99 survey responses represented 28% of the study population. With smaller populations (<1,000), a sample size of 30% or above is recommended for the data to be representative of the population (Neuman 2004). For a margin of error of 5% or less and a confidence level of 90% or above with the population of 351 Massachusetts municipalities, the sample size would need to be 154 or higher (Raosoft 2004). These factors limited the inferences that could be made about the Massachusetts tree warden population with the survey data, especially for those questions that had fewer respondents due to survey logic flow.

B. Tree Warden Demographics

The professional and educational backgrounds of tree wardens in this study provide a way of thinking about the lenses through which tree wardens view their work. It is known that not all tree wardens have a background in arboriculture, and, in trying to capture this, the survey asked respondents to describe their arboricultural backgrounds with choices that included different levels of education and certification. Overall, 52% of respondents possessed professional arborist certification, characterized by International Society of Arboriculture certification or Massachusetts certified arborist certification. Still, this suggests that a large portion of tree wardens do not work primarily in arboriculture. In contrast, nationally, 61% of communities have an ISA certified arborist on staff (Hauer and Peterson 2016), and in the state of Connecticut, 57% of tree wardens were found to possess a professional certification or license (Ricard 2005). These differences could be attributed to variation or changes in the roles of tree wardens over time, or the response dynamics for the survey, for example.

Massachusetts requires that tree wardens of municipalities with populations over 10,000 "be qualified by training and experience in the field of arboriculture and licensed with the department of food and agriculture" (Massachusetts General Laws 2022). In service of this requirement, the Massachusetts Tree Wardens and Foresters Association offers the Massachusetts Qualified Tree Warden certificate, a six-session, in person training series that covers a broad range of topics relevant to managing an urban forest. I expected that respondents with the Qualified Tree Warden certificate would have corresponding higher rates of participation in urban forest management practices. However, the opposite seemed true. Qualified Tree Wardens (without arborist certification) were less likely to have urban forest management plans or tree inventories, and instead were more closely associated with improper pruning technique. The

small sample size limits the significance of these findings, but they highlight potential gaps in the Qualified Tree Warden training program.

The job titles of tree wardens in this study also differed as compared to other studies. This is most remarkable in the proportion of respondents whose title is urban forester/municipal arborist, which comprised 41% of respondents in this study. This is compared to only 5% of responding tree wardens holding the title of city forester/arborist in Connecticut (Ricard 2005), and in line with the national average of 46% (Hauer and Peterson 2016). This may reflect the long history of tree wardens in New England forming a professional identity. Alternatively, it may indicate a shift in attitudes over time toward urban forestry as a separate field, as urban trees have gained acknowledgement for their roles in increasing the climate resilience of municipalities.

Results were more consistent between Massachusetts and Connecticut with the title of director (or assistant director) of public works, which was by far the most common response for Connecticut (46%) and in this study was the second most frequent choice (38%) (Ricard 2005). However, nationally, in only 14% of communities is a public works employee responsible for the municipal trees, though collectively over 30% of those accountable for the daily management of municipal tree programs are not arboriculture professionals (Hauer and Peterson 2016). This underscores that there is a place for arboricultural training in municipal forestry, as a significant proportion of those that are tasked with maintaining municipal trees do not necessarily have extensive arboricultural knowledge to draw upon.

Population was associated with higher levels of arboricultural certification and education in tree wardens, and tree wardens with more arboricultural knowledge managed their urban forests more systematically. These tree wardens were more likely to have urban forest

management plans and active tree inventories. They also utilized pruning cycles and provided training to tree workers at higher rates. Municipalities with larger populations tend to occupy correspondingly larger areas, with many more public shade trees to manage. Furthermore, given the Massachusetts additional qualification requirement for tree wardens of municipalities with populations greater than 10,000 (Massachusetts General Laws 2022), it is possible that large cities have urban forester positions that require ISA or Massachusetts arborist certification.

C. Urban Forestry Practices & Pruning

The survey results suggested that cities with larger populations tend to have more active urban forest management, using tree inventories, forest management plans, and pruning cycles as key indicators. Population was an explanatory variable for urban forest management plans and tree inventories.

A quarter of survey respondents reported that their municipalities have urban forest management plans. This can be compared to another Massachusetts study, in which 57% of responding tree wardens agreed or strongly agreed that "management plans are important to successful urban forest management" (Rines et al. 2010). This statement does not necessarily mean that municipalities have active management plans, but it does suggest that responding tree wardens understood the value of urban forest management plans. Overall, the number of respondents that reported urban forest management plans in this study is much lower than other studies have found. The most powerful example of this is that nationally, 55% of communities "systematically manage their trees" (Hauer and Peterson 2016).

The trend of lower numbers for Massachusetts continues when looking at tree inventories as an indicator of active forest management. In my study, a little more than one-third (37%) of respondents said that their municipality had an active tree inventory, as compared to two-thirds

nationally (Hauer and Peterson 2016). While systematic management does not require an urban forest management plan or an active tree inventory, it is likely that a formal plan is a part of systematic management.

This study also provided an opportunity to compare pruning practices in Massachusetts to national practices. Pruning frequency in this study aligned with practices nationally. The majority of survey respondents prune trees every 4 – 6 years; the national average is every 6.6 years, with a desired frequency of every 4.8 years (Hauer and Peterson 2016). Nationally, the main priorities for pruning urban trees are the removal of dead or hazardous branches and preventative maintenance (Hauer and Peterson 2016). These two can be interpreted as pruning to eliminate structural deficiencies and conflicts with the environment, the descriptor used in this study. Pruning to remove dead, dying, or diseased tree parts and to resolve problems with structure or conflicts with the environment were also shown to be the two highest priority pruning objectives in this study. However, the findings indicate that resolving conflicts takes a higher priority than removal of dead branches, which is in contrast to the United States more broadly (Hauer and Peterson 2016).

