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Can Volunteers Learn to Prune Trees?

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CAN VOLUNTEERS LEARN TO PRUNE TREES?

A Thesis Presented

By

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ABSTRACT

CAN VOLUNTEERS LEARN TO PRUNE TREES?

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Volunteer pruning programs are becoming an important tool in helping municipal arborists manage the urban forest. To find if volunteers can learn to prune trees well, the ability of volunteers to prune small trees after receiving training was assessed in three different ways, a written exam, a pruning prescription assessment, and a pruning cut assessment. Volunteers were assigned to either an indoor, lecture-based training or an outdoor, hands-on training session. After the training volunteers were asked to complete a written exam to gauge their understanding of the curriculum. Volunteers were then asked to perform a pruning prescription on small street trees indicating where they would prune to remove structural issues and branches growing into signs and walkways. Finally, volunteers were asked to make a removal cut and reduction cut using hand pruners. Volunteers who received indoor training performed significantly better on the written exam. Both training groups performed well on the pruning prescription assessment. At each location, volunteers who received the outdoor training scored significantly higher than the indoor group on their pruning prescription. The type of training received did not affect a volunteer’s ability to make good pruning cuts. These results indicate that, given proper training, volunteers can learn to prune small trees to the satisfaction of an arborist.

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CHAPTER 1

INTRODUCTION

Trees provide many benefits for urban ecosystems, but they also have costs associated with them. The impact of many of the most valuable benefits provided by trees is directly tied to the size of a tree and the biological functions of tree leaves are often the drivers of these benefits. For example, trees with more leaf surface area can remove more pollution from the air because they directly remove pollution when they absorb air into their stomata (Nowak et al. 2014). But larger trees have a higher cost associated with them.

As trees grow and age, they experience health and stability issues; and if planted in a location that is too small, they also can conflict with their environment. Branches can die and pose safety risks, roots can crack sidewalks and damage sewer systems, and leaves can block traffic signs. Larger cities can spend millions of dollars each year to maintain the trees currently growing along their streets in addition to the millions of dollars they need to spend to fix the damage caused by trees (McPherson et al. 2007, Hauer and Peterson 2014). To maximize the value of the benefits provided by trees, it is important that the costs of having them in our cities is as low as possible.

One way to do this is by using volunteers. Arborists are skilled workers and are expensive to hire, so cities often cannot afford to keep many on staff. The municipal arborists that do work for cities are also often busy dealing with damage from storms and higher risk trees. Many cities use volunteers to undertake low risk tree care activities like watering and planting (Galloway et al. 2006, Mincey and Vogt 2014). Increasingly, cities are allowing volunteers to train with arborists to learn how to prune trees and then form volunteer pruning organizations that help take care of the pruning needs of small public trees, but there has not been any research done to quantify how well they can learn to prune.

Benefits of Trees

When properly managed, trees can provide several benefits for communities ranging from providing animal habitat to bolstering neighborhood economies (Wolf 2005, Sanesi et al. 2009). There are four main classifications of ecosystem services that trees provide: (i) regulating, (ii) supporting, (iii) provisioning, and (iv) cultural (Hassan et al. 2005). Regulating services include temperature regulation, pollution management, and energy use reduction. Supporting services come from the role trees play in an ecosystem and include primary production, water cycling, and nutrient cycling. Provisioning services are derived from the products taken from trees; wood, food, and biofuel are examples. Cultural services can range from spiritual importance to the enjoyment we get by looking at trees.

Improving air quality is one of the most well documented ecosystem services. Fine particulate air pollution is a global issue, no country is immune to the declining quality of the air we breathe, and it is likely that every individual on the planet is affected by this issue. Fine particulates are responsible for several health issues in humans ranging from acute bronchitis and asthma in children (Dockery et al. 1996) to mortality in the elderly and people with preexisting conditions (Laden et al. 2006). When trees are in-leaf, fine particulates are deposited, especially when leaves are waxy or have hairs. Additionally, groups of trees can disperse clouds of particulates floating through an area by physically breaking up the clouds and further trapping particulates on their leaves. The larger a tree grows, the more leaves it will have, and the more deposition will occur. Depending on the size of a city and canopy cover, trees can filter out thousands of kilograms of fine particulate pollutants from air in cities (Nowak et al. 2013b).

Trees also remove CO_2 from the atmosphere during photosynthesis. Large amounts of CO_2 in the atmosphere result in a stronger greenhouse effect, a main driver of global climate change. Trees absorb atmospheric CO_2, and through the process of photosynthesis, convert it to and store it as biomass. Because they have more leaf surface area and biomass, larger trees sequester more CO_2 and store more carbon. Urban and community trees in the United States are estimated to store between 1.25 and 1.47 billion tonnes of CO_2, worth an estimated $106.9 billion in total (Nowak et al 2013a). As trees continue to grow, they sequester more CO_2; since this effect is cumulative, the value of CO_2 stored by individual trees will continue to grow in tandem with the size of the tree (McPherson 2007).

Another well documented regulatory service is trees reducing the amount of energy spent on heating and cooling. The Urban Heat Island (UHI) is an effect caused by the built infrastructure of an urban or suburban area and how that environment can heat and cool compared to naturalized areas or undeveloped areas. The surfaces of an urban environment absorb more heat from the sun and reflect less heat than natural surfaces due to their color and building materials (Taha 1997). When trees are in-leaf, they block sunlight and the more trees there are the less sunlight that makes it through to warm whatever surface is underneath (Streiling and Matzarakis 2003). Larger trees can mean more shade and a smaller UHI. Since this is such a localized effect, it is important to have a large dispersal of large, mature shade trees in a city to benefit each neighborhood. This service can be quantified by the amount of energy use it saves on heating and cooling annually. Lower street temperatures mean less energy and money spent on air conditioning, and slower winds in winter means less is spent on heating. In the United States, trees reduce national energy use by 7.2% which comes out to $4.7 billion in electricity use and $3.1 billion in heating use each year (Nowak et al. 2017).

Fresh fruit, lumber, potable water, and biofuel are all examples of commodities that trees can provide. In many cities there is a food access issue. Many people live in neighborhoods with no grocery store, or with no store that stocks fresh, quality produce. Managing the urban forest to create edible landscapes can help residents supplement their diets with fresh produce and better understand forest management (McClain et al. 2012). Picking an apple off a tree in a community garden or park is a way residents can directly interact with trees and benefit from something trees provide. Newly planted trees rarely produce fruit, and it takes several years for them to start producing desirable quality fruit. Having older, well established urban orchards could supply a small stream of fruit for a community.

Examples of cultural services provided by trees are their impact on the mental health of residents and their aesthetic appeal. Cities are characterized as being fast paced, loud, expensive, and competitive, all of which can harm someone's mental health. It is generally understood that large trees can act as a barrier between noise pollution and residents that dampens sound (Dzhambov and Dimitrova 2014). Planting trees or shrubs with dense foliage between residential spaces and sources of excessive noise can block the noise and provide respite. Additionally, enjoying nature is an outlet for many people, and leads to stronger, more social communities (Zhang et al. 2014). Building social capital can be a challenging task, but it is evident that having well maintained trees in a community makes it a little easier. It is hard to quantify the value of mental health and spiritual importance compared to energy saved and pollutants removed, but it is still important to factor these benefits in when appraising the value of a tree.

The aesthetic appeal of trees is another important cultural service they provide. The aesthetic value trees provide is often a reason people want to keep trees around in their community (Schroeder et al. 2006) and it is often difficult to put a price on people liking how something looks. However, large mature trees in the front yard raised the sale price of homes 3.5%-4.5% (Anderson and Cordell 1988). How much that percentage is worth is entirely dependent on the existing property value, but for more expensive homes that could mean mature trees could be worth many thousands of dollars on private property.

Costs of Maintaining the Urban Forest

Like any asset, there are costs to maintain trees in a developed setting that range from taking care of the trees themselves to dealing with their impact on the built environment around them. These costs can be broken down in a few different ways. The first cost is purchasing the tree from a nursery or purchasing the seedling to grow in a municipal nursery. There is also a cost of the labor associated with planting the tree: workers need to transport the tree to the planting site, dig the hole, prepare the tree to be planted, plant the tree, mulch the planting, potentially stake the tree, and then clean up the planting site. Finally, the newly planted tree will need to be maintained over the course of its life.

Maintenance is the most expensive part of tree care. A survey of 667 communities in the United States found that, on average, the annual budget per municipal tree was $42.59 (Hauer and Peterson 2016). Two-thirds of the annual budget went directly to tree care: (i) planting (14.2%), (ii) tree pruning (23.3%), (iii) tree removal (24.5%), and (iv) stump removal (3.6%) (Hauer and Peterson 2016). An earlier report found that municipalities spend between $20 and $30 annually to maintain a single tree (McPherson et al. 2007). The largest costs were pruning (between $6 and $12 per tree) and planting ($10 per tree) (McPherson et al. 2007)

Further costs of the urban forest come from how trees interact with infrastructure. Trees can lift sidewalks, block signs, grow into power lines, and damage sewer systems. In 2007, New York City spent around $3 million each year to repair sidewalks from tree damage (McPherson et al. 2007). This figure does not account for damages caused by people tripping and injuring themselves on broken sidewalks and does not address accessibility issues posed by mounded and broken sidewalks. When trees are planted near intersections and not properly maintained, there is a chance that they can block stop signs or street signs, creating a dangerous situation for everyone using the road.

Trees can be a nuisance beyond the damage they cause to infrastructure. When trees are uncared for, low branches can block business signs, obscure lines of sight causing safety concerns, and their fruit can be messy. Homeowners consistently cite cleaning up fallen leaves and twigs as a reason to not have trees on their property. In addition, people worry about trees reducing sight lines in parks and other areas which can make an area dangerous. Trees reduce the amount of crime in areas where they are well taken care of, but in more industrial areas where there is less vegetation management, the plants could fail at reducing crime (Troy et al. 2021). This should provide further incentive to care for trees on a wide scale and make tree pruning more accessible and publicly recognized.

Finally, there are several health issues that trees can exacerbate. Every spring when plants start to flower, millions of people suffer from allergies with symptoms ranging from a sore throat to debilitating headaches. Trees release a large amount of pollen and other organic compounds into the air that can cause allergic reactions, seasonal allergies, and can even aid in people developing asthma (Lovasi et al. 2013).

Optimizing the Benefit-Cost Ratio of Trees

To ascertain the value of an asset, economists often compute benefit-cost ratios. For trees growing in developed landscapes, computing their benefit-cost ratio is imperative because municipal tree care budgets are limited. Municipalities that are underfunded are often understaffed and unable to keep up with recommended pruning cycles. They also could take longer to respond to storm damage. In response to a survey of urban foresters, 47% felt that their tree care program was underfunded and 50% cited lack of funding as an impediment to operating effectively (Hauer and Peterson 2016).

There is a consistent method to determine the cost-benefit ratio of trees. A typical analysis based on McPherson et al. 2007 involves 4 steps. (i) Calculating benefits and costs over 40 years, (ii) adjusting for local prices of benefits, (iii) adjusting for local prices of costs, and (iv) calculating net benefits and benefit-cost ratio. In practice, this method involves estimating benefits provided by the tree being planted based on the species of tree and how big it will grow, where each year the estimated annual benefits and costs increase, and simply adding the dollar value of all the benefits provided together and subtracting the estimated costs.

Managing an urban forest is not a simple project and being an arborist is not an easy job. Working in the arboricultural industry exposes individuals to dangerous scenarios and requires workers to perform tasks working at height in a tree and use dangerous equipment. The arboricultural industry is one of the most dangerous industries and high rates of injury and fatality are regularly reported (United States Bureau of Labor Statistics 2019). As such, hazardous tasks like pruning and removing large trees should only be done by qualified professionals. While arborists that are trained need to focus on more difficult and dangerous tasks, they often run out of time in their workweek to focus on the smaller tasks like pruning newly planted trees and fall behind in their pruning cycles.

