***Agrilus planipennis* (Emerald Ash Borer): A comprehensive Review of Biology, Impact, Management, and Data Resources**

I. Executive Summary

The Emerald Ash Borer (*Agrilus planipennis*) is an invasive species of Asian origin that poses a serious threat to ash trees (*Fraxinus* spp.) in North America. Since its first detection in the United States in 2002, it has spread rapidly, leading to widespread tree mortality, disruption of ecological balance, and significant economic losses. The main damage caused by this insect comes from its larvae, which feed beneath the bark, creating characteristic “S”-shaped galleries that destroy the vascular system of the tree and ultimately cause its death.

Effective management of this pest requires an Integrated Pest Management (IPM) approach centered on early detection and intervention. This approach combines monitoring and detection methods such as purple prism traps and girdled trap trees, classical biological control programs involving the release of Asian parasitoid wasps (*Oobius agrili, Tetrastichus planipennisi, Spathius galinae*), cultural practices including the removal of infested trees and diversification of species composition, and chemical control methods such as systemic trunk injections with emamectin benzoate, which are especially effective in protecting high-value trees.

In the long term, sustainable management depends on integrating current IPM practices with ongoing scientific research. Future research priorities include modeling the potential impacts of climate change on the beetle’s spread, improving the effectiveness of biological control agents, understanding post-invasion ash regeneration dynamics, and applying spread modeling to optimize management strategies in urban settings. Available genetic and genomic datasets also provide an essential foundation for tracing invasion pathways and developing next-generation control tools.

This report presents a structured review of the biology of the Emerald Ash Borer, its ecological impact, existing management strategies, and key data resources that can support future research.

II. Introduction

The Emerald Ash Borer (*Agrilus planipennis*) is an invasive beetle of Asian origin and poses a major threat to ash trees (*Fraxinus* spp.) in North America. Since it was first detected in the United States in 2002, it has spread rapidly and is now present in more than 35 states and 5 Canadian provinces. This expansion has led to widespread tree mortality, disrupting ecological balance and causing significant economic losses. In Texas, the beetle was first reported in 2016, and since then it has spread to multiple counties across the state.

The main damage to trees comes from the larvae, which feed just beneath the bark in the nutrient and water-conducting tissues. By creating characteristic “S”-shaped galleries, the larvae disrupt the tree’s vascular system and eventually kill the tree. This report aims to provide a structured overview of the Emerald Ash Borer, including its biology, impacts, current management methods, and available scientific data sources.

Throughout the document, the life cycle, physical traits, and identification methods of the beetle are described in detail. The report also outlines Integrated Pest Management (IPM) strategies used to control the pest. These strategies include monitoring with traps, biological control agents such as parasitoid wasps, cultural methods like the removal of infested trees, and chemical treatments such as insecticides. Finally, the report highlights available visual and genetic datasets for researchers, ongoing studies on issues like the effects of climate change, and potential future research directions.

III. Biology and Identification of *Agrilus planipennis* Fairmaire

Emerald ash borer (*Agrilus planipennis*) (Coleoptera: Buprestidae) is a wood-boring beetle characterized by its metallic emerald green coloration and the bright coppery-red dorsal surface of the abdomen, which is unique among North American *Agrilus* species.[2,3] It is native to Asia, occurring in Russia, Mongolia, Japan, China, and Taiwan.[1]

Life Cycle: Egg, Larva, Pupa, Adult

The life cycle of the emerald ash borer (*Agrilus planipennis*) consists of four main stages: egg, larva, pupa, and adult.[1] Females can live up to six weeks in the field, laying 60–90 eggs on average, though some may produce as many as 200.[4] Eggs are deposited individually in bark crevices, flakes, or cracks and are initially ivory to white, later turning brown or reddish-brown before hatching. They measure 1.0–1.23 mm in length and 0.6–1.0 mm in width.[1,4] Development time varies with temperature, ranging from 7–19 days.[1,4]

