Strategic Cross-Sector Conservation Approaches for Managing Emerald Ash Borer (Agilus planipennis) Invasions in Vermont

Strategic Cross-Sector Conservation Approaches for Managing Emerald Ash Borer (*Agilus planipennis)* Invasions in Vermont

Emma Graham

University of Vermont

2025

STRATEGIC CROSS-SECTOR CONSERVATION APPROACHES FOR MANAGING EMERALD ASH BORER (*AGRILUS PLANIPENNIS*) INVASIONS IN VERMONT

AN HONORS THESIS PRESENTED BY

EMMA GRAHAM

TO

FACULTY OF COLLEGE OF ARTS AND SCIENCES

OF

THE UNIVERSITY OF VERMONT

APRIL 2025

ABSTRACT

This study highlights the critical role of cross-sector collaboration and community-based conservation in managing invasive species, with a focus on the emerald ash borer (*Agrilus planipennis*, EAB hearafter) in Vermont. Both the scope and process of my research aims to highlight a key takeaway from my academic journey as an Environmental Studies major, which

is that understanding complex ecological issues demands both scientific analysis and social inquiry. Drawing on a comprehensive literature review and Geographic Information System (GIS) analysis, my thesis examines the spread and ecological impacts of EAB across the region. My methodology integrates qualitative interviews with experts in the field to evaluate the effectiveness of various mitigation techniques. These findings are complemented by an in-depth examination of local conservation initiatives and relevant case studies. By integrating these various methods, my research offers a more comprehensive perspective on the effects of EAB and the diverse, location-specific responses it has prompted. Emphasis is placed on the value of coordinated, multi-stakeholder approaches, underscoring how partnerships across public, private, and nonprofit sectors can enhance the efficacy of invasive species management. The study concludes by outlining opportunities to strengthen collaborative frameworks aimed at improving EAB response strategies and broader regional resilience to biological invasions. It also sheds valuable insights into the potential of utilizing holistic research methods that span and connect across disciplines.

EXECUTIVE SUMMARY

Title: Strategic Cross-Sector Conservation Approaches for Managing Emerald Ash Borer (*Agrilus planipennis*) Invasions in Vermont: Emma Graham

KEY RESEARCH QUESTIONS

I applied three main methods to understand this issue from multiple perspectives and sought to answer the following questions: *What insights into future conservation opportunities can Geographic Information Systems (GIS) provide? What methods are experts currently employing* *and what are the attitudes/motivations associated with these mitigation methods? How can integrating diverse perspectives lead to a more comprehensive and culturally inclusive model of invasive species management?*

WHY THIS MATTERS

Global ecosystems are rapidly transforming due to interacting drivers of environmental change, including habitat loss, pollution, climate change, and biological invasions. Invasive alien species alone contribute to 60% of global extinctions and are solely responsible for 16% (IPBES 2023). Managing these species comes at a high cost—over $423 billion annually worldwide, with U.S. damages exceeding $130 billion each year (IPBES, Roy, H. E., et al., 2023). The invasive EAB poses a threat to Vermont's ash trees, which consist of green ash (*Fraxinus pennsylvanica*), black ash (*Fraxinus nigra*), and white ash (*Fraxinus americana*), and could lead to widespread ecological impact. By investigating the effectiveness of mitigation methods in Vermont, this research can offer valuable insight into the factors that lead to successful invasive species management. It also highlights findings about the importance of community and collaboration practices, showing a future in conservation that catalyzes socioeconomic development while also meeting environmental goals.

TABLE OF CONTENTS

1 INTRODUCTION

Background

Biological invasion refers to the introduction, either intentional or accidental, of a species into a new geographic region where it establishes, persists, and potentially spreads. These species, termed nonnative (or nonindigenous, exotic, or alien), are typically introduced outside their natural evolutionary range. While most introduced species fail to persist, and many that do establish remain localized and benign, a small but growing subset becomes invasive. Invasive species spread rapidly and can cause significant ecological disruption.

The number of invasive species is spreading at unprecedented rates (IPBES 2023), posing significant threats to ecosystems and biodiversity worldwide, driving up economic costs, and jeopardizing human health and well-being. As the issue of invasive species persists and expands, the need for reliable and effective management strategies becomes more pressing. The EAB~~,~~ (*Agrilus planipennis fairemaire*)~~,~~ is one of the most destructive and costly forest pests in the United States (Cossé et al., 2011). As of 2024, it has been found in 37 states – a rapid spread since 2002, when it was initially detected in southeastern Michigan (McDowell, 2024). There are 16 species of native ash in the US that are vulnerable to the EAB and so far, millions of individual trees have died due to the invasive beetle (Gould et al. 2021).

The environmental consequences of EAB are severe, leading to widespread changes across ecosystems and the decline of native species (Johnson, 2021; Gougherty, 2023). Managing EAB infestations costs millions of dollars annually to municipalities, property owners, federal managers and other stakeholders that are affected due to removal costs, quarantine enforcement, and other obstacles that arise with invasive species management (Howarth, 2024). A 2021 APHIS report estimates that federal and state resource managers spend at least $29.5 million per year to manage EAB populations (Gould et al. 2021). Beyond economic costs, EAB also disrupts local communities, impacting cultural practices and recreational activities, especially for certain Indigenous communities, to whom certain types of ash are a cultural keystone species (USDA, 2024; Constanza et al., 2017).

Given the limited methods of detection and control and the high costs associated with managing the EAB, complete eradication is not considered feasible (Gould et al., 2021). Current strategies focus on management and containment, emphasizing the importance of community conservation and citizen science in invasive species management. It is a promising notion that mitigation methods for invasive species are most successful when implemented through an interdisciplinary approach (N'Guyen et al., 2015). This paper seeks to find how collaboration at the community level, especially incorporating Indigenous and citizen science, can be particularly effective in early detection, rapid response, and long-term management of invasive species.

Methodology

The methodology employed in this research is multifaceted, encompassing a literature review and case study evaluation to assess the ecological effects of the EAB, a conceptual investigation of non-dominant perspectives, a Geographic Information System (GIS) analysis, qualitative interviews, and the consolidation of my findings into recommendations for future action. These diverse methods work to provide both spatial and human-centered perspectives—GIS reveals large-scale patterns and changes in land use, while interviews offer grounded insight into community responses, values, and adaptation strategies. Case studies serve as a bridge between these approaches, contextualizing broad trends within specific ecological and social landscapes. I utilized an integrated methodology to reflect the inherently interdisciplinary nature of my field, Environmental Studies. Both the scope and process of my research aims to highlight that understanding complex ecological issues demands both scientific analysis and social inquiry. By combining these approaches, my research achieves a more holistic understanding of EAB's impact and the nuanced, place-based responses it has generated.

Literature Review and Case Study Evaluation

I conducted a literature review on the biological component of the Emerald Ash Borer, its long-term ecological effects, and non-dominant science perspectives. Case studies were selected based on their relevance to community conservation efforts and the inclusion of non-dominant perspectives. Additionally, the studies focusing on the long-term ecological impacts of the EAB were chosen from regions in the United States where the infestation has been present for the longest duration. These case studies provided valuable insights into the practical applications of community conservation and highlighted successful collaborative efforts.

GIS Analysis

I conducted a GIS Analysis using data sourced from Vermont Open Geodata Portal and Vermont Invasives. This analysis aimed to track the spread of EAB and identify affected areas within Vermont. By leveraging spatial data, this study was able to visualize the extent of the infestation and its proximity to areas of high biological significance, offering an outlook for key areas to focus on in conservation. This study also attempted to investigate one of the most common dispersal modes through which EAB spreads, which is firewood. To do so, I overlapped existing Vermont campsites over infested areas to see if any correlation could be deduced.

By visualizing the invasion in a geographic context, the GIS maps provide not only a powerful diagnostic tool but also a strategic one. It enables stakeholders—such as forest managers, policymakers, and community planners—to identify priority zones for intervention and monitoring. This spatial awareness supports more targeted and efficient management efforts, emphasizing the value of geospatial tools in ecological research and environmental decision-making.

Qualitative Interviews

To validate the research and gain more nuanced perspectives on current mitigation strategies, I interviewed seven practitioners within the conservation sector, the federal government, and other private and non-private sectors. The interviews were designed to be semi-structured, guided by conversational flow rather than a rigid set of questions. This approach was chosen to facilitate more organic responses and gain deeper insights into the interviewees' perspectives and thoughts. By allowing the conversation to occur naturally, the interviews served to get to know the interviewees personally and understand the emotional landscape surrounding their work. This dual focus helped to enrich the research by incorporating both technical insights and human elements.

Each interview lasted approximately one hour, providing ample time to delve into the intricacies of mitigation methods and their effectiveness. The interviews aimed to gather expert insights and firsthand experiences, thereby enriching the understanding of current conservation efforts. The qualitative data obtained from these interviews were analyzed to identify common themes, critical strategies, and effective practices. (See appendix for further details on interviews).

Outlook

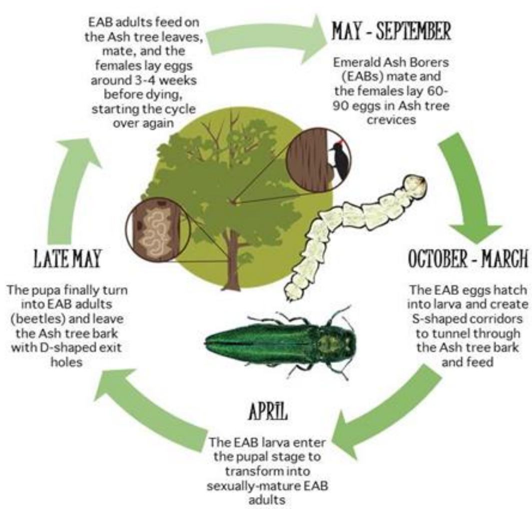
I conclude with an evaluation of collaborative frameworks, emphasizing the importance of cross-sector partnerships in combating the EAB infestation. By analyzing the effectiveness of existing collaborations, the study aims to propose enhanced strategies for future partnerships. This forward-looking perspective is intended to foster a more integrated approach to invasive species management, leveraging the strengths of various stakeholders to achieve sustainable outcomes.

2 LITERATURE REVIEW AND CASE STUDY EVALUATION

Overview of the Emerald Ash Borer

The EAB, an invasive species of beetle native to eastern Russia, northern China, Japan, and Korea, was first detected in the United States in southeastern Michigan during the summer of 2002 (U.S. Department of Agriculture, 2025). It is hypothesized that the EAB was introduced to the United States via solid wood packing materials transported on cargo ships or airplanes originating from Asia (Smith, A., 2020; U.S. Department of Agriculture, 2025). Adult EAB are a metallic green and are between 0.95-1.27 cm long and 0.16 cm wide. Their small size – about a grain of rice – can make them challenging to detect. Figure 1 below intends to provide a clear visual of the EAB's life cycle, demonstrating how the majority of the EAB life cycle takes place as larvae feed, develop, and pupate inside host trees. Their evasive nature is another factor that makes detection difficult.