Structurally pruning young trees is important. Many trees can develop structural issues like codominant stems and poor branch attachments when they are immature, newly established trees. This can lead to increased risk in the future when the tree grows larger. The goal of structurally pruning a tree is to remove flaws in the crown of the tree to reduce the likelihood of failure of branches and trunks, and to make sure the branching of a tree is compatible with the site it is planted at. Pruning trees when they are small eliminates future risk in addition to lowering future tree care costs. Structural pruning can prevent the growth of codominant stems that result in increased wind loading on the trunk (Gilman et al. 2015), reducing the likelihood of failure from wind loading. Removing these structural issues on a young tree ensure that as a tree matures structural issues will not develop into branch, stem, or trunk with a high risk of failure, posing danger to targets around the tree. If these issues do not develop in mature trees, then the cost of maintaining mature trees will be drastically lower without the need for intensive structural pruning.

It is cheaper and less time consuming to structurally prune a tree when it young. Caring for trees when they are younger and easier to work on can reduce the projected future costs and difficulty of tree maintenance. The average cost of pruning a mature tree for the first time is $34.40, compared to the cost of $.7-$3.10 to prune a newly established tree for the first time (Ryder and Moore 2013). Depending on the species, an arborist could prune small, young trees for nearly two decades for the same cost as pruning a mature tree once. The cost is also less because smaller trees generate less debris when they are pruned and do not require heavy or advanced equipment to prune. Many newly established trees can be pruned with hand and pole pruners and a hand saw.

To further reduce the costs of planting and maintaining trees, municipal arborists can enlist the help of volunteers. Using volunteers to help manage and maintain the urban forest is becoming more and more popular. It is practical to ask volunteers to prune newly established trees since they will not need more than hand pruners, hand saws, and a pole pruner. For every tree a volunteer prunes, that is one less tree a municipality will need to prune. If volunteers can be trained to identify structural issues in the crown of young trees, they should be able to prune the tree and remediate the structural issues found in young trees, preventing the tree from maturing with these issues and developing more structural flaws. This will further offset the cost of maintenance and will result in a tree's benefits overtaking the cost of a tree earlier on in the tree's life.

Citizen Forestry

Throughout the United States communities and municipal arborists are looking for other ways to offset the costs of maintaining a healthy urban forest. A method of offsetting these costs is the use of volunteers and citizen scientists. The term "Community Forestry" is used to refer to this partnership that has been built between municipal arborists, nonprofits, and members of the community to manage the urban forest. In the United States alone there are more than 300,000 volunteers that contribute an estimated 1.5 million hours of labor each year, accounting for 5% of all public tree care activities in the country (Hauer et al. 2018).

With the tree care activity being performed by volunteers making up just a small percentage of total activities there is room to grow the involvement of volunteers in municipal tree care. In communities with volunteer tree care programs, tree planting is the most common activity with 85% of communities having volunteers participate in tree planting (Hauer et al. 2018). Next to tree planting, watering is the next most common activity for volunteers to participate in with half as many communities reporting volunteer watering efforts and even less reporting volunteer participation in pruning, pest management, and removal. These three least common activities are likely to not be more complicated than planting a tree, but they do pose much greater risks. Pruning and removals involve the use of sharp tools, ladders, and other equipment and pest management can involve the use of pesticides and herbicides, where planting a tree can be done with a shovel and water. The differences in risk and physical difficulty of tasks could attribute to their popularity for volunteers.

In activities where volunteers do participate, they generally perform quality work. In urban neighborhoods where volunteers participated in tree planting in California and Pennsylvania trees had between a 95% and 99% survival rate (Roman et al. 2015) showing that, given proper instruction, volunteers can plant trees without compromising survivability. Further, when tasked with helping with a tree inventory, volunteers were able to (i) accurately determine the species of a tree, (ii) measure DBH and crown size, (iii) assess vigor, (iv) measure crown dieback, and (v) recommend management needs at a level like that of certified arborists (Bloniarz and Ryan 1996, Hallett and Hallett 2018). Being able to identify the species of a tree and assess its condition are important parts of an arborist's job. If volunteers can accurately perform these tasks like arborists, they are able to provide communities with a very basic assessment of risk trees in the community and help municipal arborists gather data to improve their management capabilities.

Finally, watering trees is important. All newly planted trees in urban environments need to be watered, and volunteers are important in making sure newly planted trees get watered. Since it takes many years for the value of benefits provided by trees to eclipse the cost of installation and maintenance it is important that when a tree is planted, it stays planted and it stays healthy. When communities work together to water trees the mortality for trees is less than that of communities with no watering programs (Mincey and Vogt 2014). Higher survivorship of newly planted trees results in less time and money spent on removing and replacing dead trees. Trees with established watering agreements also showed increased growth than those with no community watering support (Mincey and Vogt 2014). Hastening the growth of trees could potentially help them produce benefits for the community faster, the faster trees grow foliage, the faster the value of their benefits will accumulate. Community tree watering can build social capital and potentially be a gateway activity for other tree care activities.

There is a clear case to be made for the efficacy of volunteers in these types of community forestry programs. Because of this, there is reason to believe volunteer participation should be expanded to other facets of tree care. There is, however, a lack of research to investigate volunteers' ability to prune trees. This research proposes to find how well volunteers will be able to perform in this scenario and if they are able to prune up to the standards of a certified arborist. Additionally, this research seeks to find the best way to train volunteers to accomplish the goal of structurally pruning small trees. Using a series of three assessments: (i) a written exam, (ii) a pruning prescription assessment, and (iii) a pruning cut test.

CHAPTER 2
METHODS

Study location

I conducted the research at three cities in Massachusetts, USA: Greenfield, Northampton, and Springfield (Figure 1). Figure 1 also indicates the specific location in each city where I conducted the research. In each city, the trees I used for the research were growing in “tree belts” between the street and sidewalk. Greenfield is in USDA Hardiness Zone 5b; Northampton and Springfield are in USDA Hardiness Zone 6a. I selected the cities because each had an active tree committee whose members were interested in (i) participating in the research and (ii) raising awareness of both trees in the community and the committee itself.

In each city, I selected streets based on (i) relatively low vehicular traffic and street noise and (ii) the availability of enough individuals of the same approximate age, size, and species to accommodate the number of volunteers expected to participate in the study in the city (morphological data for individual trees can be found in Table 1).

Curriculum Development

Between January and May 2018, I developed a curriculum to train volunteer participants in proper pruning technique. I developed the curriculum based on standard industry texts (Gilman, 2012; Anonymous, 2017; Lilly et al., 2019) and consultation with arboriculture instructors at (i) five vocational high schools in Massachusetts and (ii) the University of Massachusetts – Amherst (UMass). In face-to-face or phone interviews, I asked each instructor (eight in total) two broad questions: “What are the most important aspects of pruning instruction to focus on?” and “What are the most effective pedagogical techniques to train students how to prune?”

Appendix A includes the curriculum, which consisted of the following sections: tree physiology, tree structure, pruning tools, safety, and cutting technique. In the section on tree physiology, I focused on relevant aspects of anatomy (branch protection zone, cambium, xylem, phloem) and morphology (bark, branch bark ridge, branch collar), as well as primary and secondary growth. I also presented information on how trees respond to pruning in terms of post-pruning growth and the process of compartmentalization of decay in trees (CODIT).

In the tree structure section, I focused on introducing volunteers to the concept of tree structure, the components of good structure, and growth patterns that indicate poor structure in trees. I trained volunteers to identify (i) codominance, (ii) scaffold branches, (iii) weak and strong branch unions, (iv) included bark, (v) crossing branches, and (vi) the lowest permanent branch. Additionally, I trained volunteers on where they might see patterns of poor tree structure and why they pose increased risk associated with amenity trees.

Regarding safety and pruning tools, I explained the hazards of working in a residential setting and how to (i) establish a safe working area; (ii) use personal protective equipment (PPE); and (iii) safely use hand pruners, loppers, hand saws, and pole pruners.

Finally, I instructed volunteers on making pruning cuts. I explained how to properly make removal and reduction cuts, and how to remove branches too heavy to hold with one hand by precutting it away from the branch collar. In addition to teaching volunteers good pruning techniques, I trained them to avoid several harmful pruning tactics (topping, tipping, flush cutting, bark stripping, and leaving a stub) and explained why they are harmful to a tree.

Volunteer Recruitment and Training:

In the summer of 2019, I contacted local tree wardens, tree commissions, and volunteer organizations to inquire about their willingness to participate in the research study. I also posted flyers on the UMass campus and in local towns and cities announcing an opportunity to learn how to prune trees by participating in the study.

In January 2019, I conducted the volunteer training in Northampton, Mass.; In November 2020, I conducted the volunteer training in Greenfield, Mass.; in February 2021, I conducted the volunteer training in Springfield, Mass. In each city, volunteers completed two forms and a survey. The first form was the Consent Form for Participation in a Research Study. The second form was a liability waiver provided by whatever city the training was being held in. If a minor was interested in participating in the study, an accompanying adult filled out a parental consent form.

On arrival, volunteers completed a survey to screen them for experience in any aspect of horticulture or arboriculture (responses can be found in Table 2). On the survey, volunteers self-assessed their experience working with trees and other plants. They also indicated where they learned about the study, if they had participated in citizen forestry before, and if they had professional experience working with trees. Dates and times for each training session and assessment can be found in Table 3.

I conducted two types of training in Northampton and Springfield. I assigned volunteers to one of two training groups prior to their arrival at the study location. One group received indoor training that was based on a classroom setting and consisted of a PowerPoint assisted lecture, and a brief question and answer session before proceeding to the assessment portion of the workshop. The outdoor training group received training on a separate day but covered the same topics by using trees at the study site as examples instead of a PowerPoint, the outdoor training session then had a period of hands-on guided practice pruning small street trees. In Greenfield, I was not able to offer indoor training because of the COVID-19 pandemic; I assigned all volunteers to receive outdoor training.

In Northampton, I held the indoor training session on 12/7/19 in a classroom at Smith College (Table 3). I presented a two-hour PowerPoint lecture that included a ten-minute break after one hour, and fifteen minutes for questions at the end. I incorporated volunteers' questions from the first training session into the remaining training sessions to ensure that I covered the same topics for all sessions. Next, volunteers completed a written, 15-question multiple-choice exam, with a time limit of 30 minutes. After the exam, volunteers took a 45-minute break for lunch. Following lunch, volunteers, arborists assisting with the study, and I reconvened for the pruning prescription and pruning cut assessments.

I held the outdoor training session in Northampton on the next day, 12/8/19 (Table 3). The training used living trees in the urban landscape as examples instead of PowerPoint slides, I instructed volunteers on the subjects in the curriculum for 45 minutes. I then gave volunteers pruning tools and PPE, then assigned them trees to prune with certified arborists guiding them through the process of pruning a small tree for structure and site compatibility, they did this for 90 minutes. After the training, I gave participants 10 minutes to ask any questions about the topics covered and then administered the written exam for which participants were given 30 minutes to finish. Once they turned in their written exam, participants took a 45-minute lunch break.

In Springfield, the indoor session was converted into online training sessions over Zoom because of the COVID-19 pandemic. Online sessions for the indoor type were held the night before the pruning prescription and pruning cut assessments on 2/20/21 (Table 3). The next morning, participants arrived at the study location and proceeded to perform the pruning prescription assessment and pruning cut assessment in the same way as in Northampton.

The Springfield outdoor session ran similarly to the outdoor session in Northampton. On the morning of 2/20/21, I instructed participants on the subjects in the curriculum using trees in the landscape as examples for 45 minutes. I then broke participants into smaller types where they worked with certified arborists to prune small trees around the study location for 90 minutes. After the training, I gave participants 10 minutes to ask any questions they might have had about the topics covered and then administered the 30-minute written exam and dismissed participants for a 45-minute lunch once they turned their exam in.

In Greenfield I only held an outdoor training session on 11/28/20. It followed the same structure of the Northampton outdoor session where I trained participants on the curriculum for 45 minutes, and then supervised them in hands-on tree pruning practice for 90 minutes.

Volunteer Assessment:

I evaluated volunteers' pruning ability in the following three ways: (i) assessing their ability to prescribe pruning actions, (ii) assessing their ability to make pruning cuts, and (iii) assessing their retention of training material.

