Characteristics and Perceptions of Cost-share Funding for Emerald Ash Borer Mitigation in Virginia Urban Areas

Peter W. Stewart

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P. Eric Wiseman, Chair

John F. Munsell

Scott M. Salom

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ABSTRACT (ACADEMIC)

Since most invasive forest pests first establish in urban areas, detection and containment of these pests within cities is important to the health of all forests. While the emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) has proved difficult to contain, efforts continue to mitigate the impacts of its spread. As part of those efforts, the Virginia Department of Forestry (VDOF) initiated its Emerald Ash Borer Treatment Program (EABTP) in 2018, providing financial incentives for insecticidal protection of ash trees. To better understand the role of incentives in promoting urban forest health, I conducted a study of properties, households, and practitioners involved in the program's first year.

To examine where EABTP funding helped pay for tree protection, I conducted tree inventories on 16 urban participant properties. Concurrently with tree inventory work, I conducted web and mail surveys to examine homeowner engagement in preservation of threatened trees. Finally, to investigate the role of forest practitioners involved in program implementation, I conducted web surveys of VDOF foresters and Virginia arborists. Results demonstrated that on urban participant properties—typically large and wooded—white ash (*Fraxinus americana)* was the dominant species. Results from homeowner surveys demonstrated broad support for personal investment in tree preservation, and the significance of attitudinal predictors towards those intentions. Results from practitioner surveys demonstrated substantial, though not unanimous, support for the program as a benefit both to clients and forests. Implications of these findings are discussed in the context of future urban forest health initiatives.

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ABSTRACT (PUBLIC)

Because most non-native forest pests arrive in cities before spreading to rural areas, detecting and containing these pests within urban forests is important to all forested areas. One non-native pest, the emerald ash borer (EAB), has proved difficult to contain, but there are ongoing efforts to limit the damage it causes as it spreads. As part of those efforts, the Virginia Department of Forestry (VDOF) began its Emerald Ash Borer Treatment Program (EABTP) in 2018, which offered partial reimbursement for the cost of protecting ash trees with insecticide. To better understand how reimbursement payments might help promote the health of urban trees, I studied the properties, households, and practitioners involved in first year of the program.

To examine where EABTP funding helped pay for tree protection, I conducted inventories of all trees on 16 participating properties in urban areas. At the same time, I conducted web and mail surveys to examine how homeowners thought about urban tree preservation. Finally, I conducted web surveys of VDOF foresters and Virginia arborists, to investigate roles of these practitioners in implementing the program. Results indicated that on urban participant properties, which were typically large and wooded, white ash was the dominant species. Results from homeowner surveys demonstrated broad support for personal investment in tree preservation, and the significance of attitudes in predicting that support. Results from practitioner surveys demonstrated substantial, though not unanimous, support for the program as a benefit both to clients and forests. These findings are discussed in the context of future urban forest health programs.

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CHAPTER 1 – INTRODUCTION

1.1 Research Background

Pests and pathogens present an immense threat to North American forests, having caused greater economic and ecological impact than wildfire, drought, or severe weather (Liebhold 1995). Invasions of non-native forest pests typically orginate in cities (Paap et al. 2017) for several reasons: cities function as transportation nodes for freight which may tranport invasive species; cities also contain both a high proportion of non-native tree species which may host non-native pests, and a high proportion of stressed trees susceptible to attack (Pautasso et al. 2015). Damages to urban forests from a single invasive pest may reach into the tens of billions of dollars (Kovacs et al. 2010); economic and ecological damage can compound when infestations spread into surrounding rural forests (Lovett et al. 2016). For these reasons, forestry officials, commercial arborists, and urban residents all have important roles in the detection and containment of invasive forest pests.

More than 450 invasive forest pests and 16 pathogens known to cause damage have been documented in North America since 1860 (Aukema et al. 2010). Since its arrival in the late 1990s, emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire) has become the most economically destructive of all of these (McCullough and Mercader 2012). It important to note, however, that a comparison of damage caused by invasive forest pests does not include damage caused by either the southern pine beetle (*Dendroctonus frontalis* Zimmerman) or the mountain pine beetle (*Dendroctonus ponderosae* Hopkins), both native to North America. In addition to creating widespread economic and ecological damage, EAB causes such high mortality rates that entire native ash species (*Fraxinus* spp., Family: Oleaceae) are threatened with extirpation (Lovett et al. 2016). For many areas of the eastern U.S. where the ash borer has been present for

several years, there may be few ash trees left to preserve. Yet for other communities where EAB has recently been detected or is projected to arrive, insecticidal treatment of ash trees may yield cost savings compared to tree removal, retention of benefits provided by mature urban trees (Sadof et al. 2017), and the continued genetic viability of seed-producing trees.

In 2018, Virginia Department of Forestry (VDOF) began offering cost-share payments for the insecticidal treatment of ash trees through its Emerald Ash Borer Treatment Program (EABTP). The program aimed to incentivize treatment of valuable ash trees on public and private lands among those for whom the initial expense of treatment might be a barrier (VDOF 2018a). Additionally, since no treatments provide indefinite protection, this program also aimed to 'jumpstart' continued, independent treatment among participants (Chamberlin 2018a). Unlike similar programs administered in neighboring states, Virginia's EABTP accepted applications from individual homeowners, in addition to organizations and municipalities. This program completed its first funding period in August 2018, with 107 total participants, of whom 90 were homeowners. The remaining 17 participants were comprised of 6 nonprofit or neighborhood organizations, 5 municipalities, 3 businesses, and 3 educational institutions.

1.2 Research objectives

Because of its unique participant pool, the EABTP provided an important opportunity for studying the influence of financial incentives on the management of urban forest pests, particularly in residential areas. Through this research, my intent was to provide insight into outcomes of the 2018 EABTP and the potential application of incentive programs for management of other urban forest pests. There were two facets to my research: (1) conducting tree inventories of urban participant properties, and (2) conducting survey research with the two

primary EABTP stakeholder groups of homeowners and forest practitioners. Primary stakeholder groups were in turn each comprised of two discrete sampling frames: among homeowners, I contacted program participants, and a sample of general households. Amont practitioners, I contacted VDOF county foresters and arborists within Virginia. My research objectives and questions were:

1) To characterize urban EABTP participant properties.
    - What types of properties commonly received funding?
    - What contributions did ash trees make to the forest composition and appraised landscape value of participant properties?
    - Are property characteristics associated with species composition of landscape trees?
2) To examine urban homeowner engagement in preservation of threatened urban trees.
    - Are attitudes towards tree preservation different between program participants and general households?
    - What characteristics are most strongly associated with homeowners' willingness to pay for preservation of threatened trees?
    - What characteristics are most strongly associated with interest in cost-share participation?
3) To examine forest practitioners' engagement in preservation of threatened urban trees.
    - Are specific professional characteristics associated with differing perceptions of threats posed by forest pests?
    - What characteristics are most strongly associated with interest in cost-share participation?
    - What are the most commonly-cited reasons for interest or lack of interest in the EABTP?

CHAPTER 2 – LITERATURE REVIEW

2.1 Biological Invasions in North America

Non-native species are those which humans have transported from one region to another; precisely defining which species are not native to a region can be complex (Richardson and Pyšek 2004). In the western hemisphere, native species are typically defined as those present in the Americas prior to European settlement (NRCS 2019). This date coincides with the beginning of an era of transoceanic trade—an unprecedented movement of people, goods, and biota. Today, despite regulation concerning inadvertent transport of biotic material across oceans or state lines, there are well over 50,000 non-native species in the U.S. alone (Pimentel et al. 2005). Not all non-native species are necessarily invasive; this label is applied to those that cause unacceptable economic damage or threaten local biodiversity or ecosytems (Schmiedel et al. 2016).

Biological invasions are often conceptualized as occurring in stages; with each succeeding stage, fewer introduced species survive. Four stages of invasion commonly described are long distance transport, colonization, establishment, and geographic spread (Theoharides and Dukes 2007). A rule of thumb proposed by Williamson (1996) states that only 10% of species survive each successive transition, such that for every 1000 species in transport, only 1 will survive long enough to spread across a region. Since survival of non-native species in unfamiliar territory is somewhat counterintuitive, several hypotheses attempt to account for their apparent success in new bioregions. Two of the most well-known hypotheses are *enemy release*, which credits an invader's success to a lack of co-evolved enemies, and its converse, *novel weapon*, in which prey or host organisms of the invaded environment possess no evolved defenses against the invader's attack mechanisms (Alpert 2006). Through these pathways or others, the number of non-native species in North America continues to grow—among forest pests only, at least two

new species become established annually (Aukema et al. 2010). Of invasive forest pests currently present in the U.S., wood- and phloem-boring insects (primarily Coleopterans) account for few species overall, but account for a large share of economic damage, and are becoming established at an increasing rate (Aukema et al. 2011). For most forest pests, the first three stages of invasion take place between and within cities; spread to forested rural areas is likely only after a pest or pathogen has established itself on urban host trees (Paap et al. 2017).

2.2 Historical Impacts of Invasive Forest Pests and Pathogens

While emerald ash borer (EAB) is judged to be the most destructive of any invasive forest pest in North America (McCullough and Mercader 2012), it is not unique in causing widespread economic and ecological damage (Aukema et al. 2011). Additionally, quantitative comparisons of damage to forests caused by invasive species often omit consideration of invasive forest pathogens, whose impacts in North America have been equally, if not more widespread than those of insects (Loo 2009). A discussion of EAB's 21st century impact is better understood, then, in the context of invasive forest pests and pathogens in North America over a much longer period. For that purpose, included here are descriptions of four forest invaders (two pests and two pathogens), each of which likely established in an urban area and subsequently caused widespread damage to North American forests.

One of the earliest and most well-known examples of an invasive forest pest infestation in North America is that of the gypsy moth (*Lymantria dispar* L.). This lepidopteran foliar-feeder, native to Europe, was brought to Medford, MA in the late 1860s by French amateur scientist Etienne Leopold Trouvelot, and soon escaped through the window of his lab (Liebhold et al. 1989). Within 10 years, moths were heavily defoliating the neighborhood, and by 1890 the

State of Massachusetts was appropriating money for its control, followed by the Federal Government in 1906 (McFadden 1991). The 20th century saw repeated outbreaks extending over millions of square miles of forest, and several concerted management campaigns, including the current 'Slow the Spread' campaign, initiated in 1995 (McManus and Csóka 2007). Through this campaign the USDA Forest Service and partner agencies have been largely successful in containing the gypsy moth to the northeastern quadrant of the country through coordinated trapping and aerial spraying of pheremonal disruptants (Sharov et al. 2002).

A second long-established and devastating North American forest invader is chestnut blight, caused by *Cryphonectria parasitica* (Murrill) M.E. Barr, a fungal pathogen likely transported from its eastern Asian range on nursery stock in the early 20th century (Griffin 2000). Within 50 years of its 1904 identification in the Bronx, NY, this pathogen spread through the entire range of the American chestnut (*Castanea dentata* (Marshall) Borkh.), virtually wiping out the species as an overstory tree (Rigling and Prospero 2018). Stump sprouts from trees killed decades prior still grow today, although they are inevitably killed off by the pathogen before reaching sexual maturity (Paillet 2002). Restoration of the American chestnut, once dominant in eastern North American forests, has been for decades the ongoing work of researchers dedicated to developing resistant hybrids and cultivars (Clark et al. 2019).

Like chestnut blight, Dutch elm disease is caused by rapidly spreading forest pathogens (*Ophiostoma ulmi* (Buisman) Nannf. and *O. novo-ulmi* Brasier), although their region of origin is unclear (Brasier 1990). Diseased trees were first recorded in Cleveland, OH in 1930, thought to be infected from veneer logs imported from Europe (Schlarbaum et al. 1997). Attacking primarily American elm (*Ulmus americana* L.), these pathogens also spread quickly, vectored by multiple bark beetle species, and encompassed the elm's native range within 50 years. While

some elms in forest settings displayed resistance, urban cultivars succumbed rapidly to the disease, leading to a dramatic loss of tree cover in many midwestern and northeastern cities, where American elms had been heavily planted as street trees (Campanella 2003). White and green ash (*Fraxinus americana* L. and *F. pennsylvanica* Marshall) were often planted as replacement trees, because of tolerance to urban conditions and attractive form (MacFarlane and Meyer 2005).

In 1996, the Asian longhorned beetle (ALB) (*Anoplophora glabripennis* Motschulsky) was first identified in Brooklyn, New York, noticed for the dime-sized exit holes left on tree trunks (Haack et al. 1996). A separate infestation was detected soon after in Chicago, followed by others in urban areas of New Jersey, Massachusetts, and Ontario (Dodds and Orwig 2011). Because this wood-boring cerambycid was observed to kill a wide ranges of host trees, including common urban genera such as *Acer, Aesculus,* and *Salix,* eradication campaigns quickly began in all affected locations (Haack 2006). These campaigns, funded by USDA-APHIS, consisted of outreach, detection efforts, destruction or treatment of potentially infested trees within a buffer zone, and an enforcement of quarantine on potentially infested products (Smith et al. 2001). While new infestations have occurred in the northeastern U.S. and as far away as Sacramento, CA, several of the earliest infestations have been declared eradicated by APHIS (*American Nurseryman* 2013). The relative level of success achieved in containing these infestations stands in contrast to the unchecked spread of the emerald ash borer. However, the potential for widespread damage remains—because of the number of ALB host species, a widespread infestation in urban forests alone could cause 30% tree mortality and a corresponding loss of $669 billion in value (Nowak et al. 2001).

2.3 Arrival, Spread and Impacts of the Emerald Ash Borer

Emerald ash borer, a phloem-feeding buprestid beetle native to eastern Asia, is several times smaller than ALB in its adult stage and more difficult to detect. While EAB was first identified in the Detroit metropolitan area in 2002, dendrochronological analysis shows it may have been present as early as 1997 (Siegert et al. 2014). The invasion's likely epicenter was an industrial area of Wayne County, MI, close to interstate highways, airports, and shipping terminals. Within fifteen years of arrival, the beetle had created more economic damage to U.S. forests than any other invasive pest in the nation's history (McCullough and Mercader 2012). By 2019, 22 years after its estimated arrival, EAB populations had spread to cover much of the range of eastern North American ash (*Fraxinus* spp., Family: Oleaceae), killing millions of trees across 35 U.S. states and 5 Canadian provinces (EAB Information Network 2019). Significant ecological effects are also expected among bird, mammal, and insect species which rely on ash species for food or habitat (Liu 2018). Figure 1 displays the 2019 North American extent of the EAB infestation and the historical range of ash species.

In its native east Asian range, emerald ash borer has only been observed attacking declining ash trees. In North America, however, it aggressively infests healthy trees, including all 16 ash species native to the continent (Cappaert et al. 2005). Resulting ash mortality rates are typically over 99% in heavily infested areas (Knight et al. 2013). Successive attempts to eradicate or contain infestations have been unsuccessful, primarily because of the difficulties of detecting low-density populations and enforcing quarantine regulations (Liu 2018).

Economic impacts of EAB damage are comparatively highest in urban areas, where costs to local governments and homeowners are many times greater than timber value losses in rural areas (Aukema et al. 2011). Urban costs include insecticidal ash treatment, removal and

replacement, in addition to associated property value loss. Kovacs et al. (2010) projected a $10.7 billion loss due to EAB in urban areas alone, for a 25-state area over the period 2010-2019. This figure did not include losses to property value and significantly underestimated the EAB's rate of spread over that period, indicating true costs may be higher. High costs to urban areas are a function of the prevalence of white and green ash as landscape and street trees. Ironically, ash trees were most common in northeastern and midwestern cities where they had been used to replace American elm trees lost to Dutch elm disease (MacFarlane and Meyer 2005).

Until the arrival of EAB, native ash species made up 1.5% of Virginia's forested lands, ranging from over 6% relative abundance in Northern Piedmont counties to essentially 0% in some coastal locations, shown in Figure 2 (FIA 2019). These data are drawn from the five-year FIA sampling cycle 1998-2002, and represent relative abundance of ash species in rural forests, prior to the arrival of the ash borer in the state. Significantly, relative abundance of native ash species among street tree populations mirrored that of forested lands. In one study, researchers conducted street tree inventories and compiled street tree inventory data for a total of fourteen Virginia municipalities, spanning the years 2003-2010. Among these cities, distributed across Virginia bioregions, native ash relative abundance ranged from 0.1% to 5.8%, and averaged 2.0% across studied cities (Wright 2011).

EAB was introduced to Virginia via nursery stock within a year of its initial 2002 Michigan detection. Virginia forestry officials initiated a rapid eradication campaign at the infested site, destroying all ash trees within a half-mile radius and instituting a meticulous detection program (Asaro 2007). These efforts temporarily provided an example of successful EAB eradication, until the summer of 2008 when the beetle was again detected in multiple Fairfax County sites. Eradication was abandoned in favor of a strategy of containment within a

five-county quarantine zone (Asaro 2008). Quarantine of northern Virginia counties in turn was abandoned by 2012, at which point widespread detections in Virginia led USDA-APHIS to designate the entire state within the federal EAB quarantine zone (Asaro 2013). By 2019, of 130 Virginia counties and independent cities, only 37 remained without a confirmed EAB detection (Chamberlin 2019). Figure 3 displays the year of initial EAB detection, by Virginia county.

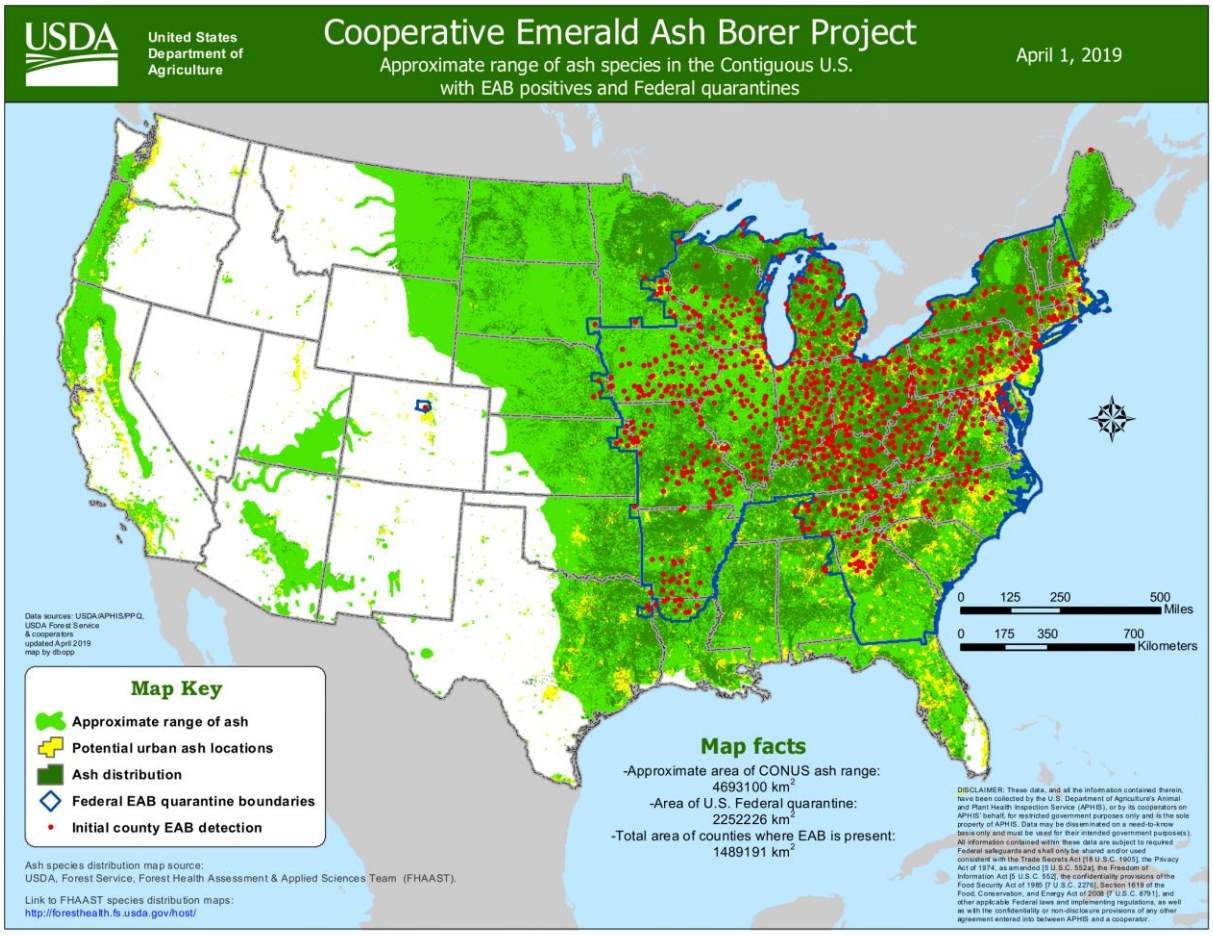

Figure 1. Map of the range of ash species in the U.S. and the extent of the EAB infestation, as of April 2019.

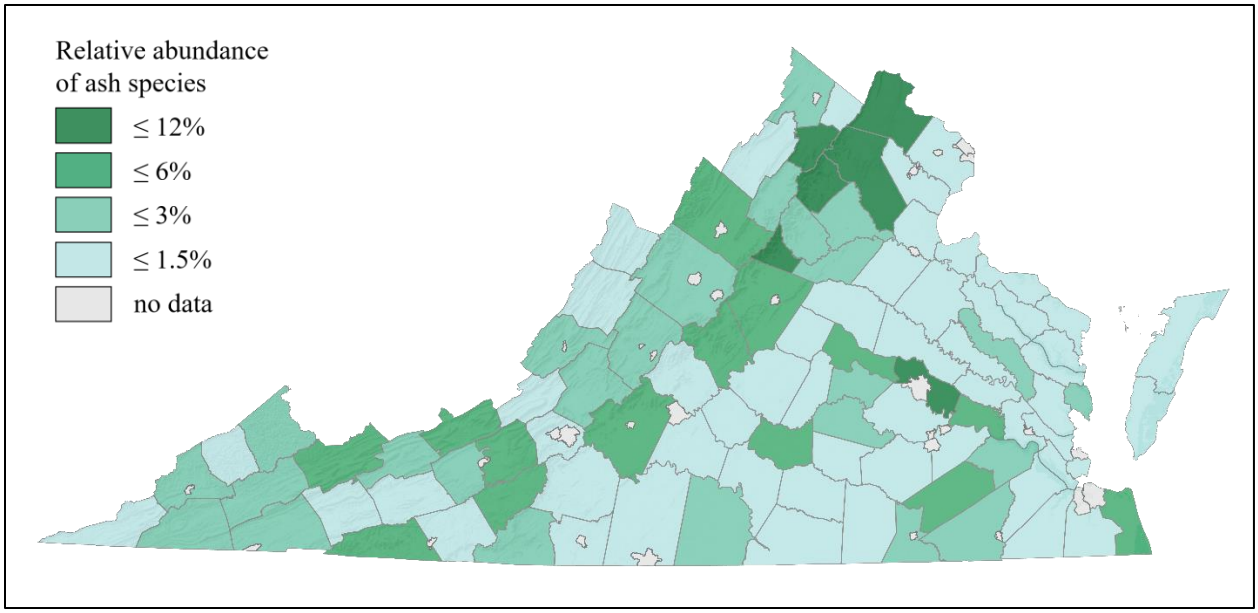

Figure 2. Map of relative abundance of ash species, by county, in Virginia before the arrival of EAB. Data were drawn from 1998-2002 FIA data.

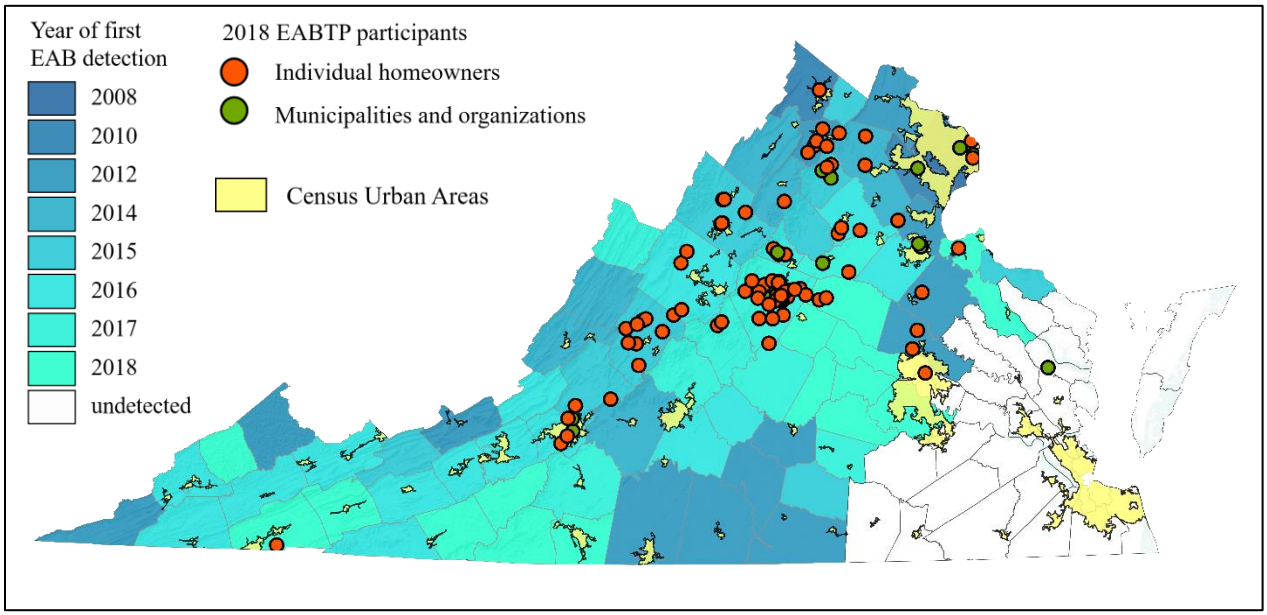

Figure 3. Map showing the spread of EAB across Virginia, with Census Urban Areas displayed, and rough locations of 2018 EABTP participants.

2.4 Biology and Control of EAB

In Virginia, EAB typically undergoes complete metamorphosis in one year, with adult emergence taking place in early May (Chamberlin 2018b). During the month following emergence, adult beetles feed on ash foliage, mate, and lay eggs in bark crevices (Liu 2018). Females may lay up to 80 eggs, and show a preference for stressed trees as oviposition sites (Jennings et al. 2014). Neonate larvae hatch in mid-summer, bore inwards through the bark, and begin to feed in phloem, cambium and outer sapwood, carving characteristically serpentine galleries (Cappaert et al. 2005). Larvae complete four instars while feeding from July until November, followed by an overwintering stage. Pupation lasts for approximately one month in spring, after which the new adults tunnel out though the bark, leaving a distinctive D-shaped exit hole (Van Driesche and Reardon 2015).

Damage caused to ash trees by foliar feeding of adult beetles is minimal compared to the effects of larval feeding in vascular tissue. As the density of larval galleries increases in a tree, translocation of nutrients and water is greatly reduced—resulting in visible crown thinning and dieback (Herms and McCullough 2014). Within five years of on-site EAB detection, a stand of ash trees is likely to experience a 99% mortality rate (Knight et al. 2013). Declining trees typically display shoot and branch dieback progressing downwards through the crown, and often produce heavy epicormic growth on the trunk and lower crown (Van Driesche and Reardon 2015).

Coordinated regional campaigns to contain EAB using chemical and cultural methods, such as the efforts described in Virginia, have repeatedly proven unsuccessful. Much EAB-related research today is instead directed toward identifying resistance and regeneration capacities of ash species. Studies conducted on site characteristics of ‘lingering ash’ pockets in

the Midwest have noted the higher survival rates of ash trees at a distance from other ash (e.g., Knight et al. 2011, Kappler et al. 2018). Others studies have investigated successional dynamics of germination and 'orphaned' ash seedlings in EAB-infested forest stands, concluding that silvicultural management is essential to ash survival (Klooster et al. 2018, Granger, Zobel, and Buckley 2017).

For years, researchers have also investigated the potential for biocontrol of EAB through introduced insect natural enemies. While several native North American bird, insect, and fungi species feed on EAB, none have been observed to significantly suppress its population (Bauer et al. 2015). In its native east Asian range, however, natural enemies can reduce EAB population density by as much as 74% (Liu et al. 2007). Following years of quarantined trials, USDA-APHIS has approved the U.S. release of four Asian hymenopteran parasitoids (USDA-APHIS 2017), all of which parasitize EAB eggs or larvae at high rates in experimental settings (Jennings et al. 2016). Researchers theorize that biocontrol agents in the future may protect surviving and regenerating ash by reducing the severity of EAB outbreaks (Duan et al. 2018).

While control of EAB populations is not yet feasible, an infestation's impact may be mitigated on a municipal scale through planned use of tree removal and insecticidal treatment. Effective protection of individual ash trees can be achieved through the application of systemic insecticides to a tree's trunk or root system, disrupting larval development in phloem tissue (Smitley, Doccola, and Cox 2010). In particular, trunk injections of emamectin benzoate can reduce EAB larval densities by 99% and provide protection against infestation for three years (McCullough et al. 2011). However, high cost of treatment creates a significant barrier to tree treatment both for municipalities and property owners. The commercial cost of emamectin injection can be as high as $15 per inch of trunk diameter (about $6 per centimeter) (Chamberlin

2018b). At this rate, treatment of an 18" DBH tree (46 cm) would cost $288—if extended to the ash population of an entire municipality, costs can quickly reach six or seven figures.

2.4.1 Strategies for Municipal EAB Management

Urban forestry officials facing a recently detected or approaching EAB infestation must weigh short- and long-term costs of multiple management strategies, and importantly, the benefits accrued through these actions. If no action is taken, close to 100% mortality of a municipality's ash trees can be expected within eight years of initial EAB detection (Sadof et al. 2011). Many municipalities' urban forestry budgets have been overwhelmed by the volume of tree removal necessitated by EAB, which peaks 5-7 years following initial local detection of the borer (Sadof et al. 2017). With planning, a city's urban forestry department can distribute the concentrated financial burden of tree removal over many years, and at the same time sustain urban forest value through insecticidal treatment of strategically selected trees.

To help municipalities plan for EAB infestation, researchers have modeled urban forest growth under a range of management scenarios, predicting total costs and resulting net benefits in retained urban forest value. As assessed by benefit-to-cost ratios, model predictions strongly support the use of insecticidal treatment for all or most ash trees, as opposed to options of preemptive tree removal, or removal and replacement (Vannatta, Hauer, and Schuettpelz 2012, Sadof et al. 2017). Planning may also include outreach and coordination with private property owners, whose properties typically represent 90% of the urban forest (Moll 1993). Spatially-explicit models incorporating privately-owned trees in municipal EAB planning indicated higher overall tree survival rates (McCullough and Mercader 2012) and further improved benefit-to-cost ratios (Kovacs et al. 2014).

2.4.2 State-level EAB Management Cost-Share Programs

Since 2012, forestry and natural resource agencies in several eastern states have developed programs to promote EAB management planning among municipalities and residents. These programs grew out of research conducted during earlier stages of EAB infestation in the Midwest (Liu 2018). Programs developed by Pennsylvania, Maryland, Virginia, and North Carolina offer a combination of training and funding to municipalities who develop detailed EAB management plans. In all cases, program guidelines advocate for the use of emamectin benzoate, if insecticides are to be a management component. Eligibility guidelines vary, but generally allow only municipalities and other public agencies to apply for assistance. Among these programs, Virginia's Emerald Ash Borer Treatment Program is unique in accepting applications from private property owners.

The earliest of these programs, Pennsylvania's Department of Conservation and Natural Resources' (PDCNR) Community Ash Management Plan (CAMP) program began accepting applicants in 2012. Participating municipalities or agencies receive training in i-Tree inventory software and EAB biology, and up to $5000 in funding to implement an ash management plan. Participants must choose from one of four strategies: (1) no action, (2) selective management, (3) preemptive management, and (4) aggressive management (Liu 2013). In 2017, Maryland's Department of Natural Resources-Forest Service (DNR-FS) initiated its Emerald Ash Borer Treatment Program, a 50/50 cost-share program for ash tree treatment by municipalities, state agencies, and private conservation easements. Like Pennsylvania's program, applicants must develop a written Community Response Plan, an accompanying tree inventory, and demonstrate need based on public value of trees or potential hazards (MD DNR-FS 2017). North Carolina Forest Service's Ash Protection Program, begun in 2018, allows only municipalities to apply for assistance with ash tree treatment. A single municipality may receive up to $5000 for tree

treatment, at the reimbursement rate of $12 per inch diameter (NCFS 2018a). Program guidelines do allow, however, for funds to pay for treatment of trees on private land at local officials' discretion (NCFS 2018b).

In contrast to eligibility requirements of other programs, Virginia Department of Forestry's (VDOF) Emerald Ash Borer Treatment Program (EABTP) funds ash tree treatment among municipalities, private organizations, *and* individual property owners. Initiated in 2018, this cost-share program offered 50% reimbursement of tree treatment cost, capped at $1250 for individuals and $5000 for organizations or municipalities. Funding priority was designated for applicants from counties with no detected EAB presence, followed by those from counties where first detection occurred post-2014 (VDOF 2018c). EABTP's application process was designed to require minimal paperwork—application materials include a one-page form signed by a VDOF forester and a bid for tree treatment from a licensed contractor (VDOF 2018c). In its initial year, EABTP program participants included 90 homeowners, 5 municipalities, and 12 educational, business, nonprofit, or other organizations (Bean 2019).

2.5 Historical and Current Context of Incentive Programs

Cost-share programs such as Virginia's EABTP have been developed within the broader context of financial incentive programs, administered for decades by state and federal natural resource and conservation agencies. Depending on context, these programs may be described as conservation incentive programs, voluntary incentive programs, financial incentives, or simply cost-share. I will use *cost-share* and *incentive program* interchangeably, to refer generically to all types of incentive programs. Programs range in purpose from conservation objectives such as habitat protection to economic concerns like timber supply. What programs share is the objective

to correct a perceived market failure in which private landowners do not have sufficient incentive to produce *external benefits* from their land, such as food, fiber, or ecosystem services (Caldas et al. 2016). Ecological benefits in particular, may also be described as *public goods*—those from which all may benefit without diminishing another's enjoyment (Goldman et al. 2007). Whether intended to stimulate tree planting, soil conservation, or tree preservation, incentive programs aim to compensate private property owners for investment in publicly-beneficial work the landowners either cannot afford or from which they would not realize substantial personal benefit.

Within U.S. forestry, an educational Extension Service was first authorized through the Clarke-McNary Act of 1924, ten years after the establishment of the Agricultural Extension (Boyd et al. 1988). Through the Norris-Doxey Cooperative Farm Forestry Act of 1937, direct forestry assistance was first offered in the form of subsidized planting stock and forestry demonstrations (Barden et al. 1996). Program objectives shifted over time from a focus on timber production to include multiple forest management objectives, such as those of the Forestry Stewardship Program, authorized through the Cooperative Forestry Assistance Act of 1978 (Kilgore et al. 2007). Over the same period, state forestry agencies also began administering incentive programs, such as Virginia's Reforestation of Timberlands, which has been operating continuously since 1970 (Cumbia 2018).

Other forestry programs have incentivized proactive responses to forest pest outbreaks. The Southern Pine Beetle Prevention and Restoration Program (SPBRP), a USFS incentive program, has promoted thinning, burning and re-planting across all southern states in response to repeated beetle outbreaks (Nowak et al. 2008). VDOF disburses federal SPBRP funding to Virginia landowners through its own Pine Bark Beetle Prevention Program (Watson et al. 2013).

Longstanding incentive programs operate within other land management contexts, notably those administered by the USDA Natural Resources Conservation Service (NRCS). Since 1985, the NRCS's Conservation Reserve Program has paid farmers to take ecologically sensitive lands out of production, spending $1 billion annually for the program's first 15 years (Feng et al. 2005). NRCS programs with similar habitat protection objectives have included the Wetlands Reserve Program, Grassland Reserve Program, and Working Lands for Wildlife (Ciuzio et al. 2013).

Despite the history and prevalence of incentive programs within forestry and natural resource management, there is little evidence of their use in urban settings, prior to state-level EAB management programs. One of the few predecessors to Virginia's EABTP is Minnesota Department of Natural Resource's (MN-DNR) ReLeaf program, administered from 1991 to 2008. This program was initiated to protect trees from oak wilt, a highly virulent disease caused by the invasive fungal pathogen *Ceratocystis fagacearum* (Bretz) Hunt. Grants were made available to municipal officials through this program for two specific management actions only: tree removal, and vibratory plowing, a technique to cut root grafts (Kokotovich and Zeilinger 2011). Significantly, the program did not fund fungicidal trunk injection—a treatment at that time in common use, but with little research support.

