Planning For Pest Readiness:

Building Climate Resilience in Seattle's Urban Forest with a Community-centric Approach

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Abstract

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The urban forest not only plays an important role in providing ecological benefits, but it is also positively associated with public health, especially for communities of color and low-income people who already suffer from environmental injustice. In the fields of landscape architecture and urban forestry, invasive tree pests have rarely received much attention in the planning and design of the urban environment. Yet, they have the potential to weaken and kill massive amounts of trees because they can spread without the control of natural enemies. With the effects of climate change, urban trees will be under greater stress, which makes them even more vulnerable to pests.

This thesis focuses on pest resilience as an integral part of urban forest stewardship through a community-centric approach. Using GIS analyses and case studies, I identify the most ecologically and socially vulnerable communities in Seattle based on their susceptibility to pest infestation and summarize best practices for education and engagement for tree care. I further develop a community engagement framework with an emphasis on environmental justice, while providing resources and recommendations for the City of Seattle and community organizations to approach the pest issue. I also discuss the implications of this research for the urban forest departments in Seattle and for landscape designers.

PLANNING FOR PEST READINESS

Building Climate Resilience in Seattle's Urban Forest with a Community-centric Approach

Master of Landscape Architecture Thesis

LUYU ZENG

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1 INTRODUCTION

1.0 Overview

I became interested in urban forestry as a research topic because urban forests are complex systems that engage urban ecology, environmental justice, and public health. With my interest in climate change and my experience working in the Trees for Seattle program in the City of Seattle, I further narrowed down the topic to invasive tree pests, an area that I had less knowledge about. However, it has become an increasing threat to the urban forest due to climate change, making trees stressed and therefore more vulnerable to pest infestations. Pest readiness became the perfect research focus as it intersects with socio-ecological systems of urban forestry and environmental justice. Trees are also closely related to public health in terms of physical, mental, and social well-being because trees can reduce heat stress, alleviate mental stress, and encourage social interactions, especially in the urban environment (Dobbs et al., 2017; Wolf, 2017). Invasive tree pests can cause massive tree dieback that results in the loss of these ecosystem services. With my interest in community engagement and public education, I believe doing this project can contribute to my understanding of my role as a landscape designer and raise the awareness of practitioners in planning and designing urban landscapes for climate resilience.

1.1 Critical Stance

To me, the aesthetics and cultural significance of trees are always inspirations for art and designs with nature. Besides their aesthetics, in urban landscapes, trees make up an imperative infrastructure that provides ecosystem services such as remediating air pollution, filtering stormwater runoff, and alleviating urban heat island effects (Dobbs et al., 2017).

As urbanization intensifies, urban parks and trees are one of the few places that can provide food and shelter for wildlife and are therefore critical to support biodiversity (Ferrini et al., 2017). Trees can also encourage outdoor physical activity that improves cardiovascular and mental health (Ulmer et al., 2016; Wolf et al., 2020). With the challenges of climate change, urban forests can sequester carbon for storage in trunks and roots and mitigate rising temperatures. However, the urban forest will need to withstand the challenges of the urban environment first, such as soil compaction, narrow root spaces, and urban heat island effect. City dwellers don't know how to properly take care of them or don't always understand who is responsible for caring for trees in certain areas, resulting in negligent care and loss of ecosystem services.

Besides threats like development pressure and climate change, pest invasion has emerged as the most prominent but the least prepared threat for trees in the last few decades in the United States, with the potential to cause massive tree dieback. The loss of trees on a big scale will induce extensive loss of ecosystem services that can take decades to restore and result in expensive financial remediation. In addition, the absence of trees can lead to poor health consequences. According to one study, extensive tree dieback due to Emerald Ash Borer infestation has been linked to the increasing occurrence of respiratory disease in the U.S. Northeast during the 2000s, which indicates the significant impact of tree loss on public health (Donovan et al., 2013).

Landscape designers deal with tree selection regularly. Although we consider the aesthetics, functions, and maintenance at a site scale, we don't necessarily concern ourselves with selecting trees from a broader perspective or emphasizing tree diversity at the neighborhood or city scale. Certain landscape typologies like allées and boulevards usually consist of the same tree species in close proximity to each other, which opens up the possibilities for devastating tree loss (Raupp & Gonthier, 2017). After Dutch elm disease killed American elm trees that dominated the streetscape in the U.S. in the 1960s, the tendency for practitioners was to resolve the problem by replacing elm trees with maple and ash trees. The trees then faced other threats with the arrival of the emerald ash borer and Asian longhorned beetles that viciously attack maple and ash trees (Raupp & Gonthier, 2017). This is an important indication that it is not enough to simply replace one species with another because there will always be exotic pests that can attack a certain species of trees. Instead, as we consider climate adaptation and resilience for tree selection, it is imperative to understand the dynamics of pests, their potential to disrupt the urban forest, and the need for functional diversity of the urban forest.

Even though most intentional pest introductions have been monitored and regulated by USDA, the unintentional introductions of pests through vessels, vehicles, and hitchhikers are the ones that are hard to control as they can happen anytime (Murray, 2020). The question becomes not if but when pest invasion will happen and how to deal with it quickly when it happens, as pest invasion requires timely response to prevent further spread of the pests and minimize the damage. In Seattle, winter moth (*Operophtera brumata*) and bronze birch borer (*Agrilus anxius*) have arrived and the situation has been monitored closely for control (as shown in Figure 1-1 and 1-2). However, several other pest diseases like Asian longhorned beetle (*Anoplophora glabripennis*), emerald ash borer (*Agrilus planipennis*), and sirex wood wasp (*Sirex*

Figure 1-1. The leaves of bigleaf maple damaged by winter moth in and around Dr. Jose Rizal Park in Seattle.

Figure 1-2. Close-up of a damaged leaf with a larvae of winter moth

Figure 1-3. European white birch near my home, suffering from bronze birch borer infestation

noctilio) could have an extensive impact on our urban forest potentially if their population became well established in the city (Ciecko et al., 2012). The risk can be very high considering the influx of visitors and trade happening in Seattle every day. Additionally, the damage made by wood borers may go unnoticed until significant defoliation occurs. At this time, it may be too late to rescue the trees because the pests have already conquered and moved on to other trees. Once the population of pests is established and the spread continues, the pests can wipe out susceptible trees within a few years, and the chances to eradicate the pest will be very slim and at a huge cost.

Eventually, state and local governments will bear the financial costs of responding to tree pest invasion, while private property owners may bear the financial and mental costs due to the absence of trees (Lovett et al., 2016). Taking emerald ash borer as an example, one study has shown that in the United States, the municipal forestry budget increased about $280.5 million per year on average after 5-8 years of detection of emerald ash borer (Hauer & Peterson, 2017). The budget change was drastic compared to the time periods after 1-4 years of infestation and after 9-12 years of infestation, mostly because pests have incubation periods that delay the

onset of tree dieback, and most of the budget was spent on treatment on trees and removal (Hauer & Peterson, 2017). Cities in the Northeast and Midwest of the United States have been dealing with numerous exotic pest invasions, and local municipalities and landowners have suffered deeply from both the ecological and financial costs due to lack of preparation (Lovett et al., 2016). These cities have scrambled to put together emergency responses, secure funding, and develop programs to help communities replace the trees and educate the public. However, Seattle can do better by preparing for pests before they arrive and putting the protocols in place. With the guidance of the Urban Forest Pest Readiness Playbook in the State of Washington in 2019, the City has assembled a committee for invasive pests that consist of staff from various urban forestry departments working on risk assessment, public outreach, and response protocol.

However, limited resources require targeted actions and collective efforts to sustain the movement, especially considering that many existing urban forestry programs, including Seattle's, depend on partnerships with non-profit environmental organizations to reach out to private property owners. With 67% of land as residential areas that take up 72% of tree canopy in Seattle (City of Seattle, n.d.), public education and community engagement on pest issues are critical to the success of a pest readiness program.

Yet the environmental field is still dominated by wealthy white people in the United States, and minorities are "severely underrepresented, according to research conducted in 2014 (Taylor, 2014), even though they are often the victims of environmental harms. And contrary to common perception, communities of color often really care about their environment because their health is on the line, but they are unwilling to participate because of racism (Finney, 2014). In the wake of race, inclusiveness, and equity discourse, environmental community engagement must emphasize environmental justice to remedy the damages that had accumulated over decades of systemic racism, especially in urban environments, where social systems have made lasting impacts on ecological systems (Schell et al., 2020). Without critical considerations for environmental justice, the acceptability of environmental community engagement will not be genuine and last for long.

As a landscape designer with a certain knowledge of trees and experience with public outreach practices in the urban forestry field, understanding of socio-ecological connections of trees and systematic, interdisciplinary thinking put me in the unique position to investigate the dynamics of pest issues, bring up the concerns, and facilitate community connections. This thesis aims to increase understanding of the threat of invasive pests in socio-ecological systems and focus my resolution on a community-centric approach with an emphasis on environmental justice. I choose the city of Seattle as my study area partly because I am more familiar with municipal urban forestry and other environmental organizations in Seattle during my internship at Trees for Seattle program, but also because the City recently formed the Seattle Committee on Invasive Pest in order to come up with a pest readiness plan by adopting the Urban Forest Pest Readiness Playbook in the State of Washington as a pilot project. In addition, in 2015, the mayor of Seattle at the time launched the Equity & Environment Initiative (EEI), with the intent to address environmental injustice using a community-centric approach (City of Seattle, 2015). Aligned with the initiative, I propose to construct a community engagement framework as a suggestion for the pest readiness plan that helps build up the climate resilience of Seattle's urban forest against sudden rapid pest invasions as a way to prepare for long-term environmental change.

The community engagement framework that I envision will focus on public education and engagement strategies. Public education can help residents understand the importance of trees and knowledge about pests by visualizing tree benefits and potential impacts of pest invasion and offering recommendations to prepare for potential issues with City's help. The engagement will then be targeted to facilitate the discussion among the neighborhood about what actions make sense and what additional help is needed to be better prepared.

In summary, in this thesis, I intend to explore the relationship between urban forestry and public health through the impacts of pest invasion by articulating how climate change and environmental injustice exaggerate the implications for certain vulnerable communities. The key to building up pest readiness is to anticipate and prepare to respond to the threat by identifying and assessing the existing risk in the city of Seattle and learning from other cities' experiences. This thesis aims to research ways to raise awareness of pest issues and establish equitable and inclusive partnerships that address the concerns of different stakeholders, especially the communities of color, to sustain the efforts of pest readiness. Ultimately, by developing a community engagement framework as part of the pest readiness plan, I hope to help guide the city agencies and communities to safeguard and steward the urban forest together.

1.2 Research Questions

How can we plan for pest readiness of Seattle's urban forest through a community-centric approach?

1. What is the spatial composition of Seattle's urban forest and how is it related to ecological and social vulnerability of the neighborhoods?
2. What can Seattle learn from other cities about engaging communities in pest readiness and tree stewardship?
3. How can the city of Seattle better engage and empower communities about pest readiness?

2 LITERATURE REVIEW

2.0 Overview

To understand the key factors in play and identify the knowledge gap for research, I conducted a literature review on different aspects of urban forests as a dynamic socio-ecological system and how pests can disrupt that system. The investigation explores whether and how the urban forest is ecologically significant for social life and public health. This literature review also explores how invasive pests have the potential to further disrupt a system that is already in danger with the gradual impacts of climate change. I examined the theories of environmental justice, the motivations behind pro-environmental behaviors, and the concepts of community engagement and community science. At the end of the chapter, I summarize the relationship of the key concepts into a conceptual framework that guides the rest of my research.

2.1 Urban Forest

Trees make up an essential part of the unique ecosystem in the urban environment. Historically, trees were not only used to satisfy basic needs like food, medicine, clothing, and dwellings but also serve spiritual purposes and are considered sacred living beings to some people, including Native Americans (Hauer et al., 2017). Gradually, with colonization, the utilization of trees became more unsustainable and valued less as living organisms and more for profit. Throughout the U.S., forests were logged to make spaces for settlements, including Seattle (Klingle, 2007). The reintroduction of trees into the urban landscape started with the idea to beautify cities and bring nature back, especially in the United States. There were two movements in the 19th Century through which reforestation took place --- the City Parks Movement and the City Beautiful Movement (Hauer et al., 2017). Starting with the city parks movement, Frederick Law Olmsted, the founding father of landscape architecture, wanted to bring nature back to cities by creating urban parks with extensive use of trees in the mid-19th Century (Hauer et al., 2017). City beautiful movement was borne out of the Columbian Exposition of 1893 in Chicago, where the city was planted with trees on streets, parkways, and parks, and inspired many other cities to do so (Hauer et al., 2017). Each movement played its own part to facilitate replanting trees to establish green streetscapes and parks in cities.

Urban forestry as a term was first used in 1894, with the attempt to combine traditional forestry practices with the management of urban parks (Hauer et al., 2017). However, in the 20th Century and especially after World War II, as the urban environment expanded, trees became "expendable" and made way for housing (Hauer et al., 2017). The focus on urban trees shifted from street trees to beautify the cities to trees in private yards, so a sense of collective responsibility around the urban tree canopy diminished.

In addition to the larger context, individually and collectively, trees are significant socially and ecologically. Individually, specific tree species can showcase the significance of culture and spiritual connections. For example, cherry trees and cherry blossoms are significant for the Japanese culture because of their ephemeral qualities, and they are often gifted to other countries as a symbol of friendship with Japan (*Seattle's Glorious Pink Cherry Blossoms Are a Celebration of Spring and Nature*, 2020). For example, the cherry trees in Seattle and Washington D.C. were gifted by Japan, and every spring, the blossoms make the cities famous as tourist attractions. The trees have become part of the identity of these cities. Trees can also serve as "living memorials" and witness significant social and environmental events (McMillen et al., 2016). In these instances, trees commemorate the event and the loss of lives. In the main campus of the University of Washington, London plane sycamore trees were planted along Memorial Way to honor U.W. students and faculty who sacrificed their lives in World War I, as shown in Figure 2-1 (University of Washington, n.d.). Trees can be a powerful memorial because of their tenuous qualities in the face of disasters or other critical historical events as symbols of resilience. For example, in New York City, the Callery pear tree near Ground Zero that survived the 9/11 terror attack was rescued, protected, replanted on-site as a memorial, and groves of trees were added in honor of the victims (*The Survivor Tree | National September 11 Memorial & Museum*, n.d.). This is just one example of how urban trees can be crucial to social life and hold meaning on a personal and broader scale.

Collectively, trees make up canopy cover that provides a variety of ecosystem services, which consist of provisioning, regulating, supporting, and cultural services ("non-material benefits from ecosystems", like inspirations for culture and art), as defined in the Millennium Ecosystem Assessment in 2005 (Dobbs et al., 2017, p. 52). The concept of urban tree cover, or canopy cover, was developed with the intent to define trees as a collective, which allows the assessment of ecological patterns and processes (Zipperer et al., 1997). Compared to tree inventory that documents the details of individual trees, urban tree canopy cover emphasizes the cumulative ecological benefits that trees contribute collectively. Urban tree canopy can regulate microclimate to reduce the urban heat island effect, filter air pollution from

automobile exhaust, reduce noise, and provide habitats for wildlife, including food and shelter (Dobbs et al., 2017). Landscape typologies like green infrastructure, which depend on the ability of trees to intercept rainwater, have been developed in recent years to mimic natural processes in urban landscapes, slowing down stormwater, filtering and taking up pollutants to improve water quality. In the face of climate change, trees are an essential part of the urban ecosystem that can significantly contribute to mitigating these negative impacts.

2.2 Climate Change

Trees are currently the best way for us to alleviate the effects of climate change because they can sequester carbon and thereby reduce excessive carbon dioxide in the atmosphere which is vital to reduce global warming. However, urban trees have also become more vulnerable because of climate change, especially in the harsh urban environment, where they need to deal with complex abiotic and biotic factors that deter their growth. Abiotic environmental factors such as soil compaction, drought, and heat stress can weaken the trees (Percival, 2017), while biotic factors such as invasive plants, animals, insects, and pathogens can defoliate and further kill the trees (Ferrini et al., 2017). Invasive plants such as English ivy can compete with trees for resources and strangle them, which increases the risk of trees dying. Wounds and decay that anthropogenic forces can cause can also create entrances for invasion (Raupp & Gonthier, 2017).

Climate change can influence and weaken trees in the following ways: rising temperature, water cycle changes, and increasing pest and pathogen activities, as shown in Figure 2-2 (Safford et al., 2013). Each of these will be considered in more detail below.

1. Rising temperature

According to a report by the Climate Impacts Group at the University of Washington, intensive use of fossil fuels has caused greenhouse gas release higher than any time in history, which has increased the atmospheric temperature by about 1 degree Celsius. If left unchecked, the increase can reach 1.5 degrees Celsius any time between 2030 and 2052 with its current rate (Snover et al., 2019). Specifically for Washington state, a 1.5 degree Celsius increase in temperature can increase heat stress for trees. Although on the surface, extra carbon dioxide may be beneficial for tree to utilize, trees have limited capacity for carbon sequestration, and increasing heat stress can result in negative effects such as loss in nutrients and water from the soil and deter tree growth, which will overshadow any benefits that increasing atmospheric carbon can bring to the trees (Safford et al., 2013).

2. Water cycle changes

Water cycle changes manifest in two ways, winter and summer precipitation. Increasing winter precipitation like snowstorms and long-term ice loading can increase tree damage, which gives a chance for potential pest invasion (Safford et al., 2013). Decreasing summer precipitation also increases transpiration of water from the soil, which can add drought stress to trees and

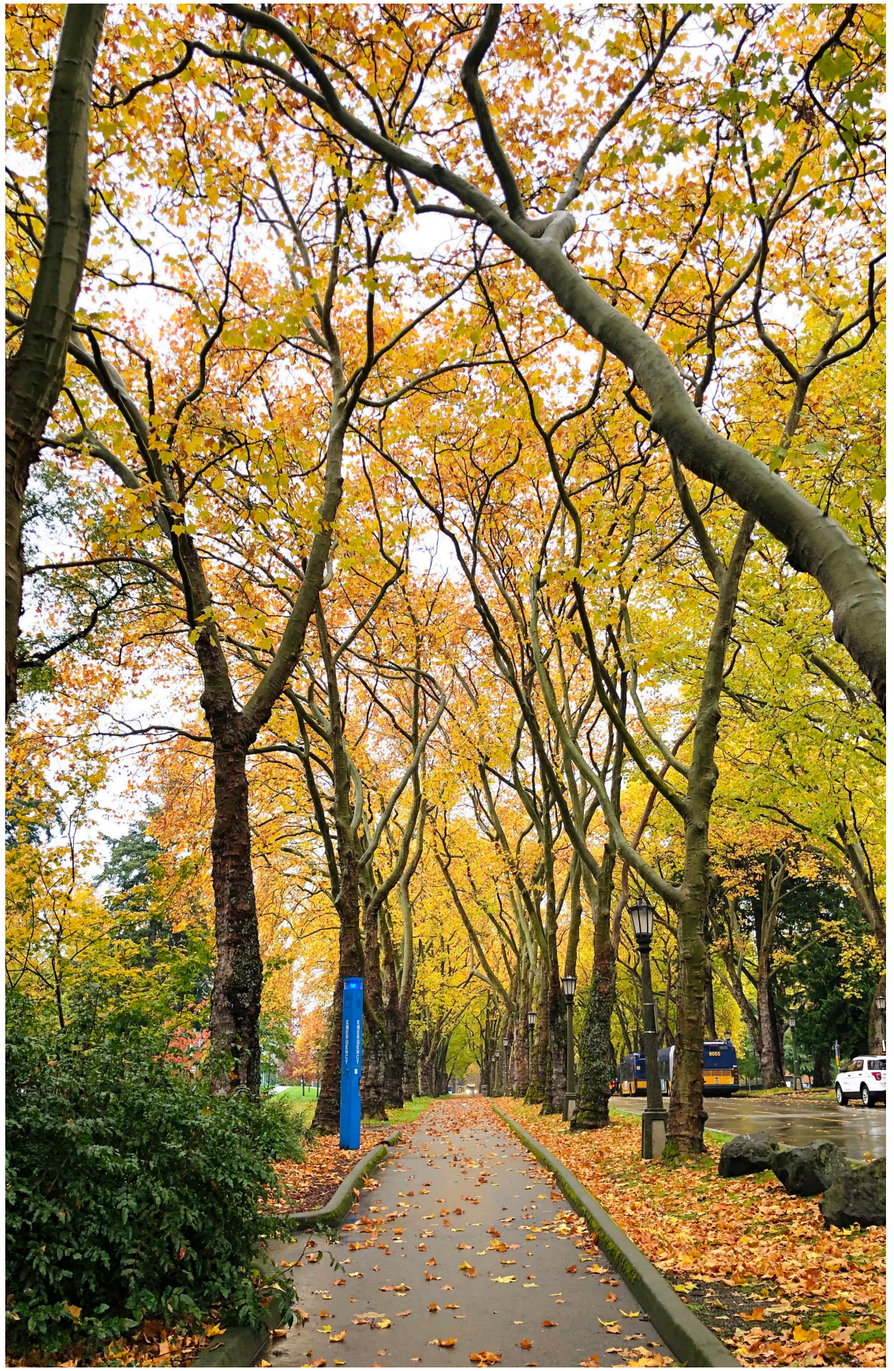


Figure 2-1. London plane sycamore trees planted along Memorial Way in UW

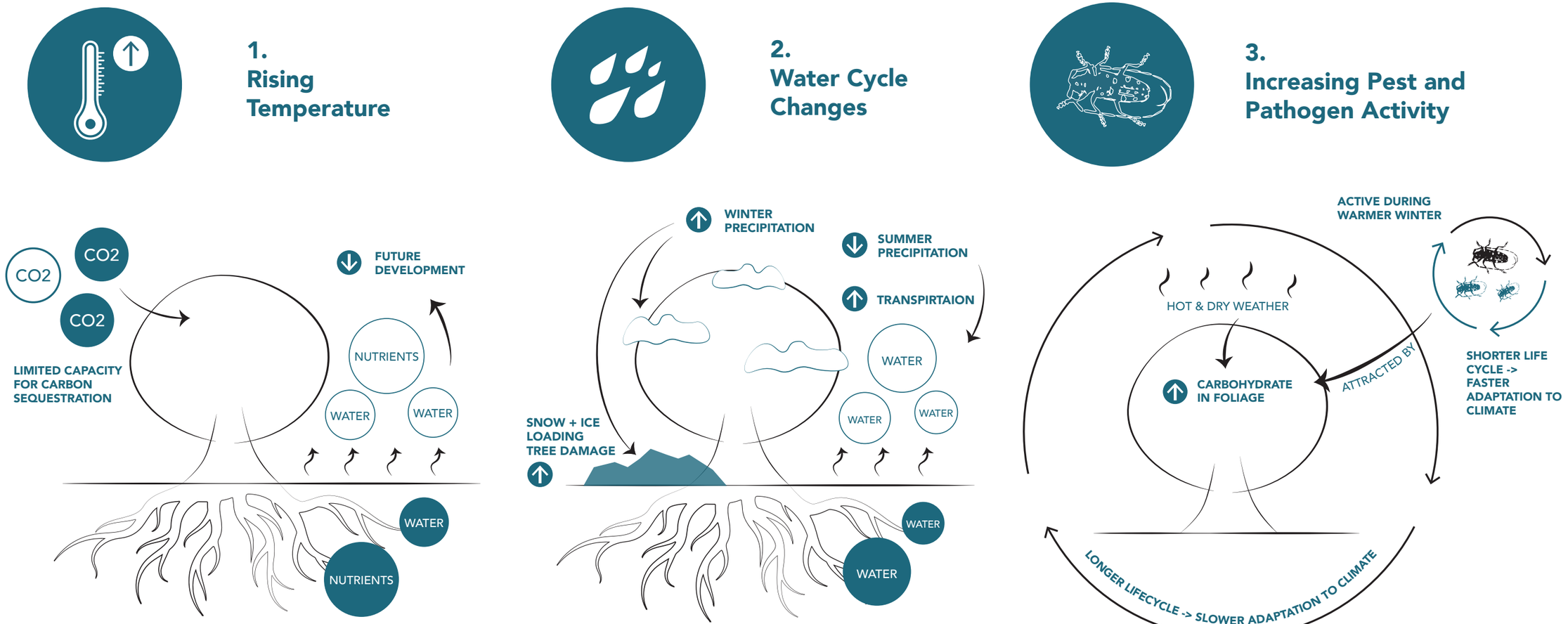


Figure 2-1. Climate change impact on the urban forest

increase their susceptibility to pests.

3. Increasing pest and pathogen activities

Hotter and drier weather in summer may also cause an increased ratio of the carbohydrate content in foliage, making trees more attractive to pests and pathogens, while in winter, pests will be more active and invade trees (Safford et al., 2013).

With the rising temperature, pests can potentially shift territories up north to find new hosts, adding new unknown threats. Changing precipitation patterns may change pest life cycle and population dynamics, resulting in favorable living conditions, and subsequently more aggressive attacks on hosts (Dhang & Dhang, 2017). Even if pest life cycles won't change, the trees themselves may become more vulnerable to attack under the stressful condition of longer drought or storm and the impacts of frequent extreme weather (Tubby & Webber, 2010). The impact could be substantial and devastating to the trees, as they become more susceptible to attacks from pests. Even though climate change may have an equal effect on disrupting the life cycles of both pests and trees, pests have shorter life cycles that allow them to evolve and adapt to the changing climate faster, whereas trees have a relatively long life cycle and thus they adapt more slowly, making them vulnerable to increasing populations of pests (Safford et al., 2013).

In this thesis, I focus on pest resilience of the urban forest as a way to build climate resilience. Resilience is defined as "the capacity of a system to persist and adapt to sudden shocks (e.g., pest outbreaks) and global environmental change", which manifests in two ways, the resilience of ecosystem services that urban forest provides and the resilience of "the urban forest itself" (Dobbs et al., 2017, p. 59). The regulation and provisioning ecosystem services that trees provide can help reduce the impacts of rising temperature and extreme weather events on human health, but the resilience of the urban forest depends on our planning and management to maintain functional diversity that can respond to various environmental changes and potential pest issues (Dobbs et al., 2017).

2.3 Pest Invasion and Infestation

Within the context of this research, the concept of a "pest" is borrowed from the Washington state Urban Forest Pest Readiness Playbook, which defines a pest as "an insect or pathogen, nonnative to Washington that uses trees as a host in urbanized areas whose invasive characteristics cause substantial economic and ecological harm and are capable of spreading to new areas of the state (Washington Invasive Species Council, 2019, p. 14)." Unlike in natural forests, where insects and pathogens are commonly seen as disturbances that belong to natural processes, invasive insects and pathogens in cities and suburbs were rarely considered a severe issue before Dutch elm disease hit. Expert stakeholders in the Pacific Northwest rank invasive species detection and management and improving public appreciation and understanding of trees quite highly in terms of importance in urban forestry research needs (Wolf & Kruger, 2010). This highlights the current knowledge gap of pest management in experts' research and the need to increase the public's understanding through outreach and engagement.

To understand the origin of the pest problem, it is crucial to learn about the invasion pathway. This can be divided into categories of intentional introductions and unintentional introductions. The intentional introductions in the U.S. identified by Lovett et al., involve two pathways: "live plants and wood packaging materials like pallets and crates" (Lovett et al., 2016, p. 1437). In particular, wood borers are the highest threat because they lay their eggs within the wood and tend to be less visible until detailed examination. Figure 2-3 shows the pathway invasion pathways and a timeline of policies to intervene. Since World War II, global trade has increased exponentially, as well as the use of wood packaging in containerized shipping (Lovett et al., 2016). The completion of the Interstate Highway System in the U.S. around the same time further facilitated the movement of humans and items with vehicles across states, which potentially contributed to the spread of pests to new geographic areas. By the early 21st Century, many pests with high impacts to the urban forest, such as the fungus that caused Dutch elm disease and wood borers like Emerald ash borer and Asian longhorned beetle, were discovered in cities and have subsequently caused millions of tree loss and billions in financial impacts (Lovett et al., 2016). Although a little too late, policies like ISPM-15 (International Standard for Phytosanitary Measures No.15) were then put in place around the same time to prevent the introduction of new pests. In addition, research conducted at the regional scale has found that the Asian longhorned beetle (ALB) incident rate was associated with human population density (Huang et al., 2020). Although the particular role that people play in the spread of pests remained unclear, it is highly possible that humans were the primary vector for spread. Policies have been enforced and currently, some pests with high impact haven't arrived in Seattle yet. However, as one of the major international port cities on the West Coast, the probability of influx is very high.

We need to be particularly concerned about invasive pests because trees have no defense mechanism against them since they haven't encountered them before. This means that even healthy trees can be under attack. The normal relationship between trees and insects can be benign or harmful, as native insects are part of the ecosystem. Through evolution over several life cycles, trees can develop defense mechanisms slowly. These defenses can either be general or target specific insects. Pests and insect pathogens can only attack trees in their most vulnerable conditions (i.e., when trees face stressors from the physical environment). Notably, invasive pests don't have natural enemies on an entirely different continent, so they can propagate without control, disrupting the balance of the ecosystem (Raupp & Gonthier, 2017). In addition, native trees don't have any defense mechanisms against the pests, so they are rendered powerless. Coupled with the fact that pests can attack multiple genera of trees and lack diversity in urban tree composition, the result will be devastating tree loss, like in the cases of Dutch elm disease and emerald ash borer.

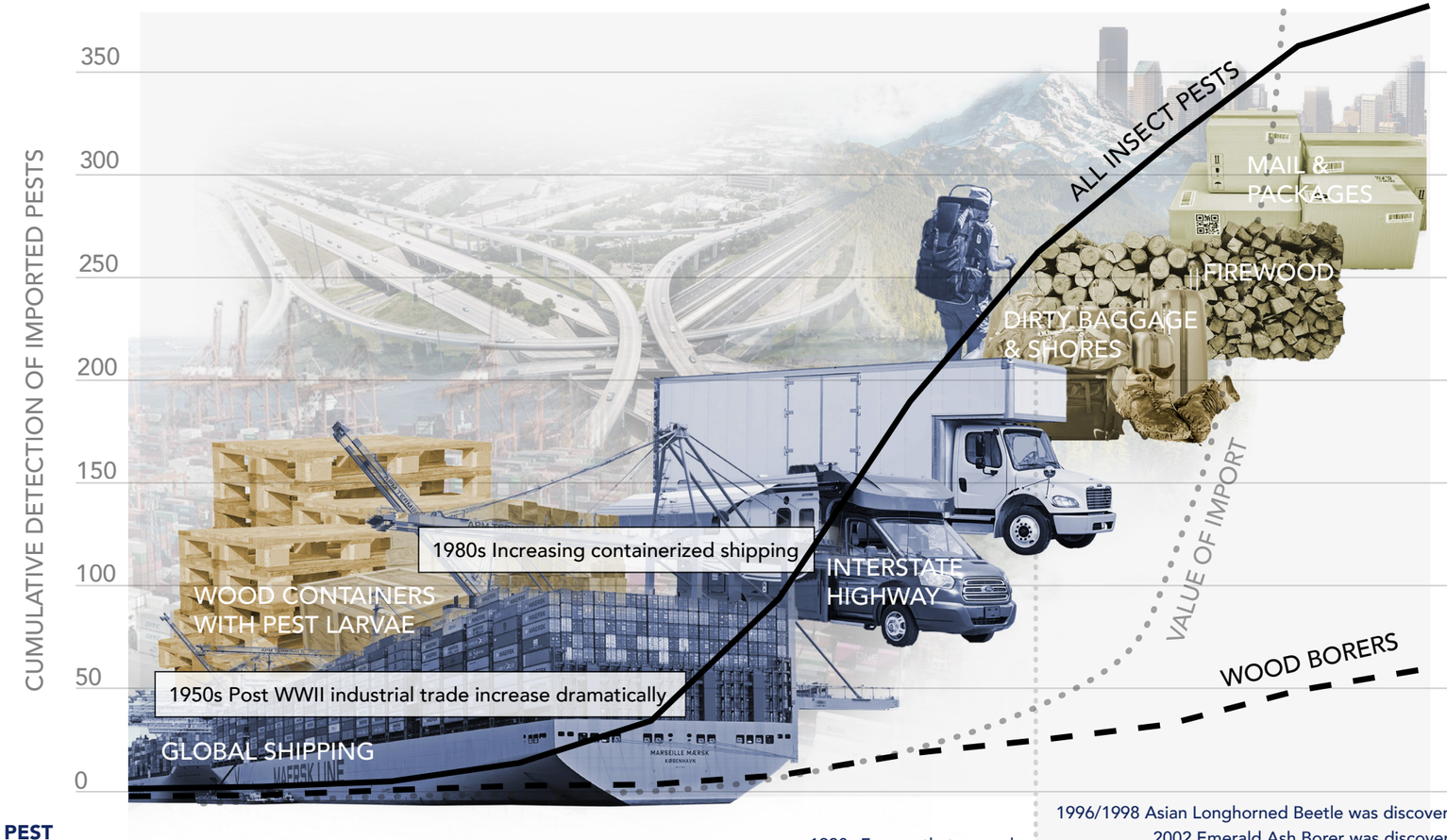
Figure 2-4 shows the invasive pests' pattern of spread and the corresponding strategies for intervention. Once invasive pests arrive and are localized in a new area, the eradication strategy may work if there is quick detection and response to

the pests. Still, the pests can go unnoticed and delay showing signs of invasion because of their incubation period (Lovett et al., 2016). Due to the lack of natural enemies, they can propagate quickly and establish in the area, either defoliate, weaken, or kill the trees. Once the population reaches a certain limit, they will start spreading to look for new tree hosts and reduce competition. In Minneapolis, emerald ash borer appeared only in one neighborhood but later wreaked havoc on every ash tree in the city where a high concentration of ash trees was located (Hauer & Peterson, 2017). When something like this occurs, it is hard to control the pests, and the only strategy to protect trees is on a case-by-case basis. Because pests can sometimes target a wide range of tree species as hosts, tree loss can be very high, and the cost will eventually fall on the local government and private property owners (Lovett et al., 2016; Murray, 2020). The most cost-effective time to intervene is at the prevention stage or to eradicate pests before they are well established and rely on the help of detection (Bush, 2020; Looney et al., 2016; Murray, 2020). This is why early detection is vital.