To evaluate volunteers' understanding of their training, I administered a written exam that consisted of 15 multiple choice questions. I did not allow volunteers to ask questions about the content of the exam but did help clarify wording. Volunteers took the exam immediately following their training session. I graded the written exam as the percent of correct answers on a scale of 0% - 100%. For example, if a volunteer answered 13 of 15 questions correctly, their grade was 87%. The written exam also included an image on which volunteers attempted to label the branch collar and branch bark ridge, and to draw a line indicating a proper pruning cut. On the first version of the exam, the image was on the back page of the test and many participants did not notice it and failed to complete it. On the second printing of the exam, the image appeared in black and white which resulted in participants asking many clarifying questions, so I did not include this section of the written exam in my analyses.

The pruning prescription focused on volunteers' ability to identify and remedy structural issues. To do this, I issued volunteers fluorescent flagging tape, assigned them to a specific tree, and asked them to develop a pruning prescription for the tree. Volunteers developed prescriptions based on two stated pruning objectives given a pruning cycle of 3-5 years: (i) create good structure and (ii) make the tree compatible with its site. Volunteers either marked with a pencil or tied flagging around branches they would prune to remedy structural issues they identified on the tree, but they did not make any pruning cuts.

After volunteers completed their pruning prescriptions, a certified arborist reviewed their prescriptions. The arborist reviewed the pruning prescription with the participant and asked them what their goal was for each pruning action. If the arborist felt that making a cut where the participant indicated would not remedy the structural issue or create another issue, then the arborist recorded a disagreement with the participant on their prescription. The arborist also recorded a disagreement if the participant failed to address a structural issue. After discussing his review of their performance, the arborist assigned two grades to the prescription attempt. The first grade was based on the proportion of total prescribed pruning actions that the certified arborist disagreed with. Disagreements included both pruning actions that the certified arborist deemed incorrect and pruning actions the certified arborist recommended but the volunteer did not recommend. For example, if a volunteer prescribed 10 pruning actions and the certified arborist thought that 2 were incorrect and that the volunteer failed to take 1 pruning action, the total number of disagreements would be 3 and the proportion of disagreement would be 30%. The volunteer's pruning prescription score was equal to one minus the proportion of disagreements—70% based on the preceding example. The second grade was based on whether the pruning prescription, overall, was acceptable in the certified arborist's opinion. The certified arborist assigned a grade of 0 for not acceptable and 1 for acceptable.

To assess volunteers' ability to make pruning cuts I asked them to make a single reduction cut and a single removal cut using hand pruners. I graded volunteers' cuts as 0 for not acceptable and 1 for acceptable based on three criteria: (i) whether they damaged the branch collar, (ii) whether they damaged the branch-bark ridge, (iii) whether they left a stub. I also graded the three individual criteria as 0 (not acceptable) or 1 (acceptable).

I enlisted four certified arborists from each community to write pruning prescriptions for each tree. The arborists reported the number of pruning cuts they would make, described the structural issues they identified, and explained how they would remediate each issue. The purpose of this participation was to act as a control on the certified arborist who assessed participants' pruning prescriptions. If the arborist that graded volunteers had disagreed with an excessively large amount of the actions taken by volunteers, I would be able to compare the structural issues identified by the other arborists and compare that to the responses from volunteers.

Data Analysis:

My primary interest was to determine whether the type of training participants received (indoor and outdoor) influenced their ability to prune. I created statistical models to investigate the performance of participants who received each type of training with respect to the following eight response variables: (i) written exam score, (ii) pruning prescription score, (iii) acceptable pruning prescription, (iv) acceptable reduction cut removal cut, (v) acceptable removal cut, whether the (vi) branch bark ridge and (vii) branch collar were intact after making pruning cuts, and (viii) not leaving a stub when making the reduction and removal cuts. I also investigated whether the following covariates influenced the response variables in my statistical models: study location, tree species, tree height (cm), diameter at breast height (cm), number of branches, prescription trial, and self-rated previous experience with plants.

To determine whether I could combine data from three locations, I ran a correlation analysis in R using the 'corrplot' package (Wei and Simko 2017) that included a variance inflation factor (VIF) for each pair of variables. Response variables that were highly correlated ($VIF \geq 0.5$) (Craney and Surles 2002) with the study locations were analyzed separately. Pruning prescription score was the only response variable that I analyzed by location. Because participants in Greenfield only received outdoor training, I did not analyze pruning prescription scores of volunteers in Greenfield. I analyzed the remaining response variables (written exam score, acceptable reduction cut, acceptable removal cut, branch bark ridge and branch collar intact after making cuts, not leaving a stub) with the combined data from all three study locations.

I used beta regression to analyze the written exam and pruning prescription scores because it is well suited to analyzing data that is a proportion bounded between 0 and 1 and would allow results to be interpreted as an odds ratio (Cribari-Neto and Ferrari 2004). For both proportional response variables, I created a series of models based on all possible interactions of predictors that applied to each response variable. Then I selected the best model: the one with the lowest AIC_C value. I compiled a list of different beta regression models in R using the "*betareg*" function from the "betareg" package (Cribari-Neto and Zeileis 2010) and compared their AIC_C values using the "MuMIn" (Barton 2020) and "AIC_Cmodavg" (Mazerolle 2020) packages. To analyze written exam score, I considered the following predictors: training type, self-rated previous experience with plants, and study location. To analyze pruning prescription score, I considered the following predictors: training type, study location, self-rated experience working with plants, tree species, tree height, tree dbh, number of branches per tree, and, in Springfield, trial number.

I used Fisher's exact test to compare the number of acceptable and unacceptable reduction cuts, removal cuts, and pruning prescriptions made by each training type. I also used Fisher's exact test to investigate whether the number of participants in each training type who did and did not damage the branch bark ridge or the branch collar and who did and did not leave a stub when making their reduction and removal cuts differed. If Fisher's exact test showed a significant difference between the performance of participants who received indoor or outdoor training, I used logistic regression to model the data. For model selection, I used the "*glm"* function in R to create a list of models for the acceptable removal cut, acceptable reduction cut, branch collar intact, branch-bark ridge intact, and not leaving a stub, and included the following predictors: training type, self-rated experience working with plants, and study location. I compared these models using the 'AIC_{C}modacg' (Mazerolle 2020) package.

CHAPTER 3

RESULTS

Written Exam

The best model to predict written exam score was a univariate model including the predictor variable training type (model selection in Table 4 and model parameters in Table 5). Neither study location nor participants' self-rated experience with plants influenced the written exam score. The mean score (85%) of participants who received outdoor training (n = 26) was significantly ($p < 0.001$) lower than the mean score (93%) of participants who received indoor training (n = 20) (Figure 2). For both training types, written exam scores ranged from 53% to 100%.

Pruning Prescription Assessment

In Northampton, 28 volunteers (split evenly between indoor and outdoor training) prescribed pruning actions for 7 trees. Each volunteer worked on a single tree, which produced 4 different prescriptions for each tree. In Greenfield, 5 volunteers prescribed pruning actions for 3 trees; each volunteer had one trial on each tree, which produced 5 different prescriptions for each tree. In Springfield, 13 volunteers (split between 7 indoor participants and 6 outdoor participants) prescribed pruning actions for 7 trees; each volunteer had two trials, resulting in 5 trees receiving 4 pruning prescriptions each, and two trees (trees 6 and 7) receiving 3 pruning prescriptions each.

Nearly all participants in the Northampton and Springfield study locations (96%) provided acceptable pruning prescriptions, and the proportion of unacceptable pruning prescriptions was not significantly different ($p = 0.957$) between participants who received indoor or outdoor training. However, the type of training did influence the pruning prescription score.

In Northampton, pruning prescription scores ranged from 37% to 100%. The best beta regression model to predict pruning prescription score was the univariate model that included only training type (Table 7). The mean score (82%) of volunteers who received outdoor training (n = 14) was significantly (p = 0.005) greater than the mean score (66%) of volunteers who received indoor training (n = 14) (Figure 3). The addition of continuous (number of branches, tree height) or random (tree) predictor variables did not improve the model to predict pruning prescription score (Table 7).

In Springfield, the pruning prescription scores ranged from 75% to 100%. The best beta regression model was the univariate model that included only training type (Table 7). The mean score (92%) of participants who received outdoor training (n = 7) was significantly higher (p = 0.021) than the mean score (85%) of participants who were part of the indoor training type (n = 6) (Figure 4, Table 8). The addition of fixed (trial, number of branches, tree height, dbh) or random (tree) predictor variables did not improve the model to predict pruning prescription score (Table 7).

In Greenfield, all participants received outdoor training (n = 6), and their pruning prescription scores ranged from 29% to 100%. The average pruning prescription score was 61% with a standard deviation of 16%. Two participants in each trial (four participants in total) did not develop acceptable pruning prescriptions, all the unacceptable pruning prescriptions were for tree 2, which had the most branches (30) of the three trees measured in Greenfield.

The pruning prescription data collected from certified arborists in Northampton and Springfield was not analyzed. In Northampton, the lowest number of pruning actions prescribed for a tree by arborists was 4 and the highest was 14. The grading arborist's prescription for each tree was like the average number of pruning actions taken by the arborist group for each tree (Table 9). In Springfield, the lowest number of pruning actions prescribed was 6 and the highest was 16.

Pruning Cut Assessment

With one exception (see below), the type of training participants received did not affect their ability to make good pruning cuts (Table 10). When making removal cuts, most participants did an acceptable job of not damaging the branch bark ridge (91%) or branch collar (85%) and not leaving a stub (91%); and most did an acceptable job overall (85%). When making reduction cuts, most participants also did an acceptable job of not damaging the branch bark ridge (91%) or branch collar (87%) and not leaving a stub (87%); and most did an acceptable job overall (83%). But when making reduction cuts, none of the participants who received outdoor training left a stub, but 30% of participants who received indoor training did leave a stub—a significant difference ($p = 0.003$). Self-rated experience with plants did not influence the difference between training types (Table 11).

CHAPTER 4
DISCUSSION

This is the first study to investigate the effectiveness of different methods to train novice volunteers how to structurally prune recently transplanted small street trees. This study is important because using volunteers to structurally prune small street trees reduces current (and very likely future) maintenance costs. My results suggest that while the type of training did influence some pruning skills, nearly all trained participants made acceptable pruning prescriptions and pruning cuts. This result provides some confidence that training volunteers to prune small street trees may be a cost-effective way to maximize the benefits they provide. But several limitations are important to consider because pruning trees is a complicated process. There were study limitations including sample size, phenology, tree species, impact of COVID-19, logistical issues, and pedagogical methods all had an impact on this study, which are all important to consider when discussing the findings in this study.

Limitations

Study limitations included a small sample size, which limited the analyses I was able to conduct and the inferences I was able to make from the results. With a small sample size, individual data points have more weight, which means a single data point has a larger impact on hypothesis tests than in data sets with large sample sizes. There was a large range in pruning prescription scores from each location, and one high or low score could change a group's mean and produce a significant difference in group comparisons. A larger data set could better reflect the population mean for each training group, reducing variability, and allow removal of outliers from the dataset when conducting analyses. Small sample sizes also impact the depth of each analysis. Fewer observations result in fewer degrees of freedom, which restricts the number of parameters that can be included in a model. I was unable to include the parameter of location as a random effect due to insufficient degrees of freedom which limited my analysis. To solve this, I analyzed the data for pruning prescription separately for each location separately. This method of data analysis still allows conclusions to be drawn. However, including the effect of location would have allowed data from the pruning prescription assessment to be pooled across the three study locations, giving me a larger sample size, a more robust model, and the ability to investigate whether the random effect of location was a significant predictor of pruning assessment score.

Another study limitation included working with large groups of people. Throughout the pruning prescription test, many volunteers were left with nothing to do while they waited for the arborist to grade their prescription, which took several hours, and was the longest part of the training. A workshop with more than 14 volunteers could have been more time consuming, and perhaps lead to bored or frustrated volunteers. Some participants were frustrated due to the wait time necessary for the certified arborist to assess their pruning prescription, and some left before their pruning assessment. The additional delays, which would likely occur with a greater number of participants, would increase frustration and some participants may not stay for the duration of a pruning workshop. Future studies with larger sample sizes could aim to host more workshops with fewer people, minimizing downtime for volunteers and an overall more positive and effective training experience.