Larvae represent the longest stage of development, lasting about 300 days and passing through four instars.[1,4] They are translucent to white, slightly flattened, with a brown head mostly covered by the prothorax and pincher-like appendages on the last abdominal segment.[1,3,4] Feeding occurs beneath the bark in the outer phloem and vascular cambium, producing serpentine or S-shaped galleries that disrupt water and nutrient transport in the tree.[1,3,4,5] Fully mature larvae reach 25–32 mm (1.0–1.3 in) in length, although some can grow up to 1.5 in.[1,3,4,5] In fall, fourth-instar larvae excavate chambers in the outer bark or sapwood, where they curl into a J-shape before transforming into prepupae.[4]

The pupal stage is relatively short, lasting about 20 days at 18–20 °C.[1] Pupae measure 11–16 mm in length and 3–5 mm in width and are located in chambers excavated by larvae within the inner bark or sapwood.[1]

Adults emerge in spring by chewing characteristic D-shaped exit holes approximately 3–4 mm wide.[1,4] They are metallic emerald green, measuring 7.5–13.5 mm in length, with the dorsal surface of the abdomen a distinctive bright coppery-red.[2,3,4] Newly emerged beetles feed on ash leaves for about one week before mating, causing minimal defoliation.[4] Laboratory studies indicate females live an average of 20.5 days and males 22.8 days, though in the field females survive longer.[1,4] Adults remain active during warm and sunny conditions, often sheltering in bark crevices or foliage during storms.[7]

Physical Description and Distinguishing Features

EAB shows distinct morphological traits at each stage of its life cycle, which are essential for accurate identification.

- **Adult:** Adult Emerald Ash Borers are metallic wood-boring beetles measuring 7.5–13.5 mm in length.[4] Some descriptions report individuals ranging between 10.0–13.0 mm, making them somewhat larger and more brightly metallic green than most other U.S. *Agrilus* species.[2,3] Their body is uniformly bright, metallic emerald green, with the elytra usually appearing slightly duller and darker green. Variable reflections of brassy, coppery, or reddish tones can also occur, especially on the pronotum and ventral surfaces.[2,3] Rare specimens may appear entirely coppery-red, bluish-green, or green with bluish elytra.[2,3]
  A key diagnostic feature is the dorsal surface of the abdomen, which is bright coppery-red in this species and visible only when the elytra and wings are raised.[2,3] This metallic red dorsum is unique among North American *Agrilus* species and provides the simplest distinguishing characteristic for identifying Emerald Ash Borer.[2,3] In addition, the pygidium bears a longitudinal mid-dorsal ridge (carina) that projects beyond the abdominal tip as a blunt, slightly notched spine, visible even when the elytra are closed.[2]

Adults emerge in the spring by chewing characteristic D-shaped exit holes approximately 3–4 mm wide in the bark of host trees.[1,4] Newly emerged beetles feed on ash leaves for about one week before mating, though this causes minimal defoliation.[4] Laboratory studies report that adult females live an average of 20.5 days (ranging 3–52 days), while males survive an average of 22.8 days (ranging 3–53 days) after emergence.[1] A typical female may live around six weeks and lay 60–90 eggs, though in some cases up to 200 eggs may be produced.[4] These features, combined with their distinctive coloration and abdominal characters, make adult Emerald Ash Borer readily identifiable.

- **Pupa:** Emerald ash borer pupae measure 11–16 mm in length and 3–5 mm in width.[1] The pupal stage is relatively short, lasting an average of about 20 days at 18–20 °C.[1]
- **Larva:** Emerald ash borer larvae are translucent to white and slightly flattened, with a brown head mostly covered by the prothorax and a pair of brown pincher-like appendages on the last abdominal segment.[1,3,4] Their mouthparts are the only visible external structures of the head.[1] Larvae feed beneath the bark, first in the outer phloem and vascular cambium, producing curved, serpentine, or S-shaped galleries that disrupt the transport of water and nutrients within the tree.[1,3,4,5]
  The larval stage is the longest part of the life cycle, lasting about 300 days and consisting of four instars.[1,4] During this period, larvae molt between instars while tunneling under the bark.[4] Fully mature larvae average 25–32 mm (1.0–1.3 in) in length, though some can reach up to 1.5 inches.[1,3,4,5] In fall, fourth-instar larvae excavate chambers about 1.25 cm into the outer bark or sapwood, where they curl into a J-shape. Inside these chambers, they shorten into pre pupae before transitioning into pupae that later emerge as adults the following spring.[4]
- **Egg:** Emerald ash borer eggs are deposited individually in bark crevices, flakes, or cracks, where they remain protected.[1,4] They are initially ivory to white, later darkening to brown or reddish-brown a few days after being laid.[1,4] Eggs measure about 1.0–1.23 mm in length and 0.6–1.0 mm in width.[1,4] Hatching time varies with temperature and environment: at 18–23 °C they hatch in 17–19 days, at 24–26 °C in 12–13 days, and under typical conditions in about 7–10 days.[1,4] Female fecundity is variable, with dissections showing averages of 32 fully formed and 71 immature eggs per female, while other studies report 40–53 eggs laid.[1]