A possible explanation for the divergence of urban forest management practices described in this study and nationally (Hauer and Peterson 2016) might be related to population differences. Hauer and Peterson (2016) reported results that did not reflect smaller municipalities (population < 2,500), which, in general, have disproportionately smaller budgets.

Overall, my study gave some insights into the motivations and purposes of municipal tree pruning in Massachusetts. The similarly small proportions of respondents who indicated that (1) pruning was associated with pruning cycles and (2) pruning was undertaken to improve young tree structure suggests that reactive tree care is common in municipalities in Massachusetts.

These findings are not surprising considering that so many respondents noted that the highest priorities in their municipality were pruning to remove dead, dying, or diseased tree parts and to resolve conflicts with the trees' environment. I speculate that the lack of proactive pruning was related to a lack of resources, which has often been cited as a limitation of effective urban forest management (Stobbart and Johnston 2012, Grado et al. 2013, Hargrave et al. 2022), and given that most urban foresters in Massachusetts (Rines et al. 2010) and nationally (Hauer and Peterson 2016) acknowledge the value of active management.

The American National Standards Institute publishes guidelines for tree care operations and tree worker safety, the A300 and Z133, respectively. These guidelines are not legally binding, and participation in them is generally voluntary, unless stipulated by a contract. The A300 provides guidance on tree pruning technique that reserves the trees' mechanisms for compartmentalization, the process by which a tree closes off a wound, preventing the spread of pathogens and decay throughout the trunk (American National Standards Institute 2014). The branch collar of a tree contains tissue and hormones that are activated when the branch is removed and act to close over, or compartmentalize, the wound. Cutting into or too far outside the branch collar can impair this mechanism, leaving the tree more vulnerable to decay. Three-quarters of municipalities in this study stipulated that their tree workers follow the A300 standards (American National Standards Institute 2014). Taken alongside the finding that 23% of respondents described a typical pruning cut in their municipality to violate A300 recommendations, there is an opportunity for targeted training to have an impact on the long term outcomes for urban trees.

Tree care involves dangerous work, with tree care workers 15 times more likely to suffer a fatality as compared to the national average (Ball 2022). Robust safety standards and practices

can mitigate some of the risk and protect workers from unnecessarily hazardous situations. The Z133 from the American National Standards Institute offers guidelines to protect tree workers from preventable injury (American National Standards Institute 2017). In this study, only two-thirds of responding municipalities required tree workers to adhere to the Z133 standards, which leaves one-third of workers especially vulnerable. Tree care operations without explicit safety programs put their workers at risk of injury. Worker safety training, awareness, and review of safety standards are essential.

D. Pruning Workforce

The work of tree pruning can be broken down into two steps. Before cutting branches, urban forest managers need to make decisions about the purposes, objectives, and volume of the tree pruning. Sometimes, these are called pruning prescriptions. These prescriptions might also extend to how a cut should be executed; an individual knowledgeable in the A300 standards can guide others in preserving the branch collar as pruning proceeds, and ensure that the tree retains enough foliage to sustain its life processes (American National Standards Institute 2014). Certified arborists are required to have full mastery of these concepts and would provide expert and professional guidance for how trees should be pruned.

Half of survey respondents indicated that a certified arborist makes some pruning recommendations in their municipality. However, because respondents were able to choose multiple options, another way to look at this data is that in 55% of responding municipalities, certified arborists do not influence all pruning decisions. Instead, many decisions are made by non-arborist crew leaders and individual members of the tree crew. This is a potentially large share of decisions with bearing on the longevity of municipal trees being made by workers who are not adequately trained on how to make those decisions.

With a pruning prescription, or guidance on how and what trees should be pruned, the second step, tree pruning itself, can proceed. This work is shared among tree wardens, private contractors, and municipal employees from parks, highway, or public works departments. Respondents were allowed to choose multiple answers for who was responsible for pruning, which explained the wide range of answers. However, one trend emerged: In many municipalities, municipal employees complete at least some pruning work. The variation of who prunes trees could lead to disparate outcomes for municipal trees, even within municipalities. Some trees might be pruned by arborists with multiple certifications and years of education, while others might be pruned by municipal workers with relatively less knowledge and experience, potentially resulting in unnecessarily large wounds.

Paraprofessional municipal tree workers typically do not have an arboricultural educational background and may not be aware of the proper removal technique or safety protocols. The high proportion of municipal workers completing pruning work underscores the need for quality training to ensure that public trees remain healthy and structurally-sound and that tree workers remain safe.

E. Pruning Training

Generally, the best practices for adult education and training can be divided into 5 main areas: establishing and maintaining a connection to the learners' work or another real-life application, content, environment, structure and modality, and feedback. These elements cover the process of curriculum planning, delivery, and evaluation, all of which are components of effective training. Based on the results of this study, a potential trend over the past 20 years is that municipalities are providing more training to their tree workers. In 2005, only 36% of tree crews in Connecticut received training (Ricard 2005), whereas a majority of respondents to this

survey (70%) indicated that municipal tree workers receive training to complete their work. These results suggest that urban forest managers are aware of the need for training and are more able to allocate resources to provide it.

Training content should activate and connect to learners' backgrounds, skills, and experiences, and directly reinforce their work within the constraints of their positions (Knowles et al. 2005). When surveyed tree wardens specified the topics most commonly covered by training, personal protective equipment/safety and proper cut angle and location were almost universally addressed. These topics are both highly relevant and essential to successful pruning work. The pattern of topics covered by training generally followed a hierarchy of direct relevance, with writing pruning prescriptions and tree physiology as the least common subjects. These results show that the prioritized subjects of pruning training are more directly applicable to the work of tree pruning. This is consistent with the research-based recommendations in adult education (Sticht 1999, Knowles et al. 2005).

