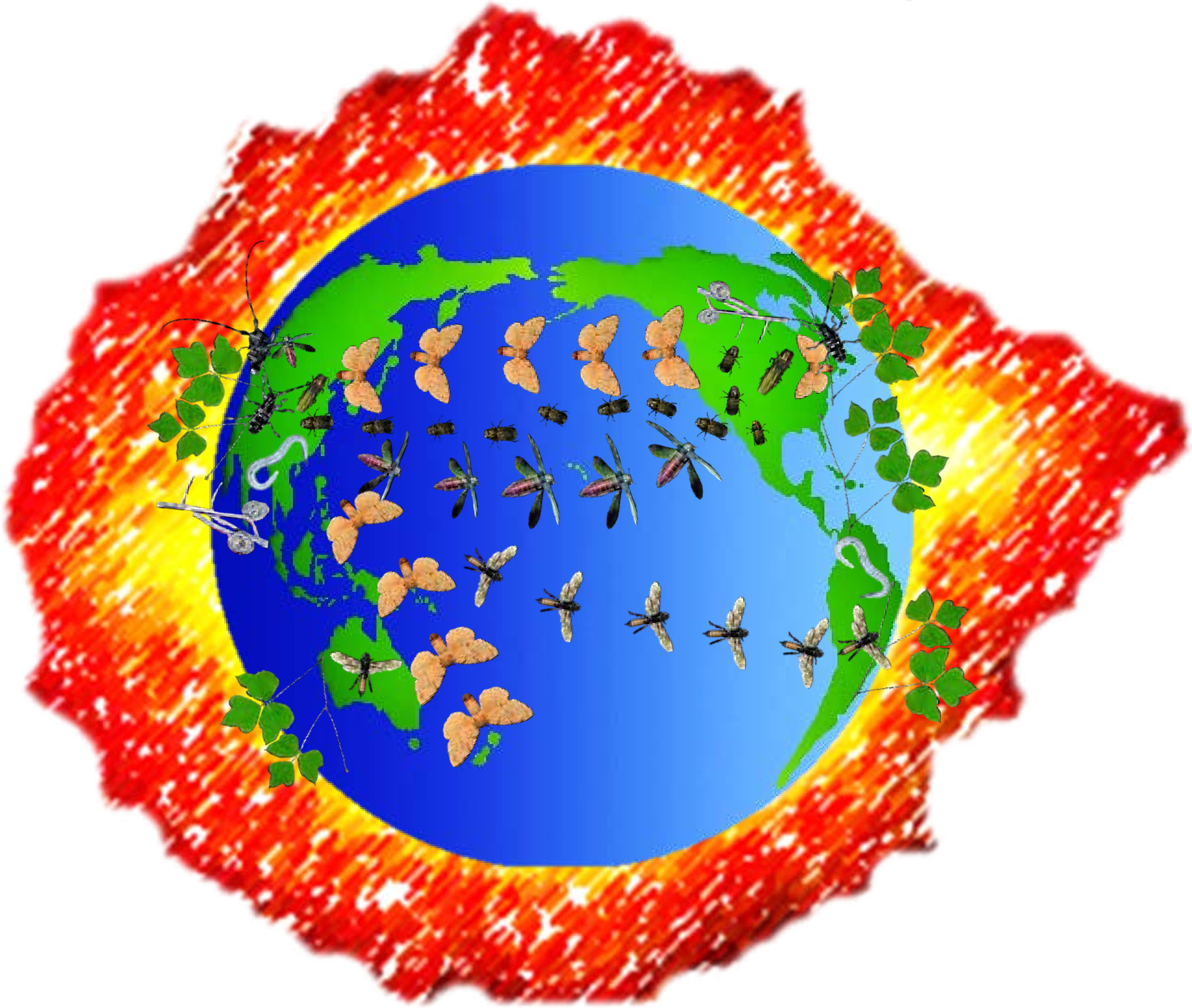
United States Department of Agriculture

XXVII USDA Interagency Research Forum on Invasive Species



Shared Problems – Shared Solutions

Annapolis, MD | January 12-15, 2016

US Forest Service

Forest Health Technology Enterprise Team

FHTET-2016-09
December 2016

The abstracts were submitted in an electronic format and were edited to achieve only a uniform format and typeface. Each contributor is responsible for the accuracy and content of his or her own paper. Statements of the contributors from outside the U. S. Department of Agriculture may not necessarily reflect the policy of the Department. Some participants did not submit abstracts, and so their presentations are not represented here.