Host Plants and Feeding Behavior

Emerald ash borer primarily attacks ash trees (*Fraxinus* spp.), including green ash (*Fraxinus pennsylvanica*), white ash (*F. americana*), black ash (*F. nigra*), and blue ash (*F. quadrangulata*).[1,3] In North America, no infestations have been observed on non-ash species.[1] Outside of North America, adults have been reported on *Juglans* spp., *Pterocarya* spp., and *Ulmus* spp., but experimental studies showed that larvae fail to develop successfully on these non-ash hosts, with nearly 80% of eggs deposited on *Fraxinus* logs.[1] In addition to ash, the white fringetree (*Chionanthus virginicus*) has also been identified as a host.[3]

After hatching, larvae feed beneath the bark and phloem, producing characteristic S-shaped galleries that disrupt nutrient flow within the tree.[7] Pupation occurs during winter, and adults emerge in spring through D-shaped exit holes.[7] Adult beetles live for about three weeks, remain active during warm and sunny conditions, and may shelter in bark crevices or foliage during storms.[7]

Geographical Distribution

The emerald ash borer (*Agrilus planipennis*) is native to Asia, where it occurs in Russia, Mongolia, Japan, China, and Taiwan.[1] It was accidentally introduced into the United States in the 1990s in wood packing material from eastern Asia and was first detected in Michigan in 2002.[1,6] From there, it spread rapidly, and within five years had been confirmed in Illinois, Indiana, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia.[1]

Since its discovery, the beetle has expanded widely across North America. It has now been reported in at least 35 U.S. states and 5 Canadian provinces[5], with more recent records confirming its presence in 2024 in over 40 states including Alabama, Colorado, Connecticut, Georgia, Iowa, Kentucky, Louisiana, Minnesota, New Jersey, New York, North Carolina, Texas, and Wisconsin.[3] In Canada, it is established in Ontario, Quebec, and several additional provinces.[1,3]

The insect was first found in Texas in 2016 near the Louisiana border.[5,6] Since then, it has spread across much of the northeastern, southern, and mid-western regions of the state. By July 2024, it had been detected in 27 additional Texas counties beyond the original Harrison County detection, including Bowie, Cass, Denton, Dallas, Grayson, Hood, Johnson, McLennan, Parker, Tarrant, and Wise.[5,6] All infested counties are placed under quarantine by state and federal agencies to slow further spread.[3,6]

Updated distribution records for the emerald ash borer are maintained through coordinated national monitoring efforts. Current U.S. county level distribution data are compiled by the U.S. Department of Agriculture Animal and Plant Health Inspection Service, while consolidated regional summaries and maps are provided by emeraldashborer.info. These resources are used by state and federal agencies to track spread, inform quarantine decisions, and support management planning.[7,22]

Table 1: Key Characteristics of Emerald Ash Borer Life Stages

Life Stage	Size (approx.)	Color/Appearance	Key Distinguishing Features	Typical Location
Adult	7.5-13.5 mm(0.3-0.5 in)	Bright metallic emerald green; elytra slightly duller/darker; variable brassy, coppery, or reddish reflections; rare forms coppery-red, bluish-green, or green with bluish elytra	Dorsal surface of abdomen bright coppery-red (unique among *Agrilus* in N. America); pygidium with mid-dorsal ridge projecting as blunt, notched spine; characteristic D-shaped exit holes (3–4 mm)	On ash leaves (feeding), under bark of host trees, dispersing in spring/summer; overwinter in ground or under bark
Pupa	11-16 mm long, 3-5 mm wide	White	N/A	Inner bark or sapwood chambers excavated by mature larvae
Larva	25-32 mm (1.0-1.3 in)	Translucent to white; brown head mostly covered by prothorax; slightly flattened; pincher-like appendages on last abdominal segment	Legless; mouthparts only visible external head structure; feed in outer phloem/cambium, forming curved or S-shaped galleries	Beneath bark in phloem/cambium; outer bark or sapwood chambers in fall
Egg	1.0-1.23 mm long, 0.6-1.0 mm wide	Ivory to white when laid, darkening to brown	N/A	Bark crevices, cracks, and flakes on ash trees