Another limitation were the incongruencies between indoor training sessions. Due to the COVID-19 pandemic, I was not able to hold an indoor workshop for the Greenfield, MA study location. I was also unable to hold a ‘classroom’ indoor session for Springfield, MA, and instead hosted a Zoom session the night before the assessments and made the session available for streaming on YouTube. For Springfield participants, this resulted in a longer time between receiving the training and the assessments when compared to participants in Northampton and Greenfield.

Finding ways to host pruning workshops amidst a global pandemic was a challenge. Some professional educators felt that remote learning may have negatively impacted student's ability to learn (Hobbs and Hawkins 2020). Teachers felt that remote classes made learning more difficult because students were not in their typical learning environments, lacked peer-to-peer collaboration, and teachers had difficulty accessing teacher materials (Russo et al. 2021). According to Russo (et al. 2021), educators do not prefer remote learning because they cannot enforce attendance and it is difficult to maintain students' attention remotely. In my remote pruning workshops, participants did not seem to have trouble focusing on the presentation, as evidenced by their high written exam scores, likely because the workshop was shorter than a typical secondary school day and participants chose to attend. There is reason to further explore the effect of remote learning on arboriculture-based workshops. Many trade associations award certifications to candidates who meet certain criteria and pass exams; for candidates to keep their certifications, associations require credential holders to earn education credits to prove they are up to date on new information. There are many opportunities to earn education credits online and through a better understanding of how candidates retain information learned remotely, trade associations and adult education programs can refine their continuing education programs.

Another limitation in this study was instructor skill. I am not an experienced educator and there may have been inconsistencies between each workshop and how the presentation was delivered. The curriculum (Appendix A) includes primary topics to cover when teaching novices how to prune trees. I vetted the curriculum with experienced arboricultural and horticultural instructors to ensure key topics were covered and delivered in a pedagogically sound way. Though I aimed to provide clear and concise workshops, participants often learn in various ways, which were difficult to account for in each workshop. Instructor efficacy can be improved overtime, which may result in higher performing participants. This could explain the participants from the Springfield location scoring higher on their pruning prescription scores. Since the

Springfield training sessions occurred last in the study, I may have become a better instructor after administering two previous training sessions and participating in other volunteer education programs. Between the Greenfield and Springfield training sessions I had the opportunity to work with volunteers on projects unrelated to tree pruning. I was able to practice interacting with volunteers and increase my confidence and skill as a teacher, which may have contributed to the higher scores of Springfield participants.

Only three species of trees were used in this study, and all were broadleaf decurrent deciduous shade trees native to North America. A volunteer assessing an excurrent growth habit may visualize the tree structure more effectively due to the simple growth habit of excurrent trees with a single straight trunk which is usually perpendicular to the ground with whorls of lateral branches along the trunk. Comparatively, decurrent trees can have several leading stems, several scaffold branches, and branches attached at different of angles. These characteristics of decurrent trees can result in more complicated crown structure when compared to excurrent trees. Volunteers may be more familiar with specific growth patterns based on their region's common species. A volunteer who has never seen an excurrent tree may think it has been heavily pruned due to the innate shape of the tree. Most trees used in the pruning prescription assessment had codominant stems, dead branches, and branches which blocked sidewalks. Volunteers identified each issue and could likely identify these same structural problems with excurrent street trees. However, the practice of developing scaffold branches was also taught to volunteers. Excurrent trees often do not need pruning to develop scaffold branches (Lily et al. 2019), and a volunteer may make unnecessary or harmful removal cuts to develop scaffold branches. To investigate whether volunteers could identify the structural needs of different growth patterns, a future study could train volunteers and have the volunteers create prescriptions for decurrent trees first, and then excurrent trees second. Afterwards, the study could assess pruning prescription score between growth habits. This study could establish whether the same training could be applied to both decurrent and excurrent trees. Volunteer pruning programs in areas where excurrent trees are used as street trees should include training on pruning excurrent trees so volunteers have the proper knowledge to prune them.

Pruning and phenology are intertwined and there are benefits and detriments to pruning at various times of year (Lilly et al. 2019). I held all the workshops in winter when trees were leafless. Though there is no evidence to suggest that pruning for structure is easier when a tree is leafless, it is possible that leaves could obscure the structure of the tree, making it more difficult to prune effectively. Researchers interested in tree structure and geometric features needed to collect imagery when trees are leafless or just flowering to accurately assess the structure of a tree (Torres-Sanchez 2018). Examining crown structure in a leaf-out tree may result in an inaccurate assessment of structure and could result in a worse assessment than when the tree is leafless. To help determine if identifying structural issues on leafless trees is easier, participants could create pruning prescriptions for trees when they are in-leaf, and then participants should create prescriptions for leafless trees of the same species. Participants' pruning prescription scores could then be compared between leafless and in-leaf trials.

Finally, participants were tested almost immediately following their training sessions, except for the participants in Springfield's indoor group, who watched their training online the day before their assessments. I did not test training retention amongst participants. It is possible that the curriculum was stored in participants' short-term memory, and exam and pruning scores would have decreased in the following months after the training was conducted. In the medical field, researchers found that after three months, nurses in training retained 98% of their equipment usage skills, and that there was no significant difference in skill retention between shorter and longer training courses (Bomholt et al. 2019). Another study, which measured the retention of CPR effectiveness in high school students, found a consistent decline in skill over 52 weeks (Chamdawala 2021). Skill decay when the skill is not practiced is a well-documented phenomenon (Arthur et al. 1998). Some volunteers could go months or weeks between their group pruning outings, and without a refresher course or time to practice, their skills could diminish. With diminished skills volunteers could damage a tree or hurt themselves through poor pruning practices. Future research could find the effect of skill decay on pruning by evaluating how long volunteers retain their training, and how many hours of training volunteers need before the information is stored in their long-term memory. This study could be conducted by testing participants using the same assessments once a week for up to two months after a pruning workshop to determine degradation in performance. In practice, volunteers in the field who are pruning trees months after their training courses, will likely be supervised by an arborist or another more experienced volunteer who can provide them a short refresher course. These refresher courses could help remind volunteers of forgotten pruning knowledge, allow volunteers to ask additional questions, and cover any potential knowledge gaps developed over time.

Volunteers

Volunteer recruitment for research participation can be a difficult task. Since participation in the workshops required several hours of dedication on a weekend, many potential participants were reluctant to attend. Each workshop had at least 5 individuals sign up who did not attend, and in Springfield 10 people failed to attend the workshop. These workshops were also held outside in the coldest months of the year, which likely deterred potential volunteers. Researchers planning to study volunteer tree pruning in warmer months to avoid this deterrent need to be aware that this study does not address pruning trees when they have leaves, flowers, fruit, or other phenological differences.

Volunteer retention is also difficult and future long term volunteer pruning studies may face challenges with volunteer retention. Other citizen forestry studies provided their participants with compensation and had high retention over a longer period (Bloniarz and Ryan 1993, Bancks et al. 2018). Providing volunteers with motivation to participate in these studies is important.

Other citizen-science based research has found that with each successive week of volunteer participation, the odds that they return the following week decrease by 4% (Jennings et al. 2020). I offered volunteers safety equipment and hand pruners to keep as compensation or their participation. If I were to conduct a similar study investigating volunteer participation and retention, I would attempt to secure support from a municipality to make participants local tree stewards or offer monetary compensation.

Volunteers had a wide range of responses when asked what their previous experience was working with plants and trees. Most commonly, volunteers only had experience working with trees and plants in their own garden or yard, either when they were children or as homeowners. The most experienced participant in the Northampton workshop indicated in the survey that they were a “master gardener” looking to expand their knowledge on trees, since they mainly work with shrubs and herbaceous plants. This participant was the only member of their training type to have zero disagreements on their pruning prescription. Most volunteers assessed themselves as having experience working with trees or other woody plants but only two had professional experience working with trees, both of whom had been landscapers.

Based on model comparison, experience working with plants and previous participation in community forestry activities did not have a significant impact on any assessment response (written exam score, pruning prescription score, pruning cut success). Volunteers are not often motivated to participate in an activity by their previous experience or expertise in a field (Ryan et al. 2001). Someone who is a board-certified master arborist may not be inclined to participate in community forestry activities simply because they are skilled in the field. It is expected that volunteers who ranked themselves as “experienced” would perform better than other volunteers who ranked themselves as “unskilled”. However, because volunteers were ranking themselves based on experience working with herbaceous plants, and not with trees, their responses may not have been accurate. Additionally, volunteers who self-report their experience might not provide accurate measures of their experience working with trees. Participants who ranked themselves as "very experienced" did so because of their involvement in master gardener programs or on landscaping crews. These types of experiences might not directly translate to experience with pruning trees specifically for structure. These results suggest that even if a participant in community forestry has an extensive background working with plants, there is no guarantee they can successfully prune trees without training and should not be exempt from a local certification or training process.

Written Exam

Both the indoor and outdoor training types in each study location performed well on the written exam. This written exam was administered directly following the training sessions, except for the participants from the indoor training in Springfield who watched their training session online the day before and shows that the training volunteers received is enough for them to answer questions about the structural pruning of trees. This is consistent with other findings, that volunteers can accurately understand foundational arboricultural topics and skills like measuring height, DBH, species identification, and condition assessment after they receive training (Bloniarz and Ryan 1993, Roman et al. 2016).

Participants from the indoor training type were more likely to perform better on the exam than the outdoor training type and had a significantly higher mean score compared to the outdoor training type. Since the written exam was designed to test comprehension of what was taught in both types of training, a classroom experience could be more conducive to learning the curriculum. In contrast, the outdoor training appeared to be better for learning the context of pruning trees, since participants who received outdoor training performed better on the pruning prescription assessment. However, studies that compare the effects of classroom learning versus case-based learning on how well nursing students could learn medical skills found that the case-based training group (analogous to the outdoor training type in my study) had better problem solving and critical thinking skills compared to the traditional classroom training group (Yoo and Park 2015, Liang 2020). It could be expected that the outdoor training group would perform better on all the assessments because of their exposure to hands-on training. Conversely, some educators and researchers also see classroom and text-based learning as a strong method to teach students information in a non-contextualized setting, for example, how students would see questions written on an exam (Allchin 2013). The slides I used in the presentation used similar wording to the questions in the written exam, and many questions on the exam were based on slides I presented, which gave the indoor training group additional context for questions presented on the exam. I covered the same topics in my oral presentation to the outdoor training group, however, the added visual aid of the slides for the indoor training may have conveyed the curriculum more effectively, giving the indoor group an advantage on the written test.

The indoor training group's average score was 8% higher than the outdoor group. Because the exam contained 15 questions, each question was worth 7% of the grade, so participants who received indoor training effectively answered one more question correctly on average than participants who received outdoor training. In practice, a volunteer who answers one additional question correctly does not necessarily make them a more knowledgeable volunteer. A future study could draft a written exam with more questions and different styles of questions other than multiple-choice, which would allow a more in-depth analysis of written exam performance. There are other common exam question types aside from multiple-choice, which require more critical thinking. These questions could skew in favor of the outdoor training group. For example, an open-ended question could allow a participant from the outdoor group to explain, in detail, the pruning process from a first-person perspective allowing them to give context in their answer.

I examined individual questions to see if patterns emerged in which questions were answered incorrectly by each group. Overall, I found mostly a random distribution of questions that were answered incorrectly, except for one question. In Springfield, six participants from the outdoor group incorrectly answered the first question while only 1 from the indoor group answered it incorrectly. However, I noted a volunteer complained that wearing a mask muffled my speech and that passing trucks occasionally made it more difficult for participants to hear the lesson. When I was teaching the answer to this question, a truck may have passed by, drowning out my voice to everyone but the closest participants. Anecdotally, social distancing, masks, and noise pollution made it difficult for several participants to hear me speaking throughout the workshop, and I had to repeat myself on several occasions.

