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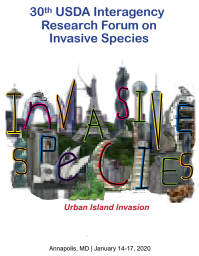

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FOREWORD

This meeting was the 30th 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

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PRESENTATIONS

Keynote Address

EMERGING SPECIES AND NEW TOOLS TO FORECAST INSECT INVASIONS

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ABSTRACT

Globalization is leading to an exponential increase in the introduction of non-native insects into other continents without any saturation being observed. In Europe, this increase is mainly due to the arrival of phytophagous species, which have established at a rate of 11.5 new species per year since the beginning of the 2000s, which is 2.5 times more than 50 years ago. A similar trend is observed in North America, New Zealand and China despite largely different phytosanitary regulations. In Europe, the non-native phytophagous insects are significantly more associated with woody plants (ca. 6.1 new species detected per year since 2000) than with herbaceous plants, probably in connection with the explosion of the global ornamental trade. Thus, 451 non-native insect species have established on forest, ornamental and fruit trees and shrubs in Europe by 2019. A growing number of the newcomers are said to be "emerging" because previously unknown as invaders elsewhere, even unknown to science, or considered harmless in their areas of origin. As such, these species were not regulated before their arrival in Europe, and the phytosanitary control devices at the borders did not target them. The definition of tools allowing the identification of potential invaders upstream of their arrival as well of tools allowing an early, generic detection at arrival is therefore essential today in order to have the necessary warning devices. Given the importance of non-native insects associated to woody plants, we targeted this group for defining such tools.

The establishment of sentinel plantations in other continents aims at identifying the potential invaders through two devices with distinct objectives. Sentinel plantings correspond the planting of non-native woody species in an export region, for example European trees planted in China, in order to identify the insects of the planting area likely to colonize these non-native trees. Such plantings would supply a list of insect species that are potentially threatening if they are introduced to the importing country. On the contrary, sentinel nurseries involve the planting of commonly exported species within this exporting country, for example Chinese plants planted in China before exporting to Europe, but in the absence of any phytosanitary treatment. This design would allow to identify insects that could be introduced into the importing country through trade in live plants. Both types of sentinel designs have recently been tested in China. The planting of six European species has made it possible to list more than one hundred species of Chinese insects capable of colonizing them, four of which representing a serious potential threat if introduced to Europe. Sentinel nurseries using the 6 most exported Chinese trees and shrubs to Europe revealed 106 associations between trees and insect species, of which 90% were previously unknown. The setting up of such sentinel nurseries in the early 2000s would certainly have warned the danger of invasion by the box tree moth, *Cydalima perspectalis*, with imports of Chinese box trees before the moth arrives in Europe, all sentinel plants having been attacked during our experiments. New, larger-scale sentinel plantings are planned in the coming years in China, South Africa and the USA along with the development of an European Horizon 2020 project called "HOMED".

On the other hand, early detection of such non-native species upon arrival at potential points-of-entry is also challenging if we want to apply effective eradication measures. Because pheromone components

are often conserved at world level among related species in long-horned beetles (Cerambycidae), we expected to define generic, multicomponent lures in order to detect "unkown" species arriving from other continents. Such lures may also allow to minimize the costs and required manpower. We thus tested the generic attractiveness of different blends of pheromones composed of increasing numbers of pheromone components at both potential points-of-entry and in natural forests in France during 2014 to 2017. It finally resulted in the definition of an 8-component pheromone blend, composed of fuscumol, fuscumol acetate, geranylacetone, monochamol, 3-hydroxyhexan-2-one, *anti*-2,3-hexanediol, 2-methylbutanol, and prionic acid. The 8-component bled was used a bait on either black cross-vane or black multifunnel traps, to which were added host volatiles (ethanol and [-] α-pinene). This lure combination confirmed a generic attractiveness for long-horned beetles, without apparent antagonistic effects between components. In 2018 and 2019, black multifunnel traps baited with this blend captured in French forests a total of 126 native cerambycid species, which represented 52% of the country's fauna, including more than 50% of the species in 25 of the 41 cerambycid tribes present in the region. At potential points-of-entry, captures with the same trapping design concerned 38 cerambycid species including 8 non-native ones, two of which having never been reported in Europe, yet. Such trapping designs also allowed to detect non-native bark and ambrosia beetles (*Xylosandrus* spp.) and platypodids (*Euplatypus* spp.) in forests and ports. Traps baited with the 8-component pheromone blend are presently tested in different regions of China, North America and Australia in order to define lists of non-native species that could be trapped at arrival in Europe, these species being also barcoded for an easier and quicker identification.

However, these black traps caught very few jewel beetles (Buprestidae) whereas such species may also constitute a serious threat to forests (e.g., the emerald ash borer, *Agrilus planipennis*). Therefore, we compared the attractiveness of green and black multifunnel traps baited with the same 8-component blend complemented with ethanol and [-] α-pinene. The green traps effectively captured 25 species of buprestids of which 15 *Agrilus* spp. but the number of cerambycid species, as well as the number of individuals, significantly decreased with regard to the trappings by black traps. We would probably need to deploy traps of different colours, and baited with different lure combinations to detect both cerambycids and buprestids in ports of entry.

PRESENTATIONS

Research Reports

A FOUR-YEAR, SEVEN-STATE REFORESTATION TRIAL WITH EASTERN HEMLOCKS (*TSUGA CANADENSIS*) RESISTANT TO HEMLOCK WOOLLY ADELGID (*ADELGES TSUGAE*)

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ABSTRACT

We have conducted over a decade of research into rare eastern hemlock (*Tsuga canadensis*; hemlock) trees that appear resistant to hemlock woolly adelgid (*Adelges tsugae*; HWA). Following vegetative propagation of these rare individuals, in 2015 we planted size- and age-matched HWA-resistant and HWA-susceptible hemlocks in HWA-infested forest plots in seven states. In 2019, we re-surveyed the plots; 96% of HWA-resistant hemlocks survived compared to 48% of susceptible trees. The surviving HWA-susceptible trees were also shorter, produced less lateral growth, had shorter drip lines, and had lost more foliage than HWA-resistant trees. Our results suggest that HWA management may benefit from additional research exploring the identification, characterization, and use of HWA-resistant eastern hemlocks in future reforestation efforts.

NATIVE WOOD-BORING BEETLES TRAPPED AT PORTS-OF-ENTRY CAN HELP TARGET LIKELY INVADERS

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ABSTRACT

The constant increase in the volume of traded commodities has caused an impressive number of non-native species introductions around the world. This number is expected to further increase due to expanding trade networks and incorporation of new trade partners that can act as sources of new species. The latter trend is valid for several organisms, especially wood-boring insects. Bark and ambrosia beetles (Coleoptera: Curculionidae; Scolytinae) and longhorned beetles (Cerambycidae), in particular, are considered as extremely successful invaders. Hidden within wood-packaging materials, roundwood logs and live plants, these beetles are often moved both throughout their native biogeographic region and among continents (Meurisse et al. 2019). In this context, biosecurity surveillance plays a key role. Among the tools currently available for surveillance activities, traps baited with attractants are commonly used because they are efficient, commercially available at low costs, and can benefit from the growing knowledge on chemical ecology of insects and availability of newly synthesized semiochemicals (Poland and Rassati 2019). Several countries deploy traps baited with pheromones and kairomones at ports of entry and the surrounding forests to intercept potentially incoming non-native species. Nonetheless, several native species are commonly trapped along with the non-native individuals.

The origin of native species trapped at ports of entry has never been investigated yet. These species can either originate from forests surrounding the ports or from other native areas and then conveyed to the ports through national maritime trade. To unravel these mechanisms, we analyzed 3 yr of trapping records of native bark- and wood-boring beetles (Cerambycidae and Scolytinae) collected at 12 Italian ports and their surrounding forests (Rassati et al. 2018). Several species that occurred either inside or outside their native Italian range were found at the monitored sites (ports and surroundings). The abundance of native species found outside their native range (for instance, species trapped in south Italy but living only in the north) was most strongly linked to the amount of national imports arriving at the port where trapping occurred, suggesting that they were likely introduced to the monitored ports from other Italian ports. Species richness and abundance of those species found within their native range were most strongly associated with the amount of forest area occurring in the surrounding landscape, suggesting that they could have arrived in the ports from the nearby forests. In addition, we compared the pool of native species found at Italian ports with lists of insects that other countries have intercepted on imports from Italy (i.e., USA and New Zealand). As a general trend, we found that the more abundant a species at the shipping points in the exporting country, the higher the rate of interceptions in the importing country.

This study demonstrates the importance of identifying and analyzing the pool of native species that can be trapped at ports, both from an ecological point of view, documenting range expansion of native species, and from a practical point of view, allowing the creation of lists of wood-boring beetles that could easily be moved by trade. Such information can help improve targeting of potential invaders in early-detection trapping programs carried out around the world.

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USING THE BIOLOGY AND BEHAVIOR OF THE ASIAN LONGHORNED BEETLE TO HELP ERADICATE POPULATIONS IN THE U.S.: NEW TOOLS TO ASSESS RISK

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ABSTRACT

Background

The Asian longhorned beetle (*Anoplophora glabripennis* Motschulsky) is an invasive polyphagous wood-borer native to China and the Korean Peninsula. Beetles bore into the cambium and xylem of infested trees leaving galleries and tunnels that reduce the quality of the wood, expose the tree to secondary damage, and weaken the physical structure of the tree. The use of infested wood as solid wood packing material (pallets, crates, dunnage, etc.) has allowed the beetle to move internationally, and breeding populations of the beetle have been found in Europe, Canada, and the United States.

The broad host range of the Asian longhorned beetle includes economically and ecologically important trees including maples, poplars, ash, elms and beech. The diversity of suitable hosts and the potential for the beetle to significantly impact forested and urban systems as led members of the EPPO (European and Mediterranean Plant Protection Organization), Canada, and the United States to develop more stringent regulations for the treatment and use of solid wood packing material, and to adopt policies of eradication when infestations are detected.

Programs to eradicate populations of the Asian longhorned beetle generally include two phases; delimitation surveys to determine the spatial extent of the infestation and to identify the boundaries for management, and eradication surveys to identify and remove individual infested trees. While in some cases, the full removal of all host material could offer an economical and efficient path to eradication, the infestations in the United States are located in highly fragmented urban and sub-urban landscapes with large and diverse communities of land-owners and stake-holders. As a result, full host removal efforts are not always feasible, and eradication programs focus on determining the infestation status for each individual tree on the landscape, typically though the use of visual surveys from the ground by personnel with binoculars, or from within the canopy by tree climbers. Due to variations in field conditions, the requirements of the program, and the efficacy of survey methods, multiple surveys of a stand may be required.

Risk Tools

Due to the time and costs associated with surveys, there is a need to provide program managers and stakeholders with tools to assess the progress and impacts of eradication programs in order to optimize and prioritize the deployment of survey personnel. To address this need, three tools have been developed to quantify the distribution of risk within Asian longhorned beetle infested landscapes, and to assess changes in this risk as surveys and eradication programs progress. The first of these tools is

called ALBRisk v1.1 and is focused on quantifying the distribution of risk on the landscape based on reconstructed patterns of beetle dispersal. Using data collected by eradication programs (locations and levels of infestation for individual trees), the tool carries out three primary tasks including;

1) Reconstruct patterns of beetle dispersal on the landscape using the locations of known infested trees.
2) Use patterns of beetle dispersal to develop directional dispersal kernels for the beetle. These dispersal kernels provide estimates of the probability that a beetle which disperses from an infested tree will move a specified direction and distance.
3) The dispersal kernels are then applied to the locations of each known infested tree on the landscape, and the probabilities from each tree are compiled to provide an estimated probability of infestation for each location on the landscape (based on the distribution of infested trees and assumed rates of beetle dispersal). The result is a map that describes the distribution of risk on the landscape prior to management efforts.

The output generated by ALBRisk can also be used as input for two additional tools called ALB Dynamic Risk-A v1.0 and ALB Dynamic Risk-B v1.0. Generally both of these tools are used to;

4) Update the landscape risk maps by integrating the reduction in risk resulting from ground surveys, climbing surveys, and full-host removals.

Individually and in combination these tools can also be used to by researchers and eradication program managers to;

5) Evaluate the effects of parameters such as dispersal propensity and survey efficacy on the intensity and distribution of risk on the landscape.

The tools ALB Dynamic Risk-A v1.0 and ALB Dynamic Risk-B v1.0 share a common focus, to modify the estimated risk on the landscape by including the effects of surveys and host removals, however, the tools use different approaches. ALB Dynamic Risk-A uses a simplified approach, in which the risk for a given location is calculated as the product of the initial risk (calculated by ALBRisk), and the probabilities of failure for each survey for a given location. This approach requires only the number and type of surveys conducted and does not integrate the order in which the surveys were conducted or the time between surveys. ALB Dynamic Risk-B includes the effects of the survey chronosequence, with the effect of each survey applied in the order in which the surveys were conducted and with survey efficacy modified based on the elapsed time between each survey. This approach includes the assumption that longer periods of time between surveys increase the probability of detection based on the idea that if a stand is infested the population of beetles will growth through time, and the increase in the size of the beetle population leads to an increase in the probability that the infestation will be detected.

Example Results Based on Worcester, MA

The application of these tools to the available data for the Asian longhorned beetle infestation in and around Worcester, MA reveals several key patterns.