		or reddish-brown after a few days		

IV. Management and Control Strategies

Effective management of the emerald ash borer requires a comprehensive and adaptive strategy, primarily based on Integrated Pest Management (IPM) principles.

Integrated Pest Management (IPM) Principles for *Agrilus planipennis*

Integrated Pest Management (IPM) is an approach that combines pest monitoring with cultural, biological, and chemical methods to suppress populations below levels that cause significant damage.[8] A comprehensive IPM strategy is crucial to slow the spread of the emerald ash borer and reduce the density of existing populations.[1,9]

Monitoring and Early Detection Methods:

Within an IPM framework, monitoring and early detection are essential for limiting the spread and damage caused by the emerald ash borer, as they allow for timely identification of infestations and the implementation of control measures.

- **Population Monitoring via Traps:** Large purple prism traps are widely used in government-sponsored survey programs and are visible in public spaces such as parks and recreation areas.[8] These traps are coated with adhesive and equipped with lures that remain effective in the field for about 20 days. Improvements in lure chemistry have increased effectiveness, though further refinement is needed.[8] Prism traps are typically hung in the mid to lower canopy of ash trees of at least 20 cm in diameter before EAB emergence.[8] Other trap designs, such as green funnel and double-decker traps, have also been employed, often baited with volatiles like (Z)-3-hexenol, Manuka or Phoebe oil, and even female sex pheromones.[10] Detection efficiency varies, ranging from 70–80% in low-density populations to 100% in high-density areas, but there is no consensus on the best trap–lure combination.[10]
- **Girdled Trap Trees:** Girdling, the removal of bark and phloem to attract ovipositing females, is a highly effective detection method, particularly in areas with low EAB densities.[10] Although more labor-intensive and lethal to the girdled tree, this method often surpasses canopy traps in detection success.[10] Girdled trees may also serve as population sinks when destroyed after larval infestation is confirmed, thereby reducing local EAB numbers. However, in areas with high populations and limited phloem, attacks may spill over to neighboring trees.[10] Combining girdling with systemic insecticide treatments has been suggested to create lethal trap trees, though such approaches are not widely implemented.[10]
- **Visual and Public Monitoring:** In addition to traps and girdling, simple visual monitoring by the general public remains important, as current trapping materials and techniques are not yet perfected.[8] Early detections in asymptomatic trees can also involve branch sampling, where upper canopy branches are debarked to locate galleries, although this method is too labor-intensive for large-scale surveys.[10]

Biological Control

Management of the emerald ash borer (EAB) relies heavily on integrating natural enemies with complementary strategies to suppress populations.[1,8] Shortly after the pest was first detected in North America, woodpeckers were identified as a major source of mortality, feeding on late-instar larvae and pupae in infested trees.[1] In addition, native parasitoids such as *Atanycolus cappaerti* (Braconidae) and *Cerceris fumipennis* (Crabronidae) have been observed attacking EAB, though parasitism rates by most native species remain relatively low.[1,8]

In response, a classical biological control program was launched in 2007, introducing parasitoids from EAB's native range in Asia.[8,10] The program initially released three Hymenopteran parasitoids: *Oobius agrili* (Encyrtidae), an egg parasitoid, *Tetrastichus planipennisi* (Eulophidae), a larval endoparasitoid, and *Spathius agrili* (Braconidae), a larval ectoparasitoid.[1,8,9] In 2015, *Spathius galinae* was added from the Russian Far East to improve control success in northern regions.[8,10] At present, *T. planipennisi*, *O. agrili*, and *S. galinae* are established and widely released, while *S. agrili* remains poorly established outside a few sites.[10]