Cover image and graphic: Melody Keena "Shared Problems – Shared Solutions".

Pesticide Precautionary Statement

References to pesticides appear in some technical papers represented by these abstracts. Publication of these statements does not constitute endorsement or recommendation of them by the conference sponsors, nor does it imply that uses discussed have been registered. Use of most pesticides is regulated by state and federal laws. Applicable registrations must be obtained from the appropriate regulatory agency prior to their use.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Federal Recycling Program

Printed on recycled paper

27TH
USDA INTERAGENCY RESEARCH FORUM ON INVASIVE SPECIES

January 12-15, 2016
Annapolis, Maryland

Compiled by:

Katherine A. McManus
USDA Forest Service, Northern Research Station, Hamden, CT

For additional copies of previous proceedings (through 2012) contact Katherine McManus at (203) 230-4330 (email: *kmcmanus@fs.fed.us*).

FOREWORD

This meeting was the 27th 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 Agriculture Research Service. The Group's original goal of fostering communication and providing a forum for the overview of ongoing research among the Agencies and their cooperators continues to be realized and facilitated through this meeting. This proceedings documents the efforts of many individuals: those who organized and sponsored the meeting, those who provided oral and poster presentations, and those who compiled and edited the contributions. The proceedings illustrates the depth and breadth of studies being supported by the agencies and their many cooperators and demonstrates the benefits and accomplishments that can result through the spirit of collaboration.

ACKNOWLEDGMENTS

The program committee would like to thank the four USDA agencies for their continued support of this meeting, the University of Delaware for assistance with the registration process, and the Management and Staff of the Loews Annapolis Hotel.

Thanks to Melody Keena for providing the cover artwork, "Shared Problems – Shared Solutions".

Program Committee Michael McManus, Joseph Elkinton, Jian Duan, David Lance, Therese Poland

Local Arrangements Katherine McManus, Therese Poland

Proceedings Publication USDA Forest Service Forest Health Technology Enterprise Team

Registration Assistance provided by Brooke Uhde and Heather Morgan of the University of Delaware

On-Site Assistance Rebecca Upton, USDA-APHIS, retired

We also acknowledge, *in memoriam,* Kurt W. Gottschalk. Kurt's dedication and contributions to his profession, to his coworkers, family and friends will not be forgotten. After his sudden passing in August 2015, it seemed fitting to recognize Kurt – in a small way – at the 2016 Research Forum. Kurt's vision for the forestry profession has recently been recognized further by the Society of American Foresters (SAF). Kurt was a strong advocate for the SAF Science Fund to be a well of support for members' scientific work. To honor and foster Kurt's vision, SAF has reimagined the Science Fund in his name and vision. The Kurt Gottschalk Science Fund will build on its mission and help "recruit, engage, develop, and diversify SAF's membership and the next cadre of leaders in natural resource professions."

In Memory of Kurt W. Gottschalk (April 30, 1952 - August 10, 2015)
Research Forester, USDA Forest Service

In 2015 we lost our scientific colleague and friend, Kurt Gottschalk, who played a pivotal role in US Forest Service Research, including serving as a co-organizer of the USDA Interagency Research Forum. Here we offer a short biography of Kurt in remembrance.

Kurt grew up on a farm near Bloomington, IL. He earned a B.S. in forestry at Iowa State University in 1974 and both his M.S. and Ph.D. in Forestry at Michigan State University in1976 and 1984. Kurt met his wife Janice Johnston in a community theatre group in Warren, PA, and married in 1980. They had two daughters, Stephanie and Katherine.

