Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Northern Research Station | General Technical Report NRS-235 | August 2025

Proceedings, 32nd USDA Interagency Research Forum on Invasive Species

January 9-12, 2024
Graduate Annapolis Hotel
Annapolis, MD

Citation
McManus, Katherine, A.; Poland, Therese; Havill, Nathan, comps. 2025. **Proceedings, 32nd USDA interagency research forum on invasive species.** Gen. Tech. Rep. NRS-235. Madison, WI: U.S. Department of Agriculture, Forest Service, Northern Research Station. 95 p. https://doi.org/10.2737/NRS-GTR-235.

Abstract
This document contains abstracts and papers of the oral and poster presentations offered at the 32nd USDA Interagency Research Forum on Invasive Species held in Annapolis, MD, in January 2024. The forum, sponsored by the Forest Service, Animal and Plant Health Inspection Service, National Institute of Food and Agriculture, and Agricultural Research Service, illustrates the depth and breadth of studies supported by the agencies and their cooperators.

Manuscript received for publication August 2024

Published by:
USDA Forest Service
One Gifford Pinchot Drive
Madison, WI 53726
August 2025

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Proceedings, 32nd USDA Interagency Research Forum on Invasive Species

January 9-12, 2024
Graduate Annapolis Hotel
Annapolis, MD

Compiled by:
Katherine A. McManus
Therese Poland
Nathan Havill

In memory of Mike McManus, 1937-2023
He brought scientists from around the world together for scientific exchange and friendship

Sponsored by:

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FOREWORD

This meeting was the 32^{nd} in a series of annual USDA Interagency Research Forums that are sponsored by the Forest Service, Animal and Plant Health Inspection Service, National Institute of Food and Agriculture, and Agricultural Research Service. The Group's original goal of fostering communication and providing a forum for the overview of ongoing research among the Agencies and their cooperators continues to be realized and facilitated through this meeting. This proceedings documents the efforts of many individuals: those who organized and sponsored the meeting, those who provided oral and poster presentations, and those who compiled and edited the contributions. The proceedings illustrates the depth and breadth of studies being supported by the agencies and their many cooperators and demonstrates the benefits and accomplishments that can result through the spirit of collaboration.

Acknowledgments
The program committee would like to thank the four USDA agencies for their continued support of this meeting, and the Management and Staff of the Graduate Annapolis Hotel. Thanks to Bella D'Amico and Vince D'Amico for providing the cover artwork, *"In memory of Mike McManus"*, and Vince D'Amico for poster coordination.

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Special thanks
Kristine LaVigna and Vince D'Amico for facilitating Forum registration

Bella D'Amico and Vince D'Amico for cover artwork

Vince D'Amico for poster coordination

Management and Staff of the Graduate Annapolis

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VASCULAR STREAK DIEBACK – AN EMERGING THREAT TO REDBUD NURSERY PRODUCTION IN THE SOUTHEASTERN UNITED STATES

Fulya Baysal-Gurel[1], Prabha Liyanapathiranage[1], and Farhat Avin[1]

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ABSTRACT

Vascular streak dieback (VSD) is the current terminology used to describe plants that exhibit a commonly reported set of symptoms including leaf scorching, tip dieback, and vascular streaking. In 2020, a *Rhizoctonia*-like organism, currently identified as *Ceratobasidium theobromae* (CT) [synonym, *Rhizoctonia theobromae*], was isolated from redbud trees exhibiting VSD symptoms, sometimes along with known canker-causing fungi such as *Botryosphaeria dothidea*, *Didymella* spp. and *Diaporthe* spp. Despite its rapid dissemination throughout the industry, the CT fungus exhibits fastidious growth, creating challenges in isolating and maintaining pure cultures of the fungus, and more importantly, conducting Koch's postulates. CT was originally described as associated with VSD of cacao trees in Asia and was previously listed as a priority pest in the U.S. However, it has been difficult to accurately diagnose and detect CT to gain a further understanding of its role in VSD. It is also unclear how long this organism has been present in the U.S. and whether or not it was introduced on imported plant material. In addition to redbud, VSD has been found in multiple states and in more than 20 ornamental and woody plant species including crape myrtle, dogwood, hydrangea, magnolia, and maple. The current study was designed to identify an effective management strategy to improve plants' health by reducing VSD-related symptoms and Ct population levels in VSD-symptomatic redbud plants. A fungicide efficacy trial was conducted in McMinnville, TN in 2022 with 3-year-old redbud plants that were exhibiting VSD-related symptoms, and natural occurrence of Ct had been confirmed using PCR on the same plants. VSD pressure was high with non-treated control plants showing 88.3 percent leaf scorch severity at the end of the trial. All treated plants had significantly lower leaf scorching compared to the non-treated control plants. Foliar application of Postiva at 20 fl oz/100 gal and Mural at 7 oz/100 gal in 14-day application intervals were the most effective treatments in reducing leaf scorching severity. qPCR primers developed for the detection of Ct were able to quantify the Ct DNA amount from the symptomatic tissue of treated and non-treated plants. Non-treated control plants were identified with the highest amount of Ct DNA. Another study was conducted in a commercial nursery in TN using a completely randomized design with 10 replications with 2-year-old redbud plants. Eastern redbud (*Cercis canadensis*), eleven *C. canadensis* cultivars and one *C. chinensis* cultivar were evaluated for leaf scorching, defoliation, leaf yellowing, interveinal chlorosis and vascular streaking as a result of natural occurrence of VSD between May-Sep 2022. Leaf samples collected from redbuds were also analyzed for macro and microelements. Redbud cultivars with yellow foliage and papery leaf texture were more susceptible to VSD than other tested cultivars, which showed leaf-scorching symptoms starting in late May. VSD-tolerant cultivars that possess dark green and purple foliage and thick leathery leaves exhibited leaf-scorching symptoms in late Aug. None of the tested cultivars exhibited 100 percent resistance to VSD during the growing season. Based on foliar nutrient analyses, some of the yellow foliage cultivars that were exhibiting higher susceptibility to VSD also had higher levels of nitrogen, sulfur, and phosphorous, and low levels of micronutrients such as boron, iron and aluminum. Susceptibility screening information will be beneficial in breeding programs to obtain hybrids with promising characteristics and increased resistance to VSD. Overall, the results will help nursery producers make management decisions for this emerging threat that affects the redbud production in the region.

BALSAM WOOLLY ADELGID POPULATION TRENDS IN NORTHERN UTAH

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ABSTRACT

The balsam woolly adelgid (*Adelges piceae* Ratz., BWA), an insect native to south-central Europe, is an invasive pest of true firs (*Abies*) in North America. There have been at least two independent introductions of BWA into North America, one to the maritime provinces and northeastern US in the early 1900s and a second to the west coast of the United States (US) in the 1920s (Havill et al. 2021). In the western US, BWA had spread to Oregon by 1930s and to north central Idaho by 1983 (Livingston et al. 2000). BWA was first reported on subalpine fir (*Abies lasiocarpa*) in northern Utah in 2017 (Alston et. al. 2018). To better understand how climate may influence continued BWA population spread throughout the range of true firs in the Intermountain and Rocky Mountain regions field-collected data from five sites was used to describe life-cycle timing as a function of temperature and the role of tree moisture stress on population size. In 2021 and 2022 two generations per year were found, although there was extensive overlap in life stages, including during winter. Soil water potential sensors at each site suggest a positive relationship between low tree moisture stress and the number of live BWA adults in the spring and fall generations. Data on a hypothesized first instar dormancy in summer and winter are lacking, and it is unclear what traits might be used to control seasonality.

Using data from a single winter-accessible site, survival of early instars (unsettled and settled first instar crawlers and second instars) was found to be greater than adult survival during winter 2022-23, particularly on the lower tree bole below the snowline. Following a temperature recording at the site of -22.3 °C in late January, however, a large amount of mortality in all life stages was observed. The number of days below -10 °C had a significant negative impact on the size of the spring generation, and the overall population growth rate between 2021-2022 and 2022-2023 declined significantly. Despite a large amount of mortality in winter 2022-23 however, populations remained active the following summer. Based on estimated historical temperatures, our sample period (2021-2023) was among the warmest in the last several decades, but historically temperatures <-20 °C were common at several of the sample sites. These results suggest that extreme winter temperatures may restrict, although not eliminate, BWA population spread.

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LOOKING FORWARD: THE IMPACTS OF ASIAN LONGHORNED BEETLE ON FORESTS IN SOUTHEASTERN NEW ENGLAND

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ABSTRACT

Over the past several decades, the United States has been experiencing an influx of nonnative pests which have the potential to permanently alter the composition, structure, and function of forests. Asian longhorned beetle (ALB) is an invasive pest that came into Worcester County, MA in 2008, where the first instance of this species invading both urban and natural forested areas was documented. 30,000 trees were removed over the course of 10 years as part of management efforts focused on harvesting all host species, primarily *Acer spp*., to prevent ALB spread. We examined forest compositional and structural development following three different eradication treatments (full host removals, herbicide, and stump grinding) and patterns with adjacent unimpacted areas. Overall, the results of our observational study found that forests were recovering following similar pathways documented after other disturbances in southern New England forests. Forest types shifted to primarily oak-hickory or pine dominance following the removal of all *Acer spp*. Landscape simulations of the long-term effects of ALB management and climate change on forests in Worcester County and Cheshire County, New Hampshire using LANDIS-II found that climate had a more pronounced effect on long-term forest conditions. Overall, the results of this work suggests these mixed species forests are resilient to the impacts of ALB management strategies, given the compensatory response of other non-host species. The long-term negative impacts of climate change on overall forest biomass levels argues for adaptation strategies to sustain these forests under future Asian longhorned beetle and climate change impacts.

EMERALD ASH BORER HOST RANGE EXPANSION AND NATURAL ENEMY RESPONSES: IMPLICATIONS FOR BIOCONTROL

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ABSTRACT

Emerald ash borer (EAB, *Agrilus planipennis* Fairmaire), an invasive wood-boring beetle native to Northeast Asia, was first detected in Michigan in 2002. Since then, it has spread to 36 U.S. states and 5 Canadian provinces and has killed hundreds of millions of ash trees (*Fraxinus* spp.). EAB was long thought to exclusively attack members of the *Fraxinus* genus, but in 2015, Don Cipollini at Wright State University discovered EAB activity on white fringetree (*Chionanthus virginicus* L.), a member of the Oleaceae family closely related to ash. Subsequent surveys revealed active EAB infestations of white fringetree in multiple locations where the range of ornamental and/or native white fringetree overlaps with that of ash. The presence of EAB adult exit holes on these naturally infested white fringetrees indicates that this host supports complete development. However, relative rates of EAB development and survival on white fringetree versus ash have not yet been determined. Differences in EAB growth rate on white fringetree versus ash may lead to phenological mismatches with introduced biocontrol agents, decreasing their effectiveness at suppressing EAB populations and creating a natural enemy-free space. On the other hand, if EAB survival is low on white fringetree, this emerging host may actually serve as an ecological trap for EAB. In this study, we compare the development and population growth rate of EAB on white fringetree versus ash and the associated response of larval parasitoids.

In the USDA-ARS Beneficial Insect Introduction Research Unit (BIIRU) lab, we infested 48 bolts each of Oregon ash (*Fraxinus latifolia* Benth.), green ash (*Fraxinus pennsylvanica* Marsh.), and white fringetree at a standard density of 200 eggs per m^2 using lab-laid EAB eggs. Starting 4 weeks after oviposition, we debarked 3 bolts of each species every other week until 14 weeks post-oviposition to determine larval development rates. We measured each larva uncovered during debarking and determined its larval instar. Starting 6 weeks post-oviposition, we also set up choice tests every other week in which we presented gravid, naïve *Spathius agrili* (Braconid larval ectoparasitoid) females with one infested bolt of each of the three species (Oregon ash, white fringetree, and green ash) for 3 days. We then removed the wasps and dissected each exposed bolt to determine larval fates (parasitized versus unparasitized).

To understand EAB development and parasitoid responses to white fringetree in a natural environment, we also conducted a field experiment. We infested stems or branches of 13 white fringetrees and 13 white ash trees planted near a woodlot at the USDA ARS BIIRU in Newark, DE in summer 2022. After 2 growing seasons, we cut and debarked the infested stems or branches and recorded the fates of all larvae. We then conducted life table analysis of EAB cohorts to determine the net reproductive rate (R_0) of EAB on white ash versus white fringetree. This was calculated as the ratio of the number of individuals at the start of generation 2 to the number at the beginning of the previous generation, with any number less than 1 indicating population decline.

In the lab, we found that EAB larvae developing in white fringetree did not reach the mature larval instar ("J-L") within 14 weeks post-oviposition. However, larvae developing in green ash and Oregon ash began reaching the mature larval stage just 4 weeks post-oviposition. By 10 weeks, 100 percent of larvae developing in green and Oregon ash had reached the mature instar, as opposed

to none of the larvae developing in white fringetree. Similarly, none of the white fringetree larvae exposed to *S. agrili* were parasitized during the 14-week study, while larvae developing in green ash and Oregon ash were parasitized beginning 6 weeks post-oviposition.

The field study showed that EAB survival on white fringetree was lower than on ash. The mean R_0 of EAB developing on ash was 2.56 (SD = 2.27), compared to 0.03 (SD = 0.10) on white fringetree. Only one larva out of 158 on white fringetree reached the mature larval instar during this study. Larvae developing on white ash were parasitized by the introduced larval parasitoids *Spathius* spp. and *Tetrastichus planipennisi,* as well as a native parasitoid in the genus *Atanycolus*. Life table analysis revealed that these parasitoids together reduced the R_0 of EAB in ash by approximately 35 percent. In contrast, none of the larvae developing in white fringetree were parasitized.

Overall, this study suggests that EAB populations are not self-sustaining on white fringetree. While some larvae are able to survive to adulthood (evidenced in previous literature and by the one larva able to survive to the mature larval "J-L" stage in the field), the proportion of EAB on fringetree that can reach reproductive maturity is low; most EAB on this host die prematurely, which suggests that white fringetree may serve as an ecological trap for EAB.

Because larvae on white fringetree do not often develop to instars susceptible to parasitism, there was no evidence in the field or lab of parasitoid activity on EAB in white fringetree. This does not necessarily mean that parasitoids are unable to find and attack EAB on white fringetree, but rather that there is not much opportunity for them to do so. In white ash, on the other hand, parasitoids did significantly suppress EAB population growth. In sum, our results indicate that white fringetree is unlikely to serve as a reservoir for EAB. Although parasitoids may not often attack EAB developing on white fringetree, this study suggests that the plant's defenses are enough to keep the reproductive rate down.

PHOSPHONATE SOIL TREATMENTS IMPROVE TREE HEALTH AND SUPPRESS FOLIAR NEMATODE DENSITIES IN AMERICAN BEECH WITH BEECH LEAF DISEASE

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ABSTRACT

American beech (*Fagus grandifolia* L.) saplings exhibiting symptoms of beech leaf disease were treated with soil applications of potassium phosphite (PolyPhosphite 30™ 0-0-27 fertilizer) from 2017-2022 (n=20 for treated and untreated, respectively). Potassium phosphite was applied via soil injection at the base of the tree at a rate of 2 oz + 14 oz water / inch trunk diameter. Treated trees on average had 3-fold greater canopy cover as untreated control trees, and half the number of fine dead twigs and branches. Density of the foliar nematode *Litylenchus crenatae maccannii*

implicated as the causal agent were much lower in treated relative to untreated trees in 2021 (7 vs. 98 nematodes / cm^2 leaf area, respectively) and 2022 (13 vs 164 nematodes / cm^2 leaf area, respectively).

In 2023, half of the previously untreated trees were treated for the first time, and half of the previously treated trees were left untreated. This resulted in the following four treatments (n=10): (1) trees treated every year from 2017-2023; (2) trees treated every year from 2017-2022 and then left untreated in 2023; (3) trees left untreated every year from 2017-2022 and then treated in 2023; and (4) trees never treated. In October 2023, nematode densities in trees treated for the first time in 2023 were much lower in trees that had never been treated (3 vs. 78 nematodes / cm^2 leaf area, respectively). Nematodes were not detectable in trees that had been treated every year and were barely detectable in trees treated from 2017-2022 (0.1 / cm^2).

Gene expression studies are underway at The Ohio State University to determine if defense genes are upregulated by the potassium phosphite treatments, as suggested in the literature. Another study was initiated in 2021 to determine if the treatment protocol will be as effective for protecting mature trees as we observed in this study for saplings.

IMPACTS OF SPOTTED LANTERNFLY ON COMMON HARDWOOD TREES

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ABSTRACT

Spotted lanternfly (SLF; *Lycorma delicatula* White; Hemiptera: Fulgoridae) invaded the US from Asia and was first detected in Pennsylvania in 2014. Since that time, populations have spread to at least 17 states in the Northeast, Mid-Atlantic, Midwest, and Southeast. It feeds voraciously on phloem sap from a broad range of host plants, with a preference for tree of heaven (*Ailanthus altissima* (Mill.) Swingle), grapevines (*Vitis* spp.), and several common hardwood tree species. Prior to the studies presented here, there was a significant lack of empirical data on the impacts of SLF on its hardwood tree hosts, many of which are important timber and/or ornamental species.

We evaluated the impacts of 4th instars and adults confined to whole trees (2020) on gas exchange attributes (carbon assimilation [photosynthetic rate], transpiration and stomatal conductance), selected nutrients, and diameter growth using young saplings of four host tree species planted in a common garden in the fall of 2018 (Lavely et al. 2022). Fourth instars confined in whole tree enclosures to silver maples (*Acer saccharinum)* for 10 days at 0, 40, 80 or 120 insects/tree reduced soluble sugars in branches in a density-dependent manner, and reduced tree diameter growth by >50 percent the following growing season. In contrast, 4th instars in whole tree enclosures at the same densities and duration had no effects on black walnut (*Juglans nigra)* at any density. Adults confined at the same four densities for 21 days to silver maple or tree of heaven suppressed carbon assimilation in tree of heaven but had minor effects on silver maple. In contrast to nymphs, adult SLF did not impact nutrient concentrations or tree growth. The greater impacts of 4th instars compared with adults on silver maple may be because the trees used for adults were twice the diameter of the trees used for nymphs. In general, we've found that smaller trees are more affected by SLF than larger trees.

In fall 2018, we also established 10 large multi-tree enclosures in Berks County, PA (Hoover et al. 2023). This study was initially designed to test the hypothesis that SLF could develop and reproduce without ever having access to tree of heaven (results reported in Uyi et al. 2020). Each enclosure contained one planted silver maple and one weeping willow (*Salix babylonica* L.*)*. Half (5) of the enclosures also contained a planted tree of heaven, while the other half (5) contained a planted river birch (*Betula nigra* L.). In the spring of 2019 and 2020, we released newly hatched first instars (Year 1; 2019) or third instars (Years 2-4), which were reared on these trees to adults. During the 2019 and 2020 field season, we measured leaf gas exchange attributes, selected nutrient concentrations, and tree diameter growth to determine if any of these metrics were affected by SLF feeding pressure (number of individuals on a given tree) over time. In 2021 and 2022, we continued using these multi-tree enclosures to rear SLF for another study, so we continued to monitor tree growth over another two-year period to determine if repeated seasonal exposure has cumulative impacts, but we did not take physiological measurements during these latter two years except for starch storage in roots.

Long-term feeding over four consecutive seasons significantly reduced diameter growth and below-ground starch storage in roots of young silver maples, willows, river birches, and trees of heaven in a density-dependent manner (Hoover et al. 2023). In Year 3 when feeding pressure

was the lowest, silver maple and willow recovered with greater diameter growth than in Year 2, but tree of heaven did not. Nutrients essential for photosynthesis and growth (iron, sulfur, and phosphorus) were reduced in leaves of all tree species compared to controls in Year 2.

This long-term, controlled study used young saplings, which are more sensitive than larger trees to SLF (Leach 2022; Lavely et al. 2022). Moreover, we maintained feeding pressure on the same trees for four seasons, although densities were much lower in the third year of this study, which allowed most trees to recover to some extent. In nature, this degree of continuous, repeated attack is rarely seen across the entire season, except for tree of heaven. SLF moves often among different hosts and to different geographic locations during the season, presumably to maximize access to sufficient phloem-derived nutrients (Urban 2020). If these insects had not been confined, they would likely have moved to new hosts at some point each season, especially individuals confined without access to tree of heaven. The continuous pressure on these trees was, therefore, a worst-case scenario. We would not expect growth reductions to be this marked in response to SLF, except for tree of heaven, which can experience heavy feeding over several months and in multiple years in a row, such that mortality of this species in the field is not uncommon. Note that we rarely observe SLF kill established hardwood trees, except for tree of heaven, saplings (e.g., black walnut) or trees stressed by other factors (Leach 2022). Despite the intense pressure the trees in our study experienced, it's important to note that none of these trees died.

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INVASIVE GRASSES – THE IMPORTANCE OF GENOTYPES, TRAITS, AND THE ABILITY TO ADAPT TO NOVEL ENVIRONMENTS

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ABSTRACT

The Poaceae (12,000 species worldwide and 1,182 species in North America) is the fifth largest plant family after Asteraceae (32,000 worldwide; 2,413 in North America), Orchidaceae (28,000 worldwide; 208 in North America), Fabaceae (19,000 worldwide; 1,345 in North America), and Rubiaceae (13,500 worldwide; about 187 in North America). There are an estimated 254 invasive grass species in North America, which makes up 13.2 percent of all North American invasive plants, estimated at 4,845 (Laginhas et al. 2022), and 21 percent of all North American grasses. Invasive Asteraceae species only make up 9 percent of the Asteraceae species in North America, suggesting that invasive grasses are overrepresented as invasive species compared to some of our largest plant families. The success of grasses is due in part to having long-distance dispersal mechanisms, quick establishment via seed with large starch reserves and short generation times, flexible ecology with C_3 and C_4 photosynthetic systems, resilience to disturbance, and the ability to modify their environments (Linder et al. 2018).