Pruning Prescription Test

Participants were able to perform pruning prescriptions well: pooling data from all locations, only 6 of 69 pruning prescriptions were not acceptable, and the number of acceptable pruning prescriptions did not differ significantly between either training group. These results demonstrate that if volunteers from a range of backgrounds are provided with proper training, they can likely learn to identify and remedy the structural issues in a small tree's crown well enough to satisfy an arborist. Previous studies that compared arborists to volunteers found that although arborists were slightly more consistent in their performance when inventorying trees, identifying tree species, and assessing the condition of trees, volunteers were able to perform these tasks well (Bloniarz and Ryan 1993, Bancks 2018). When a volunteer measures or identifies a tree for an inventory, there is one correct answer. A volunteer who assesses the condition of a tree for an inventory should apply arboricultural knowledge and think critically to determine the condition of a tree. Compared to tree identification and measurement, tree condition assessment is more subjective. When assessing the condition of a tree, a volunteer needs to consider factors such as species, location, crown vitality, and investigate for signs of pest and disease. A volunteer who assesses the condition of a tree needs to synthesize their observations and then assign a categorical heath rating to the tree. Volunteers who perform tree risk assessment to the satisfaction of researchers and arborists demonstrates that volunteers can learn subjective arboricultural concepts (Bloniarz and Ryan 1993, Bancks 2018).

In Northampton and Springfield, the outdoor training groups had a higher average pruning prescription score by a significant margin. This finding contrasts with the results of the written exam which found the indoor groups performed better. It does, however, agree with predictions made by teachers and professors who were interviewed for the curriculum. Several of the teachers and professors thought that the outdoor group would likely perform better than the indoor group. They often see students develop confidence in their abilities with more practice, so participants who had time to work on a tree and see structural issues in person would perform better than those who had only seen examples on a screen. This aligns with findings from the medical field where the effects of traditional classroom learning versus hands-on and case-based learning is documented. Hands-on and case-based learning resulted in students who were better at problem solving and critically thinking than students who engage in only lecture-based learning (Yoo 2014, Gholami 2021). The outdoor group had more opportunities to practice their critical thinking skills through hands-on training before their final assessment.

Hands-on learning is likely an important part of skill development for pruning and other technical skills. Learning by doing is well documented in the medical field. It is a common practice to teach aspiring surgeons how to perform surgery through hands-on experience (Stith 2017). Further research in the medical field demonstrates that the best predictor of a good surgeon is their hand-eye coordination and other visual-spatial skills (DesCoteaux and Leclere 1995). Since arborists are tree surgeons, there is an overlap of training techniques which are relevant to both arborists and surgeons. Much like human surgeons, the pruning ability of an arborist or volunteer could possibly be predicted by hand-eye coordination and spatial awareness. It is unsurprising that the outdoor group, with their hands-on practice, would perform better on the pruning prescription. Spatial awareness could be important in the creation of a pruning prescription. Visualizing future growth, realizing which direction branches are pointing, and envisioning how a tree will interact with its environment are some examples of how spatial awareness could be important when pruning trees. The practice of hands-on skill of tree pruning potentially gave the outdoor group the advantage over the indoor group to develop pruning prescriptions in the field.

Pruning Cut Assessment

There were no significant differences in the number of acceptable removal pruning cuts between indoor training groups and outdoor training groups. In the removal cut test, 39 out of 46 participants performed acceptable cuts. Volunteers who performed acceptable cuts left the branch-bark ridge and branch collar intact and did not leave too large of a stub. Seven participants failed the assessment by cutting into the branch collar, four volunteers cut into the branch bark ridge in addition, which resulted in a flush cut instead of a proper pruning cut. Seven failures did not provide a large enough sample to determine if there was a specific reason participants failed this assessment. Understanding why volunteers perform improper pruning cuts could be useful for future training courses. It is important to explain to volunteers what unacceptable pruning cuts are. If one mistake is more common than others, instructors could focus on common mistakes in future professional and volunteer training courses.

The reduction cut test yielded similar results as there was no significant differences in the number of acceptable reduction cuts between the indoor and outdoor training groups. In total, 38 out of 46 total participants performed acceptable reduction cuts. The only difference between the two groups in the reduction cut dataset was that more volunteers from the indoor group left large stubs when making their reduction cuts. Upon further investigation of this relationship using logistic regression, I found that an additive model of training group and experience best predicted the data, but neither predictor had a significant relationship to the response.

Both training groups performing well on the pruning cut assessment potentially demonstrates how important experience and building confidence is with subjective tasks. Making a pruning cut has a clear objective and there is a right and wrong way to make a cut (Lilly et al. 2019). Pruning also requires spatial awareness and practiced motor skills. The lack of subjectivity in making a pruning cut may have allowed the indoor group to find success in the pruning cut assessment. In comparison, volunteers practicing and building confidence during the outdoor training might have also led to successful participants.

Conclusion

One implication of this research is when given the appropriate training, volunteers can learn to prune small trees to the approval of an experienced arborist. Three hours of training and hands-on practice may be an adequate amount of training. Additionally, for a volunteer to have a holistic understanding of pruning, including basic tree biology, effective pruning methods, safety, tool use, and structural pruning concepts, volunteers should be trained using both lecture-based and hands-on training.

Citizen Forestry is an important tool for managing the urban forest. Volunteer engagement in urban forestry is a good predictor of tree health (Mincey and Vogt 2014). Volunteer involvement shows that an engaged community who maintain their urban forest with effective planting practices and watering strategies will have a high percentage of healthy street trees. Community forestry initiatives should work to expand their use of volunteers to participate in tasks beyond planting and watering. Properly pruned trees lead to fewer structural issues and healthier trees (Anonymous 2017). When trees are in good condition and have strong structure, it costs less money to maintain them. Structurally pruning trees when they are young results in lower tree care costs for municipalities (Ryder and Moore 2013) and pruning small and newly planted trees is within the capability of trained volunteers.

Arborists and their communities need to justify the management costs of maintaining an urban forest to their state and local governments. Justifications which include the health and socioeconomic benefits that healthy trees provide to their community. It is imperative to keep the cost of planting and maintaining trees low because it can take decades for a tree's benefits to outweigh their costs (McPherson 2007). If tree maintenance costs keep increasing, it may be more difficult for municipalities to justify their forestry program budgets. In the future, municipal arborists will continue to face restrictive budgets, understaffing, new invasive pests, trees suffering from abiotic stressors, and trees with structural issues. To help with these concerns, municipal arborists should seek volunteers to supplement their workforce when pruning small trees to develop strong structure and ensure site compatibility.

Tables and Figures

Table 1. Morphological data for trees used in the pruning prescription assessment. Tree ID number, diameter at breast height (DBH), height, and number of branches for each tree used in the pruning prescription assessment in (a) Northampton (*Carpinus caroliniana*), (b) Springfield (*Nyssa sylvatica*), and (c) Greenfield (*Ulmus americana*).

Location	Tree ID	DBH (cm)	Height (cm)	Number of Branches
(a)	1	3.8	366	22
	2	3.6	305	29
	3	4.6	366	20
	4	3.8	305	19
	5	3.8	427	27
	6	5.1	396	33
	7	2.8	366	21
	Mean	3.9	361	24.4
	Stdev	0.7	45	5.3
(b)	1	5.1	366	32
	2	8.9	396	48
	3	7.2	518	40
	4	5.7	518	50
	5	4.4	244	19
	6	5.1	457	27
	7	4.4	305	24
	Mean	5.8	401	34.3
	Stdev	1.6	105	12.0
(c)	1	8.9	457	22
	2	8.1	427	30
	3	7.4	457	25
	Mean	8.1	447	25.7
	Stdev	0.8	18	4.0

Table 2. Written exam score, self-assessed experience with plants (on a scale of 1 – 5), and previous participation in citizen forestry for each volunteer participant in the pruning study in (a) Northampton (n = 28), (b) Springfield (n = 13), and (c) Greenfield (n = 6).

Location	Training	Volunteer ID	Written Exam Score	Experience (Type, Self-assessment)	Participation
(a)	Indoor	2	100%	Yardwork/Garden, 2	No
	(n = 14)	3	80%	Yardwork, 1	No
		4	100%	Garden, 4	No
		5	100%	Planting, 4	Yes
		6	100%	Fruit Tree/Garden, 3	No
		7	87%	Garden, 3	No
		8	100%	Planting/Yardwork, 3	Yes
		11	100%	Yardwork, 1	No
		12	87%	Garden, 3	No
		13	67%	Garden, 4	No
		14	100%	Garden, 1	No
		15	93%	Pruning/Yardwork, 4	Yes
		16	93%	Fruit Tree, 4	No
		18	60%	Landscaping, 5	No
	Outdoor	24	80%	Yardwork/Planting, 3	Yes
	(n = 14)	23	80%	None, 1	No
		28	93%	Fruit Trees/Planting, 4	Yes
		25	93%	None, 1	No
		27	87%	Yardwork, 3	No
		26	93%	Yardwork, 3	No
		41	100%	Yardwork/Garden, 2	No
		46	100%	Garden, 1	No
		43	80%	Invasive/Trail, 3	Yes
		51	93%	Trail, 3	Yes
		42	87%	Garden, 2	No
		40	67%	Yardwork, 1	No
		44	100%	Garden, 1	No
		45	80%	Fruit Tree/Garden, 2	No
(b)	Indoor	1	67%	Houseplants, 3	No
	(n = 6)	2	100%	Garden, 4	No
		3	93%	Garden, 2	Yes
		4	67%	Lawn, 2	No
		5	100%	Garden, 5	Yes

		6	93%	Garden/Lawn, 3	No
	Outdoor (n = 7)	7	80%	Garden, 3	No
		8	87%	Volunteer, 4	Yes
		9	87%	Fruit Trees, 4	No
		10	53%	Garden, 4	No
		11	87%	House Plants, 3	No
		12	93%	Conservation, 3	No
		13	93%	Garden/Lawn, 3	No
(c)	Outdoor (n = 6)	1	93%	Planting/Yardwork, 4	Yes
		2	93%	Planting, 3	Yes
		3	87%	Lawn/Yardwork, 4	No
		4	100%	Garden, 2	No
		5	80%	Garden, 2	No
		6	100%	Planting, 1	Yes

Table 3. Date and time of each training type and three assessments for volunteers in (a) Northampton, (b) Springfield, and (c) Greenfield.

			Date / Time		
Location	Training Type	Training	Written Exam Time	Pruning Prescription Assessment	Pruning Cut Assessment
(a)	Indoor	12/7/19	12/7/19 12:00	12/7/19 13:00	12/7/19 13:00
	Outdoor	12/8/19	12/7/19 12:00	12/8/19 13:00	12/8/19 13:00
(b)	Indoor	2/20/21	2/21/21 10:00	2/21/21 11:00	2/21/21 11:00
	Outdoor	2/20/21	2/20/21 11:00	2/20/21 12:00	2/20/21 12:00
(c)	Outdoor	11/28/20	11/28/20 13:00	11/28/20 13:45	11/28/20 13:45

Table 4. Beta regression models to predict written exam score from one or more predictors (training group, study location, and previous experience with plants); the models used pooled data from all study locations. Model parameters include the number of predictors (K), Akaike's Information Criterion corrected for small sample sizes (AIC_C), comparison of model AIC_C with AIC_C of the best model (Delta_AIC_C), log likelihood (LL), goodness of fit (ModelLik), and cumulative AIC_C weight (Cum. Wt.).

Model	K	AIC_C	Delta_AIC_C	ModelLik	AIC_C Wt.	LL	Cum. Wt.
Group	3	-121.02	0	1	0.77	63.80	0.77
Null	2	-118.14	2.88	0.24	0.18	61.21	0.95
Study Location	4	-115.15	5.87	0.05	0.04	62.06	0.99
Group+Experience	7	-112.05	8.97	0.01	0.01	64.50	1.00
Experience	6	-108.72	12.30	0.00	0.00	61.44	1.00

Table 5. Parameters of the best beta regression model to predict written exam score using the pooled data from all study locations. A univariate model including the effect of training type produced the best AIC_C value (Table 4). The reference level is for participants who received indoor training.

Coefficient	Log Odds	Odds Ratio	Std. Error	z value	Odds Ratio (% change)	p value
Intercept (Indoor)	2.46	11.69	0.27	9.17		<0.001
Outdoor Training	-0.67	0.51	0.29	-2.28	0.49	<0.001

Table 6. Contingency table of participants' pruning prescriptions (acceptable, unacceptable); data pooled from the Northampton and Springfield study locations; p-value is from Fisher's Exact Test.