2.6 Analysis of Incentive Programs and Landowner Participation

Within forestry and extension research, the land management decisions of nonindustrial private forest (NIPF) landowners have been extensively studied, particularly in relation to incentive programs. Analyses typically focus on either assessing the biophysical outcomes of incentive payments or investigating landowner participation. Econometric methodologies are

applied to either objective, while studies of landowner participation also include those employing social psychological methodologies.

Assessment of biophysical outcomes of forestry incentive programs among NIPF landowners is typically conducted through econometric analysis of measurable market goods. Researchers may employ a cross-sectional comparison among landowner groups (e.g., Hardie and Parks 1991) or time-series analysis of one location (e.g., Kline and Butler 2002) to examine the effect of incentives on known quantities, such as acres of forestland planted or board-feet of timber harvested. Analyses control for regionally- or temporally-varying effects such as land value, planting costs, or interest rates to determine whether financial incentives have achieved program objectives (Sun 2007). For instance, in a cross-sectional comparison of 13 southern states, Li and Zhang (2007) found a significant, positive association between NIPF acres planted and all four federal incentive programs evaluated. Biophysical outcomes of incentives for forest health treatments are more difficult to measure than those targeted at increased harvesting or planting, because of the confounding effects of weather and fluctuations in populations of pests or their natural enemies. However, Asaro, et al. (2017) noted that the recent decrease in southern pine beetle infestations correlates with federal incentives for pre-commercial thinning through the Southern Pine Beetle Prevention Program, indicating possible causal effect.

While biophysical outcomes may be measured and modeled for programs already in effect, researchers also investigate the likelihood of landowner participation in new programs, or in existing programs under different terms. Thresholds for participation are identified through contingent valuation, an economic measurement technique for non-market goods (Carson et al. 2001). Of interest are the measured values *willingness-to-pay* (WTP) and more commonly *willingness-to-accept* (WTA)—economic thresholds assigned by landowners to proposed

management actions. For instance, Kline, et al. (2000) found that payment thresholds necessary for landowners to forego timber harvest varied strongly by landownership objective. Lal, et al. (2016) investigated per-acre payment necessary for landowners to convert non-forested land into woody biomass production, and similarly found WTA depended on current land use and acreage. Studying Virginia's Pine Bark Beetle Prevention Program (PBPP), a program somewhat analogous to the EABTP, Watson, et al. (2013) determined that increasing payments beyond 50% would result in only minimal participation gains.

While the goal of contingent valuation research among landowners is to identify optimal incentive payment amounts, choice modeling attempts to predict a specific landowner decision from a variety of social and geographical variables. Commonly conducted using the random utility maximization model, this technique is a special case of multinomial logistic regression in which a discrete choice is modeled as a function of several random and orthogonal parameters (Train 1998). For instance, Joshi and Arano (2009) found the likelihood of landowners undertaking silvicultural management to be associated with educational attainment, income, forest acreage, and whether the property had been inherited. Similarly, participation in the PBPP was associated with the presence of pine on the property, education level, and the reason for landownership (Watson et al. 2013). In their study of converting non-forested land to biomass production, Lal, et al. (2016) found likelihood of planting pine to be associated with younger age, inherited land, longer ownership tenure, larger family size, and the presence of a written forest management plan.

Although random utility maximization analyses employ logit or probit models of mutually exclusive outcomes, landowner economic decisions are also modeled as a continuous functions using ordinary least squares regression. For example, in a large-scale analysis, Brooks

(1985) modeled acres of forestland planted across southern states as a function of cost-share payments, rotation length, and planting cost. In a similar study, Zhang (1996) modeled silvicultural investment of British Columbia forest landowners as a function of land tenure rights, soil quality, and biogeoclimatic zone.

Finally, social psychological theory provides an alternative perspective for the study of landowner decision-making in relation to incentive programs. Under this theoretical perspective, specific behavioral intentions are modeled as functions of measured attitudes, beliefs, and perceived norms, rather than externally-observable characteristics such as age, income, or gender. One common framework, The Theory of Reasoned Action (TRA), describes a pathway of behavioral intention that is first influenced by attitudes and subjective norms toward the behavior. Attitudes and norms are in turn informed by beliefs about behavioral outcomes and beliefs about others' normative views (Ajzen and Fishbein 1980). Further, while external characteristics such as age or income may in fact predict or even influence behaviors, they hold no necessary relationship to the behavior (Ajzen and Fishbein 1980), and are likely to be unreliable predictors in different social settings.

Using the framework of the TRA, Sorice and Conner (2010) investigated landowner intention to enroll in a habitat conservation program, finding that attitudes and subjective norms towards participation to be the only significant predictors in a substantially-fitting model. Similarly, in a study of participation in the NRCS's Wetlands Reserve Program, Luzar and Diagne (1999) found that pro-environmental attitudes predicted intention to participate although perceived peer norms did not have a significant effect. Research attention to attitudes and beliefs does not preclude consideration of external variables, however. In a study of forest landowners considering enrollment in a habitat conservation program, Farmer, et al. (2017) found that

significant predictors included both pro-environmental and family-related attitudes, along with the external characteristic of property size.

2.7 Summary of Literature

North American forests have experienced widespread economic and ecological damage from a series of invasive pests and pathogens; this trend is likely to continue. Urban forests receive a disproportionate share of this damage because of their role as 'beachheads' for biological invasion (Paap et al. 2017), damage that is compounded when pests find susceptible monocultures of urban trees (Alvey 2006). For these reasons, urban forest professionals and property owners have the potential to greatly reduce the severity of local and regional infestations through coordinated detection and containment of newly-arriving forest pests.

The spread of the EAB across the eastern U.S. has created more economic damage than any other invasive forest pest, and the long-term survival of eastern ash species is in question. State forestry and natural resource agencies have responded by designing cost-share programs for municipalities that incentivize insecticidal protection of ash trees. Virginia's EABTP also extends assistance to private property owners.

Incentive programs such as the EABTP have been developed for rural landowners by conservation and natural resource agencies since the early 1970s. Landowner participation in these programs has been intensively studied over this period. To further the conservation objectives of a program, researchers use economic and behavioral analyses to identify factors associated with the likelihood of landowner participation. There is little documentation of incentive programs designed to promote conservation objectives in urban settings; for this reason, there is a knowledge gap regarding how such a program might function. It is important to note that the actions of an urban homeowner regarding landscape trees on her property are not so

obviously an economic decision as commercial tree planting or harvest. However, since landscape trees are both a source of benefits and costs to property owners, decisions regarding their management are influenced by economic factors (Soto et al. 2018), among others.

Virginia's EABTP provides one opportunity to study the functioning of conservation incentives among urban property owners. Because of the continuous threat posed by invasive pests to North American forests, the relevance of this research extends beyond EAB mitigation. The EABTP provides a model for engaging private property owners in mitigating threats to forest health—threats which are posed both by newly-arriving invasive pests and other established, potentially destructive pests such as the Asian longhorned beetle.

CHAPTER 3 – SITE CHARACTERISTICS OF URBAN EABTP PARTICIPANT PROPERTIES

3.1 Introduction

In January 2018, Virginia Department of Forestry (VDOF) began offering cost-share assistance for the insecticidal protection of ash trees through its' Emerald Ash Borer Treatment Program (EABTP). In the program's initial year, individual homeowners in urban areas made up 26% (28) of all participants (107). This chapter focuses on the biophysical characteristics of urban properties which received funding through the 2018 EABTP.

While the EABTP was not directed specifically towards urban homeowners, their inclusion as eligible applicants created an important opportunity for study. Since urban forests are central to the early containment of invasive forest pests (Paap et al. 2017), and most urban forests are privately-owned (Moll 1993), participation of urban homeowners in an urban forest health initiative is of research interest. To inform an assessment of the EABTP and potential implications for similar initiatives, I collected remote and on-site data for urban EABTP participant properties.

There were three specific topics addressed through this research: (1) characterization of the physical characteristics and locations of properties, (2) significance of ash species to the landscapes of properties, and (3) potential associations between the physical characteristics and the tree species composition of properties. For the first of these topics I aimed to describe urban properties and neighborhoods that benefited from EABTP funding. With the second topic, my goal was to describe the prevalence of ash trees on urban participant properties, to offer some information regarding its motivational effect. As a component of this analysis, the prevalence of ash on participant properties was also compared to that of surrounding municipalities, for added context. Lastly, by examining associations between physicial and biotic characteristics of urban

properties, I aimed to test the predictive power of site characteristics in identifying properties at high risk in a pest infestation.

3.2 Methods

3.2.1 Definition of target population

VDOF approved a total of 121 applications for the 2018 EABTP. Program policies prioritized funding of applications from the small number of Virginia counties with no detected EAB presence in 2018 (VDOF 2018d). Ultimately, all but two approved applications were received from counties with confirmed EAB infestations (see Figure 3). Fourteen applications were eventually cancelled either by the homeowner for reasons of cost or timing of treatment, or by VDOF for reasons of poor tree condition or other disqualifying factors (Bean 2019). The remaining 107 applicants who ultimately received cost-share payments for approved ash treatment through the 2018 EABTP will be referred to here as program participants. Of these 107 program participants, 17 (16%) were public or private organizations, including municipalities, historical sites, homeowners' associations, educational institutions, and businesses. The remaining 90 participants (84%) were single-family homeowners; 28 of these residential properties were in urban areas. I selected these properties as the target population for site inventory and analysis, referred to hereafter as urban participant properties (UPP).

3.2.2 Selection of Sites

Meetings between researchers and VDOF before the launch of EABTP in January 2018 established a data-sharing framework for this research. Since application forms were public records, most application data were shared with researchers. Application data included site

locations, number and size of ash trees, and quoted costs of treatment. However, per agreement between VDOF and researchers, contacting applicants by phone or email was limited only to those applicants who had checked an opt-in box on the program application. A 2018 EABTP application form is included in Appendix D. Addresses contained on application forms were compiled and geocoded in ArcGIS Pro 2.2 (*ArcGIS Pro* 2018) (hereafter 'ArcGIS'), then joined with statewide parcel data available through Virginia Geographic Information Network (VGIN 2018a), to create a geographic database of properties of all participant homeowners.

From this database, urban properties were identified by overlaying participant locations on U.S. Census Urban Areas (U.S. Census Bureau 2018) in ArcGIS. The term Census Urban Area (CUA) refers collectively to city-sized *urbanized areas* and town-sized *urban clusters*, both which are defined by population density and land use patterns (U.S. Census Bureau 2012). Virginia contains 75 CUAs, irregular polygons which combine and extend beyond single-municipality jurisdictions (see Figure 3).

Of the 28 EABTP homeowner participants located in urban areas, 23 had previously opted-in to follow-up contact on the program application. Requests for permission to conduct on-site tree inventories were emailed to these homeowners in October 2018, and from this group, 17 agreed to participate. In late November and early December of 2018, tree inventory work was carried out over four days in locations between Roanoke and Alexandria. In total, 16 properties were inventoried, yielding a 57% sample of all 28 UPP.

3.2.3 Data Collection: Participant Properties

Two types of data were combined for analysis of site characteristics across UPP: compiled geographic data from public records, and on-site tree inventory data. First, five

geographic variables with relevance to forest composition were compiled from publicly-accessible sources. *Parcel size* was selected for its potential association with site species diversity, and household income. *Parcel tree cover* was selected to account for potential effects of extremely high or low tree cover on species composition. This proportional value was derived from Virginia's Statewide Landcover Dataset, a supervised classification with 1m resolution (VGIN 2018b). This composite dataset makes use of a number of state and federal datasets ranging published between 2005 and 2014. *Historical ash abundance* was included as an approximation of regional climatic or physiographic suitability for ash species. This was derived from county-level FIA data for the period 1998-2002 (USFS 2018a), collected prior to the ash borer's arrival in Virginia. *Time since EAB detection* at the county level served as a proxy for EAB population density, and was compiled from VDOF data (Chamberlin 2018b). *Time since residence construction* was of interest because of potential association between site species composition and distinct eras of landscape planting preferences. These data were drawn from individual searches in tax parcel databases for each respective UPP address.

To add a much greater level of detail, on-site tree inventory data were collected for 16 UPP in November and December of 2018. At each location, a complete inventory was conducted of all trees with a diameter at breast height (DBH) of 4.0 inches (10 cm) or greater. Printouts of parcel polygons overlaid on aerial imagery of each property served to indicate property boundaries in cases when property owners were not present. For each tree, species and DBH were recorded, along with five other dimensional measurements, two locational measurements, a condition rating, and a planting site descriptor. All data were initially recorded on paper before being copied to a spreadsheet. A data collection form is included in Appendix E.

Since measurements were conducted during the dormant season, tree condition rating was not based on relative canopy thinning, as is common in studies of ash tree survival (see Bick et al. 2018). Instead, I rated tree condition (0-100%) based on the relative absence of dead limbs, the relative absence of wounds or defects, and the relative presence of live buds on branch tips. Condition ratings were collected for all tree species, as a component of a calculated tree appraisal value. Ratings were not intended as a measure of response to emamectin benzoate injection for ash trees, because treatment efficacy is not visibly evident until the growing season subsequent to treatment, at the earliest (Smitley et al. 2008).

Inventoried parcels ranged in size from 0.14 ac to 1.67 ac (0.055 ha to 0.676 ha), and in tree cover from 11.7 to 91.2%. For parcels containing unmaintained wooded areas, a single subplot of the parcel was sampled rather than the whole property. Subplots were selected to include the residence and encompass regularly maintained areas. Subplots were defined using landscape or building elements visible from aerial imagery as vertices, to aid later calculation of area in ArcGIS. This strategy was employed on 5 of 16 properties. Similarly, on 2 properties, the area inventoried was selected to intentionally exceed parcel boundaries to reflect *de facto* boundaries of the property as it was maintained by the homeowners.

3.2.4 Data Processing: i-Tree Eco

Before conducting further analysis, i-Tree Eco (hereafter 'Eco') (USFS 2018b) was used to calculate additional UPP variables from inventory data. Eco is an urban forest benefits modeling program which estimates tree benefits using allometric relationships, climate data, and measured tree dimensions. In addition to tree benefits, output includes *Leaf area* and *Structural value*. *Leaf area* is an allometric calculation of the total surface area of a tree's canopy,

describing the three-dimensional effects of a tree's canopy on a residential site. *Structural value* (SV) is an estimated replacement cost, as calculated by the Council of Tree and Landscape Appraiser's trunk formula method (Komen and Hodel 2015).

A third Eco-derived variable used in analysis is *Importance value* (IV), calculated for a single tree or a species as the sum of *Relative abundance* and *Relative leaf area*. This index describes the all-around importance of a tree species to a site, combining its relative contribution to total stem count and total leaf area. For clarity, *Relative importance value* (RIV) is reported here, calculated as IV/2*100, and ranging from 0-100%. A table summarizing species composition variables derived from Eco calculations is included in Appendix A.

3.2.5 Data Compilation: Urban Forest Assessments

One of the objectives of this research was to investigate whether participant properties were representative of surrounding urban forests, or whether these properties were outlying cases—in effect, dense 'stands' of ash trees in largely ash-free urban forests. While FIA data described above provides a measure of county-level ash suitability, traditional FIA sampling does not include urban areas (USFS 2019a). Instead, data were compiled from a 2010-2011 project where Virginia Tech faculty, staff, and students conducted Urban Forest Assessments (UFA) for five municipalities across Virginia using city-wide, plot-based techniques (Virginia Tech 2018). UFA data were collected during a period when EAB was recently established in northern Virginia but had yet to spread outward from that region. UFA were conducted in three municipalities which surround or neighbor most UPP sites and involved plot sampling across all land uses.

UFA datasets from the 2010-2011 project include estimates and standard errors by species for stem count and structural value. From estimated tree count and structural value, *Relative abundance* (RA) and *Relative structural value* (RSV) of all species were calculated to facilitate comparison with site data. UPP sites within 15 miles (24 km) of the geographic center of a UFA municipality were paired with that municipality. This technique paired 13 of 16 UPP properties with 3 baseline UFA datasets, and excluded 3 UPP sites from analysis. A table of site and municipal pairings with calculated distances is included in Appendix A.

Given the small sample size (n=13) and concerns about measurement precision in UFA data, the nonparametric exact sign test was used to compare species distribution metrics between properties and their surrounding urban forests. Unlike a paired *t*-test or a Wilcoxon signed-rank test, the exact sign test makes no distributional assumptions, comparing only the frequency of positive or negative differences between paired samples. Using this technique, the *Relative abundance* and *Relative structural value* of ash species were compared between 13 participant properties and UFA data from surrounding municipality of each propertey. Three sites were excluded from analysis because no UFA data had been collected in their vicinity.

3.2.6 Data Analysis

As a check on the external validity of site selection, inventoried and non-inventoried UPP were compared using two-sample *t*-tests of five geographic variables. Following these tests, a series of exploratory and inferential analyses were conducted using inventoried UPP as the experimental unit. First, as a descriptive tool, hierarchical cluster analysis was employed to define a typology of UPP by site characteristics. Secondly, the prevalence of ash trees were compared both among participant properties, and between properties and their surrounding urban forests, using

ANOVA, post hoc contrasts, and exact sign tests. Finally, ash *Relative importance value* and *Relative structural value* were were modeled as functions of site characteristics, using multiple linear regression.

Many analyses were conducted using relative species composition indices, calculated as a tree species' contribution to percentage of a site total. This method has the effect of giving greater weight to individual trees on sites with fewer total trees. An alternate method of comparing measurements across sites would be to standardize tree counts or basal area by parcel area inventoried. However, relative values will be employed here, because this method gives equal weight to each site, rather than individual trees. This method of calculation aligns with an analytical focus characteristics and decision-making at the household level, regardless of property size.

Two-sample *t*-tests, ANOVA and post-hoc contrasts were conducted in the R base package (R Core Team 2018), using RStudio (RStudio Team 2019) (hereafter 'R'). Cluster analysis was also conducted in R, using the package 'cluster'. Exact sign tests and multiple linear regression were conducted in SPSS version 25.0 (*IBM SPSS for Windows* 2017) (hereafter 'SPSS').

3.3 Results

3.3.1 Data Validation

Site inventories were conducted at 16 of 28 UPP properties, yielding a 57% sample. Sites that were not inventoried were omitted because of lack of homeowner interest in research participation. As a check on the representativeness of the 16-site sample, I compared means of five geographic variables between inventoried and non-inventoried properties. While there was a

marginally significant difference in tree cover between inventoried and non-inventoried sites (p=0.053), Welch's two-sample *t*-tests indicated there were no differences in means among *Parcel size, Years since home construction, Historical ash relative abundance,* and *Years since EAB detection* at the α = .05 level of significance. These results, summarized in Appendix A, indicate that the 16 properties inventoried provide a representative sample of the properties of all urban participant homeowners in the 2018 EABTP.

3.3.2 Cluster Analysis of Participant Properties

Averaged characteristics of all 28 UPP describe properties that are relatively large (x = 0.587 ac or 0.237 ha), wooded (mean tree cover = 47.8%), and that were developed in the late 1950s (mean age of home = 61.6 years). County-level (FIA) relative ash abundance averaged 3.59% for UPP, more than double the statewide number, and the average local age of EAB infestation was 3.89 years. Property characteristics for all 28 UPP are summarized in Table 1.

Table 1. Characteristics of all EABTP urban participant properties (n = 28).

	$\bar{x}$	SD
Parcel size (acres)	0.587	0.106
Parcel tree cover (%)	0.475	0.053
Years since home construction	61.6	7.9
Historical ash relative abundance[1] (%)	3.59	0.53
Years since EAB detection	3.9	0.7

[1]Summarized at the county level from pre-EAB FIA data (1998-2002)

To help characterize the types of neighborhoods which benefitted from EABTP, I developed a a typology of inventoried urban participant properties. Typologies are a common tool in landowner research, used to segment groups with minimal loss of information (Dayer et al. 2014). Using the R package 'cluster' I conducted a hierarchical cluster analysis using normalized values of the variables *Parcel size*, *Parcel tree cover*, and *Years since home construction*. This analysis met the minimal sample size threshold of 2^k, where k is the number of variables (Dolnicar 2002). From the resulting dendrogram (Figure 4), I selected a 3-cluster solution as the most interpretable, yielding two clusters of five properties each, and one of six. Mean values for property characteristics used in analysis are shown by cluster in Table 2, which includes additional site and species composition characteristics.

Cluster analysis yielded a meaningful typology, based only on the physical characteristics of parcel size, tree cover, and age of the home. Properties in Cluster 1 were largest, with a mean area of 1.00 acres (0.40 hectares), had the highest tree cover ($\bar{x}$ = 80.8%) and were developed in the mid-20th century (mean age = 42.8 years). These characteristics describe large, wooded exurban properties, often built into forested areas, and are termed here *Wooded exurban*. Associated species composition data (Table 2) indicated that properties in Cluster 1 had, on average, the highest total basal area ($\bar{x}$ = 60.2 ft^2) for all trees, but the lowest average relative basal area ($\bar{x}$ = 27.0%) for ash species.

Properties in Cluster 2, were smaller (mean area = 0.38 ac or 0.15 hectares), had a relatively lower amount of tree cover (43.2%) and were developed pre-WWII (mean age of house = 100.8 years). These characteristics include landscaped properties of urban neighborhoods developed in the 1930s and before, termed here *Historic urban*. On these

properties, both the relative abundance ($\bar{x}$ = 19.6%) and relative structural value ($\bar{x}$ = 43.0%) of ash species were higher than in the other clusters (Table 2).

Finally, characteristics of properties in Cluster 3 fell mostly between those of the other two—size and tree cover was moderate (mean area = 0.47 ac or 0.19 hectares, mean tree cover = 41.5%), as was mean age of development (25.8 years). These characteristics describe suburban development of recent decades, termed here *Contemporary suburban*. This typology of properties, in addition to its use as a descriptive tool, contributed categorical predictors to models of site species composition. On average, these properties had the lowest total basal area for all trees ($\bar{x}$ = 28.2 ft^2), and the lowest relative abundance of ash species ($\bar{x}$ = 13.2%) (Table 2).

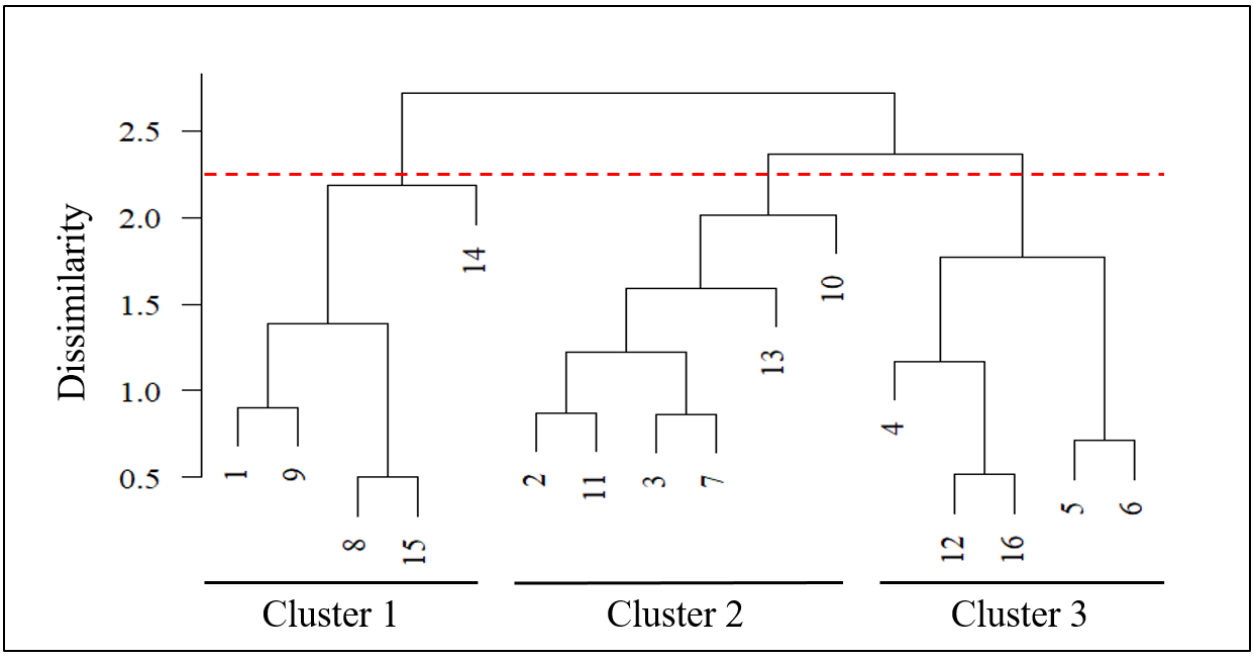

Figure 4. Hierarchical cluster analysis dendrogram of Urban Participant Properties (n=16), calculated from a distance matrix of *Parcel tree cover*, *Parcel size*, and *Years since home construction*. The cut-off point for a three cluster solution is represented by the red dotted line.

Table 2. Property characteristics by cluster membership for 16 inventoried Urban Participant Properties. Mean values are shown.

	Cluster		
	1 *Wooded exurban*	2 *Historic urban*	3 *Contemporary suburban*
Parcel size (acres)	1.00	0.38	0.47
Tree cover (%)	80.8	43.2	41.5
Years since home construction	42.8	100.8	25.8
Historical ash relative abundance (%) (county-level FIA data)	2.8	3.8	2.9
Years since local EAB detection	7.0	2.8	2.8
Number of trees on property (> 4" DBH)	33.0	15.8	21.0
Total basal area (ft^2)	60.2	28.7	28.2
Ash relative abundance (%)	17.0	19.6	13.2
Ash relative basal area (%)	27.0	43.0	31.4

3.3.3 Comparison of Species Composition Among Sites

Across all 16 inventoried UPP, white ash (*Fraxinus americana*) topped most measures of species composition. In absolute terms, as measured by total tree count (59) or total basal area (234 ft^2 or 21.8 m^2), white ash surpassed all other species by a factor of more than four. Similarly, white ash ranked higher than all others species by relative abundance, indicating that on average, it was the most common tree on each site. An ANOVA and post-hoc Tukey's HSD test demonstrated a statistically significant difference in relative abundance between white ash and all other species, with the exception of red maple (Table 3).

As measured by relative structural value—an appraisal value calculated from trunk diameter, condition, and species—white ash was also the highest-ranked species. In this case, there was a statistically signicant difference between white ash and all other species (Table 3), demonstrating that on average, this species provided greatest contribution to property value of all

tree species recorded. Figures 5 and 6 display the distributions of inventoried species by relative measures across sites. Notably, while white ash represented 16% of mean relative abundance, green ash (*Fraxinus pennsylvanica*) was present on only one site, with a mean relative abundance of 0.27%.

As with species composition, *F. americana* heavily contributed to calculated tree benefits across all sites. Tree benefits calculated by Eco include monetized values for total and annual carbon storage, runoff avoided, pollution removal, energy savings, and carbon emissions avoided. For *F. americana,* the summed monetary value of these five benefits, averaged across all sites, was nearly 6 times greater than for *Liriodendron tulipifera* L., the next largest contributor. Summaries of tree benefits, site characteristics, and species composition indices are included in Appendix A.

3.3.4 Comparison of Species Composition Between Sites and Surrounding Urban Forests

At a glance, species composition figures drawn from municipal UFA data appeared noticeably different from data collected at sites. Species with highest mean relative abundance for Roanoke, Charlottesville, and Falls Church included both the invasive species, *Ailanthus altissima* (Mill.) Swingle, and the ornamental *Cornus florida* L. Species rankings by structural value, on the other hand, were dominated by overstory trees including *Liriodendron tulipifera* and *Liquidambar styraciflua* L. Figures 7 and 8 show the distributions of species by relative abundance and relative structural value, averaged across all three UFA municipalities.

Results from exact sign tests indicated that both ash relative abundance and relative structural value were significantly higher on participant properties than in surrounding urban forests. In the case of relative abundance of ash, values were higher for all 13 properties relative

to municipalities, with a statistically significant median decrease of 10.4% (p <.001). In the case of relative structural value of ash species, values were higher for 12 of 13 sites, with a statistically significant median difference of 26.3% (p = 0.003) (Table 4).

Table 3. ANOVA comparison of the top ten species by relative abundance and relative structural value across 16 inventoried urban participant properties. Mean values are expressed as a percent of site totals.

Relative abundance			Relative structural value		
Species	$\bar{x}$	Group[1]	Species	$\bar{x}$	Group[1]
Fraxinus americana	16.59	a	*Fraxinus americana*	31.38	a
Acer rubrum	8.55	ab	*Liriodendron tulipifera*	9.04	b
Celtis occidentalis	4.92	b	*Acer rubrum*	7.70	b
Cornus florida	4.36	b	*Acer saccharinum*	5.79	b
Acer saccharinum	4.22	b	*Quercus rubra*	4.44	b
Morus alba	3.72	b	*Quercus alba*	3.34	b
Liriodendron tulipifera	3.68	b	*Quercus palustris*	3.10	b
Pinus strobus	3.59	b	*Morus alba*	2.60	b
Juglans nigra	3.16	b	*Juglans nigra*	2.55	b
Magnolia grandiflora	2.80	b	*Celtis occidentalis*	2.44	b
F	2.76		F	8.67	
p	**0.01**		*p*	**<.001**	

Bolded values indicate significance difference in means at the α = .05 level of significance.
[1]Group labels display results of post-hoc Tukey's HSD tests, indicating significant differences by letter.

Table 4. Results from exact sign test of species composition between 13 Urban Participant Properties and surrounding urban forests. Properties were paired with nearby or surrounding municipalities; median differences and Z-statistics reflect the aggregated differences between the two.

Dependent variable	Participant properties	Surrounding urban forests	Median difference	*Z*	*p*
Ash relative abundance (median)	14.3%	3.9%	10.4%	-3.33	**<0.001**
Ash relative structural value (median)	30.8%	10.4%	26.3%	-2.77	**0.003**

Bolded values indicate significance at the α=0.05 level.

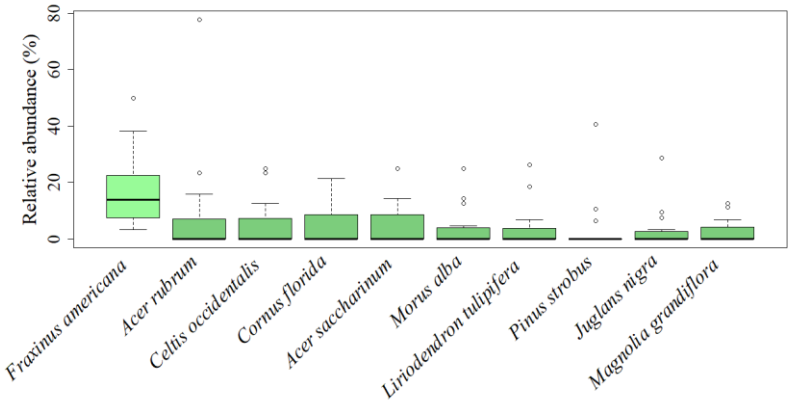

Figure 5. Relative abundance of species across 16 EABTP Urban Participant Properties. Top ten species by relative abundance are shown.

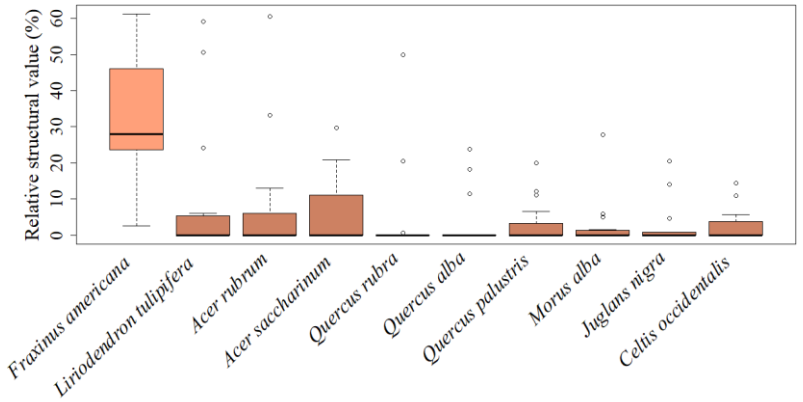

Figure 6. Relative structural value of species across 16 EABTP Urban Participant Properties. Top ten species by relative structural value are shown.

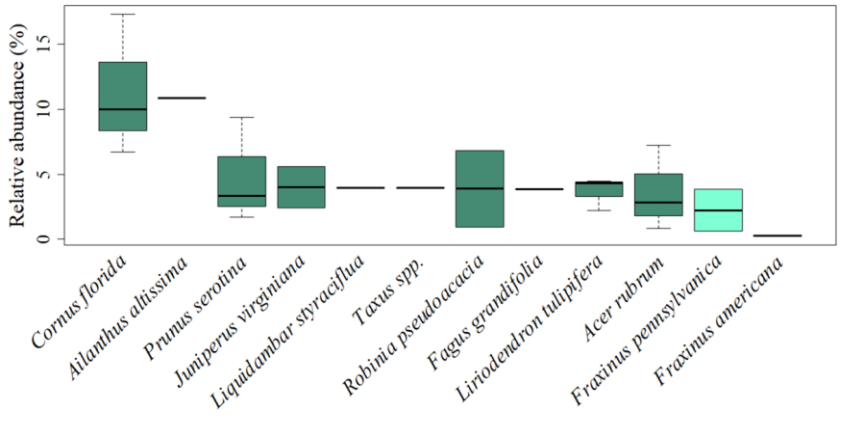

Figure 7. Relative abundance of species across 3 Virginia municipalities. Data were drawn from 2010-2011 Urban Forest Assessments of Falls Church, Charlottesville, and Roanoke. Top ten species by relative abundance are shown, with the addition of *F. pennsylvanica and F. americana.*

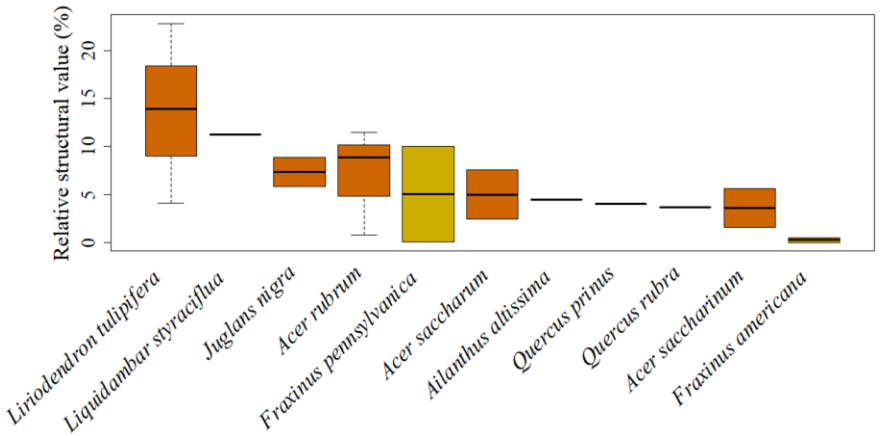

Figure 8. Relative structural value of species across 3 Virginia municipalities. Data were drawn from 2010-2011 Urban Forest Assessments of Falls Church, Charlottesville, and Roanoke. Top ten species by relative abundance are shown, with the addition of *F. americana.*

3.3.5 Linear Models of Species Composition

Following cluster analysis of property characteristics, I modeled species composition across properties using multiple linear regression in SPSS. Of the four ash-related variables measured or derived from inventory data (*Relative abundance, Relative basal area, Relative importance value,* and *Relative structural value*), I selected the two containing the most information as dependent variables: *Relative importance* and *Relative structural value*. The index *Relative importance* combines both species abundance (tree count) and leaf area in a single measure, while the index *Relative structural value* incorporates trunk diameter, a measure quadratically proportional to basal area, in addition to tree condition and species rating.

With the intention of building predictive models of site species composition that could be replicated without on-the-ground data collection, I selected only publicly-accessible predictors. Those entered in the models were cluster membership, *Years since EAB detection,* and *Historical ash abundance*. Cluster membership summarized the variables of *Parcel size, Parcel tree cover,* and *Years since home construction,* and was entered in the model using dummy variables. Cluster 2 was left out of models as a reference level—with the smallest lot size, least tree cover, and oldest age of home construction, it provided the most interpretable point of comparison.