During Gottschalk's career he published over 130 papers, delivered hundreds of invited presentations, and participated in numerous training sessions, workshops, and field tours as an invited speaker and instructor. He consulted and gave presentations in England, France, Germany, Austria, Croatia, Hungary, Romania, Slovakia, Finland, Canada, Kyrgyzstan, Australia, and many areas across the U.S. He received a number of honors and awards including: Outstanding Hardwood Forestry Research 1995 (from the Hardwood Research Council), Certificate of Merit 1997 Awards Program for Excellence in Technology Transfer (US Forest Service Northeastern Research Station), Fellow Society of American Foresters 2001, and Outstanding Contribution to Silviculture 2005 (USDA Forest Service).

Kurt began his career with the Forest Service when he was an undergraduate student, working summers for the Fremont National Forest in Oregon. Upon finishing graduate school, he was hired as a Research Forester in Warren, PA, in 1979. With the formation of a new unit focusing on silvicultural methods for managing the gypsy moth, Kurt transferred to Morgantown, WV, in 1983. He became Project Leader of the unit in 1987, and continued serving as Project Leader for the rest of his career. When the Northern Station re-organized in 2008 he became Project Leader of a combined larger unit of 14 scientists in Morgantown, WV, East Lansing, MI, and Hamden, CT. At the time of his death in 2015, Kurt was the longest-serving Project Leader in the Forest Service. In that capacity, Kurt mentored many scientists and helped them in their careers.

Throughout his career, Gottschalk greatly influenced the course of research in the US Forest Service and elsewhere. Few people were as knowledgeable of protocol in the Forest Service as Kurt. Yet, he was not a stickler for rules but instead was a great resource for figuring out how to accomplish what needed to be done. During his career, Gottschalk left his mark on the US Forest Service in many ways, as well as on other organizations such as the Society of American Foresters and IUFRO (International Union of Forest Research Organizations). Kurt greatly influenced the lives and careers of many researchers and professionals in natural resource management for over 35 years. He remains greatly missed.

Contributed by Andrew Liebhold[1], Therese Poland[2], Katherine McManus[3], Robert Haack[3] and Michael McManus[3]
[1]USDA Forest Service, Northern Research Station, 180 Canfield St., Morgantown, WV 26505; [2] USDA Forest Service, Northern Research Station, 3101 Technology Blvd., Suite F, Lansing, MI 48910; [3] USDA Forest Service, Northern Research Station, 51 Mill Pond Rd., Hamden, CT 06514

In Memory of
Kurt W. Gottschalk, Research Forester
(April 30, 1952 - August 10, 2015)

Contributed by Andrew Liebhold, Therese Poland, Katherine McManus, Robert Haack and Michael McManus

Kurt grew up on a farm near Bloomington, IL.

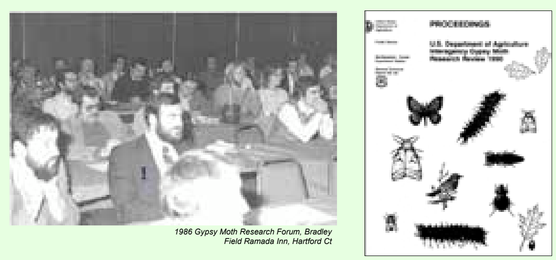
Kurt received a bachelor of science in forestry at Iowa State University in 1974. He earned both his masters degree in silviculture / forest ecology and his PhD in tree physiology at Michigan State University in 1984.

Kurt and Janice met in a community theatre group in Warren, PA, and married in 1980. They had two daughters, Stephanie and Katherine.