Despite variation in establishment and parasitism efficiency—ranging from <6% to 30% in introduced areas compared to up to 65% in the native range—these parasitoids have shown moderate success in slowing EAB spread and aiding ash regeneration.[10] Surveys also highlight S. galinae as particularly promising, with evidence of natural spread and increased control effectiveness.[10]

Beyond parasitoids, pathogens have also been evaluated as biocontrol agents.[9] The entomopathogenic fungus *Beauveria bassiana* demonstrated high virulence in both greenhouse and field trials, with applications significantly reducing populations of larvae and adults.[9] Autodissemination devices such as the FraxiProtec™ trap achieved infection rates up to 40%, though further refinement is needed for broader field effectiveness.[10]

Together, the combination of parasitoid releases, natural predators, and microbial control illustrates the central role of biological control in the long-term management of emerald ash borer.[1,8,9,10]

Cultural Control Practices

Cultural management of the emerald ash borer (EAB) emphasizes preventing further spread and reducing available breeding material. Removing unhealthy or infested ash trees is a priority, as larger trees over 10 inches in diameter produce more beetles and contribute more heavily to population growth.[6] Once removed, infested wood must be processed appropriately through chipping, grinding, or heat treatment to prevent the emergence of adults.[9] Replacement of removed ash with non-ash species is encouraged, while planting a diverse array of tree species helps reduce the risk of future large-scale losses.[6]

Girdling can also be applied as a cultural control technique. By removing sections of bark and phloem, selected trap trees attract ovipositing females; once infestation is confirmed, these trees can be destroyed, acting as population sinks.[10] This approach may be combined with other management tools, but when implemented carefully, it contributes to reducing local EAB densities and slowing spread.[10]

Chemical Control

Chemical control of the emerald ash borer (EAB) is an important management option, particularly in urban landscapes and on privately owned trees, though it is also used to protect ash in natural forests and conserve genetic diversity.[10] A variety of insecticides are available, including sprays and systemic products applied through trunk injections and soil drenches.[1,8,10] Among these, systemic insecticides with emamectin benzoate as the active ingredient are considered the most effective and long-lasting, providing protection for two to three years even under high pest pressure.[6,8,10] Other insecticides, such as imidacloprid, dinotefuran, and azadirachtin, have demonstrated variable efficacy depending on application timing, soil conditions, and tree size.[1,8,10]

Four main application techniques are commonly used: soil-applied drenches or injections, trunk-injected systemic insecticides, basal trunk sprays, and broadcast foliar sprays.[8,10] Soil applications may take several weeks to be translocated within the tree, particularly for larger ash, and have yielded inconsistent results in some field studies.[8,10] Trunk injections, although wounding to the tree and more costly, are highly effective when performed correctly, with emamectin benzoate trunk injections achieving greater than 99% control.[8,10] Basal trunk sprays with dinotefuran are available for smaller trees but generally offer lower and less consistent control.[8] Broadcast foliar sprays can kill adults and newly hatched larvae before they bore into trees, but they are not effective against larvae already feeding internally and are generally discouraged due to negative impacts on beneficial insects and pollinators.[8,10]

Chemical treatment success depends on early intervention, ideally before more than 30–40% canopy decline, as trees with heavier dieback rarely benefit from treatment.[6,8,10] Applications should be made in early spring before or during the initial stages of infestation, avoiding ash flowering periods to reduce risks to pollinators.[10] When applied under proper conditions and integrated with other management practices, chemical control can effectively reduce EAB populations and prolong the survival of ash trees.[1,6,8,10]

V. Available Datasets and Resources

Datasets and resources on the emerald ash borer are crucial for understanding its possible economic and ecological effects, its life cycle, and how it spreads. They form the basis for studying this species and guiding future research initiatives.

Image Datasets for EAB

- **General Visual Resources:**
  - The websites *invasive.org*[11] and *bugguide.net*[12] can be considered useful visual resources for the emerald ash borer. They include images of some life stages of the species, as well as detailed examples of the damage it causes to ash trees and illustrations related to management methods.
  - Additionally, *inaturalist.org*[13] offers community-contributed observations and photographs of the emerald ash borer, covering some of its life stages and occurrences, along with general information about the species' biology, ecology, and impacts.