Although it may be simply for expediency, the nearly universal "on the job" training of tree workers in municipalities in Massachusetts incorporates many factors that positively affect outcomes for adult learners. These include matching the environment to the content, opportunities to practice with feedback, an established positive relationship between the learner and the instructor, and a familiar setting. The latter two features are not guaranteed in the "on the job" setting, but are more likely given smaller groups and a pre-existing relationship amongst trainees (workers) and between them and the trainer. By fostering a strong growth climate within these training sessions–where trainees are able to practice, make mistakes, and ask questions, learners will be comfortable, invested, and engaged (Mezirow 1997, Knowles et al. 2005, Hammond 2015, Kolb 2015).

In the case of municipal pruning training and in the context of this survey, assessment types are a metric that can illuminate whether there is space for supervised practice and feedback, an important component of effective andragogy (Mezirow 1997, Knowles et al. 2005, Kolb 2015, Metcalfe 2017). The three main assessment types are: written, skills demonstration, and oral examination. Of those three, only the skills demonstration constitutes a setting in which both sides of the practice-and-feedback exchange can occur, and within the survey population, skills demonstration represented a large majority of assessments. Of those that administer post-training assessments, all included skills demonstration. Oral and written assessment were only used in conjunction with other forms of assessment. Thus, according to the results of this survey, skill demonstration is a unifying component of assessing the effectiveness of municipal pruning training. Leveraging assessment as a learning opportunity deepens learners' knowledge and the length of skill retention.

F. Implications & Recommendations

New England is particularly susceptible to increasing temperatures associated with climate change (Young and Young 2021). Trees can be an effective way to help cities mitigate the effects of the changing climate. They improve the environmental conditions around them by cooling buildings, streets, and sidewalks with their shade (McPherson et al. 2005, Donovan and Butry 2009, Nowak and Greenfield 2018), slowing the flow of vast rushes of stormwater with their roots (McPherson et al. 2005, Soares et al. 2011, Roy et al. 2012, Shetty 2023), and clearing the air of harmful pollutants (McPherson et al. 2005). Trees also absorb large amounts of carbon dioxide and store it as carbon in their trunks, branches, and leaves, and a large portion of it remains sequestered for the lifetime of the tree (Lv et al. 2016, Nowak and Greenfield 2018).

Thus, the longer a tree lives and the healthier it is while it is alive, the more it is able to provide in terms of ecosystem services, including carbon sequestration.

Management of urban forests for climate mitigation and carbon storage should include specifications for tree pruning because pruning a young tree encourages a more stable structure and removes conflicts with its surroundings when the tree is small, making it easier and less costly to maintain. These effects influence the health and longevity of a tree, maximizing its positive environmental contributions. However, simply having specifications for pruning and following through do not guarantee those benefits. The technique of branch removal and the volume of plant matter removed can have detrimental effects on the tree, so high quality training on proper technique is essential.

The structure and modality of training– the how– should include the following: clear objectives, demonstration of skills and concepts, opportunities for practice and feedback, opportunities for reflection and self assessment, and activities in which learners collaborate and share knowledge. Training objectives should meet the needs of the workers and support them in meeting the demands of their jobs. The objectives, in turn, should inform the method and the environment. Research indicates that the educational environment should match the content (Sticht 1999, Knowles et al. 2005); in other words, if workers are learning to prune trees, they should learn to do it outside, with actual trees, for best outcomes. Furthermore, the learning environment should have a strong growth climate (Mezirow 1997, Knowles et al. 2005, Hammond 2015, Kolb 2015). This can be accomplished with a familiar instructor, such as the crew leader, who is knowledgeable and provides feedback on trainees' work in a way that encourages them to practice, and identify and learn from mistakes. Lastly, when learners are able

to visualize concepts and skills through demonstration, they are better able to practice and absorb the information (Bandura 1986, Kolb 2015).

While my study did not address tree worker demographics like race, age, and sex, it is worth discussing andragogical strategies that support educational success across the demographic spectrum. Some of the teaching techniques specific to diverse learners, or learners that are not members of the dominant culture, have already been mentioned as general best practices; however, a more in-depth explanation is warranted.

The field of Culturally Responsive Teaching, or Culturally and Linguistically Sustaining Teaching Practices, seeks to define explicit ways to engage and support diverse learners to ensure their educational success. Most studies apply these principles to school-age students (3–18), with adult applications specific to literacy and English language learning. However, these strategies are relevant and extend to a range of educational settings and are especially essential when an educator from the dominant culture (in this case, White, male, neurotypical, middle-class American) is instructing students from backgrounds that are not included in the dominant culture. Given that 39% of the United States workforce is Black, Hispanic or Latinx, or Asian, and that the largest percentage of all Hispanic or Latinx workers work in the natural resources, construction, and maintenance industries (United States Bureau of Labor Statistics 2023), it is likely that some paraprofessional tree workers are members of non-dominant cultures.

Culturally Responsive Teaching employs strategies like collaborative work, frequent feedback, goal-setting, opportunities for practice and application, and a safe environment for academic risk taking, but views them through the lens of social-emotional-cultural-linguistic support. The foundation for this is the instructor-learner relationship, which should be collaborative, caring, and validating for the learner, and acknowledge and celebrate students'

varying cultural backgrounds and native language skills (Johnson and Owen 2013, Tighe et al. 2013). The basis for this is neuroscience: as social beings, our brains constantly seek to reduce social threats and increase connections with others, and positive relationships are a powerful way to diminish those social threats (Hammond 2015).

The diversity of learners extends to trainees with learning disabilities as well, like attention-deficit/hyperactivity disorder (ADHD). Neurodivergent disabilities like ADHD are common, representing about 15-20% of the U.S. adult population (Kessler et al. 2006, Doyle 2020, Centers of Disease Control and Prevention 2021, Centers of Disease Control and Prevention 2022), and so it is likely that neurodivergent individuals are present in the arboricultural workforce. There are common threads through adult education best practices, culturally and linguistically sustaining practices, and different learning ability accommodations. An easy-to-use framework for accommodation learners with disabilities is the Universal Design for Learning Guidelines (CAST 2018). These break the process of learning into engagement (why), representation (what), and action and expression (how). A training that draws upon these guidelines would attend to the specific needs and interests of the learners, present information clearly and with multiple representations (visual, oral, etc.), and allow learners to demonstrate their knowledge through different modalities (Tighe et al. 2013, CAST 2018).