With 67% of trees in Seattle located on private properties, pest control and management efforts greatly depend on Seattle residents. However, if they don't know

PEST INVASION PATHWAY & TIMELINE

Adapted from Lovett et.al, 2016 & Murray, 2020



PEST DETECTION

1996/1998 Asian Longhorned Beetle was discovered
2002 Emerald Ash Borer was discovered
2004 Sirex Wood Wasp was discovered

TIMELINE

1775 1800 1825 1850 1875 1900 1925 1950 1975 2000 2006

1869 Gypsy Moth was introduced

1930s Fungus that caused Dutch Elm Disease was introduced

POLICY & REGULATIONS

1914 — USDA starts to intercept phloem and wood boring insects

1912-1919 — Plant Quarantine Act of 1912 was passed and USDA implemented Quarantine 37 regulations in 1919

1982 — USDA still considers wood-boring insects as "not a big concern"

1999 — U.S. sets requirement for treatment of wood packing material from oversea

2002 — ISPM-15 was adopted and U.S. CBP is responsible for inspection at entry.

2008 — USDA APHIS inaugurates the Plant Pest and Disease Management and Disaster Prevention Program (combined with National Clean Plant Network in 2014)

TERMINOLOGY

USDA: U.S. Department of Agriculture
APHIS: Animal and Plant Health Inspection Service, an agency within USDA that regulates invasive species
U.S. CBP: United States Customs and Border Protection
ISPM-15: International Standard for Phytosanitary Measures No.15, requirement for sterilization of wood before transport

Figure 2-3. Pest invasion pathways and timeline

the potential threat of pest invasion to trees and public health, it is hard to call for actions for everyone to be prepared before the pest outbreak hits.

2.4 Trees and Public Health

Currently, cities typically use the percentage of canopy cover in urban areas as the metric to generate guidance for pest management and set up goals for tree planting because collectively, trees can provide ecosystem services that safeguard public health in terms of both physical and mental well-being, as shown in Figure 2-5 (Nguyen et al., 2017). The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (The Constitution of the World Health Organization, 1948). Urban trees enhance human physical health by providing shade, reducing surface temperature, and alleviating urban heat island effects caused by too many impervious surfaces, thereby reducing heat-related illness (McDonald et al., 2017; Safford et al., 2013). Trees can improve air quality through filtering and absorbing pollutants, such as ozone, NOx, particulate matter, and Volatile Organic Compounds (VOC), thus reducing respiratory diseases. However, it should be noted that some trees may release allergens, and specific configurations of trees can trap particulate matter (McDonald et al., 2017; Schwarz et al., 2015; van den Bosch, 2017; Wolf et al., 2020). Interactions with trees and green spaces, such as walking in the forest and planting trees, can also boost the immune system and increase microbial activities essential to human health as certain trees like cypress trees can emit phytoncides that "enhance human natural killer (N.K.) cell activity, the number of N.K. cells, and intracellular anti-cancer proteins in

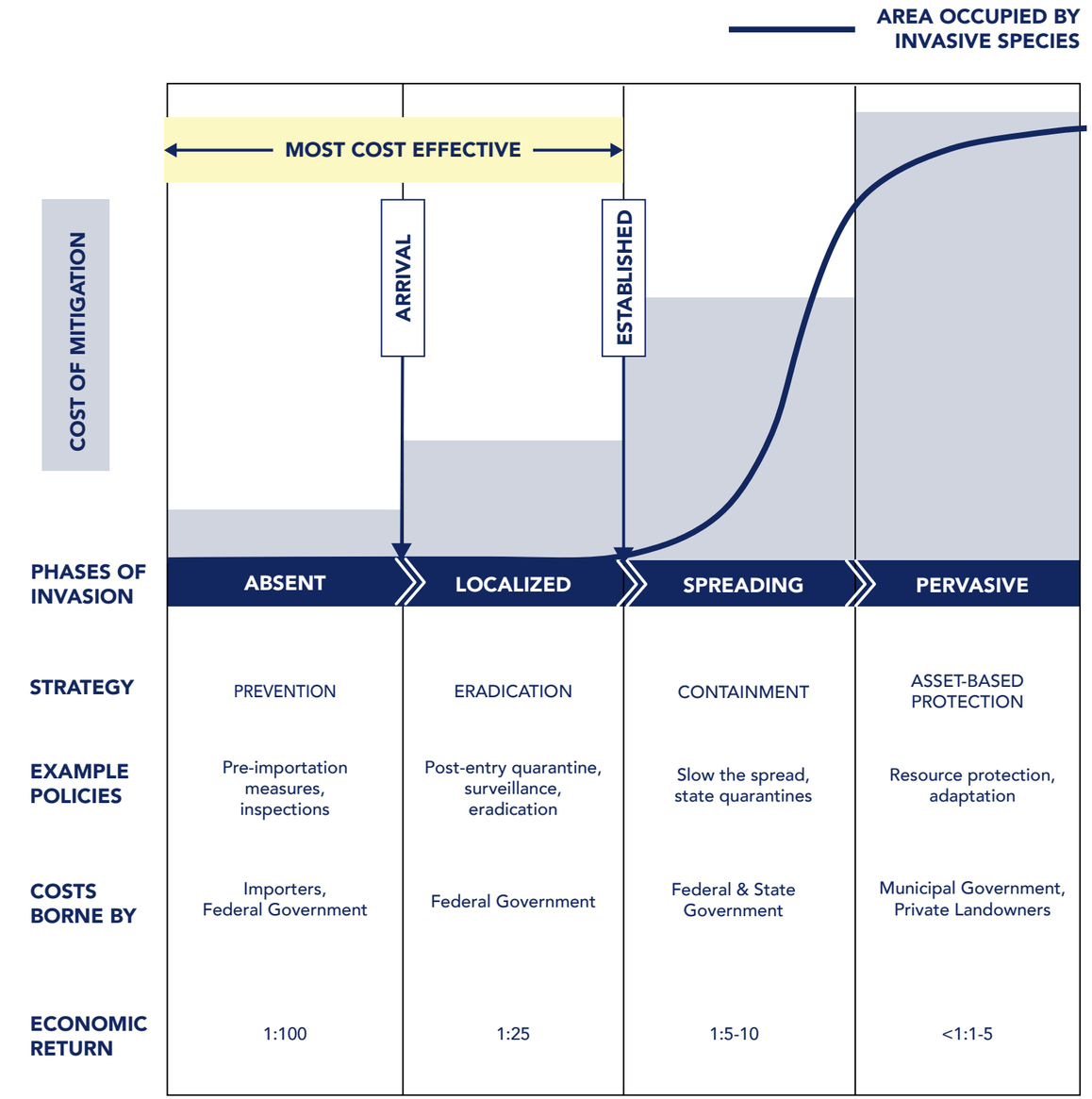


Figure 2-4. Invasive pests' pattern of spread and corresponding strategies

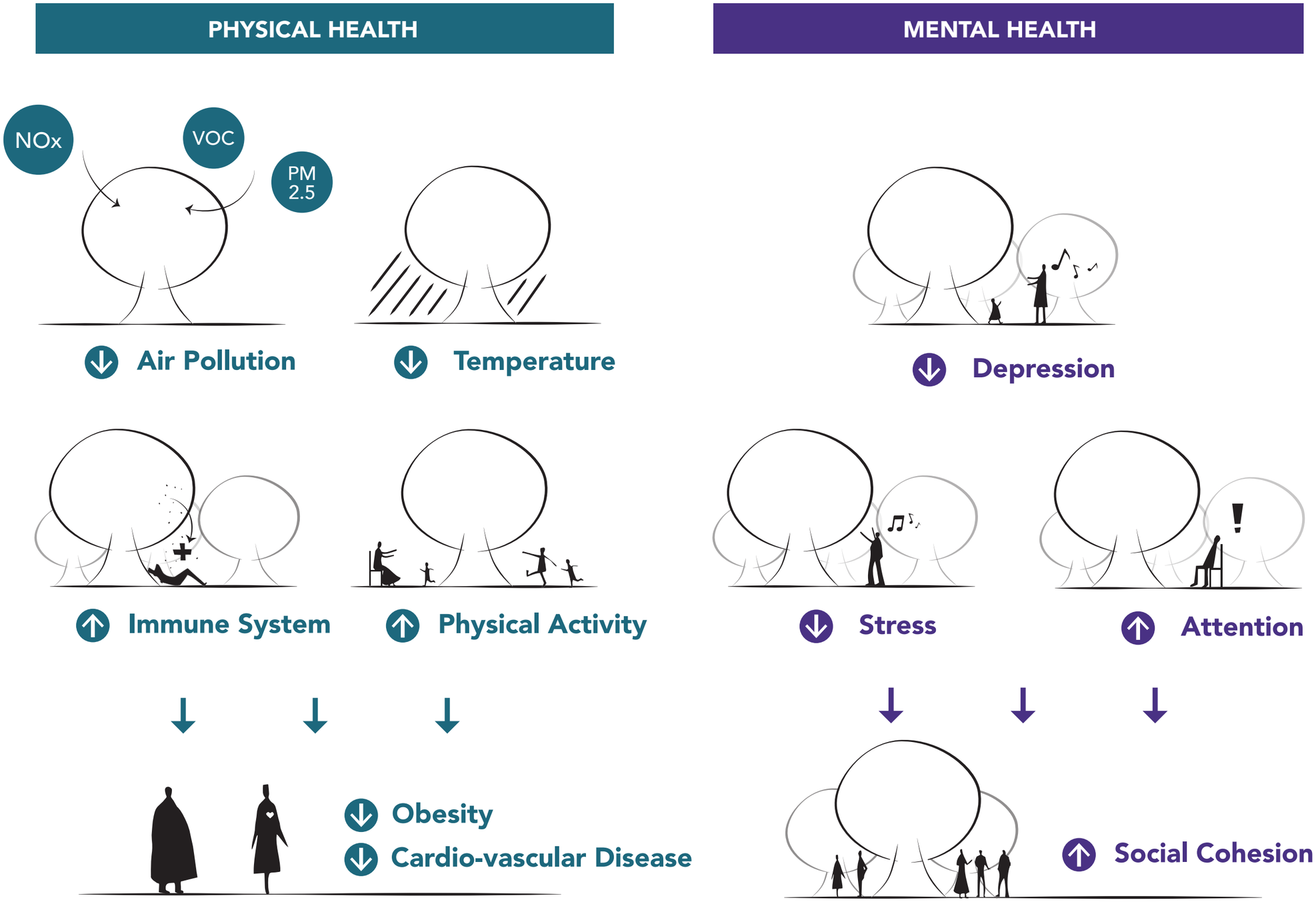


Figure 2-5. The relationship between trees and public health

lymphocytes" (Li et al., 2009, p. 951; Ulmer et al., 2016; van den Bosch, 2017; Williams, 2017).

Trees can also enhance physical health by increasing walkability, thereby increasing physical activities and reducing cardiovascular disease, respiratory illness, and obesity (McDonald et al., 2017; Schwarz et al., 2015; Ulmer et al., 2016). Conversely, research has linked massive tree loss due to emerald ash borer with increased cardiovascular and respiratory illness, which shows the significance of trees on physical health (Donovan et al., 2013).

The Meikirch Model of Health adds another dimension on top of the individual level and states "social and environmental determinants" as part of well-being (Bircher & Kuruvilla, 2014). The environmental determinants of health consist of all external factors such as the "physical, chemical, and biological aspects" of the environment that have an impact on human health, while the social determinants of health include "unequal distribution of power, income, goods, and services…and the subsequent unfairness" that may impact their ability to have a successful life (Bircher & Kuruvilla, 2014). These two aspects in the Meikirch model extend beyond the WHO definition and indicates a more recent revelation of the concept of environmental injustices that have far-reaching impacts on the health of minorities in the United States, as explained in more detail in Section 2.5.

Trees are also instrumental to mental health, especially during the process of human development and learning. Kaplan's Attention Restoration Theory explains how green spaces, and in particular, trees can help people recover from mental fatigue caused by focused, effortful attention (Kaplan, 1995; van den Bosch, 2017). Ulrich's research on the function of trees in urban landscapes further demonstrates that spending more time in green spaces and interacting with trees just visually can reduce stress, and active exploration and immersive experience can be even more effective in reducing stress (Ulrich et al., 1991).

Furthermore, trees can contribute to the attractiveness of public spaces that facilitate social connections and subsequently increase individual mental health because these are related (Wolf, 2017). Biophilia theory indicates that humans can inherently be attracted to other living organisms like trees, and therefore often prefer a more natural environment over hardscapes (Wilson, 1984; Wolf, 2017). Places with trees create pleasant public spaces that encourage people to linger more and interact with each other, which increases social ties, sense of place, and sense of ownership (Wolf, 2017). Also, a study conducted in Cincinnati after tree loss due to emerald ash borer suggested that lack of trees can correspond to increasing crime because trees show signs of care and attention and get more people out on the streets, offering a deterrent effect for potential crime (Kondo et al., 2017; Wolf, 2017). Experience with green spaces that trees are a part of can further promote pro-environmental behavior, which is explained in more detail in Section 2.6 (van den Bosch, 2017).

2.5 Environmental Justice

The urban ecological system is inextricably linked to social inequality because ecological features in cities are mostly manually designed and managed. Therefore the provision and care of urban street trees are fundamentally connected to environmental justice. In the case of pest readiness, the acceptability of environmental policies are closely related to people's perception of policy outcome, from the individual level to collective level, and on a broader scale in terms of environmental justice, as shown in Figure 2-6 (Schuitema & Bergstad, 2018). The U.S. Environmental Protection Agency defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (US EPA, 2014). Environmental justice manifests in two distinct aspects, distributive justice and procedural justice (Schuitema & Bergstad, 2018; US EPA, 2014). Distributive justice is a matter of the equal distribution of environmental goods and harms (i.e., who gets what), while procedural justice refers to whether people are equally consulted and involved in the decision-making process (Schuitema & Bergstad, 2018). From personal accounts to scholarly research, a diverse range of literature has shown that BIPOC communities are most frequently exposed to environmental hazards, such as landfills, noise, and air pollutions, which have been discriminatively located in or near their neighborhoods (Baptista, 2016; Klingle, 2007). This is because structural racism, manifested in the history of redlining and other discriminative segregation laws, has caused decades of disinvestment from environmental amenities like parks. This demonstrates distributive injustice (Schell et al., 2020). In a study that compared urban heat island effects in redlined and non-redlined neighborhoods in 108 U.S. cities, about 94% of study areas showed that redlined neighborhoods are about an average of 2.6 degrees Celsius hotter than non-redlined neighborhoods. The result is consistent with the lack of tree canopy and green spaces within redlined neighborhoods (Hoffman et al., 2020).

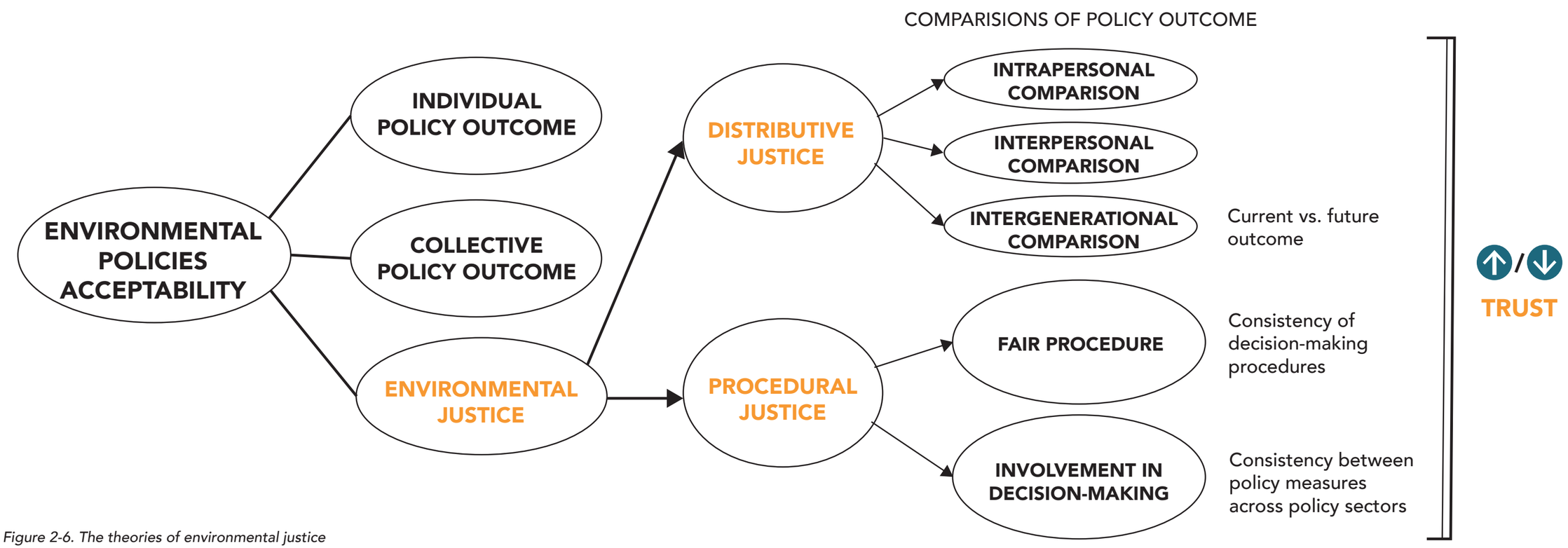


Figure 2-6. The theories of environmental justice

At the same time, the distribution of environmental amenities, such as the urban tree canopy, is also uneven and has led to negative health consequences for many communities of color. In Seattle, neighborhoods like South Park and Georgetown, which consist of a majority of people of color, only have 14.7% and 5.1% of the tree canopy, respectively, compared to the average of 28%-31% in wealthy white neighborhoods in the Northeast Seattle area (*2016 Seattle Tree Canopy Assessment*, 2016). Studies have shown that life expectancy is also significantly shorter in neighborhoods with a majority of BIPOC residents than in wealthy white neighborhoods like Laurelhurst. Some studies have connected this disparity to greater rates of asthma and lack of leisure time for physical activities in communities of color, although there is evidence that tree canopy can help with this (Gould & Cummings, 2013; The Institute for Health Metrics and Evaluation, 2017). The lack of resources already results in lower canopy cover and subsequently poorer health for people of color living in these neighborhoods.

If massive tree dieback were to happen, some Seattle residents simply don't have the time, money, or other resources to respond, which can further exacerbate health problems. Even if people know about the threat of tree dieback, they may lack access to appropriate methods to safely handle the problem without support from the city and the community. This is a challenge citywide. If a pest spreads uncontrollably in one neighborhood, it is only a matter of time until it could affect thousands of trees in the surrounding region. By that time, even if there is time and resources to handle the problem, it would be too late to save most trees and it would take a lot more energy and investment to control. Environmental injustice can be the weakest point that breaks loose and promoting justice through providing assistance and resources is the key to building pest readiness.

Also, historical exclusion in the decision-making process and lack of diversity and representation within the environmental

field can become potential barriers to the engagement process, which speaks to the second aspect of environmental justice, procedural justice. Lack of diversity and representation of minorities in government agencies and environmental organizations reflects a lack of understanding of cultural practices and concerns. This, in turn, can lead to programs and activities that are not sensitive to local residents' preferences and lifestyles and can result in low participation. Research that investigated the composition of the environmental field shows that the well-known environmental organizations are dominated by white people in terms of both practitioners and volunteers (Taylor, 2007). In comparison, minorities comprise about 77.8% of staff in environmental justice organizations around the same time (Taylor, 2007). In addition, the researcher also identified two major problems in the environmental field, lack of a workforce development pipeline and lack of effort to seek diversity within the field (Finney,2014; Taylor, 2014). Despite the good intention of tree-related engagement programs, a lack of a targeted approach and understanding of the concerns of minorities can lead to failure. A study in Portland, Oregon, has found that tree planting programs tend to be more successful in neighborhoods with higher socio-economic status, but they can also "exacerbate environmental inequality" (Donovan & Mills, 2014). The same study presents "a dilemma" that if the city chooses to focus its tree-planting program only in neighborhoods with lower socioeconomic status, then the program will not be successful (Donovan & Mills, 2014). However, without truly understanding the concerns of BIPOC communities these programs will not succeed and can even alienate people. This is the manifestation of classic exclusive practices and white supremacy. BIPOC communities are often concerned with job and housing securities, crimes, and racism, which can be combined with urban forestry efforts but not often recognized as such. For example, stewardship and planting are tied to job opportunities and can send signals of care that deter crime, but they are often ignored as a way to engage disadvantaged communities. Johnston and Shimada analyzed that if urban forestry efforts are too focused on trees, a subject that is seemingly "not that significant in comparison to jobs, housing, crime, racism, etc.," the disadvantaged communities may perceive these efforts "as an excuse to avoid tackling the more important issues", which in turn refuse any urban forestry-related efforts (Johnston & Shimada, 2004, p. 188). They also indicated that "it is vital to link the benefits of urban trees with these more pressing economic and social issues on the residents' agenda" (Johnston & Shimada, 2004, p. 188). This speaks to the importance of community engagement in urban forestry efforts in order to truly involve and engage disadvantaged communities.

Also, people often assume BIPOC people don't care about the environment, which is a false perception. In the book *Black Faces, White Spaces*, Carolyn Finney challenges that assumption with her research. She explains that African Americans are aware of the damages of environmental burdens through direct experience, but it is systemic racism that marginalizes and excludes their identities and experiences with the natural environment (Finney, 2014). In addition, traumatic experiences and past injustices can have an impact on the acceptability of environmental policies. Research studying the reason for residents' reluctance to participate in tree giveaway programs in Detroit shows that it is the history of oppression, exclusion, and mistrust that dissuades residents from engaging in the seemingly beneficial tree planting program. This history includes not being included in the decision-making process when the City cut down their trees due to the prevalence of Dutch elm disease without offering any explanation and remediation (Carmichael & McDonough, 2019). Black residents also interpreted the unfortunate event as a way for the government to surveil their lives as the event coincided with the Civil Rights Movement (*Changing the Heritage Narrative: Detroit, MI*, n.d.).

Community engagement with pest readiness cannot be separated from addressing environmental justice issues. The lack of diversity and representation in environmental organizations and government can further deepen mistrust and lower acceptability of environmental policies. However, if the municipality shows genuine intention to provide a career pathway, and address concerns and past trauma, engagement in environmental issues can be potentially effective. Taking African Americans as an example, literature has suggested that centering the environmental racism in environmental movements can generate interest in the involvement of environmental issues (Finney, 2014). There are other ways to tailor tree-related events to fit community-led agendas, promoting environmentally friendly behaviors, but first, the engagement practices need to be based on people's motivations, explored in more detail in the next section.

2.6 Motivations for Pro-Environmental Behaviors

To understand the basis for tree-related community engagement, it is crucial to examine the motivations that drive pro-environmental behaviors (PEB), which is defined as the behaviors that "benefit the natural environment and omission of acts that harm it" (Lange & Dewitte, 2019). In this case,

planting and caring for trees are pro-environmental behaviors that can help increase carbon sequestration and mitigate climate change effects.

PEB is influenced by personal values, social norms, and emotions, which can help guide community engagement practices. A diagram of the dynamics of these three factors is shown in Figure 2-8. Values that show one's personal beliefs can help guide people's behaviors in different situations (de Groot & Thøgersen, 2018; Keizer & Schultz, 2018). People with biospheric values, who are most concerned about the environment than anything else, are more likely to perform PEB than people with altruistic values, who mostly care about other people's wellbeing (Abrahamse & Matthies, 2012). The concept of ecosystem services is critical to attracting people who may be more egotistic (i.e., people who do certain things for their own benefits) by framing the environmental issues in a way that can threaten their own welfare (Abrahamse & Matthies, 2012).

On the other hand, social norms – i.e., a social group's approved rules and standards - can direct individuals' behaviors under social pressure (de Groot & Thøgersen, 2018; Keizer & Schultz, 2018). This means that even if a person may not care about the environment enough to learn about trees, if others in their community are planting trees and feel good about it, it can motivate others to start learning about trees. Yet, the effects of social norm in guiding PEB is most evident for people who are indecisive about one behavior, either not knowing about it or having mixed feelings. Thus, it is helpful to target people with knowledge and resources (Keizer & Schultz, 2018).

Emotions can also trigger strong motivations for PEB, especially strong attachments to the environment (Manzo & Devine-Wright, 2020). Past research has suggested that appealing to the public health aspect to promote PEB can be more effective to encourage behavior change than financial savings because PEB is driven by emotions (Abrahamse & Matthies, 2012). Emotions that can lead to PEB comprised two types, anticipated emotions and experienced emotions, as shown in Figure 2-8. Anticipated emotions can be predictive of whether people will act pro-environmentally (Taufik & Venhoeven, 2018). For example, if people believe that they can feel happy or satisfied after planting trees, they are more likely to do so. This speaks to the importance of knowledge and engagement, leading people to believe that they can contribute to the environment and feel good about it. Experienced emotions are feelings that are prompted after the experience of actually engaging in an activity, particularly if it was pleasurable or meaningful (Taufik & Venhoeven, 2018). Providing opportunities and gateways for people to have such an experience with fun or meaningful tree planting events or tree identification scavenger hunts can attract people to engage with trees more.

Place attachment also plays a role in motivating pro-environmental behavior, especially in the face of imminent environmental change that threatens place identity and self-identity. Place attachment manifests in the sense of place and place identity, which are formed through daily interaction and bonding with the natural and built environment through time (Manzo & Devine-Wright, 2021). Recently, natural and human-induced disasters such as flooding, wildfire, and other impacts of climate change have become more frequent and demanding on human health. Solastalgia, a newly-defined emotion, is defined by environmental philosopher Glenn Albrecht as "the distress caused by environmental change" (Albrecht et al., 2007). As an important component of the natural and built environment, trees and especially native trees, are central to people's connection with nature and place, based on the biophilia theory mentioned previously. Therefore, the loss of trees can trigger strong negative emotions driving PEB and may spur action to protect the trees. In the case of pest readiness engagement, actions like monitoring and stewardship can prevent future loss of trees. Appealing for the feeling of anticipated loss in the engagement process can be more readily accepted by people, which can inspire them to take action so that they can feel less powerless against the anticipated loss of trees. Stewardship of trees and land can also facilitate reciprocal relationships that can not only alleviate distress, strengthen social connections and connection to nature but also increase environmental resilience as a result (Nabhan et al., 2020; Varanasi, 2020).

However, it is important not to ignore the practical barriers that dissuade pro-environmental behaviors in the process of community engagement. Lack of knowledge and access to resources and historic damages from structural racism can be equally powerful in triggering negative feelings that negate any potential positive feelings that engaging in tree-related activities can have.

2.7 Community Engagement

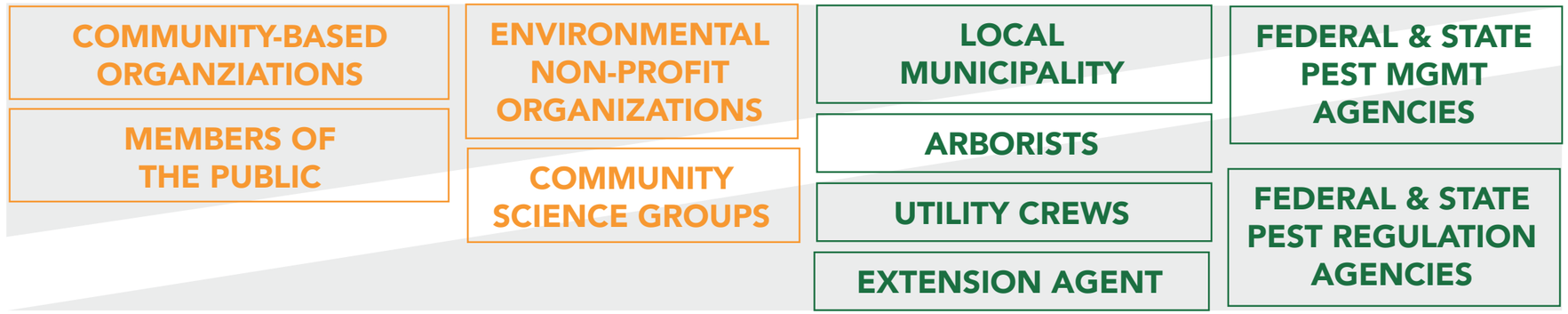
Simply relying on the work from the government to prepare for pest invasion is not enough because federal, state, and city government agencies often have limited capacity. The government can develop plans and take the lead in the effort at first, but eventually, it depends on the community efforts to carry it through. Research has shown that urban forestry

COMMUNITY-CENTRIC APPROACH

RESEARCH FINDINGS
Looney et al. 2016

CONTRIBUTION OF DETECTION OF EXOTIC PESTS IN WASHINGTON STATE 1990-2014

INVASIVE SPECIES MANAGEMENT ENTITIES



COMMUNITY ENGAGEMENT SPECTRUM

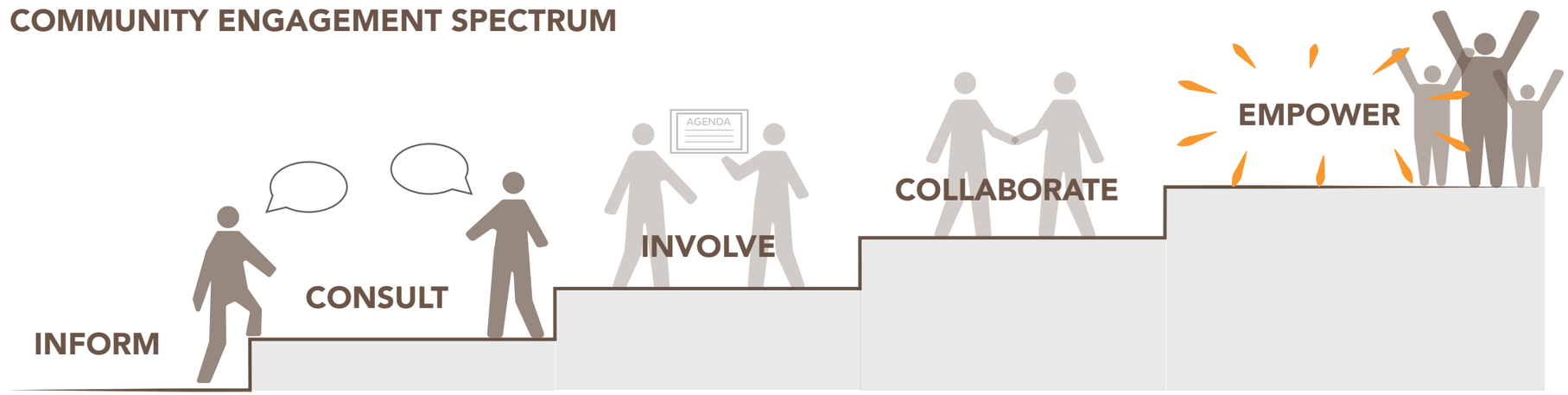


Figure 2-7. The theories of community-centric approach

efforts led by existing community-based organizations are more likely to be successful and have lasting effects. This is because, through existing place bonds and collaboration, community organizations are often more familiar with the needs of the community and know how to cater to them rather than just enforcing the goals and actions that need to happen (Schwarz et al., 2015). Moreover, studies have shown that about two-thirds of the pest detection that occurred at the early stage of invasion was discovered by well-trained citizens or civic scientists, which allowed early intervention to prevent the spread of disease (Goodwin, 2017). Specifically, in Washington state, 36% of exotic pests were discovered by private citizens, which allowed experts to intervene and monitor the situation early and effectively (Looney et al., 2016). Such findings support my argument for the need to focus on a community-centric approach.