Figure 1. EAB Life Cycle, Cornell University



As depicted in the figure above, adult EABs deposit their eggs in the crevices of ash trees, and upon hatching, the larvae burrow into the tree and commence feeding on the phloem. These larvae create galleries beneath the bark and can grow to lengths of 26 to 32 millimeters. From mid-summer to fall, the larvae feed within the inner layers of bark, subsequently overwintering within the outer bark or outer sapwood (Herms & McCullough, 2014). Upon maturation, EABs exit by chewing holes through the bark and when they emerge, they are capable of flight. While adult EAB only cause damage by feeding on ash tree foliage, the primary harm occurs during the larval stage, when larvae tunnel through the bark and disrupt the tree's ability to transport water and nutrients, ultimately compromising its health (Koch et al., 2015). Once an infestation begins, the EAB can kill a small ash tree within 1 to 2 years and a more mature tree in 3 to 4 years (North Carolina Department of Agriculture and Consumer Services, 2025). Research indicates that if 50% of an ash tree canopy has been destroyed by EAB, it is likely too late to save the tree and should be cut down instead of treated (Williamson & Liesch, 2021). Because EAB can lead to mortality in such little time, early detection methods are crucial. However, as mentioned before, detecting EAB presence is challenging and can take up to 4 years to confirm.

Long-term Ecological Consequences

Impact on Vermont's Ash Trees

The infestation of the EAB has had profound ecological, economic, and cultural impacts in the northeast since its arrival. This invasive species continues to spread rapidly across many parts of the United States (Lovett, 2022). The EAB was first detected in Vermont in 2018 in Orange County (AGR, 2025). The ash tree is integral to the ecological health and economic vitality of managed forest areas, while also playing a significant role in Indigenous cultural practices and traditions (D'Amato et al., 2023). As of 2021, ash trees compromised approximately 5% of the state's forests in Vermont (VT FPR, 2021). The three native species – green, white, and black ash—each play unique roles in the ecosystem. These trees support hundreds of species of wildlife, providing essential habitat and food (Lovett, 2022). They provide nesting and roosting places for a variety of bird species and both food and shelter for herbivore animals such as chipmunks, squirrels, deer and rabbits. Additionally, the fallen leaves of ash trees decompose and enrich the soil with vital nutrients, fostering a healthy forest floor (Lovett, 2022; McCarthy, Lindenmayer, 1998). The loss of ash trees has severe ecological impacts on local ecosystems that depend on these trees for food and habitat. Dozens of insect species depend on ash, and hundreds are associated with ash trees. If these trees are lost, creatures that rely on them could face extinction (Lovett, 2022; Nisbet et al., 2015).

Black ash trees, primarily found in Vermont's lower-lying wetlands, have deep cultural significance. For millennia, Indigenous peoples have utilized black ash for basket making, ceremonies, medicine, and art, highlighting the tree's importance beyond its ecological contributions (FS USDA, 2024). The brown ash is also utilized for its strength and flexibility, its multitude of uses making it not just an effective tool but weaving it into the cultural identity of many Indigenous people (Leet-Otley, et al., 2019). This is reflected in the creation story of the

Wabanaki people, in which the ash tree plays a central part (Hood Museum of Art). White ash, on the other hand, is crucial for the forest overstory, contributing to the canopy structure and offering shade and shelter to understory plants and animals (Lovett, 2022; Nisbet et al., 2015). Together, these ash species are integral to Vermont's biodiversity and cultural heritage.

The economic costs associated with invasive species like the EAB are substantial. These costs arise from impacts on agricultural productivity, property values, outdoor recreation, public utility operations, tourism, and efforts to control invasive species (Li et al., 2019). Managing ash trees is a time-intensive and costly task due to its vast range in Vermont. Understanding the multifaceted impacts of the EAB infestation is crucial. While the environmental effects are significant, the economic and social repercussions are equally important. Recognizing these dimensions is vital for developing comprehensive management strategies and policies, and this holistic understanding will guide the solutions proposed throughout this thesis to mitigate the widespread effects of this invasive species.

Effects on Land Cover

The effects of an invasive species on an ecosystem vary according to factors such as species abundance, functional distinctiveness, and ecosystem type (Strayer et al., 2006; Gutiérrez et al., 2014; Sesay et al., 2024). Nevertheless, valuable insights can be gleaned from prior cases of EAB invasions that have had a longer duration to develop. A particularly relevant area is the midwestern states of Michigan, Wisconsin, and Minnesota, where forests have been affected longer than anywhere else in the United States. The EAB was first discovered in the U.S. in 2002 in Flint, Michigan, establishing Michigan as the origin site for EAB research. It was later discovered in 2009 in St. Paul, Minnesota, only 100 km south of the largest concentration of black ash forests in the United States (Kolka et al., 2018). The loss of black ash due to EAB infestation has led to substantial changes in forest structure, water levels, nutrient cycling, carbon sequestration, and wildlife habitat. These wetlands are vital for maintaining water quality, regulating water quantity, and acting as carbon sinks (FS USDA, 2024).

Given the integral role that wetlands play in forest ecosystems, scientists have conducted simulation studies to predict the short- and long-term effects of the EAB infestation on black ash wetlands – one 2009 study in Chippewa National Forest, MN, to anticipate the short-term effects of EAB, and the other a 2010 study at Ottawa National Forest in Michigan to test the long-term effects of infestation (FS USDA, 2024). Incorporating different treatments such as girdling, felling, and controls, these studies have provided insights into the short- and long-term ecosystem level impacts of EAB infestations. The loss of black ash trees is expected to have several detrimental effects on native ecosystems, including increased air temperatures, shifts in understory vegetation communities, and alterations to the wetland water (Bolton et al., 2018). Specifically, the loss of black ash is anticipated to raise the water table in black ash wetlands, increasing the risk of flooding and creating a challenging environment for tree regeneration (Bolton et al., 2018). Invasive plants species, especially in the understory, are expected to increase due to an increase in canopy gaps that lets in excess light and moisture (Gougherty et al., 2023; Henkel et al., 2025). In some areas, other land covers such as herbaceous and woody shrubs are expected to dominate and potentially compete with regenerating ash seedlings, risking a transition to non-forested wetlands (Bolton et al., 2018).

The loss of black ash due to EAB infestation is expected to lead to significant alterations in nutrient and carbon cycling, affecting plant growth and community composition, microbial dynamics, decomposition, carbon sequestration, nitrogen cycling, and other critical ecosystem functions (Toczydlowski et al. 2020; Sibley et al., 2020; Mitchell et al., 2014). Ultimately, these changes in nitrogen cycling will impact the lowest trophic levels of the animal community, potentially causing cascading effects throughout the food chain (Xi et al. 2024; Nisbet et al., 2014). Furthermore, studies suggest that the absence of ash trees may contribute to increased CO_2 emissions, due to a decrease in carbon sequesters and because fallen trees release around 700kg of CO2 when they decay (Franklin, S. Jr., Pindyck, R. S., 2024; Siebold et al., 2021). While the mortality of ash trees comes with a plethora of negative side effects, it is worth it to note that it has also paved the way for some native species to flourish. In some cases where forest composition has changed, the remaining species have demonstrated resilience and adaptability by occupying the niche left vacant (Schei et al., 2024; Beckstedt, 2023). For example, in Indiana native species such as red maple and American elm have thrived and contributed to forest regeneration (Beckstedt, 2023), highlighting the ambiguous and complex effects of the EAB. It is also important to note that that the nature of pest impacts on forests may not be apparent for years or even decades (Day & McClean, 1991; James et al., 2017) and that the EAB is still a relatively recent invasion. Thus, adaptability and innovation will be critical parts of the mitigation process as the long-term effects surface. These findings underscore the critical need for strategic cross-sector conservation initiatives to mitigate the ecological impacts of the EAB in Vermont.