Training	Acceptable	Unacceptable	Total
Indoor	25	1	26
Outdoor	27	1	28
Total	52	2	54
		p-value	0.957

Table 7: Beta regression models to predict pruning prescription score from one or more fixed (training group, number of branches, tree height) and random (tree) predictors in (a) Northampton and (b) Springfield; model parameters include the number of predictors (K), Akaike's Information Criterion corrected for small sample sizes (AIC_C), comparison of model AIC_C with AIC_C of the best model (Delta_AIC_C), log likelihood (LL), goodness of fit (ModelLik), and cumulative AIC_C weight (Cum. Wt.).

	Model	K	AIC_C	Delta_AIC_C	ModelLik	AIC_C Wt.	LL	Cum. Wt.
(a)	Group	3	-26.25	0.00	1.00	0.53	16.63	0.53
	Group+Branches	4	-24.20	2.05	0.36	0.19	16.97	0.72
	Group+Tree	4	-24.10	2.15	0.34	0.18	16.92	0.90
	Null	2	-21.53	4.73	0.09	0.05	13.00	0.95
	Tree	3	-19.29	6.97	0.03	0.02	13.14	0.97
	Height	3	-19.26	6.99	0.03	0.02	13.13	0.98
	Branches	3	-19.18	7.08	0.03	0.02	13.09	1.00
(b)	Group	3	-62.38	0.00	1.00	0.26	34.74	0.26
	Group+Trial	4	-62.10	0.29	0.87	0.22	36.00	0.48
	Group+Branches	4	-61.83	0.56	0.76	0.19	35.87	0.67
	Null	2	-60.03	2.35	0.31	0.08	32.28	0.75
	Trial	3	-59.83	2.56	0.28	0.07	33.46	0.83
	Branches	3	-59.82	2.57	0.28	0.07	33.45	0.90
	Group*Trial+Group+Trial	5	-59.23	3.15	0.21	0.05	36.12	0.95
	Height	3	-57.76	4.62	0.10	0.03	32.43	0.98
	Tree*Trial+Tree+Trial	5	-57.71	4.68	0.10	0.02	35.35	1.00
	Tree	8	-47.06	15.33	0.00	0.00	35.76	1.00

Group+Tree	9	-45.83	16.55	0.00	0.00	37.54	1.00
Tree+Group+Trial	10	-42.12	20.26	0.00	0.00	38.39	1.00

Table 8. Parameters of the best beta regression model to predict pruning prescription score in (a) Northampton and (b) Springfield; in both locations, a univariate model including the effect of training type produced the best AIC_C value (see Table 7). The reference level is for volunteers who received indoor training.

	Coefficient	Log Odds	Odds Ratio	Std. Error	z value	odds ratio (%change)	p-value
(a)	Intercept (Indoor)	0.70	2.01	0.20	3.44		0.001
	Outdoor Training	0.88	2.41	0.31	2.84	1.41	0.005
(b)	Intercept (Indoor)	1.75	5.77	0.19	9.03		<0.001
	Outdoor Training	0.66	1.93	0.28	2.32	0.93	0.021

Table 9. The average number of pruning actions prescribed by arborists and the number of actions the grading arborist prescribed for each of the seven trees used in Northampton, MA.

Tree	**Average Actions Taken by Arborists**	**Grading Arborist's Actions**
1	8	8
2	10	12
3	5	7
4	6	5
5	6	6
6	10	13
7	8	8

Table 10. Contingency tables for assessments of removal and reduction cuts, including whether volunteers who received indoor or outdoor training (a) did not damage the branch bark ridge or (b) the branch collar, (c) did not leave a stub, and (d) made a satisfactory cut overall; p-values are from Fisher's Exact Test; data are pooled observations from all three study locations. Raw data are in Table 12.

		Removal			**Reduction**		
	Training	Acceptable	Unacceptable	Total	Acceptable	Unacceptable	Total
(a)	Indoor	19	1	20	18	2	20
	Outdoor	23	3	26	24	2	26
	Total	42	4	46	42	4	46
	p-value			0.4353			0.7830
		Acceptable	Unacceptable	Total	Acceptable	Unacceptable	Total
(b)	Indoor	15	5	20	16	4	20
	Outdoor	24	2	26	24	2	26
	Total	39	7	46	40	6	46
	p-value			0.1052			0.2192
		Acceptable	Unacceptable	Total	Acceptable	Unacceptable	Total

		Acceptable	Unacceptable	Total	Acceptable	Unacceptable	Total
(c)	Indoor	17	3	20	14	6	20
	Outdoor	25	1	26	26	0	26
	Total	42	4	46	40	6	46
	p-value			0.1832			0.0027
(d)	Indoor	16	4	20	15	5	20
	Outdoor	23	3	26	23	3	26
	Total	39	7	46	38	8	46
	p-value			0.4283			0.2324

Table 11. Logistic regression models to predict whether participants did not leave a stub when making a reduction pruning cut. No predictors had a significant effect. Model parameters include the number of predictors (K), Akaike's Information Criterion corrected for small sample sizes (AIC_C), comparison of model AIC_C with AIC_C of the best model (Delta_AIC_C), log likelihood (LL), goodness of fit (ModelLik), and cumulative AIC_C weight (Cum. Wt.). The additive model Group+Experience was omitted due to overfitting because of low degrees of freedom returning absolute probabilities.

Model	K	AIC_C	Delta_AIC_C	ModelLik	AIC_CWt	LL	Cum.Wt
Group	2	28.71	0.00	1.00	0.98	-12.22	0.98
Null	1	37.71	9.00	0.01	0.01	-17.81	0.99
Experience	5	37.97	9.25	0.01	0.01	-13.23	1.00

Table 12. For reduction and removal cuts made in (a) Northampton (n = 28), (b) Springfield (n = 13), and (c) Greenfield (n = 6), results ('0' = unacceptable and '1' = acceptable) of whether each volunteer's cuts (i) avoided the branch bark ridge and branch collar, (ii) did not leave a stub, and (iii) was satisfactory overall.

			Removal Cut				**Reduction Cut**			
Location	**Training Group**	**Volunteer ID**	**Branch Bark Ridge Intact**	**Branch Collar Intact**	**No Stub**	**Overall**	**Branch Bark Ridge Intact**	**Branch Collar Intact**	**No Stub**	**Overall**
(a)	Indoor (n = 14)	2	1	1	1	1	1	0	0	0
		3	1	1	1	1	1	1	0	1
		4	1	1	1	1	1	1	1	1
		5	1	0	1	0	1	1	1	1
		6	1	0	1	0	1	0	1	0
		7	1	1	0	1	1	1	1	1
		8	1	1	1	1	1	1	1	1
		11	1	1	0	1	1	1	0	1
		12	1	1	1	1	0	1	1	0
		13	1	1	1	1	1	1	1	1

		14	1	1	1	1	1	0	0	0
		15	1	1	1	1	1	1	0	1
		16	1	0	1	1	1	1	1	1
		18	1	1	1	1	1	1	1	1
	Total Acceptable		14	11	12	12	13	11	9	10
	Outdoor (n = 14)	24	1	1	1	1	1	1	1	1
		23	1	1	1	1	1	1	1	1
		28	1	1	1	1	1	1	1	1
		25	1	1	1	1	1	0	1	0
		27	1	1	1	1	1	1	1	1
		26	1	1	1	1	1	1	1	1
		41	1	1	1	1	1	1	1	1
		46	1	1	1	1	1	1	1	1
		43	1	1	1	1	1	1	1	1
		51	1	1	1	1	1	1	1	1
		42	1	1	1	1	1	1	1	1
		40	1	1	1	1	1	1	1	1
		44	1	1	1	1	1	1	1	1
		45	1	1	1	1	1	1	1	1
	Total Acceptable		14	14	14	14	14	13	14	13
(b)	Indoor (n = 6)	1	1	1	0	1	1	1	1	1
		2	1	1	1	1	1	1	1	1
		3	0	0	1	0	1	1	0	1
		4	1	1	1	1	0	0	1	0
		5	1	1	1	1	1	1	1	1
		6	1	0	1	0	1	1	1	1
	Total Acceptable		5	4	5	4	5	5	5	5
	Outdoor (n = 7)	7	0	1	1	0	0	0	1	0
		8	1	1	1	1	1	1	1	1
		9	1	1	1	1	1	1	1	1
		10	1	1	0	1	1	1	1	1
		11	1	0	1	0	1	1	1	1
		12	1	1	1	1	1	1	1	1
		13	1	1	1	1	1	1	1	1
	Total Acceptable		6	6	6	5	6	6	7	6
(c)	Outdoor (n = 5)	1	1	1	1	1	1	1	1	1

	2	1	1	1	1	1	1	1	1
	3	0	0	1	0	0	1	1	0
	4	1	1	1	1	1	1	1	1
	5	0	1	1	1	1	1	1	1
Total Acceptable		3	4	4	4	4	5	5	4

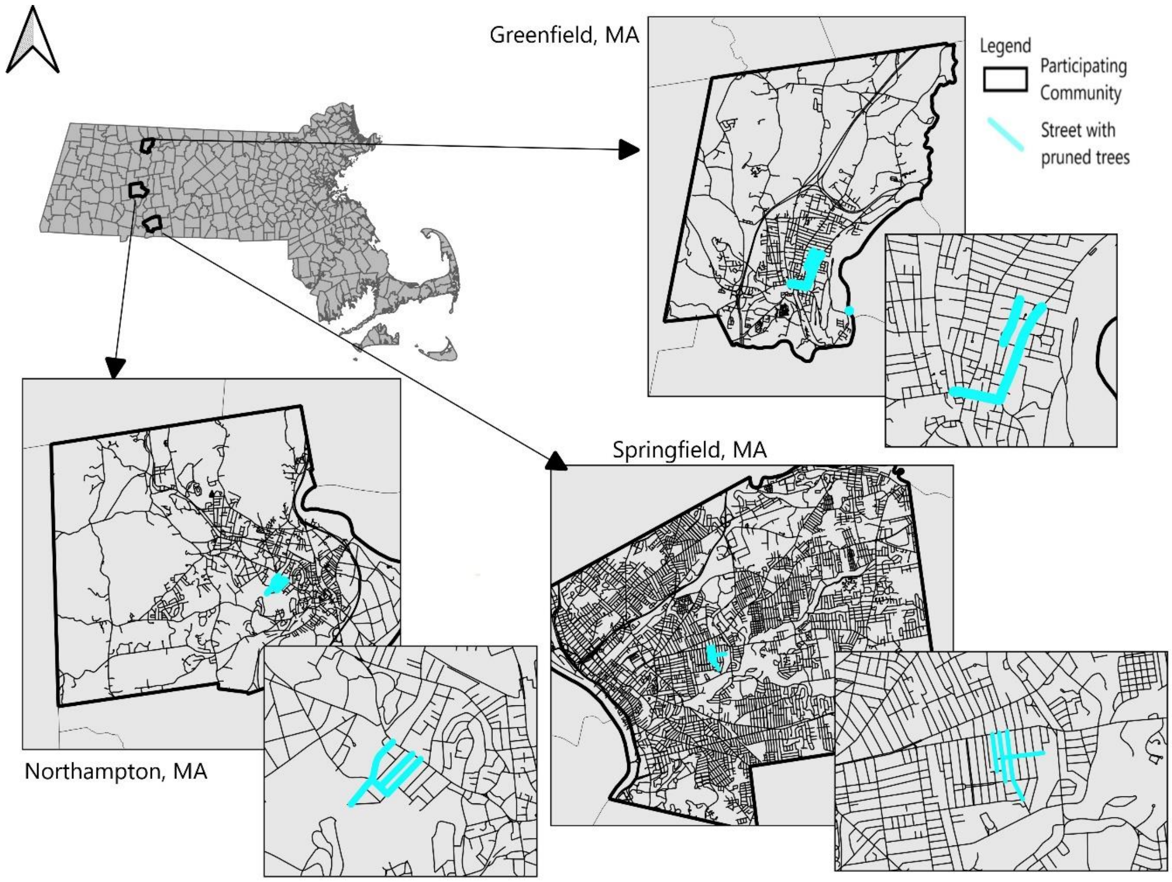


Figure 1: Communities in the state of Massachusetts that participated in the study. Streets that the workshops were held on are highlighted on the insets.