Models of ash relative abundance and relative structural value met assumptions for independence of observations, linearity, homoscedasticity of variance, collinearity, normality, and lack of influential points. However, testing indicated one outlier and nine points with high leverage in each model. The presence of several unusual points—which were not removed from the model—necessarily reduced model fit and indicate the need for a greater sample size in future analyses.

The model of ash *Relative importance value* fit poorly (R^2=1.97, Adj. R^2 = -0.095), was not significant overall (F = 0.674, *p* = .623), and did not contain any individually significant predictors (Table 5). A negative value for adjusted R^2, which is corrected for the number of parameters in the model, indicates that a model using the constant alone fits the data better than the full model. Modeled ash *Relative structural value* fit slightly better (R^2 = 0.402, Adj. R^2 = 0.185), although it too showed no significance overall (F=1.85, *p* = .190) and contained no significant predictors. The only variable of marginal significance to *Relative structural value* was *Years since local EAB infestation* (ß= -0.663, *p* = .093).

Table 5. Summary of modeled ash importance and structural value across 16 urban participant properties in the 2018 EABTP.

	Model of ash Relative importance value		Model of ash Relative structural value	
Independent Variables	*β* coeff.	*p*	*β* coeff.	*p*
(Constant)	--	0.010	--	0.001
Years since local EAB detection	-0.544	0.220	-0.663	0.093
Historical ash abundance (FIA)	-0.331	0.339	-0.314	0.296
Cluster 1 - *Wooded exurban*	0.033	0.933	-0.134	0.692
Cluster 2 - *Historic urban*	--	--	--	--
Cluster 3 - *Contemporary suburban*	-0.317	0.330	-0.461	0.114
R^2	0.197		0.402	
Adjusted R^2	-0.095		0.185	
F	0.674	0.623	1.850	0.190

3.4 Discussion

While broadly generalizable conclusions are unlikely from a small sample size, cluster analysis provided some insight into the locations where 2018 EABTP funding was utilized. Participant properties were split in roughly equal numbers between large, exurban wooded properties, smaller, urban (and older) properties, and suburban properties with characteristics roughly in between those of the others. This distribution of participant properties is not necessarily intuitive—one might expect a greater share of smaller participant properties with a single, specimen ash tree, and correspondingly low tree cover on a smaller lot. Instead, most urban-area residents interested in EABTP appear to be located on the suburban and exurban periphery, on parcels with relatively high tree cover—some likely built into secondary-growth forests.

Tests for differences in means of species composition indices across inventoried sites demonstrated the consistent dominance of white ash on these properties. With the exception of red maple, the relative abundance and structural value of white ash were significantly greater than all other species. If the opposite had been true—and ash trees were present in roughly equal number to several other species—it might suggest that tree preservation was driven primarily by appreciation of individual trees. However, the observed results indicate an association between the relative importance of ash on a residential property and the homeowner's interest in cost-share participation.

Exact sign tests confirmed that the relative abundance and value of ash trees were greater on participant properties sites than in the surrounding cities. These results must be qualified by noting the age and standard errors of UFA measurements (summarized in Appendix A), and the low sample size (n = 13) of properties compared. However, the age of the UFA datasets may in

fact serve to support the test results. UFA data were collected from 2010-2011, before the ash borer was established outside of northern Virginia. During this period, EAB was present in Falls Church, but likely did not reach Roanoke until 2016 and Charlottesville in 2017. It is noteworthy that relative ash importance and value were higher in 2018 on participant properties than compared to citywide pre-EAB figures, in the case of Roanoke and Charlottesville. These results again suggest that properties where ash preservation takes place are likely to be outliers relative to neighboring properties in terms of the number and value of threatened trees.

Because of the small sample size, only tentative conclusions could be inferred from linear modeling results, even if models had fit the data closely. The one marginally significant association was between the predictor *Years since EAB infestation* and the dependent variable *Ash relative structural value.* This negative association is intuitive—as time passes since a local initial EAB detection, the number and condition of ash trees decline, leading to a decrease in value. Interestingly, the same predictor was not associated with *Relative ash abundance*, which only accounts for the number ash trees, and not their condition. Since properties had, on average, experienced about four years of a local EAB infestation, it is likely that a sharp drop in relative abundance of ash trees might be apparent if this analysis were repeated one or two years later, as greater mortality of infested trees would likely be evident. A broader discussion of this topic and other study findings, implications, and directions for further study are included in Chapter 6.

CHAPTER 4 - HOMEOWNER ENGAGEMENT IN LANDSCAPE TREE PRESERVATION

4.1 Introduction

Financial incentive programs have been employed by U.S. agencies for decades to further soil conservation, wildlife, or forestry objectives among rural landowners, yet have rarely been employed in urban areas. However, among researchers and practitioners there is a growing focus on the health and environmental benefits provided by landscape trees and other urban natural resources (Kondo et al. 2018). Considering that over 80% of the U.S. population now resides in urban areas (USFS 2019b), it is likely the demand for public funding of urban conservation efforts will grow.

While the relatively small parcels of suburban and urban development could be viewed as a hindrance to the widespread impact of an incentive program, there may also be advantages unique to funding conservation work in cities. Compared with agricultural or forested land, the number of property owners with a personal stake in local conservation actions is many times greater in urban areas, when calculated by tree or by acre. Because of cities' density, incentive programs aimed at enlisting urban homeowners in forest health initiatives have the potential to encourage widespread engagement in pest detection and strongly augment public investment in pest management. While rare, successful eradication campaigns such as those targeting Asian longhorned beetle in Chicago, IL, Worcerster, MA, and Jersey City (Haack et al. 2010) have been accomplished through rapid, costly, and coordinated actions in urban forests.

Virginia Department of Forestry's (VDOF) Emerald Ash Borer Treatment Program (EABTP) is one of few incentive programs to include urban property owners among eligible participants. Consequently, this program provided an important opportunity for study. In its

initial year, this program provided 50% cost-share payment for treatment of ash trees to 90 private property owners, of which 28 were in urban areas. Regardless of location, EABTP funding was used for insecticidal treatment of individual landscape trees, rather than silvicultural treatment of a forest stand as might be conducted in a traditional cost-share program. In this regard, the experience of rural participants was similar to that of urban participants.

To examine the factors influencing a homeowner's participation in a forest health cost-share program, surveys were distributed to homeowners drawn from two distinct target populations. The first consisted of all homeowner participants in the 2018 EABTP (hereafter, 'program participants'). The second was defined loosely as shade-tree-owning Virginia homeowners in three urban study areas (hereafter, 'general households'). The survey instruments designed for each group shared most survey items, which allowed for comparisons between program participants and general households, who could be viewed as *potential* participants.

Stated most broadly, the objective of this research was to help inform future urban forest health initiatives. More specifically, this research addressed questions regarding homeowners' willingness to pay for the preservation of threatened trees, homeowners' interest in cost-share funding, and the difference in attitudes between program participants and a sample of urban households. By examining perceptions among both groups, this research studied the feasibility of an EABTP-like program among a broad group of urban homeowners, in addition to studying the first-year implementation of the EABTP itself.

The theoretical framework adopted here combined elements of the Theory of Reasoned Action (TRA)—focused on the predictive power of specific attitudes and underlying beliefs (Ajzen and Fishbein 1980)—and economic choice modeling, which employs externally-measurable variables as model parameters. This strategy reflected the research objective of

informing urban forest health initiatives, by identifying information with greatest utility to a hypothetical program manager—whether drawn from public databases or opinion surveys.

4.2 Methods

4.2.1 Construction of Survey Sampling Frames

For all homeowner survey research, the individual household was considered to be the survey element. Survey items did request ownership status, age, and gender, but did instruct recipients regarding which member of the household should complete the survey. All survey recruitment materials and instruments were submitted first to the Virginia Tech IRB and subsequently approved by Western IRB. An IRB Exemption letter is included in Appendix H.

Program Participants

Homeowners accounted for 90 of 107 total participants in the 2018 EABTP. Of these, 28 were in urban locations, as defined by Census Urban Areas (CUAs). All 90 program participants, including those in rural and urban locations, were considered to be the target population. While the use of unique survey links allowed for disaggregation of response data by location, analysis was conducted with aggregated urban and rural data. This decision reflected an assumption, supported by later analysis, that homeowner decision-making regarding preservation of individual landscape trees would not greatly differ between rural and urban locations. Survey requests were sent only to 77 of 90 program participants—those who had previously opted-in to follow-up contact when applying to the EABTP. For the purposes of calculating response rate and examining potential nonresponse bias, however, the entire population of 90 homeowner particpants was considered to have been part of a complete sample.

General households

Construction of a sampling frame of Virginia urban homeowners with no known connection to the EABTP was accomplished using publicly-available geographic and tax assessment data. Primary household selection criteria included (1) urban location, (2) owner occupancy, and (3) likely shade tree ownership. Taken together, criteria were intended to select households with a personal stake in urban tree preservation—those whose attitudes and actions were directly relevant to urban forest health. The three primary criteria were in turn defined by a series of filtering steps conducted in ArcGIS Pro. Lists of data sources used in each step of this process are summarized in Appendix B .

(1) Urban location

Virginia counties and independent cities were initially stratified by time elapsed since EAB infestation. Strata definitions were borrowed from VDOF criteria establishing EABTP funding priority (VDOF 2018b): counties with no detected EAB presence (*undetected),* counties where EAB was detected in 2015 or later (*recent*), and counties where EAB was detected before 2015 (*established*). From within each EAB stratum, the boundaries of the most populous Census Urban Area (CUA) were selected to define study areas, then further narrowed to selected contiguous city and county jurisdictions. Limiting household sampling to a total of eight jurisdictions increased efficiency of data compilation and bulk mailing, as compared to sampling throughout an entire CUA. The resulting study areas, referred to here as Elizabeth River, Roanoke Valley, and Northern Virginia, correspond with the EAB strata of *undetected*, *recent,* and *established*, respectively. Figure 9 displays Virginia counties by EAB strata, CUAs, and study areas.

(2) Owner occupancy

Parcels within each study area were filtered to identify households with sole, direct responsibility for property maintenance. For this reason, selection criteria included only owner-occupied, single-family residences, and excluded rented homes, condominiums, or other multi-unit parcels.

(3) Shade tree ownership

Selected owner-occupied parcels with single family residences were further filtered to include only those with a high probability of shade tree ownership, using criteria for minimum area (0.2 ac) and minimum tree cover (25%). Together, these ensured an absolute minimum of tree cover and a minimum relative to parcel size. This step was intended to improve the probability of selecting homeowners with direct ownership of multiple landscape trees and accustomed to the responsibilities of landscape tree maintenance.

From parcel lists aggregated by study area, 500 records from each were selected at random to form a mailing list. Address validation removed 12 records, resulting in a final mailing list of 1,488 households. Table 6 outlines sampling frames and mailing list totals for each study area. Since the number of households in each sampling frame were not equal, the probability of selection was higher for households in study areas with fewer members. Mailing lists were not adjusted for proportionalilty to population for two reasons: (1) study area boundaries themselves did not reflect regional population distribution, and (2) roughly equal numbers of of survey responses were desired from each study area, to facilitate comparisons.

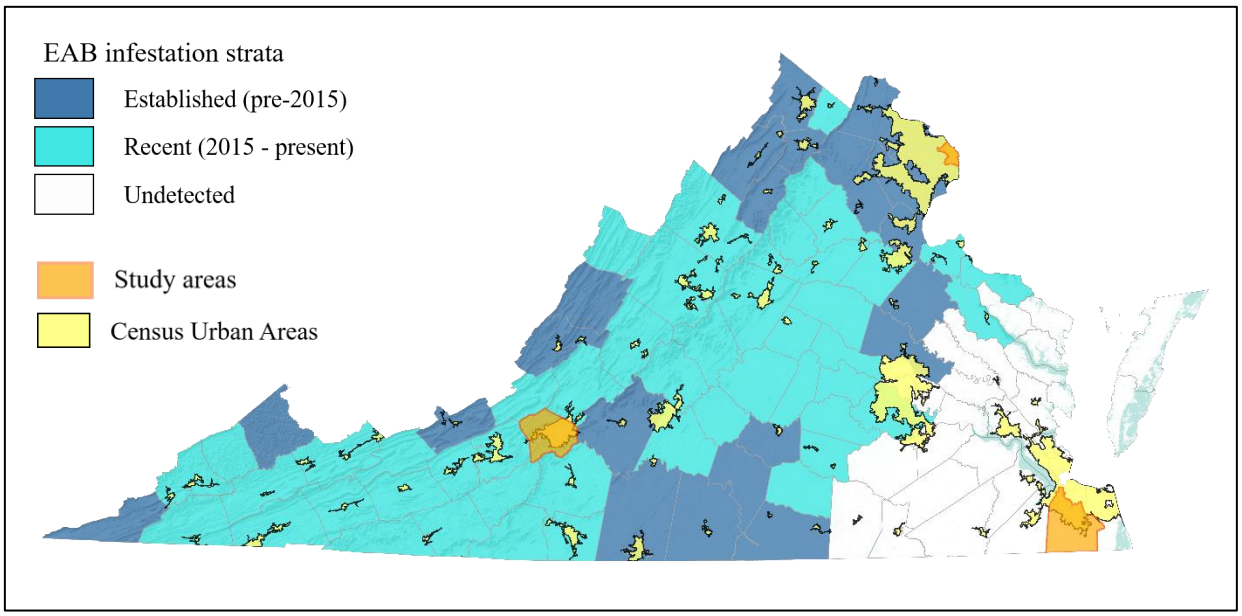

Figure 9. Map of EAB infestation strata, Census Urban Areas, and study areas for the general household survey. Infestation strata were defined by the year of initial EAB detection in each Virginia county or independent city.

Table 6. Total population, sampling frame size, and number of survey recipients, by study area for general household survey.

Study area	Jurisdictions	Total population[1]	Number of households meeting criteria (Sampling frame)	Sampling frame by study area	Survey recipients by study area
Northern Virginia	Arlington County	226,092	7,775	10,964	495
	Alexandria City	151,473	2,045		
	Falls Church City	23,620	1,144		
Roanoke Valley	Roanoke City	99,329	5,651	12,806	497
	Roanoke County	93,655	6,087		
	Salem City	25,290	1,068		
Elizabeth River	Chesapeake City	233,194	7,039	10,676	496
	Portsmouth City	96,071	3,637		
Total		948,724	34,446	34,446	1,488

[1]U.S. Census Bureau (2017a)

4.2.2 Construction and Pre-testing of Survey Instruments

While survey instruments for participants and general households were distributed by different methods, both were constructed with Qualtrics (Qualtrics 2018), employed the same structure and shared most survey items. The most important difference between the two survey instruments was that participants homeowners were asked about their experience with the EABTP, while general households were asked about interest in a hypothetical cost-share program for landscape tree preservation. With the exception of exploratory factor analyses, data from the two surveys were not aggregated for analysis.

Program participants

The survey instrument designed for participants consisted of 28 questions, with an estimated response time of 12 minutes. Survey items consisted primarily of multiple-choice questions, including one multi-item index, and a single ranked-choice response item. A summary of survey items and measurement scales is given in Appendix B, while the full text of this survey instrument is available in Appendix G.

General households

The survey instrument designed for general households consisted of 26 questions, with an estimated response time of 15 minutes. Wording of survey items was similar to those used for the participant survey but was modified to reflect two assumptions: first, that recipients would likely not be aware of the EABTP, and secondly, that most were unlikely to have ash trees on their properties. This second assumption was based on Virginia Urban Forest Assessment data, discussed in Chapter 3, indicating pre-EAB relative abundance of ash species did not exceed 4%

in Virginia municipalities. For this reason, the wording of survey items discussed “landscape tree preservation” and “threatened trees” rather than ash preservation or EAB specifically. The full text of this survey instrument is available in Appendix G.

Pre-test of Survey Instruments

To assess clarity and measurement accuracy of survey questions, a combined pre-test for homeowner survey instruments was conducted in August 2018, using the wording of the participant version. This pre-test survey instrument included all proposed survey items and one text-entry response item, asking for respondents’ comments regarding length, wording and logical flow. Pre-test survey requests were emailed to Virginia Cooperative Extension (VCE) agents working in urban areas (n = 50). This group was selected as a pre-test sample under the assumptions that many would be familiar with invasive species management, and likely would own homes within the urban areas they served. Seventeen recorded responses assisted in the improvement of several ambiguously-worded questions, and in the re-ordering of a measurement scale which initially produced inaccurate results.

4.2.3 Data Collection

Program participants

A web survey was selected as an efficient and appropriate mode to reach participants. Because current email addresses were uniformly available for all members of the sampling frame, the potential for technological response bias was minimized (Vaske 2008). Survey requests were emailed to participants, while the web survey itself was hosted by Qualtrics. In September 2018, ‘opt-in’ participants (n=77) were contacted by email with an introductory survey request. Building on elements of Dillman’s Tailored Design Method (Dillman et al.

2009), up to two reminder emails were sent with varied content to nonrespondents, separated by periods of ten days. Survey requests contained unique survey URLs, which allowed tracking of recipients' response status, and later joining of response data with geographic variables, such as tree cover. Recruitment materials and survey instrument for the participant survey are available in Appendix F. Response data were recorded and stored by Qualtrics during the period the survey was available online. The participant survey was closed at the end of December 2018, about three months after homeowners were initially contacted.

General households

A mixed-mode web+mail survey was selected to reach general households in the study areas of Northern Virginia, Roanoke Valley, and Elizabeth River. Mixed-mode surveys have the potential to compensate for weaknesses of web- or mail-only designs by offering recipients the choice of their preferred mode of response (Vaske 2008). Other advantages of a web+mail survey design over a mail-only design include lower costs, reduced response times, and potentially improved response rates (Dillman et al. 2009). While some researchers studying web+mail surveys have noted reduced response rates compared to mail-only surveys (Medway and Fulton 2012), others have documented an upward trend in the proportion of web respondents over time (Lesser and Newton 2016). Studies employing a web+mail survey design have also reported that younger age groups show preference towards an online response option (Sexton, Miller, and Dietsch 2011, de Bernardo and Curtis 2013). These findings suggested that a web+mail design would be an appropriate tool for reaching urban areas, where the adult age distribution is younger than that of rural residents (U.S. Census Bureau 2016). This assumption was later examined in an analysis of response mode.

Web and mail versions of the survey instrument were created in Qualtrics and in booklet form. To allow tracking of individual responses, identification codes were assigned to each of 1488 households. This unique code was printed on each recruitment letter and survey booklet; those responding to the web version of the survey were asked to enter the code at the beginning of the questionnaire. Except for this initial item which did not appear in the survey booklet, there were no differences in the wording or order of questions between web and mail survey versions.

In September 2018, general households were contacted by mail with an introductory letter informing them about this research project and requesting their participation. The introductory letter outlined two options for those interested in completing the survey: waiting to receive a survey booklet through the mail or completing the same survey online. The letter also supplied instructions and a URL for the web option. Two weeks following the mailing of the introductory letter, survey packets were mailed to all homeowners (n=1,488), containing a cover letter, a survey booklet, and pre-paid business reply envelope. Like the introductory letter, the enclosed cover letter provided a URL and instructions for recipients who preferred to complete the survey online. After compiling early web and mail responses, a third and final letter was mailed to nonrespondents (n=1,136) two weeks after mailing the survey packets. This letter requested participation, provided instructions for online survey completion, and offered to send a replacement survey packet upon request. The survey instrument and recruitment materials for the general household survey are available in Appendices F and G.

Web survey response data were recorded and stored by Qualtrics during the period the survey was available online. At the end of December 2018, the general household web survey was closed—about three months after homeowners were initially contacted. Survey booklet

responses received by mail were manually entered in Qualtrics with postmarked dates individually recorded.

4.2.4 Data Analysis

Recoding of Binned Data

Before other analyses were conduted, binned survey and Census data which represented underlying continuous data were recoded as continuous variable, using the R package 'binequality.' Bin midpoints were calculated as the mean value of upper and lower bin bounds, and then substituted as the recorded value. For instance, a survey response of *$50,001 to $75,000* for household income was interpreted as the mean value of $62,500.50. For uppermost bins with no upper bound, a pseudo-midpoint was estimated, using a Pareto distribution fitted to data from the two highest bins (von Hippel et al. 2017). For measures of household income, this function was fitted with an alpha value of 1.11, approximating a traditional Pareto wealth distribution. For all other binned variables with undefined upper bounds, this function was fitted with an alpha value of 111, to produce much more conservative estimates. This technique improved interpretability of results, and potentially helped re-create a more accurate distribution of data. Aside from household income, this technique was used calculate midpoints and pseudo-midpoints for variables including *Age, Age of home*, *Number of years living at property*, *Number of trees on property*, and *Years of education.*

Tests for Nonresponse Bias

To determine whether survey response data provided a basis for generalizable conclusions, tests of nonresponse bias were conducted by comparing means of external variables between respondent and nonrespondent groups. External variables included two parcel-level

property characteristics and four demographic characteristics summarized at the level of Census Block Groups. For parcel-level comparisons, *Parcel size* and *Parcel tree cover* were calculated in ArcGIS from the Virginia Parcels geodatabase (VGIN 2018a) and the Virginia Statewide Land Cover Database (VGIN 2018b).

For Block Group-level comparisons, Census-derived estimates served as geographic proxies for households contained within them. Testing of proxy variables, including aggregate Census data, has increasingly been used by researchers to assess and correct for survey nonresponse bias (Biemer and Peytchev 2013), and is an efficient option when follow-up contact with nonrespondents is not feasible (Hansen et al. 2007).

Using the U.S. Census Bureau's American Factfinder (U.S. Census Bureau 2017a), I accessed 2017 American Community Survey 5-year estimates of demographic variables for Virginia Block Groups of all respondents and nonrespondents to either survey. Census Block Groups are the smallest U.S. Census geographic divisions, drawn to include 600 to 3,000 people (U.S. Census Bureau 2010). The tables I selected for analysis were *Median Age by Sex* (B01002), *Median Household Income in the Past 12 Months* (B19013), *Educational Attainment for the Population 25 Years and Older* (B15003), and *Race* (B02001). Households in question were joined to Block Group estimates, creating a many-to-one relationship where several households might share the same Block Group estimate. Frequency data from the Census table *Race* were used to calculate a proportional variable *Minority Proportion*, defined as the proportion of all residents who did not identify as 'White alone.'

Continuous proxy variables *Parcel size, Mean age, Median household income,* and *Mean years of education* were compared using Welch's t-test, while proportional variables *Parcel tree cover* and *Minority proportion* were compared using Pearson's χ^2. Because repeated testing of

the same dependent variable (respondent group) raised the probability of Type I error, a Bonferroni correction was applied to test results, lowering the significance level to $\alpha = 0.008$.

Factor Analysis of Attitudes Towards Urban Trees

To reduce the number of predictor variables and examine potential latent structures (Yong and Pearce 2013), an Exploratory Factor Analysis (EFA) was conducted of five attitudinal survey items measure on identical 5-point Likert scales. In these survey items, respondents were asked to rate the strength of their agreement with five statements regarding the importance of urban landscape trees. For this analysis only, responses were aggregated between participants and general households, to facilitate cross-sectional comparison. Analysis was conducted using the R packages 'pysch' and 'GPArotation,' with varimax rotation selected. Two factors were retained, as indicated by the inflection point of eigenvalues in a scree plot (Costello and Osborne 2005).

Cluster Analysis of Ranked Motivations for Tree Preservation

Cluster analysis, like factor analysis, is typically employed as a dimension-reducing technique. In this case, cluster analysis was used to accomplish the opposite: from a single item on each survey, a categorical typology of homeowners was developed. The survey item in questions asked respondents to rank six motivations for ash tree (or shade tree) preservation in order of personal importance. Response data collected from this item consisted of an ordered vector of numbers 1-6, representing six ranked motivations, including a write-in option. This form of response data is potentially information-rich—examples of applications for clustered ranking data include political affiliation patterns in voting records (Gormley and Murphy 2008), or market segmentation by brand preference (Müllensiefen et al. 2018).

Ranking of motivation for preserving trees intended to measure the degree to which intrinsic or extrinsic motivation informed respondents' attitudes. Researchers have theorized that intrinsic motivations—reasons for action based on personal drive or interest—are potentially more stable than extrinsic motivations, such as financial gain (Ryan and Deci 2000). Of the five options given, intrinsic motivations were represented by the provision of wildlife habitat and prevention of species endangerment, while extrinsic motivations were represented by the importance of trees as attractive landscape elements or their contribution to property value. The fifth motivation listed—trees' provision of shade—did not clearly fit in either category.

Ranking data were analyzed using the R package 'Rankcluster.' The sorting algorithm employed measures distance from each ordered response to a given number of modal ranking patterns, forming clusters based on relative similarity (Jacques, Grimonprez, and Biernacki 2016). The optimal number of clusters was determined from an inflection point of BIC plotted against the number of clusters, similar to the technique used in factor analysis. A 2-cluster solution was selected for participants, and 5-cluster solution for general households.

Linear Models of Behavioral Intention

Homeowner engagement in urban forest health was examined through linear models of two dependent, behavioral variables. These were respondents' level of *Tree preservation intention*—meaning their willingness to pay for ongoing tree treatment—and their level of interest in *Cost-share participation*. Survey item wording varied between the two survey instruments: program participants were asked specifically about ash tree preservation and the EABTP; general households were asked about the more generic topics of landscape tree preservation, and participation in a hypothetical program for assistance with tree treatment

expense. A summary of all survey questions is included in Appendix B, while the full survey instrument is included in Appendix G.

Models were constructed of predictor variables drawn from external geographic data and survey response data, including both factor indices and cluster membership, which were derived from survey response data. The full lists of predictor variables—which totaled 17 for participants and 25 for general households—were categorized into one of three predictor classes, each consisting of 4 to 8 individual predictors: *Property characteristics*, *Personal characteristics*, and *Attitudes*. In addition to aiding interpretability of results, the three predictor classes as ordered here represent an increasing difficulty of access, from the point of view of a public official. A full list of all predictor variables, organized by class, is included in Appendix B.

Model selection was accomplished by ranking of candidate models in order of decreasing Akaike's weight (w_i), a proportional measure of relative likelihood derived from AIC. This method of model selection relies on an information-theoretic framework in which multiple competing models are evaluated in terms of information loss, as measured by AIC (Symonds and Moussalli 2011). Models within 2 AICc (a version of AIC corrected for small samples) of top-ranking models were examined as competitors to top-ranked models if they contributed no more than one additional parameter, as recommended by Arnold (2010).

Candidate models were constructed from the predictor classes of *Property Characteristics*, *Personal Characteristics*, and *Attitudes*. For both dependent variables in question—*Tree preservation intention* and *Cost-share participation*—a total of seven candidate models were fitted, constructed from all combinations of individual, paired, and grouped predictor classes. This process was conducted for both participant and general household survey

response data, resulting in a total of four top-ranked models. All modeling was carried out using hierarchical multiple linear regression in SPSS.

4.3 Results

4.3.1 Summary of Response Data

Program participants

Over a period of about three months, 53 responses were recorded, representing a 69% of response rate out of 77 participants contacted. With the inclusion of 13 additional 'opt-out' EABTP homeowner participants in the sampling frame, this is equivalent to a 58% response rate overall. Calculated from the complete sampling frame, the margin of error for a 95% confidence level was 8.63%. This value represents the sampling error associated with a hypothetical 50/50 split response, calculated from sample size and final sample (number of responses) (Vaske 2008).

Among participant respondents whose locations were known, there were twice as many from rural areas (n =34) as from urban areas (n =17). On average, respondent properties were large ($\bar{x}$ = 30.62 ac or 12.39 ha) and had high tree cover ($\bar{x}$ = 58.6%). Length of time since local EAB detection varied between respondents from 0 (undetected) to 10 years (established), with a mean value of 2.4 years.

On average, respondents were nearing retirement (mean age = 59), had completed a graduate degree ($\bar{x}$ = 19.0 years of education), and were predominantly male (60.3%). All respondents who disclosed racial or ethnic identity (n = 50) identified as White. Average annual household income was $232,000, although the variability associated with this estimate was high (SD = $160,000). Respondents reported living on their properties for an average of 11.3 years, and a majority (56.6%) reported previously paying for insecticidal treatment of landscape trees.

Between maintained and unmaintained areas, respondents reported having over 20 trees on their property ($\bar{x}$ = 21.4) and spending close to $1000 annually on tree maintenance ($\bar{x}$ = $987).

A plurality reported first hearing about the EABTP from an arborist or landscape professional (n=13), followed by VDOF or VCE employees (n=12), then coworkers or friends (n=12). Asked about the importance of preserving ash trees in Virginia, participants' mean response was 4.4 on a scale from 1 (Not at all important) to 5 (Extremely important). When asked about the likelihood of regularly paying for ash tree treatment going forward, respondents' mean score was 4.6 on the same scale. Finally, when asked about interest in re-applying for EABTP funding, the mean score was also 4.6 on a scale from 1 (Not at all interested) to 5 (Extremely interested). Table 7 summarizes these characteristics alongside those of general households. Additional attitudinal response data are discussed below with exploratory and cluster analyses.

General households

More responses were received by mail (n=206) than online (n=142). After removing 15 blank or incomplete responses, a total of 333 usable responses remained. Two responses were excluded from analysis because respondents indicated they were renting their home, and thus did not meet sampling frame criteria. An additional 10 responses representing ash tree-owning households were excluded from primary analysis, because these respondents were asked alternate versions of many survey items. After removing unusable and incompatible responses, a total of 321 responses remained, for a final response rate of 21.6%. While this response rate was considerably lower than among participants, the calculated margin of error (4.84%) was smaller than that of the participant survey due to the larger sample.

In contrast to the predominantly rural participants, all respondents to the general household survey lived in urban areas. Respondents' average parcel size was 0.442 acres (0.18 ha), a fraction of the amount for participants, but still relatively large for urban areas. Average tree cover across all respondent parcels was 45.0%—well above the 25% threshold used in sampling frame construction. Of the three study areas targeted, 125 (38.9%) responses were received from Northern Virginia, 116 (36.1%) from Roanoke Valley, and 80 (24.9%) from Elizabeth River. As of 2018, EAB infestations had been present in these these study areas for 10, 2, and 0 years of EAB respectively. Across all responses, the average length of time since EAB detection was 4.7 years, about double that of participants.

Demographic characteristics of general households were similar to those of participants. On average, respondents were also approaching retirement age ($\overline{x}$ = 58.7 years) and had completed a four-year degree ($\overline{x}$ = 17.5 years of education). A majority of respondents were male (53.6%), although the overall ratio of males to females was more balanced than among participants. Of respondents who disclosed racial or ethnic identity, 94.8% identified as White, 2.9% as Black or African American, and 1.0% as Asian. Five other racial or ethnic groups comprised a total of 1.3% of respondents. Average annual household income was $312,000, although, as with participant data, variability was high and many responses were missing (SD=$310,000). General household respondents reported living in their present homes for an average of 17.1 years, a longer period than for participants, but only 14.8% reported previously paying for insecticidal treatment of landscape trees, compared with 56.6% for participants. Respondents reported an average of 11.1 trees on their properties, between maintained and unmaintained areas, and spent an average of $463 annually on tree maintenance—values roughly half of participants.

Only 33 respondents overall (10.2%) had heard of the EABTP; the most commonly cited source of information was associates or friends (n=10), followed by TV or other media (n=9), and VDOF or VCE publications (n=7). Asked about the importance of preserving threatened landscape trees, respondents' mean score was 4.0 on a scale from 1 (Extremely important) to 5 (Extremely important). When asked about the likelihood of regularly paying for treatment of threatened trees, respondents' mean score was 3.8 on a scale 1 (Extremely unlikely) to 5 (Extremely likely). Lastly, when asked about interest in applying for cost-share assistance with landscape tree preservation, respondents' mean score was also 3.8 on a scale from 1 (Not at all interested) to 5 (Extremely interested). These values are lower than those of parallel measure for participants, but are in regard to questions about a hypothetical pest threat. Table 7 summarizes respondent characteristics.

4.3.2 Tests for Nonresponse Bias

Tests of nonresponse bias by comparing means of external variables between respondent and nonrespondent groups. Two geographic, parcel-level variables and four demographic, Census Block Group-level variables were compared for both participant and general household survey groups. For participants, no differences were evident between respondents and nonrespondents in any of the tests, indicating a final sample that was representative of all homeowner participants. For the survey of general households, tests indicated that educational attainment was significantly higher among respondents than nonrespondents, and that there were marginally significant differences in household income and proportion of minorities. Taken together, these results indicate that general household survey respondents formed a group that was more educated, and likely less wealthy and racially diverse than the sampling frame itself. Complete results for tests of nonresponse bias are available in Appendix B.

Table 7. Summary of selected survey responses and external data for program participants and general households.

Selected responses	EABTP participants (n = 53)		General households (n = 321)	
	$\bar{x}$	SD	$\bar{x}$	SD
Located in Census Urban Area (%)	32.1	--	100	--
Parcel size (acres)	30.624	80.646	0.442	0.574
Parcel tree cover (%)	58.6	26.8	45.0	15.8
Years since local EAB detection	2.4	2.2	4.7	4.4
Gender (% female)	39.6	--	46.4	--
Age	58.8	12.0	58.7	12.0
Race or ethnicity (%)				
White	100	--	94.8	--
Black or African American	--	--	2.9	--
Asian	--	--	1.0	--
Other ethnic or racial identity	--	--	1.0	--
Years of education	19	2.5	17.5	2.7
Annual household income ($)	232,000	160,000	312,000	310,000
Familiar with EAB (%)	100	--	42.1	--
Aware of EABTP	100	--	10.0	--
Years living at property	11.3	9.7	17.1	9.1
Number of trees on property (maintained areas)	10.2	3.3	7.7	4
Number of trees on property (unmaintained areas)	8.3	5.6	3.4	5
Annual tree maintenance budget ($)	987	961	463	923
Previously paid for tree pest treatment (%)	56.6	--	14.8	--
Importance of preserving ash trees/shade trees[1] (1-5)	4.4	0.7	4.0	0.9
Likelihood of regularly paying for landscape tree treatment (1-5)	4.6	0.7	3.8	0.1
Likelihood of applying for cost-share funding (1-5)	4.6	0.8	3.8	0.1

[1]Survey language differed between respondent groups: program participants were asked about 'ash tree preservation' while general households were asked about 'shade tree preservation.'

4.3.3 Analysis of Response Mode

As a descriptive analysis, logistic regression was used to model the relationship of response mode (web or mail) as a function of the self-reported demographic characteristics of general household survey respondents. Variables entered as predictors in the model were *Age*, *Educational attainment*, *Household income*, *Gender*, and *Minority status*. Assumptions of linearity of continuous variables were met, and no outliers were detected. Missing cases were deleted listwise, leaving only 231 cases in the analysis. The model was not statistically significant, χ^2 (5) = 9.359, p = .096, correctly classifying only 60.2% of cases and explaining only 5.30% of the variance (Nagelkerke R^2). However, *Age* was a statistically significant predictor (p = 0.049), negatively associated with the probability of a web response. This result suggests that younger respondents were more likely to complete the web rather than mail version of the survey, although the effect size was very small (Odds Tatio = 0.997) (Table 8). It is important to note, however, that this result provides no information regarding the effect of a mixed-mode survey on response rate. Logistic regression was conducted in SPSS.

Table 8. Binomial logistic regression results of mail vs. web responses to the general household survey using demographic predictors. Web responses were coded as 1 (n = 231).

Independent Variables	B	S.E.	*p*	Odds Ratio
Age	-0.023	0.012	**0.049**	0.997
Years of education	0.027	0.053	0.610	1.028
Household income	0	0	0.310	1.000
Female (coded 1)	-0.238	0.281	0.396	0.788
Minority status (coded 1)	-0.627	0.555	0.258	0.534
Nagelkerke R^2	0.053			
$\chi 2$	9.359		0.096	

Bolded item indicates significance at the α = .05 level.

4.3.4 Factor Analysis of Attitudes Towards Urban Trees

An exploratory factor analysis of five, equally-scaled statements regarding the importance of urban trees yielded two factors. The first factor, termed *Tree curb appeal*, combined high loadings for attitudinal statements regarding the importance of urban trees to neighborhood character and property value (Cronbach's $\alpha = 0.79$). The second factor, termed *Tree affinity*, combined high loadings for statements regarding benefits provided by trees, relative importance of trees in the private landscape, and a preference for preservation of old trees (Cronbach's $\alpha = 0.67$). Factor indices were then calculated casewise as the mean value of combined attitudinal measurements. These indices were employed as predictor variables in models of behavioral intention described below. Attitudinal statements, factor indices, and factor loadings are summarized in Appendix B.