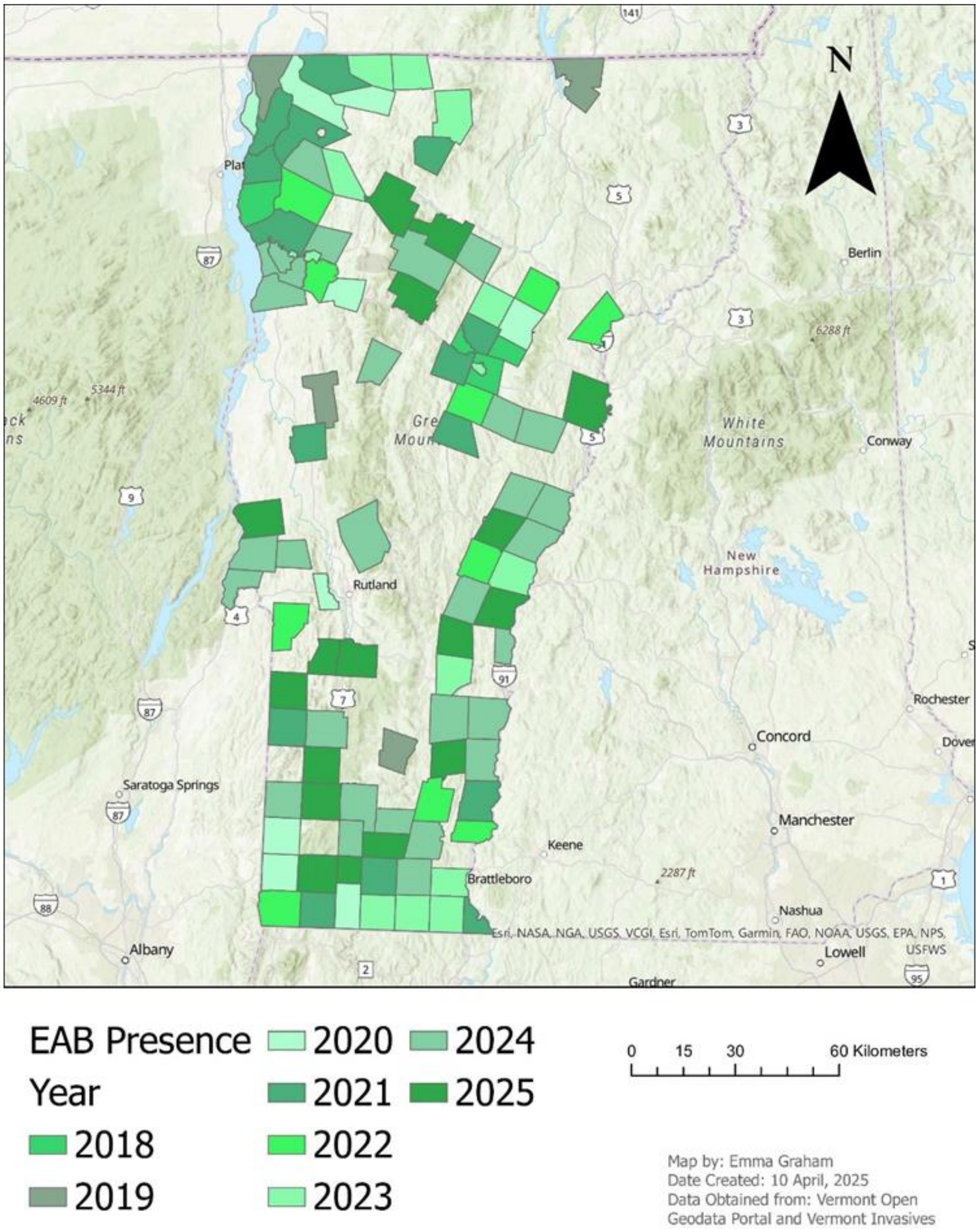
Effects on Biodiversity

In addition to their pivotal role in community dynamics and ecosystem processes, black ash wetlands serve as essential habitats for a diverse array of wildlife (Nisbet et al., 2015). In Michigan and Minnesota, young ash trees are vital food sources for deer and moose, while mature trees provide crucial nesting and roosting sites for birds and mammals (Grinde et al., 2021; Nisbet et al., 2015). The anticipated formation of canopy gaps resulting from black ash mortality is expected to significantly affect the diversity and abundance of ground-dwelling invertebrates during the early stages of ash tree mortality (Herms & Perry, 2016). A comprehensive study in northern Minnesota, documenting over 85 wildlife species, including 57 bird species, 5 amphibian species, and 23 mammal species (Grinde et al., 2021) indicated long-term effects of the extinction of ash trees in this region. The cascading ecological effects caused by ash tree fatalities highlight the urgent need to slow the spread of EAB. By implementing adaptive management strategies, it is possible to preserve the integrity of ash land cover and safeguard the diverse wildlife communities that depend on them.

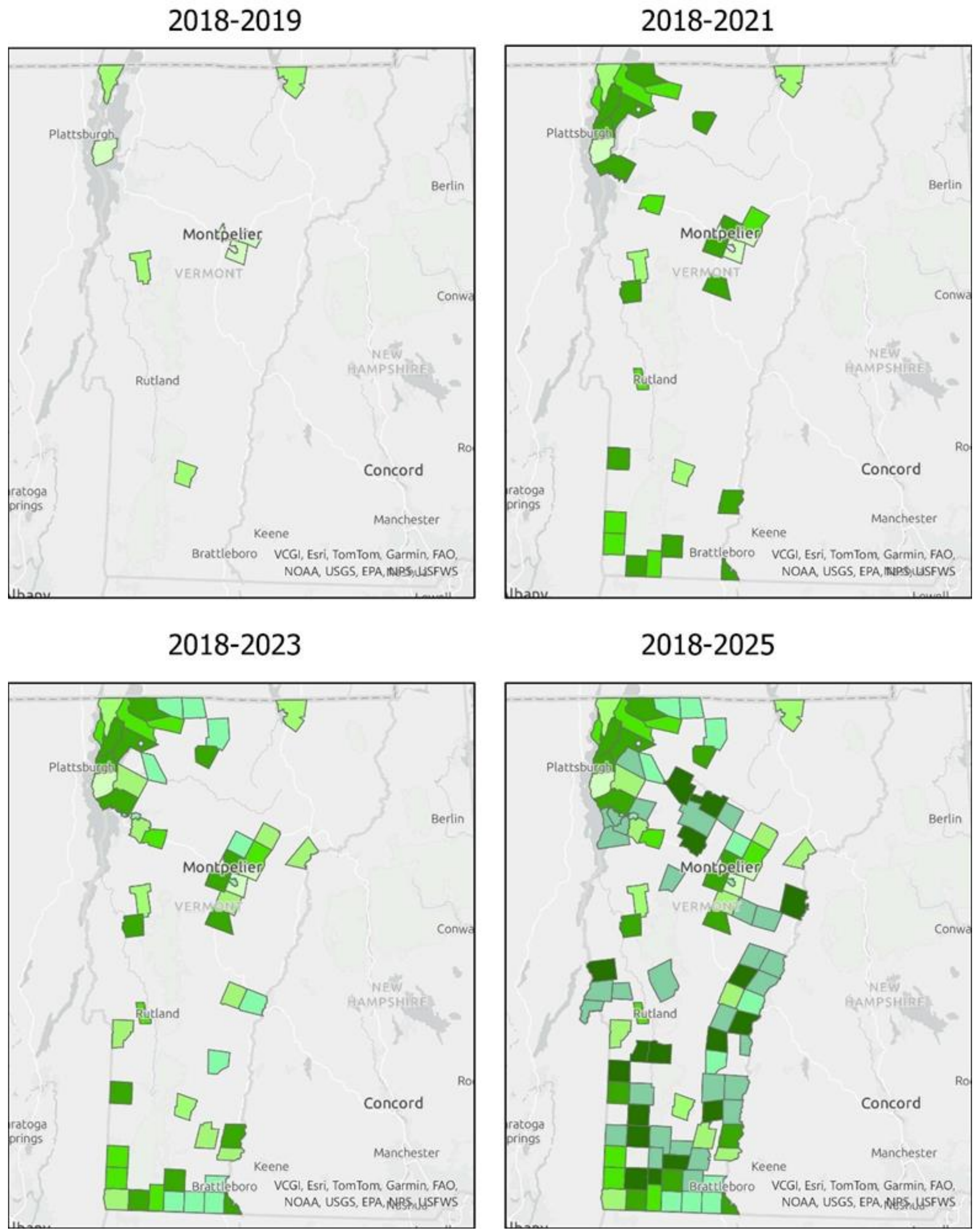
3 GIS ANALYSIS

Time Series of EAB Across Vermont

Map 1. EAB Presence by Township in Vermont



Map 2. Spread of EAB Across Vermont in 2-year Intervals


2018-2019
2018-2021
2018-2023
2018-2025
Plattsburgh
Berlin
Montpelier
VERMONT
NEW HAMPSHIRE
Rutland
Concord
Manchester
Keene
Brattleboro
VCGI, Esri, TomTom, Garmin, FAO, NOAA, USGS, EPA, NPS, USFWS

Analysis

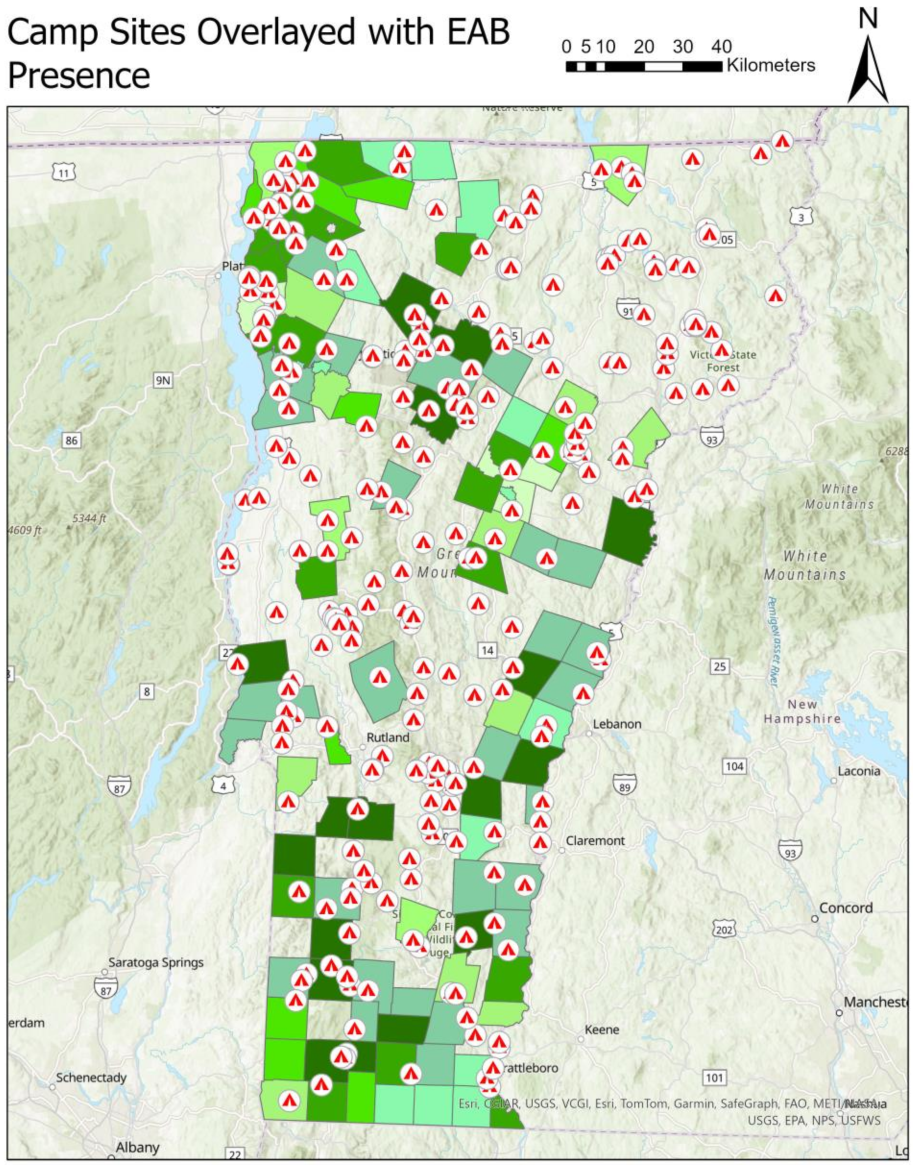
The GIS map of Emerald Ash Borer (EAB) presence across Vermont reveals a somewhat sporadic and fragmented pattern of infestation. Unlike the expected progression from a central point of introduction, the spread appears uneven, with pockets of infestation emerging in non-contiguous regions. This irregular distribution suggests that EAB movement may not be solely following predictable ecological or geographic pathways and could be influenced by a variety of human and environmental factors, including isolated incidents of firewood transport, local climatic conditions, or detection/reporting inconsistencies.