First, the use of directionality in the estimate of risk refines the estimated at-risk area by 35%, when compared to the area that would be considered at-risk using a simple omnidirectional buffer.

Second, changes in the assumed dispersal rate of gravid females (5% vs. 60%) do not change the total size of area with calculated dispersal risk. However, changes in dispersal rate do alter the distribution of risk within the at-risk landscape. A change in dispersal rate from 60% to 5% alters the total effort required to eradicate the beetle by 25%. Seeking additional data to help quantify the drivers and rates at which gravid females disperse from natal trees could substantially improve estimates of the cost and time required for eradication.

Third, the application of these tools to the eradication programs in Worcester, MA show that efforts to date have substantially impacted the risk on the landscape. Since the start of the surveys the number of high-risk hectares (hectares with a probability of infestation greater than 80%) has been reduced by 90%. The number of moderate-risk hectares (hectares with probabilities of infestation between 60 and 80%) have also been reduced by 90%, and the risk on 679 hectares has been reduced to 0 through full-host removal. These values are based on the assumptions of high dispersal/worst-case scenario, and moderate assumptions of dispersal can improve these estimates.

Tool Summary

The tools described above provide a quantitative approach to estimating the risk of dispersal on the landscape within an area known to be infested by the Asian longhorned beetle, and a method to quantify the impact of ongoing surveys and eradication programs to assess eradication progress. The tools show that each infestation has unique patterns of dispersal and risk and localized estimates are likely more suitable than a generalized “one-size-fits-all” approach. These tools continue to evolve, for information on the current status of the tools contact R. Talbot Trotter (Robert.T.Trotter@usda.gov).

THE EMERGENCE OF BEECH LEAF DISEASE IN OHIO: PROBING THE PLANT MICROBIOME IN SEARCH OF THE CAUSE

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ABSTRACT

American beech (*Fagus grandifolia*) is an important hardwood tree species in the northern United States and Canada. However, a new emerging threat to American beech has developed in northern Ohio that leads to decline, senescence and mortality of American beech leaves and has come to be called "beech leaf disease" (BLD). First observed in Lake County, Ohio in 2012, BLD has spread to 17 counties in Ohio, western Pennsylvania, western New York, as well as southern Ontario. At the Holden Arboretum, BLD now affects 97% of the accessioned beech trees in Holden's collection and in addition to American beech also affects European beech, (*F. sylvatica)*, Chinese beech (*F. engleriana*), and Oriental beech (*F. orientalis*). The disease has also become widespread within forests, with canopy cover declining from 95% in 2015 to 85% in 2017 in stands severely affected by BLD. This emerging disease has the potential to dramatically reduce the occurrence and dominance of American beech in many northern forests, with significant effects to forest ecology since beech is an important resource for wildlife.

Despite the rapid spread of BLD, the cause of the disease has been unknown. Consequently, we began work in 2017 to assess the possible causal agent of BLD by examining microbial communities associated with asymptomatic and symptomatic leaves of American beech using both molecular methods and microscopy. Sampling was conducted in a 16-year-old American beech plantation using trees previously selected for resistance to beech bark disease and planted into a common garden for evaluation at the Holden Arboretum. We also conducted sampling of leaves from trees in surrounding natural forests.

Leaf examination revealed that a high proportion of leaves contained nematodes, confirming early reports made by David McCann of Ohio State University of nematode presence on leaf tissue displaying signs of BLD. Direct sequence analysis of extracted nematode DNA coupled with morphological examination identified the best match to the anguinid nematode *Litylenchus crenatae*, a newly described nematode species isolated from Japanese beech (*Fagus crenata*) in Japan. Further examination of leaves found that *L. crenatae* could be detected within anywhere from 45% to 90% of leaves depending on the degree of visual BLD symptoms. In addition, 37% of asymptomatic leaves were positive for the presence of *L. crenatae,* as were 90% of dormant buds associated with leaves symptomatic for BLD. Additional isolation of live nematodes and inoculation onto buds of American beech in controlled greenhouse experiments showed that nematode inoculation initiated symptoms of BLD, and that injury to buds improved symptom reproduction. These data support the conclusion that the nematode *L. crenatae* is required to produce BLD symptoms.

Using molecular methods, we also found that bacterial communities were different between symptomatic and asymptomatic leaves, suggesting a possible role for bacteria in the disease. However, it is uncertain

whether bacteria play a role in BLD, are simply an opportunistic organism growing on damaged tissues, or a potential partner of the nematode. DNA sequencing returned high number of sequences identified to the bacterial genus *Wolbachia*, an intracellular endosymbiont of arthropods and found in some species of nematodes. We found little evidence that leaf fungal communities were affected by BLD, suggesting that a fungal pathogen was not related to the disease. Future research efforts are focused on identifying the role of bacterial taxa such as the genus *Wolbachia* in BLD, the potential vectors for *L. crenatae*, as well as the population dynamics of *L. crenatae.* These efforts could help determine future control efforts for this newly emerging invasive pest.

SPREAD OF WINTER MOTH AND HYBRIDIZATION WITH BRUCE SPANWORM

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ABSTRACT

Beginning in the early 2000's, severe defoliation of deciduous trees was observed in coastal parts of Massachusetts, north and south of Boston. In 2004, the cause of this defoliation was identified as a new invasive species: winter moth, *Operophtera brumata* L. (Lepidoptera: Geometridae), that is native to Europe. Over the next decade, winter moth spread at rate of >8 km per year, and caused widespread defoliation to deciduous trees and fruit crops in coastal New England. Beginning in 2005, the Elkinton laboratory documented the spread of this invasive species and its hybridization with a native congener the Bruce spanworm, *O. bruceata* Hults. This work uncovered that both species use the same pheromone compound and can readily mate with one another. Each November, beginning in 2007, we deployed pheromone-baited traps along an E-W transect along Route 2 in Massachusetts, and then more recently an additional transect along Route 1 in Connecticut. With these transects, we documented the westward spread of winter moth and the formation of stable hybrid zones between the two species in both states by genotyping field-collected males using polymorphic microsatellite loci. Now with over 10 years of field and genotype data, we have found that the overall rate of spread has reduced dramatically to approximately 0.5 km per year, though small numbers of winter moth continue to spread westward each year. Comparing these results to population models, we propose that mate choice, particularly by Bruce spanworm, may be slowing the spread of winter moth through an application of the "hybridization to extinction" paradigm. Unlike classical hybridization to extinction, however; in this case hybridization might preserve the genetic stability of a native species while driving the invasive species to extinction. Using weekly trap catches, we also have found that both species have substantial overlap in regards to the timing of male flight. At the eastern end of the transect winter moth is vastly more abundant than Bruce spanworm and the opposite is true the western end. The vast majority are meetings are thus with the opposite species at these locations and we know that hybrids are maladapted. This pattern reinforces stability of each species populations in these locations.

DEVELOPING TRAPS FOR THE SPOTTED LANTERNFLY

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ABSTRACT

The spotted lanternfly (SLF), *Lycorma delicatula*, is a phloem-feeding fulgorid generalist from China that was recently discovered in the United States. It is a serious pest of grapes and cultivated tree crops, and has been documented causing branch dieback on walnut and killing cultivated grape and hops plants. Trapping technology so far has been based primarily on sticky bands wrapped around tree trunks, usually on their primary host, *Ailanthus altissima*. These bands are messy and need to be replaced often, as they become covered in both target and non-target insects and debris. While relatively effective at capturing first and second instar nymphs, they have shown limitations in their ability to capture later nymphal stages and adults which demonstrate a tendency to avoid walking on the sticky surface. Manufacturers can also change their glue formulations without notice, potentially causing possible changes in insect capture rates. Vertebrate by-catch when using strong glues has been problematic as well. Therefore, trap technology specifically designed with SLF behavior in mind in order to improve trap efficacy is desperately needed. Our goal is to design novel traps and redesign and improve upon commercially available traps in order to optimize trap design and technology. In addition, we hope to move away from single use sticky based traps, if possible, and design traps that capture more late stage SLF, as well as fewer non-targets including vertebrates.

Prior to 2018, sticky bands were used to monitor for SLF populations. In 2018, a new trapping system, BugBarrier was tested. This trap is designed to prevent insects from walking over the glue-coated material as they will either be directed across fiber batting and onto the sticky material, or, because the glue faces inward, caught in the glue on their dorsum or wings. Following testing, more SLF nymphs and adults were captured, and in low density sites more detections occurred, on BugBarrier bands than on Webcote bands.

Circle trunk traps, a non-sticky trap to exploit the walking behavior of SLF, were modified from pecan weevil traps. Pecan weevil trap collection cups were replaced with a 1.9 L screw-top plastic jar (Lance et al. 2013). A pesticide strip was placed inside the collection container to knock down and kill the captured SLF. The opening of the trap was also expanded from 0.6 cm to 1.5 cm. These traps were then compared with BugBarrier bands, with a tree rotation halfway through the trapping period so that all trees tested both trap types. More late instar nymphs and early adults as well as mid adults, and late adults SLF were caught in circle trunk traps than on BugBarrier bands. At later periods in the year, the collection jars on some traps filled up over the course of a two week period (Francese et al. 2020).

Based on results from 2018, circle trunk traps were commercially produced and purchased by the SLF program for use in 2019. An assay was conducted in 2019 to compare circle trunk traps fitted with jars with circle trunk traps fitted with a gusseted plastic bag. The bag trap would be a potential improvement over the jar trap as it would allow the user to easily replace the full bag with an empty one, and transfer the full bag to the lab or office for sorting. To produce the circle trunk bag trap, the end of the original pecan weevil trap cup is removed, and a “tongue” created from acetate sheeting was glued to the inside of the cup. The tongue assisted in keeping the bag from collapsing so that the opening was not obstructed as the bag filled.

Traps were placed on pairs of *A. altissima* trees in the field on 19 June, and were then checked and rotated to the opposite tree in the pair, to reduce tree effects, every 3 weeks until 21 October. All SLF were returned to the lab, and sorted by developmental stage, and adults were sexed. All SLF collected have been summed over the entire field season. A total of 106,321 individual SLF were caught over the trapping period. Significantly more total nymphs and approximately 4x more adults were caught in circle trunk traps fitted with bags than with jars. More 1st and 2nd instar nymphs were also caught in bags than in jars.

The increased trap catch in the bag over the jar may be due to several factors. While the bag is periodically changed throughout the season, the jar is reused and can become covered in honeydew and sooty mold, so light entering the jar may be reduced overtime and interfere with positive phototaxis. Due to the weight of the jar, the jar must be fastened to the tree to reduce issues from the entry becoming obstructed from accumulations of dead SLF. However, the bag trap is held open by the "tongue which prevents the bag from closing on itself. Also, the flexible nature of the bag over the rigid jar allows the insects collected to fall down into the bag rather than to die obstructing the entry port.

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PRESENTATIONS

Recent Findings in Gypsy Moth Population Ecology

CANDIDATE GENES FOR FEMALE FLIGHT ABILITY IN ASIAN GYPSY MOTHS (EREBIDAE, LYMANTRIA DISPAR SPP.)

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ABSTRACT

Gypsy moths (*Lymantria dispar* spp.) parasitize a broad range of coniferous and deciduous tree hosts around the world. The European gypsy moth (EGM: *L. d. dispar*) is a recently introduced invasive species in eastern North America that can cause widespread defoliation during population outbreaks. Range spread of this species is constrained in part by the fact that EGM females cannot fly. However, female Asian gypsy moths (AGM: *L. d. asiatica* and relatives) are flight-capable, and represent a persistent invasion threat via global trade routes. We investigated the genetic basis of gypsy moth female flight ability using several approaches: (1) a genome-wide association study across the two species (2) genotype-flight associations across whole-genome sequences of flight-capable and flight-incapable inbred EGM-AGM hybrids (3) gene expression during pupal development. Our results point to several candidate loci for female flight ability, providing insight to the genetic architecture of this trait as well as potential genetic tags for rapid assessment of dispersal capacity of gypsy moths intercepted at North American trading ports.

ENTOMOPHAGA MAIMAIGA IN EUROPE

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ABSTRACT

The gypsy moth, *Lymantria dispar*, has a native distribution in temperate regions of Europe, Asia, and north Africa and was introduced to the Boston area of North America in 1869 (Pogue & Schaefer 2007). The entomopathogenic fungus *Entomophaga maimaiga*, which infects and kills gypsy moth larvae is native to Japan, northeastern China and the Russian Far East (Nielsen et al. 2005). This pathogen was first found in northeastern North America in 1989 and, since that time has spread rapidly into areas newly colonized by gypsy moth (Hajek 1999).

Gypsy moth outbreaks naturally occur in oak forests in central Europe and the Balkans (Hlasny et al. 2016). This pathogen was first successfully introduced to south central Bulgaria in 1999 and was then distributed to other areas in Bulgaria by moving resting spore-bearing cadavers. Populations of this pathogen increased, causing epizootics, and gypsy moth populations have remained low in Bulgaria since *E. maimaiga* became established (Pilarska et al. 2016).

In some other central and southern European countries, gypsy moth populations began to increase toward another outbreak cycle approximately after 2010, at which time researchers and forest managers noticed high levels of larval gypsy moth mortality in the building gypsy moth populations. The cause of the mortality of larvae collected in Serbia and European Turkey in 2011, in Greece, Macedonia (FYROM), and Romania in 2012, and in Bosnia and Hercegovina, Croatia, Hungary, and the Slovak Republic in 2013 was confirmed as *E. maimaiga* (Pilarska et al. 2016). The regional incipient gypsy moth outbreak that had been expected was not realized and it appeared that *E. maimaiga* was the dominant cause. With gypsy moth populations at low densities, additional searches for this pathogen in neighboring countries were not conducted immediately. However, in 2019 *E. maimaiga* was found in Austria (Hoch et al. 2020).