Developed by the International Association for Public Participation, the spectrum of public participation outlines different levels of engagement (See Figure 2-7) (*Core Values, Ethics, Spectrum – The 3 Pillars of Public Participation - International Association for Public Participation*, n.d.). Taking a community-centric approach to pest readiness means that community engagement should inform, consult, and involve community members in the process and go beyond collaborating and empowering residents with methods and resources to deal with the pest issue.

Moreover, community science projects are built upon people's pro-environmental behaviors, which can be driven by the mission and emotions like place attachment. Once people are aware of the potential threat and willing to take action to be prepared for the threat, community science projects are great ways for people to contribute to monitor and steward their surrounding environments easily. A common concern for delegating efforts to the communities is the accuracy of data gathered by community scientists. From tree inventory to tree health assessment, studies have found few significant discrepancies in community-gathered data. Data gathered by citizen scientists were mostly reliable and not that different from those of experts when people were given proper training and clear guidelines. This speaks strongly to the potential contributions of community-based projects (Hallett & Hallett, 2018; Johnson et al., 2018). In the long run, public education and community engagement efforts can empower the community to self-adjust from the larger citywide pest readiness framework and prepare for potential impacts with suitable actions for the community, from which the lesson could be valuable to learn.

However, existing tree-related engagement programs based on volunteerism often have the same problem with low participation from people of color and lower-income neighborhoods, indicating a need to focus on environmental justice (Donovan & Mills, 2014; Johnson et al., 2018). Johnston and Shimada (2004) suggest that it is important to establish the link between urban forestry efforts and other aspects of socioeconomic issues like racism, jobs, and crime concerning disadvantaged communities to increase participation and truly achieve social inclusion. Community engagement is a great way to help people connect tree issues with other aspects. As a critical part of the community engagement process, public education helps individuals develop the knowledge base to govern and develop actions for change, especially for communities of color, education, and opportunities for hands-on experiences can be life-changing and empowering (Bullock & Hanna, 2012).

This literature review revealed a knowledge gap in planning for pest readiness through community-centric efforts, emphasizing environmental justice, which I would like to explore in my research and eventually develop a community engagement framework. The goal for community engagement in this project is to provide recommendations for community engagement that encourage collaborative relationships and build trust and support networks that will enable tree stewardship for pest and climate resilience to carry on successfully.

2.8 Conceptual Framework for This Project

The conceptual framework (see Figure 2-8) that I have developed in this thesis intends to articulate the research problems, the proposed solution, and the theoretical framework that supports it. The left side of the Figure 2-8 shows that the problem with invasive tree pests started with deliberate introductions of pests through increasing global trade and human movement across space. With the amplified effect of climate change and uneven distribution of resources due to systemic racism, the situation in the U.S. can worsen. On the right side of the Figure 2-8, I visualize the healthy urban forest can contribute to public health, and recognizing the benefits of urban forest to public health through public education and community engagement can lead to timely detection and response to invasive pests and maintain the health of the urban forest.

The conceptual framework is established based on the motivations from pro-environmental behaviors and community science --- personal values, social norms, and emotions,

CONCEPTUAL FRAMEWORK

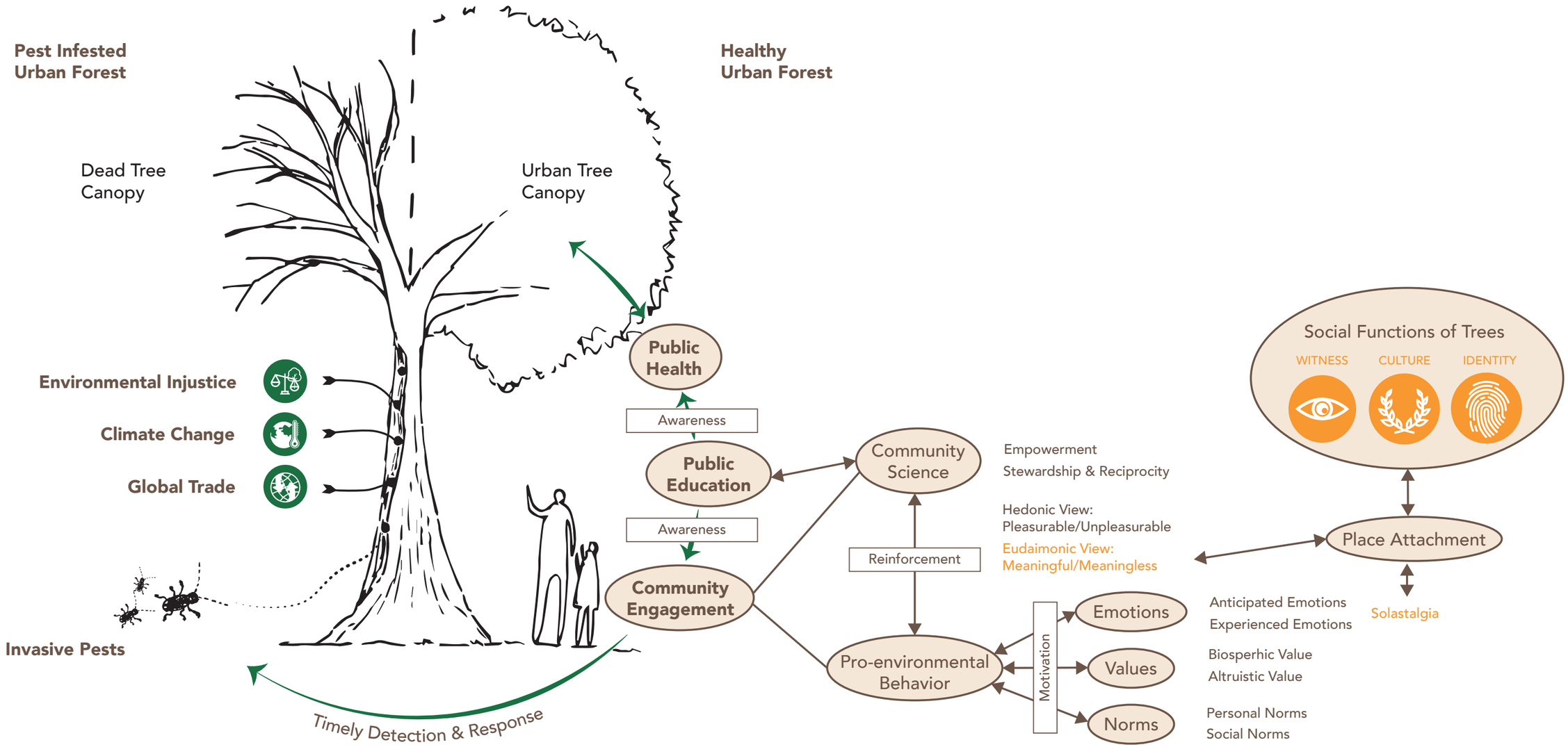


Figure 2-8. Conceptual framework for this project

which are further connected to a strong sense of place and place attachment. Place attachment is also closely related to many social aspects of trees mentioned previously, in which they serve as witness to significant events, bear cultural significance, and construct the identity of places. Specifically, solastalgia, the distress caused by increasing environmental change, can become a strong motivation recently as well, as people increasingly experienced the impacts of climate change (Albrecht et al., 2007). This research offers a community-centric engagement framework as part of a pest readiness plan, to demonstrate how city-led efforts can transition into community-led actions and eventually lead to sustainable partnerships and healthy relationships between government agents and communities.

3 METHODOLOGY

3.0 Overview

The methods for this project were selected to investigate the current status of Seattle's urban forest through the analysis of available data to generate results to guide public engagement. This study identified vulnerable communities in Seattle through GIS analyses on ecological and social aspects that reduce people's capability to respond to potential pest issues.

In addition, I used the case study method to learn from other cities about ways of engaging the public engagement around urban tree issues. Because there were few guidelines on community-centric engagement specifically for invasive pest engagement, I sought to learn from best practices and challenges from the case studies and synthesize lessons to construct the community engagement framework. With a focus on environmental justice, I looked at case studies from cities that had been through tree pest infestations to synthesize best practices, with an emphasis on those practices that address environmental justice. To overcome the challenges with the lack of documented information, I also conducted interviews with prominent environmental organizations to learn about their methods and drawbacks, which are explained in more detail in Section 3.2.1. I then distilled key elements of these practices for the development of a community-centric framework.

3.1 GIS Analysis

The GIS analysis and visualization of the extent of the potential threat of tree pests in Seattle can set the stage for raising public awareness through public education. Although there are other factors in play, knowing the threat can at least provide the basis for pro-environmental behavior (de Groot & Thøgersen, 2018). The GIS analysis was divided into two aspects, ecological vulnerability through susceptible tree analysis and social vulnerability using the racial and social equity index developed by the City of Seattle Office of Planning and Community Development that examined the health disadvantages, socio-economic disadvantages, and demographic compositions (City of Seattle Office of Planning & Community Development, 2020).

3.1.1 Ecological Vulnerability

The idea for ecological vulnerability is derived from the first benchmark of the process in the Urban Forest Pest Readiness Playbook. This tool was developed to understand the risk of infestation by identifying priority pest species, collecting tree inventory and canopy map, and performing a risk assessment, as determined as Actions #3, #6, and #7 in the Playbook (Washington Invasive Species Council, 2019).

I determined the priority pest species of concern through literature review and my informal interviews with Jana Dilley and Stephanie Helms, which are explained more in Section 3.2.1. Since most of the pests haven't arrived in Seattle yet and there was little documentation about the locations of the pests that have arrived, my GIS analysis focused on the composition and distribution of potential tree hosts. I analyzed the composition of street trees on a city scale to understand the extent of the damage to the urban tree canopy in the public right-of-way. Taking the data from the street tree inventory, part of the SDOT's Moving the Needle online performance management report in 2019, I also visualized the species and their proportions among street trees that would be susceptible to pests to see the scale of the potential problems (Seattle Department of Transportation, n.d.-a). Stepping back and taking a holistic view enabled me to see the potential extent of damages among Seattle's urban forest and help guide efforts to diversify the existing composition of the urban forest.

I conducted the GIS analysis using the datasets of trees provided by the City of Seattle. Two datasets about trees are available. One is the 2016 tree canopy assessment data (see Figure 3-2), which shows the canopy cover of the entire city and is more comprehensive (City of Seattle GIS Program, 2018). The other is the street tree inventory geospatial data, which was the vector dataset of individual trees with tree species in the right-of-way (See Figure 3-3) (City of Seattle GIS Program, 2020). The dataset is maintained by the Seattle Department of Transportation (SDOT) for management purposes and updated regularly. Even though the street tree inventory data only consist of 27% of all trees in Seattle, it is more beneficial for the purpose of this research because it contains information about tree species (2016 Seattle Tree Canopy Assessment, 2016). The detailed information of tree species is critical to identify how the spatial composition of these susceptible trees may be perceived as higher risk due to their abundance in certain areas. Ideally, the analysis would be conducted on GIS data about trees across the entire city, but the data of individual trees was not available on private and parks' properties, so this analysis only focused on trees in the public right-of-way.

I first conducted the GIS analysis on the neighborhood scale for two reasons. One was that the urban forest management units, which were established in 2016 as part of the Street Tree Management Plan, were divided into neighborhood

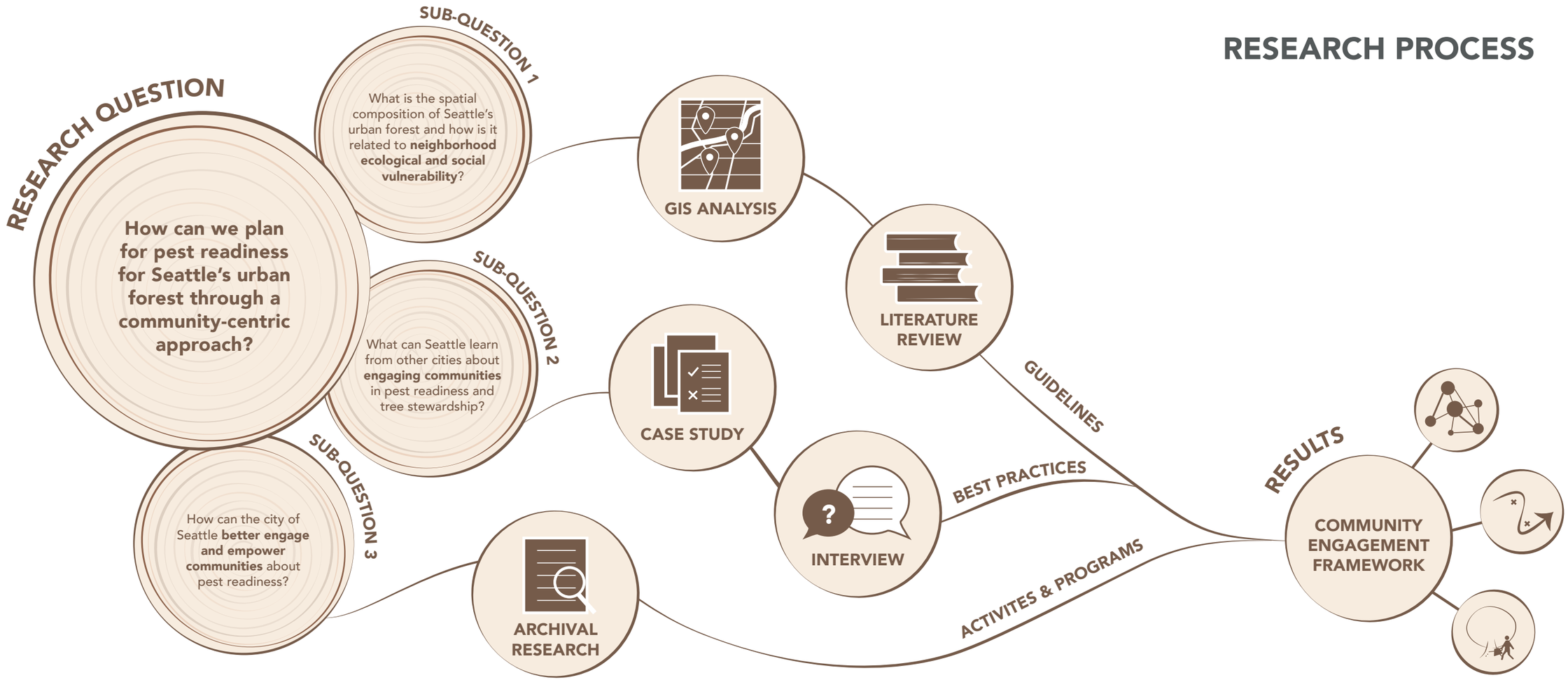


Figure 3-1. Research process diagram, showing the main research methods in response to each research question.

scales, and the data were updated at a rate of a minimum of 3 units per year (Seattle Department of Transportation, n.d.). Secondly, from my observations, the work of community environmental organizations was primarily based in specific neighborhoods, which had established deep relationships and trust among residents that can be utilized for resource mobilization in response to potential pest issues. Therefore, the implication for community engagement, resource distribution, and management would be more effective on a neighborhood scale.

3.1.2 Social Vulnerability

For the social vulnerability analysis, I focused more on the potential of people in the communities that are susceptible to massive tree loss. The analysis fits well with the Equity and Environmental Agenda established by the City of Seattle in 2015, which outlines two community-identified actions as priorities: (1) the Environmental Equity Assessment and (2) the identification of the Environmental and Equity Initiative focus area (City of Seattle, 2015). I used the racial and equity index, developed by the City of Seattle, for this analysis in order to

gauge social vulnerability in terms of socio-economic status, health burdens, and demographics. The composite index shows the degree of disadvantage for specific communities (City of Seattle Office of Planning & Community Development, 2020). I used this to cross-reference ecologically vulnerable communities and socially vulnerable communities to guide engagement efforts.

3.2 Case Study

Due to constraints of the pandemic, direct community engagement was not safely possible. Instead, the research focused on gathering insights from past successful community engagement practices in tree-related programs of other cities related to pest issues. I did this through case studies, literature reviews, and interviews. The cases were selected to include big cities in different geographic areas, covering roughly all regions of the United States. The case studies also helped demonstrate the difference between places more experienced with pests versus those that were not. I also paid special attention to cases that address environmental justice specifically in their community engagement efforts to generate valuable lessons for Seattle.

I started by looking on the Vibrant Cities Lab website created by the U.S. Forest Service, American Forests, and the National Regional Councils as a hub for research in the urban forestry field. The website contained a diverse range of resources, case studies, and guides, but it didn't have a particular section for dealing with pest issues, so I searched through the website to find cases that were related to pest issues and analyzed their strategies. From the initial research, I decided to focus on the following cities:

- New York City, NY

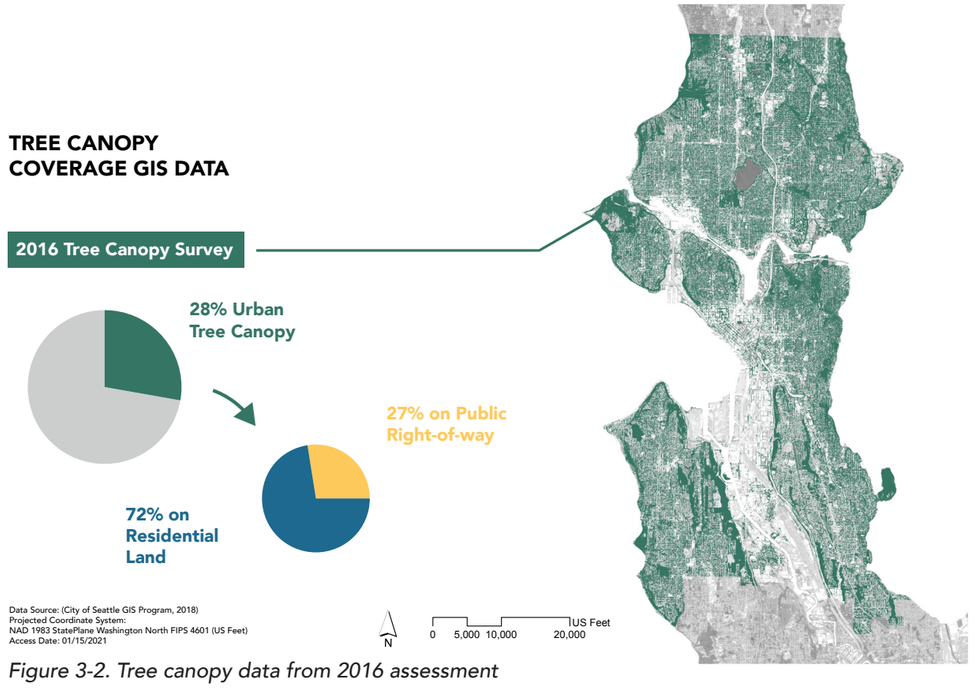


Figure 3-2. Tree canopy data from 2016 assessment

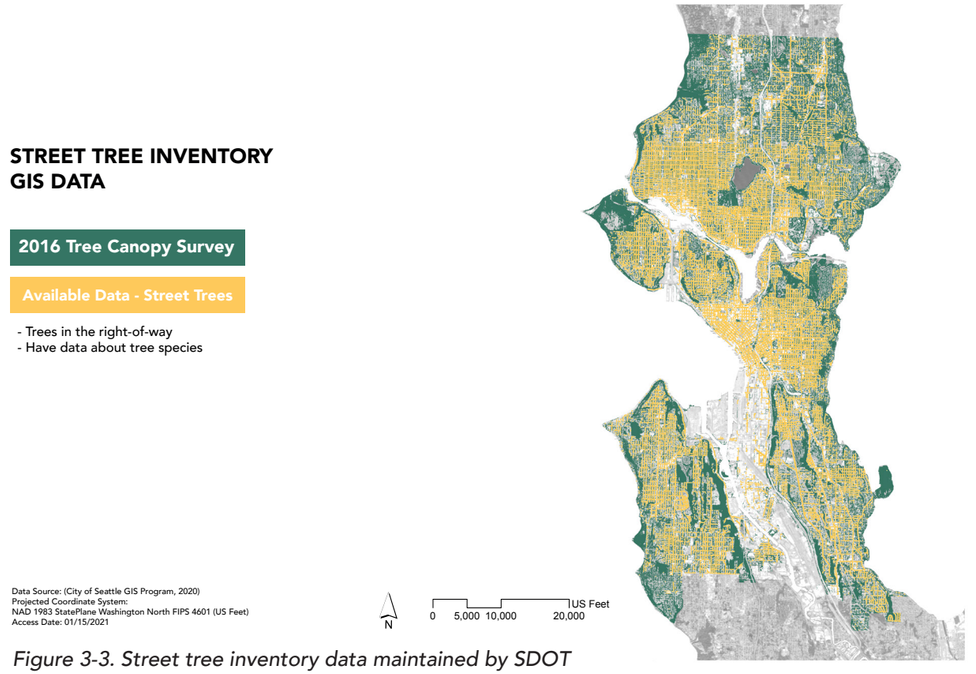


Figure 3-3. Street tree inventory data maintained by SDOT

- Austin, TX
- Sacramento, CA
- Worcester, MA
- Detroit, MI
- Baltimore, MD

Each city had significant urban forestry engagement efforts on pest or tree management. I went through and focused on my research on the prominent organizations with documented programs and practices. Even though the documentation of cases was relatively comprehensive on the website, some instances were relatively incomplete, so I also conducted an additional literature review that assessed the strategies and effectiveness of the programs.

3.2.1 Interview

In addition to the literature review, I also used the interview method to collect information for the cases. I chose the interview subjects from the organizations by looking at their websites. I then reached out to the community engagement manager of the engagement programs or program coordinators through email, asking for a 30-min interview through Zoom.

The purpose of the interview was to gain more insights on the challenges and motivation for their best practices, which information would not be available elsewhere. The interviews were semi-formally structured, which allowed me to ask follow-up questions based on their answers and gained deeper understandings. Although for different subjects, the questions I asked were slightly different, a few main questions I asked were:

1. How do your different initiatives and programs get people interested in tree stewardship events or planting? How do they respond?

2. Have you met any resistance during your engagement process? How do you address the concerns of disadvantaged communities?

3. Have you engaged with the communities around the impact of invasive pests on tree canopy? If yes, what was the method you use, and how did they respond? Do you think community scientists are valuable in the process?

Due to limitations of time and people's responsiveness, I was only able to interview a few people for certain cases. For Austin's case, I first interviewed Joshua Erickson, the Urban Forestry Program Manager of the Parks and Recreation Department at the City of Austin, recommended by my supervisor in the Trees for Seattle Program. Joshua suggested I talk to TreeFolks, which was their partner and one of the most prominent organizations focusing on urban forestry in Austin. I then reached out to Ben Bertram at TreeFolks, the NeighborWoods Program Coordinator, and managed tree planting efforts on private properties. For Sacramento's case, I watched a presentation led by Torin Dunnavant, the Director of Education and Engagement at Sacramento Tree Foundation, talking about the success of their NeighborWoods program that focused on serving under-canopied communities. For Detroit's case, I wasn't able to get in contact with The Greening of Detroit (TGD), which is an organization that focuses on residential tree planting. Instead, I interviewed Dr. Christine Carmichael, who has researched why certain Detroit residents refused free trees from TGD. She was a Ph.D. student at Michigan State University at the time of the research, but now working as a researcher at the University of Vermont. I also framed my questions differently when I interviewed Dr. Carmichael because she is more experienced with environmental justice issues. My conversation with her started with the following question and went on to be more free flow: You studied historical trauma and environmental justice in urban forestry. What are some ways you recommend that either the city, or non-profits, or community-based organizations take to start to acknowledge, understand, and repair those traumas? From her perspective, I was able to understand some challenges with TGD's work and learned about some considerations for environmental justice.

Because the organizations I selected were all based in different cities with different profiles, it was hard to establish a universal standard to evaluate their effectiveness. As a result, this research didn't intend to do so but instead focused more on their achievements through program participation and the acceptability of the programs within the communities.

In addition, I also conducted informal interviews to understand the current efforts and challenges with Seattle's effort to prepare for pest readiness. With my connections in the Trees for Seattle Program, I talked with my supervisor Jana Dilley frequently to understand Seattle's current situation. I also interviewed Stephanie Helms, who is an SDOT arborist and one of the leads in the Seattle Committee for Invasive Pests. She had experiences dealing with invasive pests when she worked for the City of Baltimore, and she also participated in writing the Urban Forest Pest Readiness Playbook for Washington State. Both of them offered incredible insights that helped me determine how the lessons from these

cases can be applied to Seattle and what the community engagement framework should focus on.

3.3 Archival Research

In the book Black Faces, White Spaces, the author Finney mentioned how the lived experience of African Americans participating in environmental movements was not recognized and therefore not represented (Finney, 2014). The same situation could potentially be true for other communities of color. To respond to this limitation, I conducted archival research to locate information in written reports and literature. Particularly, doing this research during the pandemic made it hard to access library archives, so the archival research was mostly focused on online archives like information for pests and websites for organizations. Based on my understanding through personal experience working in the Trees for Seattle program, community-based environmental stewardship organizations do exist, and they often depend on cross-promoting to gain more exposure, but people usually don't have much awareness about what opportunities are available in their communities, let alone engaging in such activities. Social media provided an excellent gateway to start my research and led me to the community-based organizations' official websites. From there, I gathered information about their missions from the "About" page or "About us" page and categorized the organizations based on different types of environmental stewardship.

The purpose of the archival research was to bring attention to this network of lived experiences that were not formally documented, which could serve as initial resources for communities to get started in the environmental field. It also shed light on the possibilities of building partnerships. The information gathered from archival research would be used to compile helpful resources as recommendations that communities and the City can work on together.

4 GIS & CASE-STUDY FINDINGS

4.1 GIS Analysis Findings

4.1.1 Ecological Vulnerability Analysis

I determine the pests of concern first through looking at 2012 Seattle's Forest Ecosystem Values analysis report, while mentioned Dutch elm disease (DED) (pathogen: *Ophiostoma ulmi* and *O. novo-ulmi*), Asian longhorned beetle (ALB) (*Anoplophora glabripennis*), and emerald ash borer (EAB) (*Agrilus planipennis*) as three potential pests (Ciecko et al., 2012). After the interview with members of the Seattle Committee for Invasive Pests, they mentioned that they are also concerned with sirex wood wasp (SWW) (*Sirex noctilio*), winter moth (*Operophtera brumata*), and bronze birch borer (BBB) (*Agrilus anxius*), which emerged more recently as threats. Among them, winter moth and BBB already showed up in certain areas of Seattle.

As a result, I selected the following pests of concern for Seattle's urban forest. The pests are all pests with potentially high impacts: Dutch elm disease (DED), Asian longhorned beetle (ALB), emerald ash borer (EAB), sirex wood wasp (SWW), winter moth, and bronze birch borer (BBB) (Lovett et al., 2016). Information about their preferred tree hosts (see Figure 4-1) was gathered from the USDA APHIS website, U.S. Forest Science website, and university extensions websites. The pests of concern will potential change in the future as new threats emerge, but for the purpose of this research, I will focus my study on these pests.

From the analysis on susceptible street tree composition on the city scale, the results (Figure 4-2) reveals that in total, invasive pests can claim up to about 53% of street trees if the status quo is maintained. In addition, the trees in a given genus could be under attack from multiple pests, which should require extra attention and care. The composition also shows that maples, which are vulnerable to Asian longhorned beetles and winter moths, compose over 20% of street trees, which presents a big risk. From observation, bigleaf maples, which are native to the Pacific Northwest, are present in many natural areas in Seattle that are not part of this analysis, which means that the actual risk can potentially be higher.

For GIS analysis on a neighborhood scale, I extracted the trees that were susceptible to pests of concern based on the genus or sometimes the species they belong to. Figure 4-3 shows a map of the results, where the brown dots represent all of the susceptible trees on top of the yellow dots that show the locations of each street tree. The map indicates that generally, the susceptible trees make up a large proportion of the street trees.

The mapping of susceptible trees also suggests certain patterns that can be meaningful ecologically for asset management purposes. In the northeast and the southwest part of the city, the patterns of susceptible trees outline major transportation corridors, such as 35th Ave NE and Beacon Ave S. Patterns like this can potentially cause a higher possibility of spreading the pests due to high connectivity and close proximity between the trees. Nonetheless, the massive tree dieback on major transportation corridors can be problematic because it will reduce walkability and increase air pollution. There are higher concentrations of susceptible trees in areas like Downtown, the Central District, Wallingford, and Ballard. You can tell that from the connected brown dots that form the street network, suggesting that almost every tree along the street would be vulnerable to pests if pest infestation occurs anywhere in the neighborhood. The loss of street trees at this scale can reduce neighborhood walkability and change a neighborhood's look, which indicates the need for more attention in management.

It was hard to quantify neighborhood susceptibility just by looking at the locations of each individual susceptible tree. In order to visualize the abundance of susceptible trees on the neighborhood scale, I used the Aggregate Points geoprocessing tool in ArcGIS to count the number of susceptible trees in each census tract and calculate their ratios in all street trees. Using the ratio as the basis for analysis normalized the disparity of the abundance of street trees between census tracts. The data for each census tract were further classified by a 5-quantile statistic model, in which each range of percentages has the same amount of data. In Figure 4-4, the different gradients of green were used to represent the ranges of percentages of susceptible trees in the census tract, in order to show the degree of vulnerability more clearly.