My research has shed light on some of the unseen forces governing urban forest management. A common trend in municipal forestry is that budget constraints determine how and to what extent best management practices are implemented (Stobbart and Johnston 2012, Grado et al. 2013, Hauer and Peterson 2016, Hargrave et al. 2022). It is therefore prudent for urban forest managers to leverage what resources they have and invest in high-return areas. Further, while the process of mapping a path forward involves identifying changes in practice or

policy, it must also highlight existing successful elements and use them as resources in the process of growth. Thus, some of the enhancements are amplifications and refocusing of existing practices.

First, urban forests are more systematically managed by tree wardens that have advanced arboricultural education and/or MCA or ISA arborist certifcation. Thus, municipalities, especially those with larger areas and the ability to hire a full-time urban forest manager, should include a requirement for professional arborist credentials in urban forest management job descriptions.

Secondly, a significant finding of my survey shows that the largest share of tree pruning (outside of independent contractors) is being done by paraprofessional municipal tree workers (i.e. employees of departments of public works, highways, and/or parks). It follows that attention should be given to the identity and skills of the trainers of this population, as these individuals have outsize power and can effect meaningful changes. Many of these trainers are supervisors, with no specific training background, and while some might view this as a reason to outsource training to professional training companies, doing so ignores an existing and valuable resource. By empowering supervisors as trainers and investing in supporting them in that role, municipalities can cultivate the root of learning–a strong, familiar relationship between the learner and instructor. The benefits of this practice are extensive. Beyond the initial relationship, with the instructor as the supervisor, opportunities for feedback as the trainee practices new skills are plentiful.

In addition, the lack of conformity with the A300's guidelines for proper pruning cuts suggests an opportunity for trainers to ensure that trainees fully master basic concepts before advancing (American National Standards Institute 2014). Furthermore, a purposeful inclusion of

"what not to do" that shows visual examples and explanations can further solidify understanding of proper pruning techniques.

Finally, my survey suggests that the majority of training occurs on the job. This is an area to amplify–when the environment matches the content, there are better learning outcomes (Sticht 1999, Knowles et al. 2005).

Overall, using learner experiences and cultural and linguistic identities as a starting point when planning instruction is an effective way to raise investment and engagement. Having clear learning objectives and training structure helps learners organize new information, and cultivating a positive relationship with students creates a fertile environment for learning. Incorporating all these strategies can optimize learning outcomes for all learners.

CHAPTER V

CONCLUSION

Expanding tree canopy cover is a large part of many cities' climate resilience plans (Boston 2016, the District of Columbia 2016, New York City 2017, Los Angeles 2018, Philadelphia 2021). This is for good reason– not only do trees provide cooling shade to buildings and sidewalks and remove particulates from the air with their leaves, they also sequester carbon as they grow, and store it in their trunks. However, urban foresters are tasked with meeting increased canopy cover goals while maintaining the trees within their cities with limited budgets. Maintenance of each tree demands between $12.85 and $65.00 per tree (McPherson et al. 2005) and with an estimated 5.5 billion trees in the urban canopy in the USA (Nowak and Greenfield 2018), costs amount to between $70 and $358 billion nationally. Spending urban forestry funds with maximum efficiency is essential for the health of urban trees in the long term.

Pruning is an area where a comparatively small investment can yield an expansive positive impact on city environments, and cities are likely reaping some of those benefits already. Gaining insight into what pruning work is being done and by whom allows training to be tailored to the learning population. Training strategies that incorporate research-based best practices can be generalized to be applicable in a variety of environments and with a diverse population. Municipalities can leverage the effective elements of the training they already provide, like utilizing crew leaders to deliver on-the-job training, and make small changes so that important topics like proper pruning technique and worker safety are focal points.

Tree pruning comprises a large portion of urban forestry budgets, with significant implications for the longevity of trees (Hauer and Peterson 2016). If pruning of municipal forests can be optimized, both in timing (earlier in trees' lives) and quality (incorporating ANSI A300

standards and/or the guidance of the ISA best management practices on pruning), more trees will be able to age into maturity, when they provide the most ecosystem services. Addressing structural problems and environmental conflicts when trees are smaller requires fewer resources. Those saved resources could be invested in proactive tree care, increased planting and nursery quality, and disease management. These management strategies combined will result in a healthier urban canopy that can age into the maximum contribution of ecosystem services, like stormwater absorption and temperature moderation.

APPENDIX A

SURVEY INSTRUMENT

Pruning & Training

Start of Block: Demographics

Introduction

Welcome to the Municipal Pruning and Training Survey!

We appreciate the time you are taking to complete this survey.

The information you provide will help guide and improve pruning training and give an interesting snapshot of urban forestry practices.

With any questions or concerns about the survey, please contact:
tsiarnacki@eco.umass.edu

Job title:

Which of these best describes your job? (choose all that apply)

- o Urban Forester/Municipal Arborist (4)
- o Utility Forester/Arborist (10)
- o Director/Manager of Public Works Department (5)
- o Director/Manager of Parks and Recreation Department (7)
- o Director/Manager of Engineering, Building, & Construction Department (8)
- o Tree Care Private Contractor (6)
- o Other (please indicate) (9)

State:

What state do you primarily work in?