Table 2: Overview of Image Datasets for EAB

Dataset Name	Primary Focus	Number of Images	Key Features / Purpose
Invasive.org[11]	Invasive and pest species (including RPS)	422	High-quality diagnostic photos, educational resource for pest ID
Bugguide[12]	Community-curated insect ID	~100	Wide coverage of life stages, location data from citizen scientists
iNaturalist[13]	Biodiversity observations	~500	Crowdsourced images, geotagged occurrences

Genetic and Genomic Datasets

Genetic and genomic resources are essential for studying the biology, morphology, and evolutionary patterns of the emerald ash borer, and several datasets on EAB are now publicly accessible.

- Bray et al. (2011) have shared a dataset that examines the genetic structure of emerald ash borer (*Agrilus planipennis*) populations across Asia and North America.[14] This dataset includes mitochondrial DNA sequences, AFLP fingerprints, and microsatellite allele data collected from multiple localities in the species' native and introduced ranges.[14] Researchers can use these data to study the geographic origin of EAB, assess its invasion potential, explore host range, and inform biological control strategies.[14] The dataset provides a valuable resource for population genetics studies, comparative analyses between native and invasive populations, and research on the mechanisms underlying EAB's spread.[14]
- Duan et al. (2021) have shared a dataset containing the complete mitogenome of the emerald ash borer (*Agrilus planipennis*).15 This dataset includes the circular mitochondrial genome with 15,942 base pairs, 13 protein-coding genes, 22 tRNAs, 2 rRNAs, and an A–T-rich region, along with nucleotide composition information.[15] Researchers can use these data to study the phylogenetic relationships of EAB with other Buprestoidea species, analyze mitochondrial gene structure and evolution, and support comparative genomics studies.[15] The dataset provides a valuable resource for genetic and evolutionary research on EAB and related beetle species.[15]
- Zhao et al. (2015) have shared a dataset on the core RNAi machinery of the emerald ash borer (*Agrilus planipennis*).[16] This dataset includes sequences and annotations for three key RNAi pathway genes—Dicer-2, Argonaute-2, and R2D2—identified from the EAB genome.[16] Researchers can use these data to study the RNAi response in EAB, explore functional genomics approaches, and develop potential gene-based pest management strategies.16 The dataset provides a valuable resource for genetic and genomic research on EAB.[16]

Population Monitoring Data

Population monitoring data, alongside genetic and genomic resources, are crucial for understanding how emerald ash borer populations spread, evaluating potential risks to ash forests, and assessing the effectiveness of management strategies.

EAB Population Data

Across eastern North America, emerald ash borer invasion has led to extensive ash mortality, yet variable levels of ash regeneration have been observed in invaded stands.[17] Forest inventory data from 2013–2018 indicate that counties invaded earlier (2002–2006) show the highest densities of ash seedlings and saplings, likely reflecting pre-invasion overstory densities.[17] Despite widespread regeneration, ash trees in the smallest overstory class are dying faster than they are being recruited from seedlings or saplings, resulting in declining population trajectories in plots invaded for more than approximately ten years.[17] These observations highlight the need for continuous population monitoring to track ash regeneration, guide management efforts, and predict the long-term ecological role of ash in the presence of EAB.[17]

VI. Ongoing Research and Future Prospects

Research on the emerald ash borer (*Agrilus planipennis*) continues to expand our understanding of its biology, spread, and impacts on ash trees (*Fraxinus* spp.) and forest ecosystems. Current and ongoing studies focus on population monitoring, regeneration patterns, urban and natural forest management, and biological control strategies. Integrating these efforts provides a foundation for developing long-term, sustainable approaches to reduce the ecological and economic damage caused by EAB. This section highlights recent findings and outlines key areas for future research.