After *E. maimaiga* was first discovered in North America in 1989 it was found in increasing gypsy moth populations in 7 northeastern states. Until 1992, the distribution of this fungus was studied as it spread to the south and west to the leading edge of the known gypsy moth distribution at that time. Studies suggested that airborne movement of *E. maimaiga* conidia could help to explain the long distance movement of *E. maimaiga* (Hajek et al. 1999, Dwyer et al. 1998); more recent studies have confirmed long distance movement of *E. maimaiga* conidia (Bittner et al. 2017, Elkinton et al. 2019). We approximated the distance of spread of *E. maimaiga* from western Connecticut (where *E. maimaiga* was first discovered and the hypothesized center of the 1989 epizootic; Weseloh 1998) to the southern edge of the distribution in 1992 (Hajek et al. 1995). We also approximated the distance from the 1999 introduction in Bulgaria

to southwestern Slovak Republic, the furthest north where *E. maimaiga* was found in 2013 (Zubrik et al. 2013, Zubrik et al. 2018a). These two distances are similar and we hypothesize that spread of *E. maimaiga* in central and southern Europe could at least in part be attributed to airborne spread of *E. maimaiga* spores that were produced in abundance as gypsy moth larvae were killed by this pathogen.

Entomophaga maimaiga has also been found infecting native gypsy moth populations in Georgia in 2005 (Kereselidze et al. 2011) but the source is unknown.

Finally, studies have been conducted of the host specificity of *E. maimaiga* in Bulgaria, Hungary, and the Slovak Republic. These studies involved extensive sampling of native lepidopteran populations to detect infection by *E. maimaiga*. Exceptionally few lepidopteran larvae infected by *E. maimaiga* were found, except infection was prevalent in the gypsy moth population from the same sites (Georgieva et al. 2014; Zubrik et al. 2018b). These results are comparable to results from host specificity studies that were conducted in eastern North America (Hajek & Butler 2000, Hajek et al. 2000, 2004).

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COLLAPSE OF GYPSY MOTH (LYMANTRIA DISPAR) OUTBREAK IN THE NORTHEASTERN U.S IN 2019

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ABSTRACT

In 2017, we recorded a substantial epizootic of *Entomophaga maimaiga* that appeared to terminate a major outbreak of gypsy moth, *Lymantria dispar* in New England that began in 2015. In 2018 however, drought in May and June returned to central Massachusetts, so there was little mortality from *E. maimaiga* and gypsy moth populations resurged to high density. We expected high levels of defoliation and consequent tree mortality in 2019. This did not occur for the following reasons. First there was substantial mortality from the egg parasitoid *Ooencyrtus kuvanae* due perhaps to the small egg mass size associated with high densities. Secondly and most importantly, there was a major mortality event that occurred during the week of hatch in early May. It rained every day for about a week, and many neonates never left the egg mass. We examined them for mortality for fungi or other pathogens and found very little. We concluded that they probably starved. Finally there was another major epizootic of *E. maimaiga* and *LdNPV* at the end of the larval stage along with high parasitism by *Cotesia melanoscela.* As a result, gypsy moth has now retreated to very low density throughout our region.

PRESENTATIONS

Emerging Trends in Spotted Lanternfly Research

NEW FINDINGS ON SPOTTED LANTERNFLY BEHAVIOR, BIOLOGY, AND SURVEY TOOLS

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ABSTRACT

Spotted lanternfly, SLF, *Lycorma delicatula*, is a polyphagous, phloem-feeding invasive fulgorid native to China. It was discovered in Pennsylvania in 2014 and has now spread to a number of neighboring states. This damaging pest feeds on a broad range of over 100 host plants, but its preferred host, tree-of-heaven, *Ailanthus altissima*, another invasive from China, is broadly distributed throughout the US. SLF can seriously damage or even kill grape vines, and threatens a range of other commodities such as fruit trees, nursery stock, and timber[1]. It has been found to accumulate in great numbers on numerous species of plants, particularly on tree-of-heaven[2]. Our main objective has been to develop semiochemical lures for detection and survey, and possibly control. As such, we have investigated both kairomones and pheromones of SLF. This overview highlights some of our work from 2018 and 2019.

Kairomones. We found that in the Y-tube, SLF quite often were significantly attracted to volatiles produced by a number of plant species when compared to a blank control. However, when offered a choice between tree-of-heaven volatiles and other plant volatiles, tree-of-heaven was either significantly more attractive than the alternative (milkweed, staghorn sumac, hops, wild grape, chinaberry, Norway spruce) or there was no significant difference (black cherry, tulip tree, alfalfa, black walnut, horseradish,

Table 1. Presence of EAD active and/or behaviorally active compounds in 17 plant species.

15 ACTIVE COMPOUNDS (rows) / 17 PLANT SPECIES (columns)	Ailanthus	Wild Grape	Hops	Black Locust	Black Walnut	Virginia Creeper	Oriental Bittersweet	Staghorn Sumac	Black Cherry	Red Oak	Chinaberry	Spicebush	Tulip Tree	Red Maple	Apple	Black Birch	Norway Spruce	TOTAL
(E,E)-α-farnesene	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	17
ß-caryophyllene	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	17
ß-ocimene	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			15
methyl salicylate	x	x	x	x	x	x	x	x	x	x	x	x		x	x			14
(E)-4,8-dimethyl-1,3,7-nonatriene	x	x	x	x	x	x	x	x	x	x	x	x	x			x		14
(Z)-3-hexenyl acetate	x	x	x	x	x	x	x		x	x	x			x		x		12
linalool	x	x	x	x		x		x	x		x	x	x				x	11
ß-ylangene	x	x	x	x	x	x	x	x		x			x					10
sulcatone	x	x		x					x	x		x						6
(Z)-3-hexenol	x			x	x					x		x						5
geranylacetone	x							x	x		x							4
methyl benzoate	x	x					x	x										4
(Z)-3-hexenyl butyrate		x	x			x					x							4
1-octen-3-ol	x		x				x											3
4-terpineol					x												x	2
TOTAL	13	11	10	10	9	9	9	9	9	9	9	8	6	5	4	4	4	

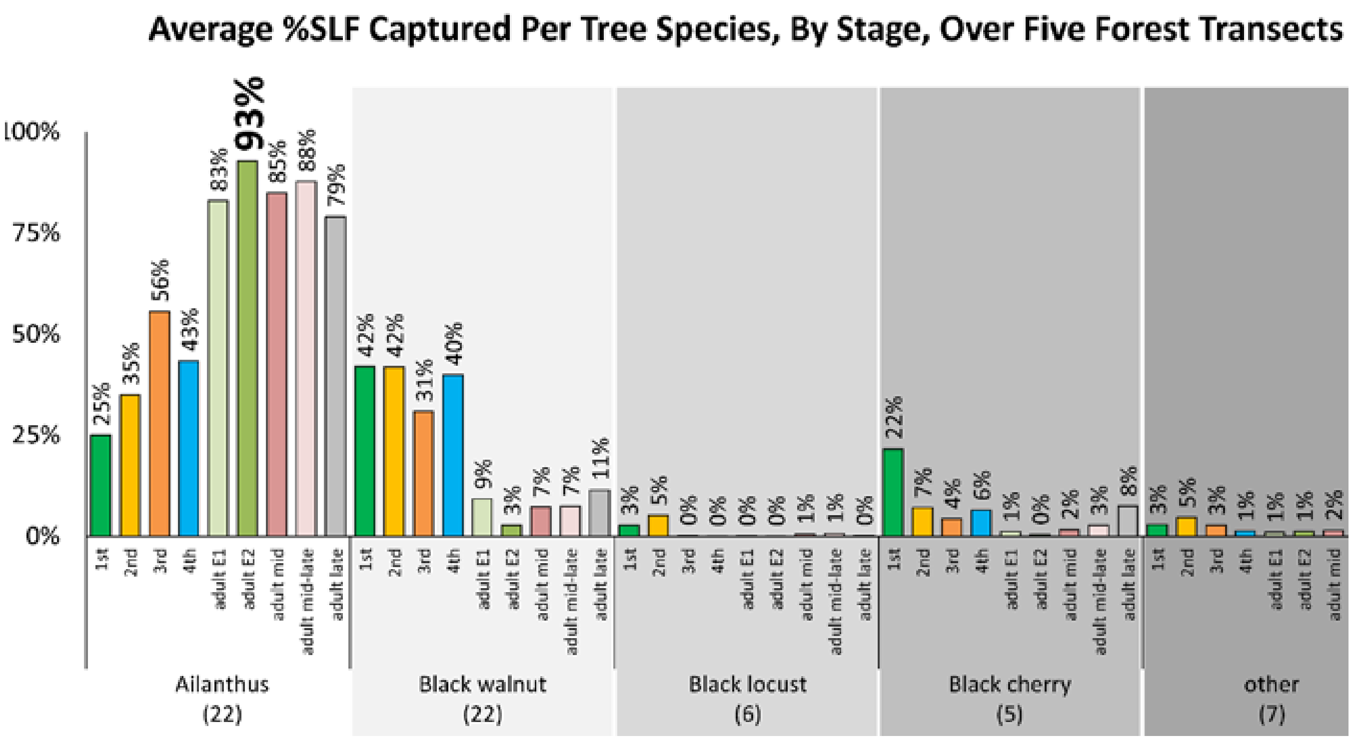
oriental bittersweet). The alternative plant volatiles were never significantly more attractive than tree-of-heaven volatiles. We conducted gas chromatography coupled with electroantennographic detection (GC-EAD) using volatiles from tree-of-heaven and several other plant species, identified a number of EAD active compounds, and tested these synthetic compounds for attraction in the Y-tube, many of which were attractive. We compared volatile profiles of 17 plant species and found that tree-of-heaven contained the largest number of these active compounds. Other highly attractive plants like wild grape, hops, black locust, and black walnut also had profiles with a large number of these compounds (**Table 1**). Norway spruce was tested because it is not attractive to SLF, and it had the least of these compounds in its volatile profile.

Phenology. In order to investigate the presence of a pheromone, we first had to understand the phenology of SLF and when mating and other physiological states were taking place. We investigated the phenology of adults in 2016, 2017, 2018, and 2019. We found that adults go through four distinct periods which we define as follows (with approximate dates based on data from 2017 and 2018):

- Early 1 (feeding – Aug. 1-24)
- Early 2 (feeding and skewed sex ratios – Aug. 25 – Sept. 13)
- Mid (mating – defined by the first observation of mating in the field – Sept. 14-30)
- Late (oviposition – defined by the first appearance of fresh eggs – Oct. 1 until death)

In 2018, we trapped for SLF on all trees along five transects and found that SLF populations in these transects concentrated increasingly on tree-of-heaven with each developmental stage. This peaked with 93% of the SLF population on trees in transects concentrating on tree-of-heaven during the two weeks prior to mating (**Figure 1**). This suggests that tree-of-heaven is important in locating mates.

Figure 1. Phenology of host preference over five forest transects shwoing average percent of SLF captured per tree species, by stage (N trees total).



Pheromones. In 2018 and 2019, we conducted investigations to understand the role chemical communication plays in SLF forming aggregations both as nymphs and adults, as well as aggregations of predominantly one sex or the other. We started with a mark-release-recapture field study in 2018 in a low SLF density area, and released SLF on the ground so that substrate vibrations could be ruled out. We found that trees "baited" with groups of adult SLF attracted significantly more marked-released SLF than control trees, suggesting the use of SLF-produced or induced semiochemicals in order to aggregate[3].

We subsequently investigated what volatiles are produced and when, and who is attracted to whom at different adult stages. In our search for sex and/or aggregation pheromones, we identified a number of attractive compounds generated by SLF, and started constructing a "semio-phenology", in other words, a timeline of when different volatiles are produced or are attractive.

In 2019, every week starting from the emergence of first instar nymphs until the beginning of oviposition in October, we collected (1) SLF body extracts (adults in 2018, also), (2) SLF honeydew, and (3) headspace from live SLF on tree-of-heaven and tree-of-heaven without SLF as controls. The third study is still undergoing analysis, however, here we report findings so far from the first two approaches.

Body extracts – Whole body solvent extracts contained enormous amounts of cuticular waxes and hydrocarbons relative to volatile components, precluding their injection into the gas chromatograph for electroantennographic detection (GC-EAD) or mass spectrometry (GC-MS). However, these extracts were tested for attraction by all stages of SLF in a dual-choice olfactometer to determine who is attracted to whom, and when. Nymphs were attracted to the whole body extracts of other nymphs, suggesting that an aggregation pheromone may exist for nymphs. We found that males were attracted to extracts from females prior to mating, but not males, suggesting a sex pheromone may also be involved. Females were not attracted to female extracts, but just after emergence, females were attracted to male extracts (**Table 2**).

Table 2. Summary of attraction of SLF to volatiles from SLF body or SLF honeydew at different life stages. Each mark represents a series of insects tested against the volatile vs control in the dual choice olfactometer (Chi square goodness-of-fit test, average N = 24, α=0.05).