4.3.5 Cluster Analysis of Ranked Motivations for Tree Preservation

Using a clustering technique for ranked-choice data, a 2-cluster solution for participants and 5-cluster solution for general households were selected. Clusters were formed around modal response patterns, and the relative distance of individual ordered responses from these patterns. For participants, the order of responses was nearly identical: those in Cluster 1 indicated that the provision of shade was the most important reason for preserving threatened trees, while those in Cluster 2 indicated that trees' value an attractive part of the landscape is most important. Modal patterns for the five clusters selected for general households showed a greater diversity of opinion: high-ranked motivations included shade and landscape value, but also the provision of wildlife habitat, property value, and the prevention of species endangerment. Table 9 displays proportional membership, mean probability of membership, and modal ranked order for each cluster, along with relevant group characteristics. Cluster membership served as an additional categorical predictor of motivation, used in models of behavioral intention described below.

Table 9. Cluster analysis of ranked statements about motivations for tree preservation. Modal order of ranked moviations[1] indicates most common ranking pattern of cluster members. Demographic mean values are included for comparison, and significant differences between clusters are noted.

	Program Participants		General Households				
	Cluster 1	Cluster 2	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Modal order of ranked motivations	1,5,2, 3,4,6	5,1,2, 3,4,6	1,2,5, 4,3,6	1,5,3, 2,4,6	5,1,2, 3,4,6	2,5,1, 3,4,6	4,2,1, 3,5,6
Number of respondents	16	37	117	33	113	51	6
Proportion of survey respondents	0.293	0.707	0.366	0.104	0.353	0.158	0.018
Mean age (binned 1-6)	4.538	4.974	4.813	4.516	5.038	4.755	4.75
Mean educational attainment (binned 1-7)	5.643	5.789	5.13	4.906	5.121	4.958	**3.875***
Mean household income (binned 1-8)	7.125	6.92	6.56	6.583	6.532	6.425	6
Mean number of maintained trees (binned 0-3)	2.143	**2.692***	1.975	2.182	1.916	1.896	**2.625***
Mean number of unmaintained trees (binned 0-3)	1.643	2.205	0.653	**1.242***	**0.991***	0.75	1.5
Percent tree cover	0.589	0.584	0.426	0.451	0.461	**0.479***	0.472

*Significantly different from the reference level of Cluster 1, within either survey group, at the $\alpha < .05$ level.

[1]Motivations were given as: 1) Ash/Trees provide shade, 2) Ash/Trees provide wildlife habitat, 3) Ash/Trees can increase property values, 4) Ash/Trees might become rare or endangered, 5) Ash/Trees are an attractive part of landscaping, 6) Other, please specify. Program participants were asked specifically about ash trees while general households were asked about 'threatened landscape trees.'

4.3.6 Linear Models of Behavioral Intention

Assumptions of multiple linear regression were evaluated for all top-ranking models. Independence of observations was verified using the Durbin-Watson statistic. Linear relationships were established between each dependent variable, full models, and independent variable, as was homoscedasticity of residuals. Tests for collinearity using calculated tolerance values did identify two pairs of highly correlated variables (Tolerance > 10) among participant data; high tolerance was resolved by dropping one variable from each pair. For all models, normality of residuals was visually confirmed from P-P plots. Tests did identify outliers, high leverage points, and influential points in all models. After an examination of the datasets, none of these unusual points appeared to be the result of error in measurement or data recording and were not removed.

Tree preservation intention

The objective of survey items asking about willingness to pay for regular landscape tree treatment was to measure the extent to which homeowners were prepared to take on tree health care as a recurring expense. For participants, the question addressed a present threat (EAB) to a specific tree genus; for general households the threat proposed was hypothetical, and no specific trees were named. Consequently, while each measure provides a reference point to the other, a statistical comparison between the two is not meaningful.

For participants, the top-ranked candidate model was *Attitudes*, comprised of seven individual predictors. The model itself was significant, although fit was relatively low (Adj. R^2 = 0.137, p = .025). Within the model, there were two marginally significant predictors: first, a positive association with *Importance of preserving ash trees* (β=0.275, p=.059), and secondly, a negative association with *Factor A - Tree curb appeal* (β=-0.409, p=.059).

For general households, the top-ranked candidate model was the paired combination of *Attitudes + Property Characteristics.* This model was significant and showed substantial goodness-of-fit (Adj. R^2 = .412, $p < .001$). Here the second-ranking model, *Attitudes,* was considered a competitor since it ranked within 2 AICc of the first and was made up of fewer parameters. Significant predictors within the top-ranking model included a positive association with *Importance of preserving landscape trees* ($\beta = 0.494$, p <. 001) and negative association with the EAB infestation stratum *Established* ($\beta = 0.129$, p = .041). Comparisons of candidate models and summaries of top-ranked models are displayed in Tables 10-13.

Table 10. Program participants: Ranking of candidate linear models for the dependent variable *Tree preservation intention.* Number of respondents varied between models from 33 to 53

Model	K[1]	Adj. R^2	RMSE	ΔAICc[2]	w_i[3]
Attitudes	**4**	**0.137**	**0.634**	**0**	**1**
Attitudes + Property	11	0.095	0.649	16.749	0
Property Characteristics	7	-0.088	0.711	18.663	0
Personal Characteristics	6	0.079	0.655	24.979	0
Attitudes + Personal	10	0.043	0.667	35.392	0
Personal + Property	13	-0.091	0.712	49.81	0
Attitudes + Personal + Property	17	-0.19	0.744	74.21	0

Bolded text indicates top-ranking model.
[1]Number of model parameters.
[2]Second-order AIC, a small sample-corrected version of AIC, a measure of model fit which minimizes information loss.
[3]Akaike's weight, a proportional measure of relative likelihood.

Table 11. Program participants: Summary of top-ranking linear model *Attitudes* for the dependent variable *Tree preservation intention* (n=53)

Independent variables	β coeff.	p
Urban tree attitudes Factor A - *Tree curb appeal*	-0.409	0.057
Urban tree attitudes Factor B - *Tree affinity*	0.413	0.071
Importance of preserving ash trees	0.275	0.059
Tree preservation motivation - *Cluster 1*	--	--
Tree preservation motivation - *Cluster 2*	0.16	0.224
Adjusted *R*2	0.137	
F	3.059	**0.025**

Bolded item indicates significance at the α = .05 level.

Table 12. General households: Ranking of candidate linear models for the dependent variable *Tree preservation intention.* Number of respondents varied between models from 239 to 309.

Model	K[1]	Adj. R^2	RMSE	ΔAICc[2]	w_i[3]
Attitudes + Property	**14**	**0.412**	**0.849**	**0**	**0.56**
Attitudes	**7**	**0.393**	**0.863**	**0.496**	**0.437**
Attitudes + Personal	14	0.447	0.824	10.99	0.002
Attitudes + Personal + Property	21	0.443	0.827	21.254	0
Personal Characteristics	7	0.158	1.016	97.555	0
Personal + Property	14	0.143	1.026	109.621	0
Property Characteristics	7	0.077	1.064	127.356	0

Bolded text indicates top-ranking model.
[1]Number of model parameters.
[2]Second-order AIC, a small sample-corrected version of AIC, a measure of model fit which minimizes information loss.
[3]Akaike's weight, a proportional measure of relative likelihood.

Table 13. General households: Summary of top-ranking linear model *Attitudes + Property Characteristics* for the dependent variable *Tree preservation intention* (n=309)

Independent Variables		β coeff.	*p*
Attitudes	Factor A - *Tree curb appeal*	0.109	0.059
	Factor B - *Tree affinity*	0.092	0.135
	Importance of preserving landscape trees	0.494	**<.001**
	Tree preservation motivation - *Cluster 1*	--	--
	Tree preservation motivation - *Cluster 2*	0.063	0.195
	Tree preservation motivation - *Cluster 3*	0.023	0.652
	Tree preservation motivation - *Cluster 4*	-0.025	0.603
	Tree preservation motivation - *Cluster 5*	0.028	0.546
Property Charac-teristics	Age of house	-0.066	0.189
	Number of trees in maintained areas	-0.015	0.744
	Number of trees in unmaintained areas	-0.025	0.64
	Parcel area	-0.045	0.357
	Parcel tree cover	-0.001	0.983
	EAB infestation strata - *Undetected*	--	--
	EAB infestation strata - *Recent*	-0.062	0.271
	EAB infestation strata - *Established*	0.129	**0.041**
Adjusted R^2		0.412	
F		15.963	**<.001**

Bolded items indicate significance at the α=.05 level.

Cost-share participation

Survey items asking about respondents' level of interest in applying (or re-applying) for cost-share assistance were intended to measure the attractiveness of a public subsidy for preservation of personal landscape trees. Participants were asked directly whether they would re-apply for EABTP in future years, while general households were asked about their interest in a hypothetical cost-share program, if trees on their properties were threatened by a future pest outbreak. As with models of *Tree preservation intention*, a comparison of predictive models for *Cost-share participation* between participants and general households may be useful for reference, but statistical comparisons between the two are not meaningful.

Despite the differing scenarios presented to each respondent group, top-ranked candidate models were very similar. In both cases, the top-ranked model was predictor class of *Attitudes*, composed of seven individual predictor variables. For participants, the model was significant and fit moderately well (Adj. $R^2 = 0.223$, $p = .003$). It contained a single significant parameter: *Importance of preserving ash trees* ($\beta = 0.513$, $p < .001$). For general households, the equivalent model was significant and showed substantial goodness-of-fit (Adj. $R^2 = 0.456$, $p < .001$). This model contained two significant, positively associated significant predictors: *Importance of preserving landscape trees* ($\beta = 0.609$, $p < .001$) and the factor index *Tree curb appeal* ($\beta = 0.110$, $p = .044$). Comparisons of candidate models and summaries of top-ranked models for *Cost-share participation* are available in Appendix B.

4.4 Discussion

Linear modeling of homeowner behavioral intention demonstrated the importance of measured attitudes in predicting homeowner intentions towards tree preservation and cost-share enrollment. In only one case did a predictor class other than *Attitudes* improve overall model fit. This exception was seen in modeling the dependent variable *Tree preservation intention* among general households, where the EAB stratum *Established* was positively correlated with an intention to treat threatened trees. This finding suggests that the experience of living through a years-long EAB infestation may influence the behavior of some homeowners towards proactive tree preservation activity, regardless of whether they owned ash trees.

In most other cases where *Attitudes* alone proved the top-ranked model, the lone significant parameter within the model was the variable *Importance of preserving ash trees* or its equivalent regarding landscape trees. The single exception to this pattern was the addition of the factor index *Tree curb appeal* in a model of general household interest in applying to a hypothetical cost-share program. The association of this index with interest in cost-share funding suggests the importance of the neighborhood amenity value of trees as a motivating factor for homeowners seeking assistance for tree preservation.

However, in every top-ranked model the only parameter with a consistent, positive association with tree preservation and program participation was the attitudinal variable *Importance of preserving ash/shade trees.* This variable originated from survey items which asked for 5-point ordinal response to questions regarding the abstract importance of ash tree (or shade tree) preservation in Virginia. Responses to these attitudinal questions proved to be the strongest and most consistent predictors of homeowners' behavioral intentions, either to treat trees at their own expense or to apply for cost-share funding.

A peripheral topic of this research was an analysis of demographic characteristics by web or mail survey response mode. Logistic regression results indicated that the probability of a web response was negatively associated with age, although the effect size was small. This finding weakly supports the premise that younger respondents, when offered a choice between response modes, are more likely to complete a survey online. It does not, however, offer evidence to support the argument that offering a choice between response modes can boost survey response rates overall. A broader discussion of this topic and other study findings, implications, and directions for further study are included in Chapter 6.

CHAPTER 5 –PERCEPTIONS OF COST-SHARE PARTICIPATION AMONG FOREST PRACTITIONERS

5.1 Introduction

Conservation and natural resource incentive programs rely on the expertise of foresters and other resource professionals to meet with landowners and discuss land management objectives. In many cases, landowners report that the opportunity to talk with foresters in person and "walk the land" is a more valuable benefit of cost-share participation than financial assistance itself (Kilgore et al. 2007). Similarly, an evaluation of the Forestry Stewardship Program in West Virginia found that the most common complaint among participating landowners was that foresters did not have time to visit their properties often enough (Egan et al. 2001). For these reasons, I aimed to broaden an analysis of Virginia Department of Forestry's (VDOF) 2018 Emerald Ash Borer Treatment Program (EABTP) by examining the role of forest practitioners in program implementation.

State- and county-level foresters have a decades-long history of providing technical assistance and administering forestry incentives among landowners (Esseks and Moulton 2000), although almost exclusively in rural areas. Conversely, commercial arborists work primarily for urban property owners, and for many, a majority of business revenue is derived from management of tree pests and pathogens. Since Virginia's EABTP provided for funding of tree treatment in any location, urban or rural, the program made use of the expertise of both practitioner groups.

Arborists were involved at two stages of the EABTP: first in submitting a bid, then later conducting the treatment. Program policies required that homeowners could only apply for funding after receiving a signed bid for treatment from a licensed pesticide applicator. Of 107 approved applications, only 3 involved landscape contractors who were not arborists (Bean

2019). Once an application was submitted, a homeowner could only schedule tree treatment after receiving on-site approval from a VDOF forester. For some arborists, months may have elapsed between bidding and conducting treatment because of VDOF stipulations regarding the timing of treatment (VDOF 2018). After conducting tree treatments, arborists were paid in full by the homeowner, as for any other contracted work. VDOF's reimbursement payment to a homeowner was disbursed only after the homeowner submitted a zero-balance invoice from the arborist.

County foresters were tasked with on-site approval of tree treatment requested by homeowners and bid on by arborists. Foresters' responsibilities for each tree proposed for treatment included (1) verifying tree genus and species, (2) confirming a minimum trunk diameter of twelve inches, and (3) assessing whether tree vitality was high enough to warrant treatment (VDOF 2018d). The threshold of tree vitality adopted by the EABTP a maximum of 30% crown dieback, a rule of thumb recommended by researchers (Bick et al. 2018). To ensure reliability of assessment, VDOF held training sessions prior to program launch with instruction and a photo guide of incremental ash tree canopy loss (Chamberlin 2018a). Of 107 total site assessments, 17 were conducted by foresters from the Forest Health division at VDOF headquarters. The remaining 90 assessments were conducted by 24 county foresters, almost all of whom held the positions of Area Forester or Senior Area Forester.

Participation in the EABTP did not dramatically alter job descriptions of either arborists or foresters but did temporarily change the day-to-day context for both. Foresters were asked to assess properties a few acres in size instead of a few hundred acres, and to scrutinize the work of tree services instead of logging contractors. For arborists, EABTP participation required waiting weeks to months for VDOF approval but offered the possibility of greater demand for ash tree injection.

As intermediaries between program administrators and participants, practitioners had great influence on the program's initial year. This is evidenced by the high proportions of program participants who cited arborists (25%) and VDOF or VCE employees (23%) as their initial source of EABTP information. Consequently, practitioners' engagement with the program will continue to affect its future success. The objective of this research was to inform future initiatives by examining the engagement of forest practitioners with the EABTP, and in urban forest health more broadly. Topics investigated included potential associations between professional experience and perceptions of threats posed by forest pests; predictors of interest in future program participation, and specific reasons for interest or disinterest in participation.

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5.2 Methods

5.2.1 Construction of Survey Sampling Frames

Survey research was conducted with samples drawn from both VDOF county foresters and Virginia arborists. Unlike homeowner surveys, in which recipients were contacted directly by mail and email, county foresters and arborists were contacted with survey requests through coordinating agencies. This method provided relatively large contact lists, but less information about recipient characteristics, compared to homeowner sampling frames.

The forester sampling frame included all VDOF county foresters who carried responsibility in reviewing EABTP applications, defined as those holding the positions of Area Forester or Senior Area Forester. This group was estimated to include 105 foresters (Bean 2019). On behalf of this research project, VDOF Forest Health officials contacted all members of the sampling frame with survey requests, effectively conducting a complete sample. From this sample, a total of 19 usable responses were recorded, for a response rate of 18.1%. For a 50/50 split response at 95% confidence level, these figures correspond to a 20.4% margin of error,

meaning that survey results can only be generalized to the sampling frame with a large amount of uncertainty (±20.4%).

Similarly, arborists were contacted through the coordinating agency of MAC-ISA, the Mid-Atlantic chapter of the International Society of Arboriculture. While the term *arborist* generically refers to a landscape tree care professional, *Certified Arborist* refers to those certified through the ISA. the sampling frame was defined less stringently to include all arborists (tree care professionals) with a business address or clients in Virginia. There were 1081 Certified Arborists in Virginia in a MAC-ISA database who formed the primary contact list, and who were contacted by email with survey requests. Follow-up survey recruitment posts in a MAC-ISA online newsletter expanded the contact list to include all MAC-ISA members (n=1139), whose membership overlapped with the primary contact list of Virginia Certified Arborists, and also included non-certified professionals, and members outside of Virginia. After accounting for recipients on both lists, the total number of unique recipients was calculated to be 1590. A total of 144 usable responses were recorded, for a response rate of 9.1%. Two specific survey items allowed for *post-hoc* parsing of response data by state location and certification status. Of the 144 respondents, 134 reported either having a business or clients located in Virginia. For a 50/50 split response at a 95% confidence level, these figures correspond to an 7.8% margin of error.

5.2.2 Construction of Survey Instruments

Survey instruments for foresters and arborists were developed using Qualtrics and shared most survey items. The foresters' survey contained 22 questions and had an estimated response time of 12 minutes, while the arborists' survey contained 30 questions, and had an estimated response time of 13 minutes. As with homeowner surveys, forest practitioner surveys were designed to assess respondents' experience with EAB, attitudes towards urban trees, and

intentions regarding future EABTP participation. A limited number of demographic characteristics were requested, along with professional characteristics such as certification status, years of experience, and job title. Finally, a series of ranking questions were included that measured respondents' relative preference for motivations for ash tree preservation, landscape tree species, perceptions of forest pest threats, and on-the-job recommendations for EAB management. A summary of survey items and measurement scales in included in Appendix C, while the full survey instrument is available in Appendix G.

Because forester and arborist survey instruments shared most questions and wording, a single pre-test instrument was sent by email to a group of twenty-five Certified Arborists located within and outside of Virginia. Response data and comments from fifteen responses informed editing of final survey versions, including improvements in clarity of wording and logical flow.

5.2.3 Data Collection

For both surveys, recipients were initially contacted with survey requests beginning in late September 2018, and with follow-up contacts through the end of October. All survey recruitment materials and instruments were submitted first to the Virginia Tech IRB and subsequently approved by Western IRB. An IRB Exemption letter is included in Appendix H.

Foresters who had previously participated in the program (n = 25) were first contacted by email in late September 2018, with a survey request message and unique URL sent by VDOF on behalf of this project. A follow-up survey recruitment post and link were included in an online VDOF newsletter on October 2, sent to all VDOF employees (n ≈ 230). While the total number of newsletter recipients was greater than the size of intended sampling frame (n = 105), the post

explained that only foresters with potential EABTP responsibility were encouraged to take the survey.

Four separate survey requests were sent to arborists by MAC-ISA on behalf of this project, beginning with a recruitment post in an online newsletter to chapter members in late September 2018. Following this, two survey requests were emailed to Certified Arborists located in Virginia, spaced by one-week intervals. Finally, a recruitment post included in a second online newsletter was sent to all chapter members in late October. After approximately three months, survey response collection for both surveys was closed on December 31, 2018.

5.2.4 Data Analysis

Tests for Nonresponse Bias

To create a reference group of foresters against which to compare survey respondents, data were compiled from VDOF online records for all county foresters with the position of Senior Area Forester or Area Forester—positions with responsibility for EABTP application review. This search yielded 64 foresters. Frequencies of foresters' *Job title*, *Gender*, and *Location* by VDOF work area were recorded, and tested against the same characteristics for forester survey respondents using a chi-square test of independence.

Testing for nonresponse bias in the arborists' survey response was complicated by the fact that two contact lists with overlapping membership were used to distribute recruitment materials. However, with anonymized membership data provided by MAC-ISA, limited tests for nonresponse bias were conducted, again using chi-square tests of independence between respondents within Virginia and a reference group of Certified Arborists within Virginia.

Frequencies were compared by group for professional *Area of practice* and for county location, aggregated by *EAB strata*. All chi-square tests were conducted in SPSS.

Factor Analysis of Attitudes Towards Urban Trees

As with analysis of homeowner response data (Chapter 3), an Exploratory Factor Analysis was conducted of five equally-scaled survey items regarding attitudes towards urban trees. For this analysis, responses were aggregated between arborists and foresters to facilitate cross-sectional comparison. From a scree plot of eigenvalues, a 2-factor solution was selected. Analysis was conducted in R, using the packages 'psych,' and 'GPArotation.'

Cluster Analyses: Motivations, Recommendations, and Perceptions of Pest Risk

Cluster analysis was employed to partition respondents according to three ranked-choice survey items. Analyses were conducted using aggregated forester and arborist data, for survey items regarding motivations for preserving ash trees, and for perceptions of threats posed by specific invasive forest pests. For arborist response data only, a third cluster analysis was conducted of ordered response data regarding EAB management recommendations.

For each cluster analysis, response data collected consisted ordered vectors of numbers representing as many as seven ranked options. Using R package 'Rankcluster' the optimal number of clusters was selected for each analysis from a plot of BIC against an increasing number of clusters. Cluster membership was assigned to individual cases and treated as nominal variables in further analyses.

Analysis of Pest Risk Perceptions

Understanding differing perceptions of risks posed by pests in relation to specific professional characteristics might be relevant to recruiting practitioner support for future iniatives. Many reasons could account for diverging perceptions of risk—for instance, in pockets of Virginia that remain unaffected by EAB, perceptions of the severity of EAB damage may be lower. Alternately, the recent arrival of 'new' pests, might alter the prioritization of resources for some foresters. One relevant example is the spotted lanternfly (*Lycorma deliculata* White) first detected in 2018 in Virginia (Day et al. 2018). Similarly, it is possible that experienced foresters and arborists may have a better understanding of risks posed by longstanding pest infestations such as the gypsy moth, which may currently attract less research attention and funding than recent arrivals.

Using chi-square analyses, null hypotheses of no association were tested between perceptions of pest risk and five variables representing professional experience. Perceptions of pest risk were represented by pest threat cluster membership referenced above, forming a a four-level categorical variable *Pest threat cluster.* Five variables representing aspects of professional experience, recoded in categorical form, were tested against these clusters for association. These included *EAB strata,* representing location within Virginia by local age of EAB infestation, *Work experience,* representing years of professional experience, *Clientele acreage,* representing the percentage of clients with properties larger than five acres, *EAB experience*, representing frequency of prior EAB-related work, and *Practitioner type*, representing a respondent's status as a forester or arborist. As a series of multiple comparisons with the same dependent variable, a Bonferroni correction was necessary to reduce family-wise Type I error, lowering the significance level to $\alpha = 0.01$. Chi-square tests were conducted in SPSS.

Linear Models of Program Participation

While survey response data suggested that foresters expressed greater interest in cost-share participation that arborists, this comparison is not necessarily meaningful. First, the large difference in sample size complicates a comparison of means. Secondly, interest in program participation expressed by foresters, whose job duties may have required participation, were not equivalent to responses from arborists, who had no obligation to the program. For these reasons, only arborist response data were included in models of program participation. Additionally, respondents without a business address or clients in Virginia were excluded from analysis, resulting in a sample size of 134.

Using data drawn from survey responses and external sources, candidate models were fitted to the dependent variable of *Interest in program participation*. This variable was drawn from a single, ordinal survey item which asked arborists about their interest in future EABTP participation, either in pricing work or carrying out insecticidal applications (see Appendix C for summary of survey items or Appendix G for full survey instrument).

As with models of homeowner intentions, candidate models were constructed from groups of three to eight individual predictors categorized by predictor class: *Professional Characteristics*, *Personal Characteristics*, and *Attitudes*. Seven candidate models were constructed from the combination of individual, paired, and grouped predictor classes. Each of these models was fitted to the dependent variable using hierarchical multiple linear regression in SPSS. Model selection was accomplished by ranking of candidate models in order of decreasing Akaike's weight (w_i), a proportional measure of relative likelihood derived from AIC.

Qualitative Analysis of Written Responses

In addition to rating their interest in program participation, practitioners were also asked to state their reasons for interest, or lack of interest in EABTP participation. Written responses provided additional insight into practitioners' level of engagement with EABTP. Of 163 aggregate respondents to both practitioners' surveys, 98 entered a response for this item. These responses were coded by twelve common themes, and graded as positive, neutral, or negative with regard to interest in program participation.

5.3 Results

5.3.1 Summary of Response Data

Respondents to the foresters' survey (n=19) were predominantly male (78%), in their mid-forties ($\bar{x}$ = 44.0 years), and had completed a graduate degree ($\bar{x}$ = 17.6 years of education). Responding foresters represented 15 different counties, where on average, EAB had been detected recently ($\bar{x}$ = 4.2 years since detection). Respondents most commonly held the position of Area Forester and reported an average of 18.5 years of experience in forestry. While only 10.5% held Society of American Foresters (SAF) certification, 73.7% held ISA certification. Regarding their work prior to 2018, foresters reported that on average, 20.0% of their working hours were dedicated to forest health-related projects and indicated their frequency of EAB-related work as 2.5, on a scale from 1 (Very rarely) to 5 (Very frequently). Additionally, foresters reported that on average, 78.2% of landowners they interacted with on the job owned more than five acres.

All respondents reported making EABTP-related property visits to review applications. The number of properties visited ranged one to twenty, averaging between five and six. Forester

respondents' average level of interest in future program participation was 3.7, on a scale of 1 (Not at all interested) to 5 (Extremely interested). Respondents' location by county are displayed in Figure 10; selected survey response data are summarized in Table 14. Additional attitudinal response data are discussed below in relation to factor and cluster analyses.

Most arborist respondents (93.1%) reported that either their business or clients were located in Virginia. The remaining 10 (6.9%) out-of-state responses were retained for initial analyses but excluded from models of EABTP participation. Respondents were predominantly male (83%), on average in their late forties ($\bar{x}$ = 47.2 years) and had continued their education beyond a four-year degree ($\bar{x}$ = 16.9 years of education). Arborist respondents represented 49 different Virginia counties, where on average, the EAB infestation was established ($\bar{x}$ = 6.8 years since detection). Respondents most commonly described their area of practice as *Urban forestry/Government* and had on average 18.9 years of arboricultural experience. As with forester respondents, a low percentage (7.0%) held SAF certification, but almost all (98.6%) held ISA certification.

Regarding their work prior to 2018, arborists reported that on average, 33.0% of working hours were dedicated to forest health, and indicated the frequency of EAB-related work as 3.3, on a scale from 1 (very rarely) to 5 (very frequently). Arborists also reported, on average, that 35.7% of landowners they interacted with on the job owned more than five acres. Of 144 respondents, 76 (52.3%) reported previously being aware of EABTP—of these, the primary source of information was VDOF or VCE employees (36.8%), followed by associates or friends (34.2%), and VDOF or VCE publications (26.3). Only nine respondents (6.3%) reported making EABTP-related property visits, either to submit bids or treat trees. The number of properties visited ranged from one to three. Arborist respondents' mean level of interest in future program

participation was 2.8, on a scale of 1 (Not at all interested) to 5 (Extremely interested), lower than the equivalent response for foresters. County locations of Virginia arborist respondents are displayed in Figure 10; selected survey responses are summarized in Table 14.

Table 14. Summary of selected survey responses and external data for foresters and arborists.

Selected responses	Foresters (n = 19)		Arborists (n = 144)	
	$\bar{x}$	SD	$\bar{x}$	SD
Years since local EAB detection[1]	4.2	3.7	6.8	3.9
Gender (% female)	22.2	--	17.7	--
Age	44.0	11.8	47.2	12.7
Years of education	17.6	1.6	16.9	2.1
ISA Certified Arborist	73.7	--	98.6	--
SAF Certified Forester	10.5	--	7.0	--
Years of professional experience	18.5	12.0	18.9	12.0
Percentage of client properties > 5 acres	78.2	19.4	35.7	30.5
Percentage of work hours spent on forest health	20.0	14.8	33.0	26.1
Frequency of prior EAB-related work (1-5)	2.5	1.1	3.3	1.2
Previously aware of EABTP (%)	--	--	52.3	--
Number of EABTP site visits or bids	5.2	5.6	0.2	1.2
Interest in future EABTP participation (1-5)	3.7	0.8	2.8	1.3

[1]There were many survey responses with unknown locations; estimates based on n=11 for foresters and n=111 for arborists.

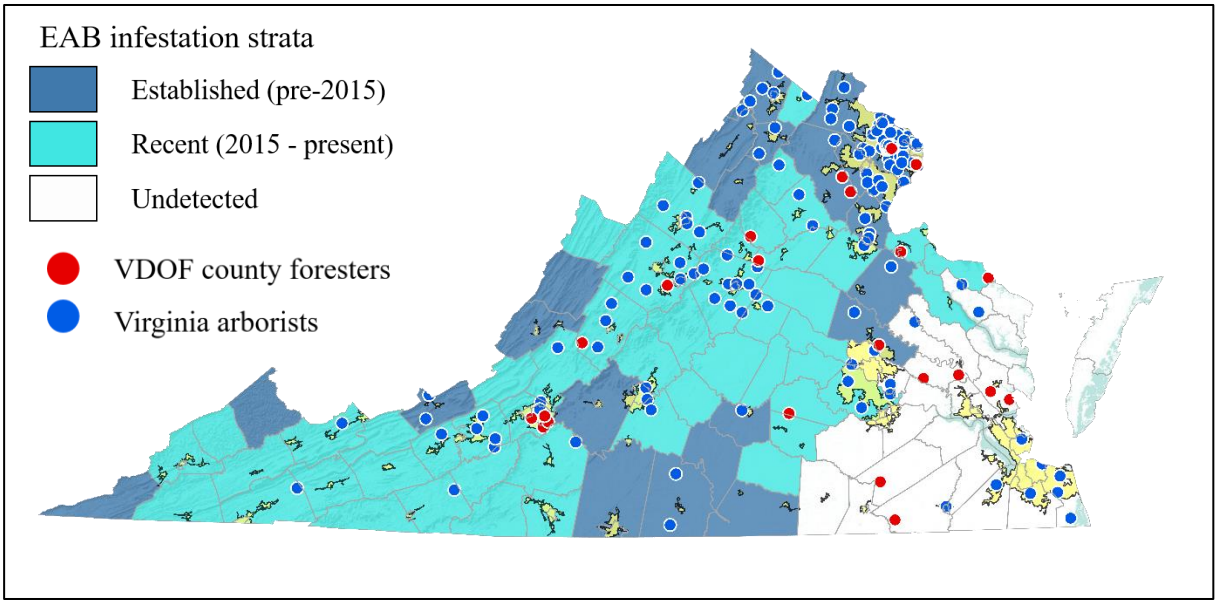


Figure 10. Map of Virginia displaying counties by EAB infestation strata (defined by year of initial EAB detection), and rough locations of forester (n=19) and arborist (n=134) survey respondents.

5.3.2 Tests for Nonresponse Bias

Tests for nonresponse bias using limited data available for both practitioner groups provided evidence of a representative response for foresters but raised questions about nonresponse bias among arborists. Between forester respondents and a forester reference group, chi-square tests showed no associations between group and *Gender, Job title*, or *Location*. While the foresters' survey drew only 19 responses, this number represents 76% of all VDOF county foresters who participated in the 2018 EABTP. From this limited analysis, survey responses appear to represent the gender ratio, experience level, and geographic distribution of a broader group of ranking county foresters. Test results are summarized in Appendix C.

For arborist repondents, chi-square tests indicated significant associations between group membership and both variables tested (*Area of practice* and *EAB strata*), although with only moderate effect sizes, as measured by Cramer's V. Post-hoc assessment of standardized residuals

indicated that frequencies of arborist respondents in listing their area of practice as *Research/Education/Training* was higher than in the reference group, and lower than the reference group for the category *Other.* This category represented landscape contractors, landscape architects, and nursery owners—professionals who are less likely to be involved in treatment of tree pests. Finally, frequencies of arborist respondents in counties within the *Undetected* EAB infestation strata were also lower than among the reference group. Taken together, these measures of association indicate that arborist survey respondents as a group, relative to the sampling frame of all Virginia MAC-ISA members, included fewer landscape professionals, a greater number of researchers or educators, and fewer people located in southeastern Virginia counties. Test results are summarized in Appendix C.

5.3.3 Factor Analysis of Attitudes Towards Urban Trees

Factor loadings of survey items on the two factors closely matched those of homeowner responses. The first factor, again termed *Tree curb appeal*, combined high loadings for responses to the belief statements regarding neighborhood character and property value (Cronbach's $\alpha = 0.67$). The second factor, termed *Tree affinity* combined high loadings for responses to belief statements regarding benefits provided by trees, relative importance of trees in the private landscape, and a preference for preservation of old trees (Cronbach's $\alpha = 0.95$). Factor indices were then calculated casewise as the mean value of the combined belief statements. Attitudinal statements, factors, associated loadings are summarized in Appendix C.

5.3.4 Cluster Analyses: Motivations, Recommendations, and Pest Risk

Cluster analysis of aggregated forester and arborist response data regarding ranked motivations for ash tree preservation yielded four clusters. Unlike ranked homeowner motivations, which focused on trees' value as landscape elements, top-ranked motivations included ash trees' provision of shade, and the necessity of preventing ash species from becoming rare. In only one of four clusters was ash trees' contribution to property value ranked in the top three. A summary of cluster analysis of ranked ash preservation motivations is included in Appendix C.

Cluster analysis of ranked responses regarding arborists' most frequent recommendations for EAB management yielded two clusters. Ranked recommendation patterns were almost identical: the insecticidal options of imadicloprid and emamectin were ranked at the bottom for both clusters, while the two top places were held by the options of 'wait and see' or tree removal. A summary of cluster analysis of arborists' EAB management recommendations is included in Appendix C.

Finally, cluster analysis of aggregated forester and arborist data regarding their ranked perceptions of threats posed by seven invasive forest pests yielded four clusters. In three out of four clusters, EAB was ranked as the top threat, followed either by hemlock woolly adelgid or Asian longhorned beetle. The remaining cluster, which was also the largest single grouping, ranked the southern pine beetle as the most threatening pest, followed by the spotted lanternfly. Table 15 summarizes cluster analysis of aggregated pest threat rankings.

Table 15. Aggregated forester and arborist response data: Cluster analysis of forest pests ranked by level of perceived threat to Virginia's forests. Modal patterns represent most common ranking of each cluster.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Modal pattern of ranked pests[1]	6,1,2,3,4,5,7	6,1,4,3,5,7,2	5,4,1,2,3,6,7	6,2,4,3,7,1,5
Number of respondents	53	30	70	10
Proportion of survey respondents	0.324	0.184	0.429	0.063

[1]Forest pests were given as: 1) hemlock woolly adelgid, 2) Asian longhorned beetle, 3) gypsy moth, 4) spotted lanternfly, 5) southern pine beetle, 6) emerald ash borer, 7) walnut twig beetle

5.3.5 Chi-square Analysis of Pest Risk Perceptions

Minimal assumptions for chi-square analysis were met for all tests: in each crosstabulation, 80% of cells contained expected values greater than 5, and there were no expected frequencies less than 1. Tests indicated no associations between any of the professional experience variables and perceptions of pest threats, at the $\alpha = 0.01$ level of significance. The only variable approaching a significant association and moderate effect size was *Clientele acreage* ($p = 0.077$, $V = 0.200$). This variable was originally recorded as a continuous measure, representing the percentage of clientele who owned more than five acres, and was recoded into three bins (0-33%, 34-66,% 67-100%) for this analysis. Test results from chi-square analysis of pest threat perceptions are displayed in Table 16.

Table 16. Chi-square analyses of independence between practitioner pest threat clusters and professional characteristics. Variables listed represent measured aspects of professional experience, recoded in categorical form. Four pest threat clusters were tested against each variable listed for independence. Number of cases varied from 142 to 163.