Some of the worst invasive grasses in the US include *Bromus tectorum* L. (cheat grass; annual, invades open areas), *Microstegium viminium* (Trin.) A. Camus (stiltgrass; annual, invades wet and dry open areas and forests), *Taeniatherum caput-medusae* (L.) Nevski (Medusa head; perennial, invades open dry areas), *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs (guinea grass; perennial, invades wet and dry open areas), *Miscanthus sinensis* Andersson (silvergrass; perennial, invades open areas and forest edges), *Imperata cylindrica* (L.) aeusch (cogon grass; perennial, invades mesic to dry open areas and woodlands, *Phragmites australis* (Cav.) Trin. ex Steud (common reed; perennial, invades wetlands, open areas), *Oplismenus undulatifolius* (Ard.) P. Beauv. (wavy leaf basket grass; perennial, invades forests); *Phalaris arundinacea* (reed canary grass; cool-season perennial, invades moist soils in open areas), and *Phyllostachys aurea* Carrière ex Rivière & C. Rivière (golden bamboo; a drought tolerant, perennial, invades open areas and woodlands). Not only do invasive grass species differ by preferred habitats and life span, the first seven of the species listed are fire-prone, often associated with shifts in the dominant vegetation type and disturbance regimes (Kerns et al. 2020). Five of the species (golden bamboo, cogon grass, reed canary grass, and guinea grass) can reach heights above 4 m (height being linked with invasive success; Canavan et al. 2019), with guinea grass having a short (Texas and drier soils) and tall form (Soti and Thomas 2022). Common reed and reed canary grass are associated with polyploid species complexes that ensure high genetic diversity even in small satellite populations (Lambertini 2019). Common reed, reed canary grass, and wavy leaf basket grass have closely related native species that make their taxonomy complicated due to potential hybridization. Cogon grass, silvergrass, guinea grass, common reed, and reed canary grass also have documented allelopathic properties (Hagan et al. 2013; Tomes 2013; Hedĕnec et al. 2014; Uddin et al. 2017; Morrison et al. 2023).

These invasive grasses share several invasive traits with other invasive species as well as some early successional native species. These traits include prolific seed production and/or vegetative spread with efficient dispersal, rapid growth, and the ability to grow in a wide range of environments. In addition, they, like other invasive plants, lacked enemies when first introduced. However, pathogen accumulation is evident; the lack of natural enemies may not continue to be an advantage the longer the species persist in their invasive range. For instance, some populations of stiltgrass show significant increased mortality due to a native fungus *Bipolaris* spp. Response to this fungus appears to be different across populations with some showing resistance (Bruckart et al. 2017).

Multiple introductions may help ensure a species' ability to rapidly adapt to new environments or pathogens, possibly through admixture and recombination, leading to the selection of novel genotypes. For instance, invasive-range populations of reed canary grass show greater genotype and allelic richness and more polymorphic loci than found in its native populations; there are also significantly more unique genotypes found in the invasive range compared to the native range (Lavergne and Malofsky 2007). Similarly, several unique, specialist populations of cheat grass have been identified that enable this species to expand its invasive range into new environments including salt deserts, warm deserts, and cold deserts (Merrill et al. 2012).

We studied the potential of such rapid adaptation in stiltgrass to colder climates, drought conditions, and different light environments. Differences in seed size of stiltgrass populations across a regional moisture gradient (Allegheny Plateau with 160 cm annual precipitation and Ridge and Valley Province with 79 cm annual precipitation) and local light gradient (roadside and forest interiors) in WV were found. Significantly different multilocus genotypes were confirmed across the moisture gradient (Culley et al. 2016). At a larger regional scale, morphological differences were noted across latitudes with awned seed forms of stiltgrass dominating northern latitudes. Other traits that differed along this gradient included longer apical internodes, narrower leaves, fewer axillary roots, earlier flowering dates, longer seed maturation time, and heavier seed in northerly populations. These traits were maintained across two generations in a common-controlled environment (inherited), which is supported by distinct genotypes found across the gradient (Barrett et al. 2022). Experimental evaluation of stiltgrass' response to drought and different light levels using seed from the Allegheny Plateau (AP) and Ridge and Valley Province (RV) showed that plants from the drier region produced more seed per inflorescence under drought and high light than plants from the AP. While both AP and RV populations absorbed more Fe under drought and high light, only RV plants absorbed more Fe under drought and low light. RV plants were better at absorbing Mn under low light, whereas AP plants were better at absorbing Zn under ample water and high light. Both AP and RV plants had lower putrescine to spermidine polyamine ratios and soluble proteins under low light whereas the RV plants had higher levels than the AP plants under higher light. GABA (amino acid) production was significantly higher under drought and high light for RV plants. These differences may be attributed to greater up-regulated gene expression in photosynthesis of RV plants, inferring greater drought-tolerance for RV populations.

Multiple introductions from an invasive plant's native region as well as from its invaded region may foster range expansion through adaptation to novel environments. Preventing new external and internal introductions may not only slow the spread of these species, but it may also decrease their invasiveness over time. Grasses serve as model organisms to study management of such range expansions because of their overrepresentation of invasive plants. Our future research includes testing if these noted genetic differences in stiltgrass confer an advantage in the new environments and if the differences in gene expression are also inherited.

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DROP-AND-LEAVE: IMPLEMENTING ALTERNATIVE MANAGEMENT STRATEGIES FOR ASIAN LONGHORNED BEETLE ERADICATION

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ABSTRACT

The Asian longhorned beetle (ALB; *Anoplophora glabripennis* Motschulsky) is an invasive wood-boring beetle that was first detected in the United States through New York in 1996. Native to China and Korea, the beetle can attack 12 genera of host trees in the United States, but it has a strong preference for maple (*Acer*) species. As larvae feed, they bore into the heartwood of their hosts, which cuts off nutrient flow and compromises the structural integrity of these trees. Eradication of ALB infestations has been achieved in the United States and is the management goal of the USDA-APHIS National ALB Program. Management includes efforts like surveys, regulatory quarantines, outreach, and host tree removals. In 2020, ALB was detected in South Carolina, which represents a novel environment for the pest. Not only is the South Carolina infestation the most southern in the US with warmer temperatures and longer growing seasons, but it also contains wetlands and swamps. In these wetland areas, typical host removal practices involving heavy equipment are not possible due to standing water and saturated soil (Coyle et al. 2021). As such, alternative management of ALB is necessary.

Ratcliff (2022) found that hand felling and leaving infested trees on the ground resulted in zero ALB survivorship, but more evidence is needed to support this method. Therefore, we will evaluate the implementation of felling and leaving infested trees on the ground for efficacy in preventing the development of ALB in environments where the use of heavy equipment is not possible. This treatment, termed "drop-and-leave," was implemented over three research sites in South Carolina in 2023. At each of the three sites, sixty trees were felled. To determine appropriate timing of the management method, thirty trees were felled in June 2023 and thirty trees were felled in August 2023 at each site. Following the cuts, trees were inventoried for existing ALB damage (exit holes and egg niches). The diameter at breast height, geographical coordinates, species, and ground contact of each tree (whether suspended in the air or completely touching the ground) were recorded. The complete visible portion of each tree was examined, and ALB damage was tallied and marked by drilling colored screws next to the damage (different colors were used for exit holes and egg niches). Each tree was re-examined in December 2023 to mark any additional "old" damage that had been missed during the June and August tree inventories.

In the summer of 2024, each of the 180 trees previously inventoried will be examined for new damage. Fresh damage will be tallied, and any tree with new damage will be dissected to confirm ALB activity/presence. In addition, three new sites will be chosen in 2024 to inventory 180 new trees using the same methods described above, meaning 360 total trees will be part of this study. As such, the present study could provide greater support for the drop-and-leave method. The implementation of drop-and-leave could provide a more cost-effective, efficient, and environmentally-friendly eradication method of ALB, not only for the South Carolina infestation but also for any future infestations that may occur.

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ASYMMETRY IN HERBIVOROUS INSECT INVASIONS; A COMPARISON BETWEEN EUROPE AND EASTERN NORTH AMERICA

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ABSTRACT

One of the questions that remains unanswered in invasion ecology is why not all continents have the same probability of establishment by non-native species. Since Niemelä and Mattson published their paper in 1996 other authors have attempted to understand the pattern presented in their results, i.e. the unequal establishment of European species in North America compared to the establishment of North American species in Europe. By linking establishment to trade volume and climate suitability the effect of external factors on movement and establishment has been determined (Isitt et al 2023). Ecological drivers of invasion success have been linked to the invasion paradox and the theory of biotic acceptance (Fridley et al. 2007). Our work is based on the compilation of herbivore associations with their host tree, expressed species counts and in number of species per host tree, for Europe and Eastern North America. These two regions were selected for their climatic similarity and because the highest proportion invasive species in North America have thus far arrived via the east coast of North America. We analyse the data investigating the difference in number of invading species in Eastern North America and Europe for the count data and for species richness per host tree. We also investigate the species-area relationship and differences in the relationship with non-native species between two regions.

We ask the following questions:

- Do non-native species count and species richness per host tree show similar differences between the regions?
- Do the non-native species establishment depend on host tree distribution area and do host trees with larger distribution ranges receive more non-native species.

We expect the number of species established in Eastern North America to be higher compared to Europe and we hypothesize this to be reflected in the species richness per host tree. We also hypothesize, following the species-area distribution theory, that non-native species richness per host tree is positively related to host tree distribution area. We explore potential mechanisms for the deviation from our hypothesis and expectations in more detail. We find that asymmetry is found both for non-native species counts and species richness per tree. When species are divided in generalist and specialist species, we find no difference in species richness per host tree for generalists but species richness per host tree is higher in Eastern North America for specialists. The pattern continues when investigating species richness per guild except for the wood borers that show the opposite pattern in species richness per host tree. The host tree ditribution area is positively related to the species richness of the non-native species with the only deviation for the folivores, where we find negative relationship with species richness in Europe. We believe that the patterns we find can be the result of the reduced host tree richness in Europe and that this might be underlying the asymmetry in non-native species presence in Northeastern America compared to Europe. Our study furthers our understanding of invasion success by providing potential ecological drivers for asymmetrical establishment of non-native species.

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THE IMPORTANCE OF NATURAL HISTORY COLLECTIONS IN INVASION BIOLOGY: EVOLUTION AND ECOLOGY IN THE INVASIVE *MISCROSTEGIUM VIMINEUM*

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ABSTRACT

Invasive species cause billions of US dollars in damage, degrade natural and agricultural lands, spread disease, and threaten biodiversity. One such species, *Microstegium vimineum* (Trin.) A. Camus (stiltgrass) is native to eastern Asia and has become highly invasive in the US over the past 100 years. First discovered in Tennessee in 1919, this species has spread to 30 US states from Texas to Maine and is now in Canada. While the ecological impacts of invasive species are well studied, their invasion histories and rapid evolution of invasive traits have only begun to be explored. Our research integrates phenotypic (i.e., physical characteristics of the plants), environmental, and genomic data in order to identify the patterns and processes behind invasiveness in plants. Using contemporary and historical herbarium collections of *M. vimineum*, our primary goal is to reconstruct the invasion process from a genomic viewpoint, addressing hypotheses related to the spatiotemporal dynamics of colonization, spread, gene flow, and adaptive evolution. We present several lines of evidence for multiple introductions and subsequent interbreeding in this species over space and time based on phenotypes, organellar genomes, and nuclear genomic sequencing. We found evidence for an initial introduction and spread of an awnless form in the southeastern USA (i.e., lacking bristle-like extensions of the florets), and at least one more introduction of an awned form with subsequent spread in the northeastern USA, followed by admixture of two distinct awn phenotypes. Our ultimate goal is to use *M. vimineum* as a model to help predict and prevent future invasions, by incorporating genomic and phenotypic information into niche-based distribution models.

INVASION DYNAMICS OF THE FAUCET SNAIL AND ITS TREMATODE PARASITES ACROSS NORTH AMERICA

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ABSTRACT

The faucet snail, *Bithynia tentaculata*, has a native distribution across much of Europe and was introduced to North America via the Great Lakes in the late 1800s. Since its introduction, this small freshwater snail has spread throughout the Great Lakes watershed and most recently invaded the upper Mississippi River Region. The snail serves as an intermediate host for several species of trematodes, which likely co-invaded with the snail. Waterfowl serve as definitive hosts for the trematodes following consumption of infected snails. The effect of the trematodes on waterfowl can be lethal and large-scale waterfowl mortality events have been observed, particularly near the leading edge of the invasive front. Several current research studies include quantifying population dynamics of both snails and trematodes to assess variation across the invaded range. We are also using genomic tools to describe the population structure of the snails and trematodes within both their native and invasive ranges to better understand dispersal history and the underlying ecological and evolutionary processes that facilitated their invasion. And finally, we are studying the outcomes of sub-lethal infections in waterfowl both in terms of the effects on the birds, and the role of the birds play in aiding dispersal of the trematodes. These projects are ongoing and fit within a larger research framework aimed at understanding the ecology and evolution of invasive parasites.

ADVANCING INVASIVE SPECIES PREVENTION: A HORIZON SCANNING APPROACH

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ABSTRACT

Managing invasive species with prevention and early-detection strategies can avert severe ecological and socioeconomic impacts. Horizon scanning, a data-driven approach that integrates risk assessment and consensus-building, has emerged as a valuable instrument for effectively prioritizing efforts in invasive species management and prevention. Results from horizon scans including a ranked list of threats, plausible pathways for arrival, and potential ecological, economic, and human health impacts, can guide efficient allocation of resources to invasive species research (e.g., identifying data gaps), prevention (e.g., risk analysis and biosecurity surveillance), and eradication (e.g., prioritize targets), which is especially important when dealing with finite biosecurity resources. In this presentation I will provide an update on ongoing horizon scans for plants in trade and Puerto Rico and the US Virgin Islands and will highlight some of the advancements made to enhance the scanning framework, as well as how results of a horizon scan for Florida are being used in prevention efforts in the Everglades and beyond.

HYBRIDS BETWEEN THE INVASIVE WILD-TYPE AND HORTICULTURAL VARIETY (VAR. RUBRA) OF COGONGRASS (IMPERATA CYLINDRICA) DIFFERENTIALLY RESPOND TO COLD

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ABSTRACT

Cogongrass (*Imperata cylindrica*) forms dense monocultures that outcompete native species, sometimes due to alterations in fire regimes and ruderal adaptations. Cogongrass is one of the world's worst weeds and is federally listed as a noxious weed. Cogongrass distribution is presently limited to the southeastern United States (USA) due to its purported cold intolerance; however, there are ornamental varieties of the species (var. *rubra* and var. *Konegii*), sold under numerous horticultural names. These horticultural cultivars have been developed multiple times and have been demonstrated to be cold tolerant; these lineages are still commonly sold throughout the USA. Ornamental varieties have been selected for and developed from various parental materials, presumably in or from East Asia and are sold as "sterile", meaning that they do not produce flowers. However, reversions of ornamental cogongrass to the wild-type (WT) invasive phenotype have been reported and these reversions produce fertile inflorescences (flower stalks). Concerns exist that hybridization between the invasive wild-type and the ornamental cogongrass varieties (*Rubra*, hereafter) may yield a hybrid that both spreads aggressively and is cold tolerant, thereby contributing to increased probability of range expansion if hybridization were to occur in the wild. Here, we investigate the potential for hybridization between the WT and *Rubra* to compare the performance of hybrid cogongrass to the invasive WT under colder ambient temperature conditions.

We first hybridized WT cogongrass with *Rubra* by hand pollination. Pollen grains from reverted *Rubra* flowers were placed onto the female flowers of a WT lineage local to Gainesville, FL, USA. Pollen grains were stored at -20 ^{0}C until the WT flowered to allow for precise hand pollination and flower stalk bagging. To ensure hybridization was successful, the parental WT and resulting hybrids, once leaf tissues emerged, were genotypically analyzed.

Rhizomes (clones) of the parental WT cogongrass and *Rubra*, with the resulting F1 hybrids, were grown together at 5 ^{0}C, 0 ^{0}C, -5 ^{0}C, and -10 ^{0}C treatments. After three weeks of growth, height and aboveground biomass were recorded. The Rubra clones failed to emerge, so all further comparisons were made between the parental WT and the F1 hybrid. Adult plants that had similar heights from the rhizome emergence response variable were then exposed to -5 ^{0}C, 0 ^{0}C, -5 ^{0}C, and -10 ^{0}C treatments for seven weeks. To assess growth in temperatures colder than what would be typical in the southeastern USA, we aimed to compare growth responses to a colder range of temperatures between the cogongrass varieties (WT, *Rubra*, and F1 hybrids). At the conclusion of seven weeks of exposure at each of the above temperatures, we recorded above- and below-ground biomass.

We found that hybridization between WT cogongrass and *Rubra* varieties does occur under a very controlled laboratory/common-garden setting and the resulting F1 hybrids do survive to adulthood. In cold temperature treatments, the F1 hybrid individuals exhibited hybrid vigor, or heterosis, resulting in greater emergence as well as above- and below-ground biomass responses than the parental WT. The higher emergence and growth of the F1 hybrids over the parental WT may suggest an increased tolerance to a colder range of temperatures.

Current WT cogongrass management assumes range expansion from the southeastern USA is limited by the wild-type's intolerance to cold. However, F1 hybrids, with their greater emergence and growth rates under colder temperatures, could result in potential range expansion beyond extant infestations. These results suggest that the continued sale of ornamental/horticultural (*Rubra*) varieties within the species of cogongrass (*I. cylindrica*) could potentially facilitate an expansion of cogongrass nationally. Indeed, it is possible that hybrids may already be occurring and are resulting in not only cogongrass expansion out of the southeastern USA, but also the emergence of novel populations in previously undetected areas. This expansion would have devastating effects on local ecosystem community dynamics, as well as on natural forests and agroforestry. Further research on the hybridization between *Rubra* lineages and the invasive WT is needed to explore F2 hybrid and backcross responses to more varied and/or extreme temperature ranges for nationwide cogongrass management.

USING MACHINE-LEARNING MODELS TO IDENTIFY CROWN CLASS CONDITION OF EAB-INFESTED FORESTS

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ABSTRACT

As an increasing number of invasive insect pests are introduced to landscapes due to global trade transport and geographic range shifts, there is a greater need for research and study on alternative methods of control beyond insecticides and pesticides. A classical biocontrol program was developed and implemented by the U.S. Department of Agriculture against the most destructive invasive beetle *Agrilus planipennis* (emerald ash borer, EAB) shortly after EAB was first detected in the U.S. in 2002. The EAB biocontrol program has since resulted in releases and establishment of several introduced biocontrol agents across over 350 counties of 32 EAB-infested states. These introduced EAB biocontrol agents included one egg parasitoid *Oobius agrili* and three larval parasitoids *Spathius agrili, Spathius galinae* and *Tetrastichus planipennisi*. While recent field studies have observed successful establishment of and as well as significant EAB suppression by these introduced agents in some earlier release sites, the contribution of the EAB biocontrol program to ash tree recovery and regrowth is currently not known. As ash trees are the host species of the EAB and the most vulnerable targets of the EAB, understanding the effect that this biocontrol program may have on ash trees is critical to assessing the success of the program (Duan et al. 2017). This project focuses on assessing the ecological impacts of the current EAB biocontrol program on ash tree survival, recovery, and regrowth to canopy trees in North America where the introduced biocontrol agents have been released in the last two decades. Collaboration with the USDA-ARS attempts to answer this question: **What methodologies can we use to assess the impact of parasitoid wasps on the EAB, and what effects do these wasps have on native ash forests after their deployment?**

To accomplish this, this project has three aims:

- **Aim 1.** To establish whether machine learning (ML) models and drone photography can serve as a new fieldwork methodology to identify crown class conditions and forest canopy cover in EAB-infested forests.
- **Aim 2.** To determine whether current field methodologies of transect surveys and crown class estimation of native ash tree forests are adequate in estimating EAB damage and recovery.
- **Aim 3.** To assess whether the crown class conditions of EAB-infested forests are recovering/regenerating over time given parasitoid/biocontrol deployment.

As the EAB and other invasive pests disperse throughout North America, monitoring of these species is critical, especially in newly infested regions that have populations of vulnerable native species. Many common methods such as transect surveys are used in ecology to monitor and detect invasive species. These methods are often limited by the number of workers, the physical conditions in the field, and the sheer geographic size of many field sites. Uses of drone imagery and machine learning represents an opportunity for enhanced research and detection capabilities that can serve as a fieldwork supplement or even substitute in certain cases.

Drone Imagery Methods

This project uses aerial drones to collect imagery of native ash forests in New England. Field collection of drone images use a commercial drone supplied by the USDA-ARS in Delaware. Images are taken from 50-meter and 75-meter altitudes above the forest canopy to standardize image resolutions and compare the effect of resolution on model performance (Hamdi et al. 2019). Field sites are areas that have either been infested by the EAB and have had a deployment of parasitoid wasps as a biocontrol method in the past, or a control site where no infestation of EAB and no releases of parasitoids have occurred. After collection, drone images are individually processed for any vulnerable trees, which will be classified on a qualitative 1-5 scale of crown condition. These images will be used in machine learning to develop a model capable of predicting forest crown class conditions for ash trees.

Field Transect Survey Methods

Field sampling procedures follow methods depicted in Duan et al 2017. To compare the machine learning model performance with field data, 50m × 2m transect surveys are collected at each field site, estimating crown class condition, number of EAB exit holes, and other signs of infestation. At each site, a Hip Chain Distance measurer is used to delineate the transect and sample any living ash tree (DBH > 5 cm). Field sites are determined by previous records of EAB sightings and releases of biocontrol agents filed in the mapBioControl database, as well as monitoring efforts from the USDA-ARS. This allows us to ground-truth the ML model and evaluate its accuracy and predictive capabilities compared to current field methodologies.

Machine Learning Methods

To test the accuracy and performance of the models, a suite of machine learning architectures will be compared and tested for the best fit. Model architectures commonly employed in image classification problems will be used, such as ResNet152V2, MobileNet, and Inception. This project uses versions of these models with previous training experience from the ImageNet dataset to determine model training performance using only the drone image dataset versus a model that has already trained from other datasets (Tao et al. 2020). To evaluate their success and accuracy, performance metrics such as Area Under Curves – Receiver Operating Characteristic curves (AU -ROC), confusion matrices, and training vs. loss plots will be compared at regular intervals to ensure model improvement.