SUMMARY OF ATTRACTION

		Male Volatiles				Female Volatiles				Male Volatiles				Female Volatiles			
Volatile source:		BODY								HONEYDEW							
		E1	E2	M	L	E1	E2	M	L	E1	E2	M	L	E1	E2	M	L
Males are (✓) / not(×) attracted to:	Early-1	×				✓				✓				×			
	Early-2	×	××			✓	✓✓				✓×				××		
	Mid		×				✓×	×				✓				×	
	Late						×	×	×								
Females are (✓) / not(×) attracted to:	Early-1	✓				×				×				×			
	Early-2	×	××			×	××				××				✓×		
	Mid		×				××					×				×	
	Late						×	×	×								

Honeydew volatiles – Honeydew was collected every week and tested for attraction to fourth instars and adults in the olfactometer. Fourth instars were attracted to the volatiles emanating from their own honeydew. Interestingly, adult male and female SLF were only attracted to volatiles from their *own* honeydew, but not to honeydew from the opposite sex (**Table 2**).

This peculiar discovery may help to explain the skewed sex ratios we have observed and documented in the field every year since we started studying SLF [2, 4, 5]. Although we still do not understand why males and females sometimes aggregate in groups of mostly their own sex, this may provide an explanation as to how they find each other to form these aggregations.

Novel attractive compounds – Although the abundance of compounds in volatile collections was too low to elicit antennal responses in GC-EAD, over 30 compounds were identified (or tentatively identified) using GC-MS. The synthetic versions of 26 of these compounds were purchased or synthesized and screened using GC-EAD, and 12 were found to be antennally active. In addition, eight of these compounds were tested and found to be attractive in the dual-choice olfactometer. Strong antennal responses and attraction occurred in response to benzyl acetate and 2-nonanone. Also of interest was 2-heptanone, which was attractive to males, and 2-octanone, which was attractive to females. These three ketones were found in both honeydew and body volatiles, whereas benzyl acetate was found only in the honeydew. That 2-heptanone and 2-octanone were attractive to opposite sexes could reveal a mechanism for the skewed sex ratios observed on tree trunks prior to mating[4]. The purpose and evolutionary advantage of this observed sex ratio shift prior to mating is not yet understood. Initial field tests were inconclusive and more field studies are planned.

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SENSITIVITY OF SPOTTED LANTERNFLY TO INSECTICIDES AND USE OF SENTINEL TRAPS ON THE INFESTATION PERIPHERY

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ABSTRACT

The infestation of spotted lanternfly (*Lycorma delicatula*) has continued to spread since it was first detected in late 2014 in eastern Berks County (southeastern Pennsylvania). This invasive pest is now established in over a dozen counties in southeastern Pennsylvania, as well as multiple counties in New Jersey, Delaware, Virginia and Maryland that border or are associated with the Pennsylvania infestation. There is great potential for this insect to spread beyond its current boundaries and recent finds in new municipalities are for the most part located adjacent to existing quarantine boundaries. The strategy to eliminate this pest is multifaceted and includes establishment and enforcement of quarantines, intensive surveys using tree sticky bands and traps, outreach and extension activities, and chemical control.

Tree of heaven (*Ailanthus altissima*) is a key host where all life stages of the insect are present but where adults are observed to congregate in large numbers. A standard control approach has been implemented that involves clearing most *Ailanthus* from a property while retaining several trees that are then treated with insecticide as trap trees. Treatment is conducted via a simple bark spray application in May or June to the lower portion of the tree trunk using a systemic insecticide (dinotefuran). Treatments applied at the highest labeled rate were effective against nymphs and when the adult stage begins maturation feeding on *Ailanthus* in August and September.

Observations of these trees during the summer verify that the treatments are quite effective, with dead lanternfly nymphs and adults readily found beneath treated trees (Figure 1). There is a concern, however, about proper timing and longevity of the treatments considering EPA label restrictions of one application per year and that adults are active between mid-July and a hard frost (December or later in Pennsylvania, depending on the year). Tree foliar residues of dinotefuran can be readily detected using a commercially available ELISA kit. Foliage samples were collected throughout the growing season over multiple years and dinotefuran residue present in leaves following bark spray treatments have been quantified.

Data from multiple studies over a four year period show that expected residues ranged from 7 to 13 ppm (average 10 ppm) following bark spray applications. Trees treated in early May maintained stable residue values into September, while an early April treatment had residue values drop by about half from August to September, when one-third of the study trees had residue values below 1 ppm. There was carry-over of residue from prior-year treatments, but values were low and ranged between 1-2 ppm.

Trunk injection of systemic insecticides is another method of applying pesticides to growing trees, although it requires the use of both specialized equipment and formulations. Such a formulation is available for dinotefuran and it achieves a similar level of control while resulting in a 7-fold decrease in the amount of insecticide applied per tree as compared to a dinotefuran bark spray application (2.7 g of active ingredient versus 19 g). Although less product is used with a trunk injection application,

residue values in foliage were 5 to 10 times higher as compared to a bark spray treatment. Residue values declined steadily between June and September, but averaged 100 ppm in June and declined steadily to a little over 50 ppm by the end of the four month period.

Spotted lanternfly (SLF) susceptibility to several systemic insecticides and two treatment methods was made over a two year period by using tarps to monitor adults falling out of the tree canopy. Sets of trees were treated via trunk injection with dinotefuran, imidacloprid (Dinocide & Imicide 10% formulations; JJ Mauget) and emamectin benzoate (Tree-age; Arborjet) and compared to the standard bark spray treatment application of dinotefuran. Injection treatments were applied at 2 mL of formulated product per diameter inch of tree using Arborjet's Quikjet Air device.

The emamectin product was only tested the first year as mortality on most sample dates was not different from the control group. However, adult SLF are susceptible to both dinotefuran and imidacloprid applied as either an injectable formulation or as a bark spray. In the first year there were about 28,000 dead SLF adults collected from 12 tarps while populations increased almost 10-fold the following year with over 252,000 SLF adults tallied from under 17 study trees. Mortality data were highly variable over time (Figure 2) and also varied greatly by individual tree, with some trees attracting and killing a disproportionate number of SLF. A single tree in the first year accounted for over a third of the catch and three of the most productive trees the following year made up over half of the total. It is of interest to note that the three most productive trees the first year were again among the most productive the following year. The attractiveness of SLF to certain *Ailanthus* trees over others within a landscape is being investigated.

A second use of these trap trees is that they can serve as toxic sentinels and be serve as an SLF monitoring tool for areas and states that are on the periphery of an infestation. SLF is a very active and mobile insect and is highly attracted to *Ailanthus*, especially at the adult stage, so an attract and kill method is a good means of detecting low population levels in an area versus an occasional visual inspection. Key transportation routes, railways, truck stops, rest areas and DOT facilities are all ideal locations in which to set up these sentinel trap trees. Additional areas of concern (vineyards) can also be readily monitored using this method.

Once a suitable area is identified to establish a sentinel *Ailanthus* tree, it is treated with a bark spray application and a 25-gallon water ring is positioned at the base of the tree. Trees should range in size between 4 and 10 inches in diameter (Figure 3). The ring can be checked for SLF lifestages every 3 to 4 weeks. State and federal partners from six states are currently deploying sentinel trap trees.

After two years of experience with sentinel trap trees, results demonstrate that they are most useful when deployed on *Ailanthus* outside of known infested areas. These traps can be effective as a means to investigate isolated incidents or for detecting SLF range expansion. Compared to an intense survey activity like sticky bands that must be checked and replaced often, sentinel trap trees can greatly reduce the amount of time and personnel needed by an agency as they manage and prepare for an SLF infestation.

Figure 1. Adult mortality is evident from this picture of a treated tree in August. Wing-flaring of adults indicates pesticide poisoning.

Figure 2. Average SLF adult mortality by date over a 6 week period.

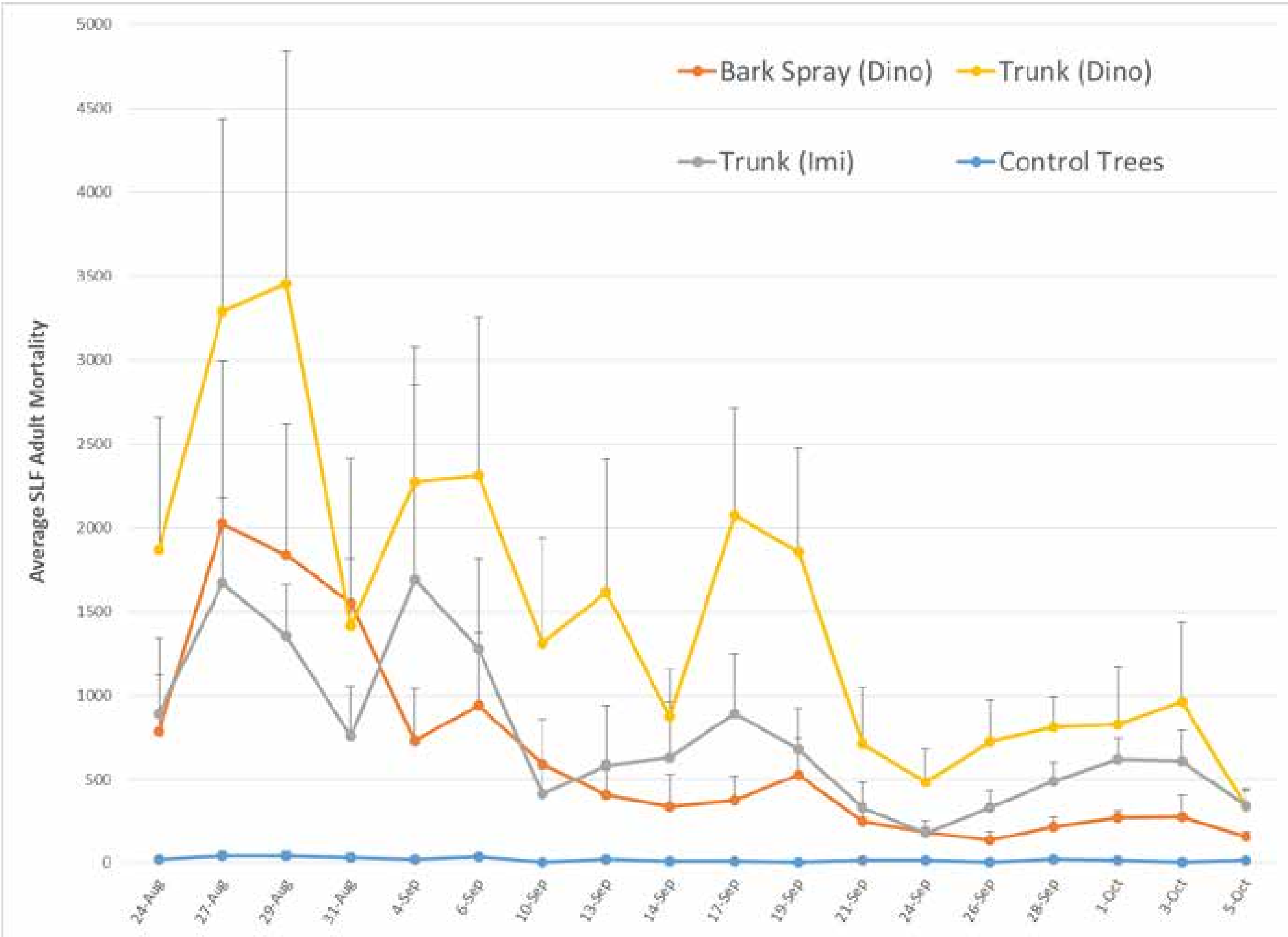

Figure 3. Sprayed tree with collection ring. Spray dries in about a ½ hour.

DEVELOPMENT OF BIOLOGICAL CONTROL METHODS AGAINST THE INVASIVE SPOTTED LANTERNFLY

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ABSTRACT

Eradication and containment of the spotted lanternfly (SLF), *Lycorma delicatula* (White), has been considerably challenging, and this devastating exotic pest has now spread to five states. Because eradication is unlikely, scientists are pursuing management strategies such as biological control. USDA scientists have been collaborating with researchers at the Chinese Academy of Forestry since 2015 to search for natural enemies of SLF throughout China. Exploratory surveys were conducted in 27 provinces in China, where scientists collected SLF egg masses and nymphs. SLF was found to be widely distributed throughout China, being recovered in 21 of the 27 provinces surveyed. To date, we have recovered one egg parasitoid, *Anastatus orientalis* Yang & Choi (Hymenoptera: Eupelmidae) and one nymphal parasitoid, *Dryinus sinicus* Olmi (Hymenoptera: Dryinidae).

Anastatus orientalis was discovered parasitizing SLF eggs in northern China in 2011 (as part of exploration for natural enemies of SLF in Korea). This parasitoid was reported to parasitized 20% of egg masses and 40% of the eggs within these masses during one of its purported two generations per year. It has established in Korea, although information on its effectiveness there is lacking. Parasitized egg masses were shipped from China to the USDA-APHIS quarantine laboratory in Massachusetts, and we have been conducting biological studies to better understand how to rear and utilize this potential biocontrol agent. Research has concentrated on parasitoid life-history (life-cycle, sex ratio, longevity and fecundity), behavior (superparasitism, competition, attractants), and optimizing rearing (oviposition, development, storage, and how to initiate and break diapause).