- o Massachusetts (MA) (1)
- o Connecticut (CT) (2)
- o Maine (ME) (3)
- o New Hampshire (NH) (4)
- o New York (NY) (5)
- o Rhode Island (RI) (6)
- o Vermont (VT) (7)

Population:
What is the population of the city or town where you work?
o less than 2,500 (1)
o 2,500 - 9,999 (2)
o 10,000 - 49,999 (3)
o 50,000 - 99,999 (4)
o 100,000 - 249,999 (5)
o 250,000 - 499,999 (6)
o 500,000 - 1,000,000 (7)
o more than 1,000,000 (8)

Arb Background:
How would you describe your arboricultural background? (choose all that apply)
o Massachusetts Qualified Tree Warden Credential (1)
o Post-high school degree in Forestry or Arboriculture (2)
o ISA certified arborist (3)
o State certified arborist (4)
o 5 or more years working in tree care (5)
o None of the above (6)

Tree inventory:
Does your municipality have an active tree inventory?
o Yes (1)
o No (2)

Display This Question:
If Does your municipality have an active tree inventory? = Yes

Inventory update:
How frequently is the tree inventory updated?
o every 1 - 3 years (1)
o every 4 - 6 years (2)
o every 7 - 9 years (3)
o every 10+ years (4)

Forest Man Plan:
Does your municipality have an urban forest management plan in place?
o Yes (3)

o No (4)

Display This Question:
If Does your municipality have an urban forest management plan in place? = Yes

FMP pruning specs:
Does the urban forest management plan include specifications for tree pruning?
o Yes (1)
o No (2)

Pruning cycle:
Does your municipality prune trees on a pruning cycle?
o Yes (1)
o No (2)

Display This Question:
If Does your municipality prune trees on a pruning cycle? = Yes

Pruning frequency:
How often does your municipality prune each tree within the pruning cycle?
o every 1 - 3 years (1)
o every 4 - 6 years (2)
o every 7 - 9 years (3)
o every 10+ years (4)

Display This Question:
If Does your municipality prune trees on a pruning cycle? = Yes

Years in cycle:
How many years do municipal trees stay in the pruning cycle?
o 4 years or less (1)
o 5 - 10 years (2)
o 11 - 20 years (3)
o 21 - 40 years (4)
o Trees do not age or grow out of the pruning cycle. (5)

First prune:
How many years after planting are municipal trees first pruned?

o within the first 2 years (1)
o after 3 - 4 years (2)
o after 5 - 6 years (3)
o after 7 - 9 years (4)
o after 10 or more years (5)

Pruning motivation:
About what percentage of municipal tree pruning occurs:
As a part of the pruning cycle : _____ (1)
In response to citizen/business requests : _____ (2)
To address city-identified hazards : _____ (3)
Other (please indicate) : _____ (4)
Total : _____

Pruning objective:
About what percentage of municipal tree pruning is to:
Improve the structure of the tree : _____ (1)
Remove conflicts with trees' environment & infrastructure : _____ (2)
Address damaged/dead/diseased branches : _____ (3)
Other (please indicate) : _____ (4)
Total : _____

Pruning cut:
How would you describe a typical pruning cut in your municipality?
o Flush to the stem or trunk (1)
o Through the branch collar parallel to the stem (2)
o Well outside the branch collar, leaving a stub (3)
o Just outside the branch collar (4)
o Not sure / don't know (5)

Pruning decisions:
Which of the following best describes how pruning decisions are made in your municipality? (choose all that apply)
o A certified arborist makes all decisions and completes pruning on their own. (1)
o A certified arborist makes pruning recommendations for each tree that are completed by a different municipal employee. (2)
o The leader of the tree crew (if not a certified arborist) directs the pruning cuts that are made. (3)
o Each member of the tree crew decides how to prune trees individually. (4)
o A private contractor makes most pruning decisions. (5)

Pruning workers:
Who completes pruning work in your municipality? (choose all that apply)
o Qualified Tree Warden (1)
o Tree Warden who is a State Certified Arborist (2)
o Tree Warden who is an ISA Certified Municipal Specialist (3)
o Tree Warden (no further certification) (7)
o Private Contractor with certified arborist(s) on staff (4)
o Private Contractor that is TCIA accredited (5)
o Private Contractor with no accreditation or certified arborist on staff (8)
o Municipal employee (Parks / Public Works) (9)
o Other (please indicate) (6)

A300:
Does your municipality require tree workers to follow the ANSI A300 standards?
o Yes (1)
o No (2)
o Not sure (3)

Z133:
Does your municipality require tree workers to follow the Z133 safety standards?
o Yes (1)
o No (2)
o Not sure (3)

Pruning by worker:
About what percentage of municipal tree pruning is completed by each worker type?
Municipal arborist / Urban forester : _____ (1)
Municipal employee (Parks / Public Works) : _____ (2)
Private Contractor : _____ (4)
Other (please indicate) : _____ (5)
Total : _____

Display This Question:
If Who completes pruning work in your municipality? (choose all that apply) = Tree Warden (no further certification)
Or Who completes pruning work in your municipality? (choose all that apply) = Municipal employee (Parks / Public Works)

Or Who completes pruning work in your municipality? (choose all that apply) = Qualified Tree Warden
Or Who completes pruning work in your municipality? (choose all that apply) = Tree Warden who is a State Certified Arborist
Or Who completes pruning work in your municipality? (choose all that apply) = Tree Warden who is an ISA Certified Municipal Specialist
Or Who completes pruning work in your municipality? (choose all that apply) = Other (please indicate)

Pruning training mun:
Do municipal employees or volunteers receive training on how to prune trees properly?

- o Yes (1)
- o No (2)

Display This Question:
If Who completes pruning work in your municipality? (choose all that apply) = Private Contractor with certified arborist(s) on staff
Or Who completes pruning work in your municipality? (choose all that apply) = Private Contractor that is TCIA accredited
Or Who completes pruning work in your municipality? (choose all that apply) = Private Contractor with no accreditation or certified arborist on staff

Pruning training con:
Do private contractor employees receive training on how to prune trees properly?