The data analysis shows that the median percentage of tree susceptibility is between 50%-54%, which suggests that more than half of the census tracts in Seattle have more than 50% of street trees susceptible to pests. The highest percentages occur in census tracts near Downtown and the Central District, which corresponds with the previous observation. The comparison of ecological vulnerability between North Seattle and Southeast Seattle demonstrates the need to focus engagement on environmental justice. Southeast Seattle neighborhoods have similar percentages of susceptibility with North Seattle neighborhoods like Wallingford, Fremont, and Ballard, even though overall, there are fewer street trees in

PESTS OF CONCERN & SUSCEPTIBLE TREE HOSTS

FOR SEATTLE, WA

Graphic credit: Luyu Zeng

Asian Longhorned Beetle (ALB)
Anoplophora glabripennis

Ash (*Fraxinus*)
Elm (*Ulmus*)
Golden Raintree (*Koelreuteria*)
London Planetree (*Platanus*)
Maple (*Acer*)
Buckeye (*Aesculus*)
Katsura (*Cercidiphyllum*)
Mimosa (*Albizia*)
Mountain Ash (*Sorbus*)
Birch (*Betula*)
Poplar (*Populus*)
Willow (*Salix*)

Winter Moth
Operophtera brumata

Oak (*Quercus*)
Maple (*Acer*)
Apple (*Malus*)

Ash (*Fraxinus*)
Cherry (*Prunus*)
***Blueberry** (*Cyanococcus*)
Crabapple (*Malus*)
Elm (*Ulmus*)

Sirex Wood Wasp (SWW)
Sirex noctilio

Pine *(Pinus sp.)*

Ponderosa pine (*P. ponderosa*)*
Lodgepole pine (*P. contorta*)*
Monterey pine (*P. radiata*)
Loblolly pine (P. taeda)
Slash pine (*P. elliottii*)
Shortleaf pine (*P. echinata*)
Jack pine (*P. banksiana*)

Bronze Birch Borer (BBB)
Agrilus anxius

Birch *(Betula sp.)*

European white birch (*B. pendula*)
Whitebarked Himalayan birch (*B. jacquemontii*)

Paper birch (*B. papyrifera*)**
Gray birch (B. populifolia)
Sweet birch (*B. lenta*)
Yellow birch (*B. alleghaniensis*)

River birch (*B. nigra*)

Dutch Elm Disease (DED)
Pathogens: Ophiostoma ulmi & Ophiostoma novo-ulmi

Elm (*Ulmus*) native to North America and Europe

American elm (*U. americana*)***
Red/slippery elm (*U. rubra*)
Rock elm (*U. thomasii*)
English elm (*U. procera*)
Smoothleaf elm (*U. minor*)

Elm (*Ulmus*) native to Asia

Japanese elm (*U. davidiana var. japonica*)
Chinese elm (*U. parvifolia*)

Emerald Ash Borer (EAB)
Agrilus planipennis

Ash (*Fraxinus*)

LEGEND **Genus** Species common name (*Scientific name*)

DEGREE OF SUSCEPTIBILITY Preferred hosts | Other susceptible hosts | Resistant

Note: *Blueberries are not considered as trees or used as street trees so they are excluded in the analysis
**The specific tree species is native to the Pacific Northwest
***DED-resistant American elm cultivars have been developed, such as Valley Forge and Princeton

Figure 4-1. Pests of concern in Seattle and susceptible tree hosts

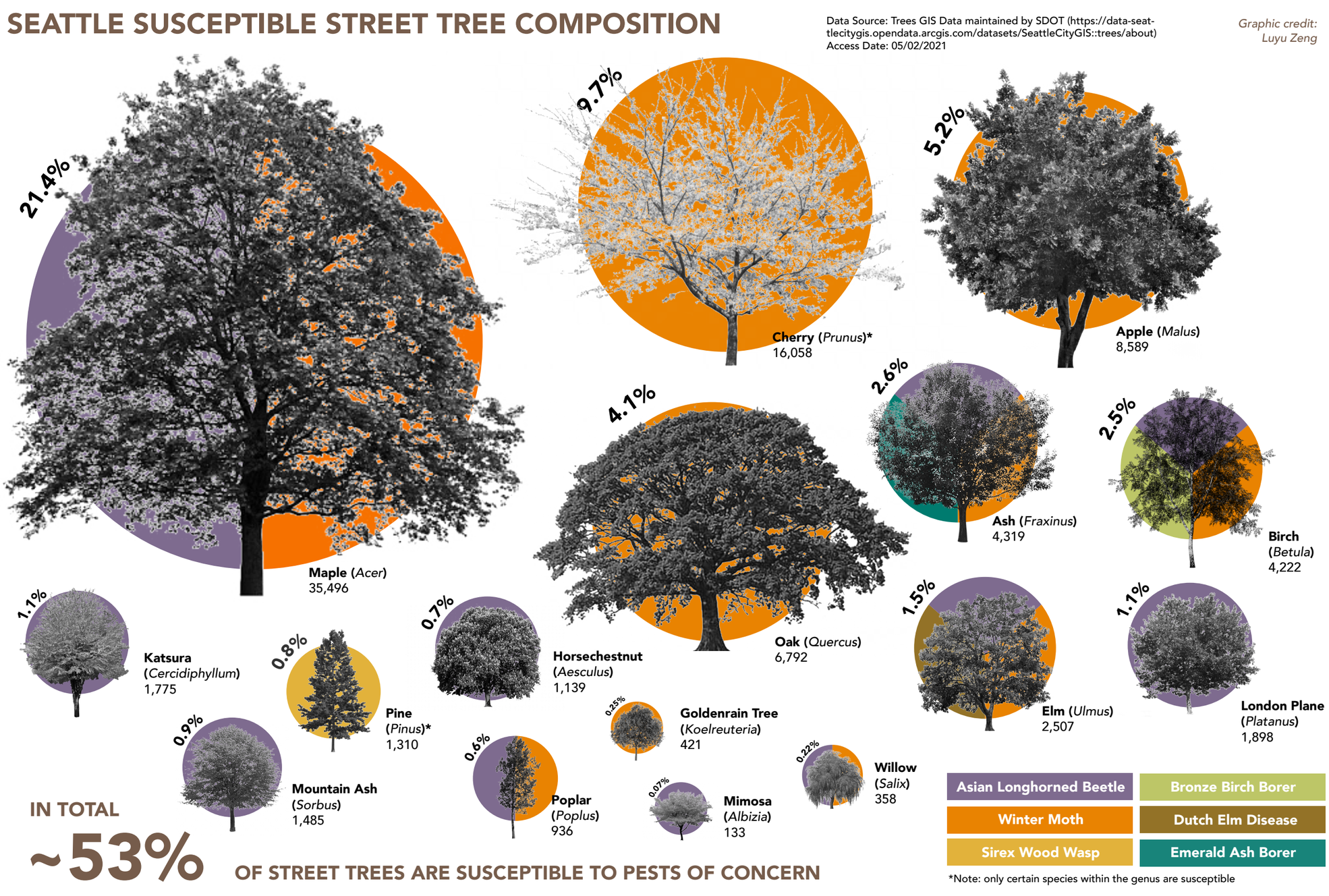


Figure 4-2. The composition of susceptible street trees in Seattle

DISTRIBUTION OF SUSCEPTIBLE TREES

2016 Tree Canopy Survey

Available Data - Street Trees

Street trees susceptible to pests of concern

Asian longhorned beetle (ALB)
Anoplophora glabripennis

Winter moth
Operophtera brumata

Bronze birch borer (BBB)
Agrilus anxius

Pests that already arrived in Seattle

Sirex wood wasp (SWW)
Sirex noctilio

Emerald ash borer (EAB)
Agrilus planipennis

Dutch elm disease (DED)
Pathogens: Ophiostoma ulmi & Ophiostoma novo-ulmi

Data Source: (City of Seattle GIS Program, 2020)
Projected Coordinate System:
NAD 1983 StatePlane Washington North FIPS 4601 (US Feet)
Access Date: 01/15/2021

N

0 5,000 10,000 20,000 US Feet

Figure 4-3. Map of the distribution of street trees susceptible to pests of concern

Southeast Seattle. For the purpose of this research, I consider the ecological vulnerability of over 50% of susceptible trees as vulnerable areas for the next step of the analysis. This is shown as the census tracts with the three darkest shades of green color in Figure 4-4.

However, this GIS analysis assumes that pests have equal preference for all trees they feed on, while in reality, they have varied preferences and limited capacity in their life cycles. The actual spreading mechanisms for each pest require more research on pest dynamics and preference to validate. Due to limited time and access, I focus my research on an asset-based approach rather than the biotic dynamics of pests. This limitation is discussed more in Chapter 6.

Even though it was not a complete analysis for every individual tree in the city, this analysis of street trees shows the extent of damages that these potential tree pests would create in the future. The findings from GIS analysis reaffirm that there is a need to be concerned about potential pest infestation in Seattle based on the spatial composition of current street trees, which have varying degrees of vulnerability depending on the neighborhoods in which they are located. The results from the ecological vulnerability analysis also show that regardless of the number of trees within the neighborhood, the ecological vulnerability can be similar. However, communities with less social capital can be more vulnerable in the case of pest infestation and tree dieback. This is addressed in the next section.

4.1.2 Social Vulnerability Analysis

The social vulnerability here implies the level of vulnerability if street trees are in peril, but also the capacity to properly maintain the planted trees. Before going into the details of the analysis, it is important to note that the analysis excludes parks, arboretums, and universities as those facilities, including trees, are managed separately by entities with more resources. In Seattle, street trees are regulated by SDOT, but can be planted by both SDOT and private citizens (Street Trees, n.d.). If private citizens are the ones planting the street trees, they are responsible for maintaining them (Street Trees, n.d.).

For the social vulnerability analysis, the Racial and Social Equity Index was determined by the City of Seattle based on data from 2011-2015 Five-Year American Community Survey as guidance for planning and investment (City of Seattle Office of Planning & Community Development, 2020). I examined each aspect that made up the index -- the demographic, socio-economic, and health disadvantages -- and identified the most disadvantaged census tracts. The considerations for each sub-index were listed in each figure. Different from the map of ecological vulnerability, from Figure 4-5 to Figure 4-8, each color in Figure 4-5, 4-6, 4-7, and 4-8 represents equal intervals of the index, which makes more sense as a way to highlight the degree of disadvantages across the city. The higher the indices, which are represented as darker colors in all of the maps, the more disadvantaged the census tracts are.

The demographic disadvantage analysis considers people of color, people for whom English is not their first language, and people with foreign birthplaces. The index recognizes that people of color have been in more disadvantaged conditions and therefore weigh this aspect higher than the other two aspects.

The map in Figure 4-5 shows that the most disadvantaged neighborhoods are concentrated in South Seattle and part of west Seattle near the Duwamish River, while in North Seattle, a few census tracts near city's northern boundary and near the University District have slightly higher numbers.

For the socio-economic factors, the considerations are based on income and education levels with equal weights. The map in Figure 4-6 shows relatively similar patterns as the demographic disadvantaged analysis. The socio-economic disadvantaged areas mostly cluster around South Seattle and West Seattle. It is also important to recognize that new socio-economic disadvantaged clusters emerge in the north, and a few of those are the same census tract mentioned in the previous analysis. The similarity in disadvantaged areas suggests that people of color could potentially be in a harder financial situation to address potential problems with tree health, which would require more outreach and assistance with resources.

The health disadvantage analysis focuses on equally weighted factors that predict the poor outcome of a healthy life, such as limited time for physical activity, the presence of physical illnesses, and poor mental health. The map of results (Figure 4-7) shows similar disadvantaged areas with the previous two analyses, which implies that all three aspects (racial, socioeconomic, and health disadvantages) are connected and taking the most disadvantaged areas from the composite index that combines all three analyses can provide useful guidance for social vulnerability.

ABUNDANCE OF SUSCEPTIBLE TREES IN THE SCALE OF NEIGHBORHOODS

2016 Tree Canopy Survey

Available Data - Street Trees

+

Street trees susceptible to pests of concern

21% 44% 50% 54% 59% 88%

Percent of Susceptible Trees in the neighborhoods

Data Source: (City of Seattle GIS Program, 2020)
Projected Coordinate System:
NAD 1983 StatePlane Washington North FIPS 4601 (US Feet)
Access Date: 01/15/2021

N

0 5,000 10,000 20,000 US Feet

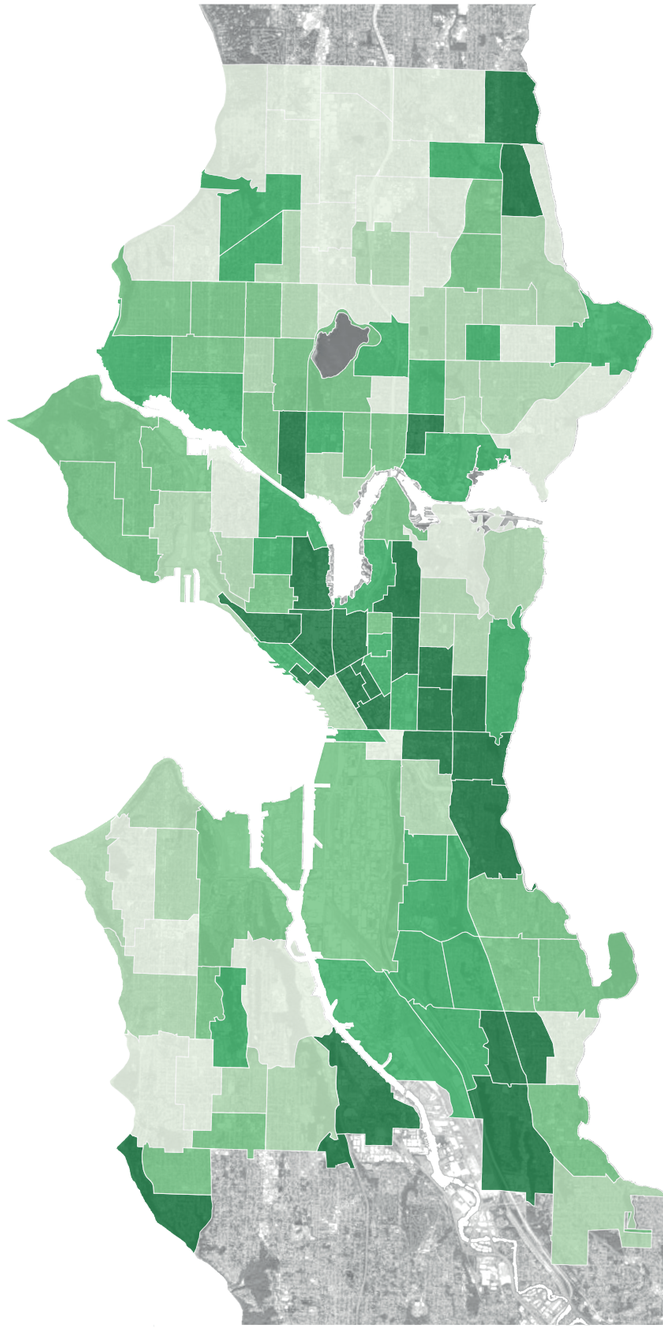


Figure 4-4. Map of the abundance of susceptible trees in the scale of neighborhoods

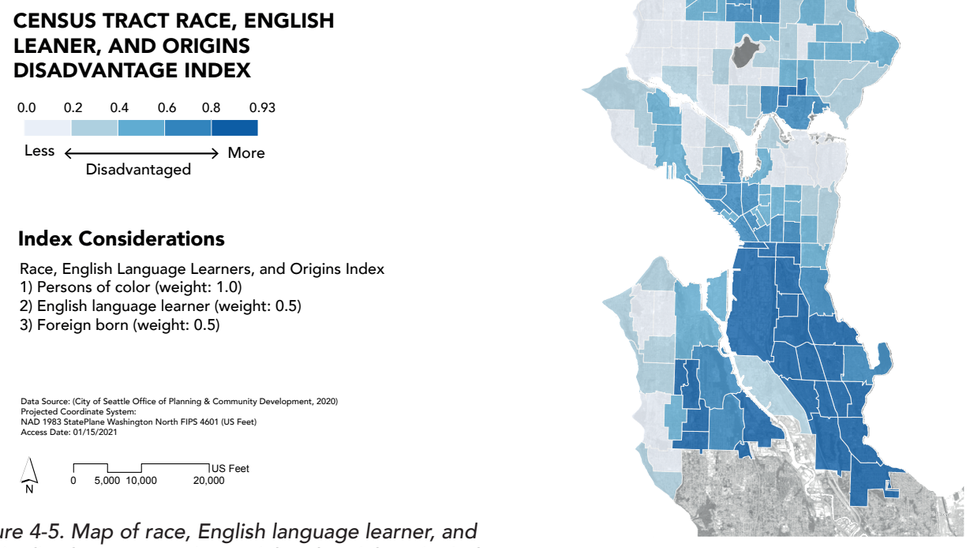


Figure 4-5. Map of race, English language learner, and origin disadvantages, using racial and social equity index

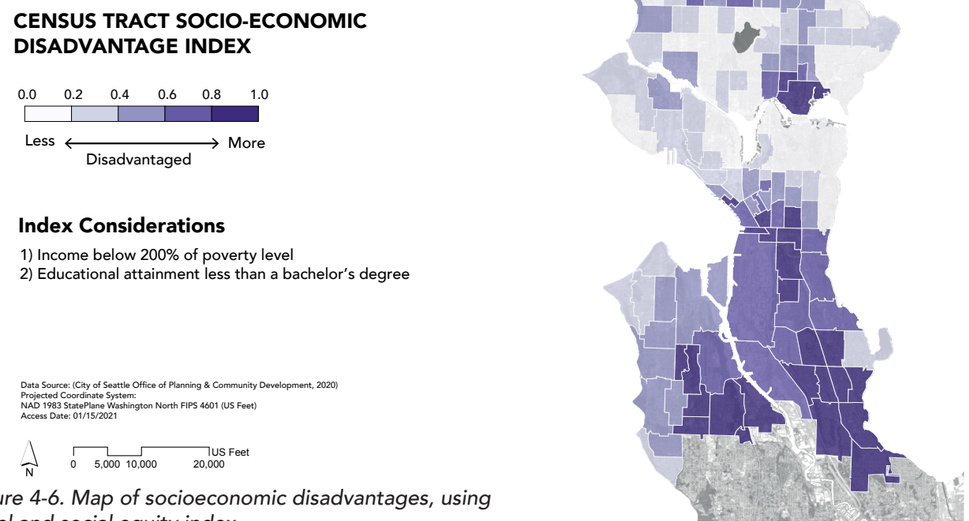


Figure 4-6. Map of socioeconomic disadvantages, using racial and social equity index

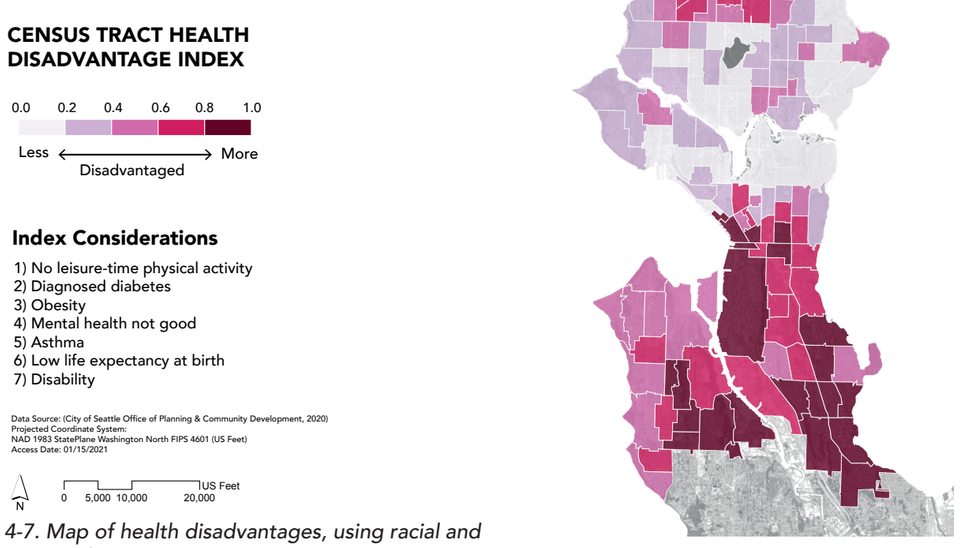


Figure 4-7. Map of health disadvantages, using racial and social equity index

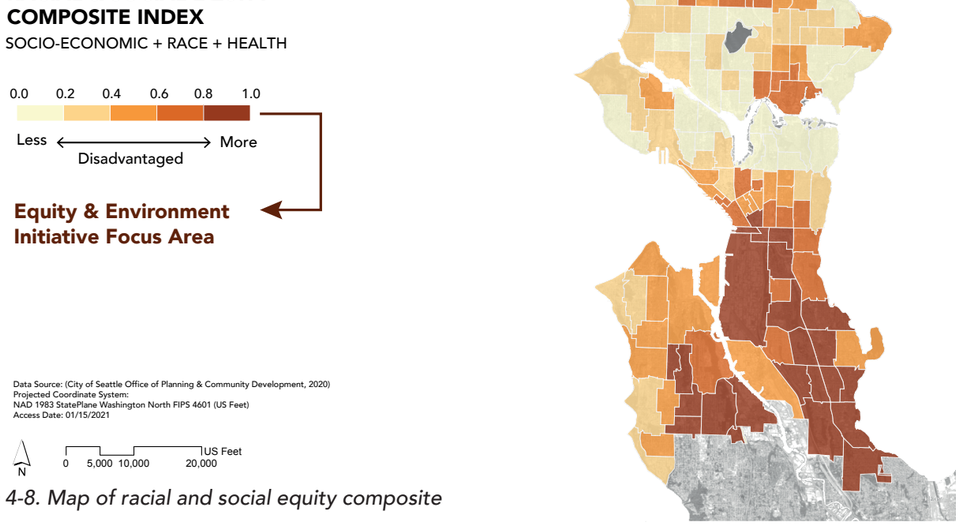


Figure 4-8. Map of racial and social equity composite index

The composite index map (Figure 4-8) shows the most socially vulnerable areas as suggestions for this research to focus on. Census tracts with the composite index of 0.8-1.0 (darkest brown color in Figure 4-8) make up the highest priority for pest management intervention, while census tracts with the index of 0.6-0.8 (brown color in Figure 4-8) make up the second-highest priority. The priority areas will be cross-referenced with the ecologically vulnerable areas to develop the final recommendation for the pest readiness engagement focus area.

4.1.3 Synthesis

The synthesis was generated from comparing the two vulnerability analyses, which further quantifies the degree of vulnerability through a ranking system. The rankings were based on the composite maps. The ranking uses values of 1-5, where the highest vulnerability was presented with a ranking of 5 and the lowest is 1 (See Figure 4-9). As mentioned previously, the vulnerable neighborhoods were determined as those rated a 4 or 5 from the social vulnerability analysis and 3-5 from the ecological vulnerability analysis.

I found it was hard to tell where to focus engagement efforts because each census tract had two vulnerability rankings and there are many combinations of rankings that vary a lot across the city, so I synthesized the information into a new map, as shown in Figure 4-10. Census tracts with higher risk should be considered as higher priorities for education and engagement. This is to make sure that local residents can understand what will happen to the street trees if pests come in and what should be done to minimize potential damages. The act of prioritizing engagement with areas that have potential higher risk and impact on people's lives is essential for building trust and transparency to avoid potential misunderstanding and to empower the communities, especially communities of color that historically tend to be left out in the process.

To visualize the area for engagement, I further cross-referenced the maps of ecological and social vulnerabilities in Figure 4-9 to synthesize the level of combined vulnerability through arranging different combinations of the rankings from both social and ecological perspective. These were divided into four levels with different perceived risk. The levels were determined based on my understanding from the literature that social vulnerability takes slightly higher priority than ecological vulnerability because limited capital and knowledge can affect not only people's willingness to address the ecological vulnerability, but also the perception of certain actions for managing trees for pests. The method of dividing them into different levels acknowledges the difference in factors that influence the perceived risk and helps identify priorities without ignoring any area with a lower risk.

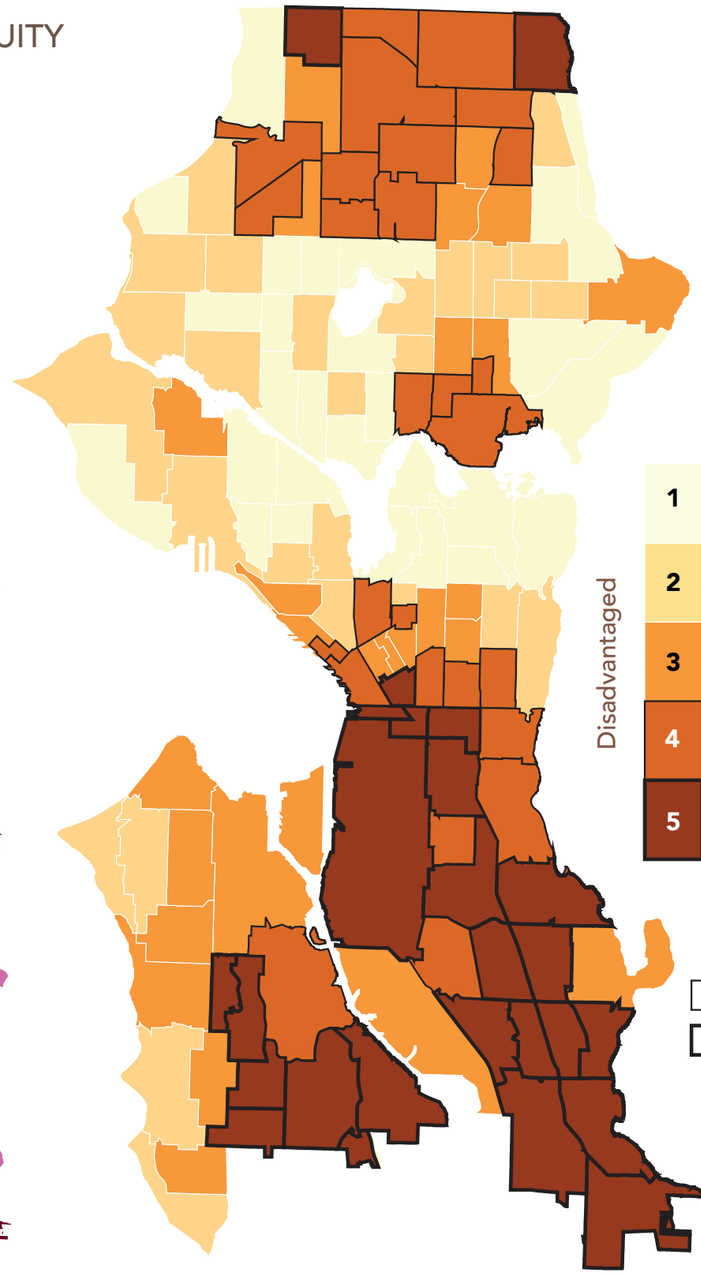
The synthesis map is shown in Figure 4-10, along with the standards for determining different levels of combined vulnerability. Level 4 should be prioritized for providing education, engagement, and resources. The priorities decrease with the level of potential risks. Based on the results, I suggest that the engagement efforts should first focus on the following neighborhoods:

- Olympic Hill / Cedar Park
- University District
- Central District
- Mount Baker
- Downtown
- Chinatown - International District
- First Hill
- South Beacon Hill/New Holly
- Brighton
- Delridge
- South Park

The analyses presented in this chapter mainly serve as a demonstrative model to quantify vulnerability to guide the distribution of resources on engagement efforts, but it is limited in terms of the breadth of the data on trees and should be complemented with communities' accounts on vulnerability in order to understand the full picture. More implications and limitations will be discussed in Chapter 6.

GIS VULNERABILITY ANALYSIS

RACIAL & SOCIAL EQUITY COMPOSITE INDEX



ABUNDANCE OF STREET TREES SUSCEPTIBLE TO PESTS OF CONCERN

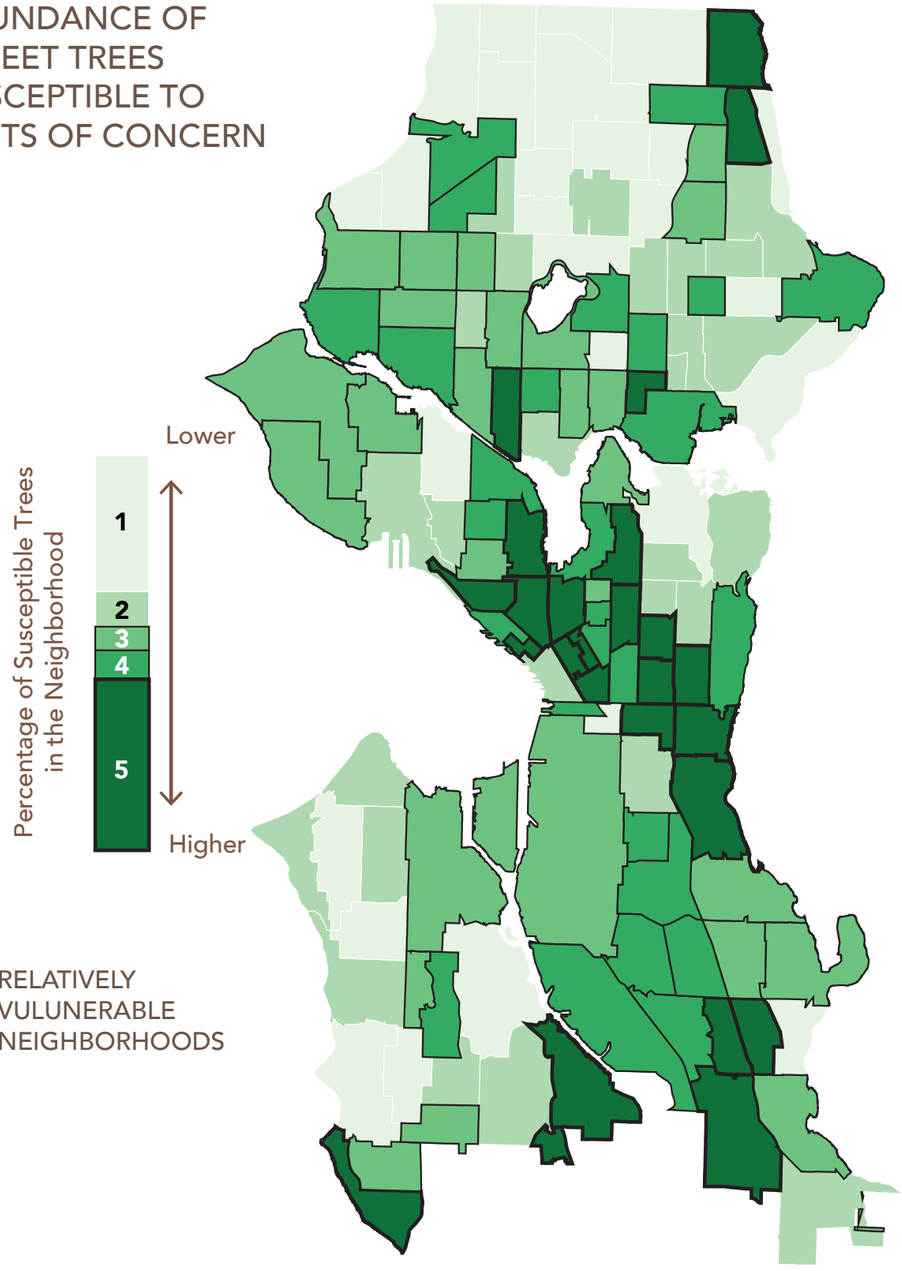
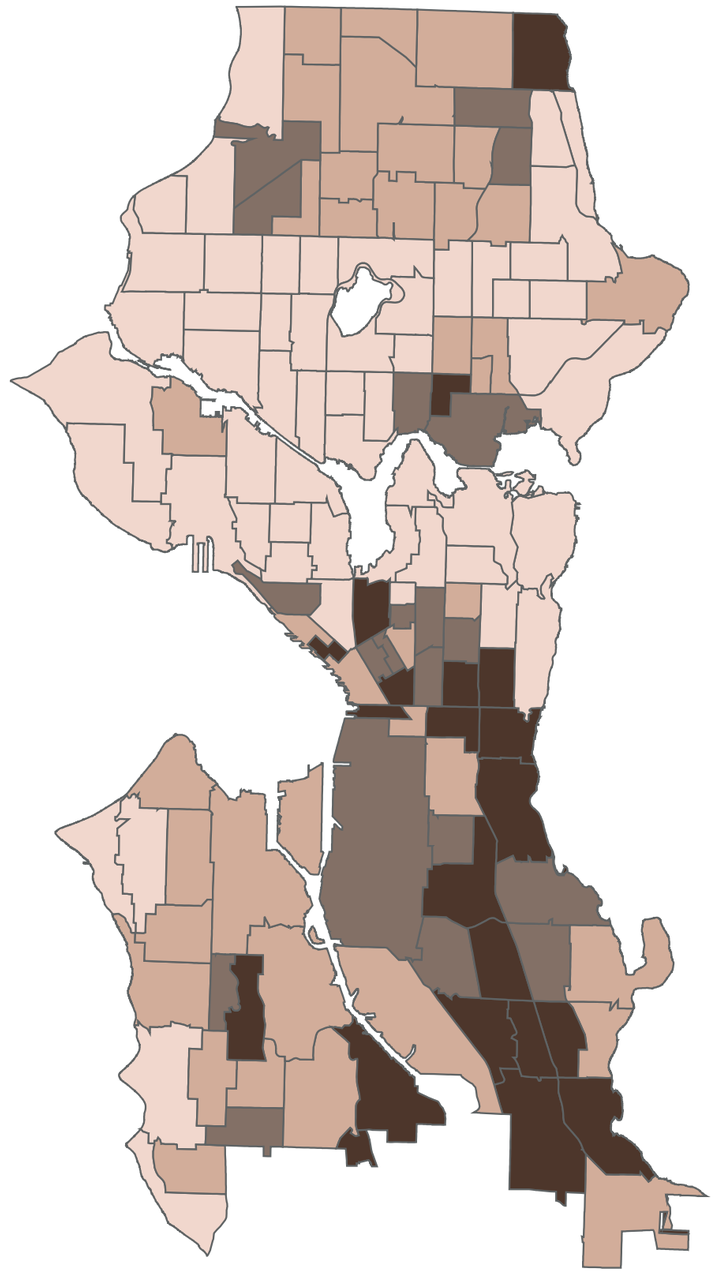


Figure 4-9. The synthesis from both ecological and social vulnerability analyses

GIS VULNERABILITY ANALYSIS

SYNTHESIS

		NEIGHBORHOODS*	
LEVEL 1	LOW RISK (1, 2) + (1, 2) + (3, 4, 5)	Ballard Fremont Wallingford View Ridge Laurelhurst Byrant Windermere	Magnolia Queen Anne Montlake Madison Park Alki Fauntleroy
LEVEL 2	MEDIUM LOW RISK (3) + (1, 2) + (3, 4) or (4, 5) + (1, 2)	Northgate Bitter Lake Ravenna Wedgewood Sand Point Interbay Rainier Beach	Beacon Hill Seward Park Georgetown North Admiral Seaview Gatewood Arbor Heights
LEVEL 3	MEDIUM HIGH RISK (4, 5) + (3, 4) or (3) + (5)	Greenwood Meadowbrook Victory Heights Capitol Hill Lower Queen Anne Industrial District/SoDo Columbia City	Belltown South Lake Union
LEVEL 4	HIGH RISK (4, 5) + (5)	Olympic Hill / Cedar Park University District Central District Mount Baker Downtown Chinatown - International District	First Hill South Beacon Hill/New Holly Brighton Delridge South Park



*Note: Neighborhood boundaries are more fluid and thus the list is only for guidance. Census tracts are more accurate.