Current Results

The machine-learning models have been trained on drone imagery collected in the summer of 2022 and 2023 from field sites in New England and Oregon. Trained on an estimated 6,000 images, the models can adjust their weights and predictions for crown class but still require more data to account for the diversity in crown class structure. Current results for binary classification between Class 1 (Healthy) and Class 5 (Dead) trees reach an Accuracy of 0.59 Precision of 0.62. This project plans to increase accuracy with improvements to the data extensions and hyper-parameters during model training, namely through implementation of the Excess Green Index on aerial imagery to increase contrast between vegetation and dead branches in images (Carvalho et al. 2019). With those improvements we hope to create benchmark ML model capable of predicting forest crown class condition can then be compared to current field methodologies used to detect EAB damage in native ash forests.

Acknowledgements

This work was done with the help and guidance of collaborators from the Quantitative Evolutionary STEM Training (QuEST) Program at the University of Vermont (NSF Program), the Biology Department of the University of Vermont, the USDA BIIRU, Oregon Department of Agriculture, and the Longwood Botanical Gardens.

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ERYTHMELUS KLOPOMOR: A PROMISING CANDIDATE FOR CLASSICAL BIOLOGICAL CONTROL AGAINST THE INVASIVE OAK LACE BUG

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ABSTRACT

Alien insect species can pose serious threats to various ecosystems worldwide (Liebhold et al. 2017; Csóka et al. 2017). Whether a non-native species can become invasive is influenced by several intrinsic, species-specific traits as well as by external biotic and abiotic factors. An important, often decisive factor is the lack regulatory effects of natural enemies (Liebhold et al. 2016).

The North American oak lace bug (OLB, *Corythucha arcuata* Say, 1832) was first found in Europe in northern Italy in 2000, and by 2023 it was recorded in 25 European and 2 Asian countries (Paulin et al. 2023). Almost all Eurasian deciduous oaks are suitable hosts, and it can also feed on many other woody plants (Csóka et al. 2019). More than 30 million hectares of oak forests provide suitable hosts for the OLB in Europe, meaning that the lack of suitable hosts will not restrict its further spread (Csóka et al. 2019; Paulin et al. 2020). Heavy infestation causes early discoloration, desiccation, and abscission of leaves, due to the OLBs feeding (both nymphs and adults) on the underside of the leaves.

Detailed studies on the long-term impact of the species are in progress, but there are many good reasons to assume that it poses multiple threats to oaks and oak ecosystems. The photosynthetic activity and transpiration were reduced by 58 percent and 22 percent respectively on heavily infested pedunculate oaks, *Q. robur* (Nikolic et al. 2019). MODIS satellite image analysis showed reduction in NDVI (photosynthetic activity) by 14.5 percent in pedunculate oak stands (Kern et al. 2021). In the long term, it may have negative effects on oak health, growth, and acorn crops. White oaks in Europe are exceptionally important in harboring extremely rich herbivore insect communities, with many rare and protected species among them (Paulin et al. 2023). The presence of OLB will most likely affect these species negatively, and reduction of oak herbivore diversity and abundance may also affect insectivores. There is also a possibility, that the oaks health decline will also have influence on mycorrhizal fungi. OLB also has a potential negative effect on surface waters and aquatic invertebrates and there are reports of more frequent human health problems (Paulin et al. 2020).

Based on current research there are only very few native enemies known in Europe. Most of them are generalist predators such as *Chrysoperla carnea*, *Harmonia axyridis* or *Theridion pinastri* (Paulin et al. 2020). None of them shows potential of regulation. There are also records of entomopathogenic fungi (Kovač et al. 2020), but we have not found significant controlling effect on OLB in field conditions.

Egg parasitoids of Tingidae have been studies in the past, mostly when their effects were of economic importance. Such cases were the parasitoids of the Chrysanthemum lace bug (*Corythucha marmorata*) (Puttler & Triapitsyn 2006); the avocado lace bug (*Pseudacysta perseae*) (Peña et al. 2009) and more recently the oak lace bug as well (Puttler et al. 2014). We aimed to study *Erythmleus klopomor* Triapitsyn (Hymenoptera: Mymaridae) the only known parasitoid of OLB.

In the first half of July 2023, we collected oak leaves with OLB egg bunches from 13 different locations in five states of the United States (Delaware, Pennsylvania, West Virginia, Virginia and Maryland). We attempted to rear parasitoids from the egg bunches, in the same time we also had to learn and develop the rearing process.

Leaves collected were first observed, and only further studied, if a large percentage of unemerged eggs was found. The leaf parts with the egg bunches were cut, producing approximately 2cm by 2cm pieces. These were then put into transparent 25ml plastic containers, with a piece of absorbent paper tissue (to collect vapour), and held at room temperature, checking daily for emergence. Parasitoids emerged on a given day were collected and put into 2ml Eppendorf tubes with 70 percent ethanol, for later identification. Checking continued until late August. Individual eggs in bunches with parasitoids were also counted, to provide information on parasitism rate for these samples.

Our initial observation was that collecting OLB eggs in the field proved more challenging, than we first assumed. In the 13 locations we were able to collect a total of 401 egg masses as samples. There were close to natural habitats, in which we found only a handful of OLB infested leaves. Our largest samples were collected in urban or close to urban areas.

During collecting we observed native generalist predators preying on OLB eggs and larvae; such as *Hyaliodes harti* Knight (Hemiptera: Miridae), and lacewing larvae (*Chrysoperla* sp.; Neuroptera: Chrysopidae). We did not observe any significant controlling effect by these species.

Out of the 401 collected samples parasitoids emerged from 98 egg bunches. Only in two locations were we unable to rear parasitoids from the collected samples; but in these locations we were unable to collect more than 15 unhatched egg bunches. In the parasitised samples we counted an overall of 3,930 oak lace bug eggs; out of which we reared 604 parasitoids. The average parasitism in parasitised samples was between 3.55 percent and 17.46 percent, with the average of averages being 14.13 percent.

In the context of classical biological control introductions, Mymarid introductions have provided spectacular results, and such opportunities should always be considered for new invasive pests (Mills 2010). The success of classical biological control with egg parasitoids has been mixed, which highlights the need to know more about their ecology and behavior.

Up to this point all results indicate that *Erythmelus klopomor* is a specialist egg parasitoid restricted to Tingidae; and *Corythucha arcuata* is its preferred host. We expect that sampling through the whole vegetation season would reveal a significant increase in parasitism rate toward the late season (September, October), explaining how the parasitoid keeps the OLB population at such a low level. It is also highly probable that the *E. klopomor* can catch up with the host density due to its rapid life cycle (ca. 2 weeks). Our expedition revealed that *E. klopomor* is widely distributed, and relatively easy to rear. From our experience, OLB egg masses can be collected in large numbers, and parasitoids can be reared with relatively little effort. Our main conclusion is that *E. klopomor* seems like a promising candidate for a biological control program, but further research efforts are unavoidable. For example, we plan to study its overwintering habits, parasitism rates throughout the vegetation season. Host specificity studies are also important to minimize the risk of the unintended side effects. These are all studies that will form the cornerstones of this species' suitability as a biological control agent.

For helping us out in the field, we would like to thank: Warren and Chris Abrahamson, Matt Buffington, Eric Day, Kim Hoelmer, Sandy Liebhold, Gino Luzader, Carol Mapes, Laura Miller and Michael Joseph Skvarla.

Funding

Our research was funded from project 'K 142858' implemented with the support of the Ministry of Innovation and Technology of Hungary from the National Research, Development and Innovation Fund, financed under the 'K22-OTKA' funding scheme.

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THE ECOLOGICAL CASE FOR BREEDING AMERICAN ELM

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ABSTRACT

Numerous interacting factors, including changes to disturbance regimes, spread of non-native invasive plants, pests, and pathogens, and a changing climate are altering the structure and composition of floodplain forests of the Eastern U.S., threatening the long-term resilience of these systems and their ability to support critical ecosystem services. Non-native pests and pathogens, in particular, threaten the ecosystem function of these forests as an increasing number of floodplain tree species, including American elm (*Ulmus americana* L.), butternut (*Juglans cinerea* L.) and all native ash species (*Fraxinus* spp.), experience high rates of mortality. American elm was the first major floodplain tree species to face waves of mortality by a non-native pest or pathogen (*Ophiostoma* spp. which cause Dutch elm disease; DED) and often, gaps left by dead elms were filled with fast-growing ash species, which are now under attack by the emerald ash borer (EAB, *Agrilus planipennis* Fairmaire). The list of tree species appropriate to replace these once abundant floodplain species is insufficient, leaving managers with inadequate tools to restore these critical ecosystems.

American elm has multiple characteristics that make it a desirable tree for floodplain restoration plantings and a suitable candidate for the intensive resources required of a disease resistance breeding program. The tree has a particularly large range, extending from southern Canada down to Florida and westward to the Great Plains. Given its abundance and dominance in many floodplain forests throughout this range, the species was considered a foundation species (Marks 2017). American elm grows well in a range of environmental conditions (one reason it was widely planted in cities and towns across the country), and is tolerant of both shade and flooding, a combination of traits that, with its fast growth rate, makes it particularly useful for underplanting in floodplain forests. The ecological value of this species has not been extensively studied, though the available literature demonstrates the species' importance for biodiversity; elm supports over 200 species of Lepidoptera (Tallamy and Shropshire 2009), which in turn attract insectivorous birds, e.g. warblers. The seed of American elm, which mature in early spring, is an important source of calories for many songbirds as they navigate their annual spring migration. The species provides nesting sites for various wildlife, including wood ducks (*Aix sponsa* L.), warbling vireos (*Vireo gilvus gilvus* Vieillot), bronzed grackles (*Quiscalus quiscula* subsp. *versicolor* Vieillot) and fox squirrels (*Sciurus niger cinereus* L.), and is particularly favored by Baltimore orioles (*Icterus galbula* L.; McClure 1944). Finally, a growing body of literature indicates that American elm is likely to adapt well to predicted climate change scenarios (Iverson et al. 2016). This finding, together with several studies demonstrating the high survival rates of American elm planted in ash wetlands (e.g. Palik et al. 2021), support the planting of elm, in combination with other species,

to protect and/or restore these imperiled ecosystems that play an important role in mitigating the increased precipitation and flooding that is expected in our rapidly changing climate.

No open-pollinated seed sources of genetically diverse, DED resistant American elm seedlings are currently available. To address this need, the Northern Research Station (NRS), in collaboration with many federal, state, university and non-profit partners, leads the NRS American Elm Breeding and Restoration Partnership. The objective of the partnership is to develop locally adapted and genetically diverse American elm seed orchards to provide a source of improved seed for restoration of degraded floodplain habitats. To date, survivor American elms native to four regions have been collected and are in various stages of the resistance screening process: lower Midwest (OH, MI, IL, 31 accessions), New England (25 accessions, Figure 1.A.), northern MN, WI and MI (32 accessions) and most recently, the upper Mississippi River Watershed (32 accessions). New analyses using recent and historic DED inoculation data establish, for the first-time, adequate levels of heritability for resistance traits (generalized h^2 between 0.06 – 0.63, depending on the site). This implies that parents that exhibit some DED resistance transmit this trait to their offspring and that breeding DED resistant American elm is possible through selection. Inoculation trials have identified several lower Midwest trees with resistance levels similar to commercially available DED-resistant American elm cultivars (Figure 2). The partnership has initiated several studies to evaluate establishment success of American elm planted in floodplain restoration trials, including an ash floodplain restoration study in three Ohio sites (established in 2011), a riparian restoration study on the Finger Lakes National Forest (established 2015, Figure 1.B.), and an urban riparian restoration study located in Columbus, OH (established 2018); research that will contribute to an improved understanding of the ecological value of this once dominant species.

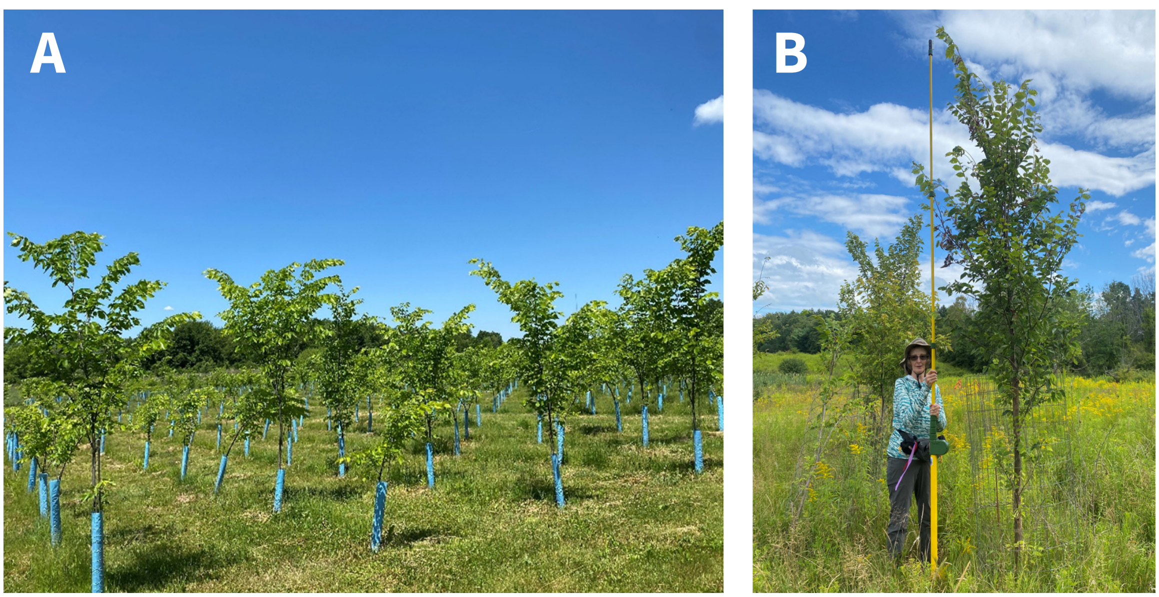

Figure 1.—A) American elm resistance trial in central Ohio. Includes clones and progeny of 25 large survivor American elms from New England. These trees will be inoculated in 2025 with the fungus that causes Dutch elm disease. **B)** USFS Northern Research Station Biological Sciences Technician Nancy Hayes-Plazolles measuring an American elm planted in a riparian restoration study on the Finger Lakes National Forest.

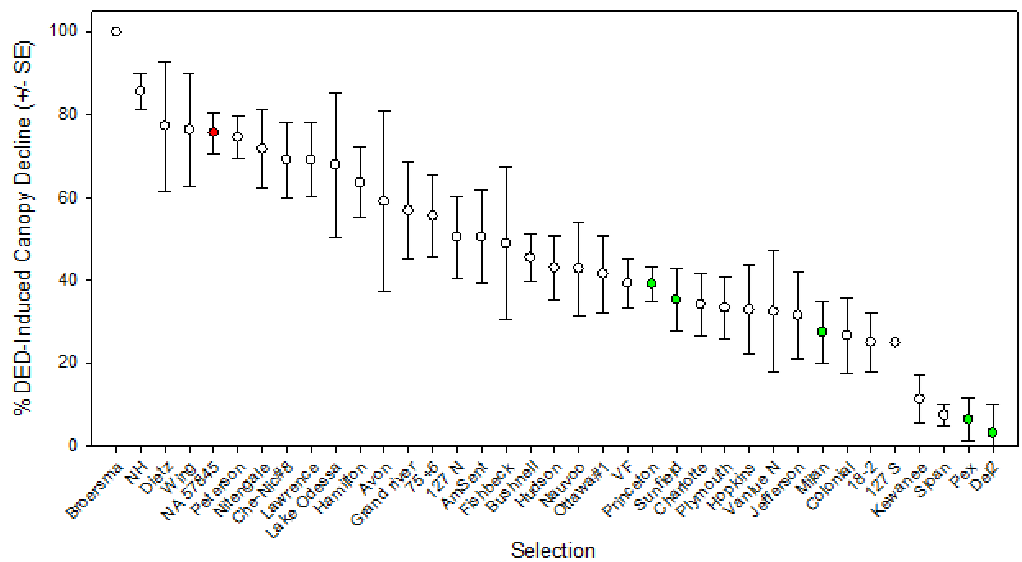

Figure 2.—Mean percent Dutch elm disease (DED) induced decline for clones of 37 American elm selections, two years after inoculation. NA 57845 (red circle) is a DED susceptible control. The selections marked by green circles are DED resistant controls. The remaining selections are clones of large survivor American elms found in OH, MI and IL.

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FROM ADELGES TO ZEUGOPHORA: PREDICTING THE NEXT HIGH-IMPACT INSECT INVADERS IN NORTH AMERICAN FORESTS USING I-TREE PEST PREDICTOR

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ABSTRACT

The worldwide interest in fostering interconnectedness among continents has led to increasing rates of international biotic interchange that threaten the health and resilience of our global forest ecosystems. Though most species introductions result in little ecological impact, introduced, herbivorous insects pose a significant threat to forest ecosystems due to the small, but prodigious, proportion that cause significant impacts, such as regional host mortality or functional host extinction. Robust forecasts of insects that are likely to cause substantial impacts have largely remained elusive, though they would improve biosecurity measures and could help prevent the introduction of some potentially catastrophic insect species akin to the spongy moth (*Lymantria dispar dispar*) and hemlock woolly adelgid (*Adelges tsugae*) in North America.

For this study, we used data from introduced herbivorous insects currently established and associated with North American trees to identify drivers of impact and develop models and a tool that can predict impact of insects that have not yet arrived in North America. We quantified host breadth for each insect using phylogenetic diversity (i.e., host breadth; the sum of phylogenetic distances between the host tree species in the insect's native range) and found that host specialization is a continuum. Individual phylogenetic host breadth was used to partition insects into "specialist" and "generalist" categories. From there, we evaluated four submodels as potential drivers of insect impact – (i) insect traits, (ii) host traits, (iii) host evolutionary history, and (iv) insect evolutionary history – and found that the significant submodels varied by insect host type (conifer versus hardwood) and breadth but, overall, evolutionary history of the native and novel hosts was significant irrespective of insect host type and breadth. The significant submodels were consolidated into five composite models and built into an i-Tree Pest Predictor tool (https://pestpredictor.itreetools.org/) that can help forecast which North American trees, out of 360+ hardwoods and 50+ conifers, are most at risk, if any, from a non-native insect should it establish.

Ultimately, the tool, now available through i-Tree, is being used to develop a risky insects database. Along with sentinel trees and other risk assessments, this tool will help predict the next high-impact insect invaders in North American forests *before* they invade, which can aid decision-making and help provide directed feedback to improve biosecurity measures. Similar tools can be developed for other nations to better predict the risk that non-native forest insects pose around the world.

FOREST TREE RESISTANCE BREEDING – SUCCESS STORIES IN THE PACIFIC NORTHWEST

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ABSTRACT

Non-native, invasive forest pathogens and pests have caused high levels of damage and mortality to some of our native tree species, affecting the health of our forests and the ecosystem services derived from them. To restore these species in forests will require resistance breeding programs that find and use the rare individuals with genetic resistance to the damaging pathogen or pest.

The USDA Forest Service is a world leader in forest tree resistance breeding. Programs for several tree species have developed populations of genetically resistant parent trees whose progeny are being used successfully in restoration and reforestation. Several of the most advanced and internationally well-known programs are in the Pacific Northwest, based at Dorena Genetic Resource Center (DGRC). Two of these programs involve western white pine (*Pinus monticola* Dougl. ex D. Don) and whitebark pine (*Pinus albicaulis* Engelm.) and the disease white pine blister rust (WPBR), caused by the non-native pathogen *Cronartium ribicola* J.C. Fisch. in Rabh.; another program involves Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.) and Port-Orford-cedar root disease, caused by *Phytophthora lateralis* (Tucker & Milbrath).

In January 2023, whitebark pine was listed as 'threatened' in the U.S. under the Endangered Species Act. A national restoration plan for whitebark pine has been proposed, and the availability of genetic resistance to white pine blister rust will be a key to its success. Progeny of more than 1500 parent trees of whitebark pine from Oregon and Washington have been screened for resistance to WPBR since 2002. Seeds from the highest resistant whitebark pine parents are now being used in restoration efforts without further breeding. Screening progeny of additional parents will increase the number of resistant parent trees that can be used for restoration as well as increase genetic diversity in the plantings. For western white pine and Port-Orford-cedar, seed orchards are now supplying resistant seed for reforestation, and breeding to increase the level of resistance continues.

One of the keys to successful resistance programs is to move as quickly as possible from basic research to operational screening and breeding. Cooperators and partners have also been essential for success, providing seed from candidate trees, land for field trials, and planting resistant stock. Management support has also been key. Ultimately, the programs are successful when land managers use the resistant seed and re-establish populations. Monitoring of resistant plantings over decades will establish the durability and stability of genetic resistance.

In July 2023, a national workshop on forest tree resistance breeding programs was held at DGRC, and most of the active programs in the U.S. were represented. The workshop provided an opportunity for newer programs to see the programs and facilities at DGRC firsthand and to exchange ideas and information that will help to strengthen all the applied programs. One of the featured programs was the effort to develop chestnut blight resistance, caused by *Cryphonectria parasitica* (Murr.) Barr., within American Chestnut (*Castanea dentata* (Marsh.) Borkh.). The ACCF effort uses only pure American chestnut and some of the planted trees are now more than 30 years old (https://www.accf-chestnut.org/). In both the U.S. as well as worldwide the current success stories are spurring increased interest in resistance breeding.

CELLULAR INSIGHTS OF BEECH LEAF DISEASE

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ABSTRACT

The beech leaf disease nematode, *Litylenchus crenatae* subsp. *mccannii,* is recognized as a newly emergent nematode species that causes beech leaf disease (BLD) in beech trees (*Fagus* spp.) in North America. The fast progression and impact of BLD in North America has the potential to drastically change beech forests, with ecological implications for beech associated ecosystems and biodiversity. First identified in Ohio in 2012, BLD has rapidly spread and is now reported in 13 additional states, as well as in Ontario, Canada. Changes of leaf morphology induced by BLD can provoke dramatic effects into the leaf architecture and consequently to tree performance and canopy development. The initial symptoms of BLD appear as dark green interveinal banding patterns of the leaf. To understand the cellular basis of BLD, we employed different approaches of microscopy to provide an exhaustive characterization of nematode-infected buds and leaves. Histological sections revealed a dramatic cell change composition of these nematode-infected tissues. Diseased bud scale cells were typically hypertrophied and showed a high variability of size, probably related to their stage of development during nematode interaction. Hyperplasia and hypertrophy of the different leaf cell layers, particularly of the spongy mesophyll, resulted in the typical interveinal leaf banding. These discrepancies in leaf cell structure were depicted by an abnormal rate of cellular division of the leaf areas infected by the nematode, promoting a significant increase of the leaf thickness. The formation of symptomatic BLD leaves is therefore orchestrated by distinct cellular processes, involving an initial abnormal ectopic cell division, followed by cell expansion. These results revealed a high specialized mode of parasitism of *L. crenatae* subsp. *mccannii*.