USDA Forest Service Laboratory, Morgantown, WV

Kurt began his career with the Forest Service working summers for the Fremont National Forest in Oregon. He was hired as a Research Forester in Warren, PA, in 1979. With the formation of a new unit focusing on silvicultural methods for managing the gypsy moth, Kurt transferred to Morgantown, WV, in 1983. He became project leader of the unit in 1987. He continued serving as project leader for the rest of his career. When the Northern Station reorganized in 2008 he became project leader of a large unit of 14 scientists in Morgantown, WV, East Lansing, MI, and Hamden, CT. At the time of his death in 2015, Kurt was the longest-serving project leader in the Forest Service. In that capacity, Kurt mentored many scientists and helped them in their careers.

Kurt was a member of his church choir and over the years served on many boards with the First United Methodist Church and Western Pennsylvania Conference of the United Methodist Church. Kurt's dedication to his church took him to Belize in August 2015 where he participated on a church mission to help build a home for a needy family. He passed away while on the mission trip, serving others and doing what he loved.



1986 Gypsy Moth Research Forum, Bradley Field Ramada Inn, Hartford Ct

Kurt was always a key organizer of the annual USDA Interagency Research Forum on Invasive Species. He served as editor or co-editor of the proceedings since 1991

Kurt in X Country

Kurt in X Country

Kurt in X Country

Kurt in X Country

During Kurt's career, he published over 130 papers, gave dozens of invited presentations, and participated in numerous training sessions, workshops, and field tours as an invited speaker and instructor. He consulted and gave presentations in England, France, Germany, Austria, Croatia, Hungary, Romania, Slovakia, Finland, Canada, Kyrgyzstan, Australia, and many areas across the U.S. He received a number of honors and awards including: Outstanding Hardwood Forestry Research 1995 Hardwood Research Council, Certificate of Merit 1997 Awards Program for Excellence in Technology Transfer, Fellow Society of American Foresters, and Outstanding Contribution to Silviculture 2005 USDA Forest Service.

IUFRO

Society of American Foresters

Kurt receiving SAF Fellow Award

Kurt was a member of the Society of American Foresters since 1974, and served the organization in various capacities, including serving on the Board of Directors. From 1996-2002, Kurt served as editor of the *Northern Journal of Applied Forestry*. Kurt was also active in IUFRO including service as coordinator of the IUFRO working party 1.01.06 - Ecology and Silviculture of Oak.

CONTENTS

Research Reports 26

Abstracts 48

PRESENTATIONS

Keynote Address

PHEROMONES FOR DETECTION AND MONITORING OF INVASIVE AND NATIVE CERAMBYCID BEETLES

Jocelyn G. Millar[1] and Lawrence M. Hanks[2]

[1]Department of Entomology, University of California, Riverside CA, 92521
[2]Department of Entomology, University of Illinois, Urbana IL, 61601

ABSTRACT

The beetle family Cerambycidae comprises about 35,000 described species, distributed across all continents except Antarctica. The beetles are essential components of natural ecosystems as primary decomposers of dead wood, while also opening up the resource to other insects and fungi. They also maintain forest health by culling diseased or weakened trees. However, a minority of species have the potential to be significant pests of natural and urban forests, and orchards. Some cerambycids are also known to vector severe plant pathogens such as pine wilt nematode.

Cerambycids are also some of the most invasive insects because of the ease with which their long-lived larvae are transported around the world by international commerce, in wooden pallets, packing cases, dunnage, raw logs, and finished wood products. The problem is exacerbated by the difficulty in detecting the larvae buried deep within the wood. Once in their new habitats, their populations can increase rapidly, in part because they have been released from the natural enemies with which they coevolved in their native countries. Their ranges can also expand rapidly, both by natural dispersal by the adults, and by long-distance movement of infested firewood or other woody materials by humans. Management of new invasions has been problematic because of the lack of sensitive and specific tools for detection and delineation of the range of new infestations, and for monitoring the efficacy of eradication efforts. Unlike many of the other major groups of pest insects, until very recently powerful attractants such as pheromones have not been available for use in detection and monitoring programs for cerambycids. In fact, up until a decade ago, the general consensus was that cerambycids probably did not use pheromones for long range attraction. Instead, it was thought that the sexes were brought together for mating by their mutual attraction to host plants, with males then actively patrolling up and down tree trunks to locate females.