Researchers in China have reported that *A. orientalis* has two periods of emergence from SLF egg masses (May and September). It was hypothesized that female wasps oviposit into fresh SLF egg masses in the fall, adults emerge in the spring, and emerging adults parasitize as yet un-emerged SLF eggs. Field data from China suggested this might not be the case. Our collaborators collected egg masses in April and the emerging adults were allowed to oviposit on those masses. A month later, when the eggs were dissected, many eggs contained developing parasitoid larvae, as anticipated. However, a sample collected in the field in late July revealed very few parasitoid larvae; they had all emerged prior to collection. There are no SLF eggs available for oviposition in July in China, so it is likely they were using at least one host other than SLF for reproduction. We designed a study to elucidate the particulars of the *A. orientalis* life-cycle. One hundred egg masses were collected in Beijing in early March and shipped to the APHIS quarantine facility in Massachusetts. Fifty egg masses were placed in a growth chamber that mimicked the temperature and day length of Beijing, China, and the remaining egg masses were reared under conditions that mimicked Pottstown, Pennsylvania. Emerging wasps were collected daily and provided new egg masses to parasitize. Under Beijing conditions, *A. orientalis* adults started emerging in early July, which would explain our field observations. This population went on to have a third generation in the fall, when SLF

egg masses would be available in the field. Pennsylvania temperatures are generally cooler than those in Beijing, and emergence of adults in both May and July was slightly later than that observed in China. However, there was no fall generation of *A. orientalis* under Pennsylvania conditions. While SLF is moving south to where conditions would more closely resemble those found in Beijing, the extra summer generation is still problematic. We compared the climate throughout China to those in Pennsylvania and have identified locations where parasitoid populations might be better synchronized with SLF. In one of those locations, Yantai (Shandong Province), some egg parasitoids did not emerge in the spring like *A. orientalis* and might be a species with a one-year life-cycle. We plan to collect egg masses from Yantai and investigate a possible new species.

If *A. orientalis* has a summer generation, which our evidence suggests it does, then it will need to attack at least one host other than SLF. We conducted host specificity testing, prioritizing large, univoltine planthoppers that are closely related to SLF and overwinter as eggs. To date we have seen reproduction in seven of the 18 species tested (39%). This includes one Fulgoridae (*Poblicia fulginosa*), four Pentatomidae (*Euschistis servus, Chinavia hilaris, Podisus maculiventris,* and *Halyomorpha halys*) one Coreidae (*Anasa armigera*), and one Saturniidae (*Antheraea* sp.). We also observed oviposition on another Pentatomid (*Thanta custator*) and a Bombycidae (*Bombyx mori*), although as of this writing it is too early to know if progeny will be produced. All of the species produced males, but female adults emerged from only three of the non-target hosts. These females were smaller than females emerging from SLF, however, they were able to produce progeny when provided SLF eggs. Future research on SLF egg parasitoids will include 1) collection of egg masses in Yantai to determine if there is another species/biotype, 2) confirm a July generation of *A. orientalis* in China, 3) collect non-target species related to SLF in China to determine if they are attacked by *A. orientalis*, 4) conduct choice tests for species that *A. orientalis* attacked in no choice tests, and 5) conduct life-table studies in South Korea to determine if *A. orientalis* is contributing to the decline of SLF populations in that country.

We have conducted less research on the nymphal parasitoid *Dryinus sinicus* because we collected it later (2018), it is univoltine, and rearing its host, second instar SLF nymphs, is challenging. Female wasps have raptorial forelegs that they use for gasping SLF nymphs, which they temporarily parasitize during oviposition. Parasitoid larvae develop on the outside of the SLF nymph in a protective sac called a thalacium. A conservative estimate of parasitism levels is 20-40%. We currently have this species in colony, where it is overwintering as pupae in cocoons, and this spring we will be concentrating on developing effective methods to rear this species.

In conclusion, we have discovered and are studying two potential biocontrol agents and hope to discover more in China. There is still much research to be done, however, before a biocontrol program against the SLF can be implemented.

PRESENTATIONS

Socio-economic Aspects of
Invasion Biology

PLANTS, PEOPLE AND PESTS: CAN UNDERSTANDING VALUES, ATTITUDES AND BEHAVIOURS IMPROVE YOUR SOCIAL LICENSE TO OPERATE?

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ABSTRACT

As the range and numbers of tree pests and diseases continue to rise globally, there has been an increased interest in understanding human behaviours related to the introduction and spread of these invasive species and acceptance of control measures. Biosecurity behaviours in people can depend on their values and beliefs that in turn influence their attitudes towards the risk (of the pest or the management options to control the pest), legitimacy of the management advice and perceived efficacy of the proposed approach to management and control of the pests and diseases. Potential responses also depend on the type of pest or disease and the expected level of ecological and financial risk. Gaining a social license to operate (SLO) is important, particularly where pest or disease management is led by public sector entities who are held to account for the social and environmental impacts of operational policies and programmes. An SLO is often negotiated in a particular context with a set of engaged stakeholders and community members and must be actively maintained throughout operations and beyond. Trust between managers and their stakeholder or community is central to social licence influenced by good engagement and communication and agreement around procedural fairness. In tree health, there is a greater need to understand the social dimensions that can contribute to a SLO and people's perspectives and behaviours are particularly under-researched in an urban context where residents and other non-traditional managers of urban trees, street trees and woodlands are involved.

We focus on a specific example of the oak processionary moth (*Thaumetopoea processionea*) or OPM and explore whether increased exposure to the pest could have detrimental impacts on the future of the iconic British oak in the city and the people who enjoy them. OPM was accidentally introduced into London on imported oak trees in 2006 and has been slowly spreading but to-date this pest is largely confined to Greater London. The OPM caterpillars are particularly distinctive as they move (process) in long lines across the trunks of oaks to reach the foliage. OPM will defoliate oak trees leaving them potentially vulnerable to other pests and diseases and stress factors but a larger concern is the potential human and animal health risks from interaction with the caterpillars' thousands of tiny urticating hairs. These readily detach and can be blown some distance in the wind or linger in the caterpillar nests and around the base of the trees. Coming into contact with the hairs or inhaling them has the potential to cause itching and respiratory problems. In addition to the potential risks to human and animal health, there is a range of indirect impacts that need to be considered. For example, managers of publicly accessible areas with oak trees and OPM are at risk of financial losses if they close sites to avoid harm to the public or where there is a reduction in visitors as people intentionally avoid potentially hazardous or unsightly parks and gardens. OPM is regulated in the UK to minimize risk of new introductions and reduce spread. Early attempts at eradication of OPM failed and significant resources have since been spent by government on monitoring and controlling OPM through the use of insecticides or bio-pesticides to slow the spread. Surveying for OPM and issuing of statutory notices for control is currently based on a geographical zoning system consisting of core (guidance given to land managers) and

control (Statutory Plant Health Notices issued to state that the nests should be sprayed) zones to ensure that the UK keeps its protected zone status. However, the biggest threat to the British oak may be that the perceived risks associated with OPM, and costs of management can lead to decision-making that includes felling existing oak trees and/or not planting oak in the future. We identified a need to better understand awareness, risk perceptions and decision-making around OPM management.

We interviewed 29 land managers to determine how they make decisions about OPM risks and weigh up the management options against the impacts these could have on the social and economic values associated with oak and the biodiversity they support. Evidence for human health impacts amongst the visiting public were lacking but there were concerns that organisations need to carry out their public duty of care and reduce risks of contact with OPM. Reputational damage from not managing OPM is also potentially greater in urban areas where there are larger numbers of people that can encounter OPM and more potential for complaints over health impacts. Most land managers interviewed accepted responsibility for OPM management on the trees that they own. There was higher support for biological control as a measure but a lack of knowledge amongst some about what this involves. In terms of implementation, there was less support for spraying chemicals (insecticides/pesticides), although certain land managers such as gardeners and contractors were more accepting due to recent experiences of dealing with other pests and diseases. Nest removal was considered to be an effective measure by many we interviewed although re-infestation of the tree is more likely to occur without the spraying of insecticides or bio-pesticides. There was also a widespread perception that spraying would not be considered acceptable by the public and so respondents talked of using this option at times of day when fewer people were around to avoid any potential public concern over spraying impacts. Land managers face a number of challenges in dealing with OPM including low levels of knowledge, particularly amongst private residents. Even knowledgeable land managers were still uncertain of OPM behaviour and the full range and efficacy of management options available. The greatest concern was the financial costs of management measures, which are hard to justify given the lack of evidence on health impacts to date. Collective action could potentially reduce costs and collaboration should be an important component of OPM management particularly as lack of action from one land manager can increase the challenge of managing OPM levels for neighbours. However, the sheer variety of sites and difficulties in identifying ownership in cities can hinder communication. Access to financial support may be an important consideration where landowners are unable to meet the costs of control.

In urban areas there are complex trade-offs between values and risk which may lead to management decisions that are not aligned with current government policy. We found that land managers were taking a risk-based approach and managing OPM where it posed the highest potential risk to people. A risk-based approach moves beyond a 'one-size-fits-all' or 'command and control' style of management and focuses efforts where it is most needed and socially acceptable. It allows for continued government involvement and guidance whilst permitting land managers to manage according to their needs and those of their neighbours. A risk-based approach also recognises there are difficult trade-offs to be made where there are different governance contexts and levels of risk to human, animal/biodiversity and oak health of OPM across multiple and varied sites. Taking into account the diversity of stakeholder values, perspectives and requirements may provide a more sustainable long-term solution and provide a SLO that ensures the future of oak in the city.

POSTERS

COLD HARDINESS IN *SPATHIUS GALINAE,* A LARVAL PARASITOID INTRODUCED FOR BIOCONTROL OF EMERALD ASH BORER IN NORTH AMERICA

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ABSTRACT

The ability of a biocontrol agent to acclimate to and survive the climate of intended introduction locations is a critical attribute for successful biological control of invasive pest. In an effort to control the invasive emerald ash borer (EAB) *Agrilus planipennis* Fairmaire, for protection of North American ash (*Fraxinus* spp.) trees, three biocontrol agents, one egg parasitoid and two larval parasitoid species, were introduced to the United States from the native range of EAB starting in 2007. While two of the three originally released parasitoids established self-sustaining populations across the U.S., *Spathius agrili* Yang (Hymenoptera: Braconidae) did not establish in the northern U.S. More recently, *S. galinae* Belokobylskij & Strazanac, a congener of *S. agrili* native to the Russian Far East, was approved for release in the U.S. in 2015, and is expected to survive northern U.S. climates better than *S. agrili*. In order to investigate the ability of *S. galinae* to acclimate to and survive below-freezing temperatures, we determined the cold tolerance of overwintering mature *S. galinae* larvae by measuring their supercooling point (SCP) after exposure to winter temperatures at four different field locations that span a gradient of plant hardiness zones. We observed a significant effect of overwintering location on SCPs of *S. galinae* larvae collected from field populations, with lower SCPs observed at locations with lower minimum ambient temperatures. Proportions of larvae emerging as adults did not differ between *S. galinae* overwintered at different sites suggesting that larvae were equally able to survive overwintering across locations by reducing their SCP. Our findings provide strong evidence that *S. galinae* can reduce SCP in response to below-freezing temperatures, leading to increased cold tolerance. The increase in cold hardiness of *S. galinae* in response to below-freezing temperatures may account for survival differences between *S. galinae* and *S. agrili* and should be considered in delineation of the optimal geographic range for biocontrol releases against EAB in North America.

ENTOMOPATHOGENIC FUNGI INFECTING SPOTTED LANTERNFLIES

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ABSTRACT

The spotted lanternfly, *Lycorma delicatula* (White), was first detected in southeastern Pennsylvania in 2014 and has since expanded its range to five more states and has been detected in four more. In fall 2017, spotted lanternfly cadavers with fungal outgrowth were sent to our lab and determined to be killed by *Beauveria* – a genus of fungal entomopathogens known to infect sap-sucking insects. In 2018, our lab made repeated visits to Berks County, Pennsylvania and we found epizootics occurring in fall, caused by the fungal entomopathogens *Beauveria bassiana* and *Batkoa major*. In 2019, we conducted field trials spraying *Beauveria bassiana* to manage spotted lanternfly populations in a public park in southeastern Pennsylvania. Preliminary results found that one application of *Beauveria bassiana* could kill approximately 50% of 4th instar nymphs or adults within 14 days. We will also share some work on lab and field-based bioassays that used biopesticides, with fungal entomopathogens as active ingredients, to control spotted lanternflies on grapes.

INFLUENCE OF TRAP COLOUR, TRAP TYPE AND TRAP HEIGHT ON DETECTION OF THE INVASIVE BEECH LEAF-MINING WEEVIL, *ORCHESTES FAGI* L.

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ABSTRACT

The beech leaf mining weevil, *Orchestes fagi* L. (Coleoptera: Curculionidae), is a pest of beech trees in Europe that has recently become established and invasive on American Beech in Nova Scotia, Canada. We tested the effects of trap type, trap colour and trap height on the numbers of *O. fagi* captured per trap with the objective of developing a survey tool to monitor the weevils' spread. We captured *O. fagi* in significantly greater numbers on yellow, green, or white traps than on light blue, dark blue, or red traps. There were no significant interactions between trap colour and trap design. Sticky triangular prism traps (20 cm tall x 12.5 cm wide on each of three sides) caught significantly more *O. fagi* than did non-sticky intercept traps regardless of colour. Green traps placed in the upper third of beech trees caught more *O. fagi* than green traps placed at shoulder height but the difference was not significant. Mean catch of *O. fagi* was significantly greater on yellow sticky triangular prism traps than on commercially sourced yellow sticky cards, due mainly to the larger surface area. Our results suggest that yellow or green sticky prism traps would be useful tools for monitoring the spread of *O. fagi* in North America.