The patchy nature of the data complicates efforts to draw definitive conclusions about the trajectory of the invasion. While some clusters of EAB presence align with roadways or developed areas, other infested zones appear more isolated, raising questions about detection accuracy or previously undetected sources of spread. Additionally, the limitations of current reporting mechanisms and uneven survey coverage may contribute to gaps in the data.

Despite these uncertainties, the GIS map remains a valuable tool for identifying areas that warrant further investigation. It highlights the need for more comprehensive monitoring and a deeper analysis of contributing factors such as human activity, ash tree distribution, and environmental conditions. This preliminary spatial visualization underscores the complexity of tracking invasive species and the importance of integrating additional datasets and fieldwork to build a clearer picture of EAB dynamics in Vermont.

Campsites Within EAB-Infested Areas

Map 3. Campsites Intersecting Areas with EAB presence



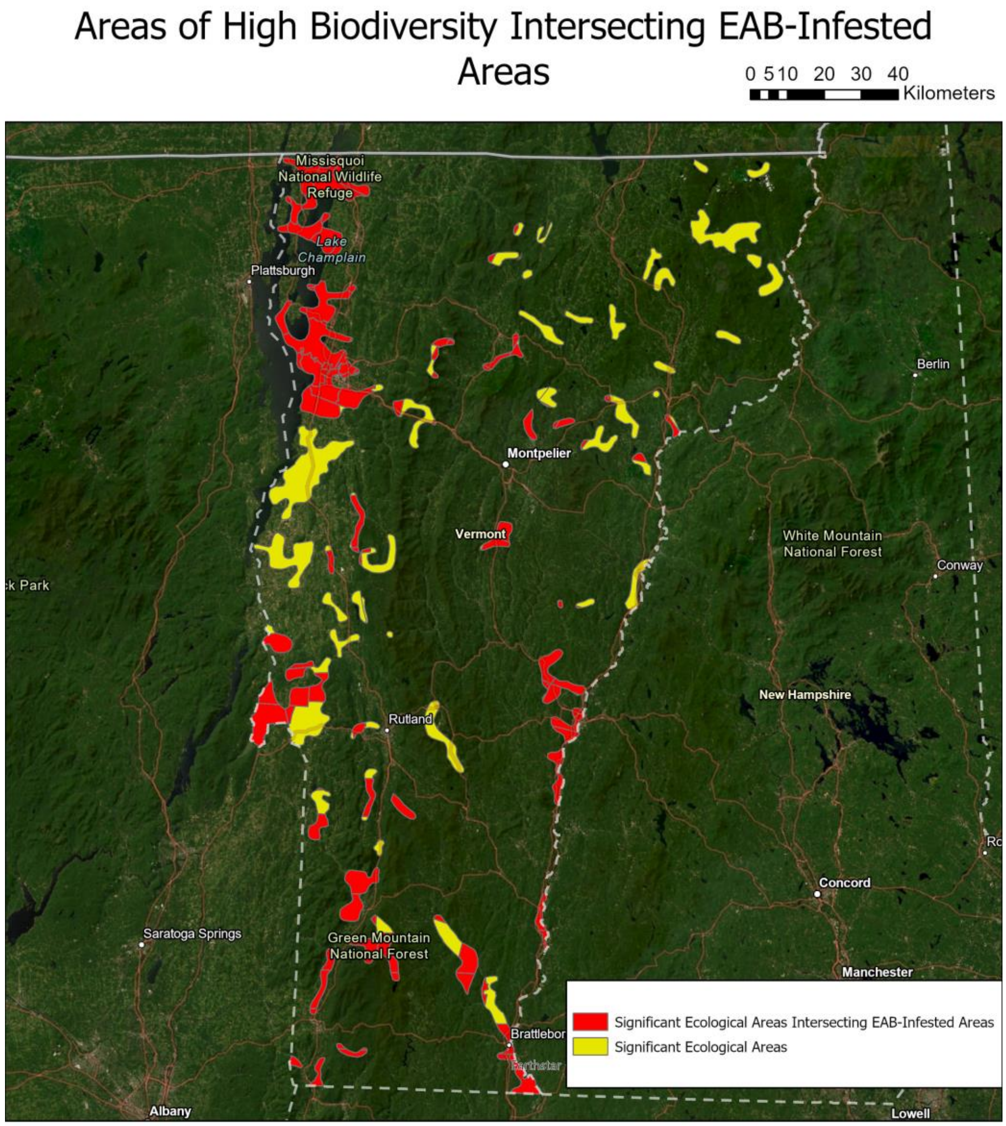
Analysis

GIS analysis reveals that 46.5% of Vermont's campsites are located within areas currently infested by the (EAB). EAB-infested areas make up 42.6% of Vermont's landcover.

While these numbers are not significant enough to draw a concrete conclusion, this overlap suggests a potential pathway for the continued spread of the invasive species, particularly through the movement of firewood—a well-documented vector for EAB dispersal. Campsites often serve as points of human activity where firewood is transported from one region to another, sometimes across long distances, inadvertently introducing EAB to new areas. The spatial correlation between infestation zones and campsite locations underscores the need for targeted outreach and policy enforcement in recreational areas. While EAB spread is influenced by both natural and human-driven factors, the high concentration of campsites within infested zones raises concerns about how unregulated firewood movement may be accelerating the invasion. However, as a disclaimer, it is important to consider that this correlation could be attributed to campsite's general proximity to forested areas. This finding still has the potential to support existing state and federal guidelines that discourage or restrict transporting firewood and highlights the importance of expanding public education campaigns and campground-specific mitigation strategies. Ultimately, the GIS data not only visualizes the current ecological risk posed by EAB but also identifies key human behaviors and infrastructure that potentially contribute to its spread. By pinpointing high-risk locations, this analysis provides a practical tool for informing more effective prevention and containment efforts across Vermont.

EAB-Invaded Sites Overlayed with Areas of High Biological Diversity

Map 4. Areas of High Biological Significance Intersecting EAB-Infested Ares



Analysis

GIS analysis reveals a notable overlap between Emerald Ash Borer (EAB) infestation zones and several areas of high biological diversity. These areas of biological significance were originally mapped by the Vermont Biodiversity Project with the intention to identify a network of areas of high biodiversity value that deserve conservation attention (Vermont Center for Geographic Information, 2000). 57% of biologically significant landcover is within EAB-infested areas. This spatial intersection is cause for concern, as it underscores the potential for the EAB to contribute to significant ecological disruption in some of the state's most valuable and vulnerable natural areas.

Areas high in biodiversity often rely on the presence of a variety of native tree species, including ash, which plays a key role in forest structure, nutrient cycling, and habitat provisioning (Berthon etl al., 2021). By highlighting the areas where EAB presence intersects with high-biodiversity zones, the GIS map serves as an early warning system for conservation planning. These findings stress the urgency of implementing targeted management strategies in ecologically sensitive regions and prioritizing monitoring and mitigation efforts where biodiversity is most at risk. The visualization not only identifies critical areas for intervention but also reinforces the broader ecological implications of invasive species spread across interconnected landscapes.

4 MITIGATION STRATEGIES

Interview Responses

The interviews I conducted reveal a diverse array of mitigation techniques, each reflecting the unique motivations and values of the institutions represented by the experts (i.e., government-based programs, non-profits, academia, and tribal members). The approaches to invasive species management varied significantly, highlighting the complex and sometimes even political nature of conservation efforts. The experts' strategies ranged from short-term interventions, such as injecting insecticides to quickly reduce pest populations, to long-term preservation efforts, including holistic methods like seed collection and habitat restoration. These differences underscore the varying goals and values within the field. *Table 1* provides a brief overview of key terms that will be expanded upon in the following section.

Table 1. Mitigation Methods Mentioned in Interviews

Term	Definition
Insecticides/Injections	Insecticides can be applied directly to infested trees or used as preventative measures on healthy trees to protect them from future infestations.
Biocontrol	Biological control, or biocontrol, uses natural enemies such as parasitoids, predators, pathogens, or antagonists to reduce plant pests or diseases.
Lingering Ash	Lingering ash are trees that show natural resistance to EAB and are crucial for breeding programs aimed at developing EAB-resistant ash populations
Seed Collection	These methods aim to safeguard the genetic diversity of native plant species, ensuring their survival and resilience in the face of invasive threats by collecting and storing seeds in seed banks to later be used for regeneration.
Community Involvement and Education in Invasive Management	Engaging local communities in conservation. Educational programs raise awareness about the ecological impacts of invasive species and equip community members with the knowledge and skills needed to identify and report infestations.
Trap Trees	Intentionally treated to attract emerald ash borers, drawing them away from healthy ash trees. Trap trees are selected and then girdled or treated with chemicals to make them targets for EAB. Once EAB are detected, trap trees are removed to reduce the local population.
Silviculture and/or Early Detection	Focuses on rehabilitating and enhancing natural ecosystems to improve their resilience against invasive threats.

Notable Methods

Out of the mentioned mitigation methods, four stood out as particularly relevant to this study, and are as follows: *Biological Control, Tree Injections, Seed Collection & Lingering Ash, and Community Engagement.* Key points and responses associated with these methods were pulled from the interviews and summarized below.