However, over the past decade, a large body of evidence has accumulated which indicates that this dogma was almost certainly incorrect. **Contrary to previous beliefs, this new evidence suggests that a large number and possibly a majority of cerambycid species do indeed use powerful long-range attractant pheromones**, as well as at least two types of short-range pheromones. Thus, we now have powerful tools available for detection and monitoring of a number of cerambycid species, including both native species which may become pests, and invasive species.

The volatile pheromones used for long-range attraction are of two different types. First, male beetles in the cerambycid subfamilies Cerambycinae, Spondylidinae, and Lamiinae sex-specifically produce aggre-

gation pheromones that typically attract both sexes. The males produce relatively large amounts of these pheromones (>0.1 mg per hour), and so pheromone lures must contain correspondingly high doses of 50-100 mg of pheromone (or more) in order to have an average release rate of several milligrams per day. The activity of these pheromones varies with species: in some species, the pheromones are attractive by themselves, whereas in others, attraction to the pheromones is increased by host plant volatiles. In the most extreme cases, neither the pheromones alone nor the host plant volatiles alone are attractive, but when combined, they are highly attractive. The use of combination lures containing both pheromones and host plant volatiles is particularly important for species infesting conifers.

Conversely, from the available data, it appears as though species in the subfamilies Prioninae and Lepturinae use female-produced sex pheromones, which can attract males from distances of several hundred meters. These are produced in much smaller amounts than the male-produced aggregation pheromones described above, but males are very sensitive to them, so that lures only need to contain a milligram or less pheromone. To date, no volatile pheromones have been identified from the three remaining cerambycid subfamilies, but these subfamilies are all small.

In addition to volatile pheromones, cerambycids use contact pheromones for short-range confirmation of species and sex, once the male and female have been brought together by the volatile pheromones described above. These contact pheromones consist of a subset of the long-chain, nonvolatile lipids on the beetle's cuticle. They are female-specific, or present in much larger proportions on the female cuticle than that of the male. Thus, as soon as a male touches a female, the presence or absence of the contact pheromone allows the male to immediately determine a female's species and sex, to ensure that he is trying to mate with a female of his own species.

There is fragmentary but increasing evidence that cerambycids also may use trail pheromones. Specifically, a female may leave "footprints" which can be detected by a male, which he can follow to find the female. It is unclear whether females actively deposit these residues, or whether they are just wiped off the female passively as she walks over a substrate. It may be more difficult to work out methods of exploiting these pheromones for practical purposes because they are nonvolatile, so that males have to contact them for any behavioral response to occur.

Having powerful semiochemical attractants available for monitoring purposes is useless if you do not also have effective traps. Another crucial factor in the development of pheromone baits for cerambycids has been a dramatic increase in the effectiveness of traps. A number of sequential studies have shown that either cross-vane panel intercept traps or multifunnel Lindgren traps are probably the most effective trap type for detection and monitoring of cerambycids. However, the single most important factor in improving trap efficiency has been to coat the trap and collection cup surfaces with the emulsified Teflon known as fluon, to render the surfaces too slippery for beetles to hang on to. **Use of fluon on traps can increase trapping efficacy more than tenfold**. Use of collection cups containing a killing solution (e.g., propylene glycol, or water with detergent) also enhances trap retention.

Overall, in the past ten years, attractant pheromones or likely pheromones have been identified for what is now likely several hundred species, and the numbers are growing almost daily. Several trends have started to emerge from this accumulated data. First, as mentioned above, it appears as though the use of attractant pheromones may be divided along subfamily lines: to date, all pheromones identified for species in the Cerambycinae, Lamiinae, and Spondylidinae have been male-produced aggregation pheromones, whereas all known pheromones from the Prioninae and Lepturinae are female-produced sex pheromones. As more pheromones are identified, it will remain to be seen whether this clear breakdown along subfamily lines will hold up. Furthermore, it is likely that this division among subfamilies as to what types of volatile pheromones are used reflects some fundamental difference in the biology or ecology of these subfamilies, but it is not yet clear what that might be.