- o Yes (1)
- o No (2)
- o Not sure (3)

Display This Question:
If Do municipal employees or volunteers receive training on how to prune trees properly? = Yes
Or Do private contractor employees receive training on how to prune trees properly? = Yes

Training format:
What is the format of the pruning training tree workers receive? (choose all that apply)

o Online (1)
o In person seminar/lecture (2)
o On the job (3)
o Other (please indicate) (4)
_____
o ⊗Don't know (5)

Display This Question:
If Do municipal employees or volunteers receive training on how to prune trees properly? = Yes

Trainer ID:
Who provides pruning training? (choose all that apply)
o Certified arborist (1)
o Supervisor (if not certified arborist) (2)
o Outside training company (indicate name of company) (3)
_____
o Other (please indicate) (4)
_____
o ⊗Don't know (5)

Display This Question:
If Do municipal employees or volunteers receive training on how to prune trees properly? = Yes

Refresher:
Do municipal tree workers receive refresher trainings?
o Yes (1)
o No (2)
o Not sure (3)

Display This Question:
If Do municipal tree workers receive refresher trainings? = Yes

Refresher freq:
How often do municipal tree workers receive refresher trainings?
o every 1 - 2 years (1)

- o every 3 - 5 years (2)
- o every 6 - 10 years (3)
- o every 11+ years (4)

Display This Question:
If Do municipal employees or volunteers receive training on how to prune trees properly? = Yes

Assessment:
How are pruning trainees assessed? (choose all that apply)

- o Written test (1)
- o Practical skills demonstration (2)
- o Oral exam (5)
- o No assessment (4)
- o Other assessment (please indicate) (3)

Display This Question:
If Do municipal employees or volunteers receive training on how to prune trees properly? = Yes

Training topics:
What topics are covered in pruning training? (please indicate)

	Yes (4)	No (5)
Tree physiology (1)	o	o
PPE / Safety (2)	o	o
Structural pruning (3)	o	o
Pruning prescriptions (4)	o	o
Proper cut angle & location (5)	o	o
Tools / Maintenance (6)	o	o
Types of pruning cuts (7)	o	o
Setting up a work site/site inspection (8)	o	o
Other (please indicate) (10)	o	

APPENDIX B

ADULT TRAINING RUBRIC

Adult Training Rubric					
Training Title	**Location**	**Trainee population**	**Instructor type**	**Instructor:Learner Ratio**	
Element	**0** element not observed	**1** <25%; connections are not made explicit	**2** 26% - 50%; some connections are made explicit	**3** 51% - 75%; more than half of connections are made explicit	**4** >75%; connections are made explicit
Training builds on learners' background knowledge and skills					
Training addresses the needs and constraints of the learners' work					
Content is relevant to work					
Learners are involved in the selection of content					
Training environment matches the task/content					
Training occurs within compensated work hours					
Training environment has strong growth climate					
Training objectives are clear					
Demonstrations of skills and concepts					
Opportunities for practice and feedback					
Opportunities for reflection					
Opportunities for trainees to collaborate/share knowledge					
Feedback type (indicate)					
Assessment (if present, indicate)					
Format of training (indicate)					

BIBLIOGRAPHY

The 193rd General Court of the Commonwealth of Massachusetts. 2024. Massachusetts census data. <https://malegislature.gov/Redistricting/MassachusettsCensusData/CityTown> Accessed 6 February 2024.

American National Standards Institute. 2014. American national standard for tree care operations-tree, shrub, and other woody plant maintenance-standards practices (pruning). ANSI A300 part 1. American National Standards Institute, New York, New York.

American National Standards Institute. 2017. Tree care operations-pruning, trimming, repairing, maintaining, and removing trees, and cutting brush-safety requirements. ANSI Z133.1. American National Standards Institute, New York, New York.

Ball, J. 2022. Tree worker safety by the numbers: another us vs. them. TCI Magazine. <https://tcimag.tcia.org/tree-care/tree-worker-safety-update-by-the-numbers-another-us-vs-them/>.

Bancks, N., E. A. North, and G. R. Johnson. 2018. An analysis of agreement between volunteer- and researcher-collected urban tree inventory data. Arboriculture & Urban Forestry 44(2):73–86.

Bandura, A. 1986. Social foundations of thought and action: a social cognitive theory. Prentice-Hall. Englewood Cliffs, New Jersey.

Bloniarz, D., and H. D. Ryan. 1996. The use of volunteer initiatives in conducting urban forest resource inventories. Arboriculture & Urban Forestry 22:75–82.

Boston, City of. Climate ready Boston. 2016.

Brown, S., A. Easley, D. Montfort, J. Adam, B. V. Wie, A. Olusola, C. Poor, C. Tobin, and A. Flatt. 2014. Effectiveness of an interactive learning environment utilizing a physical model. Journal of Professional Issues in Engineering Education and Practice 140:04014001.

CAST. 2018. Universal design for learning guidelines version 2.2. <http://udlguidelines.cast.org>. Accessed 25 January 2024.

Cavalari, A. A., G. Del Nero Velasco, C. L. Da Silva-Luz, A. S. Rosa, A. De Abreu Neder Waetge, E. De Souza Barbosa, F. C. M. Biazzo, H. E. Kavamura, C. A. Da Silva Filho, E. B. De Freitas Back Silva, and G. M. Locosselli. 2024. Predicting tree failure to define roles and guidelines in risk management, a case study in São Paulo / Brazil. Urban Forestry & Urban Greening 91:128181.

Centers for Disease Control and Prevention. 2022. Autism spectrum disorder data and statistics. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. Atlanta, Georgia.

Centers for Disease Control and Prevention. Attention-deficit / hyperactivity disorder (ADHD) data and statistics, 2021. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. Atlanta, Georgia.

Clark, J., and N. Matheny. 2010. The research foundation to tree pruning: a review of the literature. Arboriculture & Urban Forestry 36:110–120.

Donovan, G. H., and D. T. Butry. 2009. The value of shade: estimating the effect of urban trees on summertime electricity use. Energy and Buildings 41:662–668.

Donovan, G. H., D. T. Butry, Y. L. Michael, J. P. Prestemon, A. M. Liebhold, D. Gatziolis, and M. Y. Mao. 2013. The relationship between trees and human health. American Journal of Preventive Medicine 44:139–145.