Figure 4-10. The synthesis map with different levels of composite vulnerability

4.2 Case Study Findings

Generated from archival research, literature review, and interviews, the main findings from the case study are shown in Figures 4-10. Other than simply presenting the lessons from each city, I further organized the results in a way that is suitable to inform potential pest management practices at different stages of pest infestation. The strategies are offered as helpful practices to adopt for a particular stage of pest infestation. The following subsections will focus on explaining the findings in detail.

4.2.1 Findings from New York City: strategies before infestation

Before pest infestation, the municipality's strategies should concentrate on performing a risk assessment and engaging with the public around potential issues. Currently, SDOT has an inventory of street trees. The inventory is managed through 27 Urban Forestry Management Units, which was created by the City specifically for management purposes (Seattle Department of Transportation, n.d.-b). Each unit consists of one to two neighborhoods in Seattle. However, staff at SDOT only have the capacity to update "a minimum of three [urban forest management] units per year" through a few full-time staff and summer interns (Seattle Department of Transportation, n.d.-a). SDOT has the goal to "complete a 100% inventory of all street trees in Seattle by the end of 2024" (Seattle Department of Transportation, n.d.-b). While efforts are ongoing, it can be hard to keep up with the needs of risk assessment to prepare for potential pest issues because the inventory update is inconsistent and takes too long to update once due to limited staff.

Instead of just conducting the technical work, tree inventory and monitoring can create opportunities for learning about trees, engaging with trees, and empowering people with knowledge and skills (Johnson et al., 2018). Even though city urban forestry departments may not have the capacity to lead such events, other community partners like non-profit environmental organizations are based in communities. They are doing similar work and should be supported with greater visibility and resources. The following case study on New York City illustrates how leveraging community efforts for tree inventory and providing community-based resources can encourage more involvement to achieve multiple goals at once.

New York City, NY

New York City set an excellent example for organizing tree monitoring efforts with TreeCount2015 and maintaining the STEW-MAP project, the grassroots environmental stewardship network, which is a valuable resource for socio-ecological systems like urban forestry.

TreeCount2015 was a volunteer-based tree inventory effort led by the City of New York Department of Parks and Recreation (NYC Parks) (2015 Street Tree Census Report, 2017). Unlike previous tree censuses performed in 1995 and 2005, the program oriented towards involving communities as the lead of the efforts through recruitment and training to raise public awareness, encourage appreciation, and develop interests in the urban forest. The efforts from 2,241 community members eventually contributed to 34% of data collection on over 225,000 street trees with 96% accuracy (2015 Street Tree Census Report, 2017; Johnson et al., 2018).

Community organizations were instrumental to the movement. They helped with recruiting volunteers and organizing individual events for training and data collection. In total, 46 community partners participated in TreeCount 2015, ranging from the typical local stewardship and conservancy groups to the more atypical partnership like schools, universities, and AFROFUNK, a cultural music festival performed mostly by black artists in New York (2015 Street Tree Census Report, 2017). The partnership brought in new energy and increased the exposure of TreeCount2015 to people who had never participated in events related to urban forestry before (2015 Street Tree Census Report, 2017). For example, collaboration with science classes in local schools and universities was great opportunities to apply science education into actual practice through tree identification and mapping and helped increase the sense of value and appreciation to the environment and the place that strengthened the sense of belonging.

Similar motivations were common among participants who responded to the post-participatory survey, who viewed TreeCount as the opportunity to show that they value trees, to give back to the community, and to learn about trees as three top desires for participating (Johnson et al., 2018). Even though the report of TreeCount2015 showed that participation in such events contributed to increasing knowledge and skills, it only benefited the typical participants of community science projects because the volunteer composition was not diverse. In the analysis, the dominant demographic of the participants were "well-educated, middle-aged, white", while the "underrepresented were NYC residents of color and individuals without college degrees", which would require more targeted outreach to encourage participation (Johnson et al., 2018, p. 69). Nonetheless, findings still show promising results that can be utilized to attract more ethnically diverse people. The study has shown

CASE STUDY FINDINGS

What can Seattle learn from other cities about engaging communities in pest readiness and tree stewardship?

Seattle, WA

SDOT representative at Seattle Commitee of Invasive Pest

Romolini et al., 2016

Detroit, MI
Historical narrative & environmental justice
Local green jobs workforce development

Dr. Christine Carmichael

Carmichael & McDonough, 2019

Greening of Detroit Website

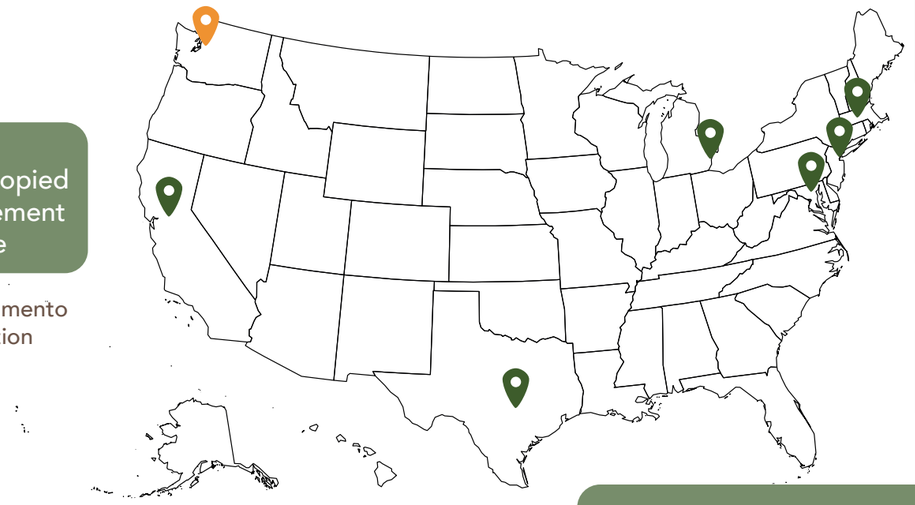
Worcester, MA
Coordinated replanting efforts with different stakeholders

Worcester Tree Initiative website

Vibrant Cities Lab

Sacramento, CA
Creative under-canopied community engagement
Community science

Staff at Sacramento Tree Foundation



New York City, NY
Community science for tree inventory
Database and interactive map for environmental stewardship organziations

Johnson et al., 2018
Landau et al., 2019

USFS STEW-MAP project

Baltimore, MD
Tree planting initiative
Career pathway for green jobs

Vibrant Cities Lab

TreeBaltimore website

Baltimore Tree Trust website

Austin, TX
City & non-profit partnership
Tree removal program

Community Engagement Manager at TreeFolks

Staff at Austin Parks Department

LEGEND

PEST INFESTATION PHASES

PRIMARY ACTIONS TO TAKE

BEFORE INFESTATION	DURING INFESTATION	AFTER INFESTATION
Education Tree Assessment	Pest Detection Treatment Removal	Replanting

RESEARCH METHODS USED

ARCHIVAL RESEARCH

LITERATURE REVIEW

INTERVIEW

Figure 4-11. Findings from case studies

the fourth-highest motivation for participation was associated with the partnership with AFROPUNK, which attracted 257 participants to join the effort in exchange for a free ticket to the festival. Even though it consists of a small number of total participants, this partnership yielded the highest number of participants in all partnerships (2015 Street Tree Census Report, 2017). This shows that incentives and partnerships with other fields like music and art can help attract people who may not be interested in tree programs otherwise, including BIPOC. The opportunity can serve as great introduction for them to get further involved in urban forestry efforts.

Another relevant project in New York City, the Stewardship Mapping and Assessment Project (STEW-MAP), was a research project conducted by the U.S. Forest Service in 2007, 2015, and 2017. STEW-MAP intended to "visualize the often 'unseen network' of stewardship actions" to increase people's environmental awareness, which extends beyond simple tree-related stewardships and focuses broadly on actions caring for all aspects of the environment, such as gardens and waterfronts (USDA Forest Science Northern Research Station, n.d.). The categories that the stewardship groups take on range from "conserve, manage, monitor" to "transform, educate, and advocacy", which include examples like tree planting, beach clean-ups, and youth environmental summer camps (Landau et al., 2019, p. 1). The project highlights that ecological stewardship not only contributes to caring for the environment but also building and binding communities for social change across different geographic scales (Landau et al., 2019). From professional stewards to grassroots organizations, partnerships with government agencies and private organizations help sustain the programs and amplify the influence of programs with shared goals (Landau et al., 2019).

The power of this project extends beyond simple visualization and the data and continues to be used as guidance for funding and resources to foster stewardship and care (USDA Forest Science Northern Research Station, n.d.). The recent partnership with Pratt Institute SAVI lab for data visualization and the exhibition Who Takes Care of New York? in 2019 further increased public awareness on the social network of environmental stewardship through mapping, art, and narrative and encouraged people to become part of the effort (Pratt SAVI Lab, n.d.). The upcoming online dashboard will make all of the data public as resources for people to engage and find their own opportunities, which further encourages community actions in any way that collectively helps build future environments (USDA Forest Science Northern Research Station, n.d.).

4.2.2 Findings from Austin and Sacramento: strategies during infestation

Timely pest detection, treatment, and removal should be prioritized if there is pest infestation. The cases from Austin, Texas, and Sacramento, California exemplify the roles that environmental organizations can play in bridging the communities and the municipality.

Austin, TX

For Austin's case, I interviewed Joshua Erickson, the urban forestry program manager at the City of Austin Parks and Recreation Department, and Ben Bertram, the NeighborWoods program coordinator at TreeFolks, one of the largest non-profits in the Central Texas region focusing on urban forestry. The interviews reveal a strong partnership between the city and the non-profit organization on engagement efforts and some challenges.

With previous experience working in urban forestry departments in Seattle, Joshua mentioned how the City of Austin has a similar model of organization related to urban forestry as the City of Seattle. Each municipal department, Austin Water, Watershed Protection, Austin Energy, Public Works, Development Services, and Parks, oversees Austin's urban forest, and there is an urban forester who will coordinate city-wide responses. Joshua pointed out that the Parks Department has a good relationship with prominent urban forestry-related or park-related non-profit organizations, like TreeFolks and Parks Foundation, which assisted with engagement and volunteer management. However, Joshua indicated that the lack of regular stewardship or educational programs like Seattle's Trees for Seattle program is a missed opportunity for these organizations to introduce more people to participate in and provide engagement opportunities within the parks department.

Nonetheless, TreeFolks is an organization with 30 years of history and a strong network in the region for engagement. The partnerships with different departments in the City of Austin make their efforts even more substantial. TreeFolks works with the City of Austin on residential tree giveaway events through the NeighborWoods program, planting new trees in parks and near waterways through CommuniTrees Program, and replanting after disturbances in Travis County Floodplain Reforestation program ("TreeFolks 2019-2020 Annual Report," n.d.). The communities that were prioritized are identified by the Austin Community Tree Priority Map,

which highlights a priority score for vulnerable communities who need resources and assistance through the assessment of four categories: Environment, Social Vulnerability, Community Investment, and Health & Well-Being (City of Austin, 2020). According to Ben, the City would identify specific neighborhoods through this map as recommendations for TreeFolks to engage with. TreeFolks then helped find passionate people in the neighborhood and trained them as forest stewards to conduct planting projects.

Within the Neighborwoods program, the Remove & Replace initiative was targeted to help lower-income people who cannot afford to remove hazardous trees by professional tree care companies and replace damaged trees with new healthy trees for free ("Remove and Replace," n.d.). According to Ben, the program was funded by TreeFolks and the City of Austin, and they contracted with a local tree care company in exchange for promotion. Despite the good intention, the program had to pause in April 2020 because of a lack of funding, and they are in the process of finding new grants for it to continue. Ben talked about how "people don't normally make the connection between removing an old tree and planting a new tree," which makes it hard for programs like this to get funding.

When asked about the plan and efforts to engage the public on pest issues, Joshua responded that there is currently an ongoing effort to create a coordinated management plan to deal with the emerald ash borer. However, each department has a very different approach, and it is hard to come up with a solution that fits all needs. The situation is similar to what I learned from Stephanie Helms, the lead in Seattle Committee for Invasive Pest, where each department has different approaches to data collection and record-keeping, and it would require a lot of coordination to make it work.

Ben brought up oak wilt as another pest on their watch list, and they've done some targeted outreach to direct behavioral change. The messaging encourages the change in pruning timing by creating yard signs and providing resources on proper pruning to reduce oak wilt infection through open wounds. However, other than these targeted methods and calling for larger media coverage on the potential threat, they haven't done much about preparing for invasive pests. Similarly, Tree Folks didn't focus much on invasive pest outreach because there is a larger imminent problem they face with flooding each year killing more trees, while the pests that they are primarily concerned with, like EAB and oak wilt, only attack certain species of trees, and therefore make them less of a threat wherever there is not a large population of ash and oak trees.

Yet Ben did mention how Austin's direction changed in recent years to emphasize holistic urban forest health by increasing tree age diversity and species diversity, which drives tree planting efforts. When asked about the relationship between climate change and tree selection, Joshua also explained how planting for climate resilience depends on efforts on all fronts, from the Development Services Department to nurseries and landscape design companies. Even though the Development Services Department updates their guidance for climate adaptable tree lists, it will take some effort to get the nursery to change their supply to make the recommended trees commercially available. He added that Austin could not purchase enough trees to drive the market, so adding diversity and shifting preference will have to depend on the ethics of landscape designers to make the right choices for tree selection with the goal of climate resilience in mind.

Sacramento, CA

The case study of Sacramento, California, focuses on the two programs offered by the non-profit organization Sacramento Tree Foundation (SacTree), which has almost 40 years of history working on urban forestry issues in Sacramento. The information was gathered from an interview with Torin Dunnavant, the Director of Education and Engagement, the presentation at the Conference in Partnership in Community Forestry in November 2020, and supplemented with a literature review. The findings show how SacTree leads in tree monitoring programs with community science and focuses on under-canopied engagement.

American elm (Ulmus americana) and English elm (Ulmus procera) in Sacramento were planted back in the mid-19th Century because they reminded settlers of the aesthetics of the east coast landscape, and they transformed the landscape of Sacramento with those trees (McPherson & Luttinger, 1998). However, after decimating elm trees in the U.S. Northeast, Dutch elm disease was detected in Sacramento for the first time in 1990. This started the city's battle to save the canopy (McPherson & Luttinger, 1998).

Transformed from the previous CalFire monitoring project, SacTree's Save the Elms Program (STEP) was established in 1994 to train and recruit volunteer community scientists to monitor city-maintained susceptible elm trees for Dutch elm disease (DED) (Nannini et al., 1998). The funding is from the City of Sacramento Department of Public Works, which houses the Urban Forestry Department (Sacramento Tree Foundation, n.d.). From 1995-2005, the volunteers

had successfully detected 442 cases that resulted in timely treatment and removal to slow down the spread of the disease, but the pause in the program from 2006 to 2016 had added pressure to the City's urban forest team and potentially led to more infected elms (Sacramento Tree Foundation, n.d.). The program was brought back in 2016, but there was already a loss of about 25,000 elm trees and tremendous ecosystem services they provided (Sacramento Tree Foundation, n.d.). In a 2018 tree canopy assessment conducted by Davey Resource Group, even though only 878 American elms remained, which consist of 1.01% of the inventory, these trees still contribute to the "greatest per tree cumulative air quality benefits" with their large canopy and most significant cumulative annual benefits (Urban Tree Canopy Assessment Sacramento, CA, 2018, p. 23).

The loss of elm trees with their wide canopy has the power to change the look of a neighborhood, especially the trees on the streets and in the parks, which was reported as one of the motivations that drove volunteers to participate in this program (Nannini et al., 1998). According to Torin, the volunteers are mainly recruited from nearby neighborhoods where elm trees are concentrated. Once identified, they went through training sessions conducted by SacTree staff and City arborists. They will then go out to make observations on their own during the summer when the symptoms are most visible. The results are reviewed by SacTree staff and then organized to report to the City's urban forestry team, which would go out and test the tree sample for verification and potential removal (Sacramento Tree Foundation, n.d.). The removed wood will be recycled through the Urban Wood Rescue program, which salvages local lumber for discounted sale. The program and the clarity of the process have brought participants satisfaction. They believe that they've contributed to the neighborhood by saving the rest of the trees while learning valuable skills in the process (Nannini et al., 1998). However, despite the program's success in leading to early detection of DED, the volunteer-based program mainly attracts white people, even though there are a certain number of susceptible elm trees near the neighborhoods with more communities of color as well, according to Torin. He suspected that it might be because the communities of color are mostly renters in the area, who may have less commitment to their environment, or they haven't done a good job promoting the program to them. While Torin's claim may not be accurate because he didn't do extensive research on this, it did show that for the STEP, the staff didn't invest much in engaging with communities of color but mostly relied on traditional volunteer base.

Knowing that there is low canopy coverage in certain parts of north and south Sacramento, the NeighborWoods program is dedicated to serving under-canopied communities with "resource inequality" within Sacramento County, which is funded by state and city governments like California cap-and-trade tax and other taxes (Dunnavant et al., 2020; Sacramento Tree Foundation, 2020, p. 5). Torin explained that the funding is then used to hire community organizers to work with community members to explore what programs work for the communities. In the process, SacTree works with elected officials to build relationships with community-based organizations to facilitate events, build trust, and find ways to establish long-lasting effective partnerships. The model for working with the under-canopied communities has been successfully replicated for 10 communities, each of which identified their unique needs and concerns for issues related to urban forestry. SacTree was able to develop programs as a response to this input. The model of NeighborWoods is further developed as a community action toolkit with documentation, which is used in this project as a reference and listed in Appendix B.

Figure 4-11 illustrates the transition of power from SacTree to the community leaders, with diminishing "outside support" and increasing "neighborhood leadership" (Sacramento Tree Foundation, 2020, p. 9). With the support of SacTree, the community organizers lead the action, find resources, and establish partnerships with local schools, private organizations, and community members. From looking at the cases of each neighborhood as described by their organizers, some common themes emerged. Many trees in several neighborhoods, like Arden Park, Cordova Vineyards, and South Natomas, were distressed by various diseases like DED, anthracnose, and mistletoe, which led to declining tree canopy, but these communities lacked resources to cut the trees down, remove the stumps, and plant new trees (Sacramento Tree Foundation, 2020). Torin mentioned how they came up with stump removal events that helped people who hesitated to make spaces for new trees, which also educated them to deal with maintenance issues with the resources from SacTree. In other cases, while it seems hard to approach people and suggest they invest in their private trees, starting with planting and education in public spaces like parks and schools can be helpful to establish common grounds, increase awareness, and develop appreciation among students and communities, like in the case of the South Natomas neighborhood in Sacramento where diverse ethnic communities live.

When asked about the possibility of combining the two programs, Torin indicated that it would be a little complicated because the funding source of the NeighborWoods program directed where they should spend the efforts, but he also recognized the limitation of STEP currently. He also had doubts about whether the model for recruiting community leaders would work for a project that focuses more on community science because he considered the nature of community leaders different from more a science-oriented person, which is debatable from my point of view.

4.2.3 Findings from Worcester, Detroit, and Baltimore: strategies after infestation

After initial pest infestation, treatment, and removal, replanting and maintenance for long-term resistance should be the goal for community efforts. This section examines precedents from Worcester, Massachusetts; Detroit, Michigan; and Baltimore, Maryland, for how they have developed strategies to manage tree pests after an infestation has occurred. The case of Worcester demonstrated how to respond to large-scale tree dieback through coordinated planting, while Detroit and Baltimore emphasize addressing the misunderstanding of disadvantaged communities related to trees through genuine engagement and providing a career pathway.

Worcester, MA

Historically, trees with large canopies, like chestnuts, elms, and maples, mainly served as street trees in Worcester, but an invasive fungus that caused chestnut blight and Dutch elm disease, and other disturbances led to massive tree loss in the city (Beetles Attack, Worcester MA Fights Back, n.d.). As a response to make up for all the loss of trees, the

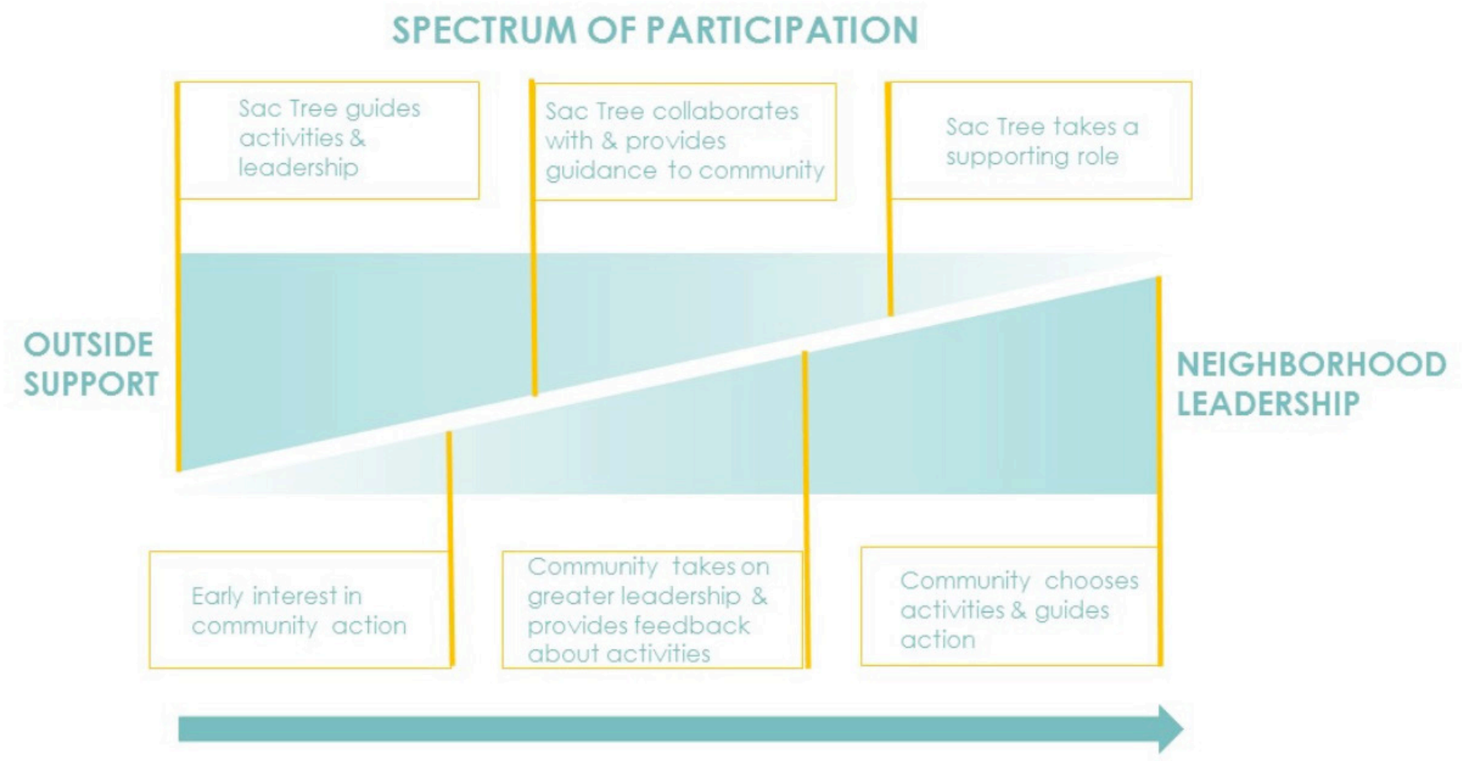


Figure 4-12. NeighborWoods Program's community spectrum of engagement. Image credit to Sacramento Tree Foundation

city selected maple trees, especially Norway maples, as a replacement because they can grow fast and start providing ecosystem services soon (Freilicher, 2011). Yet focusing on only one species in the recovery has caused the monoculture among street trees, where maples comprise 80% of 117,000 Worcester's street trees before the Asian longhorned beetle (ALB) invasion in 2008 (Beetles Attack, Worcester MA Fights Back, n.d.). The monoculture created the perfect hotspot for ALB and resulted in the removal of 29,000 trees just in the course of three years after the initial discovery of the invasion (Freilicher, 2011). The repetitive loss of trees on a large scale due to pests and natural disasters has driven the effort to focus on replanting efforts, particularly after the ALB invasion. What was different this time were two aspects: the determination to establish a program that would continuously support the replanting efforts called Worcester Tree Initiative (WTI) and the public-private partnership in which various entities in the city participated (Beetles Attack, Worcester MA

Fights Back, n.d.; Freilicher, 2011; USDA Northeast Climate Hub, 2017).

1) Sustaining the replanting effort through WTI

With the determination of a local Congressman and Lieutenant Governor, WTI was established in 2008 for recovering from ALB through planting. The initiative specified that "no more than 10 percent of any one species was to be planted in the community" to prevent any disasters similar to this one (Beetles Attack, Worcester MA Fights Back, n.d.). WTI provided free trees to residents and allowed them to choose particular species and sizes they preferred during pre-registration, which helped with "data organization and management" (Nguyen et al., 2017, p. 30). The process also helped with tracking and studying preferences, which guided the efforts for increasing the future diversity of the urban forest (Freilicher, 2011; Nguyen et al., 2017). The engagement process also turned out to be really helpful and was described as a "healing process" for private property owners to receive a new free tree after losing a tree to ALB (Freilicher, 2011, p. 10).

2) Extensive public-private partnerships

The tree replanting effort in Worcester would not be successful without the support of diverse private groups and public agencies from all sectors of society.

Since the origin of WTI was due to ALB, USDA Animal and Plants Health Inspection Services (APHIS) and Massachusetts's Department of Conservation and Recreation (DCR) were involved in providing expertise and funding for detection, removal, and replanting in public properties such as parks (USDA Northeast Climate Hub, 2017). In Dodge Park, volunteers from local schools and businesses came together to support the tree planting and watering process (Beetles Attack, Worcester MA Fights Back, n.d.). On private properties, WTI worked directly with residents, but they also collaborated with a housing agency known as Worcester Common Ground to turn vacant lots into productive orchards for Bhutanese refugees. WTI also assisted a local watershed group to reduce runoff by planting trees in neighborhoods (Beetles Attack, Worcester MA Fights Back, n.d.).

The diversity of collaborations not only highlighted the importance of the urban forest in every part of the city but also showed possible partnerships with all stakeholders. Although some problems emerged with low tree survival rates in schools where the newly planted trees were not appropriately maintained, agreements that demanded continuous monitoring and maintenance helped establish responsibility with involved parties (Freilicher, 2011).

In an interview with Ruth Seward, the executive director of the WTI in 2019 published on the Tower Hill Botanic Garden website, Ruth mentioned that the biggest accomplishment of WTI was "replanting over 30,000 trees in the Asian Longhorned Beetle Zone", which includes Worcester and several surrounding towns that suffered from ALB too (Burgess, 2019). WTI is now transformed into a "permanent community outreach department" of Tower Hill Botanic Garden in Worcester, which allows them to expand their capacity and continue engaging communities with free tree planting opportunities (Burgess, 2019). The case of Worcester enables people to see the importance of an urban forest that is connected with all aspects of the city. It also inspires me to think about what potential partnerships are possible, which helps with the construction of frameworks for engaging diverse stakeholders and indicates potential funding sources to prepare for replanting goals on a large scale.

Detroit, MI

In the early 20th Century, Detroit, Michigan was charmed with trees and praised as the "City of Trees" because allegedly it had the highest tree coverage among any industrial city in the U.S. (Carmichael & McDonough, 2019). However, due to the economic recession in the 1970s, the city defunded many departments, including the urban forestry department, resulting in fewer staff and subsequently less care and maintenance (Carmichael & McDonough, 2019). In the same period, DED spread to Detroit, and EAB was also discovered in 2002. Many of the trees on streets or other city-owned properties were infected with DED and EAB, which were either cut down and never got a replacement or were left standing dead because there was no one to cut them down (Changing the Heritage Narrative: Detroit, MI, n.d.).

In 1989, The Greening of Detroit (TGD), a local non-profit environmental organization dedicated to restoring Detroit's tree canopy, was established. They had small successes in the past, but the disparities in tree canopy were still clearly visible where communities of color were located (Changing the Heritage Narrative: Detroit, MI, n.d.). In 2014, the City of Detroit tried to address the inequality with more funding given to TGD to scale up the efforts to give away free trees to people in minority neighborhoods, but the efforts were surprisingly rejected by 25% of 7500 residents that TGD reached out to (Changing the Heritage Narrative: Detroit, MI, n.d.). The investigation to figure out why was conducted by Dr. Christine Carmichael, who I had the fortune to speak

with to learn in-depth about her work interviewing the residents and the staff of TGD. The study of the historical narrative among residents who refused trees revealed that the experiences of long-term neglect, mistrust in the government's actions, and racial injustice all contributed to the unwillingness of people to accept new trees. Interviewees expressed concern that the trees may not get properly maintained by the city and that people would eventually have to do their own work with little assistance. In contrast, residents who accepted trees often had positive experiences with tree services in the past (Carmichael & McDonough, 2019). In addition, Dr. Carmichael explained that Detroit's top-down approaches had resulted in distrust among the disenfranchised communities because they had to deal with the negative consequences of DED and EAB without proper management from the city. Many communities of color were not consulted when the city came in and cut down their trees for the control of DED in the 1970s, which had led to the perception that the city wanted to surveil them because the trees never got replaced (Changing the Heritage Narrative: Detroit, MI, n.d.). Even though the residents who refused free trees were well aware of the benefits of the trees on human health, the resentment against the city's lack of care and engagement in any decision-making process led to the rejection of trees. The rejection was not necessarily of the trees but more about the government, as indicated by Dr. Carmichael's interviews with the staff of TGD (Carmichael & McDonough, 2019).