THE RELIABILITY OF GENITALIA FOR MONITORING THE SPREAD OF THE INVASIVE WINTER MOTH IN EASTERN NORTH AMERICA

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ABSTRACT

Winter moth, *Operophtera brumata* (WM), is an invasive species to North America that causes widespread defoliation to deciduous trees and fruit crops. Winter moth is currently established in multiple states across the United States as well as multiple provinces across Canada. Pheromone-baited traps have been widely used to document the presence of winter moths in the United States. Unfortunately, a native species, the Bruce spanworm, *Operophtera bruceata* (BSW) uses the same pheromone which consists of a single volatile compound, in contrast to the blend of compounds typical for many insect species. As a consequence, traps everywhere in North America fill up with one or both species, and they are virtually impossible to distinguish based on wing coloration. In previous studies, a subtle difference in the male genitalia (called the uncus) was proposed to distinguish WM and BSW, however; as these two species are known to hybridize in the invasive range of WM, it is unclear how reliable this measurement is for identification of pure or hybrid individuals. Subsequently, DNA sequences of the barcoding section of the CO1 gene and the nuclear gene G6PD have been shown to readily distinguish between two species, and the G6PD gene can be used to identify F1 hybrids. Here we test the accuracy of these measurements by comparing morphological analyses with molecular identifications. We collected moths across an East to West transect in Massachusetts, and then measured the width of the uncus at two points (termed the "tip" and the "middle"). Individuals were then genotyped using polymorphic microsatellite loci and identified as either pure BSW, pure WM, or hybrids using the Bayesian assignment software Structure. We found that both measurements were highly significant between pure species, with the middle measurements showing a mean difference of 42.2 μm ($t_{431.3}$ = -30.83, p<0.001) and the tip measurement showing a mean difference of 40.76 μm ($t_{419.5}$ = -32.51, p<0.001). By comparing morphological identifications (using tip measurements of < 108 μm classified as BSW, > 132 μm was classified as WM, and 108 μm ≥ x ≤ 132 μm as hybrids), we found that 95% of BSW specimens were correctly identified, 92% of WM specimens were identified correctly, while only 4.5% of hybrids were identified correctly. Our results indicate that uncus measurements can be a useful marker for performing preliminary species-level identifications, though molecular analysis are required for accurate assignment of hybrids and for uncus measurements that fall in intermediary ranges.

EFFICACY OF TRUNK INJECTION AND BOLE SPRAY TREATMENTS AGAINST SPOTTED LANTERNFLY AND ASSOCIATED SOOTY MOLD PRODUCTION

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ABSTRACT

The spotted lanternfly (SLF), *Lycorma delicatula (White),* an invasive planthopper native to southeast Asia, was discovered in Berks County, PA in 2014. It has since spread to additional counties in southeast PA, DE, MD, NJ and northern VA, and sighted in CT, MA, NY and WV. Direct control option for SLF are limited. We were interested in determining the efficacy of the efficacy of systemic insecticides (imidacloprid, azadirachtin and acephate) and two experimental active ingredients (P and C) using trunk injection and/or bole spray techniques against different SLF life stages and associated sooty mold. Imidicloprid injections and Experimental P bole spray treatments provided the best overall protection of host trees by causing high levels of mortality, thus reducing numbers on the trunk, feeding on the host, and low levels of sooty mold. The acephate injection did not appear to cause much in the way of direct mortality, rather it appears that it deterred nymphs and adults from feeding and/or staying on the host, thus reducing sooty mold production and egg laying. Experimental formulation C and azadirachtin do not appear to be activity against SLF. However, these and the other treatments will be monitored in 2020 to determine their effect on egg viability and length of residual activity.

METHODS FOR RECOVERING *OOBIUS AGRILI* HUANG AND ZHANG (HYMENOPTERA: ENCYRTIDAE), AN INTRODUCED EGG PARASITOID OF EMERALD ASH BORER, *AGRILUS PLANIPENNIS* FAIRMAIRE (COLEOPTERA: BUPRESTIDAE)

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ABSTRACT

Oobius agrili is an egg parasitoid that is being introduced into North America as part of a classical biological control program for emerald ash borer, an exotic wood-boring beetle from Asia that threatens the nation's ash (*Fraxinus*) resource. Recovering *O. agrili* at release sites is challenging due to its small size (ca., 1mm) and the difficulty of locating emerald ash borer eggs that are laid in bark cracks and crevices. We compared four *O. agrili* recovery methods: 1) rearing adults from bark (bark rearing); 2) sifting field-collected bark to locate parasitized emerald ash borer eggs (bark sifting); 3) placing sentinel emerald ash borer eggs in screened envelopes on ash trees and examining for parasitism (sentinel eggs); and, 4) placing yellow pan traps on ash trees for capturing adults (yellow pan traps). In 2016, we applied all four methods to each of 40 trees at 4 sites where *O. agrili* was established in Michigan. In 2017, we applied all four methods to 10 trees at 3 sites. In 2018, we applied all methods except sentinel eggs to each of 10 trees at 3 sites. Mean number of *O. agrili* recoveries and trees positive for *O. agrili* were compared among sampling methods for each year. Results demonstrated that yellow pan traps and bark sifting recovered *O. agrili* at all sites and during all years, and consistently had a higher percentage of *O. agrili* positive trees and number of *O. agrili* recoveries. Bark rearing did not recover *O. agrili* at one site in 2016 when 40 trees were sampled, and one site in 2017 when 10 trees were sampled. Sentinel eggs recovered *O. agrili* at all sites in 2016 and 2017; however, low overall recovery numbers did not justify the amount of labor that this method required. The number of fresh woodpecker feeding holes on sample trees, which is evidence of recent EAB attack, was highly correlated with the number of *O. agrili* recovered with yellow pan traps, bark sifting, and bark rearing, and marginally correlated with sentinel eggs. Most *O. agrili* were field-collected from yellow pan traps and sentinel eggs between 400–1200 degree days (base 10°C; start date = Jan 1). The amount of labor and technology varies among the methods tested (i.e., rearing emerald ash borer adults or eggs; number of site visits required; sample collection and processing time), and each provides different information regarding *O. agrili* establishment success (i.e., *O. agrili* seasonal activity and presence; percent parasitism; presence of other emerald ash borer parasitoids).

THE NATIVE PARASITIC NEMATODE *DELADENUS PROXIMUS*: ASSOCIATED FUNGI AND IMPACT ON *SIREX NIGRICORNIS*

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ABSTRACT

As *Sirex noctilio*, an invasive woodwasp in the northeastern US, expands its range, attention has turned toward native siricid species to find potential natural enemies. In Australia, where *S. noctilio* has been present since the 1950s, and in other regions in the southern hemisphere, a control regime using *Deladenus siricidicola*, a parasitic nematode, has been developed. When parasitic, *D. siricidicola* can sterilize *S. noctilio* (the goal for biological control) but this doesn't always occur. The strain of nematode originally used worked well against the strain of *S. noctilio* in Australia, but it can work less well controlling other *S. noctilio* strains. In North America, *D. siricidicola* appears to have very little impact on *S. noctilio*. However, there is a native parasitic nematode, *Deladenus proximus*, that is known to effectively parasitize and sterilize the native *Sirex nigricornis* and we know it will also parasitize *S. noctilio*. A complication to *D. proximus* being used as a biological control agent is that these *Deladenus* species are dimorphic, having both parasitic and mycophagous life stages. Species and strains of *Amylostereum* spp. (white rot fungi and symbionts of *Sirex*) used by *S. noctilio* can strongly influence the viability of *Deladenus* for control. Thus, interactions between woodwasp/fungus/nematode strains must be considered and understood for efficient biological control.

Our research investigated the use of *Amylostereum* species and strains by native *S. nigricornis* populations in Louisiana and Arkansas, with the goal of identifying *D. proximus* that utilize *A. areolatum*, the fungus most commonly associated with the invasive *S. noctilio* when it is mycophagous. Thus far, most *S. nigricornis* sampled from Arkansas are associated with *A. chailletii* but in Grant Parish, LA, 26% of collected *S. nigricornis* carried *A. areolatum*. In the studied *S. nigricornis* populations, 6.7-42.6% were parasitized by *D. proximus* with mean sterilization rates of 75-88%. These results suggest that populations of *A. areolatum*-associated *D. proximus* occur and using these could increase the chances of successful biological control of *S. noctilio* using *Deladenus* in North America.

A NOVEL NON-STICKY TRAP DESIGN SUITABLE FOR THE MONITORING OF SOME JEWEL BEETLES (COLEOPTERA, BUPRESTIDAE) IN EUROPE

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ABSTRACT

A light, easy to handle and maintain non-sticky trap type could facilitate monitoring and detection of the Asian emerald ash borer *Agrilus planipennis* Fairmaire (EAB) and other jewel beetle populations. Sticky material-free jewel beetle catches are highly advantageous because there is no need to clean them with chemicals before determining to species. We carried out a series of trapping experiments in an ash (*Fraxinus pennsylvanica* Marshall) forest belt, an oak forest (*Quercus petraea* [Matt.] Liebl.) and in thuja (*Thuja* spp.) nurseries to test our latest experimental trap designs, which possess the above features of a non-sticky trap.

Our results suggest that the light green MULTz trap design may be suitable for catching a multitude of buprestid species in Europe, including the ash-related *A. planipennis* and *A. convexicollis* Redtenbacher, some of the European oak-related *Agrilus* species (*A. obscuricollis* Kiesenwetter, *A. graminis* Kiesenwetter, *A. angustulus* (Illiger), *A. laticornis* (Illiger)) and the cypress jewel beetle, *Ovalisia festiva* (Linnaeus).

The multi-funnel Lindgren trap is also an efficient non-sticky trap design for catching EAB. While MULTz traps catch sizeable numbers of jewel beetles, in a direct comparison of the two trap types in Russia, green 12-funnel Lindgren traps caught about twice as many EAB. The lower absolute catch numbers of the MULTz traps are compensated by easier handling at a much lower estimated cost. MULTz trap is also suitable to catch live jewel beetles, ensuring specimen quality.

ONTOGENY AND DEFENSIVE INDUCTION SHAPE THE DIVERSITY OF SECONDARY METABOLITES WITHIN GREEN ASH (OLEACEAE: *FRAXINUS*) IN NEW HAMPSHIRE

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ABSTRACT

The invasive emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) was accidentally introduced into North America three decades ago and has since spread rapidly across the United States. This has resulted in the death of millions of ash trees (Oleaceae: *Fraxinus*), severe ecological damage to natural and managed forests, and billions of dollars in economic losses. In North America, *Fraxinus* do not share a coevolutionary history with *A. planipennis*, allowing the beetle to quickly colonize and kill its hosts. While all *Fraxinus* encountered by *A. planipennis* appear to be susceptible to the beetle, smaller diameter trees experience reduced colonization by *A. planipennis* compared to larger trees. We hypothesized that patterns of colonization by *A. planipennis* are explained by the chemical profiles of *Fraxinus*, and predicted that ash of different ages have different chemical profiles. Our hypothesis was evaluated by sampling and analyzing the phloem tissue of green ash, *Fraxinus pennsylvanica* Marsh., across four size classes with three treatments: control (no colonization or induction), colonization by moderate to high densities of *A. planipennis* larvae introduced experimentally as eggs, or defensive induction with 0.5 M methyl jasmonate (MeJa) painted onto the bark surface four times over seven days. All trees were covered in funnels of Tyvex sheeting to protect eggs from weather and control for this effect on other trees. The parasitoid *Tetrastichus planipennisi* was released over an eight-week period in August and September. All trees were removed and peeled in October of the same year (2018) and peeled, both to remove experimentally augmented populations of EAB and to assess EAB survival, larval development and parasitism rates.

Our preliminary analysis identified 115 unique compounds across all samples. Prior to treatment and in controls, trees did not significantly differ in the number of compounds or unique compounds present. After treatment with either MeJa or EAB-exposed trees, the two smallest size classes of trees had significantly greater numbers of compounds and more unique compounds compared to the two largest size classes of trees. We used non-metric multidimensional scaling to compare the chemical profiles of the four size classes of *F. pennsylvanica* in our study. Prior to treatment some compounds were shared amongst size classes, but there was a large divergence in the chemical profiles of ash phloem according to size class after defensive induction. Ongoing analyses will identify compounds driving these interactions and evaluate quantitative differences among compounds identified in our study as well as differential responses by EAB and parasitoids. Our research will provide insight into population dynamics of *A. planipennis*, as well as increases our understanding of defensive strategies of *Fraxinus*, informing horticultural or silvicultural strategies to maintain *Fraxinus*, in light of the current invasion by *A. planipennis*.

BEHAVIORAL RESPONSE OF THE SPOTTED LANTERNFLY EGG PARASITOID *ANASTATUS ORIENTALIS* TO CHEMICAL TRACES LEFT BY TARGET AND NON-TARGET ADULTS

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ABSTRACT

The spotted lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae) was first recorded in the United States in Pennsylvania in 2014 (Barringer et al. 2015), and it has since spread to several other mid-Atlantic states and is causing significant damage to grape production and poses risks to several other crops (Lee et al. 2019). Research to develop a classical biological control program targeting spotted lanternfly is underway. The egg parasitoid *Anastatus orientalis* (Hymenoptera: Eupelmidae) is one promising natural enemy being studied in biosecurity containment facilities to evaluate the ecological risks and benefits of potential release in North America. In initial no-choice host range testing, a native fulgorid, *Poblicia fuliginosa*, has shown intermediate levels of parasitism by *A. orientalis* compared to attack on spotted lanternfly. Previous research indicates that *A. orientalis* responds to kairomones left on surfaces by adult spotted lanternfly, initiating motivated searching behavior which likely increases host finding ability by the parasitoid (Malek et al. 2019). Here, we compare the response of *A. orientalis* to cues left on glass slides by spotted lanternfly to those left by the non-target *P. fuliginosa*.