Deksissa, T., L. Liang, P. Behera, and S. Harkness. 2014. Fostering significant learning in sciences. International Journal for the Scholarship of Teaching and Learning 8(2):12.

Dillman, D. A., J. D. Smyth, and L. M. Christian. 2014. Internet, phone, mail, and mixed-mode surveys: the tailored design method. 4th edition. John Wiley & Sons, Hoboken, New Jersey.

District of Columbia. Climate ready DC. 2016.

Doyle, N. 2020. Neurodiversity at work: a biopsychosocial model and the impact on working adults. British Medical Bulletin.

Escobedo, F. J., D. C. Adams, and N. Timilsina. 2015. Urban forest structure effects on property value. Ecosystem Services 12:209–217.

Fawcett, R., B. Kane, and D. V. Bloniarz. 2024. Training volunteers to prune recently planted, small street trees. Arboriculture & Urban Forestry jauf.2024.006.

Fore, L. S., K. Paulsen, and K. O'Laughlin. 2001. Assessing the performance of volunteers in monitoring streams. Freshwater Biology 46:109–123.

Foster-Smith, J., and S. M. Evans. 2003. The value of marine ecological data collected by volunteers. Biological Conservation 113:199–213.

Gillett, D. J., D. J. Pondella, J. Freiwald, K. C. Schiff, J. E. Caselle, C. Shuman, and S. B. Weisberg. 2012. Comparing volunteer and professionally collected monitoring data from the rocky subtidal reefs of Southern California, USA. Environmental Monitoring and Assessment 184:3239–3257.

Gilman, E., J. Miesbauer, and F. J. Masters. 2015. Structural pruning effects on stem and trunk strain in wind. Arboriculture & Urban Forestry 41.

Grado, S., M. Measells, and D. Grebner. 2013. Revisiting the status, needs, and knowledge levels of Mississippi's governmental entities relative to urban forestry. Arboriculture & Urban Forestry 39.

Guthrie, E.R. 1960. The psychology of learning, revised edition. P. Smith, Gloucester, Massachusetts.

Hammond, Z. 2015. Culturally responsive teaching and the brain: promoting authentic engagement and rigor among culturally and linguistically diverse students. Corwin, a SAGE Company. Thousand Oaks, California.

Hargrave, J. R., R. W. Harper, B. J. Butler, and J. T. Mullins. 2022. Municipal forest program management in the United States of America: a systematic review. Forests 14:35.

Hauer R. J. and W. D. Peterson. 2016. Municipal tree care and management in the United States: a 2014 urban & community forestry census of tree activities. Special Publication 16-1, College of Natural Resources, University of Wisconsin – Stevens Point.

Hauer, R. J., N. Timilsina, J. Vogt, B. C. Fischer, Z. Wirtz, and W. Peterson. 2018. A volunteer and partnership baseline for municipal forestry activity in the United States.

Hilbert, D., L. Roman, A. Koeser, J. Vogt, and N. Van Doorn. 2019. Urban tree mortality: a literature review. Arboriculture & Urban Forestry 45.

Johnson, J., and L. Owen. 2013. Reaching a culturally diverse immigrant population of adult English language learners. Journal of Adult Education 42:1.

Kessler, R.C., L. Adler, R. Barkley, J. Biederman, C. K. Conners, O. Demler, S. V. Faraone, L. L. Greenhill, M. J. Howes, K. Secnik, T. Spencer, T. B. Ustun, E. E. Walters, A. M. Zaslavsky. 2006. The prevalence and correlates of adult ADHD in the United States: results from the National Comorbidity Survey Replication. American Journal of Psychiatry 163(4):716-23.

Knowles, M. S., E. F. Holton, R. A. Swanson, and ProQuest. 2005. The adult learner: the definitive classic in adult education and human resource development, sixth edition. Elsevier, Amsterdam, Boston.

Kornell N., and J. Metcalfe. 2013. The effects of memory retrieval, errors, and feedback on learning. In V. A. Benassi, C. E. Overson, and C. M. Hakala, editors. Applying science of learning in education: infusing psychological science into the curriculum. American Psychological Association Society for the Teaching of Psychology. Washington, D.C.

Kolb, D. A. 2015. Experiential learning: experience as the source of learning and development, second edition. Pearson Education Ltd, Upper Saddle River, New Jersey.

Kosmala, M., A. Wiggins, A. Swanson, and B. Simmons. 2016. Assessing data quality in citizen science. Frontiers in Ecology and the Environment 14:551–560.

Lilly, S. J., E. F. Gilman, and E. T. Smiley. 2019. Best management practices: pruning, third edition. International Society of Arboriculture, Atlanta.

Lindenmayer, D. B., W. F. Laurance, J. F. Franklin, G. E. Likens, S. C. Banks, W. Blanchard, P. Gibbons, K. Ikin, D. Blair, L. McBurney, A. D. Manning, and J. A. R. Stein. 2014. New policies for old trees: averting a global crisis in a keystone ecological structure: rapid loss of large old trees. Conservation Letters 7:61–69.

Linsey, J., A. Talley, C. White, D. Jensen, and K. Wood. 2009. From tootsie rolls to broken bones: an innovative approach for active learning in mechanics of materials. Advances in Engineering Education 1(3):1-23.

Los Angeles, City of. Resilient Los Angeles. 2018.

Luley, C., S. Sisinni, and A. Pleninger. 2002. The effect of pruning on service requests, branch failures, and priority maintenance in the city of Rochester, New York, U.S. Arboriculture & Urban Forestry 28:137–143.

Lv, H., W. Wang, X. He, L. Xiao, W. Zhou, and B. Zhang. 2016. Quantifying tree and soil carbon stocks in a temperate urban forest in northeast China. Forests 7:200.

Massachusetts General Laws. 2022. Part I: administration of the government. Title XIV: public ways and works. Chapter 87: shade trees.