MODERN DIAGNOSTIC APPROACHES FOR SURVEILLANCE OF INVASIVE PATHOGENS

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ABSTRACT

In modern diagnostics, we can use different molecular approaches to address different questions, and choosing the right approach is critical for the data we collect to be meaningful. One important distinction is between targeted and untargeted diagnostic approaches. Targeted approaches are those that will confirm the presence or absence of specific target organisms, while untargeted approaches are those that will result in a more or less accurate inventory of the multiple taxa of a target group (e.g., the community of fungi, bacteria, or viruses) present within a sample. Another possible distinction is between laboratory-based and field-portable technology. Each approach has advantages and disadvantages in terms of sensitivity, specificity, speed, cost, practicality, and complexity of data interpretation. The choice of which approach is best for a given situation will depend on several factors, including what question we are trying to address. In this presentation, we will provide an overview of two innovative techniques that are gaining traction in forest health. The first one, Loop-mediated Isothermal AMPlification (LAMP), is recommended for field-based targeted diagnostics, and the second one, DNA metabarcoding, is recommended for laboratory-based untargeted diagnostics.

LAMP is an isothermal DNA amplification reaction that utilizes the strand displacement activity of *bst* DNA polymerase (an enzyme isolated from *Bacillus stearothermophilus*) and up to six primers to initiate a cycling reaction that can synthesize up to 10^9 copies of the target region in less than an hour. The rapid yield of such high quantities of amplified DNA allows for visualization of the product via either colorimetric or fluoresce-based approaches, both of which do not require complex equipment and are easily achieved on portable instruments. LAMP is also less sensitive to reaction inhibitors than PCR-based assays and can thus be performed with crude DNA extracts, which is a critical feature for field portability. Because during the reaction the primers have to recognize and bind to a minimum of six to a maximum of eight distinct sequences, LAMP is considered highly specific. One limitation of the approach is that LAMP assays allow for the recognition of one target organism at a time and hence can be limited in their scope. However, the technology has proven helpful for the surveillance of numerous forest pests and pathogens, especially invasive and/or quarantine organisms. While multiplex reactions (i.e., targeting two or more organisms at the same time) are theoretically possible, they have not yet been successfully developed in forest health.

The term DNA metabarcoding refers to next-generation sequencing approaches that amplify regions of the DNA that have high taxonomic discriminating power for a given group, thus allowing for the simultaneous identification of multiple taxa (i.e., the community of organisms) within the same sample. Short-read based metabarcoding approaches, such as the Illumina platform, have been widely used for the characterization of microbial communities in a diagnostic context. One of their limitations, however, is a low taxonomic resolution, which is due to both the use of short read lengths, which carry limited informative sequences and the targeting of one single discriminating region at a time, which is often not enough to discriminate among closely related species. Despite continuous expansions of reference databases, the flexibility of short-read metabarcoding as a diagnostic tool is constrained by the lack of robust sequence reference databases that include multiple diverse taxonomic loci. More recently, long-read sequencing

platforms such as Pacific Biosciences and Oxford Nanopore Technologies have been adapted for amplicon sequencing and overcome these limitations, owing to their ability to capture all of the relevant information in an entire taxonomic DNA region. The precision of taxon identification can be enhanced through the simultaneous sequencing of multiple whole loci, which may be easily compared to readily available reference databases such as NCBI RefSeq. Additionally, the application of target-capture techniques enables the design of bespoke probe sets that allow for the enrichment of wide arrays of taxonomic loci from target organisms and greatly accelerates the precise characterization of microbial communities. As a technique, DNA metabarcoding is a maturing approach and significant limitations still stand in the way of widespread adoption. Currently, sequences of multiple loci cannot be concatenated, and identification of taxa is limited to comparisons of identities derived from multiple separate single locus analyses. Metagenomics, or the simultaneous sequencing of all DNA from a sample using long-read approaches, addresses this issue but is often exceedingly expensive for diagnostic applications. No matter the technology employed, metabarcoding and metagenomics are significantly more expensive than most targeted analyses on a per-sample basis. The financial burden of these analyses may be alleviated as the material cost of sequencing continuously decreases; however, care must be taken to employ these technologies in appropriate use cases.

LEPTOGLOSSUS LEAF-FOOTED BUGS AS GLOBALLY IMPORTANT INVASIVE SPECIES: PROSPECTS FOR BIOLOGICAL AND BEHAVIORAL CONTROL TO PROTECT FORESTS

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ABSTRACT

There are more than 60 species of leaf-footed bugs in the genus *Leptoglossus,* all native to the Americas (Brailovsky 2014). There are several pests in North America belonging to this genus:

- *Leptoglossus zonatus*: Pest of tree fruits and nuts, especially in California; native to tropical & subtropical Americas;
- *Leptoglossus clypealis*: Juniper and other fruits; native to western North America; has expanded its range into eastern North America;
- *Leptoglossus occidentalis*: Feeds on pine and other conifer seeds; Native to western North America; globally invasive and a major pest of pine harvested for pine nuts as well as other conifers;
- *Leptoglossus phyllopus*: Generalist pest of citrus, pecans, fruits, vegetables; native to southern USA and Mexico;
- *Leptoglossus oppositus*: Generalist, occasional pest; native to eastern USA; and
- *Leptoglossus gonagra*: Tropical generalist, pest of citrus, passionfruit, nuts, coffee, squash, beans, etc. Native to New World and (?) Old World tropics; found throughout tropics.

Leptoglossus occidentalis, the western conifer seed bug (WCSB), was originally known as a pest of Douglas-fir (*Pseudotsuga*) seed plantations in the US Pacific coastal states and British Columbia. Its host range includes pines and other conifers. According to Lesieur et al. (2019), genetic analysis points to multiple introductions from eastern North America to Europe, and subsequently, it has spread to northern Africa, across Asia, through Turkey to Russia, China, Korea, and Japan, and to non-native pines and pine plantations in Chile and South Africa.

Pine nuts are a fascinating and species-diverse crop, generally wild-harvested (see Calcagni 2019 for overview). Historically, Europe (*Pinus pinea,* stone pine, in the Mediterranean region), North America (*Pinus edulis* (piñon), *P. monophylla* (oneleaf piñon), *P. lambertiana* (sugar pine), and several additional species), and Asia are major producers. The bulk of the global pine nut crop is harvested in Asia. The major producing areas there are China, Russia, and the Korean peninsula (*Pinus koraiensis, P. sibirica, P. pumila, P. gerardiana*, and additional species). The harvesters of pine nuts are generally poor or subsistence rural populations. The impact of WCSB is apparently pretty severe on pine nut harvests, as evidenced for instance by reports from Turkey (Ïpekdal et al. 2019) and Chile (Loewe-Muñoz et al. 2021), but so far damage is not well documented for Asia.

There is a strong conservation concern that, if the pine forests are no longer productive for pine nuts, they will be much more likely cut down for wood, or otherwise put in jeopardy. There are a number of wild pines, including those not commonly harvested, that may be threatened by

impacts on their reproduction by seed, and other conifer genera are also attacked (Lesieur et al. 2014). It is not known whether South American conifers including important and charismatic trees in the families Araucariaceae, Podocarpaceae, and Cuppressaceae, are vulnerable to WCSB attack, but they are potentially at risk (Faúndez & Rocca 2017).

Leptoglossus zonatus is a pest of tree fruits and nuts in the tropical and subtropical Americas. It is reported as the most serious pest of pistachios and almonds in California, and also a key pest of pomegranates in California, satsuma mandarin in Florida, cashews, passionfruit and diverse crops including corn (maize) (Daane et al. 2019; Stahl & Daane 2023).

The spread of *L. clypealis* to eastern North America, and its status as a pest of tree fruit and nuts in the western USA (Wheeler 2018), along with ecological niche modeling, prompts concern that the potential invasion of Europe by this juniper-feeding bug might have serious consequences (Olivera et al. 2021).

Leptoglossus gonagra (synonym *L. australis*) is essentially pantropical and an outlier in the genus in that it is widespread in the Old World as well as the Americas. It is know as citron bug, squash bug, or passionfruit bug, having a wide host range including economically important fruits and vegetables.

Biological controls of *Leptoglossus* bugs include parasitoids of the egg and adult stages. The scelionid egg parasitoid *Hadronotus pennsylvanicus* (synonym *Gryon pennsylvanicum*) is known as an important natural enemy of *L. gonagra*, *L. zonatus, L. occidentalis*, and other *Leptoglossus* and *Anasa* spp. (Coreidae) (Yasuda 1998; Yasuda and Tsurumachi 1995; Straser et al. 2022; Boyle et al. 2024). *Hadronotus pennsylvanicus* populations need study as to their potentially differing host specificity and efficacy of host regulation. Tachinid flies, particularly *Trichopoda pennipes,* attack adult bugs and have a broad host range, including Pentatomidae.

Hadronotus pennsylvanicus has been under study for >10 years (Roversi et al. 2011) as a candidate for introduction against invasive *L. occidentalis* in Italy, but this classical biological control project has not been permitted for any releases in Europe, in spite of its narrow host range.

The recently-discovered male-produced pheromone, leptotriene (Millar et al. 2022) is attractive to both male and female *L. zonatus* and *L. occidentalis* as well as some, but not all, additional *Leptoglossus* species. This compound could be very useful for detection, monitoring, and possibly population management by mass-trapping or other attract-and-kill tactics. Development of field trapping tactics is underway for *L. zonatus* (Wilson et al. 2020 and unpublished data). Pheromones of *Leptoglossus gonagra* males (semiochemistry unknown) are also attractive to its egg parasitoid (Yasuda 1998; Yasuda and Tsurumachi 1995).

An international collaborative approach to *Hadronotus* systematics and assessment of appropriate natural enemy introductions could address biological control of multiple species in native and invaded areas. Discovery and exploitation of the chemical ecology of the genus is already underway, and needs further investigation of additional species, optimization of deployment of pheromones as well as potential combination of pheromones with plant-derived kairomones.

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AN INTERNATIONAL COLLABORATIVE PROJECT TO DEVELOP AND ASSESS SURVEILLANCE METHODOLOGIES FOR AGRILUS BEETLES (EUPHRESCO PROJECT 2020-A-337)

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ABSTRACT

The jewel beetle genus *Agrilus* (Family Buprestidae) has over 3000 species, all of which are strictly phytophagous, with adults feeding on leaves and larvae feeding on the living subcortical tissues of trees and shrubs (Kelnarova et al. 2019). Larval feeding can be sufficient to kill the host plant, especially when it has already been weakened by other abiotic and/or biotic factors (Kelnarova et al. 2019 and references therein). Furthermore, *Agrilus* species have a proven invasive potential facilitated by their relatively long-lived larvae that are readily transported within nursery plants, firewood, and wood packaging material, whilst adult beetles have good dispersal ability through active flight periods (Kelnarova et al. 2019). As a consequence, some *Agrilus* species have the potential to become significant invasive pests after being accidentally introduced into new geographic areas leading to wide ranging environmental, economic, and social impacts. Hence, *Agrilus* beetles constitute a high-risk group of invasive wood-boring pests, comparable to both longhorn (Cerambycidae) and bark beetles (Curculionidae: Scolytinae and Platypodinae) and should be considered a high priority group when developing early detection and surveillance programmes.

With the exception of emerald ash borer (*Agrilus planipennis* Fairmaire), there is relatively little information published within the scientific literature on surveillance and monitoring protocols for the wood-boring beetles of the *Agrilus* genus. Although across Europe and North America there have been a growing number of field trials and research projects undertaken in the past decade, that have started to investigate methodologies for capturing and assessing not only *Agrilus* species but other Buprestidae (e.g., *Buprestis*, *Chrysobothris*, *Coraebus*) in a variety of contexts. This Euphresco project aimed to consolidate the European and North American studies that have been conducted so far, and with key collaboration from experienced researchers aimed to start to develop more generic trapping techniques for this important phytosanitary group of wood-boring insects. As well as reviewing the current knowledge on available trapping and monitoring techniques employed for *Agrilus* species, collaborators were encouraged to evaluate trap designs with and without volatile lures in a variety of forest and woodland settings to assess the efficiency and species diversity of captures.

The main objectives of the Euphresco project were:

- Collate and review evidence from previous European and North American *Agrilus* species surveillance and monitoring studies.
- Contribute to designing and evaluating generic *Agrilus* trapping techniques.
- Validate detection methods to determine specific *Agrilus* species presence - selected traps and lures were deployed and evaluated for their effectiveness at trapping native and non-native *Agrilus* species.

In North America there have been numerous non-native *Agrilus* species that have been accidentally introduced and that have subsequently established (Digirolomo et al. 2019), with emerald ash borer (*Agrilus planipennis*) being the most infamous. Similarly, emerald ash

borer has also invaded and established in Europe, in both Russia (Baranchikov et al. 2008) and Ukraine (Drogvalenko et al. 2019). A North American species of *Agrilus*, the two-lined chestnut borer (*Agrilus bilineatus*), has also been introduced, and likely established, in Turkey (Hizal & Arslangündoğdu 2018). Since the *Agrilus* genus has over 3000 known species there is a high probability that as a consequence of the ever-expanding global trade in resources and commodities, and changing climate patterns, there will likely be an increase in the frequency with which *Agrilus* species will be intercepted in new locations around the world. Hence, understanding what surveillance approaches could be utilised for detecting these wood-boring insects and monitoring their spread is a vital first step in establishing national invasive insect monitoring programmes.

Both the USA and Canada, along with several European countries already have ongoing research and monitoring activities underway concerning several species of buprestids with an emphasis on *Agrilus* beetles, so this Euphresco project was an opportunity to consolidate and evaluate some of those approaches that may be used to detect and monitor for this large genus of wood-boring beetles. With a significant emphasis on conducting fieldwork, the results of the field trials, conducted over the two years of the project, aimed to lead to research outputs that would contribute to developing best practice guidelines for early detection methodologies, and surveillance and monitoring strategies for the buprestids as a whole, and for specific *Agrilus* species. Three main field trials were conducted by collaborators involved in the Euphresco project in 2021 and 2022 (Santoiemma et al. 2024; Williams et al. 2023), with the primary aim of investigating whether traps originally developed for EAB surveillance might be effective tools for capturing other *Agrilus* species within oak woodlands/forests; (i) Trial 1 focused on simply appraising green multi-funnel traps (ChemTica) versus green sticky prism traps (Andermatt) with no lures (plant volatiles) attached to the traps. These traps were deployed in the live oak canopy (10-30m above ground), in open, sunny locations, and trapping was undertaken from mid/late May until mid/late August to cover the main flight period of adult *Agrilus* beetles. Results from this trial indicated significant variability in trap catches between the two trap designs across locations, with prism traps in some locations outperforming multi-funnel traps significantly in terms of the abundance of both the total numbers of *Agrilus* caught and counts of an individual species captured. However, in other locations there were no significant differences between the two trap designs in their ability to capture *Agrilus*; (ii) Trial 2 evaluated the green multi-funnel and green sticky prism traps with and without the green leaf volatile, 3Z-hexenol present. As 3Z-hexenol is widely used on traps for EAB surveillance this trial aimed to establish whether it would increase trap catches of other *Agrilus* beetles when traps were deployed in oak trees in woodland or forest settings. This essentially was a repeating of Trial 1, with traps set-up in a comparable manner in the mid to upper green canopy of oak trees, but with added replicates of both trap designs with 3Z-hexenol lures attached. Results from this trial indicated far more clearly than in Trial 1 that prism traps tended to outperform green multi-funnel traps in terms of species richness and abundance of *Agrilus* species captured, and in addition the 3Z-hexenol lure did not appear to be an influential factor in the trap catches of *Agrilus* beetles (Santoiemma et al. 2024); (iii) Trial 3 assessed whether adding adult *Agrilus* decoys to the surfaces of green flight interception traps (Synergy Semiochemicals Corp.) improved trap catches of *Agrilus* beetles. Results were somewhat disappointing and demonstrated that the presence of *Agrilus* decoys on traps did not influence *Agrilus* species richness or abundance in any location (Santoiemma et al. 2024).

The over-riding conclusions from the collaborative field trials conducted within the framework of the Euphresco project were that both trap designs were clearly effective tools for use as early detection, monitoring, and surveillance approaches for adult *Agrilus* beetles, although the evidence suggested that the green sticky prism traps do outperform the green multi-funnel traps. In addition, it was apparent that adding adult *Agrilus* beetle decoys or the green leaf volatile 3*Z*-hexenol (used in emerald ash borer monitoring and surveillance programmes in North America), does not improve trap catches of *Agrilus* in general trapping programmes within oak woodlands. Other plant volatiles may increase trap catches of target *Agrilus* species, but considerable effort collaborating closely with chemical ecologists would be required to identify the individual and blends of host plant volatiles that might be effective for specific *Agrilus* species, particularly for high priority invasive species. Whilst visual stimuli are important to adult *Agrilus* beetles, as has been shown for emerald ash borer (*A. planipennis*), there is still considerable effort required to identify what visual stimuli are important for other *Agrilus* beetles. Hence, it should not be assumed that green coloured traps will be effective for every *Agrilus* species, so evaluation of other trap colours and shapes (since trap profiles may be important) is likely to be vital for other emerging invasive *Agrilus* species.

The international cooperation within this Euphresco project provided valuable information for respective plant protection organizations on potential optimal surveillance approaches for this target group of wood-boring insects (Williams et al. 2023). Hence, including green traps (either, sticky prism traps or Fluon-treated multi-funnel traps) in the mid to upper canopy of broadleaved trees in areas at risk of woodborer introduction via global trade, will increase the probability of detecting *Agrilus* species, in annual surveillance programs for non-native woodborers. The field trials conducted within the framework of this Euphresco project highlighted that green traps even without lures can be useful tools for monitoring *Agrilus* when proper placement of traps (in sun exposed parts of host tree crowns) is observed. However, it must be ensured that experts are available for the determination of the *Agrilus* specimens caught in traps, since morphological identification of individual species is particularly challenging.

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POSTER
Abstracts

HAPLOTYPES AND LIFE HISTORIES OF ANASTATUS ORIENTALIS, EGG PARASITOID OF SPOTTED LANTERNFLY IN CHINA

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ABSTRACT

Over the past few years, we have been conducting various field studies in China and growth chamber studies in the U.S. to look at the life history of *Anastatus orientalis* as it relates to parasitism of the spotted lanternfly. Unfortunately, the various pieces of evidence are sometimes contradictory. We have preliminary genetic evidence that suggests that we may be dealing with at least two haplotypes or maybe even two different species of *A. orientalis* in China. The purpose of this study is to monitor the haplotypes and life histories of spotted lanternfly egg parasitoids in Beijing, China to investigate which genetic groups or haplotypes are present and which might be synchronized with spotted lanternfly egg availability. The objective of this study is to collect emerging wasps monthly and determine their genetic type. At the same time, we will collect parasitoid larvae from the egg masses from which adults emerge to determine which genetic types are in the larval stage throughout the summer. The results show that there are 1-2 generations of *A. orientalis* a year; During the spring emergence period, 53.78 percent of *A. orientalis* (Haplotypes A, C, D, E, F) emerged, some unhatched spotted lanternfly eggs were at the embryo stage and were parasitized beginning in spring by first generation females of *A. orientalis*. These *A. orientalis* eggs (F2) developed to mature larvae and entered diapause in June and July; The remaining 46.22 percent of wasps (Haplotypes B, C, D, E) did not emerge in spring and entered diapause as mature larvae; Finally, 90.21 percent of *A. orientalis* (F1 and F2) emerged in September, and freshly laid spotted lanternfly egg masses were parasitized beginning in fall by the first and second generation of females.

THEY'RE HERE!
INTRODUCED PARASITOIDS OF EMERALD ASH BORER ARE ESTABLISHED IN TENNESSEE

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ABSTRACT

On July 27, 2010, emerald ash borer (EAB) was identified in Tennessee at a truck stop in Knox County. This represented the first confirmation of this invasive insect pest in the southern U.S. since its initial identification in southern Michigan in 2002. EAB is now present throughout eastern and middle Tennessee having been found in 65+ of 95 counties, where it has killed ca 20 million trees. A biological control program against EAB was initiated in Tennessee in 2012. From 2012 to 2016, more than 264,000 parasitoids (*Spathius agrili* and *Tetrastichus planipennisi*) were released at 9 locations in 7 counties. Yellow pan traps (YPT) were installed in 2015 and monitored at the release sites for 3 years. The few parasitoid recoveries in 2015, 2016 or 2017 suggested that both species could overwinter in Tennessee, but their establishment was uncertain. In 2020 monitoring of existing YPT at 6 of the release sites was restarted, and in 2021 a multi-year study that utilizes EAB-infested ash bolts in addition to the YPT was begun to assess establishment of these introduced parasitoids of EAB, last released in 2016 in Tennessee. Both introduced parasitoid species have established in Tennessee with 16 recoveries of *Spathius agrili* confirmed by DNA analysis. *S. agrili* was recovered in 2020, 2022, and 2023 from 3 locations in 3 counties. *T. planipennisi* was recovered in the years 2020 thru 2023 from 4 locations in 4 counties including a recovery 8 km north of the nearest release. Surprisingly, another exotic parasitoid species, *S. galinae*, was recovered from 9 locations in 5 counties in 2020 thru 2023, including recoveries 3 km and 11 km distant from the nearest study site. This species had not been released in Tennessee, although field cage studies to assess its parasitism and overwintering had been conducted in 2015 and 2016. It is believed that a few individuals escaped from these studies. *Spathius* sp. prepupae were recovered on November 1, 2023, while peeling a sentinel bolt from a location in middle Tennessee (Smith County) and will be sent for DNA analysis to determine species. The purpose of this poster was to highlight the establishment of *S. agrili*, possibly the first known occurrence; and to provide an overview of recoveries of parasitoids of EAB in a southern climate and encourage other southern states, where releases have been made, to monitor for parasitoid establishment and dispersal.