Professional characteristics	Pearson's $\chi 2$	df	*p**	Cramer's V
EAB strata	4.505	6	0.609	0.124
Work experience	8.158	6	0.227	0.158
Clientele acreage	13.382	6	0.077	0.200
EAB experience	11.566	12	0.481	0.161
Practitioner type	2.400	3	0.494	0.121

*Tested against a Bonferroni-corrected significance level of $\alpha = 0.01$

5.3.6 Linear Models of Program Participation

The data met multiple linear regression assumptions for independence of observations, linearity, homoscedasticity, lack of collinear predictors, and normality. No outliers or influential points were identified; however, 11 points with high leverage were identified. Since a review of the data provided no evidence of error, no cases were removed.

Of seven candidate models for the dependent variable *Interest in program participation*, the top-ranked model by Akaike's weight (w_i) was *Professional characteristics*, although this model was poorly-fitting and not significant (Adj. $R^2 = 0.033$, $p = 0.166$)). An equivalent model within 2 AICc of the top-ranked model was *Attitudes*, also with poor fit and nonsignificant F-ratio (Adj. $R^2 = 0.034$, $p = 0.139$) Table 17 displays model fit, error, and ΔAICc for all candidate models.

Within the model *Professional characteristics*, the lone significant predictor, *EAB management recommendation - Cluster 2* ($\beta = 0.627$, $p = 0.02$) was positively correlated with program participation. This binomial variable grouped respondents into two clusters according to

ranked preference for EAB management strategies—those in Cluster 2 preferred a "wait-and-see' approach over tree removal. Table 18 displays a summary of the model *Professional characteristics.* There were no significant predictors with the equivalently-ranked model *Attitudes*, although the factor index *Tree affinity* was marginally significant ($\beta = 0.222,\ p = .055$). This multi-item index combined agreement with statements regarding benefits provided by trees, their relative importance next to other landscape elements, and a preference for preservation of declining trees. A second, marginally significant predictor within this model was *Sales expectations* ($\beta = 0.157,\ p = .099$). The positive correlation here indicates an expectation that participation might be good for business. Table 19 displays a summary of the model *Attitudes.*

Table 17. Arborist response data: candidate models for *Interest in future program participation*

Model	K	Adj. R^2	RMSE	ΔAICc	w_i
Professional characteristics	**8**	**0.033**	**1.269**	**0.000**	**0.422**
Attitudes	**5**	**0.034**	**1.269**	**0.578**	**0.316**
Personal characteristics	3	-0.026	1.307	2.010	0.154
Personal + Attitudes	8	0.013	1.282	4.538	0.044
Professional + Attitudes	13	0.055	1.255	5.132	0.032
Personal + Professional	11	0.200	1.278	5.405	0.028
Personal + Professional + Attitudes	16	0.054	1.256	9.720	0.003

Bolded rows show top-ranking models. The model *Attitudes* is considered a competitor to *Professional characteristics* since it is within 2 AICc and has fewer parameters.

Table 18. Arborist response data: Summary of model *Professional characteristics* for the dependent variable *Interest in future program participation.*

Independent variables	β coeff.	*p*
EAB infestation strata - *Undetected*	--	--
EAB infestation strata - *Recent*	-0.507	0.279
EAB infestation strata - *Established*	-0.223	0.645
Years of professional experience	-0.006	0.607
Percentage of clientele with < 5 acres	-0.003	0.432
Percentage of forest health work hours	0.006	0.201
Frequency of prior EAB-related work	0.034	0.781
EAB management recommendation cluster	0.627	**0.020**
Adjusted R2	0.033	
F	1.582	0.166

Bolded items indicate significance at the α=.05 level.

Table 19. Arborist response data: Summary of the model *Attitudes* for the dependent variable *Interest in future program participation.*

Independent variables	β coeff.	*p*
Factor index 1 - *Tree curb appeal*	-0.066	0.566
Factor index 2 - *Tree affinity*	0.222	0.055
Ash preservation motivations - Cluster 1	--	--
Ash preservation motivations - Cluster 2	0.063	0.571
Ash preservation motivations - Cluster 3	0.116	0.368
Ash preservation motivations - Cluster 4	-0.085	0.480
Expected effect of EABTP on sales	0.157	0.099
Adjusted R2	0.034	
F	1.658	0.139

5.3.7 Qualitative Analysis of Written Responses

Aggregate forester and arborist written responses regarding level of interest in program participation were coded by 12 common themes, and each graded as positive (45), neutral (24), or negative (29). The two most common themes given *for* program interest were the benefits of EABTP towards ash preservation (n=19), and the assistance the program provided for clients (19). Some examples of reasons for interest in the program, included:

"We need to preserve a large enough population to allow development of genetic resistance…"

"Giving my clients more options for treatment is always a better way to go."

"We take care of many trees. If our clients wish to participate, that is great."

The two most common themes in reasons given for lack of interest were a regional low abundance of ash trees (n=12), and the perceived unsustainability of the program model (n=6). Some examples of reasons for lack interest in the program included:

"Consider EAB a wakeup call to replace tree diversity."

"More government paperwork to deal with. The treatments I perform work well."

"Most of the ash that I see in Fairfax County are too far gone…"

Finally, written responses graded as neutral consistently expressed the idea that participation in the EABTP was not relevant to the respondent's job duties. Many of these respondents were employees or utility contractors whose work would not take them into contact with residential clients.

5.4 Discussion

While EAB management was the top-ranked pest threat for most forest practitioners, it was one of several competing concerns. Newly detected pests, new discoveries in research, and changing ecological conditions all contribute to forest practitioners' understanding of risk, which may differ from that of the public (Liebhold 2012). Tests for association between professional characteristics and perceptions of pest risk did not, however, identify any strong links between professional experience and perception of risk.

Models of arborists' interest in future EABTP participation were poorly fitting and not statistically significant. Significant and marginally significant predictors identified within top-ranked models are of little substantive value, but perhaps suggest directions for future research.

The significance of the second EAB management recommendation cluster in a model of program participation may indicate that preference for a slower-moving approach to pest management is associated with interest in EABTP. Alternately, the inverse relationship may provide a clearer explanation: a preference for preemptive tree removal may be associated with low interest in EABTP participation. Other marginally significant predictors of program participation included on one hand, *Tree affinity*, a factor index favoring a non-market valuation of urban trees, and on the other, *Sales expectation*, emphasizing the profitability of program participation.

Written responses contributed to a more nuanced understanding of practitioners' attitudes towards EABTP. Of those who perceived the program as relevant to their work, positive responses outweighed negative responses by a ratio of about 3:2. The primary reasons given for interest in participation was the program's importance for ash preservation and how it may benefit clients. Most practitioners who responded with reasons for lack of interest in EABTP participation did so based on low abundance of ash trees in their localities, whether due to historically low ash abundance or an established EAB infestation. A few, however, expressed a lack of interest in the EABTP based on a perception of its unsustainability—specifically, six respondents stated a belief in the economic or ecological inefficiency of EABTP funding. A broader discussion of this topic and other study findings, implications, and directions for further study are included in Chapter 6.

CHAPTER 6 – THESIS CONCLUSION

6.1 Summary of findings

6.1.1 Urban Participant Properties

Properties of urban EABTP participants (n=28) were relatively large and wooded, with a mean parcel size of 0.587 acres and tree cover of 48%, and on average, were developed in the mid-20th century (mean house age = 61.6 years). A cluster analysis of 16 inventoried properties using these three variables partitioned properties into three groups, termed *Wooded exurban*, *Historic urban*, and *Contemporary suburban*. Both parcel size and tree cover were highest for the first cluster and lowest for the second.

A total of 365 trees and 57 species were inventoried across 16 properties visited. Mean species abundance was 10.1, with a mean Shannon index of *H'* = 1.99. Across all sites, white ash (*Fraxinus americana)* outperformed all other species in terms of relative abundance (16.6%), relative basal area (34.3%) and other related indices. By contrast, green ash (*Fraxinus pennsylvanica*) was barely present—represented by a single tree on one site. Measured by relative abundance, other species commonly found across sites were red maple (*Acer rubrum* L.– 8.5%), hackberry (*Celtis occidentalis* L. – 4.9%), flowering dogwood (*Cornus florida* – 4.4%), and silver maple (*Acer saccharinum* L.– 4.2%).

Comparisons of species composition between participant properties and surrounding urban forests indicated clear differences. Measured as a percent of total, ash relative abundance on urban participant properties was almost four times greater than in residential areas of surrounding municipalities. Measured by relative structural value, ash on participant properties also outvalued those in surrounding municipalities by a factor of three. Data for surrounding municipalities were drawn from urban forest assessments conducted in 2010-2011, a period

during which the ash borer was not yet present in most of Virginia. This fact serves to emphasize the unusually high number of ash trees on participant properties, relative even to pre-EAB levels.

Linear models of site species composition as a function of property characteristics were not successful in fitting the data. A model of ash *Relative importance value* fit the data poorly (Adj. R^2 = -0.095) and did not contain any significant predictors. A second model of ash *Relative structural value* showed slightly better fit (Adj. R^2 = 0.185) and contained one marginally significant predictor, *Years since local EAB detection* (p = 0.093).

6.1.2 Homeowner Engagement in Landscape Tree Preservation

Survey research conducted with homeowner participants of the EABTP and a general household population indicated broad support for personal investment in tree preservation and broad interest in cost-share funding. Respondents to both surveys were predominantly white, majority male, and in their late fifties. Apparent differences between the two groups included the much larger average parcel size of primarily rural participant respondents (32.1 vs. 0.44 acres), and participants' lower average household income ($232,000 vs. $312,000). Participants also reported, on average, two more years of education than general household respondents. An assessment of whether choice of survey response mode (mail or web) was influence by demographic characteristics did not demonstrate any strong effects, although a small association was evident between increasing age and a web response (p = .049, Odds Ratio = 0.977).

Models of behavioral intention consistently demonstrated the importance of attitudes in predicting behavior, as compared with personal or property characteristics. Significant or marginally-signficant predictors of willingness to pay for regular tree treatment included an abstract agreement with the importance of preserving trees for both survey groups. For

participants, this variable was joined by a negative association with the factor index *Tree curb appeal*, while for general households, location in the *Established* EAB strata was also positively associated. For models of interest in future cost-share enrollment, agreement with the abstract importance of tree preservation was again significant for both survey groups. Among general households, the factor index *Tree curb appeal* was also positively associated.

6.1.3 Practitioner Perceptions of Cost-Share Participation

Survey research conducted with VDOF county foresters and Virginia arborists demonstrated many similarities between two groups. Both groups reported an equivalent level of professional experience ($\overline{x}$ =19 years), with a mean of 18 years of education for foresters, and 17 years for arborists. Responding foresters were also apparently younger ($\overline{x}$ =44 years) than arborists ($\overline{x}$ =47 years), and there was a greater proportion of female respondents among foresters (22%) than arborists (17%). Few from either group held SAF certification (11% of foresters, 7% of arborists), while majorities held ISA certification (74 and 98%, respectively). Notably, while not directly comparable measures, interest in cost-share participation appeared higher among foresters ($\overline{x}$ =3.7 out of 5) than arborists ($\overline{x}$ =2.8).

A cluster analysis of practitioners' ranked perceptions of threats posed by seven invasive pests grouped respondents in four clusters based on commonalities in ranking patterns. Membership in these clusters was tested for association against a series of five professional characteristics, to assess the influence of these factors on pest management priorities. No significant associations were detected.

Models of arborist interest in program participation were developed using three predictor classes: *Professional characteristics*, *Personal characteristics,* and *Attitudes.* Neither of the two

top-ranking models were significant or fit the data well. However, within the model *Attitudes, Tree affinity* was a significant predictor (p=0.055), potentially indicating the importance of non-market valuation of trees in program participation. Other marginally significant predictors included a preference for 'wait and see' EAB management approach, and the expectation of increased sales due to program participation.

Written responses regarded interest or lack of interest in the program demonstrated that a number of survey respondents did not work in a position where EABTP was directly relevant. Of those for whom the program was relevant, positive responses outweighed negative ones by a ratio of 3:2. The most common reason for interest of participation was to promote ash preservation; the most common reason for lack of interest was an insufficient local ash tree population. .

6.2 Implications

6.2.1 Urban Participant Properties

Comparisons of species composition between sites and cities demonstrated that ash trees were roughly three times more abundant and valuable on participant properties than in surrounding urban forests. This contrast suggests an important research topic—the identification of a threshold value or modeled relationship between site ash abundance and tree preservation actions. For urban forest managers, this information, combined with detailed urban forest inventory data could inform an efficient outreach strategy. For instance, in 2009 the city of Milwaukee conducted a remote tree inventory of the entire urban forest using hyperspectral and LiDAR data. With ash trees identified on private property, officials were able to alert close to 30,000 homeowners of the risk posed by EAB and the need to treat or remove trees (Sivyer

2010). Efforts such as these could be fine-tuned with information regarding which homeowners are most likely to act based on a threshold number or size of threatened trees.

Average characteristics of urban participant properties describe a relatively large, wooded, mid-century development. Notably, participants in urban areas made up less than one-third of all individual homeowner participants. From this we can gather that in the EABTP's first year, funding was directed primarily to rural areas, and secondarily to large, wooded properties on urban peripheries. Cluster analysis further helped illustrate that among urban properties (n=28), likely only one-third of these were in moderately dense neighborhoods (Cluster 2 median parcel size = 0.39 acres).

The geographic trends identified have positive implications for preservation of ash genetic diversity and some tree benefits. Compared to smaller, urban lots where most trees are likely to be clonally-reproduced cultivars, on rural and wooded exurban properties, many more trees have naturally regenerated from open-pollinated seed. The genetic diversity preserved in these trees represents an important resource for research (see Koch et al. 2015) and the ongoing survival of ash species. Additionally, the above-ground biomass of forest-grown trees is greater than of open-grown, maintained urban trees (Nowak et al. 2013). This implies that preservation of ash trees on wooded, urban edges will result in greater carbon storage than equivalent actions in more densely populated neighborhoods.

However, since an individual tree's canopy is limited by neighboring trees and may even retreat in the presence of fast-growing ones (Spector and Putz 2006), net tree benefits are not necessarily maximized by funding preservation of trees on predominantly wooded lots. Since tree benefits such as energy savings, runoff avoidance, and pollution removal are related to the physical dimensions of a tree's crown (Lee et al. 2016), trees in lower-canopy areas may be able

to provide greater per-tree benefits. In addition to questions of tree benefits, since tree cover is correlated with socioeconomic status in many U.S. cities (Schwarz et al. 2015), distribution of funding to a city's wooded perimeter also raises questions of environmental justice. While concerns about the intra-city distribution of funding were not part of EABTP's statewide policies, these topics likely would be relevant if similar programs were to be implemented on a municipal level.

Consistently high relative importance and structural value of white ash across all inventoried sites demonstrates the significance of these trees to the landscapes of program participants. While there were several sites where other species where more numerous, white ash ranked as the species with highest relative structural value on nine of sixteen properties inventoried. The consistent abundance and value of white ash across sites again suggests the interesting topic of identifying a threshold level of ash trees—or another threatened species—as a predictor of homeowner engagement in landscape tree preservation.

While white ash was present on all sites, green ash was represented by a single tree on one property. White and green ash are the two most widely distributed ash species in North America; while they differ in site requirements, both were common statewide in Virginia forests before the arrival of EAB (Granger et al. 2017). Cultivars of both green and white ash were heavily planted as street trees from the 1940s to the 1990s (Poland and McCullough 2006), and Urban Forest Assessment data from 2010-2011 shows that green ash were likely more abundant than white ash in Roanoke and Charlottesville. The current disparity between the species evident from on-site inventory data may reflect a difference in the species' resistance to EAB infestation, which has been documented by multiple researchers (see Koch et al. 2015). The greater

susceptibility of green ash to EAB, then, could inform tree preservation initiatives—through preferential funding for green ash treatment, or other prioritization mechanisms.

While cluster analysis provided an interpretable typology of properties, the categories produced were not significant predictors in linear models of site species composition. Models of ash *Relative importance* and *Relative structural value* employed the predictors of cluster membership, *Years since EAB infestation*, and *Historical ash abundance*. None of these predictors were significant in either model, although *Years since EAB* infestation was marginally significant for the model of *Relative structural value*. This negative association is intuitive—as time has passed since a local initial EAB detection, the number and condition of ash trees has declined, leading to a decrease in value. With a greater sample size and a better-fitting model, this association could be used to model a decline in appraised value of ash trees for a single property over the course of an EAB infestation—information which might prove helpful to homeowners or insurers. Researchers have constructed city-wide models for a similar purpose, with the aim of informing decision makers (see Vannatta, Hauer, and Schuettpelz 2012, or Sadof et al. 2017). A parcel-level analysis of value lost through inaction or preserved by tree treatment could likewise assist homeowners in budgeting decisions.

While predictive models of site ash importance and structural value were not statistically significant here, this mode of analysis has been successfully employed by other researchers. An analysis of Boston, MA residential landscapes found associations between vegetation structure and property characteristics, include parcel area, year of construction, and architectural style (Ossola et al. 2019). Schmitt-Harsh et al. (2013) described how tree species composition in Bloomington, IN residential parcels varied by decade of property development—notably, white ash were commonly planted in that locality only in the 1950s and 1970s. A geospatial analysis of

urban vegetation diversity in Ballarat, Australia similarly found that a property's physical characteristics outperformed socioeconomic characteristics in predicting tree cover and species richness (Kendal et al. 2012). Notably, in a 2017 study, researchers found greater success in using cluster analysis to classify street trees by land type or development era, compared to trees on residential properties (Nitoslawski et al. 2017). This type of parcel-level species composition modeling, while unlikely to be generalizable beyond a regional scale, could prove useful for municipal forest planning in the absence of detailed inventory data.

6.2.2 Homeowner Engagement in Landscape Tree Preservation

The relative homogeneity of respondent demographic characteristics demonstrates the relevance of broader outreach both for cost-share programming and for conservation research. Statewide, about 77% of Virginia residents identify as White, while 19% identify as Black, and 3% as Asian (Wikipedia contributors 2019). Across racial groups, 9% identify as Hispanic (Pew Research Center 2016). Respondents to the EABTP participants' and general households survey were almost exclusively white and on average, in their late fifties. Differing rates of homeownership by race and ethnicity are unlikely to explain this disparity—at the national level, homeownership rates range only between 42% and 72% among ethnic groups (U. S. Census Bureau 2017). For this reason, it is likely that there are sizeable populations of minority homeowners in Virginia who may be unaware of or not engaged with conservation funding such as the EABTP or conservation research, such as this project.

Additionally, younger homeowners were likely underrepresented among EABTP participants and among household survey respondents. Nationally, homeownership rates for those between 25 and 29 are just under 33%, and reach 57% for those between 35 and 39 (U. S.

Census Bureau 2017b). In designing the general households' survey, a web+mail design was selected based on research indicating its effectiveness in increasing response rates among younger respondents (e.g., Sexton, Miller, and Dietsch 2011, de Bernardo and Curtis 2013). Response data offered only minimal support for this hypothesis—while decreasing age was significantly associated with a web response, the effect was negligibly small. However, a choice of response mode is only one of many survey design aspects relevant to response rates. For researchers, other strategies for increasing minority response including contacting residents through community networks (Swanson and Ward 1995), or the use of snowball sampling (Perez et al. 2013). Low participation or response rates among younger and minority homeowners calls for a diversity of input and creative strategies to expand project outreach of cost-share programming and conservation research.

Models of homeowner *Tree preservation intention* and *Cost-share participation* demonstrated the consistent significance of attitudinal predictors, as opposed to externally observable characteristics. *Tree preservation intention* measured a respondent's stated likelihood of investing personal funds in the long-term treatment of a threatened landscape tree, while *Cost-share participation* measured interest in a public subidy for tree treatment. For all top-ranking models of either dependent variable, the attitudinal predictor *Importance of preserving ash/shade trees* was significant or marginally significant. At first glance, this relationship is obvious—those who feel strongly about the importance of preserving landscape trees from pests are also the most likely to invest in tree treatment. However, this finding also demonstrates a useful principle for program planning—that strong supporters of urban forest health initiatives may reliably be enlisted from groups already involved in tree preservation. Tree stewardship groups and urban cooperative extension programs are two examples of organizations based on shared interest in

protection of urban natural resources (Day et al. 1997). Many members of these groups possess prior interest in tree preservation, familiarity with local urban forests, and social networks of their own. For these reasons, urban forest health initiatives could benefit from their involvement.

What is perhaps more surprising than the consistent importance of attitudinal predictors is the apparent lack of predictive power of most personal and property characteristics. Many of the characteristics tested here, such as lot size or the age of a house, are available through public databases, and for that reason have the potential to inform program outreach with few expenses upfront. Yet almost none of these variables, from household income to the number of trees on a property, showed any influence on the dependent variables of interest.

In constrast with the lack of findings here, the literature on cost-share enrollment among non-industrial private forest (NIPF) landowners provides many examples of the predictive power of personal or property characteristics. Studies have documented the significance of educational attainment (Watson et al. 2013), property size (Kline et al. 2000), and household income (Joshi and Arano 2009) as predictors of enrollment in cost-share programming. In a closer analogue to this research, Conway and Bang (2014) found that while household income, ethnicity, homeownership and canopy cover made no contribution to a model of support for a urban tree planting program, educational attainment and age of neighborhood development were predictive. While in this research it is possible that relatively homogeneous samples may have limited statistical power, related findings indicate the possibility of constructing predictive models of homeowner decision-making using external characteristics.

Models of behavioral intention did identify one significant assocation apart from attitudinal predictors—a positive association between the *Established* EAB stratum and the willingness to pay for tree treatment among general households. In counties within this stratum,

EAB had been present for at least ten years. This finding indicates that personal awareness or experience of EAB damage may lead to greater willingness to invest in tree preservation. It also suggests the importance of communicating with residents living ahead of an impending invasion front, since they may be less likely to act without an immediate reason to do so. While this association may seem seem uncontroversial, there are confounding variables which weaken a causal claims. First, relative to the rest of the state, household income is high in many of the northern Virginia counties within the *Established* stratum. Secondly, relative to the entire state, ash trees were historically highly abundant in the same geographic region (see Figure 2). Consequently, while it is interesting to note the association between local age of EAB infestation and willingness to pay for tree treatment, it is not possible to know, from these data, whether this finding would be generalizable across the state.

6.2.3 Practitioner Perceptions of Cost-Share Participation

Survey responses from both foresters and arborists represented most regions of Virginia, although no forester responses were recorded from southwestern Virginia. Response rate was low for foresters (18.1%) and even lower for arborists (9.1%), reducing the generalizability of study findings. While the final sample was also low for foresters (n=19), this group represented more than three-quarters of all county foresters who had participated in the 2018 program. Interestingly, almost 75% of foresters reported having ISA certification, compared to a level of 10.5% for SAF certification. By itself, this statistic is an interesting finding—demonstrating the growing the relevance of this primarily arboricultural certification to the current work of VDOF county foresters. Additionally, this statistic suggests that EABTP site visits and approval of individual trees for treatment were not far removed from some foresters' prior job duties.

The two top-ranking models for arborists' interest in future EABTP participation included, separately, attitudinal and professional characteristics. Neither model was significant nor fit the data well. While of very little statistical value, the lone significant predictor was the binary variable *EAB management recommendation cluster,* in the model *Professional Characteristics*. This result may indicate a greater likelihood of program interest among arborists with a preference for a 'wait and see' approach, when recommending a course of action to clients with ash trees, instead of preemptive tree removal. This result highlights the fact that some arborists may favor preemptive tree removal above all other options. Because dead ash trees are known to quickly become brittle, there are likely significant safety concerns tied to such a recommendation (Barnes et al. 2019). Not surprisingly, arborists expressing this preference were also unlikely to express strong interest in the EABTP. These results together demonstrate how arborists display a variety of attitudes and professional opinions regarding tree preservation and EAB management. An awareness of these multiple points of view is valuable in enlisting arborist participation in future cost-share initiatives.

Finally, practitioners' written responses regarding interest (or lack of interest) in the EABTP help to further describe multiple viewpoints. About one-quarter of those responding indicated that EABTP was not relevant to their line of work, a figure that by itself reduces the generalizability of remaining responses. Of the remaining responses, the ratio of positive (interested in EABTP participation) to negative (uninterested) was roughly 3:2. Considering that the work of foresters and arborists is essential to program implementation, this is a relatively narrow margin of support. Many of the negative responses regarded external conditions, such as lack of financial need or EAB awareness among clients, or simply a local lack of ash trees. Others addressed respondents' internal attitudes or opinions, such as lack of time for paperwork,

an opposition to chemical use, or the view that EABTP incentives were unsustainable. On the other hand, the two most common (non-neutral) responses overall were positive: the opinion that EABTP was beneficial for ash preservation, and the opinion that the program was beneficial for clients. These two opinions align closely with EABTP's program objectives of preserving populations of ash trees and 'jumpstarting' this work among Virginia residents (Chamberlin 2018a). These responses demonstrate that support for EABTP, while not universal, is strong among many practitioners.

6.3 Study Limitations

Strength of conclusions in parts of this research were limited by sample size. The number of participant property inventories (n=16) and the number of forester respondents (n=19) were below a commonly-accepted threshold of 30 necessary for the application of the central limit theorem (CLT) to non-normally distributed data (Howell 2013). For these datasets, statistical tests that rely on the CLT were avoided, except for linear models of ash importance and value on participant properties. These models, which were not significant, were presented as an exploratory exercise.

In addition to limitations of absolute sample size, strength of survey research conclusions were also limited by large margins of error in three out of four cases. Margin of error, or sampling error, is a calculated percent range within which a population mean is likely to fall, for a given confidence level (Vaske 2008). At the 95% confidence level, the calculated margin of error for the general households' survey was ±4.84%, compared with larger values for the arborists' survey (±7.79%), EABTP participants' survey (±8.63%), and the foresters' survey (±20.4%).

Potential for nonresponse bias also affected the generalizability of some survey results. For the general household survey, tests for nonresponse bias indicated that educational attainment of respondents was significantly higher than that of nonrespondents. The same tests also indicated marginally significant differences in household income level and the proportion of minorities. Taken together, nonresponse test results indicate that general household survey responses reflect a sample that is slightly more educated, wealthier, and more racially homogeneous than the sampling frame. For the arborists survey, tests for nonresponse bias also indicated that researchers or educators were overrepresented, and that landscape professionals and arborists in southeastern Virginia were underrepresented, compared with a reference group of MAC-ISA members statewide.

Another important limitation in analysis of tree inventory data was the timing of data collection. Since tree inventories were conducted after leaf drop, assessments of tree condition were less accurate than if they had been made during the growing season. Condition ratings were based on the relative absence of dead limbs, the relative absence of wounds or defects, and the relative presence of live buds on branch tips. However, these dormant season assessments necessarily made use of much less information than a visual assessment of tree canopy. A second, related limitation was a lack of accurate information on the treatment status of individual ash trees. Because much of the data collection was conducted without a homeowner present, there was often no clear way to determine which ash tree had been treated in 2018 or before. Even when homeowners were present, not all were certain of the status of individual ash trees. This gap in data collection prevented comparison of the condition of trees treated prior to 2018 to others treated in 2018, or untreated trees. It also precluded an analysis of factors that might influence the treatment of certain ash trees over others.

Survey instrument design limited the number of usable responses, and possibly the response rate itself. Because the general households' survey was designed to capture responses from ash owners and non-ash owners separately, it contained two logical paths. On the paper version of the survey, the complexity of question structure may have contributed to a number of blank or unusable responses. Further, since the number of ash-owning households was so small (n=10), these were excluded from analysis because much of the response data was not comparable to that of remaining households and did not constitute an adequate sample size on its own.

The topic of ash-owning households points to another significant limitation of homeowner surveys: the lack of an appropriate 'control' group of ash-owning households against which to compare EABTP participant responses. Comparison of participant responses to those of general households might prove interesting but is not valid for inferential testing because the circumstances faced by either group were completely different. Had a large number (>30) of ash-owning households been identified in the general household sample, a meaningful comparison could have been drawn between their interest in tree preservation and that of actual program participants. Potentially, this mode of analysis could identify predictors of ash preservation among a sample of specifically ash-owning households, and measure the potential influence of EABTP cost-share assistance among a wider pool of eligible applicants. Instead, remaining households were asked about their intentions to preserve trees from a theoretical pest threat, and about their interest in a hypothetical cost-share program. While these responses were useful on their own, they are less directly applicable to the present EAB infestation.

Finally, the inclusion of ranked-choice items on survey instruments limited the types of possible analyses, particularly for practitioners' surveys. These items had been included in

surveys for three reasons: (1) to reduce survey length by collapsing several Likert-scale items into a single ranking item, (2) to maintain respondent interest with varied item format, and (3) to gather information about relative preference that might not be gleaned from side-by-side Likert-scale items. While ranking items did serve the first purpose, and possibly the second, analysis of the resulting data yielded very little information, as judged by test results. Arborist and forester surveys contained ranking items regarding ash preservation, pest threat perceptions, and EAB management recommendations. From these items, each containing 5-7 ranking options, only one significant result was identified in further analysis. While it is possible ranking items could be improved with clearer wording and stronger separation between options, anecdotal evidence from this research suggests these items are a poor method of measuring preference.

6.4 Future Research

Many studies have been conducted on the effects of emamectin benzoate and other insecticides on EAB in controlled, experimental forests (e.g., Smitley, Doccola, and Cox 2010, McCullough et al. 2011, McCullough et al. 2019). There are fewer examples of trials conducted in conducted in urban "field" conditions (e.g., Bick et al. 2018). While conducting trials with street and landscape trees adds many sources of variability, this experimental approach allows for testing of insecticidal performance in the stressful, urban conditions where most treated trees are located. Further testing of short- and long-term outcomes of insecticidal regimens for a variety of urban planting sites could benefit the hands-on work of tree preservation.

Further study of urban residential properties and households can help inform forest health initiatives in urban areas. The growing availability of urban FIA data (USFS 2014) may provide one avenue of pursuing this research. This USDA Forest Service program extends traditional

FIA plot-based, cyclical inventory into urban areas. In one example, researchers analyzed urban FIA data and plot locations to map and measure levels of tree canopy inequity (Mills et al. 2016). For locations where these data are available, neighborhood-level projections of tree species composition are possible. In contrast to this research, where households were selected based on relative tree cover, a survey sampling frame could be constructed at the neighborhood level using species-specific criteria from recent FIA data. This level of detailed urban inventory data has previously only been available for municipalities which have conducted plot-based tree inventories. Urban FIA opens possibilities for region- or nation-wide analyses of urban forest composition coupled with targeted household survey research.

Increasing availability of top-down urban forest assessments also creates possibilities for research and management of forest pests. As in the case of assessments conducted by the city Milwaukee in 2009 (Sivyer 2010), hyperspectral imagery combined with LiDAR data allows for the identification of several tree genera with a accuracy of 80% or greater. In contrast with plot-based sampling, which helps estimate species composition of the surrounding area, remote sensing techniques have the potential to map out individual trees by genus on individual parcels. Currently, the techniques involved are technically sophisticated and costly, and may be time-consuming conduct on a large scale. However, for locations where such assessments have already been conducted, fine-grained analyses of parcel-level tree inventory data coupled with household data are possible.

A related, but somewhat contrasting direction for research is the construction of models for tree species composition at the parcel level. In this research, linear models of site species composition as functions of property characteristics were poorly fitting and not significant, likely due to small sample size. Other research has demonstrated the feasibility of this approach—for

instance, modeling parcel carbon storage as a function of development era (Schmitt-Harsh et al. 2013) or parcel vegetation as a function of the owners' lifestyle behavior (Grove et al. 2006). These techniques, while likely to be highly region-specific, could potentially help urban foresters characterize urban vegetation across a city using few data inputs, and at very low cost.

Finally, further research is needed regarding attitudes of urban property owners towards tree preservation specifically, and urban ecosystems in general. This research has focused on identifying predictors of strong interest or disinterest in tree preservation and cost-share participation, with the intention of projecting the appeal of these practices broadly. A related direction for further study would focus on those with no strong inclination for or against tree preservation and identifying potential 'nudge' factors which might help increase the number of households supporting forest health objectives. Rather than financial incentives, 'nudge' factors include new policies or ways of presenting information that influence behavior (Kuhfuss et al. 2016). A comparison of the effectiveness of a financial incentive to normative influences of behavioral change could help inform methods of urban forest health outreach.

REFERENCES

Ajzen, Icek, and Martin Fishbein. 1980. *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, N.J.: Prentice-Hall.

Alpert, Peter. 2006. "The Advantages and Disadvantages of Being Introduced." *Biological Invasions* 8 (7): 1523–34. https://doi.org/10.1007/s10530-005-5844-z.

Alvey, Alexis A. 2006. "Promoting and Preserving Biodiversity in the Urban Forest." *Urban Forestry & Urban Greening* 5 (4): 195–201. https://doi.org/10.1016/j.ufug.2006.09.003.

American Nurseryman. 2013. "Asian Longhorned Beetle Declared Eradicated in N.J., Canada," May 2013.

Andridge, Rebecca R, and Roderick J A Little. 2011. "Proxy Pattern-Mixture Analysis for Survey Nonresponse." *Journal of Official Statistics*, 27 (2): 153.

ArcGIS Pro (version 2.2). 2018. Redlands, CA: Environmental Systems Research Institute.

Arnold, Todd W. 2010. "Uninformative Parameters and Model Selection Using Akaike's Information Criterion." *The Journal of Wildlife Management* 74 (6): 1175–78. https://doi.org/10.1111/j.1937-2817.2010.tb01236.x.

Asaro, Chris. 2007. "Forest Health Review." Charlottesville, VA: Virginia Department of Forestry. http://www.dof.virginia.gov/infopubs/_fhr/FHR-2007-05_pub.pdf.

———. 2008. "Forest Health Review." Charlottesville, VA: Virginia Department of Forestry. http://www.dof.virginia.gov/infopubs/_fhr/FHR-2008-05_pub.pdf.

———. 2013. "Forest Health Report." Charlottesville, VA: Virginia Department of Forestry. http://www.dof.virginia.gov/infopubs/_fhr/FHR-2013-01_pub.pdf.

Asaro, Christopher, John T. Nowak, and Anthony Elledge. 2017. “Why Have Southern Pine Beetle Outbreaks Declined in the Southeastern U.S. with the Expansion of Intensive Pine Silviculture? A Brief Review of Hypotheses.” *Forest Ecology and Management* 391 (May): 338–48. https://doi.org/10.1016/j.foreco.2017.01.035.

Aukema, Juliann E., Brian Leung, Kent Kovacs, Corey Chivers, Kerry O. Britton, Jeffrey Englin, Susan J. Frankel, et al. 2011. “Economic Impacts of Non-Native Forest Insects in the Continental United States.” *PLoS ONE* 6 (9): e24587. https://doaj-org.ezproxy.lib.vt.edu.

Aukema, Juliann E., Deborah G. McCullough, Betsy Von Holle, Andrew M. Liebhold, Kerry Britton, and Susan J. Frankel. 2010. “Historical Accumulation of Nonindigenous Forest Pests in the Continental United States.” *BioScience* 60 (11): 886–97. https://doi.org/10.1525/bio.2010.60.11.5.

Barden, Charles J., Stephen B. Jones, and Larry E. Biles. 1996. “Extension Forestry Education: Reaching the People Who Make Decisions.” *Journal of Forestry* March: 31–35.

Barnes, Elizabeth, Cliff Sadof, and Lindsay Purcell. 2019. “Avoid Deadly Risk of Dying Ash Trees with Timely Tree Removal.” https://www.purduelandscapereport.org/article/avoid-deadly-risk-of-dying-ash-trees-with-timely-tree-removal/.

Bauer, Leah S., Jian J. Duan, Juli R. Gould, and Roy Van Driesche. 2015. “Progress in the Classical Biological Control of *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) in North America.” *The Canadian Entomologist* 147 (03): 300–317. https://doi.org/10.4039/tce.2015.18.

Bean, Meredith. 2019. “Unpublished Data.” Charlottesville, VA: Virginia Department of Forestry.

Bernardo, Dana Huyser de, and Anna Curtis. 2013. “Using Online and Paper Surveys: The Effectiveness of Mixed-Mode Methodology for Populations Over 50.” *Research on Aging* 35 (2): 220–40. https://doi.org/10.1177/0164027512441611.

Bick, Emily N, Nora J Forbes, Christopher Haugen, Grant Jones, Shawn Bernick, and Fredric Miller. 2018. “Seven-Year Evaluation of Insecticide Tools for Emerald Ash Borer in *Fraxinus pennsylvanica* (Lamiales: Oleaceae) Trees.” *Journal of Economic Entomology* 111 (2): 732–40. https://doi.org/10.1093/jee/toy018.