Foraging behavior by *A. orientalis* differed from controls for all movement parameters evaluated: faster turning, greater distance moved, longer time spent on the slide, and a slower walking speed. Spotted lanternfly residues resulted in these same trends for three of the parameters tested when compared to *P. fuliginosa*, except there was no difference in angular velocity between the two species. *Poblicia fuliginosa* did not differ from controls in any comparison. Concentrations of kairomones on hexane-rinsed slides that had been exposed to adult planthoppers were too low to detect chemical components of the putative kairomone.

While initial no-choice host range tests show that *A. orientalis* can develop in the native *P. fuliginosa*, this study indicates that the non-target planthopper would not be detected as readily as the invasive spotted lanternfly. We will attempt to increase the concentration of spotted lanternfly chemical traces so that components altering parasitoid searching behavior can be identified. Further non-target testing is ongoing, and more research needs to be completed before a risk assessment can be developed for *A. orientalis* release.

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ANOPLOPHORA GLABRIPENNIS (COLEOPTERA: CERAMBYCIDAE) FLIGHT PROPENSITY

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ABSTRACT

The effects of mating status, sex, beetle age, host plant quality, temperature, and wind speed on the propensity of *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae) to take flight were evaluated using a free-flight test in the laboratory. Time to initiate flight, the angle of flight, and flight capability (when beetles were forced to take flight) were also evaluated. Host quality, mating status, beetle age, sex, and temperature, and the interactions among some of these were significant predictors of flight in *A. glabripennis* in one or more of the experiments however the time to initiate flight and distance flown were not affected by any of the factors evaluated. Angle of flight was affected by host quality and wind speed. Females assessed the host quality by chewing oviposition-type pits (even on the dry dead host stem sections) before making a choice to stay or take flight. Female flight propensity peaked at sexual maturity and declined thereafter. Both sexes had a higher propensity to take flight from a stem section of dry host material than did females from a fresh one. Angle of flight was also affected by host quality. Most males (78%) flew from fresh host stem sections at least once during the four mating-status/ages tested, while only 43% of the females flew at least once after chewing an oviposition pit. Flight propensity and distance flown increased with temperature and there was no voluntary flight at 15 °C. Flight propensity did not increase with wind speeds 0.0 – 1.0 m/s but no ascending flight was observed at 0.5 or 1.0 m/s. Time to flight initiation and distance flown were not affected by any of the factors evaluated. Understanding what conditions cause the beetles to take flight, and how those conditions might influence flight distances will be instrumental in refining the program boundaries and eradication protocols for this pest. Specifically, there is a need to identify which factors increase the tendency for mated females to disperse and effectively expand the infested landscape.

STREET PALMS AND THE POTENTIAL IMPACT OF A PALM PEST ON THE US MAINLAND

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ABSTRACT

The red palm weevil (*Rhynchophorus ferrugineus*) and coconut rhinoceros beetle (*Oryctes rhinoceros*) are globally important palm pests. If they or any other palm pest were to become established on the US mainland, the greatest impact would be felt in urban areas, where palms are commonly planted as street trees. Unfortunately, urban areas are not inventoried systematically in the US or elsewhere. To address this knowledge gap, and to define an upper limit on potential losses if a major palm pest became widespread, we estimated street palm counts for all populated places in 14 states (≈9400 communities) based on a limited number (N = 407) of existing street tree inventories. We used stochastic gradient boosting to estimate the palm proportion of each community's street tree population. In western states, this proportion was determined primarily by moisture regime, while in eastern states, it was most highly influenced by the frost-free period and coastal proximity. Socioeconomic factors (e.g., home value) were less important. Separately, we estimated average street tree density (trees / km of road) at a state or regional level based on refereed literature or our own geospatial analyses. We then combined the palm proportion and street tree density values with calculations of each community's total street length. Altogether, we estimate that there are roughly 4 million street palms on the US mainland, with most in Florida (≈63%) or California (≈18%). Managing pest-affected street trees (including possible removal and replacement) can be costly, so a highly invasive palm pest could have a substantial economic impact, particularly in those two states.

SPOTTED LANTERNFLY NYMPHAL RESPONSES TO TEMPERATURE

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ABSTRACT

Accurate phenology models based on the responses of Lycorma delicatula (SLF) to a broad range of temperatures are needed for predicting when monitoring for SLF should occur, when the right stage is present for application of control methods, and what regions of the US are likely to support SLF populations. In 2019, a total of 96 SLF egg masses from the wild from five different sites in Pennsylvania were collected for the experiment. A group of 20 first instar SLF that hatched the same day were placed in a rearing tube containing a single potted Ailanthus altissima plant. Six rearing tubes containing first instar SLF were placed at each of the following constant temperatures: 10°C, 15°C, 20°C, 25°C, 30°C, 35°C, and 40°C. Newly molted SLF were relocated to a freshly prepared rearing tube with others that molted the same day for that temperature treatment. Number of days in each instar or of survival for each individual were calculated.

Most first instar larvae died between 21 and 35 days at 10°C. At 35°C the first instars that were unable to molt died before 35 days. First Instar survival in the15-30°C treatments was between 60-80% until 63 days then all but 30% of the 15°C nymphs died slowly to 105 d. At the second instar, most nymphs died by 35 d at 15 and 35°C. Survival of second instars was similar at 20 and 25°C (>85%) but lower at 30°C (~65%). Survival of the third (<30% molting) and fourth (<20% molting) instars was similar between 20 and 30°C.

Based on the Briere model, the lower and upper thresholds for development for the first instar were estimated to be 13 and 44 °C, respectively. The lower threshold for second instars was estimated to be 12°C using the Briere and 9°C for the linear model. The upper threshold for the second instar was estimated to be 35°C. The Briere model was not a good fit for the third instar data but the linear model estimated the lower threshold to be 8°C. No fourth instar models could be fit because there were too few individuals that made it to adult. Temperatures at which first instars could develop were broader that those at which the later instars could develop. Using the developmental thresholds degree day requirements for each of the first three instars were estimated. The degree day (DD) requirements for each instar increases but the base temperature decreases. The estimated DD ranges were close to those observed in the field but extend to higher DD which might be expected since we used a broad temperature range that included temperatures near the upper and lower developmental thresholds. Future work will be needed to estimate the developmental thresholds and DD for the fourth instar and to evaluate temperature effects on adults.

PREDATION OF SPOTTED LANTERNFLY (*LYCORMA DELICATULA*)

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ABSTRACT

By the necessity of evolution, most prey organisms have specialized methods of defense against predation. However, when a prey organism is introduced to a new environment with previously unfamiliar predators, their defense mechanisms may or may not be effective. Should the prey organism's defenses be effective against the predators of its new environment, this may contribute to the spread and abundance of the new organism. Spotted lanternfly (*Lycorma delicatula*; Hemiptera: Fulgoridae, SLF) have striking aposematic coloration, a powerful jumping reflex, and have been reported to contain alkaloid chemical defenses in their native environment in China. These organisms have spread rapidly in Pennsylvania since their introduction, feeding on trees and bushes and causing significant issues in Pennsylvania's agriculture and forestry. Native predators, save for a select few, have not been observed to be interested in preying upon these insects, and it is unknown if defenses of the SLF are truly preventing predation. Understanding the defenses of SLF could provide a new perspective in developing methods of preventing the spread of SLF. Three studies were conducted to examine the defenses of SLF: (1) plasticine models were used to examine aposematic coloration, (2) samples of SLF examined through Thin Layer Chromatography were used to identify ajmalicine and ailanthone, cytotoxins that SLF reportedly contained in the Chinese and Korean populations respectively, and (3) mesocosm predation experiments were used to identify the impact of SLF jumping reflex and other unknown defenses. The plasticine models contained markings consistent with avian predation, the Pennsylvania population was found to not contain ajmalicine, and green lacewing larvae and Chinese mantises did consume SLF nymphs in mesocosm experiments. This research demonstrates that the effectiveness of prey defenses may change with species introductions, a phenomenon that could be potentially exploited by targeted management interventions of problematic species in their introduced ranges.

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PLACING GREEN TRAPS IN THE UPPER CANOPY OF ASH TREES SIGNIFICANTLY IMPROVES DETECTION OF EMERALD ASH BORER

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ABSTRACT

The current method for survey of emerald ash borer (EAB) in Canada uses green sticky prism traps baited with *Z*-3-hexenol and *Z*-3-lactone placed in the low-mid canopy of ash trees on the sunny aspect, about 5 m above the ground. However, sticky traps are messy, not reusable, and in some studies have caught fewer EAB than green Fluon-coated multifunnel traps. Setting a trap 5 m above the ground is relatively easy by using a long pole with a hook on the end, but setting trap in the upper ash canopy is also relatively simple and may significantly increase the probability of detecting EAB in low density populations. Our objectives were to determine effects of trap design and trap height on mean trap catch of EAB and rate of detection (% traps positive). We compared four treatments: 1) green Lindgren 12-funnel in upper canopy; 2) green Lindgren 5-funnel in upper canopy; 3) green sticky prism in upper canopy; 4) green sticky prism 5 m above ground (the latter is Canadian Food Inspection Agency standard survey protocol for EAB). All traps in the upper canopy were set with ropes using a "Big-Shot" and baited with *Z*-3-hexenol and *Z*-3-lactone; the funnel traps were treated with Fluon. Treatments were replicated 17–19X in randomized complete block design at each of two sites with low density EAB populations: Québec City and Halifax. Ash trees acted as blocks, i.e., all 4 trap treatments were placed on the south side of the same tree. Traps were up from late June to September 2019 and checked weekly or bi-weekly. Season total EAB catches per trap were pooled from both sites and analyzed by generalized linear mixed models; detection rates (presence, absence) were analyzed by Cochran's Q test. Mean catch of EAB was significantly greater in 12-funnel traps in the upper canopy than in any other trap treatment. Mean catches in the 5-funnel trap and prism traps placed in the upper canopy were similar to each other and significantly greater than those in the prism traps set 5 m above the ground. Upper canopy traps detected EAB in 86–89% of trap blocks, regardless of trap type, and performed significantly better than prism traps placed 5 m above the ground, which detected EAB in only 50% of blocks.

A SURVEY OF THE POTENTIAL POLLINATORS OF BLACK CHERRY

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ABSTRACT

Black cherry (*Prunus serotina*) is an economically and ecologically valuable tree. Pennsylvania grows the highest quality black cherry in the world, with sales of cherry lumber and products accounting for a significant portion of the state's timber sales. However, since 2000 the USDA Forest Service and the Pennsylvania Bureau of Forestry have documented a dramatic decline in the regeneration and seed production of black cherry. It has been hypothesized that one of the factors underpinning this decline is a lack of pollination. Black cherry requires insect pollination to produce viable seed, however, little is known about the pollinator communities present in forested landscapes and the services they provide for flowering timber trees such as black cherry. The objective of this study was to determine the potential pollinators of black cherry. At three locations across Centre county, platform traps were deployed at low and high levels in the canopies of three flowering black cherry trees. Each platform trap consisted of three colored bowls, white for flies, blue for bees, and yellow for all other insects. Canopy observations were also completed amid flowering, during which all insects interacting with the blooms were hand collected. Observations and hand collections yielded high counts of fungus gnats (*Sciaridae*) and mining bees (*Andrenidae*), indicating their potential importance. Conversely, these insects appeared in low counts in bowl traps. These results suggest that standard methods of assessing insect communities in flowering trees (bowl traps) are not sufficient, and thus new approaches need to be developed for large-scale sampling.

SPOTTED LANTERNFLY *(LYCORMA DELICATULA)* HONEYDEW VOLATILES ATTRACT CONSPECIFICS

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ABSTRACT

The Spotted Lanternfly (SLF) (*Lycorma delicatula* (White)) is a phloem-feeding planthopper native to China that is now invasive to the U.S. SLF attacks and inflicts serious damage on several plant species, including grapes, hops and a host of native deciduous hardwood trees. SLF are known to aggregate in large numbers, but the precise mechanism behind this behavior is not yet known. Research into chemical attractants that may mediate aggregation and mate-finding in SLF is underway, with the goal of developing potent and specific lures for monitoring and managing this pest. SLF excrete copious amounts of honeydew while feeding. Honeydew is a source of semiochemicals in some other insect species. We described the volatile profile of adult SLF honeydew and tested compounds for antennal and behavioral activity using gas chromatography coupled with electroantennographic detection (GC-EAD), and dual choice olfactometer bioassays. Three ketones – 2-heptanone, 2-octanone, and 2-nonanone – were identified as attractants in the y-tube olfactometer, with 2-heptanone being attractive to males while the other two ketones attracted females. A fourth compound, benzyl acetate, elicited strong antennal responses and significant attraction in the y-tube for both sexes. Lures containing benzyl acetate and the ketones have been field tested and results are currently being analyzed. Additional lure development and field testing is planned for the future.