EMERGING WILT OF SASSAFRAS AND SPICEBUSH IN THE CENTRAL HARDWOOD FOREST REGION

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ABSTRACT

In 2019, wilting sassafras (*Sassafras albidum*) trees were observed in southern Indiana. While symptoms were similar to laurel wilt disease, neither its primary insect vector nor its fungal causal agent were isolated. Instead, two non-native ambrosia beetles (*Xylosandrus germanus* and *X. crassiusculus)* and a potentially novel fungus, with sequence similarity to *Ophiostoma quercus*, were recovered from wilting trees. Since the initial report, wilting sassafras were observed in Missouri and Ohio. In Ohio, wilting spicebush (*Lindera benzoin*) were also found. The objectives of this study were to document the range of wilting sassafras trees within the central hardwood forest region, not associated with laurel wilt, and to identify beetles and fungi associated with wilting trees. In 2022, we surveyed for wilting sassafras based on past reports, and in 2023 we expanded our efforts by reaching out to the public and asking them to report wilting trees. We established a network of plots containing both symptomatic and asymptomatic sassafras and surveyed sassafras and trapped for beetles throughout the growing season in 2022 and 2023. Material from trees with symptoms of wilting, beetle damage, and/or vascular staining was collected and beetles and fungi were isolated. In addition to the two ambrosia species recovered in 2019, we have recovered a third species, *Anisandrus maiche* from symptomatic trees. We also continue to recover the *Ophiostoma*-like fungus, first reported in 2019, from symptomatic sassafras and spicebush, including from beetle galleries. Currently, we are in the process of sequencing isolates of this fungus collected across our survey area, in order to provide a more precise ID. Next steps will focus on evaluating whether the fungus alone is capable of causing the observed symptoms in sassafras and spicebush.

UPDATES ON INTEGRATING BIOCONTROL AND INSECTICIDE TREATMENTS IN BLACK AND GREEN ASH FORESTS

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ABSTRACT

The emerald ash borer (EAB), Agrilus planipennis (Coleoptera: Buprestidae), is a destructive invasive forest pest causing widespread mortality of ash trees in North America. Ash has considerable economic significance and black ash basketry has cultural as well as economic importance. Green and black ash are also vital components of riparian ecosystems. This project involves integrated pest management in forested areas, integrating trunk injections of ash trees and releases of biological control agents for widespread control of EAB. A prior study in urban areas found that treated trees remained healthy while both *Tetrastichus planipennisi* and *Spathius galinae* established and dispersed widely. In New York, three green ash plots were set up in 2020 and three black ash plots were set up in 2021. The goal of this project is to test if we can conserve larger reproductive ash trees with trunk injections while biocontrol agents establish and then eventually cease using insecticides because the biocontrol agents and native natural enemies will cause sufficient EAB mortality. This work is ongoing, and we are currently treating trees while working to establish parasitoids and monitor the EAB population.

RHODODENDRON LEAF BAITING OF COASTAL CALIFORNIA WATERSHEDS FOR PHYTOPHTHORA AND NOTHOPHYTOPHTHORA

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ABSTRACT

Stream baiting of northern and central California coastal streams has been an important tool in the management of sudden oak death, a devastating forest disease caused by the invasive oomycete *Phytophthora ramorum*. *Phytophthora* species are baited with floating rhododendron leaves, serving as an early detection tool for the presence of *P. ramorum* in watersheds across more than 800 km of California coastline. While this long-standing management tool is focused on a single species of *Phytophthora*, other species of *Phytophthora* have been baited alongside *P. ramorum* and this study documents the presence and distribution of 22 *Phytophthora* and *Nothophytophthora* species across the northern and central coasts of California. Although *P. ramorum* was isolated at the greatest number of sites, several species in subgeneric clade 6 were also abundant and widespread, a common feature of *Phytophthora* stream baiting studies. Clade 3 species *P. nemorosa, P. pluvialis* and *P. pseudosyringae* were also frequently isolated in northern coastal streams. The species *Nothophytophthora caduca* and the genus *Nothophytophthora* are reported for the first time in North America along with the first report of *P. pluvialis* in California. Two novel species, *N.* sp. *californica* and *P*. sp. *aureomontensis* (a member of the *P. citricola* species complex) are provisionally named. Mitochondrial sequences revealed multiple hybridization events between *P. lacustris* and *P. riparia*. Stream monitoring can serve as an important tool for monitoring ongoing *Phytophthora* invasions as well as establishing baseline pathogen communities, critical data for preventing future invasions.

LOOKING FORWARD: THE IMPACTS OF ASIAN LONGHORNED BEETLE ON FORESTS IN SOUTHEASTERN NEW ENGLAND

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ABSTRACT

Over the past several decades, the United States has been experiencing an influx of nonnative pests which have the potential to permanently alter the composition, structure, and function of forests. Asian longhorned beetle (ALB) is an invasive pest that came into Worcester County, MA in 2008, where the first instance of this species invading both urban and natural forested areas was documented. 30,000 trees were removed over the course of 10 years as part of management efforts focused on harvesting all host species, primarily *Acer spp*., to prevent ALB spread. We examined forest compositional and structural development following three different eradication treatments (full host removals, herbicide, and stump grinding) and patterns with adjacent unimpacted areas. Overall, the results of our observational study found that forests were recovering following similar pathways documented after other disturbances in southern New England forests. Forest types shifted to primarily oak-hickory or pine dominance following the removal of all *Acer spp*. Landscape simulations of the long-term effects of ALB management and climate change on forests in Worcester County and Cheshire County, New Hampshire using LANDIS-II found that climate had a more pronounced effect on long-term forest conditions. verall, the results of this work suggest these mixed species forests are resilient to the impacts of ALB management strategies, given the compensatory response of other non-host species. The long-term negative impacts of climate change on overall forest biomass levels argues for adaptation strategies to sustain these forests under future Asian longhorned beetle and climate change impacts.

ASIAN LONGHORNED BEETLE (ALB) ANOPLOPHORA GLABRIPENNIS ERADICATION PROGRAM

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Abstract

Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky, 1853) is a cerambycid native to Asia that most likely came to the United States inside wood packaging material. The beetle weakens and can kill trees by tunneling through the vascular tissues and wood. Initial detections include Brooklyn, New York (August 1996), Chicago, Illinois (July 1998), Jersey City, New Jersey (October 2002), Worcester, Massachusetts (August 2008), Bethel, Ohio, (June 2011), and Hollywood, South Carolina (May 2020). Currently, 288.4 square miles are under federal quarantine for ALB in the United States: 110 square miles in Massachusetts; 53 square miles in central Long Island, New York; 49 square miles in Ohio; and 76.4 square miles in South Carolina. The goal is to eliminate the beetle in the United States to protect trees, industries, and the quality of the environment. The eradication program uses a combination of tactics, including: 1) Exclusion—All cargo containing solid wood packing material must be certified as heat-treated, fumigated, or treated with preservatives before arriving in the United States; 2) Quarantines—Help restrict the movement of materials; 3) Survey—Visual surveys of host trees are conducted by climbers, ground crews, or using bucket trucks; 4) Tree removal—All infested trees are removed and high-risk host trees may be removed too; 5) Chemical treatment—Host trees may be treated with the pesticide Imidacloprid to prevent infestation and reduce populations; 6) Tree replanting—Partnering agencies work to replace trees with non-host trees in areas where trees have been removed; 7) Outreach efforts—Provides information and education through ongoing grass root efforts and an annual awareness campaign; 8) Quality assurance—Ensures surveys, removals, and treatments are conducted correctly; 9) Methods developments—Field studies, trials, and laboratory research is vital in developing the science-based protocols used today to fight the beetle; A final round of negative surveys completed at least 4 years after an initial detection is needed to declare eradication. The eradication program eliminated ALB infestations in Illinois; Boston, Massachusetts; New Jersey; Brooklyn, Queens, Manhattan, Staten Island and Islip in New York; and a portion of East Fork State Park, Stonelick and Monroe Townships in Ohio.

SAVING EARTH'S FORESTS – WORKING TOGETHER TO PREVENT INTRODUCTION AND SPREAD OF NEW DISEASES

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ABSTRACT

The poster describes severe threats posed by non-native pathogens to forest tree species and ecosystems. Many such pathogens are introduced via trade in plants for planting. Countries' phytosanitary policies and programs intended to curtail such introductions are constrained by the World Trade Organization SPS Agreement, International Plant Protection Convention (IPPC), and pertinent standards.

The poster then asks for scientific studies to determine which approaches might prove most effective in reducing numbers of new introductions. Some approaches involve research to identify better predictive or detection strategies. Among questions raised are the following:

1. Should national governments, FAO / IPPC, international research organizations (e.g., IFQRG, IUFRO) undertake studies to
    a. determine current approach rates of pathogens via P4P trade? Should such studies rely on data from randomized, statistically sound inspection systems *e.g.*, USDA AQIM?
    b. evaluate efficacy of tools to detect "unknown unknowns" in places of origin, transit, ports of entry, and in importing nurseries?
    c. evaluate predictive power of pathogen traits or evolutionary history?
    d. identify microbes resident in regions from which import large numbers of plants and vulnerability of hosts in importing countries – i.e., "receptive bridgeheads" (e.g., Bonnamour et al. 2023; Isitt et al. 2023; Fenn-Moltu et al. 2023)?
2. Would expansion of international "sentinel plants" networks significantly improve pest identification and importing countries' prevention or rapid response programs?

Can significant improvement be realized through stronger enforcement of the IPPC and WTO/SPS as adopted? Does requiring phytosanitary certificates (pre-import approval) actually enhance either "cleanliness" of consignments or importing countries' detection and enforcement? Can countries ramp up enforcement actions against repeat violators? Apply more stringent regulations to highest-risk plant types, *e.g.*, whole plants? Or to protect centers of endemism? Would targeting detection efforts on "door knocker" species (Hoddle et al. 2018) improve preventive efforts overall?

If changes are needed to international rules, can they be achieved through revising IPPC standards rather than the texts of the conventions? The standards appear to allow greater flexibility than countries are currently exploiting.

EXPLORATION FOR NEW NATURAL ENEMIES OF THE ASIAN LONGHORNED BEETLE (COLEOPTERA: CERAMBYCIDAE) IN CHINA USING SENTINEL LOGS

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ABSTRACT

Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Motschulsky) is a polyphagous wood boring pest that attacks many economically important orchard, ornamental and forest trees (>100 species). This cerambycid has invaded North America and Europe. In China, many techniques have been implemented to control ALB, including forest management, trapping, chemical and biological control. Prior to this study, two native polyphagous parasitoids, *Sclerodermus guani* and *Dastarcus helophoroides* have been used throughout China to control ALB, and few other parasitoids have been reported parasitizing ALB. To discover specialist ALB parasitoids, a biocontrol program has been carried out in China since 2015 by applying the technique of deploying ALB-infested sentinel logs to attract parasitoids in five different regions in China (Beijing, Shanghai, Guizhou, Yunnan and Jilin). From 2015 to 2022, our survey discovered 12 species of hymenopteran parasitoids attacking sentinel ALB larvae or eggs, namely, *Bracon planitibiae*, *Iphiaulax impostor*, *Spathius glabripennis* sp. nov. (unpublished), *Zombrus bicolor* (Braconinae), *Callocleonymus beijingensis*, *Oxysychus scolyti*, *Zolotarewskya robusta glabripennis* ssp. nov. (unpublished), *Zolotarewskya anoplophora* sp. nov. (unpublished) (Pteromalidae), *Eurytoma morio* (Eurytomidae), *Eupelmus urozonus* (Eupelmidae), *Sclerodermus guani* (Bethylidae) and *Xorides* sp. (Ichneumonidae). Mean parasitism rates by all parasitoid species were 3.6–15.8 percent in Beijing, 1.4–16.4 percent in Guizhou, 1.6–7.1 percent in Shanghai, 5.8 percent in Yunnan and 0–0.25 percent in Jilin. Among them, *S. glabripennis* sp. nov and *O. scolyti* accounted for 1–4 percent and 2–10 percent parasitism, respectively.

SPOTTED LANTERNFLY (*LYCORMA DELICATULA*) EGG PHENOLOGY IN COASTAL CONNECTICUT

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ABSTRACT

Spotted Lanternfly, *Lycorma delicatula* (White; SLF), is an invasive phloem-feeding planthopper with a wide host range including trees, ornamental plants, and agricultural crops. Native to Southeast Asia, SLF was detected in North America in Pennsylvania in 2014 and has since spread to at least 16 states. Feeding by SLF depletes carbohydrate and nutrient stores in host plants, reducing plant growth. Effective management of SLF in North America may depend on understanding the timing of phenological stages, local within-stand movement of populations, and developmental requirements. Predicting hatch and understanding oviposition behavior may aid in determining when and how to apply management interventions. To identify relationships between the timing of oviposition, hatch date, and hatch success and examine the role of temperature in determining hatch date, we documented the abundance, location, and timing of adults and egg masses weekly during autumn of 2022 and 2023. Our study site encompassed a woodlot with a relatively low-density SLF infestation in a residential area of coastal Connecticut with a mix of hardwood species including *Ailanthus altissima* and *Acer rubrum*. During the spring of 2023, egg hatch was documented weekly for egg masses that had been marked and dated during the fall of 2022. Results indicate that an average of 79.42 ± 4.09 percent (mean ± SE) eggs hatched within egg masses. Egg hatch success (measured as proportion of hatch) was not related to either host tree species ($X^2 = 6.95$, df = 7, $p = 0.43$) or oviposition date ($X^2 = 0.01$, df = 1, $p = 0.92$). Mean (± SE) growing degree days (GDD, calculated using single sine method, base = 10.0°C) required for hatch was 295.35 (± 2.27, range = 110 - 509), approximately 3 days more than the average of reported peak hatch across its North American range. Throughout the oviposition period, adult abundance on *A. altissima* decreased, but was relatively constant on *A. rubrum*, which may indicate the movement of adults from *A. altissima* to other species as they approach oviposition. Calculating GDD may be a viable means of predicting peak hatch, but it may be of limited use in predicting the boundaries of the hatch season due to the wide range of hatching dates which spanned almost 400 GDD and nearly 2 months. The lack of a strong link between egg hatch and oviposition timing and ambient temperature suggests other factors (e.g., maternal effects, substrate, microclimate) may influence hatch timing. Future research directions include investigating the impact of microhabitat and oviposition substrate on timing of hatch and hatch success to better manage anthropogenic movement of SLF egg masses.

ADELGID POPULATION DYNAMICS MODEL 2.0: WORKING TOWARDS A DYNAMIC RESEARCH-DRIVEN SYNTHESIS MODEL

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ABSTRACT

The Adelgid Population Dynamics Model (APDM) is a stock-and-flow model (Stella® Architect) that simulates hemlock woolly adelgid, *Adelges tsugae* Annand, population density for each of the nine sequential life stages spanning the two generations observed annually in North America. The goal of the original version (hereafter, APDM v. 1.0) was to combine individual life-stage specific density-dependent survival and fecundity estimates into a synthesis model to explore the interactions between factors and population dynamics. Parameters were derived from field data from four years at seven field sites in Massachusetts. The resulting simulation indicated adelgid populations move to steady-state densities of ~1.5 adelgids/cm with stability driven by interactions between fecundity and density dependent survival. To explore the potential impacts of biological control, predation by *Laricobius* spp was added to the model by adding external mortality to winter larvae and adults and spring-produced eggs. The addition of simulated predation suggested that feeding by *Laricobius* spp may have brief and limited effects on overall HWA density due to a compensatory increase in survival of the spring generation.

Since the publication of ADPM v. 1.0, however, additional density dependent factors have been identified and predator species released. Therefore, we have updated APDM v. 1.0 to integrate these factors and mortality sources to produce APDM v. 2.0 and have tested the sensitivity of the system under both models. Results from APDM v. 2.0 indicate that the introduction of new biological control agents that feed coincident with the summer generation of eggs, rather than during spring, will have a larger impact on population control due to the density-dependent factors that enable compensation for mortality in subsequent stages. We are currently working to add additional factors, including climate driven mortality for both winter and summer life-stages, and have structured the model to encourage the addition of factors as new information becomes available. By including spatially explicit environmental conditions, APDM v. 2.0 may be used to explore interactions between intrinsic and extrinsic factors such as climate, density-dependent survival and fecundity, biological controls, and factors such as tree health that merit further study.

COMPARATIVE RESPONSES OF TWO CONGENERIC LARVAL PARASITOIDS OF EMERALD ASH BORER TO AMBIENT TEMPERATURES: IMPLICATIONS FOR BIOCONTROL INTRODUCTION

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ABSTRACT

The success of classical biological control requires alignment between new climatic conditions and the developmental needs of introduced natural enemies. Even closely related congeners with similar origins and traits can establish and perform differently on the targeted hosts (pests) in new environments due to inheritably differences in responses to climate. Temperature is as a key factor in the development of many insect taxa, including hymenopteran parasitoids used in classical biological control programs. Here we compared the host attack rate and immature development of two larval parasitoids of *Agrilus planipennis* Fairmaire, *Spathius agrili* Yang and *S. galinae* Belokobylskij and Strazenac under five different constant temperatures (17.2, 21.1, 25, 28.9, and 32.8 °). Results showed that these two parasitoids exhibited distinct patterns in host attack rate and immature development time or rate under the test temperature regimes. *Spathius agrili* parasitized host larvae at 17.2 - 32.8 °, whereas *S. galinae* failed to parasitize EAB larvae at 32.8 °. We observed higher host attack rates by *S. agrili* at higher temperatures (25 - 32.8 °C) but lower rates at lower temperatures (17.2 - 21.1 °C) than *S. galinae*. The mean development time decreased with increasing temperatures from 21.1 °to 28.9 ° for both species. Additionally, *S. agrili* developed significantly faster and emerged around 9 days earlier than *S. galinae* at 21.1 - 28.9 °. Both parasitoids diapaused at cocooned mature larvae at 17.2 - 21.1 °, with significantly higher diapause rates at lower temperatures, and slightly higher rates for *S. agrili* than *S. galinae*. These findings indicate that *S. agrili* may thrive better in warmer environments but encounter challenges in surviving and establishing effectively in colder temperatures, such as in northern US, compared to *S. galinae*. This could lead to missed opportunities for *S. agrili* to target the appropriate stages of host larvae, potentially resulting in inferior pest control in colder environments.

PARASITOID-INDUCED CHANGES IN METABOLIC RATE AND FEEDING ACTIVITY OF THE EMERALD ASH BORER (COLEOPTERA: BUPRESTIDAE): IMPLICATIONS FOR BIOLOGICAL CONTROL

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ABSTRACT

Parasitoid-host interactions form the foundation of biological control strategies against many insect pests. The emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), is a serious invasive pest of ash (*Fraxinus* spp.) trees in North America. *Tetrastichus planipennisi* Yang (Hymenoptera: Eulophidae) is a gregarious, koinobiont endoparasitoid, attacking 3rd to 4th instars of EAB larvae, which feed in the live phloem of ash trunks or branches, making serpentine-like galleries filled with larval frass. In the present study, we tested the hypothesis that *T. planipennisi* regulates the host metabolism and feeding activity to optimize its offspring development and fitness. Although parasitized host larvae increased metabolic rate and feeding activity in the first few days of parasitism, *T. planipennisi* parasitism induced an overall reduction of the metabolic rate and decrease in feeding activity of parasitized host larvae over their development period. In addition, there was a negative relationship between feeding activity of parasitized hosts and brood sizes of the parasitoid progeny. These findings may have several implications for EAB biocontrol with *T. planipennisi*. First, parasitism by *T. planipennisi* reduces the overall feeding activity of parasitized larvae and thus limits the damage to host's food plant tissues. Second, optimization of its offspring development and fitness by *T. planipennis* relies on selection of suitable stages of EAB larvae, not by regulations of the host metabolism and feeding activity via larval parasitism. Thus, the availability and abundance of suitable stages of host EAB larvae (3rd to 4th instars) are critical for successful parasitoid progeny production and population growth. Thirdly, as there was a negative relationship between feeding activity of the parasitized host and the brood size of the parasitoid progeny inside the host, superparasitism may result in reduction of the damage caused by the parasitized larvae to their host plants and thus benefit EAB biocontrol.

ELM PHYTOPLASMAS: IDENTIFICATION & PATHOGENICITY

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ABSTRACT

Phytoplasmas are important plant pathogens detrimental to plant health and relevant to agricultural, natural, and urban systems alike. Despite their significance, these microorganisms remain understudied. The paucity of information about phytoplasmas, as well as their primary and secondary hosts, their broad and often invasive vectors, and potential interactions with climate change limit our ability to appropriately predict and mitigate outbreaks across the landscape or to respond to unintended transmission. In response to an apparent phytoplasma outbreak in an American elm planting in central Ohio, we refined molecular tools to identify the culprit, delineate its footprint, and assess its pathogenicity.

Molecular Techniques confirmed the identity of the pathogen as '*Canditatus* Phytoplasma trifolii'; CPY), associated with clover proliferation yellows, a disease previously reported in herbaceous plants, not as the anticipated '*Candidatus* Phytoplasma ulmi', associated with elm yellows disease. A concurrent survey of the planting indicated that CPY was more abundant along the northern edge with lower detection levels across the planting. This pattern is typical of vector-transmitted diseases. For two years (2016-2018), a randomly selected subset of trees along the leading edge of the outbreak was tracked seasonally (spring, summer, fall, and winter) for phytoplasma and canopy health. During each time period tissues from roots, stems, branches and leaves (when available) were sampled.

Results indicate CPY can persist at low levels within trees and potentially spread quickly across a planting with significant implications for tree health. We observed significant differences in tree survival over two years. Trees testing positive for CPY had lower survival rates than those without the pathogen. These findings point to a more geographically widespread distribution of phytoplasmas and cryptic pathogens with unknown implications for broader forest health.