Biemer, Paul, and Andy Peytchev. 2013. “Using Geocoded Census Data for Nonresponse Bias Correction: An Assessment.” *Journal of Survey Statistics and Methodology* 1 (1): 24–44. https://doi.org/10.1093/jssam/smt003.

Boyd, Roy G., Barbara J. Daniels, Robert Fallon, and William F. Hyde. 1988. “Measuring the Effectiveness of Public Forestry Assistance Programs.” *Forest Ecology and Management* 23 (4): 297–309. https://doi.org/10.1016/0378-1127(88)90060-6.

Brasier, C. M. 1990. “China and the Origins of Dutch Elm Disease: An Appraisal.” *Plant Pathology* 39 (1): 5–16. https://doi.org/10.1111/j.1365-3059.1990.tb02470.x.

Brooks, David J. 1985. “Public Policy and Long-Term Timber Supply in the South.” *Forest Science* 31 (2): 342–57.

Caldas, Marcellus M., Jason S. Bergtold, Jeffrey M. Peterson, and Dietrich H. Earnhart. 2016. “Land-Use Choices: The Case of Conservation Reserve Program (CRP) Re-Enrollment in Kansas, USA.” *Journal of Land Use Science* 11 (5): 579–94. https://doi.org/10.1080/1747423X.2016.1215563.

Campanella, Thomas J. 2003. *Republic of Shade: New England and the American Elm*. Yale University Press.

Cappaert, David, Deborah G. McCullough, Therese M. Poland, and Nathan W. Siegert. 2005. "Emerald Ash Borer in North America: A Research and Regulatory Challenge." *American Entomologist* 51 (3): 152–65. https://doi.org/10.1093/ae/51.3.152.

Carson, Richard T., Nicholas E. Flores, and Norman F. Meade. 2001. "Contingent Valuation: Controversies and Evidence." *Environmental and Resource Economics* 19 (2): 173–210. https://doi.org/10.1023/A:1011128332243.

Chamberlin, Lori. 2018a. "Personal Correspondence." Charlottesville, VA: Virginia Department of Forestry.

———. 2018b. "Unpublished Data." Charlottesville, VA: Virginia Department of Forestry.

Ciuzio, Elizabeth, William L. Hohman, Brian Martin, Mark D. Smith, Scott Stephens, Allan M. Strong, and Tammy Vercauteren. 2013. "Opportunities and Challenges to Implementing Bird Conservation on Private Lands." *Wildlife Society Bulletin* 37 (2): 267–77. https://doi.org/10.1002/wsb.266.

Clark, Stacy L., Scott E. Schlarbaum, Arnold M. Saxton, and Richard Baird. 2019. "Eight-Year Blight (*Cryphonectria parasitica*) Resistance of Backcross-Generation American Chestnuts (*Castanea dentata*) Planted in the Southeastern United States." *Forest Ecology and Management* 433 (February): 153–61. https://doi.org/10.1016/j.foreco.2018.10.060.

Conway, Tenley M., and Elizabeth Bang. 2014. "Willing Partners? Residential Support for Municipal Urban Forestry Policies." *Urban Forestry & Urban Greening* 13 (2): 234–43. https://doi.org/10.1016/j.ufug.2014.02.003.

Costello, Anna B, and Jason W Osborne. 2005. "Best Practices in Exploratory Factor Analysis: Four Recommendations for Getting the Most From Your Analysis." *Exploratory Factor Analysis* 10 (7): 9.

Cumbia, Dean. 2018. “Unpublished Data.” Charlottesville, VA: Virginia Department of Forestry.

Day, Eric R., Theresa A. Delinger, Douglas Pfeiffer, Mark Sutphin, and Chris Bergh. 2018. “Pest Alert: Spotted Lanternfly, *Lycorma deliculata*.” Virginia Cooperative Extension. https://vtechworks.lib.vt.edu/bitstream/handle/10919/87882/ENTO-291.pdf?sequence=1.

Day, Susan D., Sheri T. Dorn, Diane Relf, and Roger Harris. 1997. “Advanced Master Gardener - Tree Steward: Training to Enhance Community Volunteerism".” *HortTechnology* 7 (4): 363–67. https://journals.ashs.org/horttech/view/journals/horttech/7/4/article-p363.pdf.

Dayer, Ashley A., Shorna Broussard Allred, and Richard C. Stedman. 2014. “Comparative Analysis and Assessment of Forest Landowner Typologies.” *Society & Natural Resources* 27 (11): 1200–1212. https://doi.org/10.1080/08941920.2014.933931.

Dillman, Don A., Jolene D. Smyth, and Leah Melani Christian. 2009. *Internet, Mail, and Mixed-Mode Surveys: The Tailored Design Method*. Hoboken, NJ: John Wiley & Sons.

Dodds, Kevin J., and David A. Orwig. 2011. “An Invasive Urban Forest Pest Invades Natural Environments - Asian Longhorned Beetle in Northeastern US Hardwood Forests.” *Canadian Journal of Forest Research* 41: 1729–42.

Dolnicar, Sara. 2002. “A Review of Unquestioned Standards in Using Cluster Analysis for Data-Driven Market Segmentation.” In *Proceedings of the Australian and New Zealand Marketing Academy Conference*, 9. Deakin University: Melbourne.

Duan, Jian J., Leah S. Bauer, Roy G. van Driesche, and Juli R. Gould. 2018. “Progress and Challenges of Protecting North American Ash Trees from the Emerald Ash Borer Using Biological Control.” *Forests* 9 (3): 142. https://doi.org/10.3390/f9030142.

EAB Information Network. 2019. “Emerald Ash Borer Information Network.” http://emeraldashborer.info/.

Egan, A., D. Gibson, and R. Whipkey. 2001. “Evaluating the Effectiveness of the Forest Stewardship Program in West Virginia.” *Journal of Forestry* 99 (3): 31.

Esseks, J Dixon, and Robert J Moulton. 2000. “Evaluating the Forest Stewardship Program Through a National Survey of Participating Forest Land Owners.” DeKalb, IL: Center for Governmental Studies.

Farmer, James R., Zhao Ma, Michael Drescher, Eric G. Knackmuhs, and Stephanie L. Dickinson. 2017. “Private Landowners, Voluntary Conservation Programs, and Implementation of Conservation Friendly Land Management Practices.” *Conservation Letters* 10 (1): 58–66. https://doi.org/10.1111/conl.12241.

Feng, Hongli, Catherine L. Kling, Lyubov A. Kurkalova, Silvia Secchi, and Philip W. Gassman. 2005. “The Conservation Reserve Program in the Presence of a Working Land Alternative: Implications for Environmental Quality, Program Participation, and Income Transfer.” *American Journal of Agricultural Economics* 87 (5): 1231–38. https://doi.org/10.1111/j.1467-8276.2005.00812.x.

FIA. 2018. “Forest Statistics by State [Data File].” FIA DataMart FIADB_1.7.2.00. 2018. https://apps.fs.usda.gov/fia/datamart/datamart_excel.html.

Goldman, Rebecca L., Barton H. Thompson, and Gretchen C. Daily. 2007. “Institutional Incentives for Managing the Landscape: Inducing Cooperation for the Production of Ecosystem Services.” *Ecological Economics*, Special Section - Ecosystem Services and Agriculture, 64 (2): 333–43. https://doi.org/10.1016/j.ecolecon.2007.01.012.

Gormley, Isobel Claire, and Thomas Brendan Murphy. 2008. “Exploring Voting Blocs Within the Irish Electorate: A Mixture Modeling Approach.” *Journal of the American Statistical Association* 103 (483): 1014–27. https://doi.org/10.1198/016214507000001049.

Granger, Joshua J., John M. Zobel, and David S. Buckley. 2017. “Potential for Regenerating Major and Minor Ash Species (*Fraxinus* spp.) Following EAB Infestation in the Eastern United States.” *Forest Ecology and Management* 389 (April): 296–305. https://doi.org/10.1016/j.foreco.2016.12.003.

Griffin, Gary J. 2000. “Blight Control and Restoration of the American Chestnut.” *Journal of Forestry; Bethesda* 98 (2): 22. https://search.proquest.com/docview/220789461/citation/114B6E95AE404B86PQ/1.

Grove, Jeremiah, Troy Arlington, J.P. O’Neil-Dunne, W.R. Burch, M.L Cadenasso, and S.T.A. Pickett. 2006. “Characterization of Households and Its Implications for the Vegetation of Urban Ecosystems.” *Ecosystems* 9 (4): 578–97. https://www.fs.fed.us/ne/newtown_square/publications/other_publishers/ne_2006_grove002p.pdf.

Haack, R.A., Joseph F. Cavey, E. Richard Hobeke, and K Law. 1996. “*Anoplophora glabripennis*: A New Tree-Infesting Exotic Cerambycid Invades New York.” *Newsletter of the Michigan Entomological Society*, 1996.

Haack, Robert A. 2006. “Exotic Bark- and Wood-Boring Coleoptera in the United States: Recent Establishments and Interceptions.” *Canadian Journal of Forest Research* 36 (2): 269.

Haack, Robert A., Franck Hérard, Jianghua Sun, and Jean J. Turgeon. 2010. “Managing Invasive Populations of Asian Longhorned Beetle and Citrus Longhorned Beetle: A Worldwide Perspective.” *Annual Review of Entomology* 55 (1): 521–46. https://doi.org/10.1146/annurev-ento-112408-085427.

Hansen, Richard A., Amanda Clarke Henley, Emily S. Brouwer, Adaora N. Oraefo, and Mary T. Roth. 2007. "Geographic Information System Mapping as a Tool to Assess Nonresponse Bias in Survey Research." *Research in Social and Administrative Pharmacy* 3 (3): 249–64. https://doi.org/10.1016/j.sapharm.2006.10.001.

Hardie, Ian W., and Peter J. Parks. 1991. "Individual Choice and Regional Acreage Response to Cost-Sharing in the South, 1971-1981." *Forest Science* 37 (1): 175–90. https://doi.org/10.1093/forestscience/37.1.175.

Herms, Daniel A., and Deborah G. McCullough. 2014. "Emerald Ash Borer Invasion of North America: History, Biology, Ecology, Impacts, and Management." *Annual Review of Entomology* 59 (1): 13–30. https://doi.org/10.1146/annurev-ento-011613-162051.

Hippel, Paul von, David Hunter, and McKalie Drown. 2017. "Better Estimates from Binned Income Data: Interpolated CDFs and Mean-Matching." *Sociological Science* 4: 641–55. https://doi.org/10.15195/v4.a26.

Howell, David C. 2013. *Statistical Methods for Psychology*. 8th ed. Belmont, CA: Wadsworth.

IBM SPSS for Windows, Version 25.0. 2017. Armonk, NY: IBM Corp.

Jacques, Julien, Quentin Grimonprez, and Christophe Biernacki. 2016. "Rankcluster: An R Package for Clustering Multivariate Partial Rankings," *The R Journal 6*(1): 10.

Jennings, David E., Jian J. Duan, Dick Bean, Juli R. Gould, Kimberly A. Rice, and Paula M. Shrewsbury. 2016. "Monitoring the Establishment and Abundance of Introduced Parasitoids of Emerald Ash Borer Larvae in Maryland, U.S.A." *Biological Control* 101 (October): 138–44. https://doi.org/10.1016/j.biocontrol.2016.07.006.

Jennings, David E., Philip B. Taylor, and Jian J. Duan. 2014. “The Mating and Oviposition Behavior of the Invasive Emerald Ash Borer (*Agrilus planipennis*), with Reference to the Influence of Host Tree Condition.” *Journal of Pest Science* 87 (1): 71–78. https://doi.org/10.1007/s10340-013-0539-1.

Joshi, Sudiksha, and Kathryn G. Arano. 2009. “Determinants of Private Forest Management Decisions: A Study on West Virginia NIPF Landowners.” *Forest Policy and Economics* 11 (2): 118–25. https://doi.org/10.1016/j.forpol.2008.10.005.

Kappler, Rachel H., Kathleen S. Knight, Jennifer Koch, and Karen V. Root. 2018. “Neighboring Tree Effects and Soil Nutrient Associations with Surviving Green Ash (*Fraxinus pennsylvanica*) in an Emerald Ash Borer (*Agrilus planipennis*) Infested Floodplain Forest.” *Forests* 9 (4): 183. https://doi.org/10.3390/f9040183.

Kendal, Dave, Nicholas S. G. Williams, and Kathryn J. H. Williams. 2012. “Drivers of Diversity and Tree Cover in Gardens, Parks and Streetscapes in an Australian City.” *Urban Forestry & Urban Greening* 11 (3): 257–65. https://doi.org/10.1016/j.ufug.2012.03.005.

Kilgore, Michael A., John L. Greene, Michael G. Jacobson, Thomas J. Straka, and Steven E. Daniels. 2007a. “The Influence of Financial Incentive Programs in Promoting Sustainable Forestry on the Nation’s Family Forests.” *Journal of Forestry* 105 (4): 184–91. https://doi.org/10.1093/jof/105.4.184.

Kline, Jeffrey D., Ralph J. Alig, and Rebecca L. Johnson. 2000. “Fostering the Production of Nontimber Services Among Forest Owners with Heterogeneous Objectives.” *Forest Science* 46 (2): 302–11. https://doi.org/10.1093/forestscience/46.2.302.

Kline, Jeffrey D, and Brett J Butler. 2002. “Tree Planting in the South: What Does the Future Hold?” *Southern Journal of Applied Forestry* 26 (2): 99–107.

Klooster, Wendy, Kamal Gandhi, Lawrence Long, Kayla Perry, Kevin Rice, and Daniel Herms. 2018. “Ecological Impacts of Emerald Ash Borer in Forests at the Epicenter of the Invasion in North America.” *Forests* 9 (5): 250. https://doi.org/10.3390/f9050250.

Knight, Kathleen S., John P. Brown, and Robert P. Long. 2013. “Factors Affecting the Survival of Ash Trees Infested by Emerald Ash Borer.” *Biological Invasions* 15 (2): 371–83. https://doi.org/10.1007/s10530-012-0292-z.

Knight, Kathleen S, Daniel Herms, Reid Plumb, and Eileen Sawyer. 2011. “Dynamics of Surviving Ash (*Fraxinus* spp.) Populations in Areas Long Infested by Emerald Ash Borer (*Agrilus planipennis*).” In *4th International Workshop on Genetics of Host-Parasite Interactions in Forestry*, 10.

Koch, J. L., D. W. Carey, M. E. Mason, T. M. Poland, and K. S. Knight. 2015. “Intraspecific Variation in *Fraxinus pennsylvanica* Responses to Emerald Ash Borer (*Agrilus planipennis*).” *New Forests* 46 (5–6): 995–1011. https://doi.org/10.1007/s11056-015-9494-4.

Kokotovich, Adam E., and Adam R. Zeilinger. 2011. “Exploring Social and Institutional Variation across Oak Wilt Risk Management Programs in Minnesota, USA.” *Urban Forestry & Urban Greening* 10 (1): 39–45. https://doi.org/10.1016/j.ufug.2010.09.004.

Komen, James, and Donald R Hodel. 2015. “An Analysis of the Field Precision of the CTLA Trunk Formula Method,” *Arboriculture & Urban Forestry* 41 (5) 279-285.

Kondo, Michelle, Jaime Fluehr, Thomas McKeon, and Charles Branas. 2018. “Urban Green Space and Its Impact on Human Health.” *International Journal of Environmental Research and Public Health* 15 (3): 445. https://doi.org/10.3390/ijerph15030445.

Kovacs, Kent F., Robert G. Haight, Deborah G. McCullough, Rodrigo J. Mercader, Nathan W. Siegert, and Andrew M. Liebhold. 2010. “Cost of Potential Emerald Ash Borer Damage in U.S. Communities, 2009–2019.” *Ecological Economics* 69 (3): 569–78. https://doi.org/10.1016/j.ecolecon.2009.09.004.

Kovacs, Kent F., Robert G. Haight, Rodrigo J. Mercader, and Deborah G. McCullough. 2014. “A Bioeconomic Analysis of an Emerald Ash Borer Invasion of an Urban Forest with Multiple Jurisdictions.” *Resource and Energy Economics* 36 (1): 270–89. https://doi.org/10.1016/j.reseneeco.2013.04.008.

Kuhfuss, Laure, Raphaële Préget, Sophie Thoyer, Nick Hanley, Philippe Le Coent, and Mathieu Désolé. 2016. “Nudges, Social Norms, and Permanence in Agri-Environmental Schemes.” *Land Economics* 92 (4): 641–55. https://doi.org/10.3368/le.92.4.641.

Lal, Pankaj, Bernabas Wolde, Janaki Alavalapati, Pralhad Burli, and John Munsell. 2016. “Forestland Owners’ Willingness to Plant Pine on Non-Forested Land for Woody Bioenergy in Virginia.” *Forest Policy and Economics* 73 (December): 52–57. https://doi.org/10.1016/j.forpol.2016.09.003.

Lee, Jun-Hak, Yekang Ko, and E. Gregory McPherson. 2016. “The Feasibility of Remotely Sensed Data to Estimate Urban Tree Dimensions and Biomass.” *Urban Forestry & Urban Greening* 16 (January): 208–20. https://doi.org/10.1016/j.ufug.2016.02.010.

Lesser, Virginia M, and Lydia D Newton. 2016. “Mixed-Mode Surveys Compared With Single-Mode Surveys: Trends in Responses and Methods to Improve Completion.” *Journal of Rural Social Sciences* 31 (6): 7–34.

Li, Yanshu, and Daowei Zhang. 2007. “A Spatial Panel Data Analysis of Tree Planting in the US South.” *Southern Journal of Applied Forestry*, 31 (4): 192-198.

Liebhold, A., V. Mastro, and P. w. Schaefer. 1989. “Learning from the Legacy of Leopold Trouvelot.” *Bulletin of the Entomological Society of America* 35 (2): 20–22. https://doi.org/10.1093/besa/35.2.20.

Liebhold, Andrew M., William L. MacDonald, Dale Bergdahl, and Victor C. Mastro. 1995 “Invasion by Exotic Forest Pests: A Threat to Forest Ecosystems.” *Forest Science 41(suppl_1).*

Liebhold, Andrew M. 2012. “Forest Pest Management in a Changing World.” *International Journal of Pest Management* 58 (3): 289–95. https://doi.org/10.1080/09670874.2012.678405.

Liu, Houping. 2013. “Emerald Ash Borer Management Plan for Pennsylvania Communities.” Harrisburg, PA: Pennsylvania Department of Conservation and Natural Resources. http://www.docs.dcnr.pa.gov/cs/groups/public/documents/document/dcnr_20027832.pdf.

———. 2018. “Under Siege: Ash Management in the Wake of the Emerald Ash Borer.” *Journal of Integrated Pest Management* 9 (1). https://doi.org/10.1093/jipm/pmx029.

Liu, Houping, Leah S. Bauer, Deborah L. Miller, Tonghai Zhao, Ruitong Gao, Liwen Song, Qingshu Luan, Ruozhong Jin, and Changqi Gao. 2007. “Seasonal Abundance of *Agrilus planipennis* (Coleoptera: Buprestidae) and Its Natural Enemies *Oobius agrili* (Hymenoptera: Encyrtidae) and *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in China.” *Biological Control* 42 (1): 61–71. https://doi.org/10.1016/j.biocontrol.2007.03.011.

Loo, Judy A. 2009. “Ecological Impacts of Non-Indigenous Invasive Fungi as Forest Pathogens.” In *Ecological Impacts of Non-Native Invertebrates and Fungi on Terrestrial Ecosystems*, edited by David W. Langor and Jon Sweeney, 81–96. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-1-4020-9680-8_6.

Lovett, Gary M., Marissa Weiss, Andrew M. Liebhold, Thomas P. Holmes, Brian Leung, Kathy Fallon Lambert, David A. Orwig, et al. 2016. “Nonnative Forest Insects and Pathogens in the United States: Impacts and Policy Options.” *Ecological Applications* 26 (5): 1437–55. https://doi.org/10.1890/15-1176.

Luzar, E. Jane, and Assane Diagne. 1999. “Articles: Participation in the next Generation of Agriculture Conservation Programs: The Role of Environmental Attitudes.” *Journal of Socio-Economics* 28 (January): 335–49. https://doi.org/10.1016/S1053-5357(99)00021-9.

MacFarlane, David W., and Shawna Patterson Meyer. 2005. “Characteristics and Distribution of Potential Ash Tree Hosts for Emerald Ash Borer.” *Forest Ecology and Management* 213 (1): 15–24. https://doi.org/10.1016/j.foreco.2005.03.013.

McCullough, Deborah G., and Rodrigo J. Mercader. 2012. “Evaluation of Potential Strategies to SLow Ash Mortality (SLAM) Caused by Emerald Ash Borer (Agrilus Planipennis): SLAM in an Urban Forest.” *International Journal of Pest Management* 58 (1): 9–23. https://doi.org/10.1080/09670874.2011.637138.

McCullough, Deborah G., Therese M. Poland, Andrea C. Anulewicz, Phillip Lewis, and David Cappaert. 2011. “Evaluation of *Agrilus planipennis* (Coleoptera: Buprestidae) Control Provided by Emamectin Benzoate and Two Neonicotinoid Insecticides, One and Two Seasons After Treatment.” *Journal of Economic Entomology* 104 (5): 1599–1612. https://doi.org/10.1603/EC11101.

McCullough, Deborah G, Therese M Poland, Andrew R Tluczek, Andrea Anulewicz, James Wieferich, and Nathan W Siegert. 2019. “Emerald Ash Borer (Coleoptera: Buprestidae) Densities Over a 6-Yr Period on Untreated Trees and Trees Treated With Systemic Insecticides at 1-, 2-, and 3-Yr Intervals in a Central Michigan Forest.” *Journal of Economic Entomology* 112 (1): 201–12. https://doi.org/10.1093/jee/toy282.

McFadden, Max W., and Michael E. McManus. 1991. “An Insect out of Control? The Potential for Spread and Establishment of the Gypsy Moth in New Forest Areas in the United States.” In *Forest Insect Guilds: Patterns of Interaction with Host Trees*, 153:172–86. Radno, PA: USDA, Northeastern Forest Experiment Station.

Mcmanus, Michael, and György Csóka. 2007. “History and Impact of Gypsy Moth in North America and Comparison to Recent Outbreaks in Europe,” 18.

MD DNR-FS. 2017. “Emerald Ash Borer Treatment Program Description and Application for Cost Share and Payment.” Maryland Department of Natural Resources-Forest Service. http://dnr.maryland.gov/forests/Documents/Emerald-Ash-Borer-Treatment-Program-Description-and-Application.pdf.

Medway, R. L., and J. Fulton. 2012. “When More Gets You Less: A Meta-Analysis of the Effect of Concurrent Web Options on Mail Survey Response Rates.” *Public Opinion Quarterly* 76 (4): 733–46. https://doi.org/10.1093/poq/nfs047.

Mills, John R., Patrick Cunningham, and Geoffrey H. Donovan. 2016. “Urban Forests and Social Inequality in the Pacific Northwest.” *Urban Forestry & Urban Greening* 16: 188–96. https://doi.org/10.1016/j.ufug.2016.02.011.

Moll, Gary. 1993. “A New Way to See Our City Forests.” *American Forests* 99 (9–10): 29-. http%3A%2F%2Flink.galegroup.com%2Fapps%2Fdoc%2FA14536163%2FAONE%3Fu%3Dviva_vpi%26sid%3DAONE%26xid%3D454cd460.

Müllensiefen, Daniel, Christian Hennig, and Hedie Howells. 2018. “Using Clustering of Rankings to Explain Brand Preferences with Personality and Socio-Demographic Variables.” *Journal of Applied Statistics* 45 (6): 1009–29. https://doi.org/10.1080/02664763.2017.1339025.

NCFS. 2018a. “Ash Protection Program Application.” North Carolina Forest Service. http://www.ncforestservice.gov/forest_health/LSR2018/EABApplicationpart1.pdf.

———. 2018b. “Ash Protection Program Guidelines.” North Carolina Forest Service. http://www.ncforestservice.gov/forest_health/LSR2018/LSR_Grant_Program%20Guidelines.pdf.

Nitoslawski, Sophie A., James W. Steenberg, Peter N. Duinker, and Peter G. Bush. 2017. “Assessing the Influence of Location Attributes on Urban Forest Species Composition in Suburban Neighbourhoods.” *Urban Forestry & Urban Greening* 27 (October): 187–95. https://doi.org/10.1016/j.ufug.2017.08.002.

Nowak, David J., Eric J. Greenfield, Robert E. Hoehn, and Elizabeth Lapoint. 2013. “Carbon Storage and Sequestration by Trees in Urban and Community Areas of the United States.” *Environmental Pollution* 178 (July): 229–36. https://doi.org/10.1016/j.envpol.2013.03.019.

Nowak, David J., Judith E. Pasek, Ronaldo A. Sequeira, Daniel E. Crane, and Victor C. Mastro. 2001. “Potential Effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on

Urban Trees in the United States." *Journal of Economic Entomology* 94 (1): 116–22. https://doi.org/10.1603/0022-0493-94.1.116.

Nowak, John, Christopher Asaro, Kier Klepzig, and Ronald Billings. 2008. "The Southern Pine Beetle Prevention Initiative: Working for Healthier Forests." *Journal of Forestry; Bethesda* 106 (5): 261–67. https://search-proquest-com.ezproxy.lib.vt.edu/docview/220812955/abstract/90FBFA1902154B17PQ/1.

NRCS. 2019. "Native, Invasive, and Other Plant-Related Definitions." Natural Resources Conservation Service. 2019. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ct/technical/ecoscience/invasive/?cid=nrcs142p2_011124.

Ossola, Alessandro, Dexter Locke, Brenda Lin, and Emily Minor. 2019. "Greening in Style: Urban Form, Architecture and the Structure of Front and Backyard Vegetation." *Landscape and Urban Planning* 185 (May): 141–57. https://doi.org/10.1016/j.landurbplan.2019.02.014.

Paap, Trudy, Treena I. Burgess, and Michael J. Wingfield. 2017. "Urban Trees: Bridge-Heads for Forest Pest Invasions and Sentinels for Early Detection." *Biological Invasions* 19 (12): 3515–26. https://doi.org/10.1007/s10530-017-1595-x.

Paillet, Frederick L. 2002. "Chestnut: History and Ecology of a Transformed Species." *Journal of Biogeography* 29 (10–11): 1517–30. https://doi.org/10.1046/j.1365-2699.2002.00767.x.

Pautasso, Marco, Markus Schlegel, and Ottmar Holdenrieder. 2015. "Forest Health in a Changing World." *Microbial Ecology* 69 (4): 826–42. https://doi.org/10.1007/s00248-014-0545-8.

Perez, Daniel F., Jason X. Nie, Chris I. Ardern, Natasha Radhu, and Paul Ritvo. 2013. “Impact of Participant Incentives and Direct and Snowball Sampling on Survey Response Rate in an Ethnically Diverse Community: Results from a Pilot Study of Physical Activity and the Built Environment.” *Journal of Immigrant and Minority Health* 15 (1): 207–14. https://doi.org/10.1007/s10903-011-9525-y.

Pew Research Center. 2016. “Latinos in the 2016 Election: Virginia.” 2016. https://www.pewhispanic.org/fact-sheet/latinos-in-the-2016-election-virginia/.

Pimentel, David, Rodolfo Zuniga, and Doug Morrison. 2005. “Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States.” *Ecological Economics*, Integrating Ecology and Economics in Control Bioinvasions, 52 (3): 273–88. https://doi.org/10.1016/j.ecolecon.2004.10.002.

Poland, Therese M., and Deborah G. McCullough. 2006. “Emerald Ash Borer: Invasion of the Urban Forest and the Threat to North America’s Ash Resource.” *Journal of Forestry; Bethesda* 104 (3): 118–24. https://search-proquest-com.ezproxy.lib.vt.edu/docview/220779905/abstract/8DA0E9356E204A31PQ/1.

Qualtrics. 2018. *Qualtrics*. Provo, UT.

R Core Team. 2018. *R: A Language and Environment for Statistical Computing* (version 3.5.2). Vienna: R Foundation for Statistical Computing. http://www.R-project.org/.

Richardson, David M, and Petr Pyšek. 2004. “What Is an Invasive Species?” *Crop Protection Compendium, CAB International*, Wallingford. http:/www. cabicompendium. org/cpc

Rigling, Daniel, and Simone Prospero. 2018. "*Cryphonectria parasitica*, the Causal Agent of Chestnut Blight: Invasion History, Population Biology and Disease Control." *Molecular Plant Pathology* 19 (1): 7–20. https://doi.org/10.1111/mpp.12542.

RStudio Team. 2019. *Rstudio: Integrated Development for R.* Boston, MA: RStudio, Inc. http://www.rstudio.com.

Ryan, Richard M, and Edward L Deci. 2000. "Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being." *American Psychologist*, 11.

Sadof, Clifford S., Gabriel P. Hughes, Adam R. Witte, Donnie J. Peterson, and Matthew D. Ginzel. 2017. "Tools for Staging and Managing Emerald Ash Borer in the Urban Forest." *Arboriculture & Urban Forestry* 43 (1): 15–26.

Sadof, Clifford S., Lindsey Purcell, Forrest J. Bishop, Carlos Quesada, and Zhi-Wei Zhan. 2011. "Evaluating Restoration Capacity and Costs of Managing the Emerald Ash Borer with a Web-Based Cost Calculator in Urban Forests." *Arboriculture & Urban Forestry* 37 (2): 74–83.

Schlarbaum, Scott E, F Hebard, P.C. Spaine, and J.C. Kamalay. 1997. "Three American Tragedies: Chestnut Blight, Butternut Canker, and Dutch Elm Disease." In *Exotic Pests of Eastern Forests*, 10. Nashville: Tennesse Exotic Pest Plant Council.

Schmiedel, Doreen, Eckehard-G. Wilhelm, Mechthild Roth, Cornelia Scheibner, Stefan Nehring, and Susanne Winter. 2016. "Evaluation System for Management Measures of Invasive Alien Species." *Biodiversity and Conservation* 25 (2): 357–74. https://doi.org/10.1007/s10531-016-1054-5.

Schmitt-Harsh, Mikaela, Sarah K. Mincey, Matt Patterson, Burnell C. Fischer, and Tom P. Evans. 2013. “Private Residential Urban Forest Structure and Carbon Storage in a Moderate-Sized Urban Area in the Midwest, United States.” *Urban Forestry & Urban Greening* 12 (4): 454–63. https://doi.org/10.1016/j.ufug.2013.07.007.

Schwarz, Kirsten, Michail Fragkias, Christopher G. Boone, Weiqi Zhou, Melissa McHale, J. Morgan Grove, Jarlath O’Neil-Dunne, et al. 2015. “Trees Grow on Money: Urban Tree Canopy Cover and Environmental Justice.” *PLOS ONE* 10 (4): e0122051. https://doi.org/10.1371/journal.pone.0122051.

Sexton, Natalie R., Holly M. Miller, and Alia M. Dietsch. 2011. “Appropriate Uses and Considerations for Online Surveying in Human Dimensions Research.” *Human Dimensions of Wildlife* 16 (3): 154–63. https://doi.org/10.1080/10871209.2011.572142.

Sharov, A. A., D. Leonard, A. M. Liebhold, E. A. Roberts, and W. Dickerson. 2002. “‘Slow The Spread’: A National Program to Contain the Gypsy Moth.” *Journal of Forestry* 100 (5): 30–36. https://doi.org/10.1093/jof/100.5.30.

Siegert, Nathan W., Deborah G. McCullough, Andrew M. Liebhold, and Frank W. Telewski. 2014. “Dendrochronological Reconstruction of the Epicentre and Early Spread of Emerald Ash Borer in North America.” *Diversity and Distributions* 20 (7): 847–58. https://doi.org/10.1111/ddi.12212.

Sivyer, David. 2010. “Mapping the Future for EAB Readiness and Response Planning in Milwaukee: An Update.” *City Trees* January: 16.

Smith, Michael T., Jay Bancroft, Guohong Li, Ruitong Gao, and Stephen Teale. 2001. “Dispersal of *Anoplophora glabripennis* (Cerambycidae).” *Environmental Entomology* 30 (6): 1036–40. https://doi.org/10.1603/0046-225X-30.6.1036.

Smitley, David, Terrance Davis, and Eric Rebek. 2008. “Progression of Ash Canopy Thinning and Dieback Outward from the Initial Infestation of Emerald Ash Borer (Coleoptera: Buprestidae) in Southeastern Michigan.” *Journal of Economic Entomology* 101 (5): 1643–50. https://doi.org/10.1603/0022-0493(2008)101[1643:POACTA]2.0.CO;2.

Smitley, David R, Joseph J Doccola, and David L Cox. 2010. “Multiple-Year Protection of Ash Trees from Emerald Ash Borer with a Single Trunk Injection of Emamectin Benzoate, and Single-Year Protection with an Imidacloprid Basal Drench.” *Arboriculture & Urban Forestry* 36 (5): 206–11.

Sorice, Michael G. 2012. “Retooling the Traditional Approach to Studying the Belief–Attitude Relationship: Explaining Landowner Buy-In to Incentive Programs.” *Society & Natural Resources* 25 (5): 499–512. https://doi.org/10.1080/08941920.2011.603143.

Sorice, Michael G., and J. Richard Conner. 2010. “Predicting Private Landowner Intentions to Enroll in an Incentive Program to Protect Endangered Species.” *Human Dimensions of Wildlife* 15 (2): 77–89. https://doi.org/10.1080/10871200903551985.

Soto, José R., Francisco J. Escobedo, Hayk Khachatryan, and Damian C. Adams. 2018. “Consumer Demand for Urban Forest Ecosystem Services and Disservices: Examining Trade-Offs Using Choice Experiments and Best-Worst Scaling.” *Ecosystem Services* 29 (February): 31–39. https://doi.org/10.1016/j.ecoser.2017.11.009.

Spector, Tova, and Francis E. Putz. 2006. “Crown Retreat of Open-Grown Southern Live Oaks (*Quercus virginiana*) Due to Canopy Encroachment in Florida, USA.” *Forest Ecology and Management* 228 (1): 168–76. https://doi.org/10.1016/j.foreco.2006.03.001.

Sun, Changyou. 2007. “Variation of Federal Cost-Share Programs in the United States and the Inducement Effects on Tree Planting.” *Journal of Forest Economics* 12 (4): 279–96. https://doi.org/10.1016/j.jfe.2006.09.002.

Swanson, G. M., and A. J. Ward. 1995. “Recruiting Minorities Into Clinical Trials Toward a Participant-Friendly System.” *JNCI Journal of the National Cancer Institute* 87 (23): 1747–59. https://doi.org/10.1093/jnci/87.23.1747.

Symonds, Matthew R. E., and Adnan Moussalli. 2011. “A Brief Guide to Model Selection, Multimodel Inference and Model Averaging in Behavioural Ecology Using Akaike’s Information Criterion.” *Behavioral Ecology and Sociobiology* 65 (1): 13–21. https://doi.org/10.1007/s00265-010-1037-6.

Theoharides, Kathleen A., and Jeffrey S. Dukes. 2007. “Plant Invasion across Space and Time: Factors Affecting Nonindigenous Species Success during Four Stages of Invasion.” *The New Phytologist* 176 (2): 256–73. http://www.jstor.org.ezproxy.lib.vt.edu/stable/4627161.

Train, Kenneth E. 1998. “Recreation Demand Models with Taste Differences over People.” *Land Economics* 74 (2): 230–39. https://doi.org/10.2307/3147053.

U.S. Census Bureau. 2010. “2010 Geographic Terms and Concepts - Block Groups.” https://www.census.gov/geo/reference/gtc/gtc_bg.html.

———. 2012. “Qualifying Urban Areas for the 2010 Census.” *Federal Register 77*(59): 18652.

———. 2016. “New Census Data Show Differences Between Urban and Rural Populations.” The United States Census Bureau. 2016. https://www.census.gov/newsroom/press-releases/2016/cb16-210.html.

———. 2017a. “2016 American Community Survey 5-Year Estimates.” https://factfinder.census.gov/faces/nav/jsf/pages/download_center.xhtml.

———. 2017b. “Housing Vacancies and Homeownership (CPS/HVS).” https://www.census.gov/housing/hvs/data/ann17ind.html.

———. 2018. “TIGER Products.” https://www.census.gov/geo/maps-data/data/tiger.html.