A NEW HOPE: ASH EMBRYOGENIC RESEARCH FOR CREATING EMERALD ASH BORER-RESISTANT ASH CLONES

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ABSTRACT

Genetically-based resistance or tolerance to emerald ash borer (EAB; *Agrilus planipennis*) existing in the North American ash populations may offer a route to restoration of these valuable trees. Individual native white ash (*Fraxinus americana*) and green ash (*F. pennsylvanica*) trees have been identified as potentially EAB-resistant by their persistence in populations where EAB-induced mortality exceeds 99%. These so called "lingering ash" trees constitute a potential source of genetic resistance that could be used in selection and breeding programs, and combined with mass clonal propagation to generate EAB-resistant varieties for restoration programs. Embryogenic cultures were initiated from immature zygotic embryos from open-pollinated (OP) seeds collected from lingering white ash trees in Michigan in 2015. In 2018, we initiated cultures from crosses made between lingering green ash parents by USDA Forest Service personnel in Delaware, Ohio. Following induction and proliferation of embryogenic cultures on semisolid induction-maintenance medium (IMM) with 2 mg/L 2,4-D, they were transferred to liquid IMM to establish suspension cultures. Suspension cultures were size-fractionated on stainless steel sieves and the desired cell-cluster size range was collected on nylon mesh and plated on semisolid embryo development medium (same as IMM but lacking 2,4-D) to produce synchronous populations of somatic embryos. These embryos were used in experiments to test different plantlet production treatments, which indicated that germination (radicle elongation), shoot production and conversion (complete plantlet production) were all increased by treatment with 1 mg/L gibberellic acid. Cold treatment also improved germination and conversion. Somatic seedlings were potted in potting mix and acclimatized to greenhouse conditions using clear plastic dome-covered trays containing water-saturated perlite. Ash somatic seedlings derived from OP explants grew rapidly following transfer to potting mix and 42 somatic seedlings representing 10 ash clones were successfully acclimatized, grown in the greenhouse and planted in a preliminary field test, along with EAB-resistant (*Fraxinus mandshurica*) and EAB-susceptible control seedlings. Trees planted in April 2018 established well during the 2018 growing season with the loss of only 3 somatic seedlings. Trees leafed out strongly in April 2019 and continued growth through the season. The highest growth rate during 2019 was observed for lingering white ash somatic seedlings, followed by conventional green, white, and Manchurian ash seedlings. We are currently monitoring these trees for EAB activity to assess pest selection and relative susceptibility to EAB. Future work will include an assessment of EAB colonization activity on trees planted in a common garden study.

EVALUATION OF COMMERCIAL PHEROMONE LURES FOR TRAPPING VELVET LONGHORNED BEETLE, *TRICHOFERUS CAMPESTRIS*

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ABSTRACT

The velvet longhorned beetle, *Trichoferus campestris* (Faldermann) (VLB; Cerambycidae: Cerambycinae: Hesperophanini), is native to east Asia where it is a pest of a wide range of tree species, including orchard and timber trees. Larvae of VLB can be transported in wood packing material, and individuals are frequently intercepted in port and warehouse facilities. Populations of VLB have established outside of the native range, and may threaten North American agriculture and forestry. We recently identified (2*R*, 4*R*)-2-hydroxy-4-methyl-1-phenylhexan-3-one (”trichoferone”) as the major component of a volatile, male-produced attractant pheromone of VLB. The United States Federal and State Cooperative Agricultural Pest Survey program (CAPS) recently incorporated commercially-produced lures into survey protocols. We evaluated the 2019 CAPS lures and two other commercially-produced prototype lures during field bioassays to assess the effects of formulation and lure design on capture of VLB. Traps baited with CAPS lures and one of the prototype lures (6 mil LDPE film) captured significantly more adult VLB than did traps containing lures constructed from 7 mil HDPE film, or controls. We also assessed release rate and longevity of commercial lures through gravimetric analysis. Within individual manufacturing lots, release rate and lure longevity varied substantially from manufacturer-reported specifications. We plan additional assays in Summer 2020 to improve quality control and standardization. The results of our work will assist stakeholders in surveillance of VLB.

EARLY DETECTION AND ERADICATION PROGRAM NEEDED FOR *TRAPA BISPINOSA*, A NEW SPECIES OF WATER CHESTNUT IN THE POTOMAC RIVER WATERSHED

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ABSTRACT

Eurasian water chestnut (*Trapa natans* L.) has been present in the United States since the 1880s and is a well-known invasive species. A new introduction of a relative of *T. natans* was discovered in Virginia. It was recognized as new by fruits that have 2 horns in contrast to the 4-horned fruits associated with *T. natans*. This new species was verified in 33 Northern Virginia locations by 2018. To determine its distribution scientists verified the species of any *Trapa* reported to local herbaria, extension agents, pond managers, and online invasive species databases. The locations and information on the first year of colonization, current size of colonies, recent management efforts, and verification photos of the 2-horned fruit or pink flower were incorporated into the USGS non-indigenous aquatic species database (nas.er.usgs.gov). All the recent reports (2000 to 2018) are in Fairfax and Prince William counties in Virginia. Herbaria specimens showed it was reported in Westmoreland and Stafford counties in Virginia in 1995. Scientists conducting research on this 2-horned type of *Trapa* have not found this type of Water Chestnut in other states in the NE US. It has only been reported in Virginia and in the Potomac River watershed. By 2019 a study of populations around the world revealed that its name is *T. bispinosa* Roxb. var. *iinumai* Nakano, and its DNA and morphology matched samples of this morphotype in Taiwan. Literature review and current data suggest that early detection and rapid response could help manage the distribution and spread of *T. bispinosa.*

EVALUATION OF GENETIC DIVERSITY OF ASIAN CALLERY PEAR, *PYRUS CALLERYANA*

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ABSTRACT

Pyrus calleryana Decne., commonly known as callery pear, is a popular ornamental tree mostly planted in commercial and residential areas. The species was brought in the United States (US) from China with the initial idea of breeding and developing fire blight pathogen (*Erwinia amylovora* AUTHORITY) resistance in *P. communis*. Today, callery pear is regarded an invasive species in most of the eastern and southern states of the US. The mechanisms behind the massive spread and invasiveness of the species are not well understood. To address this issue, the study aims to assess the genetic diversity of the original Asian non-cultivated specimens and early US-naturalized cultivars of callery pear. Present-day callery pears are derived from those Asian pear cultivars (either through naturalization or cross-pollination with local pears). The overarching objective of the study is the evaluation of the genetic diversity of original Asian pear specimens using microsatellite loci. The study aims to develop the molecular markers (genomic Simple Sequence Repeats [SSRs]) and to investigate their cross-amplification into related *Pyrus* species that originated from Asia, North Africa, and Europe. We hypothesize that the original Asian callery pear specimens will be genetically diverse and there will be genetic relatedness and similarities between them and the early developed cultivars. Asian pear specimens' leaf samples collected from herbaria/arboreta were used for genomic DNA extraction (n = 100). The SSR markers were developed based on the pear genomic assembly and 29 of them were used for the PCR amplification. PCR products are being analyzed on QIAxcel Capillary Electrophoresis System. The data retrieved from QIAxcel will be analyzed using R/RStudio and the population genetic software packages such as Adegenet, MASS, Poppr and Hierfstat. We expect to find limited cross-amplification of our SSR markers into related pear species. The study will help evaluate the current genetic diversity and diversity patterns within callery pear from Asian specimens and early developed cultivars. Once the genetic basis of the species is learned, it will augment the study of the invasive callery pear populations sampled across the US.

THE INVASIVE BEECH LEAF-MINING WEEVIL, *ORCHESTES FAGI*, IS KILLING MATURE AMERICAN BEECH IN NOVA SCOTIA

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Abstract

The beech leaf-mining weevil, *Orchestes fagi* (L.), is native to Europe where it commonly attacks European beech. The weevil was discovered infesting American beech in Halifax and Cape Breton Island, Nova Scotia, Canada in 2012, but anecdotal reports of defoliated beech in the Halifax area as early as 2006 suggest it established 5–10 years prior to its discovery. Our objectives were to estimate the impact of *O. fagi* on American beech in forested sites and urban areas, as well as its economic impact on owners of residential properties with mature American beech. In 2014, we established fifteen 11.28 m fixed radius plots in forested sites containing a total of 260 American beech at Sandy Lake, Oakfield, and Mt. Uniacke (n=5 plots per site), where weevil infestation levels were high, moderate, and nil, respectively. At the same time we recorded the degree of cankering by beech bark disease on the main stems of each tree. Plots were visited annually to record tree mortality (2014–2019) and percentage of leaves with larval mines or adult feeding (2016–2019). We surveyed residents of Halifax in 2016 and 2018 to determine the rate of beech mortality and costs of tree removal in urban residential areas. Between 2016 and 2019, the percentage of leaves mined by weevil larvae increased from 6% to 59% at Mt. Uniacke, from 48% to 83% at Oakfield, and from 87% to nil at Sandy Lake (because there were too few leaves to sample). During the same period, cumulative beech mortality increased from 35% to 48% at Mt. Uniacke, from 10% to 70% at Oakfield, and from 88% to 94% at Sandy Lake. Tree mortality was not associated with severity of beech bark disease, except at Mt. Uniacke which had the fewest years of defoliation by the leaf-mining weevil. Mortality rates were lower in urban areas (32% in 2016, 44% in 2018) but direct costs to property owners who hired arborists to remove dead beech trees were significant, averaging $1934 ($300–$6600) per resident in 2018.

PRELIMINARY RESULTS OF TRAPPING FOR *LARICOBIUS NIGRINUS* (COLEOPTERA: DERODONTIDAE) USING LARGE GRAVITY FUNNELS TO CATCH LARVAE DROPPING FOR PUPATION IN THE SPRING

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ABSTRACT

Laricobius nigrinus Fender has been released in Pennsylvania for nearly 20 years, as a biocontrol for hemlock woolly adelgid, a severe pest of hemlock forests (HWA, *Adelges tsugae* Annand) (Hemiptera: Adelgidae). Monitoring for its establishment and distribution has been problematic over most of that time. The most common method, beat sheeting, focuses mostly on lower limbs and is more likely to have success only if adelgid is present at high densities. In this experiment, the trapping efficacy was studied in forests where *L. nigrinus* was originally released, however now HWA are present at low densities.

Larval traps following the design of Yanzhuo Zhang (Univ. Georgia Extension) were used, consisting of 1-meter square netting in a funnel shape with a catch bottle at the bottom containing antifreeze. They were placed at 9 sites in central Pennsylvania, with at least 7 traps at each site positioned below dense, eastern hemlock canopy. Traps were monitored every 1-2 weeks for 11 weeks, from March 25 to June 13, 2019 to catch larvae dropping from hemlock trees into the soil for pupation.

These preliminary results are based on having examined approximately 40% of the trap samples. Three of the nine sites yielded *Laricobius sp.* in samples collected on May 13 and May 20, 2019. So far, a total of 57 larvae were collected in 8 traps. DNA analysis (Virginia Tech.) on two larvae identified one as *L. nigrinus* and one as *L. rubidus*. Most of the larvae were collectedfrom a site in Rothrock State Forest with declining hemlock trees having few lower branchesavailable to check forHWA.

This method can detect the presence of *Laricobius sp.*, and it may be useful where adelgid levels are at very low densities but is quite labor intensive.

IT IS TIME TO PAY ATTENTION TO INTERNATIONAL REGULATIONS, SO STAY SHARP!

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ABSTRACT

New pest establishment in Oregon has highlighted problems with US import regulations. Oregon has a small major port and a relatively small population, yet it consistently receives new exotic species. Since Oregon Department of Agriculture started tracking exotic species establishment in OR in 2007, **118 new invertebrate species** have been found. This is an average of **9.1 new species** per year. Twenty of these were known economic pests, which works out to one economic pest found approximately every 7 months. The numbers fluctuate each year (a low of 3 in 2017 and a high of 21 in 2015), but the invasion shows no sign of letting up.

There is only so much that can be accomplished by individual states. The greatest benefit will be gained by preventing the entry of new pests into the country (or the continent!). This type of regulation occurs at the Federal level and is shaped by international agreemesnts.

There are many areas where law, policy, and enforcement could be improved. Internet-based commerce needs to be better regulated, more resources need to be allotted for inspection of imports (such as containers and live plants), states where new pests are intercepted need better communication with CBP and USDA APHIS, and more resources need to be allotted along with quicker responses to newly detected pests. Specific regulatory areas that need attention include the process of deregulating pests, ISPM 15 and the efficacy of wood treatments, and risks from imports from Canada.

OLFACTORY ASSAYS USING HEMLOCK TREE VOLATILESAS POSSIBLE ATTRACTANTS FOR TRAPS MONITORING *LARICOBIUS NIGRINUS* (COLEOPTERA: DERODONTIDAE)

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ABSTRACT

Laricobius nigrinus Fender has been released in Pennsylvania for nearly 20 years, as a biocontrol for hemlock woolly adelgid, a severe pest of hemlock forests (HWA, *Adelges tsugae* Annand) (Hemiptera: Adelgidae). Monitoring for its establishment and distribution has been problematic over most of that time. More efficient methods to detect populations of *L. nigrinus* would be helpful. This study tests plant volatiles from HWA infested hemlock branches for their attraction to *L. nigrinus* for possible use as lures in monitoring traps.

A literature review was conducted to identify possible chemical attractants and similar work performed previously. From that, four chemicals were identified: methyl salicylate, benzyl alcohol, myrcene, and nonanal. Using a Y-tube as an olfactometer, adult *L. nigrinus* attraction to individual chemicals and combinations was measured.

Combinations of all four chemicals showed some level of attractiveness, while individual chemicals did not appear to be attractive.

A lure containing all four chemicals would be the most likely to show promising results. Additional testing is needed.

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