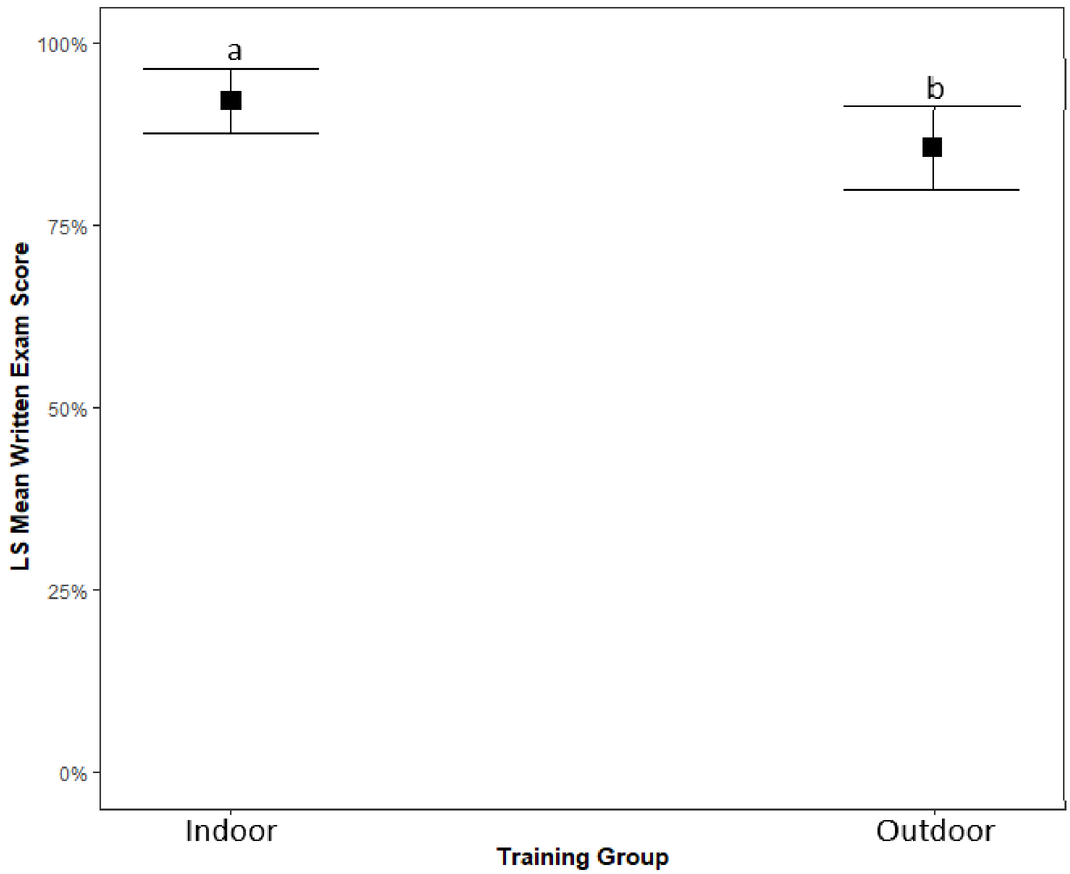


Figure 2. Least squares mean for the written exam scores based on the pooled data from each study location. The filled square indicates the mean score, and the whiskers indicate standard error. When written exam score was estimated using beta regression, "training group" was the best predictor when compared to other predictors based on AIC_C values (see Table 4). The (a) mean score (93%) of participants who received indoor training (n = 20) was significantly ($p < 0.001$) lower than the (b) mean score (85%) of participants who received the outdoor training (n = 26).

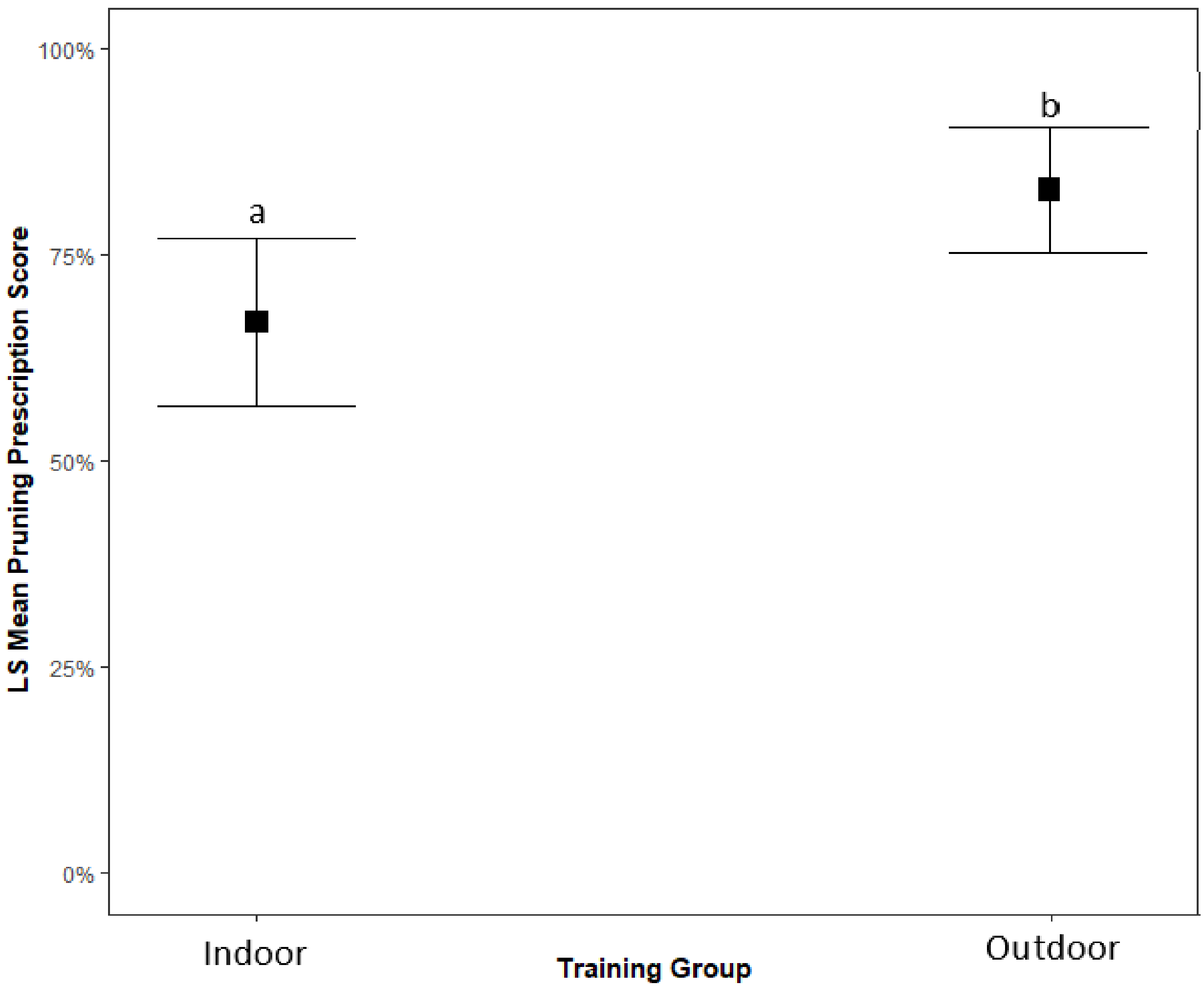


Figure 3. Least squares mean for the pruning prescription scores from Northampton, MA. The filled square indicates the mean score, and the whiskers indicate standard error. When pruning prescription score was predicted using a beta regression, training group was the best predictor when compared to other predictors based on AIC_C values (see Table 7). The (b) mean score (82%) of volunteers who received outdoor training (n = 14) was significantly (p = 0.005) greater than the (a) mean score (66%) of volunteers who received indoor training (n = 14).

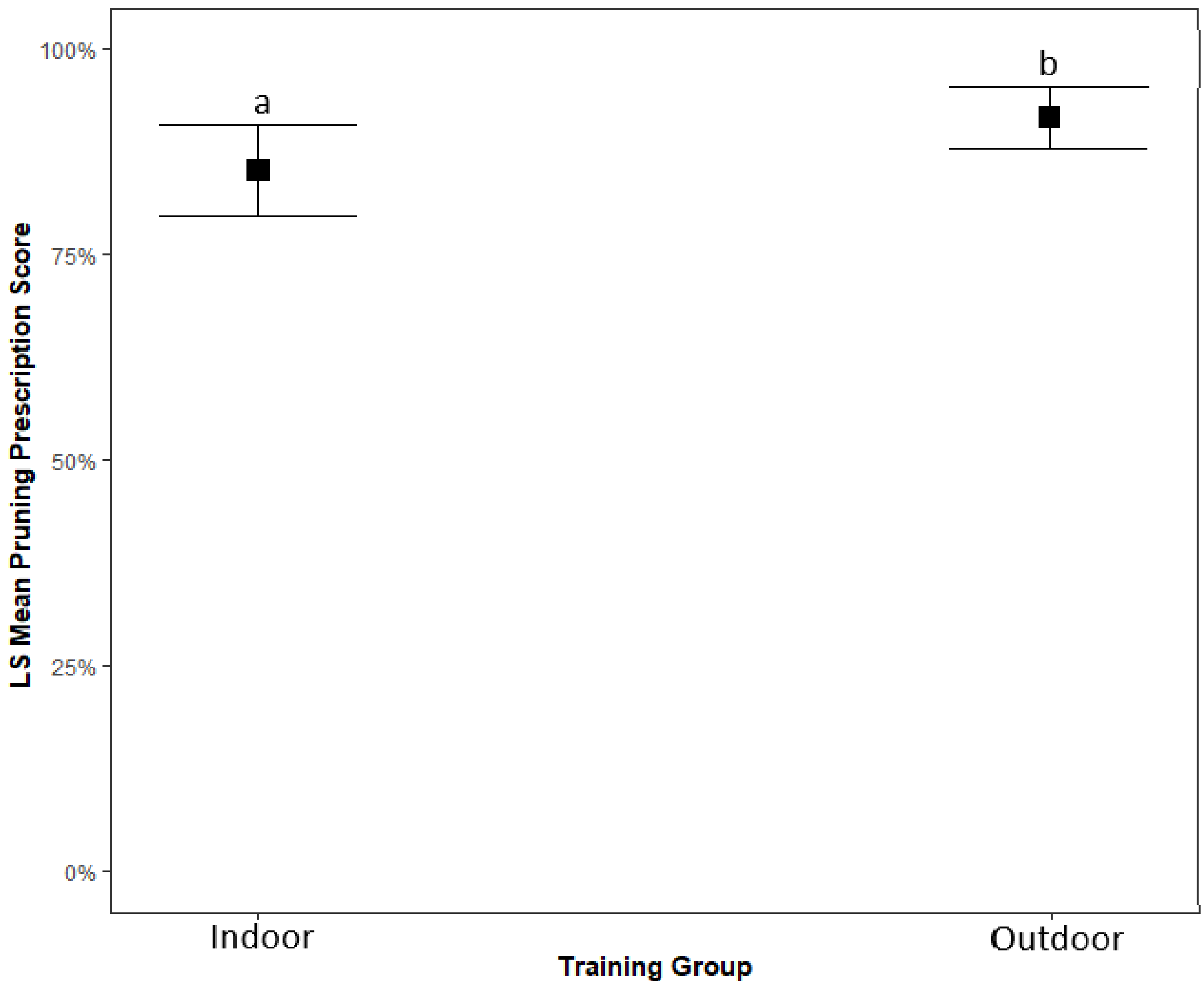


Figure 4. Least squares mean for the pruning prescription scores from the Springfield, MA. The filled square indicates the mean score, and the whiskers indicate standard error. When pruning prescription score was predicted using beta regression, training group was the best predictor when compared to other predictors based on AIC_C values (see Table 7). The mean score (85%) of participants who received (a) indoor training (n = 6) was significantly lower (p = 0.021) than the (b) mean score (92%) of participants who received outdoor training (n = 7).