OVERWINTERING PHENOLOGY OF TWO INTRODUCED SPATHIUS SPECIES ACROSS THE INVASION RANGE OF EMERALD ASH BORER

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ABSTRACT

A classical biological control program against the invasive emerald ash borer (*Agrilus planipennis* Fairmare) has been in place since 2007, however the parasitoids utilized for biological control have shown markedly different levels of success in terms of establishment. *Spathius galinae* Belokobylskij & Strazanac, which was introduced from the Russian far east, has successfully established and contributed to a reduction of EAB population growth rates in in several released areas in the Northern U.S. However, its congener *Spathius agrili* Yang, introduced from near Tianjian, China, has failed to establish self-sustaining populations in many released areas across midwestern and Mid-Atlantic regions. It is hypothesized that this is due to phenological differences between the two species that synchronize adult emergences with susceptible host stages in different climates. We are starting a field experiment that will compare the overwintering phenology, diapause, and spring emergence patterns of both *Spathius* species. We placed bolts containing developing larvae of both species within ventilated plastic jars into field sites across three states representing a latitudinal gradient of EAB's invaded range. This spring, we will collect and analyze data on the emergence timing and diapause patterns of both species using survival analysis models. This experiment will test hypotheses regarding the differential emergence patterns of these two species and if *S. agrili* is indeed more phenologically matched to presumed EAB life cycles in southern forests. Our results will have important implications for biological control of EAB across its invaded range as our results will help to shed light on the differential establishment of these two species.

CAN WE PREDICT SHIFTS IN ECTOMYCORRHIZAL COMMUNITIES IN BEECH TREES INFECTED WITH BEECH LEAF DISEASE?

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ABSTRACT

Beech trees (*Fagus* spp.) are obligately associated with ectomycorrhizal (ECM) fungi, in a mutually symbiotic relationship where the trees provide carbohydrates to the fungi in exchange for nutrients. Ectomycorrhizal fungi are essential to tree health and play an important role in nutrition, water use efficiency, and abiotic or biotic stress tolerance. Currently beech trees across northeastern forests are impacted by two diseases, beech leaf disease (BLD) and beech bark disease (BBD). Beech leaf disease (BLD) is a foliar disease caused by a putatively invasive nematode, *Litylenchus crenatae mccannii*. Early symptoms of the disease begin with dark interveinal banding on the leaves, progress into thick, dark crinkled leaves and later buds are aborted leading to canopy thinning and defoliation. The decline of beech trees due to BLD is a growing concern for Northeastern U.S. forest ecosystems, many of which are already largely impacted by BBD. The long-term impacts of tree decline on the below ground mycorrhizal community remains unknown. Changes in carbon availability due to reduced crown density and lower photosynthetic rates will likely impact the amount of readily available carbon, and subsequently, the microbial community structure. Different ECM fungi have different carbon requirements based on their exploration types. For example, long-distance exploration types have higher carbon demands and short-distance (contact) exploration types have lower carbon demands from the tree. It is unknown whether long-term disease pressure will impact components of the microbial community such as the proportion of exploration types, fungal diversity, fungal biomass, or root tip abundance. The aim of this study is (i) to determine which site characteristics are important for the progression from low to high disease severity sites and (ii) to assess if disease severity is a significant predictor in changes in ectomycorrhizal community composition in beech forests. Twenty-five trees will be selected from five sites ranging from naïve, low, and high disease severity (n=15). Fine roots will be sampled and scored for percent colonization and fungal DNA from root tips will be sequenced with Illumina Miseq using ITS1F and ITS2 primers.

WHAT WOULD SPOTTED LANTERNFLY (*LYCORMA DELICATULA*) LIFE HISTORY LOOK LIKE IF IT ESTABLISHED IN STOCKTON, CA?

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ABSTRACT

Spotted lanternfly (*Lycorma delicatula*) is an invasive insect from Asia that was first found in the U.S. in Pennsylvania in 2014 and has since spread to 16 other states. Some of this spread is natural as the insect disperses to new areas adjacent to where it is already established, but every year there are new regulatory incidents that are not adjacent to current infestations. These long-distance movements typically occur when eggs are laid on vehicles (trains, cars, etc.) or materials that are stored outdoors and moved. Spotted lanternfly has had major impacts on Pennsylvania grape vines and there is a great concern that it will eventually be introduced to California where grapes are a major crop. Previous work on the thermal responses of spotted lanternfly has suggested that it may experience mortality and adverse effects if exposed to temperatures over 35°C for extended periods of time. This study mimicked 2022 climate conditions in Stockton, CA to estimate the effects of a warmer, drier climate (where grapes are grown) on spotted lanternfly. Nymphs were provided Concord grape vine and tree of heaven to feed on and were checked daily for molts or death. Adults were held four pairs (4 males and 4 females) to a large cage and provided maple bolts for oviposition. The spotted lanternfly successfully completed development in the Stockton, CA climate regime. Nymphs went through the instars fairly quickly with mortality highest in the first and fourth instars. Weight at molt was comparable to what is seen under milder climatic conditions. The first adults were seen in June and adults lived an average of 58.0 and 69.0 days, for females and males respectively. The oldest female of the 60 individuals that were followed died at 102 days and the oldest male of the 53 that were followed died at 101 days. Oviposition began in late August and continued into November. Seventy percent of females laid an egg mass, and 32% of females laid more than one egg mass (up to 4 egg masses). The egg masses that were laid continue to be held in the Stockton, CA regime until they hatch. Because adults lived a long time and some females laid multiple egg masses, spotted lanternfly has the potential to increase in numbers more quickly in warmer climates like this where a fall freeze does not kill the adults before they would naturally die. The week-long heat wave that was simulated (40°C maximum temperature) did not have a significant impact on survival, so the Stockton, CA climate appears to be acceptable for spotted lanternfly establishment. Most of the oviposition occurred during the same time of year as it does where spotted lanternfly has already established, so completing more than one generation in a single year is unlikely. Some precocious hatch did occur in December, but the fate of these first-instars is uncertain.

CAN URBAN MAPLES TAKE THE HEAT? ASSOCIATION OF HARDCAPE AND SITE FACTORS WITH STREET TREE CONDITION IN NEW HAVEN CONNECTICUT

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ABSTRACT

Planting of shade and flowering landscape trees is ranked as the leading nature-based solution that affects the daily lives of 277 million Americans living in cities and urban areas. Each year, urban trees and forests are estimated to reduce US greenhouse gas emissions by 3% and to remove air pollution worth $6.8 billion. The shading and cooling offered by urban trees reduces heatstroke deaths, and cuts household energy consumption by 7%. However, the benefits offered by urban trees are diminished by declining tree condition. Estimates of annual urban tree mortality vary between 0.6-68%, with causes often unclear, indicating a need to identify the factors associated with urban tree decline and to quantify their impact on tree health. We report initial trends and observations from a survey on street trees in New Haven, Connecticut. In this study, we estimated how environmental factors, soil characteristics, and potential tree or planting defects associate with urban maple condition for sugar maples (*Acer saccharum*), red maples (*Acer rubrum*) and Norway maples (*Acer platanoides*). In total 120 street trees from three New Haven neighborhoods were monitored during the 2023 growing season. Diameter growth for most of these trees had been monitored in 2000, 2010, and 2020. Spatial analysis was performed to extract the percent of hardscape (impervious area) for 30 m perimeters. Trees in locations with 80-100% hardscape had on average 14% twig dieback compared to 4% dieback in locations with less than 50% pavement. Most dieback was found for Norway maples (average 12%), while red maples had least dieback (average 6%). Average diameter growth over 23 years was 0.6 cm/year for sites with 80-100% hardscape, and 1.6 cm/year for locations with less than 50% hardscape. Regarding biotic stressors, intense sooty mold was noted on the bark of 41% of sugar maples, associated with the occurrence of sap wells created by yellow bellied sapsuckers (*Sphyrapicus varius*). Basidiomycete fruiting bodies were noted on 4% of the trees. One declining sugar maple tree had visible *Biscogniauxia* cankers on a large live limb. Our tentative findings highlight the need to consider heat island effects for tree planting decisions to improve urban tree resilience in a warming climate. The next phase of the study will quantify the levels of nonstructural carbohydrates (NSC). We hypothesize that trees in warmer and heavily paved locations have lower NSC levels. We plan to continue monitoring these trees, to document mortality, and to estimate and quantify the impacts of abiotic and biotic stress on tree condition.

CLIMATE-BASED PREDICTIONS OF GEOGRAPHIC AREAS AT RISK FROM INVASIVE FOREST PATHOGENS

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ABSTRACT

Invasive forest pathogens are expected to have a greater impact on forest health under future climate-change scenarios as rapidly changing climates will likely alter the distribution of emerging pathogens and result in climatic maladaptation in trees and predispose trees to other disturbances (e.g., fire, insects, etc.). Two invasive forest pathogens, *Austropuccinia psidii* (cause of myrtle rust) and *Phellinus noxius* (cause of brown root rot disease) have been used to demonstrate bioclimatic prediction models (maps) of potential distribution under contemporary and/or projected future climates. Both invasive forest pathogens cause destructive disease on diverse tree species that are integral parts of forest ecosystems, economies, and native culture in tropical/subtropical regions. Contemporary and future prediction models were produced using Maximum Entropy (Maxent) algorithms that couple climatic data with 403 and 179 georeferenced and DNA sequence-confirmed occurrence locations for *A. psidii* and *P. noxius*, respectively. As an example, data were extrapolated from contemporary models through future climate scenarios (e.g., Year 2060 and Year 2100) to forecast geographics areas at risk for invasion by *A. psidii* subspecies (genetic groups) and *P. noxius* genetic groups under future climate-change scenarios. The utility of bioclimatic models (maps) to predict potential distribution under contemporary and/or project future climates was successfully demonstrated for genetic groups of *A. psidii* and *P. noxius*. Several genetic groups (e.g., "pandemic", "guava/Brazilian Guava", "eucalypt/rose apple" biotypes of *A. psidii* or "Eastern Asia", "Western Oceania/Japan/Taiwan" phylogenetic clades of *P. noxius*) were verified within both invasive species, and bioclimatic modeling showed that distinct genetic groups pose distinct invasive threats to distinct geographic areas, which must be recognized by regulatory agencies to limit damage from these invasive pathogens. For example, Hawaii possesses suitable climate space for the "eucalypt/rose apple" biotype from Brazil. In addition, native Hawaiian ohi'a (*Metrosideros polymorpha*) trees are very susceptible to "eucalypt/rose apple" biotype from Brazil based on inoculation tests. Therefore, it is highly likely that the *A. psidii* "eucalypt/rose apple" biotype from Brazil poses a major threat to native ohi'a trees in Hawaii, should this biotype ever be introduced. Determinations of genetic diversity and population structure of forest pathogens, in conjunction with assessments of their global distributions and suitable climate space, are essential for addressing threats of invasive pathogens and developing forest management approaches to mitigate damage from the associated forest diseases.

EVALUATING RESISTANCE OF LINGERING HEMLOCK GENOTYPES TO HEMLOCK WOOLLY ADELGID (*ADELGES TSUGAE*)

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ABSTRACT

Hemlock woolly adelgids (Adelges tsugae) are invasive insects that kill eastern and Carolina hemlocks, which are important to Appalachian ecosystems. However, some trees survive in stands where most hemlocks have died. These have been called 'lingering hemlocks' and may be resistant or tolerant of HWA feeding. Our goal is to propagate and evaluate lingering hemlocks to determine if they exhibit resistance that could contribute to reforestation efforts. To find out how different hemlock genotypes affect HWA abundance, survival, and fecundity, we propagated stem cuttings from 23 lingering hemlocks found in the southeast and infested them with HWA. We randomly selected four trees per genotype and collected two 4-centimeter-long branches from each tree over the sistens generation. In the lab, we counted live adelgids and eggs. There was large variation among genotypes, but some show greater resistance than others. We found that HWA density generally decreased from settled nymph to second stadia. In July, adelgid density ranged from 5 to 35 nymphs per 8-cm branches and 0 to 10 nymphs per 8-cm branches in October. We will continue monitoring the sistens into the progrediens generation on these trees and conduct manipulative experiments to evaluate resistance. We will also evaluate more genotypes including hybrids (eastern x Chinese). Ultimately, we would like to determine if resistant trees remain healthier than non-resistant trees and if tree resistance affects HWA biological control agents. Resistant trees have the potential to protect hemlocks from HWA feeding damage.

AN EFFECTIVE TRAP FOR SPOTTED LANTERNFLY EGG MASSES

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ABSTRACT

Spotted lanternfly (SLF) (*Lycorma delicatula* (White)), an invasive planthopper discovered in Pennsylvania, USA in 2014, continues to spread and is now present in 14 states with substantial infestations present in seven states. Population projections using adult SLF trapping or visual counts are not reliable due to the transient, migratory behavior of the adults which make population forecasts difficult. Another approach to population monitoring is utilization of the stationary egg mass stage but counting small cryptic egg masses throughout the canopy of large trees in dense woodlots is arduous and prone to error.

After several field seasons testing various trapping configurations and materials, we have identified an efficient, simple, low-cost trap termed a 'lamp shade trap' that is attached to the lower trunk area of an SLF host tree. SLF females readily enter the trap and lay eggs on the thin, flexible trap surface. A vertical trap orientation was superior, and the most productive woodlots yielded an average of 47 and 54 egg masses per trap, and several traps had over 100 egg masses.

There were 1,943 egg masses tallied from 105 traps placed at six locations in two states. Egg mass counts in the area above and below the traps and on nearby control trees yielded very few egg masses in comparison. Selection of trees 15 to 20 cm in diameter for trap placement is most efficient, yielding good egg mass abundance while minimizing the amount of trap material used.

The lamp shade trap has potential as an effective tool to identify SLF in new areas, gauge SLF population levels in woodlots and can also be used to collect and monitor egg masses for research purposes. Step-by-step instructions, pictures on LST construction and a materials list are available at: https://www.stopslf.org/stopslf/assets/File/LST-Construction-for-SLF-Egg-Masses.pdf. Source for the Journal article: https://doi.org/10.3389/finsc.2023.1154510.

Figure.—A plastic mesh trap wrapped around the trunk of an *Ailanthus altissima* tree. The trap is used to catch spotted lanternfly egg masses.

BIOLOGICAL CONTROL OF HEMLOCK WOOLLY ADELGID IN NORTH AMERICA: HISTORY, STATUS, AND OUTLOOK

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Abstract

The hemlock woolly adelgid (HWA, *Adelges tsugae*, Hemiptera: Adelgidae) is an invasive insect that threatens the ability to maintain eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*) as ecologically functional components of eastern North American forests. Since the early 1990s, a classical biological control program for HWA has been pursued using insect predators from regions of Asia and western North America where the adelgid is native. Early efforts to establish ladybird beetles (Coleoptera: Coccinellidae) resulted in the establishment of *Sasajiscymnus tsugae* from Japan, but consistently poor field recovery of this species suggests it has not been an effective biocontrol agent in the introduced range. Two additional ladybird beetles, *Scymnus ningshanensis,* and *S. sinuanodulus*, were released but did not establish. Subsequent introduction, widespread establishment and spread of *Laricobius nigrinus* and *La. osakensis* (Coleoptera: Derodontidae) has provided substantial predation on winter stages of HWA, but has not provided overall regulation of adelgid populations below levels that cause hemlock shoot growth loss and mortality. Recently, efforts have focused on prey-specific genetic lineages of *Leucotaraxis argenticollis* and *Le. piniperda* (Diptera: Chamaemyiidae), which co-occur with *La. nigrinus* in their native range of the Pacific Northwest and show promise for eventual establishment in eastern North America. This review provides a brief introduction on the ecology, evolution, and population dynamics of HWA and its hosts, detailed coverage of the predators that have been (and are being) evaluated as biological control agents, and a discussion of the overall biological program with considerations for its future implementation. The full paper is available in *Biological Control* 185 (2023) 105308.

DETECTION OF VOLATILE PHEROMONE CANDIDATES FROM CITRUS LONGHORNED BEETLE, *ANOPLOPHORA CHINENSIS*

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ABSTRACT

Citrus Longhorn Beetle (CLB), *Anoplophora chinensis* (Coleoptera: Cerambycidae) is a highly polyphagous species native to eastern and south-eastern Asia. With the increasing global trade and movement of plant materials, there is an imminent risk of CLB becoming established within Europe and North America. Once established in the USA, CLB could become a bigger agricultural problem than the closely related Asian longhorned beetle (ALB), *Anoplophora glabripennis*. Detection of these beetles is dependent on visual surveys which are inefficient and labor intensive. Identification and development of pheromone-based lures would help improve survey efforts for CLB should it become established within the US. We identified three antennally active male produced chemical components (nonanal, 4-(n-heptyloxy) butan-1-ol and 4-(n-heptyloxy) butanal) which were then tested for behavioral activity at our USDA Quarantine laboratory. When tested together in Y-tube behavioral assays a three-component blend of the identified compounds was shown to be attractive to adult female *A. chinensis*. Pheromone production and behavior of *A. chinensis* and other closely related *Anoplophora* cerambycid species is discussed in relation to mate finding and potential monitoring.

EASTERN HEMLOCK (*TSUGA CANADENSIS*) PHYSIOLOGICAL RESPONSES TO ELONGATE HEMLOCK SCALE (*FIORINIA EXTERNA*) INFESTATION

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ABSTRACT

Eastern hemlock (*Tsuga canadensis*), a major component of forests in eastern North America, is a foundation species where local biota thrive in hemlock-dominated ecosystems. The arrival of hemlock woolly adelgid (*Adelges tsugae*) in eastern North America has resulted in widespread decline. In addition, elongate hemlock scale (*Fiorinia externa*) is another invasive insect pest that is seeing significant population growth on native hemlocks. However debate remains as to whether it is a cause of concern for ongoing hemlock management programs. This project investigates if hemlock stress-induced responses are occurring at an individual branch level on chemically treated trees, with no hemlock woolly adelgid but populated with elongate hemlock scale. Objectives of this project were *i.*) determine if elongate hemlock scale infestation causes stress-induced responses of eastern hemlock at an individual branch level by measuring tree physiological properties, *ii.*) observe this interaction with respect to seasonality to determine if stress-induced responses are arising during a certain elongate hemlock scale developmental stage, and *iii.)* validate methodology by demonstrating that a workable window exists after branch detachment. Twenty eastern hemlock trees that met strict criteria, located in Tuscarora State Forest, were selected as the sample population. Two branches classified as elongate hemlock scale present and absent were selected from each tree. These were analyzed using a LiCOR 6400XT portable photosynthesis system to determine if any physiological differences existed. Sampled branches classified as elongate hemlock scale present and absent had no differences in net photosynthesis (P_{net}) or daytime dark respiration (R_{dark}) physiological variables in each sampling campaign. Having no observable difference between elongate hemlock scale present and absent branches may indicate that the densities observed in this study are not high enough to elicit hemlock stress-induced responses.

FREEZING SLUG SLIME FOR YEAR-ROUND HERBIVORE KAIROMONE STUDIES

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ABSTRACT

Kairomones are compounds emitted incidentally (i.e., not during the act of consuming a prey species) by a consumer that are detected by and benefit a prey species. The locomotion mucus produced during slug and snail movement is a kairomone that, when detected by seeds or seedlings, causes them to respond in ways that reduce their vulnerability to slug herbivory at the cost of rapid growth. We are conducting a series of studies exploring how the locomotion mucus of the invasive slug *Arion subfuscus* affects both seed germination and seedling development. Because slugs overwinter deep in the soil and grow slowly in the lab, however, it has been difficult to conduct year-round research on how *A. subfuscus* mucus affects plants.

In an effort to expand the temporal window for conducting lab-based kairomone studies, we assessed whether frozen-and-then-thawed slug mucus affected seeds in the same way as fresh slime. We allowed slugs to crawl on 1 gram of moistened sieved soil in a petri plate for one day, then removed the slugs and froze the mucus-covered soil. After forty days, we thawed the soil and exposed 20 seeds in a petri plate to it. The fresh-mucus treatment was identical except for using mucus-covered soil that had just been produced; the control treatment used mucus-free soil. Each of the three treatments was replicated 10 times for a total of 200 seeds per treatment. Average time to 50 percent germination for the 40-day experiment was 35.9 hours for the control, 32.9 hours for the fresh slime, and 32.9 hours for the frozen slime. Seeds treated with frozen and fresh slime germinated 8.3 percent faster than control seeds.

We repeated this experiment again after 75 days of freezing, with the modification that a lack of *A. subfuscus* prevented us from including a fresh-mucus treatment. Average time to 50 percent germination for the 75-day experiment was 30.8 hours for the control and 29.0 hours for the frozen slime. Seeds treated with frozen slime germinated 6.1 percent faster than control seeds. We plan on continuing this experiment at 30-day intervals until our results indicate that the frozen slime is no longer viable.

EFFECT OF DUSKY SLUG (*ARION SUBFUSCUS*) MUCUS ON BLACK MUSTARD (*BRASSICA NIGRA*)

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ABSTRACT

The invasive slug *Arion subfuscus*, a polyphagous herbivore that specializes in eating seeds and seedlings, can decimate new plant growth in forests. Slug mucus functions as a kairomone, a non-attack-related substance emitted by consumers that is detected by a prey species (in this case, plants). While snail mucus has been shown to induce defense in seedlings, it is unknown whether slugs have the same effect and whether seeds can also detect and react to such herbivore cues. We investigated how exposure to *A. subfuscus* mucus affected growth and defense in *Brassica nigra* seeds and seedling. Seeds exposed to slug mucus germinated 7 percent faster than control (water only) seeds, but the resulting seedlings weighed 15 percent less than control seedlings. To test whether this difference results from herbivore-exposed plants allocating energy from growth to defense, we conducted choice bioassays assessing slug preference for control seedlings versus seedlings that were either (A) exposed to mucus only as a seed; or (B) exposed to mucus as a seed and seedling. While slugs did not differentiate between control seedlings and ones exposed to herbivore cues only as a seed, they ate 82 percent less biomass of seedlings exposed to mucus as both seeds and seedlings. This difference likely reflects mucus-induced production of anti-herbivore defensive compounds; we are currently completing chemical assays to assess metabolite concentrations in the foliage of both control and mucus-exposed seedlings.