Biological Control:

- *Uses natural enemies-- In the case of the EAB, there are three parasitoid wasp species that are used to target. (Tetrastichus planipennisi, Spathius agrili, Oobius agrili)*
- *Primarily employed by the VT Forestry Department, which initiated treatment in 2020.*
- *Focuses on smaller trees rather than heavily infested large trees.*
- *It is anticipated that a decade of recovery will be required to observe significant effects.*
- *This method was less favored by those who practice Traditional Ecological Knowledge and tend to utilize seed collection & restoration treatments.*

Tree Injections:

- *Most common mitigation method in VT, entailing drilling small holes at the base of the tree and injecting insecticide into these holes.*
- *On average, needs to be injected about every 3 years.*
- *Also impact other native insects that feed on the tree, leading to unanticipated deaths.*
- *"The risk losing genetics of ash trees outweighs the cost of losing some of the insects."*
- *Extremely successful, but expensive (average tree is $300).*

Seed Collection & Lingering Ash:

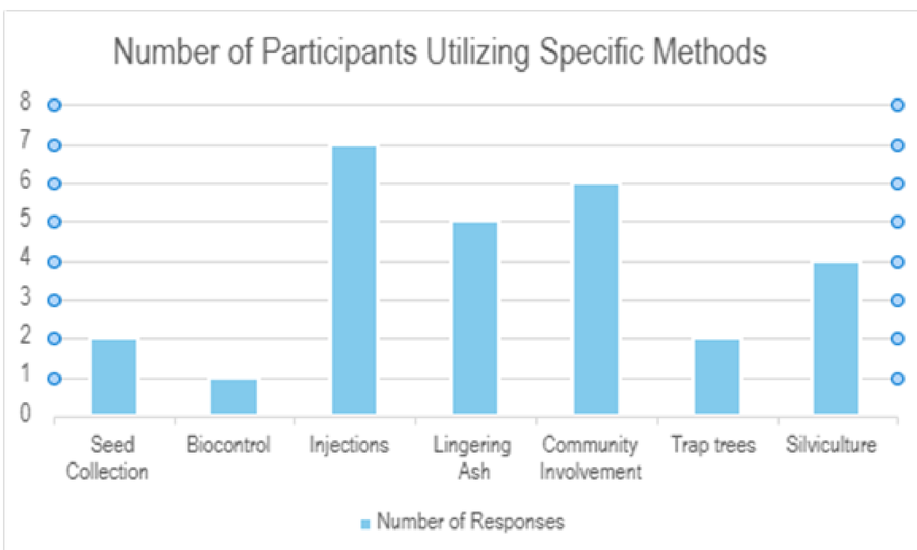
- *Ash trees provide copious amounts of seeds throughout the crown, and these are collected just before they are naturally shed from the tree.*
- *Collected seeds are stored long-term to preserve the genetic diversity of ash trees and create seed banks for future propagation and reintroduction into affected forests.*
- *Lingering ash is trees that endure infestation (display survival traits).*
- *Lingering ash can be used to cultivate resistant ash trees.*
- *Utilized to help to re-establish ash populations.*
- *Ensures that future generations have access to resilient and locally adapted trees.*

Community Engagement:

- *Local organizations, municipalities, and volunteers actively involved in various initiatives such as workshops and public meetings.*
- *Volunteers participate in ash tree inventories, helping to map and monitor the health of ash populations.*
- *Monitoring and Managing Ash (MaMA) framework has 3 projects:*
    - *Surveys: Reporting ash tree presence*
    - *Monitoring Plot Network: Requires attending a workshop helps to determine when nearby areas can be searched for lingering ash*
    - *Lingering Ash Search: Participants report healthy, native ash trees once specific mortality thresholds are met*

Figure 3 shows how often each method was utilized. In most cases, interviewees employed more than one method, expressing the importance of using a variety of measures to mitigate EAB.

Figure 2. Methods Being Used by Participants



During these interviews, I also noted if respondents made any mention of community participation, which I hypothesized to be an important factor in invasive species management. I found that most participants did mention community participation, especially in the context of detection. Due to the evasive nature of the EAB and the vast forest land cover in Vermont, it is impossible for experts to keep tabs everywhere. Thus, citizen science has played a crucial role in the detection of EAB and ash trees, even being endorsed as the most effective method of EAB identification by one interviewee. Other mentions included the Monitoring and Managing Ash (MaMA) program.

Key Takeaways

- Applying different mitigation methods is key.
- Diversifying forests is crucial to building forest health and resiliency.
- Community science efforts through early detection or through citizen science (e.g. MaMA (Monitoring and Managing Ash) programs), play a crucial role in delaying the spread of EAB in Vermont
- While some approaches, such as injecting insecticides and implementing biological control, offer prompt solutions, they also carry the risk of unpredictable long-term ecological impacts and tend to be costly

The findings from the interview process underscore the critical role of cross-sector partnerships in combating the EAB infestation. Experts from diverse backgrounds emphasized the importance of conserving the genetic diversity of ash tree species, highlighting both conventional and unconventional mitigation methods. While some approaches, such as injecting insecticides and implementing biological control, offer prompt solutions, they also carry the risk of unpredictable long-term ecological impacts. In contrast, Indigenous methods focused on seed collection and overall forest health, advocating for a more holistic and sustainable approach.

The interviews revealed a strong consensus on the necessity of collaboration across sectors, whether through sharing expertise or resources. Diversifying forests emerged as a key strategy for building resilience against EAB, with experts agreeing that a variety of interventions is essential to effectively manage the infestation. Another emerging theme is that of adaptive management, which involves continuously monitoring the effectiveness of various interventions and being flexible enough to adjust strategies as new information and technologies become available. The goal is to develop a responsive and resilient management framework that can adapt to changing conditions. The interviews also underscored the need for preservation frameworks that are both restorative and adaptive, ensuring that interventions do not compromise the ecological integrity or cultural heritage associated with species like ash trees. This emphasizes the need for a multifaceted approach to invasive species management, combining short-term and long-term strategies, and fostering cross-sector partnerships to ensure the sustainability and health of forest ecosystems.

5 NON-DOMINANT PERSPECTIVES

Overview

Invasive species are not solely an environmental issue—they also have significant economic, social, and human health impacts (Rai & Singh, 2020). Whether through costly management efforts or the threat to culturally significant species, invasives profoundly affect the communities they infiltrate. The widespread and interconnected nature of these impacts underscores the need for a multidisciplinary approach that fosters cross-sector collaboration (Dick et al., 2016). Evidence gathered from the literature review and interview phase indicates that science from non-dominant perspectives possesses the potential to significantly contribute to the mitigation efforts against the EAB, whether it is from the early stages of detection or preserving seeds for future use. Effectively engaging community members is an integral part of this process and can enhance livelihoods and biodiversity while upholding local and Indigenous values, cultures, and institutions.

Traditional Ecological Knowledge

Traditional ecological knowledge (TEK) plays a crucial role in conservation and can contribute greatly to ash tree preservation (VijayKumar, 2024). Indigenous sustainability frameworks are deeply holistic, intertwining land, language, culture, and law (Kealiikanakaeoleohaililani & Giardina, 2016). While the Brundtland Report's (released in 1987 by the World Commission on Environment and Development (WCED)) definition of sustainability, "to meet the needs of the present without compromising the needs of future generations," is succinct and effective, it fails to acknowledge the spiritual relationship between humans and the environment, which is an underlying theme that is crucial to the outlook of conservation. To adequately comprehend TEK perspectives on sustainability, one must consider the sacred relationship between humans and non-humans. TEK frameworks emphasize the interconnectedness of all elements, focusing on preserving and enhancing traditional knowledge and practices. While Western sustainability tends to view the environment as a resource from which to extract, Indigenous sustainability science "...emphasizes place, relationship, and sacred exchanges among humans and the resources required for survival" (Johnson & Larsen, 2013). Western sustainability science gauges overall wellbeing by a person's access to resources and services and is commodity-based and driven by consumerism. On the other hand, Indigenous sustainability science seeks out a sacred relationship with the environment, where resource allocation is a privilege and where humans adapt to meet the needs of the system instead of vice versa. TEK models also operate on place-based and relational knowledge, with expertise residing in local individuals who have intimate, long-term connections with their environment (Mazzocchi, 2020). By approaching conservation issues from a local perspective, individuals can tailor solutions that are unique to the needs of the area, which has the potential to lead to more effective and lasting outcomes. Indigenous science has contributed greatly to invasive species mitigation, specifically the EAB in the northeast, as will be discussed in the following case study.

Case Study 1: Indigenous Science in Ash Preservation

In the northeast and most of Vermont, there have been significant strides in combining Western and TEK science to tackle the issue of EAB infestation. As previously established, black ash (*Fraxinus nigra*) plays an important role in Tribal culture, particularly in ceremonies, medicines, oral traditions, and legends (Costanza et al., 2017). In some Indigenous cultures, including the Wabanaki, Odawa, Potawatomi, and Anishinaabe, Native American and First Nation basket makers rely upon black ash trees for their craft and traditions (Bolen, 2020). Primarily due to the cultural significance of the black ash tree and due to its vitality to ecosystem and economics, Tribal Nations in the United States and First Nations in Canada have embarked on a mission to mitigate effects of EAB and to preserve this “keystone” species. In New York, the Akwesasne Mohawk Community established the Akwesasne Task Force on the Environment (ATFE) to implement black ash restoration (Benedict & David, 2000). This community-based grassroots organization focuses on a variety of restoration methods, including collecting seeds, educating the public, and replanting trees annually (Akwesasne Mohawk, 2024). Because this task force was established before the EAB infestation, it has established a vast network and foundation of knowledge.

Ash tree preservation efforts began when Mohawk basket makers noticed the quantity and quality of black trees were declining in their area. It is unknown what specifically this decline can be attributed to, and one possible reason is that farmers cut down black ash trees for building or selling and did not replenish the seeds. Other possibilities include plant diseases, pollution, over-harvesting, and habitat destruction. (Benedict & David, 2000). ATFE has always employed strategies to improve forest health by increasing stand diversity, which are more useful now than ever to resist EAB infestation. Forest stand diversity, while deterring EAB damage, can also maximize ash tree production and regeneration. ATFE is also utilizing insecticides and biological control agents as secondary methods, although the Insecticides are not an ideal method due to their potential to contaminate ecosystems and potentially harm basket makers who often put black ash trees in their mouths during the craft process (Smithsonian, 2013).

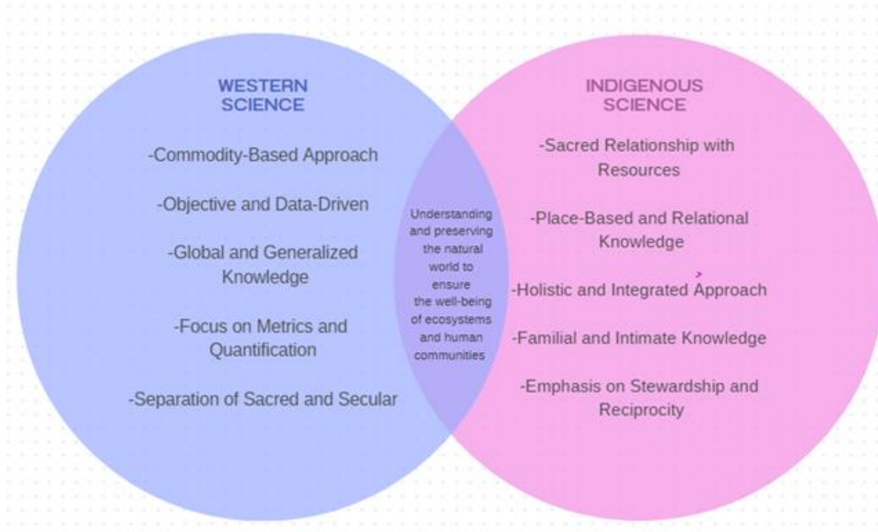
Another parallel Indigenous Framework application is that of the Wabanaki Confederacy in northern New England and adjacent Canada, which includes the Cowasuck and Nulhegan Bands of Abenaki, Houlton Band of Maliseet Indians, Mi’kmaq Nation, Passamaquoddy Tribe at Pleasant Point Sipayik, Passamaquoddy Tribe at Indian Township, and Penobscot Nation (D’Amato et al., 2023) The Wabanaki Confederacy, like the ATFE, already practiced ash tree restoration methods before the EAB was introduced. The Maine Indian Basketmakers Alliance (MIBA) has been working to preserve the craft of black ash basketry since 1993, later collaborating with researchers and foresters to form the Brown Ash Task Force (BATF) to focus on the declining health of ash trees in the area. The BATF places a strong emphasis on community engagement, combining inter-Tribal and multi-agency perspectives to inform the decision-making process. BATF aims to deter the spread of EAB by employing educational outreach about the dangers of firewood transport and proper outdoor recreation protocol.