Massachusetts General Laws. 2022. Part I: administration of the government. Title XIV: public ways and works. Chapter 41, section 106.

McGovern, M., and J. Pasher. 2016. Canadian urban tree canopy cover and carbon sequestration status and change 1990–2012. Urban Forestry & Urban Greening 20:227–232.

McPherson, G., J. R. Simpson, P. J. Peper, S. E. Maco, and Q. Xiao. 2005. Municipal forest benefits and costs in five US cities. Journal of Forestry 103:411–416.

Metcalfe, J. 2017. Learning from errors. Annual Review of Psychology 68:465–489.

Mezirow, J. 1997. Transformative learning: theory to practice. New Directions for Adult and Continuing Education 1997:5–12.

Mincey, S., and J. Vogt. 2014. Watering strategy, collective action, and neighborhood-planted trees: a case study of Indianapolis, Indiana, U.S. Arboriculture & Urban Forestry 40.

Moore, G. M. 2022. Lifetime cost models for large, long-lived, street trees in Australia. Arboricultural Journal 44:21–41.

Neuman, W. L. 2004. Basics of social research. Pearson Education Inc. Boston, Massachusetts.

New York, City of. Cool neighborhoods NYC. 2017.

Nowak, D. J., and E. J. Greenfield. 2018. US urban forest statistics, values, and projections. Journal of Forestry 116:164–177.

Pavlis, M., B. Kane, J. R. Harris, and J. Seiler. 2008. The effects of pruning on drag and bending moment of shade trees. Arboriculture & Urban Forestry 34:207–215.

Philadelphia, City of. Climate action playbook. 2021.

Harris, J. 2018. Structural pruning to correct codominant leads. Arbor Rangers LLC.

Qualtrics. 2020. Qualtrics XM Version March 2023. Qualtrics. Provo, Utah. <https://www.qualtrics.com>

Raosoft. 2004. Raosoft sample size calculator. <http://www.raosoft.com/samplesize.html>. Accessed 6 February 2024.

Ratnieks, F. L. W., F. Schrell, R. C. Sheppard, E. Brown, O. E. Bristow, and M. Garbuzov. 2016. Data reliability in citizen science: learning curve and the effects of training method, volunteer background and experience on identification accuracy of insects visiting ivy flowers. J. McPherson, editor. Methods in Ecology and Evolution 7:1226–1235.

R Core Team. 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. <https://www.R-project.org/>.

Ricard, R. M., and D. V. Bloniarz. 2006. Learning preferences, job satisfaction, community interactions, and urban forestry practices of New England (USA) tree wardens. Urban Forestry & Urban Greening 5:1–15.

Ricard, R. M. 2005. Connecticut's tree wardens: a survey of current practices, continuing education, and voluntary certification. Northern Journal of Applied Forestry 22:248–253.

Rines, D., B. Kane, H. Dennis, P. Ryan, and D. B. Kittredge. 2010. Urban forestry priorities of Massachusetts (USA) tree wardens. Urban Forestry & Urban Greening 9:295–301.

Roman, L. A., L. A. Walker, C. M. Martineau, D. J. Muffly, S. A. MacQueen, and W. Harris. 2015. Stewardship matters: case studies in establishment success of urban trees. Urban Forestry & Urban Greening 14:1174–1182.

Roman, L. A., B. C. Scharenbroch, J. P. A. Östberg, L. S. Mueller, J. G. Henning, A. K. Koeser, J. R. Sanders, D. R. Betz, and R. C. Jordan. 2017. Data quality in citizen science urban tree inventories. Urban Forestry & Urban Greening 22:124–135.

Roy, S., J. Byrne, and C. Pickering. 2012. A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban Forestry & Urban Greening 11:351–363.

Ryder, C. M., and G. M. Moore. 2013. The arboricultural and economic benefits of formative pruning street trees. Arboriculture & Urban Forestry 39(1): 17–24.

Shetty, N. H. 2023. Estimating stormwater infiltration and canopy interception for street tree pits in Manhattan, New York. Forests 14:216.

Soares, A. L., F. C. Rego, E. G. McPherson, J. R. Simpson, P. J. Peper, and Q. Xiao. 2011. Benefits and costs of street trees in Lisbon, Portugal. Urban Forestry & Urban Greening 10:69–78.

Sticht, T. G., 1999. Adult basic education: strategies to increase returns on investment (ROI). Applied Behavioral and Cognitive Sciences Incorporated. July 1999.

Stobbart, M., and M. Johnston. 2012. A survey of urban tree management in New Zealand. Arboriculture & Urban Forestry 38:247–254.

Suchocka, M., T. Swoczyna, J. Kosno-Jończy, and H. M. Kalaji. 2021. Impact of heavy pruning on development and photosynthesis of Tilia cordata Mill. trees. R. Subramanyam, editor. PLOS ONE 16:e0256465.

Tighe, E. L., A. E. Barnes, C. M. Connor, and S. C. Steadman. 2013. Defining success in adult basic education settings: multiple stakeholders, multiple perspectives. Reading Research Quarterly 48:415–435.

Van Den Berg, M., W. Wendel-Vos, M. Van Poppel, H. Kemper, W. Van Mechelen, and J. Maas. 2015. Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. Urban Forestry & Urban Greening 14:806–816.

Vogt, J., R. Hauer, and B. Fischer. 2015. The costs of maintaining and not maintaining the urban forest: a review of the urban forestry and arboriculture literature. Arboriculture & Urban Forestry 41.

Wattenhofer, D. J., and G. R. Johnson. 2021. Understanding why young urban trees die can improve future success. Urban Forestry & Urban Greening 64:127247.

Widney, S., B. Fischer, and J. Vogt. 2016. Tree mortality undercuts ability of tree-planting programs to provide benefits: results of a three-city study. Forests 7:65.

Young, S. S., and J. S. Young. 2021. Overall warming with reduced seasonality: temperature change in New England, USA, 1900–2020. Climate 9:176.