USDA-APHIS. 2017. “Emerald Ash Borer Biological Control Release and Recovery Guidelines.” Riverdale, MD: USDA-Animal and Plant Health Inspection Service-Agricultural Research Service-Forest Service. https://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/EAB-FieldRelease-Guidelines.pdf.

USFS. 2014. “Urban FIA Brochure.” USDA Forest Service. https://www.nrs.fs.fed.us/fia/urban/docs/Urban%20FIA%20Brochure%202014-opt.pdf.

———. 2018a. “FIA EVALIDator Version 1.8.0.00.” USDA Forest Service. https://apps.fs.usda.gov/Evalidator/evalidator.jsp.

———. 2018b. “I-Tree Eco.” USDA Forest Service. https://www.itreetools.org/eco/.

———. 2019a. “Urban FIA Program.” USDA Forest Service. https://www.nrs.fs.fed.us/fia/urban/.

———. 2019b. “Urban Natural Resources Stewardship.” USDA Forest Service - Northern Research Station. https://www.nrs.fs.fed.us/urban/.

Van Driesche, Roy G., and Richard C. Reardon. 2015. “Biology and Control of Emerald Ash Borer.” Morgantown, WV: USDA-Forest Service-Forest Health Technology Enterprise Team. https://permanent.access.gpo.gov/gpo59706/FHTET-2014-09_Biology_Control_EAB.pdf.

Vannatta, A. R., R. H. Hauer, and N. M. Schuettpelz. 2012. “Economic Analysis of Emerald Ash Borer (Coleoptera: Buprestidae) Management Options.” *Journal of Economic Entomology* 105 (1): 196–206. https://doi.org/10.1603/EC11130.

Vaske, Jerry J. 2008. *Survey Research and Analysis: Application in Parks, Recreation and Human Dimensions*. State College, PA: Venture Publishing, Inc.

VDOF. 2018a. “Emerald Ash Borer Treatment Program Application.” Form 6.5. Charlottesville, VA: Virginia Department of Forestry. http://www.dof.virginia.gov/forms/f06.05.dotx.

———. 2018b. “Forestry Topic 32 - Emerald Ash Borer Cost-Share Program.” FT0032. Charlottesville, VA: Virginia Department of Forestry.

———. 2018c. “Policy and Procedure - Emerald Ash Borer Treatment Program.” PP_06-002. Charlottesville, VA: Virginia Department of Forestry.

———. 2018d. “Policy and Procedure 6-2 Emerald Ash Borer Cost-Share Program.” Charlottesville, VA: Virginia Department of Forestry.

VGIN. 2018a. “VGIN Virginia GIS Clearinghouse.” Virginia Geographic Information Network - GIS Clearinghouse. 2018. https://vgin.maps.arcgis.com/home/index.html.

———. 2018b. “Virginia Land Cover Dataset.” https://vgin.maps.arcgis.com/home/item.html?id=d3d51bb5431a4d26a313f586c7c2c848.

Virginia Tech. 2018. “VT Urban Forestry Municipal Urban Forest Assessments.” https://www.urbanforestry.frec.vt.edu/eco.shtml.

Watson, Adam C., Jay Sullivan, Gregory S. Amacher, and Christopher Asaro. 2013. “Cost Sharing for Pre-Commercial Thinning in Southern Pine Plantations: Willingness to Participate in Virginia’s Pine Bark Beetle Prevention Program.” *Forest Policy and Economics* 34 (September): 65–72. https://doi.org/10.1016/j.forpol.2013.05.004.

Wikipedia contributors. 2019. “Demographics of Virginia.” In *Wikipedia, The Free Encyclopedia*. https://en.wikipedia.org/w/index.php?title=Demographics_of_Virginia&oldid=884605907.

Williamson, Mark. 1996. *Biological Invasions*. London: Chapman and Hall.

Wright, G Tyler. 2011. “An Assessment of the Potential Impacts of Emerald Ash Borer (*Agrilus planipennis* Fairmaire) on Virginia’s Municipal Street Trees.” Virginia Tech.

Yong, An Gie, and Sean Pearce. 2013. “A Beginner’s Guide to Factor Analysis: Focusing on Exploratory Factor Analysis.” *Tutorials in Quantitative Methods for Psychology* 9 (2): 79–94. https://doi.org/10.20982/tqmp.09.2.p079.

Zhang, Daowei. 1996. “Differences in Silvicultural Investment Under Various Types of Forest Tenure in British Columbia.” *Forest Science* 42 (4): 442–49.

APPENDIX A
Supplementary Tables for Chapter 3:
Urban Forest Composition of Participant Properties

List of Tables

Table 20. List of Urban Participant Properties (UPP) paired with nearest Urban Forest Assessment (UFA) municipality. Sites within 15 mi (24 km) of UFA centroid were used in analysis.

UPP site number	UPP site municipality	Nearest UFA municipality	Distance from UPP to UFA centroid (mi)
1	Front Royal	Falls Church	53.17
2	Fredericksburg	Falls Church	42.94
3	Charlottesville	Charlottesville	0.78
4	Harrisonburg	Charlottesville	35.61
5	Roanoke	Roanoke	5.51
6	Roanoke	Roanoke	5.4
7	Charlottesville	Charlottesville	1.37
8	Charlottesville	Charlottesville	3.44
9	Alexandria	Falls Church	8.21
10	Charlottesville	Charlottesville	0.82
11	Charlottesville	Charlottesville	0.82
12	Charlottesville	Charlottesville	1.02
13	Charlottesville	Charlottesville	0.95
14	Roanoke	Roanoke	10.63
15	Alexandria	Falls Church	8.22
16	Charlottesville	Charlottesville	1.02

Table 21. Summary of species composition variables for on-site inventories of Urban Participant Properties.

Variable	Description	Source
Abundance	Number of trees	On-site inventory data
Relative Abundance (RA)	Proportional contribution towards total site stem count	Calculated from site inventory data
Structural Value (SV)	Formula-derived estimate of tree replacement cost	Calculated by Eco[1] using CTLA[2] formula
Relative Structural Value (RSV)	Proportional contribution towards total site SV	Calculated from site inventory data
Leaf Area (LA)	Summed total leaf surface area	Calculated by Eco using tree dimensions and allometric relationships
Relative Leaf Area (RLA)	Proportional contribution towards total site LA	Calculated from Eco output
Importance Value (IV)	Sum of RA and RLA	Calculated from Eco output
Relative Importance Value (RIV)	Proportional contribution towards total site IV	Calculated from Eco output; equal to IV/2

[1]i-Tree Eco urban forest modeling software

[2]Council of Tree and Landscape Appraisers

Table 22. Comparisons of inventoried and non-inventoried Urban Participant Properties. *P*-value represents significance of test statistic from a comparison of means, using Welch's *t*-test for continuous data and chi-square tests for proportional data.

	Inventoried sites (n = 16)					Non-inventoried sites (n = 12)					
	min	max	median	SD	$\bar{x}$	min	max	median	SD	$\bar{x}$	*p*
Parcel size[1] (acres)	0.13	1.67	0.53	0.41	0.60	0.14	2.04	0.39	0.53	0.57	0.847
Parcel tree cover[2] (%)	0.14	0.91	0.58	0.24	0.54	0.12	0.67	0.41	0.18	0.38	0.053
Years since EAB detection[1]	2.0	11.0	2.5	3.2	4.1	0.0	11.0	2.5	3.2	3.6	0.659
Years since home construction[1]	0.17	6.80	4.44	2.17	3.20	0.17	7.15	4.44	2.21	4.11	0.683
Historical ash relative abundance[2] (%)	12.00	146.00	42.00	37.61	59.25	19.00	95.00	63.50	22.17	64.67	0.289

[1]Means compared with Welch's *t*-test.
[2]Means compared with chi-square test.

Table 23. Summary of ash species composition, sampling methods, and relative error for Urban Forest Assessments, by municipality.

	Roanoke	Charlottesville	Falls Church
Year of data collection	2010	2011	2011
Total number of 0.1 acre plots	171	74	38
Stratified by land use	yes	yes	no
Total residential 0.1 acre plots	83	28	--
Ash Relative Abundance[2]	1.17%[2]	3.85%[2]	0%[3]
Relative S.E of ash abundance estimate[1]	75.00%	64.50%	--
Ash Relative Structural Value	0.55%[2]	10.43%[2]	0%[3]
Relative S.E. of ash structural value estimate[1]	80.10%	95.70%	--
Number of paired UHP properties	3	8	2
Mean distance to UHP properties (mi)	7.18	1.28	9.42

[1]Relative standard errors calculated as S.E./estimate*100
[2]Reported only for residential land use
[3]Reported for all land uses

Table 24. Tree benefits by species across 16 Urban Participant Properties. Top ten species, by Total Annual Benefits are listed.

	Number of trees	Total C storage (lbs)	Gross C seq. (lb/yr)	Runoff avoided (ft^3/yr)	Pollution removal (oz/yr)	Energy savings ($)	C emissions avoided (lb/yr)	Total Annual Benefits ($)	Mean annual benefits (per tree, $)
Platanus occidentalis	6	645.03	17.82	26.31	8.56	0.94	2.44	99.59	16.60
Fraxinus americana	59	16453.93	251.27	212.34	69.08	9.75	23.38	954.30	16.17
Quercus palustris	10	2528.53	54.70	36.57	11.89	0.96	1.16	161.65	16.17
Acer saccharum	8	750.62	21.94	27.76	9.04	1.39	2.99	115.23	14.40
Acer saccharinum	8	1582.22	19.36	27.73	9.02	1.24	2.84	109.96	13.75
Liriodendron tulipifera	14	2400.94	44.82	52.03	16.94	0.41	0.93	179.74	12.84
Juglans nigra	9	968.59	20.74	37.74	12.28	-0.61	-2.76	100.11	11.12
Quercus rubra	9	1165.40	23.95	20.07	6.53	1.19	2.86	95.45	10.61
Pinus strobus	17	383.83	12.39	27.40	8.93	3.93	11.79	154.28	**9.08***
Acer rubrum	32	2048.79	57.08	45.60	14.83	0.13	-1.99	169.48	**5.30*****

Bolded values show significant treatment contrast from the reference level of *F. Americana*
**p*<.05
****p<.001*

Table 25. Summary of site characteristics and species composition of inventoried Urban Participant Properties (n=16). Parcel size and tree cover were compiled from public databases; the remaining data were derived from data collected on-site.

Site Number	Parcel legal acres	Parcel inventoried acres	Parcel tree cover (%)	Number of trees < 4" DBH	Total Basal Area (ft^2)	Species richness	Diversity (H')[1]	Evenness (J')[2]	Ash Relative Abundance (%)	Ash Relative Basal Area (%)
1	0.42	0.18	91.2	21	17.6	9	2.06	0.94	9.5	10.2
2	0.38	0.38	32.1	28	19.0	13	2.12	0.83	7.1	47.4
3	0.40	0.40	48.6	32	57.0	10	1.81	0.79	21.9	47.7
4	0.69	0.69	57.5	47	42.3	15	2.38	0.88	14.9	29.6
5	0.52	0.52	27	18	11.5	5	0.84	0.52	5.6	27.0
6	0.70	0.70	13.9	13	18.3	10	2.25	0.98	15.4	34.4
7	0.71	0.31	57.9	15	21.2	10	2.18	0.95	13.3	27.8
8	1.04	0.56	79.2	27	49.6	12	2.37	0.96	11.1	29.6
9	0.69	0.50	77.6	32	49.7	17	2.72	0.96	3.1	2.8
10	0.14	0.22	23.5	7	19.7	6	1.75	0.98	14.3	46.7
11	0.55	0.55	27.7	9	35.0	9	2.20	1.00	11.1	26.3
12	0.30	0.30	51.4	8	35.5	6	1.73	0.97	25.0	59.7
13	0.14	0.14	69.1	4	20.2	3	1.04	0.95	50.0	62.4
14	1.67	2.05	67.3	42	122.1	11	1.99	0.83	38.1	68.1
15	1.16	0.82	88.7	43	62.1	14	2.26	0.86	23.3	24.3
16	0.31	0.31	57.8	19	33.4	11	2.20	0.92	5.3	6.6

[1]Species diversity measured by Shannon's diversity index (H') normally ranges from 1.5 to 3.5

[2]Species evenness measured by Pielou's J' ranges from 0 to 1

APPENDIX B
Supplementary Tables for Chapter 4:
Homeowner Engagement in Tree Preservation

List of Tables

Table 26. List of geographic criteria and data sources each were drawn from, employed in construction of the general household survey sampling frame.

Variable	Description	Source
Urban location	Included Census Block Groups that are at least 75% urban, as measured by Census Urban Areas polygons.	TIGER shapefiles (U.S. Bureau of the Census 2017)
EAB infestation strata	Counties stratified by EAB infestation: *Established* (pre-2015), *Recent* (2015 to present), and *Undetected.*	VDOF records (Chamberlin 2018)
Residential zoning	Included residential land use only; mixed residential/commercial areas were excluded.	Multiple county and municipal tax parcel databases (see Table 26)
Single-family dwellings	Included parcels with only one associated address.	VGIN Address Points Geodatabase (VGIN 2018)
Owner occupancy	Included tax parcels for which owner's mailing address matched the parcel address.	Multiple county and municipal tax parcel databases (see Table 26)
Parcel size	Minimum parcel area of 0.2 acres.	Attribute of VGIN Parcels Geodatabase (VGIN 2018)
Tree cover	Minimum parcel tree cover of 25%	Virginia Statewide Land Cover Database (VGIN 2018)

Table 27. List of county and municipal data sources for land use zoning and property ownership, used in general household sampling frame construction.

Jurisdiction	Data source	URL
City of Falls Church	City of Falls Church Geospatial Services	http://www.fallschurchva.gov/158/Maps
Arlington County	Arlington County GIS Mapping Center	https://gis.arlingtonva.us/GIS/gis_mappingcenter.asp
City of Alexandria	ArcGIS Open Data Hub - Alexandria Parcels	http://hub.arcgis.com/datasets/AlexGIS::parcels
Roanoke County	Roanoke County GIS Services	https://www.roanokecountyva.gov/index.aspx?nid=76
City of Roanoke	City of Roanoke GIS Services	https://www.roanokeva.gov/518/Geographic-Information-Systems-GIS
City of Salem	City of Salem Engineering Department	https://salemva.gov/Departments/Community-Development/Engineering
City of Portsmouth	ArcGIS Open Data Hub - Hampton Roads Regional Parcels	http://hub.arcgis.com/datasets/HRPDC-GIS::hampton-roads-regional-parcels
City of Chesapeake	ArcGIS Open Data Hub - Hampton Roads Regional Parcels	http://hub.arcgis.com/datasets/HRPDC-GIS::hampton-roads-regional-parcels

Table 28. Summary of survey items and measurement scales for homeowner surveys. Language differing between the two survey instruments is noted by 'PP' for items addressed only to participants and 'GH' for items addressed only to general households

Survey items	Variable class	Measurement
PP: Likelihood of regularly treating at least one ash tree, for the foreseeable future GH: Likelihood of regularly treating at least one threatened landscape tree, for the foreseeable future	Tree preservation intention	5-point scale: 1= 'Extremely unlikely', 2= 'Somewhat unlikely', 3= 'Neither likely nor unlikely', 4= 'Somewhat likely', 5= 'Extremely likely'
PP: Likelihood of re-applying to the EABTP GH: Likelihood of applying to an EABTP-like program for other threatened landscape trees	Cost-share Participation	
What is your age?	Personal characteristics & activities	6-point scale: 1= 'Under 24', 2= '26 to 34', 3= '35 to 44', 4= '45 to 54', 5= '55 to 64', 6= '65 or older'
How many people are in your household?		Numerical entry
How many in your household are under the age of 18?		Numerical entry
Which gender do you most identify with?		Categorical: 'Male', 'Female', 'Other, please specify'
Which of the following best describe your racial or ethnic identity?		Categorical: 'White', 'Black or African American', 'American Indian or Alaska Native', 'Asian', 'Native Hawaiian or Pacific Islander', Spanish, Latino or Hispanic', 'Middle Eastern or North African', 'Other, please specify'
Is English your first language?		Categorical: 0= 'No', 1='Yes'
What is the highest level of education you've had the opportunity to complete?		7-point scale: 1= 'Less than high school', 2= 'High school graduate', 3= 'Some college', 4= '2-year degree', 5= '4-year degree', 6= 'Graduate/Professional degree', 7= 'Doctorate'

What was your household's annual income in 2017 from all earners and all sources, before taxes?		8-point scale: 1= '$15,000 or less', 2= '$15,001 to $25,000', 3= '$25,001 to $35,000', 4= '$35,001 to $50,000', 5= '50,001 to $75,000', 6= '$75,001 to $100,000', 7= '$100,000 to $150,000', 8= 'Greater than $150,000'
Property ownership (GH only)		Categorical: 0= 'Renter', 1='Owner'
How long have you lived at this property?		7-point scale: 1= '< 1 year', 2= '1 to 5 years', 3= '6 to 10 years', 4= '11 to 15 years', 5= '16 to 20 years', 6= '21 to 25 years', 7= '> 25 years'
In a typical year, how much is spent on tree maintenance?		7-point scale: 1= '0', 2= '$1 - $50', 3= '$51 to $250', 4= '251 to $750, 5= '$751 to $1500', 6= '$1501 to $2500', 7= 'Greater than $2500'
Before 2018, had you ever paid for insecticidal treatment of trees?		Categorical: 0= 'No', 0= 'Not sure,' 1='Yes'
Are you familiar with the e*merald ash borer*? (GH only)		Categorical: 0= 'No', 1='Yes'
Are there any ash trees on your property? (GH only)		Categorical: 0= 'No', 0= 'Not sure,' 1='Yes'
Before 2018, had you ever paid for treatment of ash trees?		Categorical: 0= 'No', 0= 'Not sure,' 1='Yes'
Have you heard of VDOF's Emerald Ash Borer Treatment Program?		Categorical: 0= 'No', 1='Yes'
If you know about the EABTP, please describe how you heard of it.		Categorical: 'From a VDOF employee', 'Through a VDOF publication', 'From the VDOF website', 'From a friend or associate'
If you knew of the program, were eligible, yet decided not to apply, what best describes your reason?		Categorical: 'Trees are unlikely to survive', 'EAB is not yet in this region', 'Treatment is too costly', 'Didn't have enough information'
When was the house built?	Property characteristics	8-point scale: 1= 'Before 1950s', 2= '1950s', 3= '1960s', 4= '1970s', 5= '1980s', 6= '1990s', 7= '2000s', 8= '2010s'

About how many trees are on the property in unmaintained areas?		4-point scale: 1= '0 trees', 2= '1 to 5', 3= '6 to 10', 4= '> 10'
About how many trees are on the property in maintained areas?		4-point scale: 1= '0 trees', 2= '1 to 5', 3= '6 to 10', 4= '> 10'
How strongly would you agree or disagree with these statements about urban trees: Trees are an important part of the character of a neighborhood. Shade trees add value to a residential property. Overall, shade tree benefits outweigh hazards or nuisances The condition of trees on my property matters more than the turf I'd rather spend money to preserve than to remove an old tree.	Attitudes & motivations	5-point scale: 1= 'Strongly disagree', 2= 'Somewhat disagree', 3= 'Neither agree nor disagree', 4= 'Somewhat agree', 5= 'Strongly agree'
How would you rate the importance of preserving ash trees (GH: landscape trees) in the state of Virginia?		5-point scale: 1= 'Not at all important', 2= 'Slightly important, 3= 'Somewhat important', 4= 'Very important', 5= 'Extremely important'
Rank the importance of the following reasons for preserving ash tree (GH: landscape trees), from most important (1) to least important (6) Shade Wildlife habitat Contribution to property value Tree species might become rare or endangered Trees are an attractive part of landscaping Other, please specify		Ranked-choice item

Table 29. Tests for nonresponse bias among program participant and general household sampling frames. Test statistics display Welch's t-test and Pearson's $\chi^{2.}$

	Program participants (n=90)				General households (n=1488)			
	Respondents (n=53)	Non-respondents (n=39)	Test statistic	*p*	Respondents (n=333)	Non-respondents (n=1155)	Test statistic	*p*
Parcel size (acres)	43.8	45.4	t=1.752	0.953	0.469	0.401	t= 1.75	0.0806
Parcel tree cover (%)	0.589	0.526	χ^2=0.181	0.671	0.45	0.452	χ^2<*.001*	0.986
Mean of Census Block Group median age[1]	44.6	44.9	t= -0.201	0.841	42.6	41.9	t=-1.4323	0.153
Mean of Census Block Group median household income[1] ($)	78,706	72,693	t=1.13	0.26	116,197	104,966	t=2.5686	0.0105
Census Block Group mean years of education[1]	15.3	14.8	t=1.72	0.0891	15.8	15.5	t=4.12	**<.001**
Census Block Group minority proportion[1] (%)	10.2	13.1	χ^2=0.0185	0.9	17.6	24.0	χ^2= 5.48	0.0192

Bold text indicates a significant result at the Bonferroni-corrected $\alpha < .008$ significance level.

[1]Values derived from U.S. Bureau of the Census (2017) statistics for the Census Block Groups in which residential parcels were located

Table 30. Exploratory Factor Analysis for aggregated homeowner response data: Loadings of attitudinal statements on two factors. Bolded values indicate variable grouping for calculating factor indices.

Attitudinal statements	Factor 1 *Tree curb appeal*	Factor 2 *Tree affinity*
Trees are an important part of the character of a neighborhood	**0.849**	
Shade trees add value to a residential property	**0.660**	0.477
Overall, benefits provided by shade trees outweigh the hazards and nuisances they can create.	0.386	**0.622**
The condition of trees on my property is more important than the condition of the turf.		**0.717**
I'd rather spend money to preserve a mature tree than to remove and replace it.		**0.669**
Cronbach's alpha	0.790	0.670

Table 31. List of predictors used in models of tree preservation intention and program participation. Variables used only for program participant (PP) data and general households (GH) are noted.

Predictors	Predictor class
Years living at property	Personal characteristics
Annual tree maintenance budget	
Prior treatment of landscape trees	
Familiarity with EAB	
Age	
Educational attainment	
Annual household income	
Age of house	Property characteristics
Number of trees in maintained areas	
Number of trees in unmaintained areas	
Parcel area	
Parcel tree cover	
Years since EAB detection (PP)	
EAB infestation strata - *Undetected* (GH)	
EAB infestation strata - *Recent* (GH)	
EAB infestation strata - *Established* (GH)	
Urban tree attitudes Factor A - *Tree curb appeal*	Attitudes and motivations
Urban tree attitudes Factor B - *Tree affinity*	
Importance of preserving landscape trees	
Tree preservation motivation - 2 clusters (PP)	
Tree preservation motivation - *Cluster 1* (GH)	
Tree preservation motivation - *Cluster 2* (GH)	
Tree preservation motivation - *Cluster 3* (GH)	
Tree preservation motivation - *Cluster 4* (GH)	
Tree preservation motivation - *Cluster 5* (GH)	

Table 32. Program participants: Ranking of candidate linear models for the dependent variable *Cost-share participation*. Number of respondents varied between models from 33 to 53.

Model	K[1]	Adj. R^2	RMSE	ΔAICc[2]	w_i[3]
Attitudes	**4**	**0.223**	**0.717**	**0**	**0.996**
Attitudes + Property	11	0.263	0.699	11.017	0.004
Property characteristics	7	-0.016	0.821	19.794	0
Personal characteristics	6	-0.073	0.843	28.041	0
Attitudes + Personal	10	0.037	0.799	33.774	0
Personal + Property	13	-0.292	0.925	53.394	0
Attitudes + Personal + Property	17	-0.19	0.888	72.359	0

Bold text indicates top-ranked model.
[1]Number of model parameters.
[2]Second-order AIC, a small sample-corrected version of AIC, a measure of model fit which minimizes information loss.
[3]Akaike's weight, a proportional measure of relative likelihood.

Table 33. Program participants: Summary of the top-ranking linear model *Attitudes* for the dependent variable *Cost-share participation* (n=53)

Independent variables	β coeff.	*p*
Urban tree attitudes Factor A - *Tree curb appeal*	-0.167	0.405
Urban tree attitudes Factor B - *Tree affinity*	0.059	0.784
Importance of preserving ash trees	0.513	**<.001**
Tree preservation motivation - *Cluster 1*	--	--
Tree preservation motivation - *Cluster 2*	0.174	0.163
Adjusted R^2	0.223	
F	4.735	**0.003**

Bolded items indicate significance at the α=.05 level.

Table 34. General households: Ranking of candidate linear models for the dependent variable *Cost-share participation.* Number of respondents varied between models from 239 to 310.

Model	K[1]	Adj. R^2	RMSE	ΔAICc[2]	w_i[3]
Attitudes	**7**	**0.456**	**0.853**	**0**	**0.936**
Attitudes + Property	14	0.464	0.847	5.363	0.064
Attitudes + Personal	14	0.471	0.841	27.98	0
Attitudes + Personal + Property	21	0.469	0.843	37.485	0
Personal characteristics	7	0.065	1.118	147.968	0
Personal + Property	14	0.057	1.123	157.857	0
Property characteristics	7	0.056	1.123	167.618	0

Bolded text indicates top-ranked model.
[1]Number of model parameters.
[2]Second-order AIC, a small sample-corrected version of AIC, a measure of model fit which minimizes information loss.
[3]Akaike's weight, a proportional measure of relative likelihood.

Table 35. General households: Summary of top-ranking linear model *Attitudes* for the dependent variable *Cost-share participation* (n=310)

Independent variables	*β* coeff.	*p*
Urban tree attitudes Factor A - *Tree curb appeal*	0.11	**0.044**
Urban tree attitudes Factor B - *Tree affinity*	0.018	0.754
Importance of preserving landscape trees	0.609	**<.001**
Tree preservation motivation - *Cluster 1*	--	--
Tree preservation motivation - *Cluster 2*	-0.012	0.784
Tree preservation motivation - *Cluster 3*	0.06	0.207
Tree preservation motivation - *Cluster 4*	0.081	0.078
Tree preservation motivation - *Cluster 5*	-0.026	0.544
Adjusted *R*2	0.456	
F	37.584	**<.001**

Bolded items indicate significance at the α=.05 level.

APPENDIX C
Supplementary Tables for Chapter 5:
Perceptions of Cost-Share Participation Among Forest Practitioners

List of Tables

Table 37. Summary of survey items and measurement scales for practitioner surveys. Language and items differing between the two surveys are noted by 'FOR' for items addressed only to foresters, and by 'ARB' for items addressed only to arborists.

Survey items	Variable class	Measurement
How would you rate your level of interest in participating in EABTP in future years?	Cost-share Participation	5-point scale: 1= 'Not at all interested', 2= 'Slightly interested, 3= 'Somewhat interested', 4= 'Very interested', 5= 'Extremely interested'
Please describe your reasons for interest, or lack of interest, in participating in this program.		Written response
What is your age?	Personal characteristics	6-point scale: 1= 'Under 24', 2= '26 to 34', 3= '35 to 44', 4= '45 to 54', 5= '55 to 64', 6= '65 or older'
Which gender do you most identify with?		Categorical: 'Male', 'Female', 'Other, please specify'
What is the highest level of education you've had the opportunity to complete?		7-point scale: 1= 'Less than high school', 2= 'High school graduate', 3= 'Some college', 4= '2-year degree', 5= '4-year degree', 6= 'Graduate/Professional degree', 7= 'Doctorate'
How many years of experience do you have working in your field?	Professional characteristics	8-point scale: 1='Less than 1', 2='1 to 5', 3='6 to 10', 4='11 to 15', 5='16 to 20', 6='21 to 30', 7='31 to 40', 6='41+'
Are you an SAF Certified Forester?		Categorical: 0= 'No', 1= 'Previously', 1= 'Yes, currently'
Are you an ISA Certified Arborist?		Categorical: 0= 'No', 1= 'Previously', 1= 'Yes, currently'
What is your position at VDOF? (FOR)		Categorical: 'Senior Area Forester', 'Area Forester Specialist', 'Area Forester', 'Technician', 'Other'
What is your area of practice? (ARB)		Categorical: 'Utility arboriculture', 'Commercial arb.', 'Consulting or training', 'Urban forestry', 'Other'
Is your business or agency located in Virginia? (ARB)		Categorical: 0= 'No', 1= 'Yes'

If outside of Virginia, do you have clients in Virginia? (ARB)		Categorical: 0= 'No', 1= 'Yes'
In which county or independent city do you primarily work?		Categorical: list of 135 Virginia jurisdictions
What percentage of the property owners you work with own > 5 acres?		Percentage: 0 -100%
What percentage of your working hours are spent on forest health projects?		Percentage: 0 -100%
Prior to 2018, how frequently were you dealing with EAB-infested ash trees in your work?		5-point scale: 1= 'Very rarely', 2= 'Rarely', 3= 'Occasionally', 4= 'Frequently', 5= 'Very frequently'
Did you conduct any site vists as part of the 2018 EABTP? (FOR)		Numeric entry
Are you aware of VDOF's EABTP? (ARB)		Categorical: 0= 'No', 1= 'Yes'
How did you hear about the program? (ARB)		Categorical: 'From a VDOF employee', 'VDOF publication', 'VDOF website', 'A friend or associate'
How many bids for ash tree treatment, if any, did you submit as part of EABTP? (ARB)		Numeric entry
How strongly would you agree or disagree with these statements about urban trees:	Attitudes & motivations	5-point scale: 1= 'Strongly disagree', 2= 'Somewhat disagree', 3= 'Neither agree nor disagree', 4= 'Somewhat agree', 5= 'Strongly agree'
Trees are an interested part of the character of a neighborhood.		
Shade trees add value to a residential property.		
Overall, shade tree benefits outweigh hazards or nuisances		
The condition of trees on my property matters more than the turf		
I'd rather spend money to preserve than to remove a declining tree.		

Rank the importance of the following reasons for preserving ash trees in urban forests, from most important (1) to least important (6). Shade Wildlife habitat Other, please specify Tree species might become rare Attractive part of landscaping Property value contribution	Ranked-choice item
Rank the relative level of threat from the following insect species to the forests in your region, from greatest level (1), to lowest level (7). Hemlock woolly adelgid Asian longhorned beetle Gypsy moth Spotted lanternfly Southern pine beetle Emerald ash borer Walnut twig beetle	Ranked-choice item
Rank the following species according their suitability as residential shade trees, from most suitable (1) to least suitable (9). Ignore the effects of pests. Sugar maple White oak Black cherry Black walnut Green ash American elm Yellow-poplar Eastern white pine	Ranked-choice item
Rank the following EAB management strategies by how often you have recommended them, from most often (1) to least often (5). (ARB) Tree removal Imadicloprid soil application Emamectin trunk injection Wait and see Other, please specify	Ranked-choice item
How do you expect sales of ash tree treatments would be affected if homeowners in your service area were widely aware of EABTP funding?	5-point scale: 1= 'Large decrease in sales', 2= 'Small decrease', 3= 'No effect', 4= Small increase', 5= 'Large increase in sales'

Table 38. Results from tests for nonresponse bias among respondents to foresters' survey: chi-squared tests of independence between characteristics of survey respondents and a reference group of VDOF county foresters with equivalent positions. Reference group data are drawn from online VDOF records. Table displays observed frequencies by forester group for gender, job title, and region.

		VDOF records	Survey respondents	**Total**	Pearson's $\chi 2$	*p*
Gender	Male	55	14	**69**		
	Female	9	4	**13**	0.701	0.402
	Total	64	18	**82**		
Job title	Area Forester	43	12	**55**		
	Sr. Area Forester	21	6	**27**	0.002	0.967
	Total	**64**	**18**	**82**		
Region	Western	17	4	**21**		
	Central	25	5	**30**	2.101	0.350
	Eastern	22	10	**32**		
	Total	**64**	**19**	**83**		

Bolded values display row and column totals.

Table 39. Tests for nonresponse bias among respondents to arborists' surveys: chi-squared tests of independence between characteristics of survey respondents and a reference group of MAC-ISA arborists in Virginia. Reference group data are drawn from records of MAC-ISA members within Virginia. Table displays observed frequencies by arborist group for area of practice and EAB infestation strata.

		MAC-ISA records	Survey respondents	**Total**	Pearson's $\chi 2$	*p*	Cramer's V
Area of prac-tice	Residential/ Commercial	131 (1.1)	46 (-1.1)	**177**	38.036	<.001	0.281
	Municipal/ Government	96 (-1.6)	50 (1.6)	**146**			
	Utility/Vegetation	42 (-0.2)	18 (0.2)	**60**			
	Research/Training	17 (-4.3)	24 (4.3)	**41**			
	Other	55 (4.5)	2 (-4.5)	**57**			
	Total	**341**	**140**	**481**			
EAB strata	Established	277 (-1.0)	66 (1.0)	**343**	7.484	0.024	0.102
	Recent	196 (-1.2)	49 (1.2)	**245**			
	Undetected	122 (2.7)	13 (-2.7)	**135**			
	Total	**595**	**128**	**723**			

Values in parenthesis represent standardized residuals.
Bolded values display row and column totals.

Table 40. Exploratory Factor Analysis for aggregated practitioner response data: Loadings of attitudinal statements on two factors. Bolded values indicate variable grouping for calculating factor indices.

Attitudinal statements	Factor 1 *Tree curb appeal*	Factor 2 *Tree affinity*
Trees are an important part of the character of a neighborhood	**0.899**	0.308
Shade trees add value to a residential property	**0.871**	0.400
Overall, benefits provided by shade trees outweigh the hazards and nuisances they can create.	0.329	**0.507**
The condition of trees on my property is more important than the condition of the turf.		**0.565**
I'd rather spend money to preserve a mature tree than to remove and replace it.		**0.677**
Cronbach's alpha	0.670	0.950

Bolded values indicate variable grouping for calculating factor indices.

Table 41. Aggregated forester and arborist response data: Cluster analysis of ranked statements of motivations for ash preservation.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Number of respondents	29	23	85	25
Proportion of survey respondents	0.180	0.142	0.524	0.154
Probability of membership	0.839	0.880	0.817	0.912
Modal order of ranked beliefs	1,4,2,5,3,6	1,3,5,2,4,6	4,1,2,3,5,6	4,5,1,2,3,6

Motivations were given as: 1) Ash trees provide shade, 2) Ash trees provide wildlife habitat, 3) Ash trees can increase property values, 4) Ash trees might become rare or endangered, 5) Ash trees are an attractive part of landscaping, 6) Other, please specify.

Table 42. Arborist response data**:** Cluster analysis of ranked EAB management recommendations

	Cluster 1	Cluster 2
Number of respondents	58	86
Proportion of survey respondents	0.402	0.598
Probability of membership	0.917	0.850
Modal order of ranked recommendations	1,4,2,3,5	4,1,2,3,5

Recommendations were given as: 1) tree removal, 2) imadicloprid trunk or soil application, 3) emamectin trunk injection, 4) wait and see, 5) Other, please specify.

Table 43. List of predictors used in models of program participation for arborist response data organized by predictor class.

Predictors	Predictor class
Age	Personal characteristics
Gender	
Educational attainment	
Years of professional experience	Professional characteristics
Percentage of clientele with > 5 acres	
Percentage of forest health work hours	
Frequency of prior EAB-related work	
EAB management recommendation (2 clusters)	
EAB infestation strata - *Undetected* (GH)	
EAB infestation strata - *Recent* (GH)	
EAB infestation strata - *Established* (GH)	
Urban tree attitudes Factor A - *Tree curb appeal*	Attitudes and motivations
Urban tree attitudes Factor B - *Tree affinity*	
Expected effect of EABTP on sales	
Tree preservation motivation – 2 clusters (PP)	
Tree preservation motivation - *Cluster 1* (GH)	
Tree preservation motivation - *Cluster 2* (GH)	
Tree preservation motivation - *Cluster 3* (GH)	
Tree preservation motivation - *Cluster 4* (GH)	
Tree preservation motivation - *Cluster 5* (GH)	

APPENDIX D:
2018 EABTP Application Form

Form 6.5
01/16/2018

VIRGINIA DEPARTMENT OF FORESTRY
EMERALD ASH BORER PROGRAM
COST-SHARE APPLICATION

☐ Soil Drench ☐ Injection Application Number: _____

SECTION 1 – Applicant Information

Landowner/Organization Name: _____

Note: In order to process this application, a Taxpayer ID Number is required. Therefore, please complete a State W-9 (Request for Taxpayer Identification Number and Certification) and return it with your application.