Community engagement and involvement is a priority due to its potential to offset the spread of EAB. BATF has partnered with ATFE to form a region-wide inter-Tribal contingency. This collaboration has led to further standardization and regulation of mitigation techniques. For instance, after combining forces, ATFE and BATF established a uniform protocol for inventorying ash resources, which was a product of years of research and communication. They have continued the mission of heightening public awareness and fostering partnership through outreach programs such as forester training. They have also improved communication between public and private landowners in order to align efforts a create a uniform manual for ash seed collection. Utilizing cross-sector collaboration when addressing a common issue such as invasives has the potential to address environmental issues while simultaneously fostering community development.

Discussion

Western science frameworks are often the predominant perspective in many scientific discussions and research methodologies. While both perspectives are similar in the way that they consider economic, environmental, and social dimensions, they have certain fundamental ideologies that differ (Simonds and Christopher, 2013) Drawing from multiple scholarly sources, I created the figure below to highlight these differences and to show how integrating these perspectives could lead to a more comprehensive and culturally inclusive model of invasive species management (Throsby and Petetskaya, 2016).

Figure 3. Primary Differences in Western & Indigenous Scientific Frameworks



Community Science

The next phase of this research investigates the foundation of community and citizen science, its applications, and how it can contribute to the long-term goals of invasive species management. This paper employs the term "community science" with the assumption that it operates under the primary definition and is (i) Driven by the community, (ii) Informed by local knowledge and social learning, and (iii) aimed at transforming systems to foster stewardship and achieve social-ecological sustainability (Charles et al., 2020). In certain cases, community science involves individual citizens as volunteers who collect and contribute data to a larger research project (Charles et al., 2020). Community and citizen science shows promise for EAB mitigation through ash species identification, EAB detection, and more. Not only does it aid in long-term conservation goals, community-science also aims to catalyze socioeconomic development by including local value systems and knowledge, supporting human well-being, and decolonizing conservation efforts. Citizen science can significantly contribute to scientific discovery by involving the public in data collection, analysis, and even problem identification.

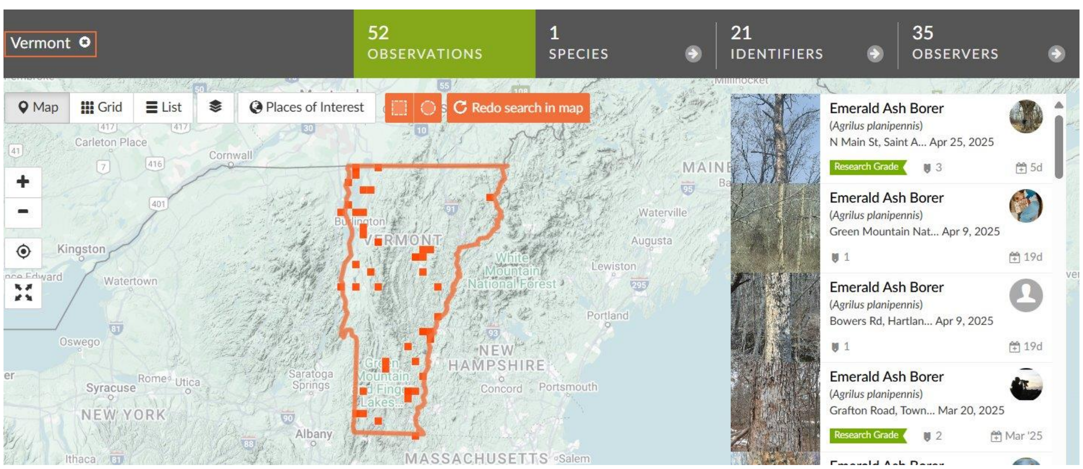
Case Study 2: Citizen Science

Due to volunteers and bird enthusiasts contributing vast amounts of data through birdwatching and reporting sightings, several studies have been able to draw significant conclusions about bird's changing migratory patterns (Birdwatching, 2025). This data, often collected via platforms like eBird and Merlin, helps scientists track changes in migration timing and correlate them to climate change. In a recent study, researchers from the University of California Davis, show that citizen science data from iNaturalist and eBird can reliably capture known seasonal patterns of bird migration in Northern California and Nevada (Carroll et al., 2025). By applying exploratory statistics and developing quantitative methods to assess species consistency across datasets, Carroll demonstrated that participatory science data can be reliably integrated into robust datasets to address broader scientific questions (Carroll et al., 2025).

Another prime example that frames citizens science through the lens of invasive species is the Snake Lungworm Alliance and Monitoring (SLAM) project in Florida. This initiative empowers residents to report sightings of snakes that may be infected with the nonnative parasite *Raillietiella orientalis*, which was introduced by Burmese pythons (University of Florida, 2025). Through educational outreach and training, community members have learned to identify and report. The University of Florida Invasion Science Research Institute (ISRI) is pursuing strategic collaboration with local conservation groups, citizen scientists, universities, and federal agencies. Their citizen science work led to a 300% increase in reporting in just one year. Participation from the community has provided scientists with crucial data to monitor the parasite's spread throughout Florida and into neighboring states.

The success of citizen science contributions has led to its implementation in ash tree conservation projects in Vermont. Through the Monitoring and Managing Ash (MaMA) framework, citizens can engage in the scientific process across three different levels of experience. By making participation available along a variety of experience levels, this project empowers communities to take part. By contributing their observations, community members help create a comprehensive database that supports conservation efforts and informs policy decisions.

Figure 4. Citizen Recorder Observations of EAB in Vermont via iNaturalist



The figure above shows citizen-recorded data of EAB observations in the state of Vermont, uploaded to the popular platform iNaturalist. When citizens become more aware of issues, gain a deeper understanding of socio-technical solutions, and feel personally invested in those solutions, they are more likely to advocate for additional changes through engagement with policymakers or other stakeholders. (Kythreotis et al., 2019). Community science can be particularly effective in the latter respect if it allows citizens to produce scientific evidence on sustainability problems or solutions. This collective effort enhances our understanding of black ash distribution and health, demonstrating the power of community science in addressing environmental challenges.

7 KEY FINDINGS

Discussion

Research & Personal Findings

This research underscores the critical importance of cross-sector collaboration in addressing the ecological and economic impacts of the Emerald Ash Borer (EAB) infestation in Vermont. By integrating efforts across various sectors, including local communities, government agencies, and Indigenous groups, the study highlights how a unified approach can enhance the effectiveness of mitigation strategies. The involvement of diverse stakeholders not only facilitates resource sharing and expertise but also fosters a more resilient and adaptive management framework. However, this study also shows how Western science can sometimes assume access to land and conduct risky methods such as biological control and insecticides, which have unknown long-term ecological impacts. Due to the cultural importance of the ash tree, it is necessary to develop a novel approach that integrates both Western scientific perspectives and non-dominant Indigenous knowledge. Doing so has the potential to enrich practices while offering a culturally inclusive model for invasive species management. Looking ahead, the emphasis on community engagement and public education initiatives will be pivotal in fostering a sense of stewardship and responsibility towards the environment. Programs like

Monitoring and Managing Ash (MaMA) demonstrate the power of citizen science in early detection and monitoring efforts, highlighting the importance of involving local communities in conservation practices.

The multi-disciplinary methodology employed in this research, combining quantitative GIS analysis with qualitative interviews, reflects the comprehensive nature of Environmental Studies and the potential for future effectiveness. While Environmental Studies is sometimes looked down upon in the scientific world for being too humanities-based or as too science-based by the arts community, I believe it offers a unique perspective that can bridge disciplines and glean insights that would otherwise not be discovered. Utilizing my diverse educational background enabled me to leverage technical skills and human-centered insights to provide a holistic understanding of EAB's impact and the strategies needed to mitigate it. By embracing diverse perspectives and fostering partnerships across various fields of expertise, we can develop more effective and resilient strategies to combat the Emerald Ash Borer and protect our natural ecosystems for generations to come.

REFERENCES

Beckstedt, M. E. (2023). Forest response following the loss of ash. Purdue University. Retrieved from https://hammer.purdue.edu/articles/thesis/strong_FOREST_RESPONSE_FOLLOWING_THE_LOSS_OF_ASH_strong/23717862

Berthon, K., Thomas, F., Bekessy, S. (2021). The role of ‘nativeness’ in urban greening to support animal biodiversity. Landscape and Urban Plannin, 205, 103959. https://doi.org/10.1016/j.landurbplan.2020.103959

Benedict, L. (2000). Handbook for Black Ash: Preservation, reforestation/regeneration. Mohawk Council of Akwesasne, Dept. of Environment. Retrieved from https://openlibrary.org/books/OL12224398M/Handbook_for_Black_Ash

BirdWatching. (2025). *The surprising economic impact of birdwatching in the U.S.* Retrieved from https://www.birdwatchingdaily.com/beginners/birding-faq/the-surprising-economic-impact-of-birdwatching-in-the-us/

Bolen, A. (2020). A silent killer: Black ash basket makers are battling a voracious beetle to keep their heritage alive. NMAI Magazine, 21(1). Retrieved from https://www.americanindianmagazine.org/story/black-ash-basketry

Bolton, N., Shannon, J., et al. (2018). Methods to Improve Survival and Growth of Planted Alternative Species Seedlings in Black Ash Ecosystems Threatened by Emerald Ash Borer. *Forests* 2018, 9, 146. https://doi.org/10.3390/f9030146

Brockerhoff, E. G., Liebhold, A. M., & Jactel, H. (2013). The ecology of forest insect invasions and advances in their management. Forest Ecology and Management, 294, 1-21. https://doi.org/10.1016/j.foreco.2012.12.032

Brundtland, G.H. (1987) Our Common Future: Report of the World Commission on Environment and Development. Geneva, UN-Dokument A/42/427. http://www.un-documents.net/ocf-ov.htm

Cadow, C. (2023). Vermont Black Ash Project: Final Report. Vermont Urban & Community Forestry Program. Retrieved from https://vtcommunityforestry.org/sites/default/files/2025-01/Black_Ash_Report.pdf

Charles, A., Loucks, L., Berkes, L., Armitage, D. (2020). Community science: A typology and its implications for governance of social-ecological systems. Environmental Science & Policy.