Dr. Carmichael further emphasized the importance of building a two-way dialogue between the city and the communities, the need to center all the programs on community experiences, needs, and concerns, and the necessity of designing these programs with communities in order to address environmental injustices. When asked about potential solutions, she indicated that these programs could be combined with the pressing needs of the communities, such as child care and food, through events in which multiple goals can be achieved at once, like Black club parties and back-to-school events. Based on her understanding through her research, the biggest priorities for the communities were economic advancement opportunities because urban forestry was funded by taxes. Subsequently, TGD established an Adult Workforce Training Program, which is a "certified Federal Apprenticeship Program" through the U.S. Department of Labor, specifically to help residents who had trouble getting employed develop skills in the landscaping field (Adult Workforce Training Program, n.d.). Direct engagement and empowerment through Detroit Conservation Corps (DCC) manifested in how many graduates of the program took green jobs and advanced leadership roles within the industry (Changing the Heritage Narrative: Detroit, MI, n.d.).

Baltimore, MD

Baltimore, Maryland's city tree-planting initiative exemplifies the effective efforts for earning trust through encouraging direct involvement and long-term partnerships among residents, which can serve as an excellent example for planting efforts after a pest infestation. Similar to Detroit, the BIPOC population of Baltimore comprises 70.3% of the population, which makes engagement with efforts addressing environmental justice particularly important (Baltimore Tree Trust, n.d.-b). TreeBaltimore was established based on an initiative to increase tree canopy to 40% by 2037. This initiative is led by Baltimore City Recreation and Parks (Baltimore Tree Trust, n.d.-b; TreeBaltimore, n.d.). Acting as the "umbrella organization" for the public and all urban forestry-related departments in the City of Baltimore, the organization helps to support grassroots organizations by providing "technical assistance, capacity building, and standards and protocol guidance" (Baltimore Tree Trust, n.d.-b). With this support, Baltimore Tree Trust (BTT) emerged as one of the leading urban forestry organizations that focus on tree canopy equity through a focus on tree canopy in disadvantaged neighborhoods one at a time to develop an appreciation of trees and earn trust (Baltimore Tree Trust, n.d.-b).

An NPR study conducted in 2019 showed that the urban heat island effect is exacerbating in Baltimore, but neighborhoods with a higher proportion of people of color and people with lower income are affected disproportionately because their neighborhoods tend to have "fewer trees, more concrete, and [are] closer to highways and factories" due to redlining (Anderson & Mcminn, 2019). BTT strived to break the status quo is to convert the impervious surface to planting spots in under-canopied neighborhoods and offering continued maintenance for two years to get the trees established and increase survival rate (Baltimore Tree Trust, n.d.-b). The act of maintenance helped send a signal of care that the communities of color and their neighborhoods have long been deprived of, which contributed to building trust and relationships through planting (Baltimore Tree Trust, n.d.-b).

Even though the communities were still wary of tree planting and the assumed responsibilities associated with it, some were still interested in potential hiring opportunities (Baltimore Tree Trust, n.d.-b). In response to the concerns, BTT partnered

with the Center for Urban Families, an organization to help secure jobs for vulnerable communities, to hire residents living near the planting sites, and introduce people to the field of urban forestry with living wages for a seasonal job (Baltimore Tree Trust, n.d.-b). The partnership also provided mentorship programs with training sessions to help individuals develop job-ready skills. If they became interested in the field, they could continue working in the short-term with tree care contractors or join the Urban Roots Apprenticeship program that helped them embark on the urban forestry industry (Baltimore Tree Trust, n.d.-a).

The hiring opportunities not only increased exposure to potential career pathways for communities of color that had the potential to change their existing misconceptions of trees but also gave them agency to get involved, earn a living, and help build their neighborhoods for the better. Besides seeking diversity in participation, BTT also strived to set an example within their organization by promoting "Black Baltimoreans into leadership and managerial positions" to increase the representation of communities of color in the environmental field (Baltimore Tree Trust, n.d.-b). Direct empowerment should be what we all aim for in the engagement work.

4.3 Synthesis

The engagement methods examined as case studies are tree stewardship programs mainly hosted by local non-profit environmental organizations with support from a city's urban forestry department. Different layers of lessons can be generated from all of the cases, including strategies for approaching community engagement regarding pest issues and considerations for environmental justice.

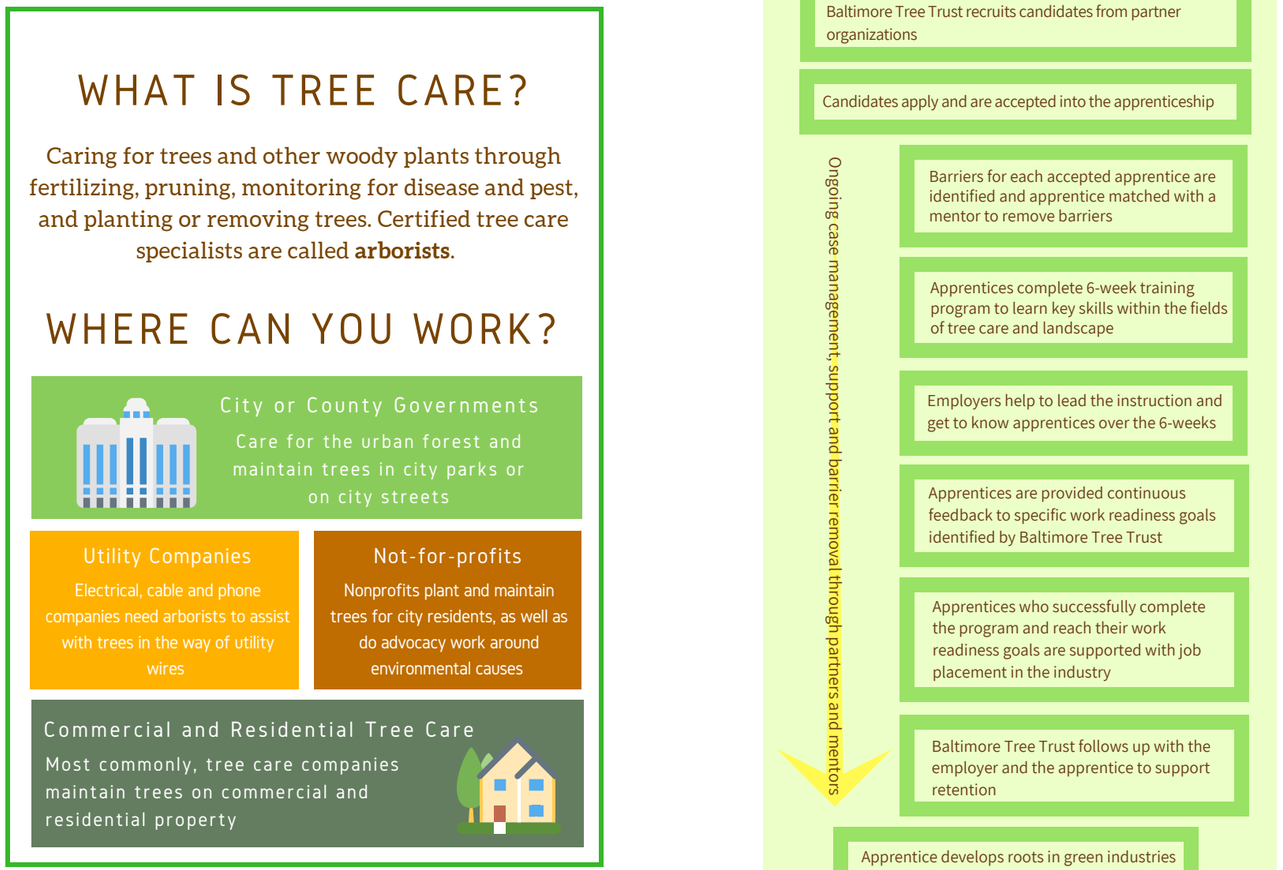


Figure 4-13. Infographics about tree care and landscaping careers and Urban Roots Apprenticeship program provided on Baltimore Tree Trust website. Image credit to Baltimore Tree Trust

4.3.1 Common themes from findings

1) Connecting other challenges that urban forest faces to address pest concerns

Each city has other problems related to trees that take priority, no matter if it is a socio-economic matter or natural disturbance. For Detroit, it is the declining economy. For Austin, it is seasonal flooding. For Baltimore, it is the urban heat island effect and its disproportionate influence on communities of color. For Worcester, it was natural disasters like "the hurricane, the tornado, the ice storm," and finally ALB (Freilicher, 2011, p. 3). What is common is that these factors are associated with historical oversight of the value of trees and will weaken and kill the trees in the future. Recovery from long-term social and ecological disturbances or rapid disturbances like pest infestation also creates a fresh

perspective for rethinking the composition of urban forestry for diversity, climate resilience, and economic opportunities. However, pest infestation is an abiotic factor that has the potential to worsen the situation and spread. Relating pest issues to other ongoing threats can help visualize and create connections through the loss of trees and invite opportunities to integrate pest education for tree planting potentially.

Connecting potential pest problems with other closely related issues can solve another dilemma on managing a readiness effort on such a large scale without adequate funding. The potential loss of trees on a large scale due to pest infestation will exacerbate the urban heat island effect, increase the speed and the amount of stormwater runoff, and eventually put public health in danger, taking more financial budgets and time to restore. The apparent relationships between trees and other socio-economic problems make it easier to argue for the case with a risk assessment to guide decision-making and establish partnership across different levels and scales, from the federal, state to the local scale. The investment in pest readiness is an investment in the efforts to fight climate change and many outcomes from pest readiness. Efforts such as tree inventory and tree monitoring can help guide decision-making in the long term.

2) Establishing partnerships with existing community partners

The traditional methods of media and pitching initiatives to elected officials about urban forestry efforts were used to gather initial interests in some cases, but all programs discussed here display the emphasis on the collaboration with community partners as the key to successful engagement with communities of color. For NYC's case with the limited turnout, Johnson et al. further indicated that "identifying the motivations by demographic characteristics" could be helpful to inform recruitment strategies, which is what community partners can help with through their connections (Johnson et al., 2018, p. 69). Working at the neighborhood scale and working through one area at a time can be helpful to set examples and encourage informal conversations within and between the communities. BTT and SacTree both used this model to approach tree planting with communities of color and learn about community needs through partnerships with community-based organizations or community liaisons. Engaging with at least the representatives of the communities shows signals of care and empowerment and is valuable to develop meaningful agendas.

3) Providing career pathway and paid opportunities in urban forestry for communities of color

Compared to volunteer programs, providing career pathways and paid opportunities for communities of color for green jobs is a valuable investment that can be life-changing, which not only empowers them with education and skills but also helps with the economic advancement of the communities. For pest readiness, community science projects like NYC's TreeCount2015 and SacTree's STEP all have the problem with lack of diversity of participants, but at the same time, they are the projects that contribute the most to pest readiness by disseminating ecological knowledge and skills for awareness and early detection. By making the training programs paid, urban forestry programs can be connected to economic opportunities that are more attractive than volunteer work, for which people may not have time when they are busy making a living. In the cases of Detroit and Baltimore, where communities of color consist of the majority of the city's population, introducing green jobs in various forms and at different levels, from seasonal workers to professional apprenticeships, can gather interest from communities of color who need job opportunities.

Establishing partnerships with local employment agencies or community-based organizations has proved to be useful to ensure communities of color are prioritized in the selection process, and that funding sources are expanded. Dedicating the paid training programs specifically to help communities of color makes the job opportunities even more powerful and meaningful for the communities themselves, as they often live in areas that need more tree canopy and stewardship. With local experiences, knowledge, and connections, local residents are already experts of their neighborhoods and have the potential to become more active with skills of urban forestry if provided the career opportunities. Although more research is needed to prove that career pathways contribute to changing perceptions of communities, it is at least the start of inclusionary and equitable approaches that give communities of color agency to get involved with the work to transform their neighborhoods for better health, aesthetics, and ownership through urban forestry. The opportunity for communities of color to take on leadership roles in the urban forestry industry can be truly transformative and inspirational for others to get involved and increase the equitable representation of the environmental field.

4) Tree removal is just as important as planting new trees

Tree removal is sensitive in the development process when the healthy trees are removed randomly without proper explanation, but with hazardous and declining trees, it is

CASE STUDY COMPARISONS

PHASE	BEFORE INFESTATION	DURING INFESTATION		AFTER INFESTATION		
GENERAL STRATEGY	Education Tree Assessment	Pest Detection Treatment Removal		Replanting		
FOCUS CITY	**New York City NY**	**Austin TX**	**Sacramento CA**	**Worcester MA**	**Detroit MI**	**Baltimore MD**
MAIN ENTITY	NYC Parks Department USDA Forest Services	Austin Parks Department TreeFolks	Sacramento Tree Foundation (SacTree)	*Tower Hill Botanic Garden	Dr. Christine Carmichael The Greening of Detroit (TGD)	TreeBaltimore (City) Baltimore Tree Trust (BTT)
LESSON	**TreeCount2015** - community science tree inventory with high accuracy - collaboration with local groups, schools, events **STEW-MAP** - documentation and visualization of grassroots environmental stewardship network	- use Austin Community Tree Priority Map to prioritize vulnerable communities for tree planting efforts **NeighborWoods Program** - remove and replace declining trees with new trees for low-income people	**Save the Elms Program (STEP)** - community science tree monitoring - quick response and transparency of process **NeighborWoods Program** - focus on under-canopied communities - paid community organizers lead the engagement	***Worcester Tree Initiative (WTI)** - coordination of long-term replanting efforts - public-private partnership across all sectors of the society (residents, schools, housing agencies, businesses, watershed groups)	- resolving historic narrative with trees through engagement - providing economic opportunities **Adult Workforce Training Program** - empowerment and engagement by providing training for skills in urban forestry	- Elevating black leadership outside and within the organization **Urban Roots Apprenticeship Program** - collaboration with local job agency for vulnerable communities - provide mentorship, seasonal jobs, short-term contract, and apprenticeship in urban forestry

*WTI was not housed within Tower Hill Botanic Garden until later.

Figure 4-14. Case studies comparison

necessary to remove and replant new and healthy ones. That being said, the intention of this research is not to encourage tree removal, and any tree removal should not be arbitrary. Instead, I am advocating for more education and financial assistance for low-income and communities of color to demystify any misconception about cutting down pest-infested trees and replacing them with a new one so that they can make decisions based on an accurate assessment with transparency.

A study investigating the motivation for tree removal in Ontario, Canada, has found that the most common reason for removal is poor tree health, which can be caused by negligent care and pest invasion (Conway, 2016). Pest-infested trees also have to be dealt with quickly and properly either through treatment or removal to prevent further spread, but they should also be replaced with new diverse trees to not only restore the environment but also safeguard the communities. Typically, for people who are not experts in the field, a lack of knowledge about trees and pests may impact the understanding of timely treatment and removal, not to mention additional challenges to engagement with communities of color for various reasons. In the case of Detroit, trees that were left standing or removed were never replaced due to lack of funding in the urban forestry department, leading to a generation of communities of color growing up without trees and not knowing about what having trees are like (Changing the Heritage Narrative: Detroit, MI, n.d.). Cases like these explain why assistance with the tree removal and replacement process is extra essential and helpful. In the case of Austin and Sacramento, free tree removal paired with free tree giveaway removes the financial barriers that many people of color are facing, while educational sessions and assistance with proper maintenance skills for the first two years increase the chances of tree survival.

The handling of wood after tree removal should also be emphasized and investigated as part of the pest readiness framework to be prepared for potential large-scale removal of trees in case it happens. The cases I included don't examine the recycling of wood closely after infestation, but the STEP program led by SacTree mentions recycling wood through the Urban Wood Rescue program as part of the process for even pest-infested wood to be adequately reused without creating more risks. Protocols like this should be developed for Seattle. It is important to make the process clear and transparent so that people can understand the necessity of removal with good intentions and guarantee replacement with new trees with diversity, like in Worcester.

4.3.2 Key Engagement Practices and Environmental Justice Consideration

I further cross-referenced the findings from the case studies to develop key practices for equitable community engagement processes and constructed the framework with general guidelines. The case studies reveal a need to address low participation from underserved communities, especially for volunteer and community science programs, which requires special considerations if the goal is to undertake equitable and inclusionary practices. One key finding from this research is that because of historical exclusion from key decision-making processes and a history of systemic racism, disadvantaged communities have come to feel alienated from environmental efforts and are less active in city-led initiatives. Acknowledging the negative memories and emotions associated with environmental and social changes during the engagement process can be the key to establishing a mutual understanding of pressing needs and concerns and selecting the right way to address the issues.

From the synthesis of findings, specific engagement practices and environmental justice considerations were generated in Figure 4-13. The practices are by no means directly applicable to certain situations of pest infestation but more as guidelines to consider when working on constructing actual programs.

The five key community engagement practices were borrowed from the long-term study on the "community-based control of invasive species" in Australia, which suggest how to truly achieve engagement and empowerment (Martin et al., 2019, p. 99). The practices highlight the importance of local experiences and ask practitioners to take a step back for stakeholders to express their concerns and decide long-term sustainable actions collaboratively. The practices capture the principles of community engagement and acknowledge the power of stakeholders, but they didn't quite address the effects of systemic racism that result in historical inequality, thereby creating barriers of mistrust and misunderstandings on issues like trees.

Combining with lessons from case studies, this synthesis intends to add to the framework with an emphasis on environmental justice considerations that the City should employ, which focus on investing in perspectives from people of color and inclusion in the decision-making process. SacTree's NeighborWoods community action toolkit provides a good model for community leaders to follow through. I consider as an excellent way to illustrate and connect to the environmental justice practices generated from the cases.

SYNTHESIS

KEY ENGAGMENT PRACTICES

Literature Review

(Martin et al., 2019)

Reflection & continous learning of socio-political dynamics behind invasive species management

Building relationship & trust between stakeholders and the government

Sharing power:
- Become the facilitator for collaboration
- Discard the expert mindset

Collaboratively choosing metrics for success

Conducting action research that focuses on socially-constructed knowledge, including systemative cycles of action & reflection

ENVIRONMENTAL JUSTICE PRACTICES

Case Studies + Interview

Value community time and knowledge as resources you need to pay for

Address mistrust and establish collborative environment

(Carmichael & McDonough, 2019)

- Allow community to determine agenda
- Value lived experience: community perspective and skills

- Establish appropriate goals with response to community pressing needs & concerns
- Situate the issue with what the communities are experiencing and develop creative solutions
- Achieve multiple goals at once

Improve responsiveness and consistency of community engagement practices through constant evaluation

(Schuitema & Bergstad, 2018)

SacTree NEIGHBORWOODS COMMUNITY ACTION TOOLKIT

(Sacramento Tree Foundation, 2020)

1. Gather community
2. Determine needs and assets
*Develop community asset map
3. Pick a project
4. Make a plan
5. Market the project
6. Organize an event
7. Celebrate success
8. Plan for the future

Figure 4-15. Guiding principles for pest readiness community engagement framework

The environmental justice practices are outlined in Figure 4-13, which focused on the following aspects. First, the community's knowledge and culture should never be taken for granted. Systemic racism and decades of disinvestment have put communities of color in disadvantaged positions. After being undervalued and ignored in the decision-making process of urban forestry, perspectives from communities of color are resources that require investment and uplifting. Second, communities of color may view trees differently than white culture, especially for trees with cultural significance. For people who speak different languages, translations of materials and programs may be required. Cultural diversity needs to be respected and supported to create an inclusive environment in planting, stewardship, and removal. Third, communities of color often have more pressing needs and concerns that may seem irrelevant to trees, but finding creative ways to adapt to these issues by coming with an offer to listen and support community initiatives can be valuable to establish long-term relationships. For example, the processes of planting, managing, and removing trees are not only ways that people can engage with the land and create more connections to it but also can provide job opportunities and increase social capital. Lastly, there is no simple solution that works forever, even for the same community. Constant re-evaluation and learning will be needed for future endeavors to keep up with potential changes and long-term relationships.

5 PEST READINESS COMMUNITY ENGAGEMENT FRAMEWORK

5.0 Seattle's Profile

Although the programs discussed in the case studies all seem to be at a relatively large scale and require a lot of effort and coordination, dividing them into stages of pest infestation is easier to organize. This would further support the stewardship network and coordinated programs that Seattle already has successfully in place. It is just a matter of orienting, strengthening, and optimizing the programs to build pest readiness and support long-term urban forest social and ecological resilience.

Within the City of Seattle, there are currently two main engagement programs in place, Trees for Seattle and Green Seattle Partnership (GSP). These programs lead the stewardship and engagement around urban forestry, but many other organizations are based in communities with neighborhood connections that can be tapped. The Trees for Seattle program is an interdepartmental program at the City of Seattle that engages the public in urban forestry efforts, which is established under Seattle's 2007 Urban Forest Management Plan with the goal to achieve 30% of tree canopy cover by 2037. The program conveys the message from all city departments related to urban forestry, such as the Seattle Public Utilities (SPU), Seattle Department of Transportation (SDOT), Seattle City Light (SCL), Seattle Parks and Recreation (SPR), etc. The program also receives public inquiries and directs them to the right entity. The program specifically focuses on engaging with people on private properties through two programs, the Tree Ambassador Program and the Trees for Neighborhood Program. The Tree Ambassador Program comprises hosting Tree Walks created by volunteers and community organizations, which foster education and appreciation for trees and support volunteer stewardship events to care for trees on public property. The Trees for Neighborhoods program supports residents in Seattle in planting free trees on their properties to increase healthy canopy cover. Both programs show the potential to support pest readiness efforts through initiating and assisting with public engagement, but it is hard with the current scope of the program and limited capacity.

Through working for the Trees for Neighborhoods Program as an intern, I was able to understand and navigate the complexity and dynamics of these different urban forestry departments, which have different responsibilities and scopes of work. I further organized a visual guide to show the organizational framework for the public to understand easily, which will be explained in detail in Section 5.5.1.

I found it valuable to engage the public with these stewardship and learning opportunities. Trees for Seattle Program also works with the Green Seattle Partnership (GSP) on engagement around the urban forest, a partnership between Seattle Parks and Recreation, Forterra, and community organizations. GSP has more frequently worked with communities to listen to their perspectives and organize stewardship events because they have a bigger funding source and therefore more staff to support the program. They have established a good model for establishing good relationships that leads to sustainable stewardship efforts, but their scope only includes forested parks. Despite the outreach efforts through in-person events, newsletters, and social media, people often reach out to the Trees for Seattle Program through email, hoping to know how they can help protect our urban forest through volunteer efforts. It's not because the engagement methods are not diverse enough, but more because people don't know where to find opportunities, and they just start to ask people who may know the best, like the staff at the Trees for Seattle Program. However, the process usually takes some time and labor to respond based on their individual needs, which is inefficient.

A study that compared Seattle's and Baltimore's stewardship networks based on STEW-MAP data reveals that a strong stewardship network does exist in Seattle and mainly concentrates on urban forestry and restoration. This speaks to the potential of utilizing the partnerships to raise public awareness through direct engagement opportunities (Romolini et al., 2016). The model like GSP with collaboration from community organizations can be applied to many other efforts related to the urban forest, such as the management of street trees, public properties like schools, and potentially private properties like local businesses, especially for pest readiness efforts. Consolidating the partnerships and establishing a stewardship network database can be valuable resources for communities and individuals to self-select the opportunities and level of engagement that they want. Projects like STEW-MAP also can facilitate more partnerships and amplify the voices and efforts of organizations that mainly serve communities of color.

However, the STEW-MAP for Seattle was last updated in 2013, and when I visited the website trying to access the data, it wasn't directly available to the public without a formal request. Due to time limitations, I didn't pursue this but instead created a map of stewardship networks based on my understanding and knowledge from my internship at Trees for Seattle. I created this as a way to offer suggestions to start,

which is explained in more detail in Section 5.5.2.

Making the stewardship and learning opportunities available and transparent for volunteers to self-match their interests, commitment, and ability can be helpful to facilitate a socio-ecological stewardship system and help elevate the efforts of small community-based organizations that are based in communities of color so that they can receive more resources to start community initiative in leading urban forestry efforts that help prepare for invasive pests.

5.1 Framework Overview

With the debut of the Urban Forest Pest Readiness Playbook, Seattle became one of the first municipalities to employ the assessment of current capacity and apply it to actual use. This has the potential to set an example for the rest of the municipalities in Washington State. Building from their effort, I developed a community engagement framework to emphasize the role that communities can play in getting ready for potential pest invasion.

As shown in Figure 5-1, the proposed framework consists of four parts: 1) goals and priorities, 2) key actions, 3) potential activities, and 4) recommendations and resources for education and engagement. Starting with goals and priorities, the framework will guide engagement that raises public awareness and empowers people with the skills and knowledge to deal with pest invasion. Because pest readiness for urban forests involves every aspect of the tree growth, from planting to removal, which also corresponds to stages of pest infestation responses, the proposed comprehensive framework outlines the key actions to take for each stakeholder and emphasizes partnership and collaboration across all scales. Potential activities are provided as examples of how these key actions can take form. The specific recommendations and resources are constructed as examples of demonstration that hopefully the City can adopt in their work.

5.2 Goals and Priorities

The goals and priorities of the proposed framework intend to address the lessons from the case studies and make sure communities of color are always included in the decision-making process. At the first few community engagement meetings, it is critical to begin by identifying the common barriers to engaging in environmental activities and articulating general goals and priorities. This will ensure that the pest readiness program is relevant from the community's perspective so that the effort is not just focusing on the city's agenda.

The goals and priorities listed in the first part of Figure 5-1 are provided as suggestions based on findings from the case studies. The goals are arranged based on the levels of priority as identified in this research. Findings from the case studies show that addressing the barriers of systemic racism and providing career pathways and economic opportunities are pressing needs and concerns that communities care about the most. I list them as the highest priorities because they can be used to gather initial interests from communities of color that normally don't connect these goals with urban forestry efforts. Building community cohesion and improving the environment through urban forestry work are the second and third goals of the engagement work because these are often widely understood as the benefits of trees and urban forestry work.

Yet, it is imperative to determine the goals and priorities with specific vulnerable communities to see how the barriers of systemic racism, lack of career pathways, and economic opportunities manifest in their lives. Although urban forestry work cannot completely address these barriers, open and honest discussions can facilitate urban forestry pest readiness practices to become more inclusive and equitable by accommodating their concerns and providing direct engagement opportunities like jobs. If, in the initial engagement process, the communities decide that these strategies are appropriate and valuable for subsequent educational and stewardship efforts, they can be used to guide people throughout the pest preparedness process and continuous urban forestry efforts. The framework defines and provides examples of how the goals can be accomplished through urban forestry and contribute to pest readiness efforts in stages through key actions and potential activities. This will be explained in the following two sections.

5.3 Key Actions

Building on the findings from the literature review and case studies, the key actions in the proposed framework are developed with strategies to deal with pest invasion in phases. The actions are further divided into different scales: the city, the community, and the individual. The synergies among these levels are also emphasized with overlapping actions to indicate that these actions require coordination and partnership to accomplish. The actions further manifest in the form of potential activities suggested in the next section.

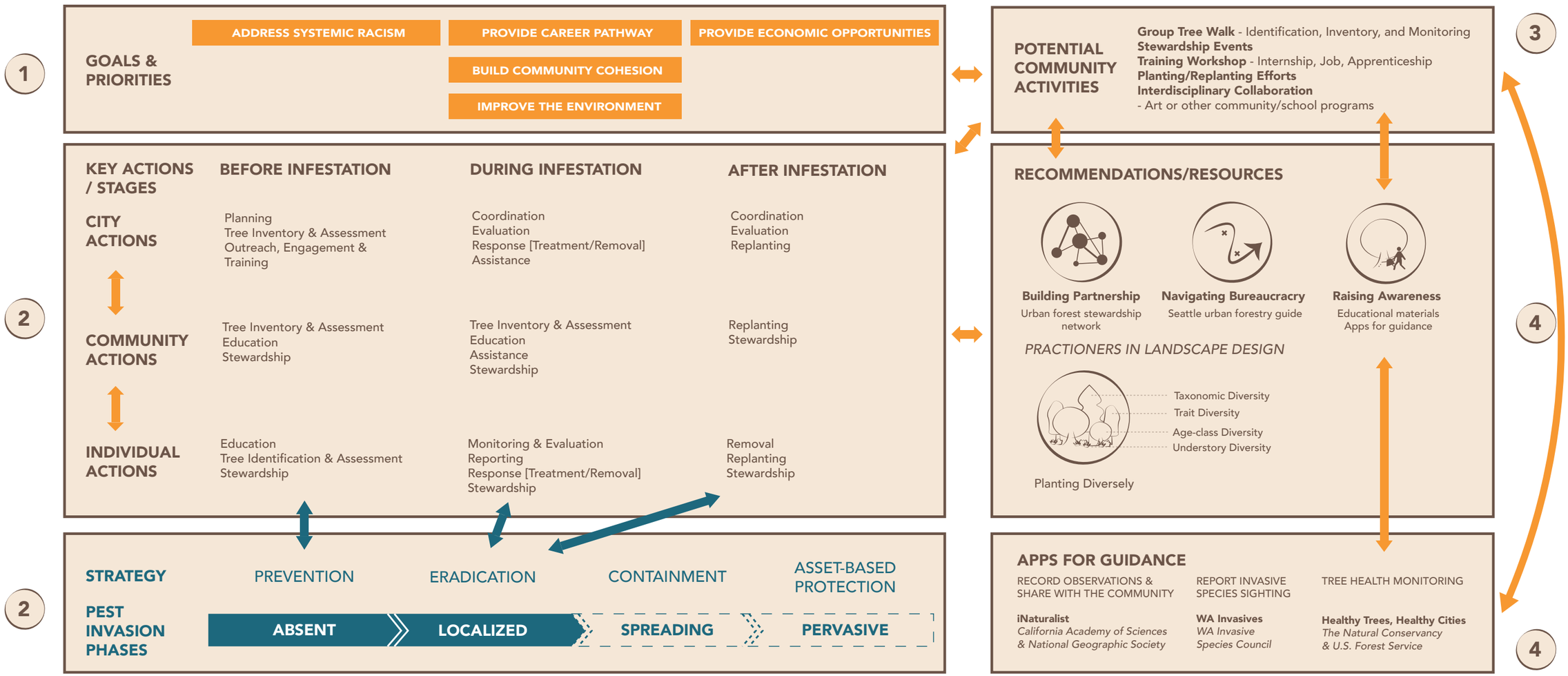


Figure 5-1. The proposed pest readiness community engagement framework

5.4 Potential Activities

As listed in the third part of Figure 5-1, the potential activities for communities of color to engage in urban forestry were generated from successful cases and can be adapted to achieve multiple goals depending on community needs. For example, group tree walks that focus on tree identification could be a way to build community cohesion, increase youth exposure to environmental concepts, and increase physical activities. Currently, Trees for Seattle's Tree Walk project only focuses on honing tree identification skills and developing an appreciation for trees through narratives on a neighborhood scale, but the project has the potential to be expanded to inventory and monitor trees for pest readiness for both educational and practical purposes. Second, stewardship events are crucial to maintaining the health of trees, which are also excellent opportunities for people to connect with the land and learn about restoration. Third, planting and

replanting efforts after pest invasion can be supported by city-wide and local planting efforts. The planting effort should be accompanied by training workshops and continuous maintenance through stewardship, whether through physical or financial assistance and consistent follow-up. The Trees for Neighborhoods Program hosts yearly events to give away free trees with workshops and assistance within the first five years to help trees get established. While the Trees for Neighborhoods Program established a great model for planting efforts, it is hard to say about other planting programs with less funding and staff for consistent efforts. Nonetheless, planting efforts can be combined with engagement and educational opportunities. DIRTCorps, a community-based environmental organization that mainly serves the South Seattle communities, utilizes planting programs as opportunities for youth in communities of color to engage in the urban forestry field. In addition, the only thing that may be missing in the current urban forest structure in Seattle is the support and assistance with the removal of declining trees for communities of color who may have difficulties. As indicated by the case studies, this is a possible issue that communities are facing, which will require developing protocols or programs to address. Meanwhile, the city and community organizations should support paid internships, training, and apprenticeships for all of the community activities. These activities can provide knowledge, skills, and living wages, and give BIPOC communities agency to care for trees in their neighborhood for better health. Offering opportunities for more BIPOC to lead in the urban forestry field is also critical to elevate BIPOC voices and reshape urban forestry programs.