Mailing Address: _____

Contact: Phone: _____ Email: _____

Property Location: County: _____ Tract Number: _____

Latitude: _____ Longitude: _____

SECTION 2 – Ash Preservation Strategy

Explain how you/your organization plans to approach maintenance, monitoring, re-treatment and outreach/education efforts concerning your ash tree(s):

_____

_____

_____

_____

Estimated Total Cost: _____ Note: In order to process this application, a treatment quote or bid must be attached.

SECTION 3 – Landowner Agreement

I request funding under the Emerald Ash Borer Treatment Cost-Share Program for the indicated project. I agree:

1. **Assistance shall be 50% of direct project costs, not to exceed $1,250 per landowner (tax identification entity) or $5,000 per organization (tax identification entity) per federal fiscal year (10/01-09/30).**
2. To refund any incentive payments along with a 10% penalty fee, if the project is not completed as prescribed.
3. To designate and assume responsibility for boundaries of the parcel where service work is to be performed; and to give VDOF employees the right to enter the property for the purpose of inspecting the progress and maintenance of the project.
4. To provide treatment quotes/bids with the initial application and to provide receipts upon completion.
5. To complete the project within the appropriate treatment time frame and 90 days from the date of approval by the Forest Health Budget Manager. Otherwise, the project will be cancelled unless a request for extension (Form 3.11 Cost-Share/AMP Project Amendment) is received within three weeks of the cancellation date detailed in the approval letter.
6. Failure to meet any of the standards described will result in forfeiture of these cost-share funds.

☐ I give permission to VDOF to share the information on this form with Virginia Tech for a study of treatment program outcomes.

Landowner/Agent Name (Print) _____ Landowner/Agent Signature _____ Date _____

SECTION 4 – VDOF Approvals

Tree #	Species	DBH (in.)	Live Crown (Percent)	Treatment Type

Comments (i.e., historic site, rare species, amount of EAB damage, etc.):

_____

_____

I certify that the above project is needed and, if properly carried out according to the above recommendations, will qualify for incentive payment under the Emerald Ash Borer Treatment Cost-Share Program.

Forester Name (Print) _____ Forester Signature _____ Date _____

Forest Health Budget Manager Name (Print) _____ Forest Health Budget Manager Signature _____ Date _____

Form 6.5
01/16/2018

VIRGINIA DEPARTMENT OF FORESTRY
EMERALD ASH BORER PROGRAM
COST-SHARE APPLICATION

SECTION 5 – Certification of Completion

I certify that the above project was completed according to the above recommendations.

Final Project Cost: _____

Final Cost-Share Amount: _____
(50% of Project Cost)

Landowner/Agent Name (Print) _____ Landowner/Agent Signature _____ Date _____

VDOF Headquarters Office/Finance Use Only

Cost Code: _____ Amount: _____ Approved for Payment: _____

APPENDIX E:
Tree Inventory Data Collection Form for Urban Participant Properties

Homeowner _____ **App. #** _____
address _____ **Date** _____
phone _____ email _____ **Time** _____

Property
Total area _____
% impervious _____ } remote data
% tree cover _____
plantable area _____

Notes: _____

all trees > 10 cm

				leaf area							
species	dbh	total height	if ash, treated?	height to live top	height to crown base	crown radius	% crown missing	crown condition	dist. to house	direction to house	landscape setting

% crown missing	Percent of the crown volume that is not occupied by branches and leaves (nearest 5%)
crown condition	100 minus the percent of the crown composed of dieback (i.e., dead branches) (nearest 5%)
direction to house	azimuth from tree to the closest part of the building
landscape setting	wooded, landscape bed, turf, fenceline, hardscape, riparian …
treated?	2018, pre-2018, unknown, no

APPENDIX F:
Survey Recruitment Materials

Introductory Email for EABTP Participant Survey

Hello (applicant name),

We are writing with a request for your participation in a survey study being conducted by **Virginia Tech** in coordination with the **Virginia Department of Forestry**. This study seeks to understand perceptions and outcomes of the Emerald Ash Borer Treatment Program (EABTP).

We're asking for the input of yourself and other EABTP applicants who gave VDOF permission to share their application information with Virginia Tech. Using the survey results, we aim to make recommendations that may help ash conservation planning by state forestry officials. Your opinions and experiences with the program are important.

Please consider taking this opportunity to complete the survey, which can be found **here**

Your participation in this survey is voluntary and no personally identifiable information will be requested in the survey or disclosed in summary reports. If you have questions or concerns about the survey, please contact us at **540-583-6191** or **stewartp@vt.edu**

Thank you for considering our request and contributing to our efforts to improve the sustainability of Virginia's urban forests.

Peter Stewart
Graduate Assistant
Department of Forest Resources & Environmental Conservation
Virginia Tech

P. Eric Wiseman, Ph.D.
Associate Professor
Dept. of Forest Resources & Environmental Conservation
Virginia Tech

Introductory Letter for General Household Survey

September 21, 2018

~Request for Survey Input~

Dear Virginia Household:

We are writing with a request for your participation in a survey study being conducted by **Virginia Tech** in coordination with the **Virginia Department of Forestry.** This study seeks to understand opinions of Virginia homeowners related to shade trees, tree pests, and funding for homeowners to help with the costs of tree preservation.

We're asking for the input of yourself and other homeowners from three of Virginia's largest metropolitan areas. Using the survey results, we aim to make recommendations that may help tree preservation planning by state forestry officials.

In about 10 days we'll send you a copy of this survey in the mail, including a business reply envelope. If you prefer, you could instead complete the same survey online, at any time.

Option 1: Wait for mail delivery of a paper survey.

Option 2: Take the survey online by visiting our website: **eab.frec.vt.edu**

Your **access code** for the survey is:
XXXXX

Please enter this code at the requested location as you complete the online survey.

Your participation in this survey is voluntary and no personally identifiable information will be requested in the survey or disclosed in summary reports. If you have questions or concerns about the survey, please contact us at **540-583-6191** or **stewartp@vt.edu**

Thank you for considering our request and contributing to our efforts to improve the sustainability of Virginia's urban forests.

Sincerely,

Peter Stewart
Graduate Assistant
Department of Forest Resources &
Environmental Conservation
Virginia Tech

P. Eric Wiseman, Ph.D.
Associate Professor
Dept. of Forest Resources &
Environmental Conservation
Virginia Tech

Introductory Email for VDOF Forester Survey

Hello (applicant name),

We are writing with a request for your participation in an urban forestry survey study being conducted by **Virginia Tech** in coordination with **VDOF**. This study seeks to understand outcomes of the Emerald Ash Borer Treatment Program (EABTP) and perceptions of it from all stakeholders.

Your input is requested as a VDOF forester with responsibility over EABTP applications. Whether or not you were personally involved in reviewing applications in 2018, we want to hear your perspective on the program. As part of this study, we are also sending surveys to homeowners and arborists, with the goal of providing combined results helpful to ash conservation.

Please consider taking this opportunity to complete the survey, which can be found here

Your participation in this survey is voluntary. Personally identifiable information will be not requested in the survey, and respondents' identities will not be able to be inferred from summary reports. If you have questions or concerns about the survey, please contact us at **540-583-6191** or **stewartp@vt.edu**

Thank you for considering our request and contributing to our efforts to improve the sustainability of Virginia's urban forests.

Peter Stewart
Graduate Assistant
Department of Forest Resources &
Environmental Conservation
Virginia Tech

P. Eric Wiseman, Ph.D.
Associate Professor
Dept. of Forest Resources &
Environmental Conservation
Virginia Tech

Introductory Email for MAC-ISA Arborist Survey

Hello Mid-Atlantic Arborists,

We are writing with a request for your participation in a survey study being conducted by **Virginia Tech** in coordination with the **Virginia Department of Forestry (VDOF)**. With this survey we are studying perceptions and outcomes of VDOF's Emerald Ash Borer Treatment Program (EABTP). This program provides up to 50% of the cost of insecticidal treatment of ash trees to eligible homeowners, organizations, and municipalities.

We're asking for the input of yourself and other arborists who work in Virginia. Whether or not you've been involved in EABTP, your input is valuable. Using the survey results, we aim to make recommendations helpful to ash conservation.

Please consider taking this opportunity to complete the survey, which can be found **here**

Your participation in this survey is voluntary and no personally identifiable information will be requested in the survey or disclosed in summary reports. If you have questions or concerns about the survey, please contact us at **540-583-6191** or **stewartp@vt.edu**

Thank you for considering our request and contributing to our efforts to improve the sustainability of Virginia's urban forests.

Peter Stewart
Graduate Assistant
Department of Forest Resources & Environmental Conservation
Virginia Tech

P. Eric Wiseman, Ph.D.
Associate Professor
Dept. of Forest Resources & Environmental Conservation
Virginia Tech

APPENDIX G:
Survey Instruments

List of Surveys

Survey 1: EABTP Applicants

Start of Block: Section 1. Background Property Information.

Q1 For this property, I am the:

- Owner (1)
- Renter (2)
- Other, please specify: (3) _____

Q2 When was the house built?

- I don't know (1)
- Before 1950s (2)
- 1950s (3)
- 1960s (4)
- 1970s (5)
- 1980s (6)
- 1990s (7)
- 2000s (8)
- 2010s (9)

Q3 How long have you lived at this property?

- < 1 year (1)
- 1 - 5 years (2)
- 6 - 10 years (3)
- 11 - 15 years (4)
- 16 - 20 years (5)
- 21 - 25 years (6)
- > 25 years (7)
- Do not wish to disclose (8)

End of Block: Section 1. Background Property Information.

Page 1 of 7

Start of Block: Urban tree attitudes

Q44 How strongly would you agree or disagree with these statements about trees in residential areas?

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
Trees are an important part of the character of a neighborhood (1)	○	○	○	○	○
Shade trees add value to a residential property (2)	○	○	○	○	○
Overall, the hazards and nuisances created by shade trees outweigh the benefits they provide (3)	○	○	○	○	○
I prefer not to have tall trees near my house (4)	○	○	○	○	○
I'd rather spend money to preserve a mature tree that is showing signs of decline than to remove it (5)	○	○	○	○	○

End of Block: Urban tree attitudes

Start of Block: Section 2. Landscape and Trees.

Q5

In a typical year, roughly how much do you spend on tree maintenance trees? Include costs for pruning, removal, fertilization, or pest control.

- ○ less than $50 (1)
- ○ $50 - $250 (2)
- ○ $250 - $750 (3)
- ○ $750 - $1500 (4)
- ○ $2500 - $5000 (5)
- ○ greater than $5000 (6)

Q6 Prior to 2018, had you ever hired a tree care company to fertilize or apply pesticides to trees?

- Yes (1)
- No (2)

Skip To: End of Block If Prior to 2018, had you ever hired a tree care company to fertilize or apply pesticides to trees? = No

Q10 Prior to 2018, had you ever hired a tree care company to treat ash trees to protect against emerald ash borer damage?

- Yes (1)
- No (2)

End of Block: Section 2. Landscape and Trees.

Start of Block: Section 3: Emerald Ash Borer Treatment Program

Q14 How did you hear about the Emerald Ash Borer Treatment Program?

- From a VDOF employee (1)
- Through a VDOF publication (2)
- From the VDOF website (3)
- From a friend or associate (4)
- Other: (5) _____

Q12 What is the status of your application with VDOF?

- Application was not accepted (1)
- Application was accepted but treatment was not conducted this year (2)
- Application approved and treatment complete; waiting on cost-share payment from VDOF (3)
- Application approved and treatment complete; payment received from VDOF (4)
- Other: (5) _____

Skip To: Q16 If What is the status of your application with VDOF? != Application was accepted but treatment was not conducted this year

Q41 If ash tree treatment was not conducted this year, what best describes the reason?

- Treatment was difficult to schedule (1)
- Treatment was too expensive (2)
- Trees have declined severely since the time of applying to the EABTP (3)
- Other: (4) _____

Q16 How would you rate your level of interest in applying to the EABTP in future years?

- Not at all interested (1)
- Slightly interested (2)
- Somewhat interested (3)
- Very interested (4)
- Extremely interested (5)

End of Block: Section 3: Emerald Ash Borer Treatment Program

Start of Block: Jumpstart Effect

Q42 If funding had not been available through the EABTP, how likely is it that you would have treated ash trees on your property this year?

- Extremely likely (1)
- Somewhat likely (2)
- Neither likely nor unlikely (3)
- Somewhat unlikely (4)
- Extremely unlikely (5)

End of Block: Jumpstart Effect

Start of Block: Participant Information

Q30 This final section asks for general demographic information to better understand our survey participants. No personally identifying information is collected here. Only combined results will be presented in our final summary report.

Q31 Including yourself, how many people live in your household?

_____

Q32 How many in your household are under the age of 18?

_____

Q33
What is your age?

- Under 25 (1)
- 26 to 34 (2)
- 35 to 44 (3)
- 45 to 54 (4)
- 55 to 64 (5)
- 65 or older (6)
- Do not wish to disclose (7)

Q34 Which gender do you most identify with?

- Male (1)
- Female (2)
- Other (3) _____
- Do no wish to disclose (4)

Q35 Are you of Hispanic, Latino, or Spanish origin?

- Yes (1)
- No (2)
- Do not wish to disclose (3)

Q36 Which of the following describes your race? *Select all that apply.*

- [ ] White (1)
- [ ] Black or African American (2)
- [ ] American Indian or Alaska Native (3)
- [ ] Asian (4)
- [ ] Native Hawaiian or Pacific Islander (5)
- [ ] Other, please specify: (6) _____
- [ ] Do not wish to disclose (7)

Q37 Is English your first language?

- ○ Yes (1)
- ○ No (2)
- ○ Do not wish to disclose (3)

Q38 What is the highest level of education you have had the opportunity to complete?

- ○ Less than high school (1)
- ○ High school graduate (2)
- ○ Some college (3)
- ○ 2 year degree (4)
- ○ 4 year degree (5)
- ○ Graduate/Professional degree (6)
- ○ Doctorate (7)
- ○ Do not wish to disclose (8)

Q39 What was your household's annual income in 2017 from all earners and all sources, before taxes?

- $15,00 or less (1)
- $15,001 to $25,000 (2)
- $25,001 to $35,000 (3)
- $35,001 to $50,000 (4)
- $50,001 to $75,000 (5)
- $75,001 to $100,000 (6)
- $100,001 to $150,000 (7)
- Greater than $150,000 (8)
- Do not wish to disclose (9)

Q40 **Thank you** for taking the time to respond to this survey. All survey responses will be aggregated in the analysis with no identifying information present in the summary report.Please check back for more information on our project page at eab.frec.vt.eduStudy results will be available in the spring of 2019

End of Block: Participant Information

Survey 2: Urban Households

Start of Block: Section 1. Background Property Information.

Q1 For this property, I am the:

- Owner (1)
- Renter (2)
- Other, please specify: (3) _____

Q2 When was the house built?

- I don't know (1)
- Before 1950s (2)
- 1950s (3)
- 1960s (4)
- 1970s (5)
- 1980s (6)
- 1990s (7)
- 2000s (8)
- 2010s (9)

Q3 How long have you lived at this property?

- < 1 year (1)
- 1 - 5 years (2)
- 6 - 10 years (3)
- 11 - 15 years (4)
- 16 - 20 years (5)
- 21 - 25 years (6)
- > 25 years (7)
- Do not wish to disclose (8)

End of Block: Section 1. Background Property Information.

Page 1 of 8

Start of Block: Urban tree attitudes

Q43 How strongly would you agree or disagree with these statements about trees in residential areas?

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
Trees are an important part of the character of a neighborhood (1)	○	○	○	○	○
Shade trees add value to a residential property (2)	○	○	○	○	○
Overall, the hazards and nuisances created by shade trees outweigh the benefits they provide (3)	○	○	○	○	○
I prefer not to have tall trees near my house (4)	○	○	○	○	○
I'd rather spend money to preserve a mature tree that is showing signs of decline than to remove it (5)	○	○	○	○	○

End of Block: Urban tree attitudes

Start of Block: Section 2. Landscape and Trees.

Q5
In a typical year, roughly how much do you spend on tree maintenance? Include costs for pruning, removal, fertilization, or pest control.

- ○ less than $50 (1)
- ○ $50 - $250 (2)
- ○ $250 - $750 (3)
- ○ $750 - $1500 (4)
- ○ $1500 - $2500 (5)
- ○ $2500 - $5000 (6)
- ○ greater than $5000 (7)

Q6 Prior to 2018, had you ever hired a tree care company to fertilize or apply pesticides to trees?

- Yes (1)
- No (2)

Q7 Are you familiar with the tree pest called the *emerald ash borer* ?

- Yes (1)
- No (2)

Q9 Do you know if you have any ash trees on your property?

- Yes (1)
- Maybe (2)
- No (3)

Skip To: End of Block If Do you know if you have any ash trees on your property? != Yes

Q10 Prior to 2018, had you ever hired a tree care company treat ash trees to protect against emerald ash borer damage?

- Yes (1)
- No (2)

End of Block: Section 2. Landscape and Trees.

Start of Block: Section 3: Emerald Ash Borer Treatment Program

Q11 Have you heard of Virginia Department of Forestry's *Emerald Ash Borer Treatment Program* ?

- Yes (1)
- No (2)

Skip To: Q15 If Have you heard of Virginia Department of Forestry's Emerald Ash Borer Treatment Program ? = No

Q14 How did you hear about the program?

- ○ From a VDOF employee (1)
- ○ Through a VDOF publication (2)
- ○ From the VDOF website (3)
- ○ From a friend or associate (4)
- ○ Other: (5) _____

Q12 If you have heard of the program, and did not decide to apply, what best describes your reason?

- ○ Trees are unlikely to survive (1)
- ○ The emerald ash borer is not in this region yet (2)
- ○ Treatment is too costly, even with assistance (3)
- ○ Didn't have enough information (4)
- ○ Other: (5) _____

Q15
The emerald ash borer is an invasive beetle that has spread rapidly across most of Virginia. It kills almost all ash trees within 5 years. However, individual trees can be successfully protected against the beetle by applying an insecticide every two years.

The Emerald Ash Borer Treatment Program (EABTP) is a Virginia Department of Forestry program which assists homeowners with the costs of ash tree treatment. Eligible applicants can receive a payment covering 50% of the treatment cost.

For example, a treating a medium-sized ash tree about 16 inches in diameter could cost up to $250. Through the EABTP, a homeowner could be receive a payment for half of that amount, or $125, up to a maximum of $1250 per household.

The EABTP enrollment period for is closed for 2018 but will reopen in early 2019.

Q16 How would you rate your level of interest in applying to the EABTP for 2019?

- Not at all interested (1)
- Slightly interested (2)
- Somewhat interested (3)
- Very interested (4)
- Extremely interested (5)

End of Block: Section 3: Emerald Ash Borer Treatment Program

Start of Block: Section 3B: Emerald Ash Borer Treatment Program

Q18 Have you heard of Virginia Department of Forestry's *Emerald Ash Borer Treatment Program* ?

- Yes (1)
- No (2)

Skip To: Q21 If Have you heard of Virginia Department of Forestry's Emerald Ash Borer Treatment Program ? = No

Q19 How did you hear about the program?

- From a VDOF employee (1)
- Through a VDOF publication (2)
- From the VDOF website (3)
- From a friend or associate (4)
- Other: (5) _____

Q21

The emerald ash borer is an invasive beetle that has spread rapidly across most of Virginia. It kills almost all ash trees within 5 years. However, individual trees can be successfully protected against the beetle by applying an insecticide every two years.

The Emerald Ash Borer Treatment Program (EABTP) is a Virginia Department of Forestry program which assists homeowners with the costs of ash tree treatment. Eligible applicants can receive a payment covering 50% of the treatment cost.

For example, a treating a medium-sized ash tree about 16 inches in diameter could cost up to $250. Through the EABTP, a homeowner could be receive a payment for half of that amount, or $125, up to a maximum of $1250 per household.

The EABTP enrollment period for is closed for 2018 but will reopen in early 2019.

Q22
If you don't have any ash trees on your property, or aren't sure, we still want your opinion.
How would you rate your level of interest in applying to a program like this one, but with funding available for tree preservation on your property?

- Not at all interested (1)
- Slightly interested (2)
- Somewhat interested (3)
- Very interested (4)
- Extremely interested (5)

End of Block: Section 3B: Emerald Ash Borer Treatment Program

Start of Block: Participant Information

Q30 This final section asks for general demographic information to better understand our survey participants. No personally identifying information is collected here. Only combined results will be presented in our final summary report.

Q31 Including yourself, how many people live in your household?

_____

Q32 How many in your household are under the age of 18?

_____

Q33
What is your age?

- Under 25 (1)
- 26 to 34 (2)
- 35 to 44 (3)
- 45 to 54 (4)
- 55 to 64 (5)
- 65 or older (6)
- Do not wish to disclose (7)

Q34 Which gender do you most identify with?

- ○ Male (1)
- ○ Female (2)
- ○ Other (3) _____
- ○ Do no wish to disclose (4)

Q35 Are you of Hispanic, Latino, or Spanish origin?

- ○ Yes (1)
- ○ No (2)
- ○ Do not wish to disclose (3)

Q36 Which of the following describes your race? *Select all that apply*.

- ☐ White (1)
- ☐ Black or African American (2)
- ☐ American Indian or Alaska Native (3)
- ☐ Asian (4)
- ☐ Native Hawaiian or Pacific Islander (5)
- ☐ Other, please specify: (6) _____
- ☐ Do not wish to disclose (7)

Q37 Is English your first language?

- ○ Yes (1)
- ○ No (2)
- ○ Do not wish to disclose (3)

Q38 What is the highest level of education you have had the opportunity to complete?

- Less than high school (1)
- High school graduate (2)
- Some college (3)
- 2 year degree (4)
- 4 year degree (5)
- Graduate/Professional degree (6)
- Doctorate (7)
- Do not wish to disclose (8)

Q39 What was your household's annual income in 2017 from all earners and all sources, before taxes?

- $15,00 or less (1)
- $15,001 to $25,000 (2)
- $25,001 to $35,000 (3)
- $35,001 to $50,000 (4)
- $50,001 to $75,000 (5)
- $75,001 to $100,000 (6)
- $100,001 to $150,000 (7)
- Greater than $150,000 (8)
- Do not wish to disclose (9)

Q40 **Thank you** for taking the time to respond to this survey. All survey responses will be aggregated in the analysis with no identifying information present in the summary report.Please check back for more information on our project page at eab.frec.vt.eduStudy results will be available in the spring of 2019

End of Block: Participant Information

Survey 3: VDOF Foresters

Start of Block: Professional characteristics

Q53
How many years' experience do you have in a forestry-related position?

- less than 1 (1)
- 1 - 5 (2)
- 6 - 10 (3)
- 11 - 15 (4)
- 16 - 20 (5)
- 21 -30 (6)
- 31 - 40 (7)
- 41 + (8)

Q51 Are you an SAF Certified Forester?

- Yes - currently hold certification (1)
- Previously held certification (2)
- No (3)

Q43 Are you an ISA Certified Arborist?

- Yes - currently hold certification (1)
- Previously held certification (2)
- No (3)

Q55
What is your position at VDOF?

- ○ Senior Area Forester (1)
- ○ Area Forester Specialist (2)
- ○ Area Forester (3)
- ○ Technician (4)
- ○ Other: (5) _____

Q58 In which county or independent city do you primarily work?

▼ Accomack County (1) ... Winchester city (134)

End of Block: Professional characteristics

Start of Block: Urban tree attitudes

Q26 How strongly would you agree or disagree with these statements about trees in residential areas?

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
Trees are an important part of the character of a neighborhood (1)	○	○	○	○	○
Shade trees add value to a residential property (2)	○	○	○	○	○
Overall, the hazards and nuisances created by shade trees outweigh the benefits they provide (3)	○	○	○	○	○
I prefer not to have tall trees near my house (4)	○	○	○	○	○
I'd rather spend money to preserve a mature tree that is showing signs of decline than to remove it (5)	○	○	○	○	○

Q48
How would you rank the following tree species as residential shade trees? Drag and drop to indicate
_____ sugar maple (1)
_____ white oak (2)
_____ black cherry (3)
_____ black walnut (4)
_____ pignut hickory (5)
_____ white ash (6)
_____ America elm (7)
_____ tulip tree (8)
_____ eastern white pine (9)

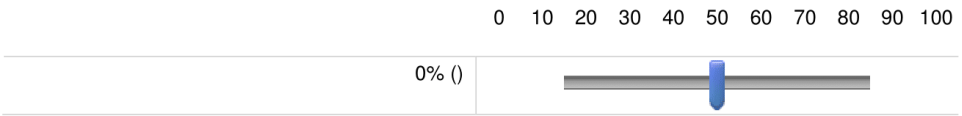
Q47
How would you rank the relative level of threat to Virginia's forests from the following insect species? Drag and drop to indicate

_____ hemlock woolly adelgid (1)
_____ Asian longhorned beetle (2)
_____ European gypsy moth (3)
_____ spotted lanternfly (4)
_____ southern pine beetle (5)
_____ emerald ash borer (6)
_____ walnut twig beetle (7)

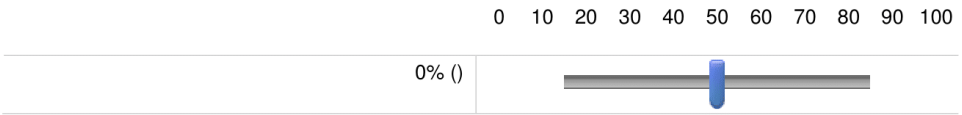
End of Block: Urban tree attitudes

Start of Block: Support for EABTP

Q45 Roughly what percentage of the property owners you work with own more than 5 acres?



Q44
Roughly what percentage of your working hours are spent on projects related to forest health (tree nutrition, pests, or pathogens)?



Q61 Prior to 2018, how frequently were you dealing with EAB-infested ash trees in your work?

- Very frequently (1)
- Frequently (2)
- Occasionally (3)
- Rarely (4)
- Very rarely (5)

Q49 Did you conduct any site visits as part of VDOF's Emerald Ash Borer Treatment Program (EABTP) in 2018?

- No (1)
- Yes - how many? (2) _____

Q16 How would you rate your level of interest in helping to implement EABTP in future years?

- Not at all interested (1)
- Slightly interested (2)
- Somewhat interested (3)
- Very interested (4)
- Extremely interested (5)

Q46 Please describe the reasons for your interest, or lack of interest, in continuing to implement this program

_____

End of Block: Support for EABTP

Start of Block: Participant Information

Q30 This final section asks for general professional characteristics to better understand our survey participants. No personally identifying information is collected here. Only combined results will be presented in our final summary report.

Q33
What is your age?

- Under 25 (1)
- 26 to 34 (2)
- 35 to 44 (3)
- 45 to 54 (4)
- 55 to 64 (5)
- 65 or older (6)
- Do not wish to disclose (7)

Q34 Which gender do you most identify with?

- Male (1)
- Female (2)
- Other (3) _____
- Do no wish to disclose (4)

Q38 What is the highest level of education you have had the opportunity to complete?

- Less than high school (1)
- High school graduate (2)
- Some college (3)
- 2 year degree (4)
- 4 year degree (5)
- Graduate/Professional degree (6)
- Doctorate (7)
- Do not wish to disclose (8)

Q40 **Thank you** for taking the time to respond to this survey. All survey responses will be aggregated in the analysis with no identifying information present in the summary report. Please check back for more information on our project page at eab.frec.vt.edu Study results will be available in the spring of 2019

End of Block: Participant Information

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Survey 4: Virginia Arborists

Start of Block: Professional characteristics

Q56
How many years' experience do you have you working in arboriculture?

- ○ less than 1 (1)
- ○ 1 - 5 (2)
- ○ 6 - 10 (3)
- ○ 11 - 15 (4)
- ○ 16 - 20 (5)
- ○ 21 - 30 (6)
- ○ 31 - 40 (7)
- ○ 41 + (8)

Q62 Are you an ISA Certified Arborist?

- ○ Yes - currently hold certification (1)
- ○ Previously held certification (2)
- ○ No (3)

Q60 Are you an SAF Certified Forester?

- ○ Yes - currently hold certification (1)
- ○ Previously held certification (2)
- ○ No (3)

Q63 What is your area of practice?

- ○ Utility arboriculture (1)
- ○ Residential or commercial arboriculture (2)
- ○ Consulting or training (3)
- ○ Urban forestry (4)
- ○ Other: (5) _____

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Q60 Is your business located in Virginia?

- Yes (1)
- No (2)

Skip To: Q61 If Is your business located in Virginia? = Yes

Q62 Do you work for clients located in Virginia?

- Yes (1)
- No (2)

Skip To: End of Block If Do you work for clients located in Virginia? = No

Q61 In which Virginia county or independent city do you primarily work?

▼ Accomack County (1) ... Winchester city (134)

End of Block: Professional characteristics

Start of Block: Urban tree attitudes

Q26 How strongly would you agree or disagree with these statements about trees in residential areas?

	Strongly agree (1)	Somewhat agree (2)	Neither agree nor disagree (3)	Somewhat disagree (4)	Strongly disagree (5)
Trees are an important part of the character of a neighborhood (1)	○	○	○	○	○
Shade trees add value to a residential property (2)	○	○	○	○	○
Overall, the hazards and nuisances created by shade trees outweigh the benefits they provide (3)	○	○	○	○	○
I prefer not to have tall trees near my house (4)	○	○	○	○	○
I'd rather spend money to preserve a mature tree that is showing signs of decline than to remove it (5)	○	○	○	○	○

Q48
How would you rank the following species as residential shade trees?
Drag and drop to indicate

_____ sugar maple (1)
_____ white oak (2)
_____ black cherry (3)
_____ black walnut (4)
_____ pignut hickory (5)
_____ white ash (6)
_____ America elm (7)
_____ tulip tree (8)
_____ eastern white pine (9)

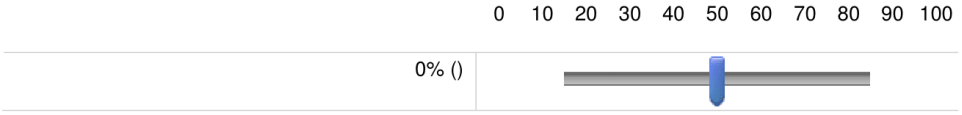
Q47 How would you rank the relative level of threat to Virginia's forests from the following insect species? Drag and drop to indicate

_____ hemlock woolly adelgid (1)
_____ Asian longhorned beetle (2)
_____ European gypsy moth (3)
_____ spotted lanternfly (4)
_____ southern pine beetle (5)
_____ emerald ash borer (6)
_____ walnut twig beetle (7)

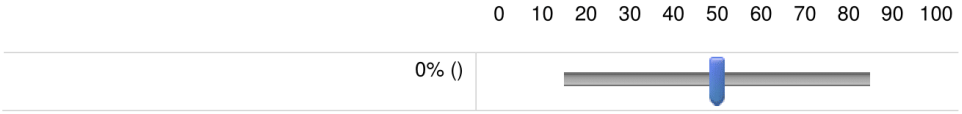
End of Block: Urban tree attitudes

Start of Block: Support for EABTP

Q45 Roughly what percentage of the property owners you work with own greater than 5 acres?



Q44
Roughly what percentage of your working hours are spent on projects related to forest health (tree nutrition, pests, or pathogens)?



Q10 Prior to 2018, how frequently were you dealing with EAB-infested ash trees in your work?

- ○ Very frequently (1)
- ○ Frequently (2)
- ○ Occasionally (3)
- ○ Rarely (4)
- ○ Very rarely (5)

Q65
Rank the following EAB management strategies by how often you have recommended them. Drag and drop to indicate
_____ Tree removal (1)
_____ Imadicloprid soil application (2)
_____ Emamectin trunk injection (3)
_____ Wait and see (4)
_____ Other: (5)

Q66 Rank the following EAB management strategies by how often clients have selected them. Drag and drop to indicate
_____ Tree removal (1)
_____ Imadicloprid soil application (2)
_____ Emamectin trunk injection (3)
_____ Wait and see (4)
_____ Other: (5)

Q52 Are you aware of Virginia Department of Forestry's Emerald Ash Borer Treatment program?

- ○ Yes (1)
- ○ No (2)

Skip To: Q54 If Are you aware of Virginia Department of Forestry's Emerald Ash Borer Treatment program? = No

Q53 How did you hear about the program?

- ○ From a VDOF employee (1)
- ○ Through a VDOF publication (2)
- ○ From the VDOF website (3)
- ○ From a friend or associate (4)
- ○ Other: (5) _____

Q49 Did you submit any bids for ash tree treatment as part of EABTP?

- ○ No (1)
- ○ Yes - how many? (2) _____

Q54

The Emerald Ash Borer Treatment Program (EABTP) was designed by the Virginia Department of Forestry to encourage the preservation of ash trees by assisting cities and homeowners with the costs of insecticidal application.

Eligible applicants can receive a payment covering 50% of the treatment cost, up to a maximum of $1250 for a residential property and $5000 for organizations.

All applications must be approved by a VDOF forester and contain a bid for treatment from a certified pest applicator. The EABTP enrollment period for is closed for 2018 but will reopen in early 2019.

Q16
How would you rate your level of interest in participating in EABTP in future years, as a contractor bidding on or carrying out insecticidal applications?

- ○ Not at all interested (1)
- ○ Slightly interested (2)
- ○ Somewhat interested (3)
- ○ Very interested (4)
- ○ Extremely interested (5)

Q46 Please describe the reasons for your interest, or lack of interest, in participating in this program

_____

End of Block: Support for EABTP

Start of Block: Participant Information

Q30 This final section asks for general professional characteristics to better understand our survey participants. No personally identifying information is collected here. Only combined results will be presented in our final summary report.

Q33
What is your age?

- Under 25 (1)
- 26 to 34 (2)
- 35 to 44 (3)
- 45 to 54 (4)
- 55 to 64 (5)
- 65 or older (6)
- Do not wish to disclose (7)

Q34 Which gender do you most identify with?

- Male (1)
- Female (2)
- Other (3) _____
- Do no wish to disclose (4)

Q38 What is the highest level of education you have had the opportunity to complete?

- Less than high school (1)
- High school graduate (2)
- Some college (3)
- 2 year degree (4)
- 4 year degree (5)
- Graduate/Professional degree (6)
- Doctorate (7)
- Do not wish to disclose (8)

Q40 **Thank you** for taking the time to respond to this survey. All survey responses will be aggregated in the analysis with no identifying information present in the summary report.Please check back for more information on our project page at eab.frec.vt.eduStudy results will be available in the spring of 2019

End of Block: Participant Information

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APPENDIX H:
Western IRB Exemption Letter

Global Leader | Proven Expert

August 14, 2018

Phillip Eric Wiseman, PhD
Virginia Tech
228 Cheatham Hall (0324)
310 West Campus Drive
Blacksburg, Virginia 24061

Dear Dr. Wiseman:

SUBJECT: REGULATORY OPINION—IRB EXEMPTION
Protocol Title: Impacts of the Emerald Ash Borer Treatment Program
Investigator: Phillip Eric Wiseman, PhD
IRB Protocol #: VT IRB-18-662

This letter is in response to your request to Western Institutional Review Board (WIRB) for an exemption determination for the above-referenced research project. WIRB's IRB Affairs Department reviewed the exemption criteria under 45 CFR §46.101(b)(2):

> (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:
> (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

We believe that the research fits the above exemption criteria. The data will be collected in a way so that the subjects can be identified, directly or through identifiers linked to the participants. However, any disclosure of the human subjects' responses outside the research will not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. You have also confirmed that the results of this study will not be submitted to the Food and Drug Administration (FDA) for marketing approval.

This exemption determination can apply to multiple sites, but it does not apply to any institution that has an institutional policy of requiring an entity other than WIRB (such as

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1019 39th Avenue SE Suite 120 | Puyallup, WA 98374-2115
Office: (360) 252-2500 | **Fax:** (360) 252-2498 | **www.wirb.com**

an internal IRB) to make exemption determinations. WIRB cannot provide an exemption that overrides the jurisdiction of a local IRB or other institutional mechanism for determining exemptions. You are responsible for ensuring that each site to which this exemption applies can and will accept WIRB's exemption decision.

Please note that any future changes to the project may affect its exempt status, and you may want to contact WIRB about the effect these changes may have on the exemption status before implementing them. WIRB does not impose an expiration date on its IRB exemption determinations.

If you have any questions, or if we can be of further assistance, please contact Amber Billingham, BA, CIP, at 360-570-1299, or e-mail RegulatoryAffairs@wirb.com.

ALB:tb
B2-Exemption-Wiseman (08-14-2018)
cc: WIRB VA Tech, Virginia Tech
WIRB Accounting
WIRB Work Order # 1-1104750-1