Costanza, K.L., Livingston, W.H., Kashian, D.M., et al. The Precarious State of a Cultural Keystone Species: Tribal and Biological Assessments of the Role and Future of Black Ash, *Journal of Forestry*, 115, 435–446. https://doi.org/10.5849/jof.2016-034R1

D'Amato, A. W., Orwig, D. A., Siegert, N. W., Mahaffey, A., Benedict, L., Everett, T., Daigle, J., Johnson, L., Catanzaro, P., & Cusack, C. (2023). Towards tree species preservation: Protecting ash amidst the emerald ash borer invasion in the Northeast. Journal of Forestry, 121(1), 1-8. Retrieved from https://harvardforest1.fas.harvard.edu/publications/pdfs/DAmato_JForestry_2023a.pdf

Day, K. R., and S. I. McClean. 1991. “Influence of the Green Spruce Aphid on Defoliation and Radial Stem Growth of Sitka Spruce.” *Annals of Applied Biology* **119**: 415–423. Retrieved from https://doi.org/10.1111/j.1744-7348.1991.tb04881.x

Dick, M., Rous, A.M., Nguyen, V.M., Cooke, S.J. (2017). Necessary but challenging: Multiple disciplinary approaches to solving conservation problems. FACETS. 1: 67-82. https://doi.org/10.1139/facets-2016-0003

Edmond, R., Sesay, V., Sesay, F., Azizi, M. I., & Rahmani, B. (2024). Invasive species and biodiversity: Mechanisms, impacts, and strategic management for ecological preservation. Asian Journal of Environment & Ecology, 23(9), 82-95. https://doi.org/10.9734/ajee/2024/v23i9600

Emerald Ash Borer Information Network. (2025). About the emerald ash borer. Retrieved from https://www.emeraldashborer.info/about-eab

Franklin, S. Jr., & Pindyck, R. S. (2024, April 1). A supply curve for forest-based CO_2 removal. *MIT Climate Portal*. Retrieved from https://climate.mit.edu/posts/supply-curve-forest-based-co2-removal

Gougherty, A. V., Elliott, J. M., LaRue, E. A., Gallion, J., & Fei, S. (2023). Positive association between emerald ash borer residence time and accumulation of invasive plants. Ecosphere, 14(12), e4719. https://doi.org/10.1002/ecs2.4719

Gould, J. S., Murphy, T., Slager, B., Bauer, L. S., Duan, J., & Petrice, T. (2021). Emerald Ash Borer Biological Control Release and Recovery Guidelines. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. Retrieved from https://aphis.stg.platform.usda.gov/sites/default/files/eab-field-release-guidelines.pdf

Grinde, A.R., Youngquist, M.B., Slesak, R.A., et al. (2021). Potential impacts of emerald ash borer and adaptation strategies on wildlife communities in black ash wetlands. *Ecological Applications*, 32:e2567. https://doi.org/10.1002/eap.2567

Henkel, S., Richter, R., Andraczek, K., Mundry, R, et al. (2025). Ash dieback and hydrology affect tree growth patterns under climate change in European floodplain forests. Scientific Reports, 15(1), 1234. https://doi.org/10.1038/s41598-025-12345-6

Herms, D.A., McCullough, D.G. (2014). Emerald ash borer invasion of North American: history, biology, ecology, impacts, and management. *Annu Rev Entomol.* 2014:59:13-30. https://doi.org/10.1146/annurev-ento-011613-162051

Herms, D. A., McCullough, D. G., Smitley, D. R., Sadof, C. S., Williamson, R. C., & Nixon, P. L. (2014). Insecticide options for protecting ash trees from emerald ash borer. Journal of Economic Entomology, 107(1), 347-359. https://doi.org/10.1093/jee/tou026

Hood Museum of Art. (n.d.). Spirit of the basket tree. Dartmouth College. Retrieved April 23, 2025, from https://hoodmuseum.dartmouth.edu/sites/hoodmuseum.prod/files/hoodmuseum/publications/spirit_of_the_basket_tree_final.pdf

Howarth, T. (2024). Ash bore beetle destroys 67,000 trees costing taxpayer $36 million. Newsweek. Retrieved from https://www.msn.com/en-us/news/world/ash-bore-beetle-destroys-67000-trees-costing-taxpayer-36-million/ar-AA1s7jpq

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). (2019). Nature's dangerous decline 'unprecedented'; species extinction rates 'accelerating'. United Nations Sustainable Development. Retrieved from https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report

Iowa State University Extension and Outreach. (2024). Emerald ash borer now confirmed in all 99 counties. Retrieved from https://www.extension.iastate.edu/news/emerald-ash-borer-now-confirmed-all-99-counties

James, P. M. A., L.-E. Robert, B. M. Wotton, D. L. Martell, and R. A. Fleming. 2017. "Lagged Cumulative Spruce Budworm Defoliation Affects the Risk of Fire Ignition in Ontario, Canada." *Ecological Applications* **27**: 532–544. Retrieved from https://doi.org/10.1002/eap.1463

Johnson, K. (2021, May 4). The impact of emerald ash borer. Illinois Extension, University of Illinois Urbana-Champaign. Retrieved from https://extension.illinois.edu/blogs/good-growing/2021-05-04-impact-emerald-ash-borer

Kealiikanakaoleohaililani, K., Giardina, C.P. (2015). Embracing the sacred: an indigenous framework for tomorrow's sustainability science. Sustain Sci, 11. 57–67. https://doi.org/10.1007/s11625 015-0343-3

Klooster, W. S., Gandhi, K. J. K., Long, L. C., Perry, K. I., Rice, K. B., & Herms, D. A. (2018). Ecological risks posed by emerald ash borer to riparian forest habitats: A review and problem formulation with management implications. Forests, 9(5), 250. https://doi.org/10.3390/f9050250

Koch, J.L., Carey, D.W., Mason, M.E., T.M. Poland., K.S. Knight. (2015). Intraspecific variation in Fraxinus pennsylvanica responses to emerald ash borer (Agrilus planipennis). New Forests 46, 995–1011. https://doi.org/10.1007/s11056-015-9494-4

Kolka, R.K., D'Amato, A.W., et al. (2018). Review of Ecosystem Level Impacts of Emerald Ash Borer on Black Ash Wetlands: What Does the Future Hold? *Forests* 2018, 9, 179; https://doi.org/10.3390/f9040179

Leet-Otley, K., Neumiller, G., & Wagner, T. (2019, June 11). Brown ash endangerment and indigenous solutions. The Lantern. Retrieved from https://web.colby.edu/thelantern/2019/06/11/brown-ash-endangerment-and-indigenous-solutions/

Li, X., Holmes, T. P., Boyle, K. J., Crocker, E. V., & Nelson, C. D. (2019). Hedonic analysis of forest pest invasion: The case of emerald ash borer. Forests, 10(9), 820. Retrieved from https://research.fs.usda.gov/treesearch/58999

Lovett, G. M. (2022). 8 billion North American ash trees at risk from emerald ash borer. Cary Institute of Ecosystem Studies. Retrieved from https://www.caryinstitute.org/news-insights/feature/8-billion-north-american-ash-trees-risk-emerald-ash-borer

Mazzocchi, F. (2020). A deeper meaning of sustainability: Insights from indigenous knowledge. The Anthropocene Review, 7(1), 77-93. https://doi.org/10.1177/2053019619898888

Mitchell, R. J., Beaton, J. K., et al. (2014). Ash dieback in the UK: A review of the ecological and conservation implications and potential management options. Biological Conservation, 175, 95-109. https://doi.org/10.1016/j.biocon.2014.04.019

National Museum of the American Indian. (n.d.). Akwesasne Mohawk: Our strategies. Retrieved from https://americanindian.si.edu/environment/akwesasne/Strategies.cshtml

N'Guyen, A., Hirsch, P.E., Adrian-Kalchauser, I., Burkhardt-Holm, P. (2015). Improving invasive spcies management by integrating priorities and contributions of scientists and decision makers. Ambio. 2016 Apr;45(3):280-9. doi: https://doi.org/10.1007/s13280-015-0723-z

North Carolina Forest Service. (2025). Emerald Ash Borer Frequently Asked Questions. Retrieved from https://www.ncagr.gov/divisions/nc-forest-service/forest-health/emerald-ash-borer-faq#Howlongdoesittakeforatreetodie-11660

Parra, G., Lance, D., Mastro, V., Reardon, R., & Benedict, C. (2011). Emerald Ash Borer National Research and Technology Development Meeting. U.S. Department of Agriculture, Forest Health Technology Enterprise Team. Retrieved from https://www.fs.usda.gov/foresthealth/technology/pdfs/EAB_FHTET-2011-06.pdf

Perry, K.I., Herms, D.A. (2016). Response of the forest floor invertebrate community to canopy gap formation caused by early stages of emerald ash borer-induced ash mortality. Forest Ecology and Management, 375, 259-267. https://doi.org/10.1016/j.foreco.2016.05.034

Rai, P.K., Singh, JS. (2020). Invasive alien plant species: Their impact on environment, ecosystem services and human health. Ecological Indicators. 111: 106020. https://doi.org/10.1016/j.ecolind.2019.106020

Schei, F.H., Arnberg, M.P., et al. (2024). Ash dieback: A single-species catastrophe or a cascade of ecological effects in the ground flora? Forest Ecology and Management, 572, 122322. https://doi.org/10.1016/j.foreco.2024.122322

Seibold, S., Cadotte, M. W., MacLean, M., & Bachelot, B. (2021). The contribution of insects to global forest deadwood decomposition. Nature, 597(7874), 77-81. https://doi.org/10.1038/s41586-021-03740-8

Selvaggio, S. (2022). "Trap Trees" offer a promising approach to slow the spread of invasive emerald ash borers. Xerces Society. Retrieved from https://xerces.org/blog/trap-trees-offer-promising-approach-to-slow-spread-of-invasive-emerald-ash-borers

Sibley, P. K., Dutkiewicz, D., Kreutzweiser, D. P., & Hazlett, P. (2020). Soil and nutrient cycling responses in riparian forests to the loss of ash (Fraxinus spp. L) from emerald ash borer (Agrilus planipennis, Fairmaire). Forests, 11(5), 489. https://doi.org/10.3390/f11050489