EVALUATING ESTABLISHMENT OF EMERALD ASH BORER LARVAL PARASITOIDS IN LINGERING ASH STANDS

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ABSTRACT

Emerald ash borer (EAB) has spread throughout most of the eastern U.S. and Canada. Soon after EAB invades an area, most overstory ash trees are killed. However, there is often a small percentage of larger trees that survive the initial EAB invasion. These trees are referred to as "lingering ash" and research has demonstrated that many of these individuals have some level of EAB resistance. However, many lingering ash trees eventually succumb to EAB attack, with survival times varying considerably among individuals and stands. Studies have demonstrated that the introduced EAB larval parasitoids, *Tetrastichus planipennisi* Yang (Hymenoptera: Eulophidae) and *Spathius galinae* Belokobylskij & Strazanac (Hymenoptera: Braconidae), can reduce EAB populations. However, for biological control agents to establish and persist, sufficient host densities are needed. Because EAB quickly reduces host resources in most invaded areas, forest stands that contain lingering ash often have low EAB densities relative to the initial invasion years. The objective of this study was to determine if introduced EAB parasitoids could establish and persist in post-EAB invaded areas with lingering ash, and thus help improve the survival rate of these trees. During 2022-2023, we conducted studies in three regions (i.e., central Michigan, northern Ohio, and central Ohio) that had been invaded by EAB between 2004-2010. In each region, we established three study sites that contained lingering ash. At each site, we monitored EAB abundance using purple panel traps and EAB larval parasitoid establishment using ash bolts containing sentinel EAB larvae [i.e., sentinel larval logs (SLLs)]. SLLs recovered at least one introduced EAB larval parasitoid species at each of the nine study sites and both species at five sites. Both parasitoid species were recovered at some sites that had no or few EAB adult captures and preliminary analyses found no significant relationship between parasitoid recoveries and EAB adult trap captures. We also compared parasitoid recoveries with EAB adult densities and distance from the nearest parasitoid release location. Although the distance between lingering ash stands and parasitoid release sites ranged from 0.1 to 36.6 km, preliminary analyses did not find a significant relationship with parasitoid recoveries and the distance to the nearest release location. SLLs recovered *T. planipennisi* as far as 36.6 km from the nearest release site (parasitoids first released at this site in 2020) and *S. galinae* as far as 19.3 km (parasitoids first released at this site in 2018). In summary, despite lower EAB densities in post-EAB invaded areas, EAB larval parasitoids dispersed several km from release sites and established in lingering ash stands.

DEVELOPING METHODS FOR FIELD DEPLOYABLE DETECTION OF CRYPTIC PATHOGENS IN TREE BREEDING PROGRAMS

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ABSTRACT

The development of populations of trees with resistance to insects and diseases is a priority to restore impacted species. Butternut (*Juglans cinerea*) is a native tree species threatened by butternut canker disease. Butternut hybridizes readily with Japanese walnut (*J. ailantifolia*), which was introduced to the US and is more resistant to butternut canker disease. However, Japanese walnut is more susceptible to another pathogen, '*Candidatus* Phytoplasma pruni,' the cause of walnut witches' broom. While not as pressing a concern as butternut canker disease, walnut witches' broom can be problematic for butternut restoration efforts. Infected trees can persist cryptically, so infected material can be unintentionally spread through activities such as grafting or establishing new plantings. Therefore, early identification of trees with walnut witches' broom can reduce the cost of planting asymptomatic diseased trees and needing to remove them after symptoms develop, thus preventing the spread of the disease to new areas. This study aimed to develop techniques for rapid and low-cost detection of walnut witches' broom in tree nurseries. To accomplish this, we evaluated molecular and spectral methods for disease detection in grafted butternut and hybrid butternut trees. Of the 88 samples tested, only four tested positive for '*Ca.* Phytoplasma pruni' using a nested phytoplasma-specific PCR. Since nested PCR often requires additional validation with sequencing, we developed primers and probes and are currently assessing whether recombinase polymerase amplification (RPA) can detect walnut witches' broom diseased trees. In addition, we are evaluating whether spectral profiling, using a handheld near-infrared spectrometer, can identify trees that test positive for walnut witches' broom. Further development of these techniques may lead to more rapid, low-cost, in-field disease diagnosis options.

EFFICACY OF INSECTICIDES FOR HEMLOCK WOOLLY ADELGID MANAGEMENT ON EASTERN HEMLOCK

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ABSTRACT

Hemlock Woolly Adelgid (*Adelges tsugae* Annand, or HWA) and Elongate Hemlock Scale (*Fiorinia externa* Ferris, or EHS) are invasive pests that have been devastating to hemlock populations throughout the eastern United States. Systemic insecticides including imidacloprid and dinotefuran are used to manage HWA and EHS. However, these neonicotinoids can be toxic to predators and may interfere with biological control. There is also limited research on the efficacy of non-neonicotinoid insecticides for HWA and EHS management due to the lack of feasibility of contact insecticides on adult hemlock trees. This has left hemlock nurseries and growers with few non-neonicotinoid insecticide options. Our goal was to test the efficacy of non-neonicotinoid insecticides that may be more compatible with biological control of HWA and EHS.

Eastern hemlock trees (3-6’ tall) were infested in June 2023 with sistens HWA nymphs. We had eight insecticide treatments and an untreated control treatment. Each treatment was replicated 10 times for a total of 90 trees. We conducted a precount of HWA nymphs on October 8, 2023 by taking six 15 cm cuttings per tree. Insecticides were applied on the same day after the precount samples were collected. We tested imidacloprid since it is a standard neonicotinoid insecticide used for HWA management. Imidacloprid was used in two treatments, it was applied as a foliar spray in one treatment and a soil drench in the other. The other six insecticide treatments, pyriproxyfen, azadirachtin, pyrethrins, cyantraniliprole, cyclaniliprole, and mineral oil, were applied as a foliar spray with a pneumatic sprayer. All insecticides were applied at 2-times the maximum label rate. Cuttings were taken the same way as the precount 1 day after treatment (DAT), 54 DAT, and 141 DAT. Only live HWA and EHS at the time of cutting were counted. Mean HWA and EHS density were analyzed using ANOVA followed by LSD means separation.

We found that foliar applied imidacloprid, pyriproxyfen, pyrethrins, cyantraniliprole, cyclaniliprole, and mineral oil all significantly reduced HWA density at 1 DAT, 54 DAT, and 141 DAT. We did not see a difference in HWA density from drench applied imidacloprid 1 DAT, but saw differences at 54 DAT and 141 DAT. Drench applied imidacloprid and azadirachtin reduced HWA density, but not significantly at any of the time points. We saw a reduction in EHS density in all treatments 1 DAT, with pyrethrins, cyantraniliprole, cyclaniliprole, and mineral oil showing the most significant differences. 54 DAT we did not see any differences in the treatments except for mineral oil where a much higher EHS density was observed. 141 DAT we saw reduction in EHS density from imidacloprid, azadirachtin, pyrethrins, cyantraniliprole, cyclaniliprole, and mineral oil, with the most significant difference being the mineral oil. Future experiments will further explore non-neonicotinoid insecticide efficacy on HWA and EHS and effects on non-target arthropod predators.

CANOPY: DETECTING FOREST DISTURBANCES AND INVASIVE INSECTS FROM LANDSAT PHENOLOGY

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ABSTRACT

Invasive insects and pathogens cause significant ecological and economic damage to the Nation's forests, but it is often highly uncertain where and when effects will occur. Traditional methods for monitoring disturbances and their causal agents by ground and aerial surveys are applied unevenly across land ownerships and jurisdictions. Important invasive establishments and impacts are often missed, leaving large forest areas vulnerable to ecological and economic damage. New and more automated approaches, especially remote sensing methods to cover large forest areas, are needed for detecting and monitoring of invasive forest insect and pathogens and their expansion into susceptible locations where they have not been detected previously. Disturbance impacts by forest insects and pathogens are often far more subtle relative to stand-replacing disturbances (e.g., logging, fire, windthrow) that are easier to map remotely. We are developing a prototype analytical procedure in Python (short name: Cano.py) that uses remotely sensed data on canopy conditions coupled with disturbance and forest composition to create map-based products suitable for USFS, state, and local agencies for locating, classifying, and describing disturbances, including invasive species, in Northeastern (Region 9) U.S. forests. Our computational framework integrates weather observations with moderate-resolution satellite images (USGS/NASA Landsat, ESA Sentinel-2) to determine local patterns of forest phenology including seasonal foliar characteristics. Departures from these historical patterns are then identified and combined with USFS and partner datasets to determine the locations, severity, and likely causes of disturbance events. The model is informed by (1) an ongoing synthesis of insect and disease agents of historical forest disturbance in Region 9 from the perspective of remote sensing; (2) a field validation campaign that adapts more traditional forest health monitoring (FHM) methods to be optimized for remote sensing investigations; (3) forest composition maps developed by FIA; and (4) plot-level forest health condition data collected by FIA. We have developed workflows for computational components of the model using Google Earth Engine and developed and run a phenological model for the Landsat image record over ~1000 sq. km of northern Wisconsin from 1984-2022. Field surveys were conducted in the same region using forest health monitoring methods adapted to support the attribution of identified disturbance agents. In summer 2023, we captured 134 survey points across northern Wisconsin covering 8 disturbance-causing insect species (3 invasive) and one invasive disease. Future research will include refining and expanding the Cano.py algorithms and workflow to finalize the model operation; determining the extent to which BIGMAP and monitoring data from FIA can improve the quality, accuracy, and sensitivity of the Cano.py method for forest disturbance detection and attribution; and expanding ground-based field surveys and model computations to cover a larger area including the Laurentian Mixed Forests of the Upper Great Lakes (i.e., USFS EP 212 in northern Michigan, Minnesota, and Wisconsin).

PHYLOGENOMICS OF *AGRILUS* WOOD-BORING BEETLES

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ABSTRACT

The genus *Agrilus* Curtis 1825 contains over 3,600 species and subspecies of mostly wood-boring beetles, including numerous introduced pests. Most notably, *Agrilus planipennis* Fairmaire, 1888 (Emerald Ash Borer, EAB) has caused billions of dollars in damage since its unintentional introduction into the United States in 2002. Most of the current taxonomy of this large genus is based upon morphological studies, and there is no comprehensive molecular framework to investigate the evolution of host plant use, or for comparative studies of pestiferous species. Besides the sheer overwhelming number of species of *Agrilus*, another factor that has hindered molecular phylogenetic inferences in this group is that many species are not particularly abundant in their native habitats, and therefore amassing a global taxon sampling of ethanol-preserved specimens is difficult. Also, comprehensive taxonomic treatments are lacking, and therefore identification of species is very difficult. In this talk, we present our efforts to generate a phylogeneomic framework for the study of *Agrilus* using a museomic approach to overcome some of these hurdles. Our taxon sampling, consisting approximately of the global diversity, was largely derived from expertly identified material in the Eduard Jendek collection of *Agrilus*, which was recently acquired by the National Museum of Natural History, Smithsonian Institution. We use a shotgun sequencing approach to generate molecular data for both high-copy regions such as mitochondrial and ribosomal markers, and explore recovery of markers used in target-capture studies in other groups of beetles. We discuss the utility of this approach for not only phylogenetic inference in large and complex groups like *Agrilus*, but also for development of diagnostic tools to help aid in identification of pest species.

EMERALD ASH BORER (EAB) *AGRILUS PLANIPENNIS* MAINTAINING ASH IN THE LANDSCAPE

Ron Weeks and Russ Bulluck

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Abstract

Emerald ash borer (EAB), *Agrilus planipennis* is a buprestid native to Asia that most likely came to the United States inside wood packaging material. The beetle attacks ash trees and its larvae feed on the living tissue that carries nutrients. This feeding damage will eventually kill the tree. EAB was first found in 2002 in southeastern Michigan and adjacent areas in Windsor, Ontario, Canada. Infestations have been found in 36 states and the District of Columbia. USDA's Animal and Plant Health Inspection Service (APHIS) works with partners to combat EAB with the shared goal of maintaining ash as a viable part of the American landscape. Current strategies include using biological control and conducting ongoing research. Using EAB's natural enemies—tiny stingless wasps—biological control aims to control the pest by introducing its natural predator. Four known stingless wasps will attack EAB larva or eggs: *Spathius agrili*, *Spathius galinae*, *Tetrastichus planipennisi*, and *Oobius agrili*. The largest wasp is about the size of a typical mosquito. Each year, the program estimates wasp production to determine the number of release sites. Then release sites are selected based on program criteria and priorities. Wasps are shipped to partners in the spring through the early fall and they are released in the preapproved areas. In 2023, the program and its biological control partners released parasitoids in 35 new counties. Bringing the program's total number of releases to 453 counties in 32 states, the District of Columbia, and Canada. To date, parasitoids have been recovered in 23 states and in 2 Canadian provinces. The wasps are already showing promise in several states, especially in terms of protecting young saplings from EAB. The most recent study that was conducted in Michigan and several northeastern states showed that the wasps are killing 20-80% of EAB in ash trees up to eight inches in diameter. The study documented that more EAB are being attacked by the wasps which is resulting in less EAB attacking ash trees, and that ash trees are regenerating in these areas because wasps are being released. APHIS wants to expand the distribution and increase the number of wasps released in infested states to help stabilize and eventually reduce EAB populations.

MOLECULAR IDENTIFICATION AND DIAGNOSTIC ASSAY OF A NATIVE PARASITOID OF THE SPOTTED LANTERNFLY

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Abstract

Tremendous management effort, including classical biological control, has been made to control the spotted lanternfly (SLF), *Lycorma delicatula* (White). There has been reports and sight of native North American parasitoid wasps attacking the invasive SLF eggs. Therefore, it is necessary to identify those native parasitoids and evaluate their impacts, which may augment the ongoing biological control effort to suppress SLF populations. We aimed to use DNA-barcoding to detect and identify native parasitoids from SLF eggs with wasp exit holes and design a multiplex qPCR assay to detect the most abundant native parasitoid species. We successfully obtained DNA sequence data from 73 of the 164 empty SLF eggs with parasitoid exit holes. Although some eggs were dominated by DNA from fungi, algae, and other invertebrates, host DNA from SLF were recovered from 30 eggs. More importantly, we obtained parasitoid DNA from 21 eggs, and 13 of which were identified as a species that belongs to the genus *Anastatus* (Hymenoptera: Eupelmidae). Additionally, those DNA matched with adult wasps emerged from SLF egg masses that were collected from Pennsylvania and maintained in laboratory. Through genetic comparison to voucher specimens of the *A. reduvii* colony from North Carolina State Extension, we identified the native *Anastatus* recovered from SLF eggs as *A. reduvii*, which has already been used for biological control of the brown marmorated stink bug. As a result, we developed a specie-specific qPCR assay to amplify *A. reduvii* mitochondrial COI sequence and then combined that with a universal 28S qPCR assay serving as an internal control for DNA extraction success. The multiplex qPCR assay was assessed for its amplification efficiency and linearity. Our study provided a broader picture of native egg parasitoid wasps attacking SLF and also a tool for continuous monitoring any increase of the attack rate by those native parasitoids, especially when SLF become a very abundant host.

PRELIMINARY STUDIES ON THE USE OF HEAT TREATMENTS TO KILL THE EGGS OF TWO INVASIVE FOREST PESTS, SPOTTED LANTERNFLY, *LYCORMA DELICATULA* (WHITE), AND SPONGY MOTH *LYMANTRIA DISPAR L*.

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ABSTRACT

The spotted lanternfly (SLF), *Lycorma delicatula* (White), and the spongy moth (SM), *Lymantria dispar* L., are two pests introduced into the eastern United States that have spread along human transportation corridors by ovipositing on vehicles and cargo. In this study, we investigated the impact of heat treatments (35 to 70°C for durations of 15 to 120 minutes) on SLF and SM egg masses to determine if heat can effectively kill the eggs. The SLF egg masses were collected from multiple sites in October and November 2022. The SM egg masses were obtained from laboratory colonies of European and Asian spongy moths. All egg masses were held in an alternating temperature regime that mimicked the climate of Scranton, PA before undergoing heat treatments in an isothermal chamber. After treatment in March, they were held in to a growth chamber at 25°C and 60 percent RH for hatch. SLF eggs exposed to 45°C for 120 minutes or 50°C for any duration showed significantly reduced hatch compared to the control and no eggs hatched at temperatures ≥ 55°C. For SM, over 90 percentof egg masses hatched at temperatures below 50°C. However, at 50°C, the percentage of eggs that hatched decreased by roughly 30 percentand 70 percent in the 15- and 30-minute treatments, respectively. Only a few eggs hatched at 55°C when subjected to 15 minutes of heat, and no eggs hatched when subjected to temperatures >55°C. These results suggest that the temperatures required to kill the eggs of SLF and SM are comparable to the heat treatments specified in ISPM 15 for killing wood-boring insects in solid wood packaging material.

NEW AND NOTABLE ADELGIDS FROM BHUTAN

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ABSTRACT

Prior to 2020, there was little existing information on adelgids in Bhutan. This changed in 2020-2021 when a country-wide survey was conducted in response to adelgid damage on *Picea spinulosa* at a conifer nursery. Sampling from this survey allowed us to sequence DNA from specimens for identification and phylogenetic analyses. We identified four new species with two of the species being particularly interesting. The first new species, *Adelges* n. sp. A., is the first known legless species in Aphidomorpha. The second new species, *Adelges* n. sp. B., shares many of the same characteristics as *A. tsugae*, however it differs in that the 1st instar exulis has round/oval wax glands proximal to the lateral row of facets on the head. In addition to the new species, a new subgenus was also described, and a new lineage of *A. tsugae* was found in Bhutan. In conjunction with this research, we are also working to update previous scientific illustrations for Adelgids. In our poster we provided new scientific illustrations for both first instar *Adelges* (*Annandina*) *tsugae* Annand, Bhutanese lineage, and Adult *Ad.* (*An.*) *tsugae*, Japanese *Tsuga sieboldii* lineage to use as diagrams of adelgid morphology.

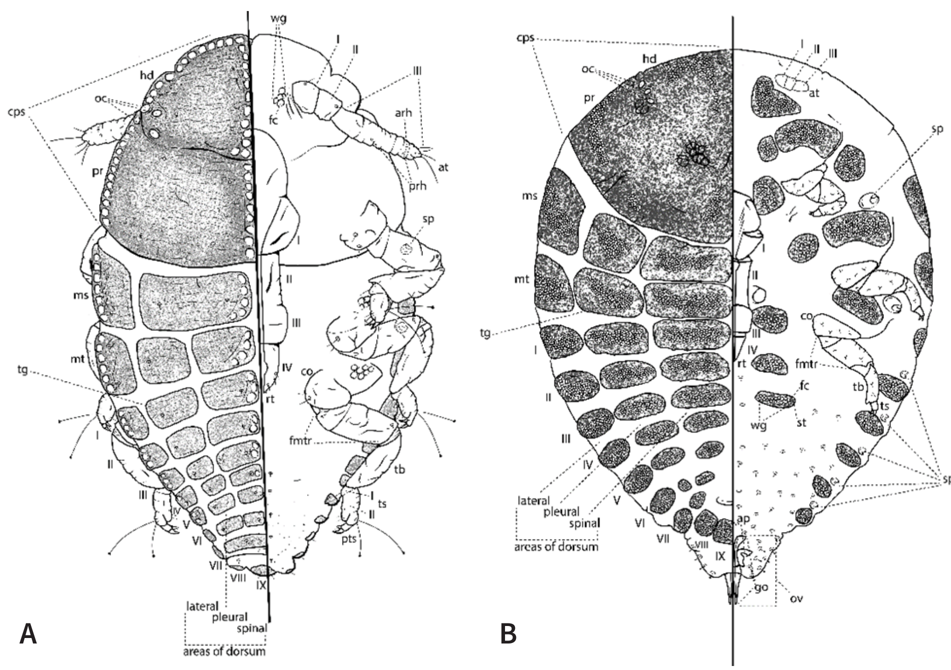

Figure A and B.—Diagrams of adelgid morphology. A. First instar [Adelges (Annandina) tsugae Annand, Bhutanese lineage]. B. Adult [Ad. (An.) tsugae, Japanese lineage]. Abbreviations: ap, apodemes; arh, accessory rhinaria; at, antenna; co, coxa; cps, cephaloprothoracic shield; fc, wax gland facet; fmtr, femorotrochanter; go, gonapophyses; hd, head; ms, mesothorax; mt, metathorax; oc, ocelli; ov, ovipositor; prh, primary rhinaria; pr, prothorax; pts, pretarsus, rt, rostrum; sp, spiracle; st, sternite (= ventral sclerite); tb, tibia; tg, tergite (= dorsal sclerite); ts, tarsus; wg, wax gland.

INVASION TRAJECTORY OF WAVYLEAF BASKETGRASS (*OPLISMENUS UNDULATIFOLIUS*), AN EMERGING THREAT TO US MID- ATLANTIC FORESTS

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ABSTRACT

First detected in the US near Baltimore, Maryland in 1996, wavyleaf basketgrass (*Oplismenus undulatifolius* (Ard.) Roem. & Schult.) is recognized as a USDA high-risk invasive species. This shade-tolerant, aggressively sprawling perennial grass is well-adapted to the forest understory. Once established, wavyleaf basketgrass forms dense patches through vigorous stolon growth, crowding out native herbaceous species and potentially impacting tree seedling regeneration. New vegetative growth emerges through leaf litter from these stolons early in the spring, giving wavyleaf basketgrass a growth advantage over other native species. By the end of the first year, plants can produce seeds that increase local patch density, as well as disperse to new locations. These seeds are elevated on 0.5m-tall inflorescences and have extremely sticky awns that easily attach to clothing, fur, or nearly anything that passes through an infested area.

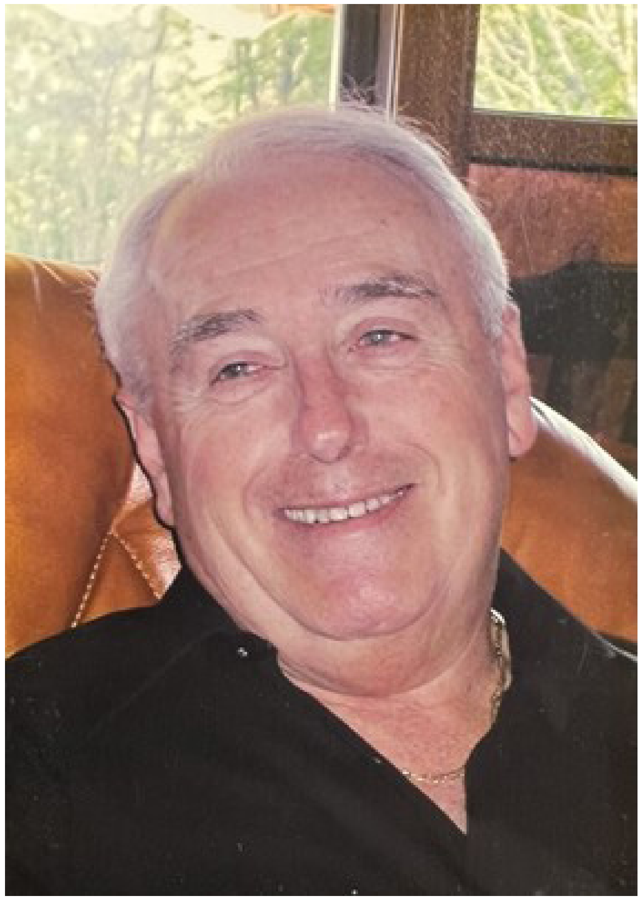
Wavyleaf basketgrass has extensively spread across Maryland, throughout Virginia since first detected near Shenandoah National Park in 2005, and is expanding to the north and west, with patches detected in Pennsylvania, West Virginia, Delaware, and Washington DC in the last five years. Much of this spread appears linked to recreational activities (e.g., along the Appalachian Trail, hiking routes, and within local parks, disc golf courses, and campgrounds). Importantly, wavyleaf basketgrass appears able to establish deeper into the forest understory than other regionally invasive grasses such as *Microstegium vimineum* (stiltgrass) and may be restricted to these shady habitats that are characteristic of congeneric species. However, little is known about the influence light has on wavyleaf basketgrass invasion success, or at what life-stage photoinhibition may affect its establishment.