APPENDIX A

TRAINING CURRICULUM

Figure 1. Outline of the curriculum used for both the indoor and outdoor training sessions. This outline includes the critical topics to understand to be able to prune a small tree for structure. It also includes the methods by which I proposed a participant's understanding of the topic would be assessed.

Volunteer Pruning Curriculum

1. To satisfactorily prune a young tree, what should someone know?
    a. Safety
        i. PPE
            1. Helmet
            2. Safety glasses
            3. Hi-vis clothing
            4. Hearing protection?
        ii. Site inspection
            1. Hazards—things that could harm you as you work
            2. Obstacles—things that could be harmed by you as you work
        iii. Setting up a work site
            1. Signs, cones
            2. Awareness of hazards & obstacles
            3. Keep sidewalks and roads clear of persons and pruned branches
    b. Tools
        i. Handsaw
        ii. Pole saw
        iii. Hand pruners
        iv. Pole pruners
    c. Tree physiology
        i. Tree parts & their functions
            1. Roots
            2. Trunk
            3. Branches
            4. Leaves
            5. Buds
            6. Xylem
            7. Phloem
            8. Cambium
            9. Branch bark ridge
            10. Branch collar
        ii. Tree growth
            1. Primary
            2. Secondary
            3. Response to pruning
                a. CODIT
                b. Woundwood & wound occlusion
                c. Regrowth
    d. How to make pruning cuts
        i. Reduction cut
        ii. Thinning or removal cut (collar cut)
        iii. Small branches (1 cut)
        iv. Larger branches (3 cuts)

    e. Structural pruning
        i. What is it?
        ii. Why is it necessary?
            1. Identify branches with weak unions
            2. Refer to CODIT and explain why it's better to make smaller cuts on younger trees than larger cuts on mature trees
            3. Why branch axial and circumferential branch spacing is important
        iii. Timeframe—how long can a volunteer reasonably and safely complete structural pruning?
        iv. How to perform
            1. Identify dead, dying, crossing, rubbing, interfering
            2. Identify lowest permanent branch (LPB)
                a. Understand how LPB might change for different locations
            3. Identify scaffold branches
            4. Identify current or future weak unions
            5. Understand maximum % foliage or % crown to remove in each year
            6. Understand how to subordinate branches to slow growth
                a. Subordinate at present to remove in the future
                b. Subordinate to decrease ratio of trunk to branch diameter
                c. Understand when to use reduction or thinning cuts
            7. What do you do in each year post-transplant?

2. To determine whether the type and amount of training affects a trainee's competence, how should you vary the type and amount of training?
    a. Exclusively indoor training
        i. PowerPoint slides with images (maybe videos) as appropriate to illustrate concepts (e.g., tree parts) and actions (e.g., how to make cuts)
        ii. Show examples of PPE and pruning tools, but participants do not use
    b. Indoor and outdoor training
        i. Indoors
            1. PowerPoint slides with images (maybe videos) as appropriate to illustrate concepts (e.g., tree parts) and actions (e.g., how to make cuts)
            2. Show examples of PPE and pruning tools
        ii. Outdoors
            1. Instructor demonstrates and participants complete
                a. Site inspection
                b. Work zone set up
                c. Assessment of which branches to prune
                d. Making pruning cuts
                    i. Choosing the appropriate tool
                e. Location of branch bark ridge, branch collar, wound occlusion
    c. Evaluation methods
        i. Outdoor
            1. Participant completes site assessment
            2. Participant sets up work zone

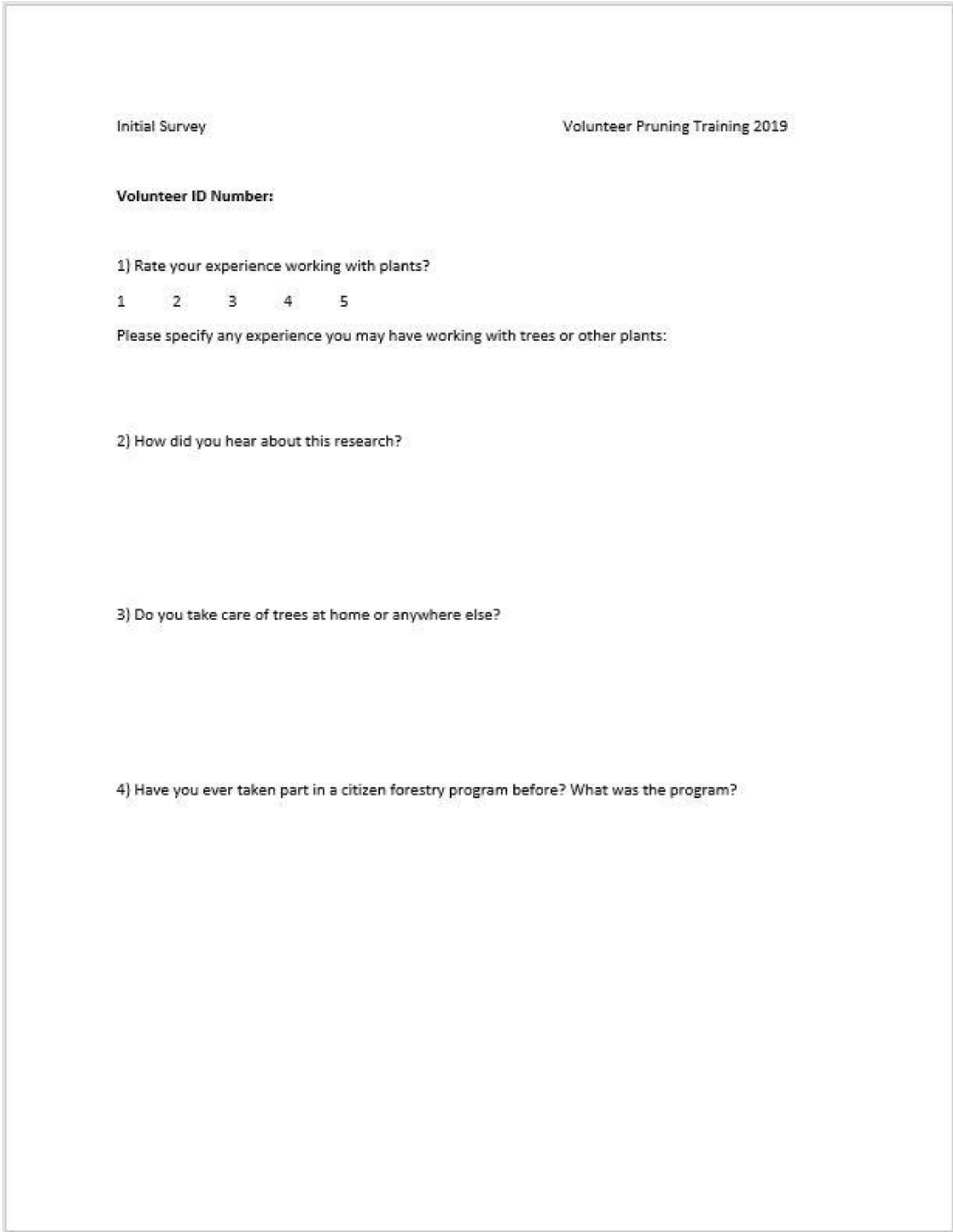
3. Which branches to prune (will need to pick a "year after transplant")
    a. Participant places labels on tree
        i. LPB, scaffold branches, which to subordinate, which have weak unions, dead/dying/diseased/crossing/etc.
    b. Participant makes cuts
        i. Removal or thinning
        ii. Reduction
        iii. Choose appropriate tool
            1. Include a range of branch sizes so participants must use all four tools

ii. Written test
1. Tree parts
2. Response to pruning
3. Set up work zone
4. Site assessment
5. Label branches to prune
    a. LPB, scaffold branches, which to subordinate, which have weak unions, dead/dying/diseased/crossing/etc.
6. Illustrate how to make cuts
    a. Thinning or removal
    b. Reduction
    c. Choose appropriate pruning tool

APPENDIX B

VOLUNTEER EXPERIENCE SURVEY

Figure 1. The survey issued to every volunteer upon their arrival to the workshop.



Initial Survey — Volunteer Pruning Training 2019

Volunteer ID Number:

1) Rate your experience working with plants?

1 2 3 4 5

Please specify any experience you may have working with trees or other plants:

2) How did you hear about this research?

3) Do you take care of trees at home or anywhere else?

4) Have you ever taken part in a citizen forestry program before? What was the program?

APPENDIX C

WRITTEN EXAM ASSESSMENT

Figure 1. The written exam that was completed by each volunteer after the training portion of the workshop ended. It includes the fifteen multiple choice questions that the grade was based on.

Volunteer ID: **/15**

1) Which of the following is NOT a main objective of structural pruning?

a. Develop a dominant leader.

b. Set the lowest permanent branch.

c. Space branches around the trunk.

d. Thin the crown.

2) The dominant-leader structure important for large-maturing trees is less important on small-maturing trees because small-maturing trees:

a. Are less likely to cause injury or property damage if they fail.

b. Usually do not have included bark.

c. Cannot be grown with a dominant leader.

d. Grow slower than large-maturing trees.

3) Permanent branches on a tree are called:

a. Scaffold branches

b. Twigs

c. Major branches

d. Co dominant branches

4) Scaffold limbs on large-maturing shade trees should be:

a. Chosen at the nursery.

b. Spaced evenly around the trunk of the tree to the top of the crown.

c. Chosen so they will droop down.

d. The prettiest looking ones.

5) What is the best way to prevent formation of codominant stems?

a. Reduce or remove branches that might compete with the leading stem.

b. Remove later branches so the codominant stem will die.

c. Trim other branches to let more light into the crown.

d. Remove roots on the side with the competing stem

6) When removing a 2-inch-thick branch at shoulder height the tool you use to make the cut should be?

a. Hand pruners

b. Axe

c. Chainsaw

d. Hand saw

7) It is important to structurally prune trees when they are young so that:

a. They can grow to be strong mature trees.

b. We spend less money pruning them later.

c. Pruning cuts leave small wounds.

d. All the above

8) When removing a branch, the best place to make a cut is

a. Through the branch bark ridge

b. Just outside the branch collar

c. 5 inches from the trunk

d. Flush with the trunk

9) If you are pruning a large branch with a hand or pole saw the best way to make a cut is:

a. Make an under cut on the branch, then remove a large portion of the branch above it, then finally remove the remaining portion of the branch at the branch collar.

b. Make a single cut at the branch collar.

c. Pull the branch until it snaps, then cut at the snap.

d. Cut so that the wound will be even with the bark, making it easier for the wound to heal.

10) What is the highest percentage of the canopy that should be pruned in one cycle?

a. 5%

b. 50%

c. 75%

d. 25%

11) What part of the tree prevents the spread of decay and disease into after a branch has been pruned

a. the branch protection zone

b. the bark

c. apical bud

d. branch collar

12) Decay is most likely to occur if

a. a small branch is removed.

b. a dead branch is removed.

c. a large codominant stem is removed.

13) The steps of the pre-cut method are:

a. cut straight through the branch.

b. make an undercut one foot out from the trunk or parent branch, make a second cut on top of the undercut, make a third cut to remove the stub

c. cut through the top of a the branch one foot out from the trunk or parent branch, make a cut to remove the stub

14) Included bark usually

a. grows in U shaped unions.

b. forms on broken branches

c. indicates a weak union.

d. should be left alone.

15) Newly planted trees should be pruned:

a. Heavily to make sure they have the right structure.

b. So that they have equal amounts of roots and branches.

c. Very little to keep them healthy.

d. To reduce the amount of wind they catch.

On the images below, label the branch collar, the branch bark ridge, and draw lines where you would make cuts to prune the branch.

APPENDIX D

PHOTOS OF TREES USED IN PRUNING PRESCRIPTION ASSESSMENT

Figure 1. The seven Carpinus caroliniana used in the Northampton, MA study area.

3

4


5


6

Figure 2. The seven Nyssa sylvatica used in the Springfield, MA pruning prescription assessments.


1


2
STOP


3


4


5


6


7

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