Lastly, innovative ways and interdisciplinary collaborations, like engaging with art institutions, can provide a creative and powerful outlet for expressing dismay, fear, and hope in the engagement process. It may be hard to visualize the impact of potential pest invasion because some pests just haven't gotten here yet, and it is hard to comprehend the damage without experiencing it first. Potentially public art or artificial technology can help with the engagement process. Collaborating with local high schools or universities can give students a chance to contribute and become stewards of the urban forests, which also fits their exploratory habit at this age.

In summary, community engagement of pest readiness efforts manifest in every aspect of urban forestry work and community activities can be a powerful way to engage people in practice. Although having a new community science program dedicated to pest detection and monitoring may be good, much work from various urban forestry organizations and community-based groups has been ongoing and can be reinforced to support pest readiness efforts. Fitting the activities to communities' needs and strengthening the message for getting ready for pests will be critical for success.

5.5 Recommendation and Resources

A critical start is for city representatives and community members to work together and build partnerships and social networks. Findings show that community environmental networks do exist but are not often recognized by city agencies as resources. Yet, they can be powerful partners. This project attempts to visualize social networks through archival research as an introductory resource for people to start engaging in environmental efforts. Resources to navigate bureaucracy are also offered to address the complexity of urban forestry departments. Finally, landscape design must emphasize diversity not only for aesthetics and biodiversity but also for building landscape resilience when facing sudden attacks of invasive pests and long-term climate change impacts. (See Appendix B for more resources such as a report on funding trees for health produced by the Nature Conservancy and the Trust for Public Land, as well as SacTree's Community Action Toolkit)

5.5.1 Seattle Urban Forestry Guide

The idea for developing the guide originates from my experience in the Trees for Seattle Program. At first, the number and diversity of departments related to urban forestry in the city are disorienting because each department is responsible for different parts of the urban forest. I created a visual guide (Figure 5-2) with the intention to call out the city agencies managing the urban forest. The departments are further arranged based on the scale of their management. This visual guide shows the strongly supported urban forestry system in Seattle and lets people know who to reach out to with questions about a particular place.

5.5.2 Stewardship Network

The stewardship network was constructed based on my limited understanding. I found out about the environmental organizations listed in Figure 5-3 through shadowing a GSP internal public engagement committee meeting and reviewing the GSP website, so the organizations presented have partnered with the GSP in some way and between themselves as well. However, I didn't want to presume these connections, so I didn't add lines in Figure 5-3 that would suggest direct connections.

RECOMMENDATION FOR THE CITY:
Streamline City Urban Forest Department responsibilities

(2020 Urban Forest Management Plan DRAFT, 2020)

Office of Planning & Community Development (OPCD) — Boarder policy for Seattle's comprehensive plan

Office of Sustainability & Environment (OSE) **Urban Forestry Commission** — Urban forest policy development & coordination

BOARDER

SCALE

NARROWER

STREET TREES

Seattle City Light (SCL)
Trees near powerlines

Seattle Department of Transportation (SDOT)
Trees on right-of-way

PUBLIC PROPERTIES

Seattle Parks & Recreation (SPR)
Trees in parks **Green Seattle Partnership (GSP)**

OR

Seattle Public Utilities (SPU)
Stormwater/water related land/facilities

PRIVATE PROPERTIES

Trees for Seattle program (in SPU)
Outreach and engagement

Seattle Dept. of Construction & Inspections (SDCI)
Permit regulation & enforcement

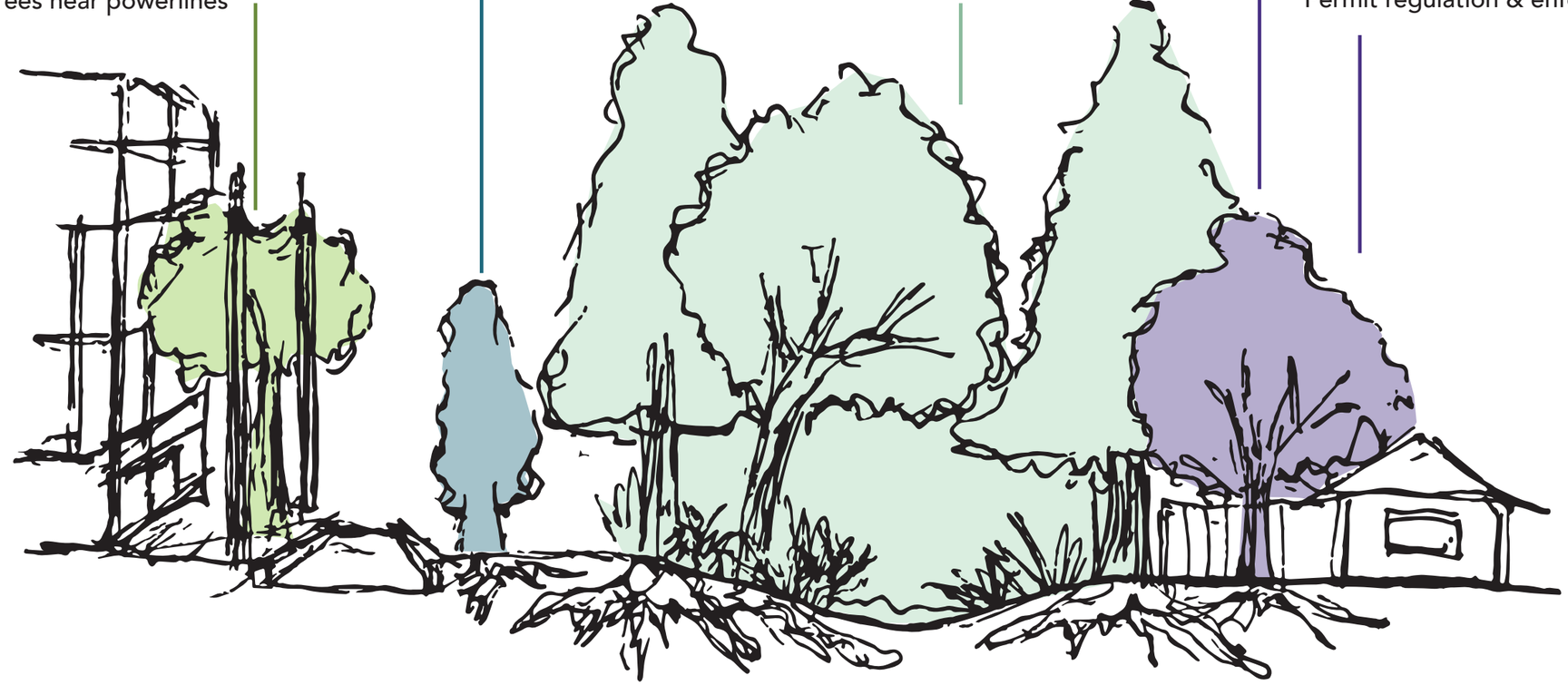


Figure 5-2. The City of Seattle urban forestry-related departments guide

The categories of stewardship, education, and advocacy were chosen from the New York STEW-MAP project (Landau et al., 2019). I determined the category for each organization based on archival research of the "About us" page in their websites, where they introduced their mission. Stewardship includes restoration and monitoring, such as weeding and tree inventory. Education focuses on teaching environmental science concepts, planting and restoration techniques, etc. Advocacy work consists of advocating for environmental justice and environmental policies. All the organizations belong to one or more categories, which have the potential to support pest readiness work. Many of them are based in neighborhoods with a high ratio of BIPOC communities or focus on serving BIPOC communities and providing stipends or living wages for them to get involved in the urban forestry work. Opportunities like these can attract more people and introduce them to the urban forestry field. I also chose to highlight youth programs in the network because these are often educational and training opportunities for youth to get an early start in the environmental field, and they are the future. Programs and organizations like these should be uplifted through partnerships to increase the capacity for pest readiness because they are often at the forefront of engaging with vulnerable communities.

The map is arranged on a spectrum from neighborhood scale to national scale, showcasing the diversity of work and opportunities for partnership. The organizations listed here do not work about urban forestry, and some are not even in the environmental field. At the neighborhood level, the types of organizations are more diverse, serving the different needs of the communities. For example, ECOSS serves small BIPOC businesses and BIPOC residents and teaches them sustainable practices, like recycling and stormwater pollution prevention, while Partnership in Employment mainly provides job opportunities for refugees and immigrants ("About Us," n.d.; ECOSS - Sustainable Solutions for All, n.d.). These community-based organizations tend to have stronger relationships with the communities and stakeholders and therefore form the partnership for urban forestry efforts can reach diverse people. It is important to note that across the spectrum, each organization has a different capacity. Regional and national organizations may have more funding and capacity to host bigger events, but they don't have relationships with communities and especially BIPOC communities. Establishing partnership across the spectrum is necessary to attend to BIPOC communities. A detailed investigation is needed to make sure the partnerships are diverse and don't overwhelm a particular entity.

5.5.3 Educational Materials

Working with the Trees for Seattle Program lead Ali Lakehart, program manager Lou Stubecki, and SDOT arborist and expert in invasive pest management Stephanie Helms, I helped develop actionable steps to detect, identify, and report invasive pests, along with educational materials for pests in concern for the general public.

Tree Pest Action Guide

The guide for actionable steps is for individuals who have questions about what is happening to their trees so that they can learn about what actions they should take to deal with the problem. The steps are described below and will be included on the Trees for Seattle's webpage. Note that the actual wording of the steps may be different from the final version on the website because this thesis is finalized before the webpage content is published. The descriptions I provide below are explanations for this thesis, not for the city's website.

1. Identify your tree

Tree identification can help narrow down the potential problems with pests based on documented susceptibility.

2. Pay attention to symptoms of trees in stress

Abnormal defoliation and canopy loss can be symptoms of trees in stress, which can be caused by pest infestation or other factors like drought, soil compaction, or root damage. More monitoring will be needed to determine the actual cause. However, stressed trees may be more vulnerable to pest invasion and also require more attention and care.

3. Look for signs of invasive insects or disease

The signs of pest infestation may manifest on the leaves or inside the bark, which can be hard to identify. In this case, it is good to seek help from certified arborists on the website of the International Society of Arboriculture (ISA) to inspect your tree. Experts in local organizations or schools like the University of Washington Botanic Gardens and Washington State University Extension may be able to help as well.

4. Monitor your tree for the extent of damage

Not all insects are invasive, and sometimes they won't do much damage to the tree. Before you get alarmed by specific symptoms, you should continue to monitor the extent of damage and take action if the situation worsens.

5. Report sighting and seek help

RECOMMENDATION FOR THE CITY:
Build Partnerships + Mapping Urban Forest Stewardship Network

LEGEND
- Youth Program Available
- Stewardship
- Education
- Advocacy

COMMUNITY-BASED ENVIRONMENTAL ORGANIZATIONS

- Delridge Neighborhood Development Association (DNDA)
- DIRTCorps - Duwamish Infrastructure Restoration Training
- Duwamish River Cleanup Coalition (DRCC)
- GotGreen
- Partner in Employment
- Na'ah Illahee Fund
- Front & Centered
- ECOSS

CITY-WIDE ORGANIZATIONS

- Green Seattle Partnership
- Plant Amnesty
- UW Botanic Garden
- YMCA Earth Service Corps (YESC)

REGIONAL ORGANIZATIONS

- Forterra
- Forest Health Watch
- Nature Vision
- Sierra Club WA
- Student Conservation Association (SCA)
- Sustainability Ambassador
- Puget Sound Sage

NATIONAL ORGANIZATIONS

- The Nature Conservancy
- EarthCorps
- Trust for Public Land
- Washington building leaders of change (WA-BLOC)
- Washington Environmental Council (WEC)

Figure 5-3. Stewardship network

If you find signs and evidence of pest invasion, you should record these, seek help from ISA arborists, and alert the authorities so that they can deal with it properly and timely to prevent further spread of the pests. You should also submit a report to Washington Invasive Species Council (WISC) and Seattle urban forestry departments through phone, email, or the WA Invasives app. More information on how to submit a report to WISC is listed in Appendix B. The actual contacts for reporting to urban forestry departments in Seattle should reference the upcoming Tree Pest webpage on Trees for Seattle's website.

Educational infographics of pests

The educational materials for pests are infographics that contain information about susceptible trees, the currently affected states, insect life cycles, and potential signs or symptoms that warrant caution. Developed based on scientific research on pests from the USDA and various university extensions, the infographics provide some basic guidelines for identifying pests visually that are easy for people to understand. Figure 5-4 shows one example of the infographic for emerald ash borer. The rest of the infographics developed for each pest of concern are included in Appendix A and will be published on Trees for Seattle's Tree Pests webpage as resources, along with additional links as detailed resources to learn more about the pests and their potential impacts on trees.

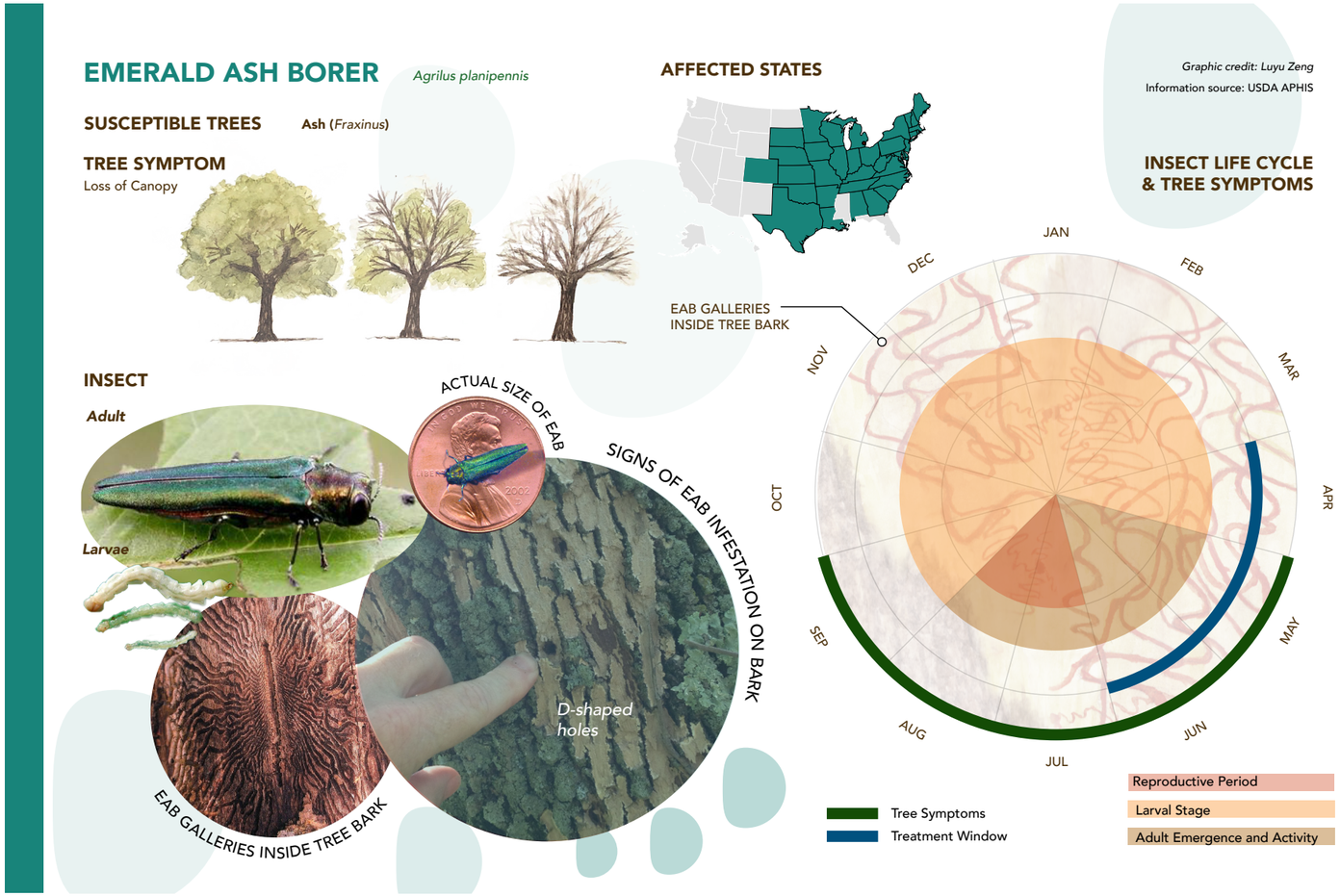


Figure 5-4. Infographic about emerald ash borer

Self-guided Apps

In addition, I also make a recommendation for some self-guided apps for people who use their mobile phones to learn more about their trees and report signs of pest infestation. As shown in Figure 5-5, the apps are virtual platforms to engage and learn about trees and other creatures in the natural world, which would be useful for both tree and pest identification. Anyone using these apps for uploading data and observations can contribute to scientific research as a community scientist with proper privacy protection. The use of these apps can lead to timely detection and response to pests. For example, Forest Health Watch, an initiative that started recently in Washington state, launched their pilot project to study western redcedar dieback by calling for community scientists to record observations on iNaturalist and analyzing their data to figure out the reasons for their decline (Forest Health Watch, n.d.). Developed by prominent and credible regional organizations and agencies, the apps provide easy access to reliable knowledge and facts for scientific documentation and explorations that are open for everyone to access with proper privacy protection. These apps can serve as self-guided tools and can complement in-person events and maximize learning. The apps are relatively easy to use and are nice resources for

reference, but for people who may not be savvy about using smartphones, assistance can be provided during events or use the educational materials mentioned previously.

Due to the scope of work for this thesis, I didn't focus much energy on detailed, actionable changes to prevent the introduction of invasive pests. However, there are many good outreach campaigns like *Don't Move Firewood* and *Play Clean Go* on the national level that are dedicated to educating people around simple behavioral changes they can make to prevent pest invasions. The links to more details about these campaigns are included in Appendix B (Resources).

5.6 Application of the Framework

Currently, the framework I propose in this project is designed for Seattle based on my familiarity with Seattle's urban forestry organization and specific spatial analysis for assessing risks that invasive pests pose for the city. To apply it to other cities in Washington state, more assessment on the current condition and potential risk of the urban forest and the foundation of the urban forestry network is needed. Forterra's Green Cities Program covers many cities in Washington state, and in these efforts, they have partnered with "local non-profits, community groups, city agencies, neighborhood leaders and local businesses" to form Green City Partnerships and steward the urban forest ("Green City Partnerships Restore Urban Forests," n.d.). The Green City Partnerships can be expanded and support pest readiness efforts when adapted to other cities in Washington state.

There are some challenges for cities outside of Washington state to apply this framework because of the differences in context. First, other states may not have guidance for

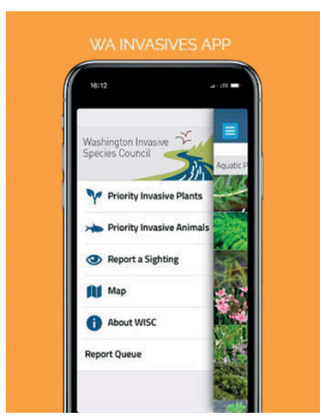
RECOMMENDATION FOR COMMUNITY MEMBERS
Ways to engage and learn

APPS

iNaturalist
California Academy of Sciences & National Geographic Society

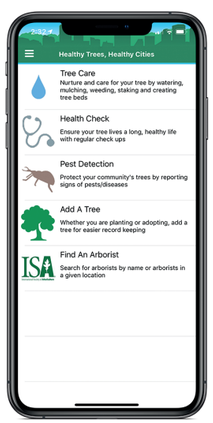
RECORD OBSERVATIONS & SHARE WITH THE COMMUNITY

Available in 16 different languages



WA Invasives
WA Invasive Species Council

REPORT INVASIVE SPECIES SIGHTING



Healthy Trees, Healthy Cities
The Natural Conservancy & U.S. Forest Service

TREE HEALTH MONITORING

Figure 5-5. Self-guided apps for stewardship: iNaturalist, WA Invasives, and Healthy Trees, Healthy Cities

municipality self-assessment, like the Urban Forest Pest Readiness Playbook, making it hard to make a case for government policy to consider it a threat. Second, the pests in concern in other parts of the state may differ due to differences in climate and weather. In some instances, pest concerns may not justify a comprehensive response. Third, the organizations of urban forestry departments in other parts of the state may be distinct. There may not be a coalition of supportive stewardship networks, which pose challenges for applying the framework.

To sum up, the proposed community engagement framework suggests goals, actions, potential activities, and resources that center community needs and concerns and support pest readiness efforts. The actual application of this framework will require a detailed investigation of existing city urban forestry efforts and social stewardship system as a foundation to apply this framework effectively.

6 IMPLICATIONS, LIMITATIONS, AND CONCLUSION

6.1 Implications

Because pest issues can be complex and the solution is closely related to all sensitive aspects of urban forestry, tree maintenance, removal, and replanting, any sound pest readiness community engagement framework requires a comprehensive approach. Such an approach is necessary to understand and address disadvantaged communities' needs and concerns in order to achieve true equity and inclusiveness. The implications for this community engagement framework are discussed in regard to urban forest departments in the City of Seattle and landscape designers in general.

6.1.1 Implications for the city

The city should prioritize diversity to ensure long-term urban forest resilience and express this through management and regulations. Different pests may require different strategies and efforts for engagement because some pests, like DED and EAB, are specialists, meaning that they only feed on trees in a particular genus, while others, such as ALB and winter moth, are generalists that can endanger a wide range of trees. However, the problem should not be reduced to simply avoiding using certain tree species because it is hard to predict when and what new pests will show up with the changing climate. In addition, it may require a lot of work before scientists can truly understand the habits of pests and develop proper treatments for trees. Different regions are concerned with different pests in their geographic area, but the pests in concern also depend on the composition of the urban forest. From the case study of Austin, the interview with the manager from Parks Department showed that they are concerned about certain pest infestation like the fungus that causes oak wilt, but they are more worried about climate change and long-term resilience, which go hand in hand.

A rule of thumb for evaluating the diversity of an urban forest on a city scale is to use researcher Frank Santamour's formula, which suggests (Urban, 2008, p. 340):

- No more than 10 percent of trees from any one species.
- No more than 20 percent from any one genus.
- No more than 30 percent from any one family.

This is critical because cities that didn't follow this in the past have suffered greatly, such as Worcester, Massachusetts. In some cities in the U.S. Northeast, elm trees were unfortunately replaced with ashes and maples, which now face threats from ALB and EAB (Raupp & Gonthier, 2017). Increasing the diversity of trees in terms of species, age, traits, and understory should be prioritized in the agenda of urban forest and enforced accordingly.

6.1.2 Recommendations for the city

The pest readiness plan should include how various city departments in urban forestry can help with pest readiness outreach in their regular work. SDOT should update their recommended planting list for trees regularly and highlight information about pest susceptibility as part of the consideration. Seattle Department of Construction and Inspections (SDCI) should analyze their data to assess current composition, and then regulate and enforce diversity with a bigger view of the city when approving permits for removal and planting on private properties. In the Trees for Neighborhoods planting workshop, more information should be provided specifically about tree pests to utilize the opportunity for public education.

Currently, for management purposes, my investigation mostly focused on assessing the problem of pest invasion based on census tracts. However, pests can easily cross human-imposed boundaries and spread with human movement. This suggests that pest readiness efforts should not stay within Seattle and requires more communication and collaboration with nearby municipalities and regions to share information. For example, in the northern Seattle's boundary right next to Shoreline, there are a few vulnerable neighborhoods and the pattern will likely not just stop in the boundary. Collaborating with the Urban Forestry Department in the City of Shoreline and surrounding areas to create a system is also important to the holistic approach for pest readiness.

6.1.3 Implications for landscape designers

By writing this thesis in the landscape architecture field, I hope to generate awareness in the field around pest issues that have deep impacts on trees and our built environment. Different from other materials we frequently use, trees are living beings and adaptive systems that change. Every design in which we incorporate trees, no matter if the project is big or small, will collectively make an impact on the urban forest. Even though we often put trees in our renderings to make the designs look better, whether or not we really understand the trees we use and how they function, is a question. Collaborating with arborists can help, but in some cases, it all depends on the landscape designers.

It is important to consider designing for pest readiness not just by simply avoiding the use of certain species, but more by emphasizing the diversity of trees in terms of species, age, trait, and understory. As I mentioned in the implications for the city, there is no way to avoid using particular trees just

because they are susceptible to certain invasive pests, since some pests can attack many tree hosts (Urban, 2008). Trees in urban areas face more challenges, which also narrows down the list of suitable trees. Designing to avoid tree pests has been emphasized more after Dutch elm disease wreaked havoc on elm trees in the last century. However, in the landscape design education that I've been through, diversity is mostly emphasized for the sake of supporting biodiversity and not for climate resilience. This has only shifted in the past few decades. Avoiding using susceptible trees will only result in less available trees to use and will eventually impact the diversity of the remaining tree composition. Depending on the pests we are dealing with and the intensity of potential attack, such as EAB and ALB, following the city's guidance to slowly adjust the trees we use and aiming for diversity should be the goal for landscape design. A replacement tree list was generated by the USDA for reference to focus on trees that can not only be resistant to ALB/EAB, but also withstand harsh urban conditions (See Appendix B). The list is comprehensive with information for many conditions that should be considered during selection. It looks comprehensive but should be used with caution as some trees may not be suitable.

Aiming for tree diversity should become our work ethic because we are constantly shaping the landscape through our design. With limited knowledge, people often select trees for their aesthetic and ecological functions but they are not aware of the potential impact of their selection. Research has found that the most common motivation for planting trees in private property is for the beauty of the trees (Conway, 2016). As James Urban pointed out: "it is hard to manage the species selection of an urban forest where the majority of trees are planted on private property" and designers should "become aware of the population mix in the vicinity of their projects and refrain from using species that are already becoming too common" (Urban, 2008, p. 340). Similar concern was raised by the urban forestry program manager for the Austin Parks Department during my interview. He indicated that the urban forestry department there doesn't purchase enough trees to influence tree selection for nursery stock, but the market does. Although these problems may seem too big for landscape designers to solve, with ecological literacy and the ability to form and frame urban spaces through practice, we should take on the responsibility to consider the bigger picture for tree selection other than just focusing on the beauty of trees. Using diverse trees that vary in terms of species, trait, and understory should be emphasized both in the education and actual practice.

Research also shows how the built environment, and especially public spaces, play a big role in people's life as the common grounds for interactions and engagement. These are spaces that people socialize and are influenced subtly. So there is a lot of potential to provide learning opportunities to the public in public spaces. SacTree in Sacramento uses planting trees in public spaces, like parks and schools, to allow people to learn and experience the benefits of trees before planting one in their yard. The designs and decisions on tree selection we make for public spaces

Figure 6-1. The understory of street trees adding diversity and acting as green stormwater infrastructure

will have an impact on people's preference for their yards. Designers should rethink public spaces as the interface of public engagement and how the use of vegetation can not only be aesthetically pleasing and functional, but also become inspirational and educational opportunities.

6.2 Limitations

The findings from this thesis should be interpreted carefully with the following considerations. First of all, data for GIS analysis is limited to trees in the right-of-way, which consist of only 27% of Seattle's urban forest. Lack of tree inventory data of parks and private properties can influence the assessment of vulnerable communities because the actual proportion of certain species, genus and family can be really different and therefore increase the level of ecological vulnerability.

The typology of trees in groves in parks can also suggest higher impact due to an abundance of tree hosts. A study of ALB infestation incidents in Italy has shown that spread and infestation risk were mostly impacted by "distance of suitable hosts from the nearest infested trees" and "number of infested trees in the surroundings", which might vary from year to year (Favaro et al., 2015), indicating that the abundance of susceptible trees was an important parameter for potential invasion. In a setting where the host tree is abundant, as in Worcester, studies had found that dispersal was more intense, rapid, and extensive from the original infestation and different from other documented infestation. This suggests that the species spread out even before fully infested existing trees (Hull-Sanders et al., 2017). In Dr. Jose Rizal Park in Seattle, where the winter moth has infested trees for the past three years, the maple and apple trees in the park are all infested and suffered severely, while a similar high impact was also seen in the Beacon Hill Food Forest nearby. This suggests a higher impact in clusters of susceptible trees.

This finding is also linked to my second limitation around the GIS analysis. The assessment on ecological vulnerability lacks consideration of pest dynamics and preference, which can also change overall vulnerability. Further research is needed to assess whether certain tree typologies present a higher risk for pest infestation in terms of speed of spread compared to others, and what that means for a pest-resilient planting design.

Also, the ecological vulnerability assessment was not performed using tree health data because it is not available. The analysis of stressed trees can be important in that it can help indicate the degree of vulnerability to invasive pests, which can often attack and quickly kill stressed trees. Such an analysis can also guide the distribution of resources to support good tree stewardship. To sum up, for ecological vulnerability assessment, a complete tree inventory and detailed assessment are needed to accurately guide the engagement efforts.

Second, for the social vulnerability analysis, the dataset of racial and social equity index didn't consider population density as a factor of disadvantage (City of Seattle Office of Planning & Community Development, 2020). However, frequent human movement can facilitate the spread of tree pests through moving firewood that contain pests to somewhere else or stepping on pest-infested soils and not cleaning the shoes after the visit and thereby infecting new areas. At the same time, trees in crowded areas are extra important because they will serve a lot of people. Detailed research will be needed to address the potential influence of population density on ecological and social vulnerabilities.

For the case studies I conducted, it was hard to determine the effectiveness of community engagement methods because there is no universal standard for evaluation. The effectiveness of these methods will depend on the actual application and approach. The thesis is also limited because there was no direct engagement to understand specific community concerns and needs related to trees and pest issues. Quantitative data doesn't tell the full story and actual community engagement is needed to incorporate people's lived experience and stories to inform effective pest management programs. Actual engagement is also needed to resolve any historical misunderstandings, if there are any, to earn trust, and to establish long-term relationships.

Lastly, in the proposed community engagement framework, the stewardship map is only shown as a demonstration. The map serves as a guide and emphasizes the need to value and establish actual relationships with non-profit and community-based organizations. The data gathered from the websites of the organizations and assigned are based on my personal understanding within a limited timeframe. The organizations themselves may have a different opinion of their responsibilities that I am not aware of. Future research is needed to develop the database and visualize the network through outreach on a bigger scale. The details of the community engagement framework should be interpreted with caution because it will not be directly applicable to other cities because of the differences in geographic area, the characteristics of pests in concern, and urban forestry organizations. The planning of outreach and engagement should depend on the city's capacity and local environmental stewardship network.

6.3 Conclusions

Using pest readiness as one aspect of climate change adaptation, the research also indicates a need to address the potential threat of pest issues that goes beyond simply avoiding using the specific trees in design. Increasing functional diversity in planting design for pest resilience and climate adaptation should be incorporated into design regulations and policies for building resilience. In addition, dedicating resources and time for engaging with vulnerable communities should be prioritized in the decision-making process.

This research synthesizes the ongoing discourse of environmental justice and inclusive community engagement practices through case studies, literature review, and archival research. The disparities of concerns and needs differ with diverse groups in different cities and neighborhoods, and therefore require further development of partnerships to understand the problem and build trust with communities. Different situations also demand creative solutions that should be determined by the communities. The proposed community engagement framework that emerged from this research could become the first guide to provide resources for larger engagement processes. Although the pest readiness engagement framework is specifically constructed for Seattle, the principles of environmental justice practices are universal and applicable to engagement about pest readiness for other cities in Washington state with thorough assessment.

6.4 Reflections

Over the course of this research, I found myself in the constant struggle due to the way I intend to address trees as a subject. Personally, I consider trees as living beings with spirits, while in the work and in other people's opinion, trees are considered as infrastructure and assets. The concept of ecosystem services further objectifies trees. However, it is hard for me to make a convincing argument without speaking the language of money and quantifying their so-called benefits for human's sake. Unfortunately, despite my will, my intentions still fall into the same trap that I aim to avoid.

As I have emphasized from the start of this thesis, the issue with invasive pests is also bigger than just the ecology of trees but also has to do with social and cultural systems, but what is important to remember is that inequalities among communities are largely due to colonization and globalization, which are bigger topics outside my scope of work yet important to recognize. Whether intentionally or unintentionally, the decisions we make, as practitioners in urban forestry or landscape design, may come with unexpected consequences despite our good will. It is important to recognize and acknowledge this in our work and be constantly reflective both internally but also in the community engagement process so that we can all learn from challenges and failure of the past and jump out of the loophole of assumption.