To better inform early-stage invasive management, we examined the seed longevity and germination of wavyleaf basketgrass under several light intensities using seeds sourced from the original introduction site across multiple collection years (Pham and Wu 2023). Seed viability remained high for 7 years, and seeds could successfully germinate after 9 years. Further, we found no impact of light intensity on germination, suggesting that wavyleaf basketgrass may be able to successfully establish in much brighter field conditions than deep forest understories typical of where is has been detected in the US mid-Atlantic region. This confirms the importance of early-stage monitoring and management before a persistent seedbank is established, as eradication becomes increasingly difficult when population regeneration is possible from seeds as well as vegetative propagules. Additionally, surveillance for new wavyleaf basketgrass seedlings may need to be expanded beyond deep-shade areas, as seeds that disperse to areas experiencing high light may still successfully germinate. We encourage natural resource managers to continue long-term monitoring efforts for wavyleaf basketgrass even after complete aboveground removal of vegetation, to detect and treat possible subsequent seedlings.

Literature Cited

Pham, D.H.; Wu, C.A. 2023. **Seed longevity and germination of the emerging invasive species wavyleaf basketgrass (*Oplismenus undulatifolius*) under varied light regimes.** Invasive Plant Science and Management. 16(4): 225-232. https://doi.org/10.1017/inp.2023.27.

IN MEMORIAM



Michael "Mike" L. McManus
1937-2023

Michael Lawrence McManus, Ph.D., 85, beloved and devoted husband of Katherine (D'Antonio) McManus, passed away on November 16, 2023.

Born in Chicago, IL, December 8, 1937, he was son of the late Lawrence P. and Mary (Selle) McManus.

Mike was a research scientist with the USDA Forest Service in Hamden, CT, for his entire career, which began in 1966 after earning his Ph.D. in Forest Entomology from Purdue University. He retired in 2010 after 41 years of service and was an active emeritus scientist up to the time of his death.

In addition to his wife, Katherine, Mike is survived by his son Brian McManus, step-son Nick DeCapua and his fiancée Shawn Dapp, his cherished grandson, Eli DeCapua, and special grandchildren Allison and Connor Dapp. Predeceased by his son, M. Patrick McManus. Mike leaves many dear friends and colleagues both here and around the world. He will be remembered as a loving, caring, kind and insightful man. 'You colored my world.'

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FORUM AGENDA

Tuesday Afternoon, January 9, 2024
Poster Session – Carrick (Powerhouse, First Floor)
3:00 – 6:00 p.m.

Wednesday Morning, January 10, 2024
Opening Session – Ballroom
8:15 a.m. – 10:00 a.m.

Moderator:
Scott Pfister, USDA APHIS, Buzzards Bay, MA

Time	Session
8:15 a.m.	Welcome – Therese Poland, USDA Forest Service, Northern Research Station, East Lansing, MI
	Mike McManus Memorial Keynote Presentations
8:30 a.m.	Evolution drives faster and bigger invasions. Ruth Hufbauer, Colorado State University, Fort Collins, CO
9:15 a.m.	Making invasion science more global, inclusive, and better. Martin Nuñez, University of Houston, Houston, TX
10:00 – 10:30 a.m.	BREAK

Research Reports
10:30 a.m. – 12:00 p.m.

Moderator:
Andreas Linde, University for Sustainable Development, Eberswalde, Germany

Time	Session
10:30 a.m.	Evaluating and prioritizing exotic plant pest threats. David Bednar, USDA APHIS PPQ,Durham, NC
10:50 a.m.	Balsam woolly adelgid invasion of northern Utah: phenology trends. Barbara Bentz, USDA Forest Service, Rocky Mountain Research Station, Logan, UT
11:10 a.m.	From *Adelges* to *Zeugophora*: predicting the next high- impact insect invaders in North American forests using i- Tree Pest Predictor. Ashley Schulz, Mississippi State University, Starkville, MS
11:30 a.m.	*Erythmelus klopomor* (Hymenptea: Mymaridae) – a promising egg parasitoid for classical biocontrol of the invasive oak lace bug (*Corythucha arcuata*) in Europe. Marton Paulin, University of Sopron Forest Research Institute, Hungary
11:50 – 1:00 p.m.	LUNCH

FORUM AGENDA CONTINUED

Wednesday Afternoon, January 10, 2024
Invasive Pathogens
1:00 – 2:40 p.m.

Moderators:
Caterina Villari, University of Georgia, Athens, GA
Enrico Bonello, The Ohio State University, Columbus, OH

Time	Session
1:00 p.m.	Vascular streak dieback - An emerging threat to redbud nursery production in the southeastern United States. Fulya Baysal- Gurel, Tennessee State University, Nashville, TN
1:20 p.m.	Cellular insights of beech leaf disease. Paulo Vieira, USDA ARS, Beltsville, MD
1:40 p.m.	Modern diagnostic approaches for surveillance of invasive pathogens. Caterina Villari, University of Georgia, Athens, GA
2:00 p.m.	North American forests are enriched with nonindigenous plant pathogens from phylogeographically similar regions of origin. Geoffrey Williams, USDA Forest Service, International Programs, Lansing, MI
2:20 p.m.	AI for healthful forests: Are we there yet? Christopher Stewart, The Ohio State University, Columbus, OH
2:40 – 3:10 p.m.	BREAK

Wednesday Afternoon, January 10, 2024
Breeding Resistance to Invasive Pests
3:10 – 4:50 p.m.

Moderators:
Jennifer Koch, USDA Forest Service, Delaware, OH
Richard Sniezko, USDA Forest Service, Eugene, Oregon

Time	Session
3:10 p.m.	Progress and forward momentum of the ʻŌhiʻa disease resistance program in Hawaii. Marc Hughes, USDA Forest Service, Institute of Pacific Island Forestry, Hilo, HI
3:30 p.m.	Forest tree resistance breeding success stories in the Pacific Northwest. Richard Sniezko, USDA Forest Service, Dorena Genetic Resource Center, Eugene, OR
3:50 p.m.	American elm restoration: an ecological case for disease resistance breeding. Leila Pinchot, USDA Forest Service, Northern Research Station, Delaware, OH
4:10 p.m.	Genomics and tree breeding: separating hype from reality. Jennifer Koch, USDA Forest Service, Northern Research Station, Delaware, OH. Glenn Howe, Oregon State University, Corvallis, OR
4:30 p.m.	Overview of the Forest Service Resistance Screening Workshop. Carrie Pike, USDA Forest Service, State, Private and Tribal Forestry, West Lafayette, IN

FORUM AGENDA CONTINUED

Wednesday Evening, January 10, 2024
Poster Session – Carrick (Powerhouse, 1ST FLOOR)
5:00 – 6:00 p.m.

Wednesday Evening, January 10, 2024
Mike McManus Tribute Presentation – Ballroom.
6:00 – 6:30 p.m.

Andreas Linde, University for Sustainable Development, Eberswalde, Germany
Andrew Liebhold, USDA Forest Service, Morgantown, WV

Wednesday Evening, January 10, 2024
MIXER – ATRIUM
6:30 – 8:00 PM

Thursday Morning, January 11, 2024
Invasive Coleoptera
8:00–10:00 a.m.

Moderators:
Joe Francese, USDA APHIS, Buzzards Bay, MA

Time	Session
8:00 a.m.	Drop- and- leave: implementing alternative management strategies for Asian longhorned beetle eradication. Courtney Johnson, North Carolina State University, Raleigh, NC
8:20 a.m.	Emerald ash borer: impacts, population dynamics, and how to leverage insecticide protection for ash genetic conservation. Kathleen Knight, USDA Forest Service, Northern Research Station, Delaware, OH
8:40 a.m.	Sentinel gardens, invasive woodborers, and artificial intelligence. Jiri Hulcr, University of Florida, Gainesville, FL
9:00 a.m.	Dispersal of pioneering mountain pine beetles from active infestations: implications to range expansion for this domestic invasive. Brian Aukema, University of Minnesota, St. Paul, MN
9:20 a.m.	Looking forward: The impacts of Asian longhorned beetle on forests in southeastern New England. Olivia Box, USDA Forest Service, Ogden, UT
9:40 a.m.	An international collaborative project to develop and assess surveillance methodologies for Agrilus beetles (Euphresco project 2020- A- 337). Dave Williams, Forest Research, Farnham, UK
10:00–10:30 a.m.	BREAK

FORUM AGENDA CONTINUED

Thursday Morning, January 11, 2024
Invasive Coleoptera
10:30 –11:50 a.m.

Moderator:
Talbot Trotter, USDA Forest Service, Hamden, CT
Jian Duan, USDA ARS, Newark, DE

Time	Session
10:30 a.m.	Drones, machine learning, and natural enemies for forest pest detection and management. Yong- Lak Park, West Viginia University, Morgantown, WV
10:50 a.m.	Evaluation of the impact of emerald ash borer and its management on North American ash survival and recovery: How can AI-learning help the endeavor? George Ni, University of Vermont, Burlington, VT
11:10 a.m.	Nuisance pest or emerging threat: What is known about the Asian needle ant? Emilee Poole, USDA Forest Service, Southern Research Station, Athens, GA
11:30 a.m.	An assessment of integrated forest pest management in the U.S. with a focus on invasive species. Tom Coleman, USDA Forest Service, Forest Health Protection,Asheville, NC
12:00 – 1:00 p.m.	LUNCH

Thursday Afternoon, January 11, 2024
Invasive weeds
1:00 – 3:00 p.m.

Moderator:
Cynthia Huebner, USDA Forest Service, Morgantown, WV

Time	Session
1:00 p.m.	An overview of invasive grasses: the importance of genotypes, traits, and the ability to adapt to novel environments and species. Cynthia Huebner, USDA Forest Service, Northern Research Station, Morgantown, WV
1:20 p.m.	The importance of natural history collections in invasion biology: evolution and ecology in the invasive *Miscrostegium vimineum*. Craig Barrett, West Virginia University, Morgantown, WV
1:40 p.m.	Hybrids between the invasive wild- type and horticultural variety (v. *Rubra*) of cogongrass (*Imperata cylindrica*) differentially respond to cold. Rima Lucardi, USDA Forest Service, Southern Research Station, Athens, GA
2:00 p.m.	Invasion trajectory of wavyleaf basketgrass (*Oplismenus undulatifolius*), an emerging threat to US mid- Atlantic forests. Carrie Wu, University of Richmond, Richmond, VA
2:20 p.m.	Unraveling the complexity of palatable African grass invasions for effective mitigation: from microbes to landscapes. Aaron Rhodes, University of Texas, AustinTX
2:40 p.m.	Developing an adaptive management framework for restoring native plant communities in the coastal marsh ecosystems of the St. Mary's River. Eric Clark, Sault Ste Marie Tribe of Chippewa Indians, Sault Ste. Marie, MI
3:00 – 3:30 p.m.	BREAK

FORUM AGENDA CONTINUED

Thursday Afternoon, January 11, 2024
Ecology of Invasive Pest Management
3:30 – 5:10 p.m.

Moderator:
Jess Hartshorn, Clemson University, Clemson, SC

Time	Session
3:30 p.m.	Invasion dynamics of the faucet snail and its trematode parasites across North America. Jennifer Koop, Northern Illinois University, DeKalb, IL
3:50 p.m.	Asian longhorned beetle in South Carolina: research successes and questions. David Coyle, Clemson University, Clemson, SC
4:10 p.m.	Assessing the potential for biotic homogenization by generalist pollinators. Harper McMinn- Sauder, Clemson University, Clemson, SC
4:30 p.m.	Emerald ash borer host range expansion and natural enemy responses: implications for biocontrol. Heather Callahan, University of Delaware, Newark, DE
4:50 p.m.	Moths, myths, and Maine: understanding browntail moth and their outbreaks. Angela Mech, University of Maine, Orono, ME

Friday Morning, January 12, 2024
Research Reports
8:00 a.m. – 11:00 a.m.

Moderator:
Andrew Liebhold, USDA Forest Service, Morgantown, WV

Time	Session
8:00 a.m.	DNA barcoding and phylogenetic studies of the chestnut gallwasp, Dryocosmus kuriphilus Yasumatsu (Hymenoptera: Cynipidae: Cynipini) in the Eastern United States. Matt Buffington, USDA ARS, Washington, DC
8:20 a.m.	Global analyses suggest that bridgeheads play critical roles in invasions by bark and ambrosia beetles. Sam Ward, The Ohio State University, Columbus, OH
8:40 a.m.	Phosphonate soil treatments improve tree health and suppress foliar nematode populations in American beech with beech leaf disease. Daniel Herms, The Davey Tree Expert Company, Kent, OH
9:00 a.m.	Historical patterns of disharmony in global insect invasions. Richard Mally, Czech University of Life Sciences, Prague, Czech Republic
9:20 a.m.	Asymmetry in Species Invasions: a comparison between Eastern North America and Europe. Maartje Klapwijk, Swedish University of Agricultural Sciences, Uppsala, Sweden
9:40 - 10:00 a.m.	BREAK
10:00 a.m.	*Leptoglossus* leaf- footed bugs as globally important invasive species: biological and behavioral control prospects to protect forests. Don Weber, USDA ARS, Beltsville,MD
10:20 a.m.	Advancing invasive species prevention: a horizon scanning approach. Deah Lieurance, Penn State University, University Park, PA
10:40 a.m.	Impacts of spotted lanternfly on common hardwood trees. Kelli Hoover, Penn State University, University Park, PA
11:00 a.m.	Concluding Remarks. Nathan Havill, USDA Forest Service, Northern Research Station, Hamden, CT

POSTER AND ORAL ABSTRACTS

Poster Abstracts	Title	Author
1	HAPLOTYPES AND LIFE HISTORIES OF ANASTATUS ORIENTALIS, EGG PARASITOID OF SPOTTED LANTERNFLY IN CHINA	Ke-Xin Bao
2	THEY'RE HERE! INTRODUCED PARASITOIDS OF EMERALD ASH BORER ARE ESTABLISHED IN TENNESSEE	David B. Bechtel
3	EMERGING WILT OF SASSAFRAS AND SPICEBUSH IN THE CENTRAL HARDWOOD FOREST REGION	Olivia Bigham
4	UPDATES ON INTEGRATING BIOCONTROL AND INSECTICIDE TREATMENTS IN BLACK AND GREEN ASH FORESTS	Theresa C. Booth
5	RHODODENDRON LEAF BAITING OF COASTAL CALIFORNIA WATERSHEDS FOR PHYTOPHTHORA AND NOTHOPHYTOPHTHORA	Tyler B. Bourret
6	LOOKING FORWARD: THE IMPACTS OF ASIAN LONGHORNED BEETLE ON FORESTS IN SOUTHEASTERN NEW ENGLAND	Olivia Box
7	ASIAN LONGHORNED BEETLE (ALB) ANOPLOPHORA GLABRIPENNIS ERADICATION PROGRAM	Kathryn Bronsky
8	SAVING EARTH'S FORESTS – WORKING TOGETHERTO PREVENT INTRODUCTION AND SPREAD OF NEW DISEASES"	Fatih T. Campbell
9	EXPLORATION FOR NEW NATURAL ENEMIES OF THE ASIAN LONGHORNED BEETLE (COLEOPTERA: CERAMBYCIDAE) IN CHINA USING SENTINEL LOGS	Liang-Ming Cao
10	SPOTTED LANTERNFLY (LYCORMA DELICATULA) EGG PHENOLOGY IN COASTAL CONNECTICUT	Jennifer L. Chandler
11	ADELGID POPULATION DYNAMICS MODEL 2.0: WORKING TOWARDS A DYNAMIC RESEARCH-DRIVEN SYNTHESIS MODEL	Jennifer L. Chandler
12	COMPARATIVE RESPONSES OF TWO CONGENERIC LARVAL PARASITOIDS OF EMERALD ASH BORER TO AMBIENT TEMPERATURES: IMPLICATIONS FOR BIOCONTROL INTRODUCTION	Ying-Qiao Dang
13	PARASITOID-INDUCED CHANGES IN METABOLIC RATE AND FEEDING ACTIVITY OF THE EMERALD ASH BORER (COLEOPTERA: BUPRESTIDAE): IMPLICATIONS FOR BIOLOGICAL CONTROL	Ying-Qiao Dang
14	ELM PHYTOPLASMAS: IDENTIFICATION & PATHOGENICITY	Charles E. Flower
15	OVERWINTERING PHENOLOGY OF TWO INTRODUCED SPATHIUS SPECIES ACROSS THE INVASION RANGE OF EMERALD ASH BORER	Mitchell A. Green
16	CAN WE PREDICT SHIFTS IN ECTOMYCORRHIZAL COMMUNITIES IN BEECH TREES INFECTED WITH BEECH LEAF DISEASE?	Elena Karlsen-Ayala
17	WHAT WOULD SPOTTED LANTERNFLY (LYCORMA DELICATULA) LIFE HISTORY LOOK LIKE IF IT ESTABLISHED IN STOCKTON, CA?	Melody A. Keena
18	CAN URBAN MAPLES TAKE THE HEAT? ASSOCIATION OF HARDCAPE AND SITE FACTORS WITH STREET TREE CONDITION IN NEW HAVEN CONNECTICUT	Susanna Keriö
19	CLIMATE-BASED PREDICTIONS OF GEOGRAPHIC AREAS AT RISK FROM INVASIVE FOREST PATHOGENS	Mee-Sook Kim
20	EVALUATING RESISTANCE OF LINGERING HEMLOCK GENOTYPES TO HEMLOCK WOOLLY ADELGID (ADELGES TSUGAE)	Emily T. Kelin
21	AN EFFECTIVE TRAP FOR SPOTTED LANTERNFLY EGG MASSES	Phil Lewis
22	BIOLOGICAL CONTROL OF HEMLOCK WOOLLY ADELGID IN NORTH AMERICA: HISTORY, STATUS, AND OUTLOOK	Albert E. Mayfield III
23	DETECTION OF VOLATILE PHEROMONE CANDIDATES FROM CITRUS LONGHORNED BEETLE, Anoplophora chinensis	Emily Maynard
24	EASTERN HEMLOCK (TSUGA CANADENSIS) PHYSIOLOGICAL RESPONSES TO ELONGATE HEMLOCK SCALE (FIORINIA EXTERNA) INFESTATION"	Robert T. Michalow

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26	EFFECT OF DUSKY SLUG (ARION SUBFUSCUS) MUCUS ON BLACK MUSTARD (BRASSICA NIGRA)	Brooke Pellegrini
27	EVALUATING ESTABLISHMENT OF EMERALD ASH BORER LARVAL PARASITOIDS IN LINGERING ASH STANDS	T.R. Petrice
28	DEVELOPING METHODS FOR FIELD DEPLOYABLE DETECTION OF CRYPTIC PATHOGENS IN TREE BREEDING PROGRAMS	Mariana S.G. Saito
29	EFFICACY OF INSECTICIDES FOR HEMLOCK WOOLLY ADELGIDMANAGEMENT ON EASTERN HEMLOCK	John D. Sauter
30	CANO.PY: DETECTING FOREST DISTURBANCES AND INVASIVE INSECTS FROM LANDSAT PHENOLOGY	Brian Sturtevant
31	PHYLOGENOMICS OF AGRILUS WOOD-BORING BEETLES	Jonah M. Ulmer
32	EMERALD ASH BORER (EAB) AGRILUS PLANIPENNISMAINTAINING ASH IN THE LANDSCAPE	Ron Weeks
33	MOLECULAR IDENTIFICATION AND DIAGNOSTIC ASSAY OF A NATIVE PARASITOID OF THE SPOTTED LANTERNFLY	Yunke Wu
34	PRELIMINARY STUDIES ON THE USE OF HEAT TREATMENTS TO KILL THE EGGS OF TWO INVASIVE FOREST PESTS, SPOTTED LANTERNFLY, LYCORMA DELICATULA (WHITE), AND SPONGY MOTH LYMANTRIA DISPAR L.	Nooshin Zandi-Sohani
35	NEW AND NOTABLE ADELGIDS FROM BHUTAN	Zephyr Zembrzuski

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Oral Presentations	Title	Author
1	VASCULAR STREAK DIEBACK – AN EMERGING THREAT TO REDBUD NURSERY PRODUCTION IN THE SOUTHEASTERN UNITED STATES	Fulya Baysal-Gurel
2	BALSAM WOOLLY ADELGID POPULATION TRENDS IN NORTHERN UTAH	Barabara J. Bentz
3	LOOKING FORWARD: THE IMPACTS OF ASIAN LONGHORNED BEETLE ON FORESTS IN SOUTHEASTERN NEW ENGLAND	Olivia Box
4	EMERALD ASH BORER HOST RANGE EXPANSION AND NATURAL ENEMY RESPONSES: IMPLICATIONS FOR BIOCONTROL	Heather L. Callahan
5	PHOSPHONATE SOIL TREATMENTS IMPROVE TREE HEALTH AND SUPPRESS FOLIAR NEMATODE DENSITIES IN AMERICAN BEECH WITH BEECH LEAF DISEASE	Daniel A. Herms
6	IMPACTS OF SPOTTED LANTERNFLY ON COMMON HARDWOOD TREES	Kelli Hoover
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