Climate Effects

Climate change is an important area of research that could significantly influence the population dynamics and geographic distribution of emerald ash borer (*Agrilus planipennis*).[18] Rising global temperatures affect the physiological development and habitat ranges of both EAB and ash trees (*Fraxinus* spp.), often increasing the overlap of suitable habitats and niches.[18] This can intensify the threat of EAB invasions across its distribution regions and potentially expand the areas at risk. Future research should focus on modeling EAB population dynamics under regional climate projections and assessing the vulnerability of ash forests to these changes to guide management and conservation strategies.[18]

Biological Control and Parasitoid Wasp Research

Research on biological control of the emerald ash borer (*Agrilus planipennis*) focuses on using parasitoid wasps to suppress EAB populations in forests.[19] This cooperative effort involves researchers from NC State University, the U.S. Forest Service, and Southern Appalachian Highlands Conservancy, targeting sites with high densities of ash trees and moderate EAB infestations.[19] Parasitoid wasps deposit their eggs on or inside EAB larvae, and the emerging wasps feed on the larvae, reducing pest populations.[19] Timing releases according to EAB phenology is critical, as wasps prefer mature larvae.[19] Research in western North Carolina, including at Prices Creek Preserve, confirmed that EAB exhibits a semivoltine lifecycle, informing the selection and timing of parasitoid releases.[19] These studies provide valuable insights for long-term, sustainable management of EAB in natural forests.[19]

Forest Control

Wilson et al. (2025) provide a dataset documenting ash regeneration and co-occurring species in forests 20 years after emerald ash borer (*Agrilus planipennis*) invasion.20 This dataset includes densities of overstory ash (>10 cm DBH), recruits (2–10 cm DBH), saplings (≥45 cm height; <2 cm DBH), and seedlings (<45 cm height), along with canopy dieback assessments in post-invasion areas of south-central Michigan.[20] Despite high mortality among mature ash trees, substantial regeneration was observed across all strata.[20] These data allow researchers to analyze patterns of ash persistence, assess the impacts of EAB on forest community composition, and guide management strategies for maintaining forest structure and biodiversity.[20]

Urban EAB Management and Strategic Planning

Hudgins et al. (2024) provide insights into optimizing management strategies to limit emerald ash borer (*Agrilus planipennis*) impacts on street trees in North America.[21] This study combines pest dispersal modeling with mixed integer programming to identify strategies that outperform conventional rule-of-thumb approaches.[21] Optimized strategies emphasized quarantines and biological control, potentially protecting nearly one million additional street trees and saving approximately $629 million.[21] These findings offer a framework for evidence-based planning, guiding future management efforts to reduce EAB damage in urban forests.[21]

VII. Conclusions

Agrilus planipennis, an invasive wood-boring beetle of Asian origin, has caused extensive and destructive impacts on ash (*Fraxinus* spp.) populations since its introduction to North America. The success of this species largely comes from its larval stage, which is the most damaging phase. Larvae create S-shaped galleries that disrupt the tree's water and nutrient transport systems. The adults are easily recognizable by their metallic emerald-green color, a coppery-red tint on the upper abdomen, and the characteristic D-shaped exit holes they leave in the bark.

Effective management of *A. planipennis* requires an integrated approach built on early detection and timely intervention. A comprehensive Integrated Pest Management (IPM) strategy should include monitoring tools such as purple prism traps and girdled trap trees, which are particularly effective at detecting low-density populations. Biological control lies at the core of management efforts, combining natural enemies like woodpeckers with classical biocontrol programs that introduce parasitoids such as *Oobius agrili*, *Tetrastichus planipennisi*, and *Spathius galinae*, all native to Asia. Cultural control practices emphasize the removal of infested trees and promoting species diversity, while chemical control, especially systemic trunk injections of emamectin benzoate, has proven highly effective in protecting high-value urban ash trees.

Future research priorities can be summarized in several key directions. First, modeling the potential impacts of climate change on the geographic distribution and population dynamics of *A. planipennis* is essential for assessing the vulnerability of future forests. Second, improving the effectiveness of biological control programs requires optimizing parasitoid release timing based on regional EAB phenology, including semivoltine life cycles, as well as advancing the field performance of microbial agents like Beauveria bassiana. Third, long-term monitoring is needed to understand post-invasion ash regeneration dynamics and to guide ecosystem restoration strategies. Finally, approaches such as pest spread modeling and strategic planning in urban environments offer opportunities to reduce economic costs while improving the efficiency of quarantines and biological control. Existing genetic and genomic datasets provide a critical foundation for tracing invasion pathways and developing next-generation, gene-based management tools.

In conclusion, the long-term sustainable management of *A. planipennis* depends on integrating these multifaceted strategies. Filling these knowledge gaps will enable the development of more targeted and evidence-based approaches to protect ash resources across both natural and urban forests.

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