Smith, A. (2020). *Emerald ash borer at Hopewell Culture National Historical Park*. U.S. National Park Service. Retrieved from https://www.nps.gov/articles/000/emerald-ash-borer-at-hopewell-culture-national-historical-park.htm

Throsby, D., Petetskaya, E. (2016). Sustainability Concepts in Indigenous and Non-Indigenous Cultures. International Journal of Cultural Property. 2016;23(2):119-140. https://doi.org/10.1017/S0940739116000084

Toczydlowski, A. J. Z., Slesak, R. A., Kolka, R. K., Venterea, R. T., D'Amato, A. W., & Palik, B. J. (2020). Effect of simulated emerald ash borer infestation on nitrogen cycling in black ash (Fraxinus nigra) wetlands in northern Minnesota, USA. Forest Ecology and Management. Retrieved from https://research.fs.usda.gov/treesearch/61017

University of Florida Institute of Food and Agricultural Sciences. (2025). Can citizen science save Florida's ecosystems? UF's efforts demonstrate surge in invasive species detection and response. Retrieved from https://blogs.ifas.ufl.edu/news/2025/03/05/can-citizen-science-save-floridas-ecosystems-ufs-efforts-demonstrate-surge-in-invasive-species-detection-and-response/

U.S. Forest Service. (2024). Loss of Black Ash from Emerald Ash Borer Infestation: Operational Studies in Minnesota and Michigan. Retrieved from https://research.fs.usda.gov/nrs/projects/eab-minnesota-and-michigan

U.S. Forest Service. (2024). *Tribes, Forest Service collaborating to offset invasive species effect on Native American culture*. Retrieved from https://www.fs.usda.gov/inside-fs/delivering-mission/sustain/tribes-forest-service-collaborating-offset-invasive-species

U.S. Department of Agriculture. (n.d.). Emerald Ash Borer. Animal and Plant Health Inspection Service. Retrieved from https://www.aphis.usda.gov/plant-pests-diseases/eab

Vermont Department of Forests, Parks, and Recreation. (2021). Emerald Ash Borer: Information for Forest Landowners. Retrieved from https://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/Forest_Health/Library/EAB%20Landowner%20FAQs.pdf

Vermont Center for Geographic Information. (2000). Vermont Open Geodata Portal. Retrieved from https://geodata.vermont.gov/datasets/630b2693c7634fa5ae619f61465de943_0/explore?location=43.850334%2C-72.538914%2C7.96

Williamson, R. C., & Liesch, P. J. (2021). Professional Guide to Emerald Ash Borer Insecticide Treatments. University of Wisconsin-Madison. Retrieved from https://eab.russell.wisc.edu/wp-content/uploads/sites/245/2021/04/EAB-Professional-Factsheet-2021.pdf

Wisconsin Department of Natural Resources. (2025). Forest Health. Retrieved from https://dnr.wisconsin.gov/topic/ForestHealth

Xi, J., Wang, J., Zhu, Y., & Xu, M. (2024). Nitrogen Deposition Reduces the Rate of Leaf Litter Decomposition: A Global Study. Forests, 15(9), 1492. https://doi.org/10.3390/f15091492

Zhang, Y., & Wang, X. (2021). Impact of climate change on forest ecosystems: A review. Forest Ecology and Management, 482, 118-127. Retrieved from https://www.sciencedirect.com/science/article/pii/S0380133021002379

APPENDIX

Table 2. Interview Responses Summarized

Mitigation Method	Interview Notes
Biocontrol	Biocontrol, as previously defined, uses natural enemies such as parasitoids, predators, pathogens, or antagonists to reduce plant pests of diseases. In the case of the EAB, there are three wasp species that are used to target. *Tetrastichus planipennisi*: A small moth that emerges from sections of ash bolts affixed to trees, locates EAB, and parasitizes them. Its smaller ovipositor is more effective on small trees. *Spathius agrili*: A parasitic non-stinging wasp, that in adult form lays multiple eggs on the surface of an EAB larva. During oviposition, the EAB larva is paralyzed, halting its development beyond the larval stage. The hatching wasp larvae then feed on the EAB larva, ultimately leading to its death *Oobius agrili*: A tiny stingless wasp used as a biological control agent against the emerald ash borer (EAB), specifically targeting EAB eggs. When Oobius agrili locates an EAB egg within tree bark, it injects its own egg inside the host egg. The parasitoid egg then hatches, grows, and ultimately kills the EAB egg In Vermont, biocontrol is primarily employed by the Vermont Forestry Department, which initiated treatment in 2020. Currently, there are six release sites distributed across Vermont: two in the Northwest, two in the Southwest, and three in the Central region. Each site has received three species of biocontrol agents from the APHIS laboratory in Michigan. The strategy focuses on smaller trees rather than heavily infested large trees, aiming to provide the next cohort an opportunity to reach maturity. During the initial phase of the recovery period, foresters collect sections of trees and place them in rearing tubes, allowing parasitoids to hatch and subsequently collecting them to verify the establishment of a population. It is anticipated that a decade of recovery will be required to observe significant effects. Biocontrol, utilizing parasitoid wasps, is effective only on trees less than 15 inches in diameter due to the limited length of the ovipositor. This method has received less acceptance from tribal members, who favor insecticide treatments.
Injections	Injections/insecticides are one of the most effective methods in mitigating the effects of EAB. While there are multiple types of injections, the primary one is

Emamectin Benzoate. Caitlin Cusack from Vermont Land Trust was on the forefront of introducing insecticides to Vermont—in 2020, after applying for a Forest Service grant to buy tree injection equipment, she began inoculating groves of ash trees. VLT has performed ash treatments on 10 properties in Vermont, where a "preservation patch" is identified and between 12-20 ash trees (mostly white ash and black ash included where possible) to be treated. Within these sites, it is ideal that at least ¾ of them are female because ash trees are dioecious and thus do not need a large presence of male trees to reproduce. They are treating around 150 total ash trees. They operate under the mindset that it is better to preserve more sites with a smaller number of trees rather than preserving fewer sites with a larger number of trees per site. There has been a large success with injections. They hope to use insecticides to preserve the genetic diversity and sites for future seed collection. VLT has also tried to protect culturally important ash trees via the method of injection. While insecticides seem to be the most effective against EAB, they also have the potential to pose environmental impacts.

Injections are also the primary mode of EAB mitigation in Urban settings. Within an urban area, EAB dead trees are more dangerous to work on and leave on site because they are brittle, making it important for municipalities to manage this risk. In Montpelier, removing ash trees along the streets in the exterior part of town to manage the risk. The Urban plan entailed treating trees downtown (15 in the first year). All major trees in the area are green ash. The injections have proved to be extremely effective and none of the injected trees have died (over 50 trees). Pesticide used is benzoate. Goes into the stem of a tree (blue-ish, sticky chemical). Tree's vascular system absorbs it and then the tree spreads it throughout its own leaves, and it grows with the tree for the following year and remains effective for 2 years. In urban settings, you cannot allow the tree to remain where it might die. Strength of trees goes down; risk of trees goes up and cost of removing trees goes up. Harder to remove a tree the more infected it gets. They are still not in the process of planting new ash trees. However, the insecticides also impact other native insects that feed on the tree, leading to unanticipated deaths. However, Caitlin points out that sometimes you must weigh the pros and cons: risk losing genetics of ash trees outweighs the cost of losing some of the insects. A whole sweep of species. Any native insect that feeds on that tree will also die. Caitlin Cusack from VLT said: "However, injection has the least potential for drift or

	impacts to non-target species because you're injecting it directly into the tree. There's not a lot of potential for leaching into roots – it goes up into the trees." It is crucial to weigh the pros and cons. The risk of losing genetics and ash trees outweighs the cost of losing some of these insects. The Forestry Department also plans to implement insecticide treatments in the upcoming year, although this initiative has not yet commenced. Injections are also expensive and time intensive. "While pesticide injection prices vary by the size of the tree, the average tree would cost $300 for every treatment, he said — which "adds up fast" when treatments need to be given every few years."
Silviculture	Tony D'Amato articulated the profound impact of ash tree loss on ecosystems, which will likely transition to non-forested conditions. He underscores the necessity of adapting to these changes and building resilience. D'Amato emphasizes the importance of diversifying forests to prevent monocultures, which are susceptible to complete devastation, thereby enhancing overall forest health. D'Amato places significant emphasis on managing resilience against EAB in Vermont by thoughtfully engaging with ash trees to enhance adaptive pathways within these ecosystems. In terms of forest health, he highlights integrative pest management, forest composition and density, and water tolerance as critical factors.
Lingering Ash	Efforts are also underway to create stands by selecting lingering ash trees that exhibit survival traits (tony). While the majority of ash trees invaded by EABs typically perish, a tiny fraction of these trees not only endure the infestation but also stay healthy while the trees around them have since passed. These resilient trees, identified among all prevalent Northeastern ash species, are referred to as 'lingering ash.' They offer a glimmer of hope as some exhibit resistance to EAB, which can be harnessed to cultivate highly resistant ash trees. MaMA (Monitoring and Managing Ash) is an initiative driven by citizen science that provides a framework for identifying and mitigating EAB invasion. US Forestry will continue to monitor for lingering ash in their sites
Community Involvement and Education in Invasive Management	Local organizations, municipalities, and volunteers are actively involved in various initiatives. These include educational workshops, public meetings, and informational mailings to raise awareness about EAB and its effects. Volunteers participate in ash tree inventories, helping to map and monitor the health of

	ash populations. For example, towns like East Montpelier have implemented proactive ash tree removal projects along key roads, paired with outreach and education to inform residents about the importance of these actions.
Trap Trees	Tree girdling is a widely used technique for mitigating the impact of the emerald ash borer (EAB) and preserving ash trees. Girdling is particularly effective in areas where cutting down trees would cause significant damage to surrounding vegetation. It is commonly employed in forest stand improvement projects to manage ash populations and create habitats for wildlife and especially in regions with high ash densities
Seed Collection	Seed collection efforts are playing a crucial role in preserving ash trees, particularly against the threat posed by the invasive emerald ash borer (EAB). Local organizations and volunteers are actively gathering seeds from healthy ash trees to safeguard their genetic diversity. These methods are primarily employed by Indigenous communities, who have been engaging in these practices for years, even before the EAB infestation. These seeds are stored and used to grow new trees, ensuring that ash populations can be restored even if EAB causes significant damage. This proactive approach not only helps maintain the ecological balance but also preserves the cultural heritage associated with ash trees, which are vital for Indigenous basket-making traditions