As one example, I can't help but also connect pests and disease on trees to the pandemic that we are still in right now and how racism and justice intertwined with all of these. Recently, I visited an exhibition about the pandemic and racism towards Asian people in Wing Luke Museum of the Asian Pacific American Experience, where I saw a digital installation created by an Asian American artist. The digital installation showed scenes of burning cherry trees using the game Animal Crossing. The artist got the inspiration from the historic event of the USDA burning cherry trees gifted by Japan after discovering that these trees were infected with disease in 1910. The artist was suggesting that she wasn't sure this claim was legitimate or not (U.S. National Park Service, n.d.). The artist further compared this historic event with people's unfounded fear, discrimination, and attacks on Asian people recently just because China is seen as the alleged origin of COVID-19. With her digital art, the artist helped me deeply realize that in urban forestry, what we do to trees and how we communicate about it matters because it is more than trees. It has cultural and social implications, whether it connects with memories of the past or a history of resilience, that everyone and especially communities of color are sensitive to yet they are often ignored in the process. As a Chinese international student, I found this parallel of interpretation really alarming yet inspiring, because many invasive pests and sometimes invasive plants also bear names of "Asian" or "Japanese", which of course means their invasiveness in an ecological sense and not in a cultural sense. Yet I cannot help but wonder, "what if they make that connection that all invasive pests come from Asia and how come I don't think about this at all when the names like English ivy were used?" I hope I am the only one thinking about this but I know I may not be. The history of racism, exclusion, and discrimination that I've seen during my short time in the United States has made a deep impression on me, and I can only imagine what Asian Americans have been dealing with all this time. Meanings

and interpretations like this should be considered in the community engagement process for urban forestry and pest readiness to address concerns, clear up any misunderstanding, and truly work towards inclusionary and equitable practices.

Although I had to leave out the more artful part that humanized this work and showcase my skills, I am glad to be able to apply my observation and expertise that I've gained from my internship to this thesis work and contribute to equity and inclusion by proposing the community engagement framework. If this past year of being in the COVID-19 pandemic has taught me anything, it is that it takes love and care to prevent a pandemic of pest infestation from happening to the urban forest we cherish and I believe in the community-centric approach of solidarity and empowerment.

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APPENDIX

ASIAN LONGHORNED BEETLE

Anoplophora glabripennis

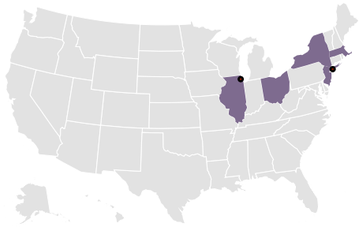
Graphic credit: Luyu Zeng

Information source: USDA APHIS

SUSCEPTIBLE TREES

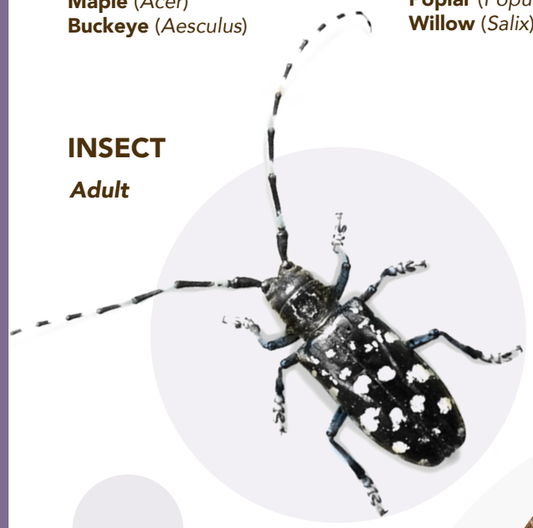
Ash (*Fraxinus*)
Elm (*Ulmus*)
Golden Raintree (*Koelreuteria*)
London Planetree (*Platanus*)
Maple (*Acer*)
Buckeye (*Aesculus*)
Katsura (*Cercidiphyllum*)
Mimosa (*Albizia*)
Mountain Ash (*Sorbus*)
Birch (*Betula*)
Poplar (*Populus*)
Willow (*Salix*)

AFFECTED STATES



INSECT

Adult



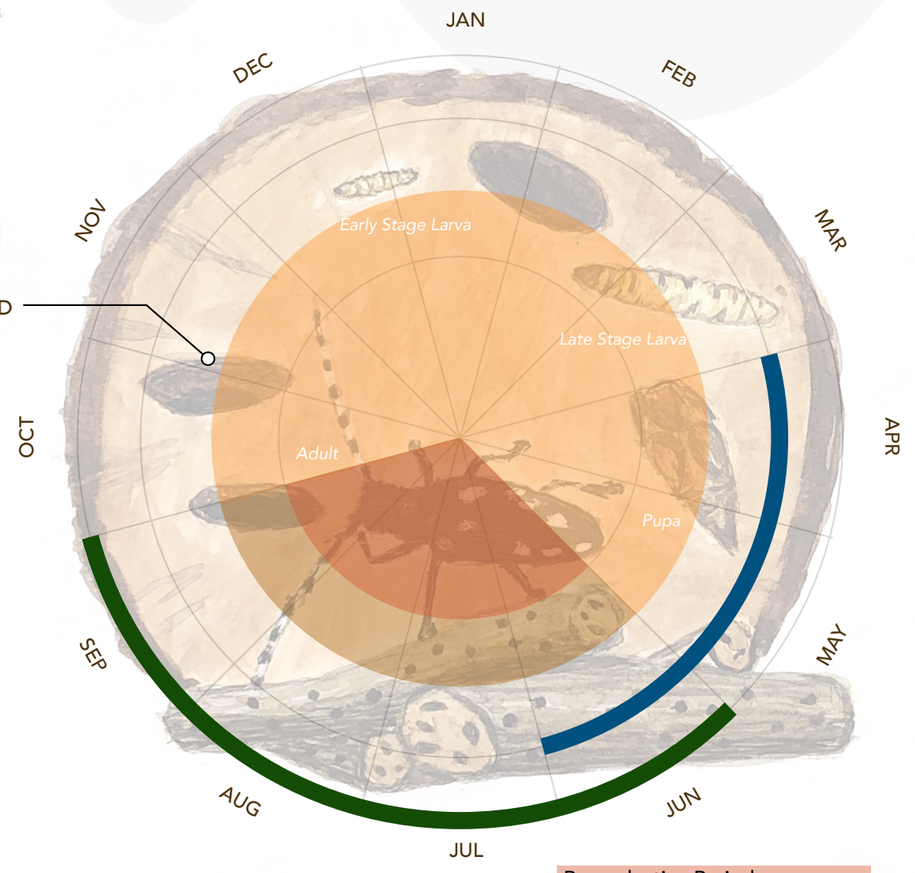
TREE SYMPTOMS

- Unusual yellowing leaves
- Branches dropping or dying

HOLES CREATED BY ALB LARVAE

SIGNS OF ALB INFESTATION ON BARK

INSECT LIFE CYCLE & TREE SYMPTOMS



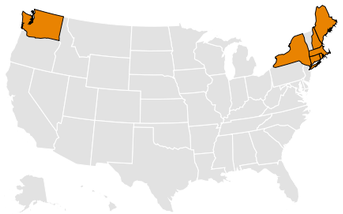
WINTER MOTH *Operophtera brumata*

SUSCEPTIBLE TREES

MOST SUSCEPTIBLE
- **Oak** (*Quercus*)
- **Maple** (*Acer*)
- **Apple** (*Malus*)

SUSCEPTIBLE
- **Ash** (*Fraxinus*)
- **Cherry** (*Prunus*)
- **Blueberry** (*Cyanococcus*)
- **Crabapple** (*Malus*)
- **Elm** (*Ulmus*)

AFFECTED STATES



INSECT

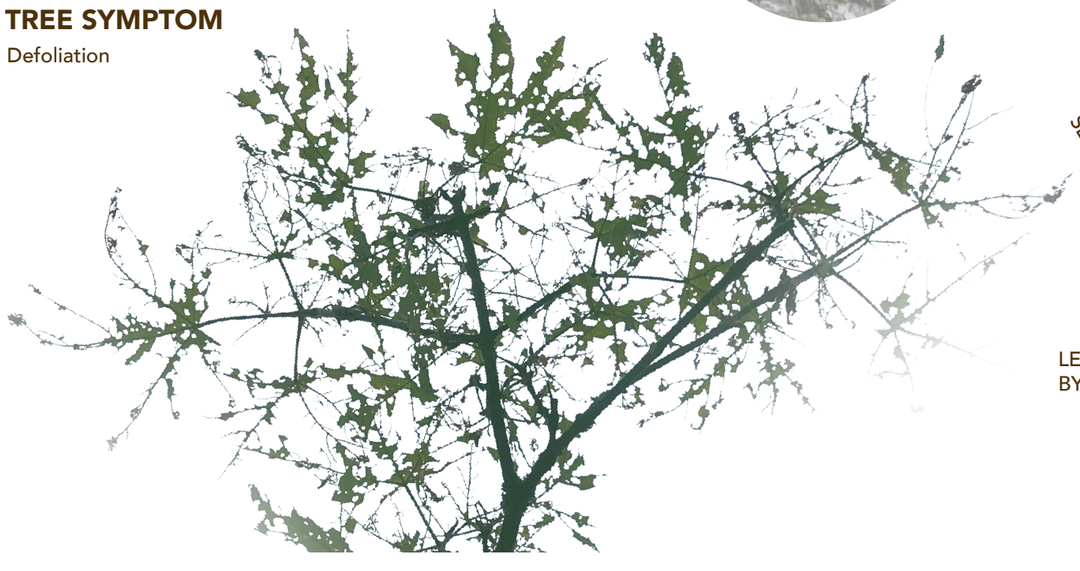
Larvae

Adult (female)

Adult (male)

TREE SYMPTOM

Defoliation

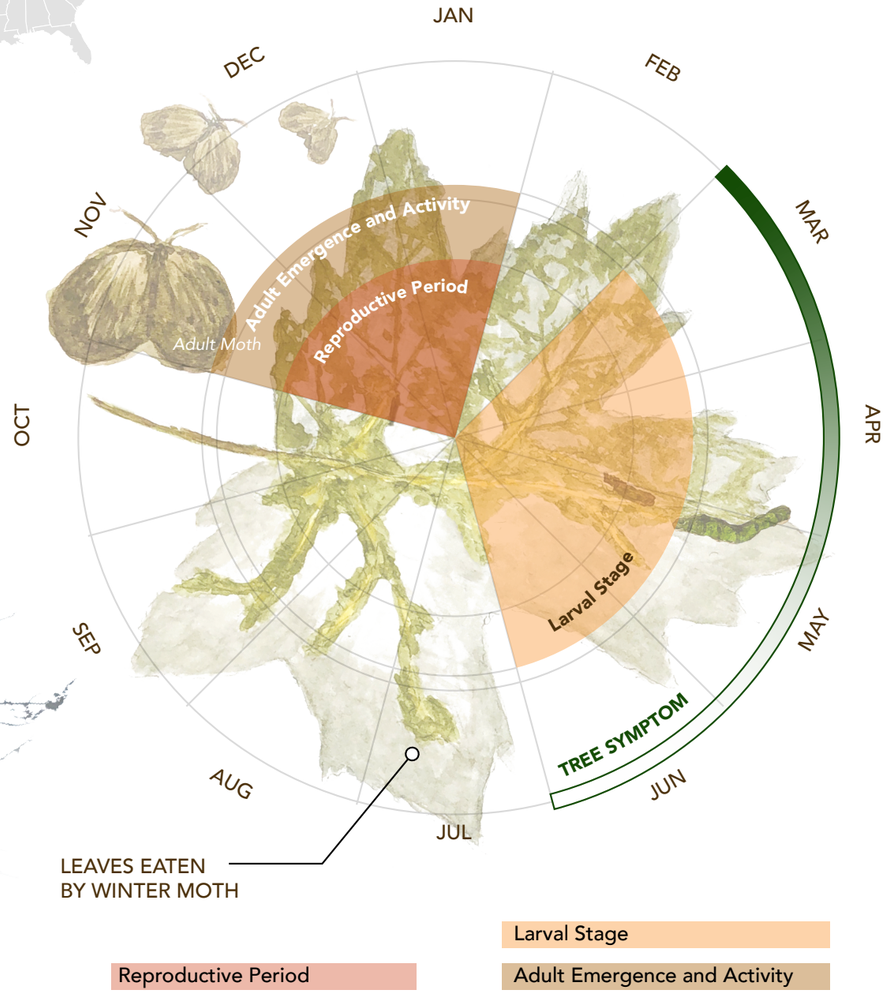


Graphic credit: Luyu Zeng

Information source: UMass Extension Landscape, Nursery and Urban Forestry Program

INSECT LIFE CYCLE & TREE SYMPTOMS

Note: Best time for treatment unknown



Larval Stage

Reproductive Period

Adult Emergence and Activity

SIREX WOOD WASP *Sirex noctilio*

SUSCEPTIBLE TREES

Pine *(Pinus)*

Ponderosa pine (*P. ponderosa*)*
Lodgepole pine (*P. contorta*)*
Monterey pine (*P. radiata*)
Loblolly pine (P. taeda)
Slash pine (*P. elliottii*)
Shortleaf pine (*P. echinata*)
Jack pine (*P. banksiana*)

*Native to the Pacific Northwest

INSECT

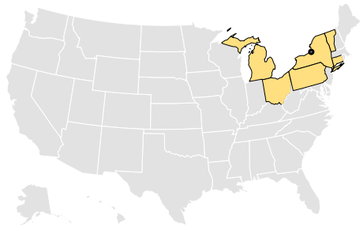
Pupae

Adult

TREE SYMPTOMS

Needles start to wilt with color change from green (normal) to yellow, and then red

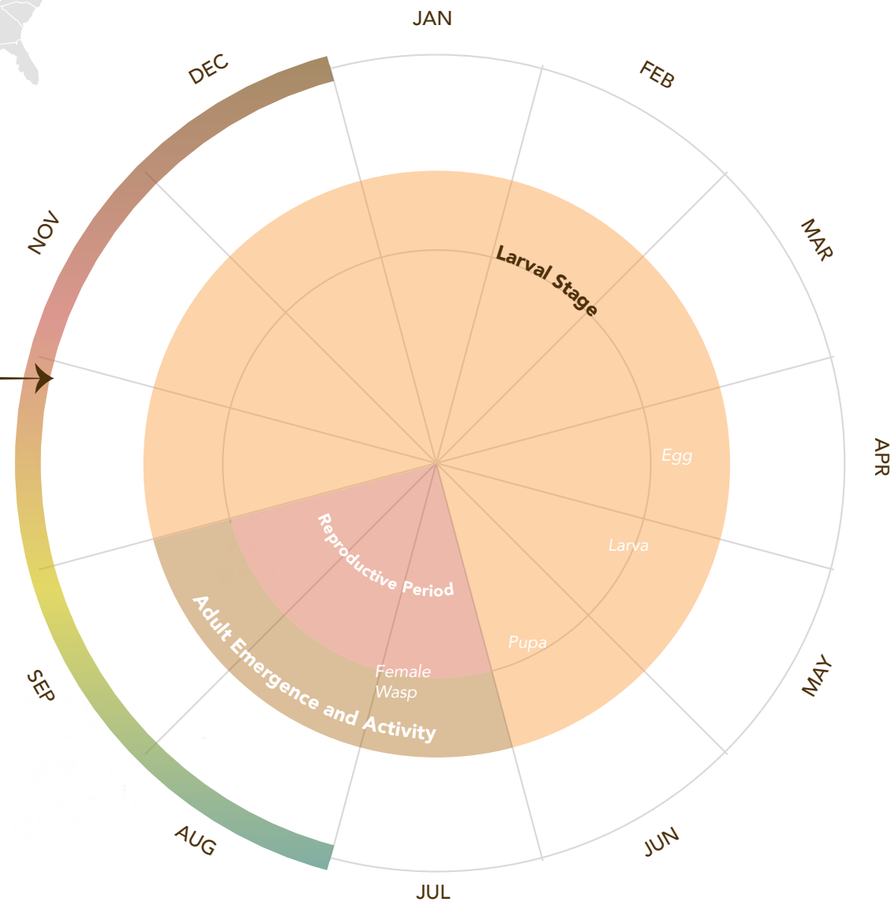
AFFECTED STATES



Work in collaboration with the Trees for Seattle Program and Seattle Commitee for Invasive Pests
Graphic credit: Luyu Zeng
Information source: Southern Regional Extension Forestry

INSECT LIFE CYCLE & TREE SYMPTOMS

Note: Best time for treatment unknown



Tree Symptoms
Larval Stage
Reproductive Period
Adult Emergence and Activity

BRONZE BIRCH BORER *Agrilus anxius*

SUSCEPTIBLE/RESISTANT TREES

Birch (*Betula*)

SEVERLY ATTACKED	European white birch (*B. pendula*) Whitebarked Himalayan birch (*B. jacquemontii*)
COMMONLY ATTACKED	Paper birch (*B. papyrifera*)* Gray birch (B. populifolia) Sweet birch (*B. lenta*) Yellow birch (*B. alleghaniensis*)
RESISTANT	River birch (*B. nigra*)

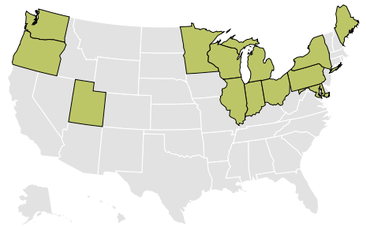
*Native to the Pacific Northwest

INSECT

Larva

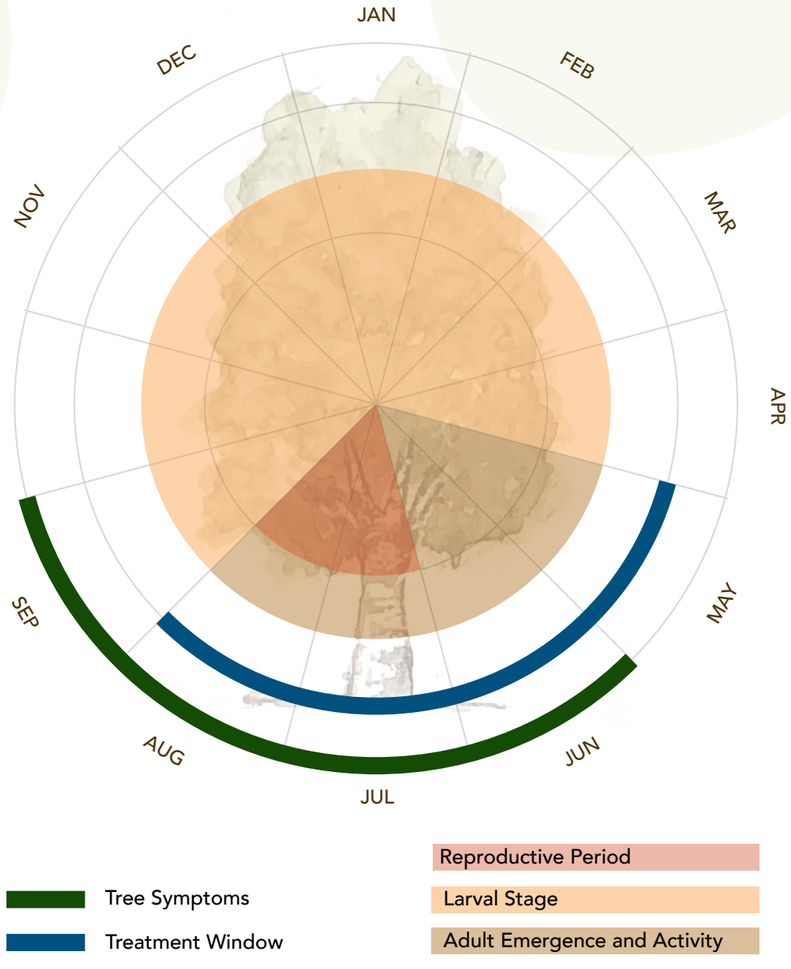
Adult

AFFECTED STATES



Graphic credit: Luyu Zeng
Information Source: USDA
Larva image credit to Purdue University Extension

INSECT LIFE CYCLE & TREE SYMPTOMS



SIGNS OF INFESTATION

Swelling or bumps on tree trunk, showing the tree healed from galleries created by BBB

D-shaped exit holes

TREE SYMPTOMS

1. Wilted leaves near the top of the tree

2. Twig and branch dieback

DUTCH ELM DISEASE

Pathogens (fungus):
Ophiostoma ulmi & O. novo-ulmi

SUSCEPTIBLE/RESISTANT TREES

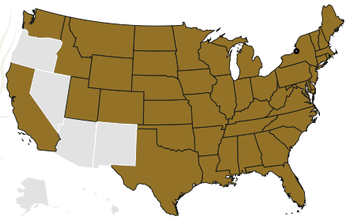
SUSCEPTIBLE

Elm (*Ulmus*) native to North America and Europe
- American elm (*U. americana*)**
- Red/slippery elm (*U. rubra*)
- Rock elm (*U. thomasii*)
- English elm (*U. procera*)
- Smoothleaf elm (*U. minor*)

RESISTANT

Elm (*Ulmus*) native to Asia
- Japanese elm (*U. davidiana var. japonica*)
- Chinese elm (*U. parvifolia*)

AFFECTED STATES



Work in collaboration with the Trees for Seattle Program and Seattle Commitee for Invasive Pests
Graphic credit: Luyu Zeng

Information source: American Phytopathological Society
Images of signs credit to Dr. Mary Gillham Archive Project

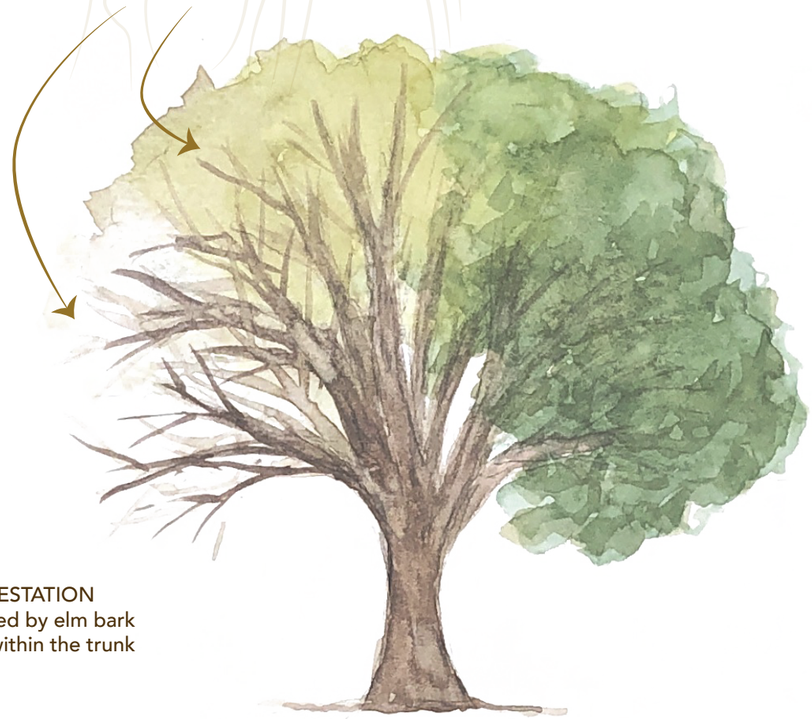
PATHOGEN & VECTOR

Pathogen is a fungus, carried by European and native elm bark beetles

SIGNS OF INFESTATION
Galleries created by elm bark beetle larvae within the trunk

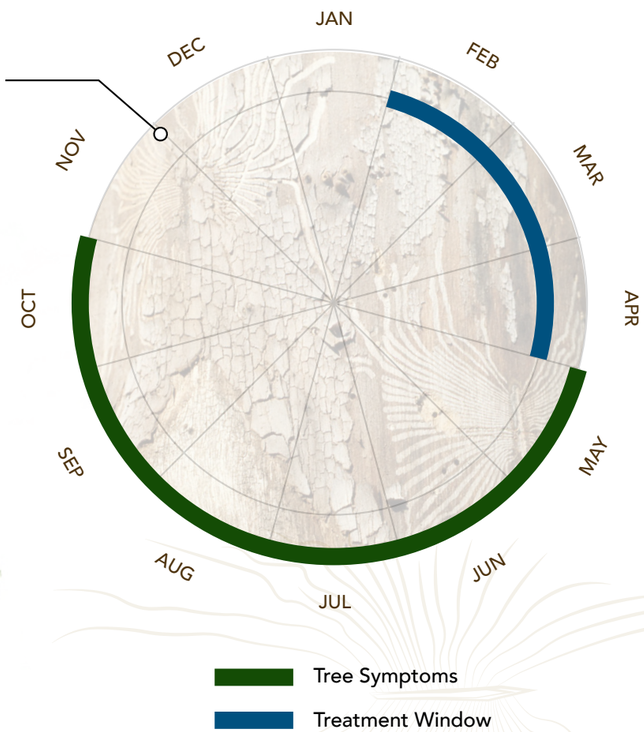
TREE SYMPTOMS

Yellowing and wilting of leaves on individual branches



ELM BARK BEETLE GALLERIES INSIDE TREE BARK

TREE SYMPTOMS & TREATMENT WINDOW



**DED-resistant American elm cultivars have been developed, such as Valley Forge and Princeton

EMERALD ASH BORER

Agrilus planipennis

SUSCEPTIBLE TREES

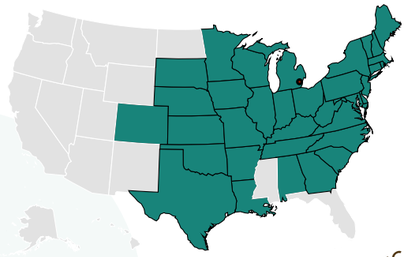
Ash (*Fraxinus*)

TREE SYMPTOM

Loss of Canopy

INSECT

AFFECTED STATES

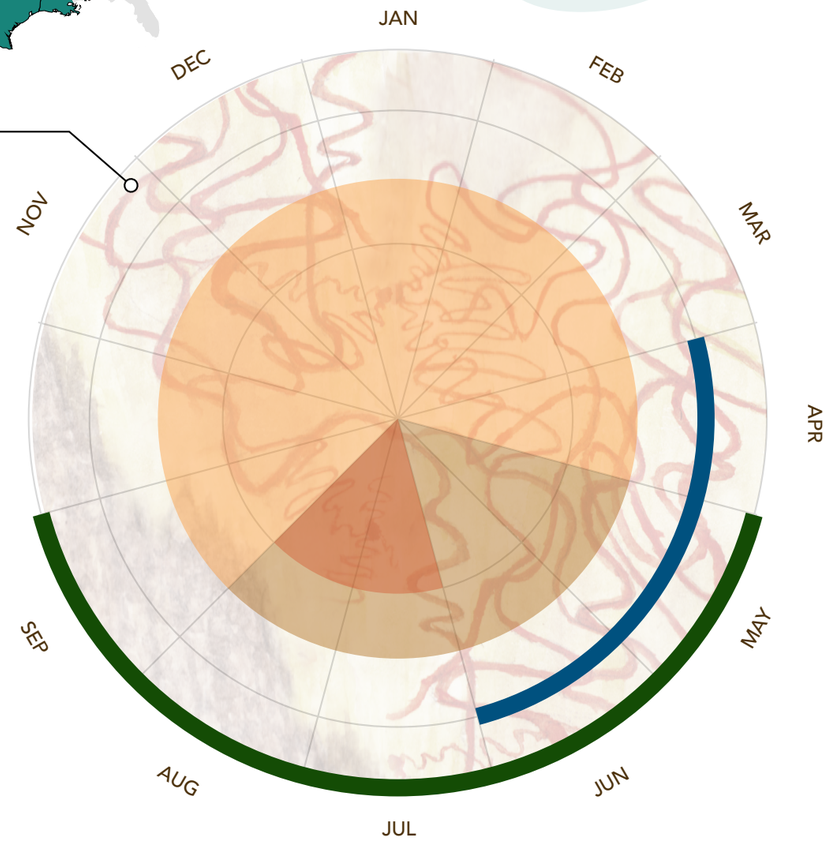


EAB GALLERIES
INSIDE TREE BARK

Graphic credit: Luyu Zeng

Information source: USDA APHIS

INSECT LIFE CYCLE & TREE SYMPTOMS



APPENDIX B: RESOURCES AND LINKS

Resources for Urban Forestry

1. The State of Diversity in Environmental Organizations (Taylor, 2014) https://diversegreen.org/research/the-challenge/
2. Funding Trees for Health: An Analysis of Finance and Policy Actions to Enable Tree Planting for Public Health (McDonald et al., 2017) https://www.nature.org/en-us/what-we-do/our-insights/perspectives/funding-trees-for-health/
3. Vibrant Cities Lab: the hub for urban forestry resources https://www.vibrantcitieslab.com/
4. NeighborWoods Community Action Toolkit: Growing Leadership, Inspiring Actions https://www.sactree.com/neighborwoods

Resources for Pests

1. Urban Forest Pest Readiness Playbook: developed by Washington Invasive Species Council for municipality https://invasivespecies.wa.gov/projects/pest-ready/
2. USDA Forest Service Alien Forest Pest Explorer https://www.nrs.fs.fed.us/tools/afpe/
3. Play Clean Go: education and awareness campaign owned by North American Invasive Species Management Association (NAISMA) https://playcleango.org/
4. Don't Move Firewood: outreached managed by the Nature Conservancy https://www.dontmovefirewood.org/
5. USDA APHIS Selecting Tree Species for Planting in Areas Where ALB/EAB Are a Concern https://www.aphis.usda.gov/plant_health/plant_pest_info/asian_lhb/downloads/replacementtreetable.pdf
6. Tree pests: information for pests in concern and reporting steps on Trees for Seattle website http://www.seattle.gov/trees
7. Washington Invasive Species Council (WISC) https://invasivespecies.wa.gov/
8. USDA Animal and Plant Health Inspection Service (APHIS) https://www.aphis.usda.gov/aphis/resources/pests-diseases

Stewardship Network

1. Delridge Neighborhood Development Association (DNDA) https://dnda.org/
2. *DIRTCorps - Duwamish Infrastructure Restoration Training https://www.thedirtcorps.com/
3. *Duwamish River Cleanup Coalition (DRCC) https://www.duwamishcleanup.org/
4. *YMCA Earth Service Corps (YESC) https://www.seattleymca.org/programs/youthprograms/earthservicecorps
5. The Nature Conservancy - Washington State https://www.washingtonnature.org/
6. *Green Seattle Partnership https://www.greenseattle.org/
7. Forterra https://forterra.org/
8. *EarthCorps https://www.earthcorps.org/
9. Forest Health Watch https://foresthealth.org/
10. *Student Conservation Association (SCA) https://www.thesca.org/
11. Trust for Public Land https://www.tpl.org/
12. GotGreen https://gotgreenseattle.org/
13. Sierra Club WA https://www.sierraclub.org/washington
14. Puget Sound Sage https://www.pugetsoundsage.org/
15. Washington Environmental Council (WEC) https://wecprotects.org/get-involved/
16. Na'ah Illahee Fund https://www.naahillahee.org/
17. Front & Centered https://frontandcentered.org/
18. *Partner in Employment https://partnerinemployment.org/
19. Plant Amnesty https://www.plantamnesty.org/
20. ECOSS (Environmental Coalition of South Seattle) https://ecoss.org/
21. *Nature Vision https://naturevision.org/
22. *University of Washington Botanic Gardena https://botanicgardens.uw.edu/
23. Washington building leaders of change (WA-BLOC) https://www.wa-bloc.org/
24. Sustainability Ambassador https://www.sustainabilityambassadors.org/

Note: * organizations with opportunities for youth

Self-guided Apps

1. iNaturalist app https://www.inaturalist.org/
2. WA Invasives app: developed by Washington Invasive Species Council https://invasivespecies.wa.gov/report-a-sighting/
3. Healthy trees, healthy cities https://healthytreeshealthycitiesapp.org/