Second, as a general trend, it appears that pheromone structures are highly conserved among closely and even more distantly related species. For example, numerous species in the subfamily Cerambycinae worldwide use 3-hydroxyhexan-2-one as a pheromone component, whereas a number of lamiine species use fuscumol, fuscumol acetate, or monochamol as their pheromones. Where pheromone components are shared among sympatric species, the species have worked out alternate mechanisms to avoid cross attraction, such as having different daily activity periods, or restricting their activities to specific strata within the forest canopy. This widespread sharing of pheromone structures has several practical ramifications. First, a trap baited with a single pheromone may catch a number of species, rather than just one. Second, because a given pheromone structure is strongly associated with specific genera, tribes, or even a subfamily, knowing the taxonomic position of a new invasive species provides us a strong indication as to which sex is likely to produce attractant pheromones, and what the pheromone structures are likely to be. This information could be enormously helpful when trying to mount a rapid and effective control or eradication program for a new invader.

Third, the structures of the pheromones used by the different subfamilies are generally quite different from one another. As a consequence, these pheromones are unlikely to interfere with each other if they are deployed in mixtures which constitute "generic" lures designed to attract a wide variety of species. Again, this is enormously useful for practical purposes, because one trap baited with a generic blend of pheromones can take the place of a number of traps, each baited with a single pheromone.

The following examples of recently identified pheromones for invasive cerambycid species provide some sense of how far we have come in a very short time. Most of these pheromones could be deployed essentially immediately in surveillance programs, because their structures are relatively simple and easily synthesized, and some are already commercially available.

1. *Monochamus* spp. are known vectors of the pine wilt nematode which has caused massive tree mortality in Asia, and which now threatens forests in much of Europe. Monochamol was identified as the pheromone of the European species, *M. galloprovincialis*, by Juan Pajares, David Hall, and coworkers in 2010, and since then it has been proven to be the pheromone of an additional 5 *Monochamus* species, and a likely pheromone component for another 8 *Monochamus* spp. and 4 additional species in related genera. These include *M. alternatus*, *M. sutor*, and *M. urussovi*, all of which are on the APHIS-PPQ list of most high-risk invasive cerambycids.

2. The citrus longhorn beetle, *Anoplophora chinensis*, also on the APHIS-PPQ high-risk list. This species has been detected in the US, although it does not appear to have established yet.

3. The velvet longhorn beetle, *Trichoferus campestris*, first detected in Illinois in 2009, attacks a wide variety of ornamental and orchard trees. Its likely pheromone has been identified and synthesized, and is awaiting field testing in 2016.

4. The Japanese cedar longhorn beetle *Callidiellum rufipenne*, which infests woody plants in the cypress family. This species has invaded the northeastern US and its range is expanding.

5. The brown spruce longhorn beetle *Tetropium fuscum*, which invaded eastern Canada in the 1990s, and is slowly increasing its range.

6. The Asian species *Xylotrechus rufilius*, which was recently intercepted in shipping entering the port of Baltimore.

In addition to their uses in surveillance and monitoring, it may be possible to exploit some cerambycid pheromones for control of specific pest species. For example, field trials over the past several years by Jim Barbour in Idaho hop gardens and Diane Alston in Utah cherry orchards have indicated that mass trapping or mating disruption using prionic acid, the pheromone of North American *Prionus* spp., can drive populations to low levels. Treatments must be continued over consecutive years, because the beetles take several years to complete development. Very recent results suggest that mass trapping or mating disruption could also be used for control of related species in the genus *Dorysthenes*, which infest sugarcane grown on >1 million hectares in southeast Asia.

There is also one further consequence from the high degree of conservation of pheromone structures within related cerembycid species, even across continents. That is, when an invasive cerambycid enters a new country, its population density will be very low and its survival and establishment will be critically dependent on finding a mate by using its attractant pheromone. Anything that interferes with the mate-finding process will decrease its chances of establishment. Thus, an invasive species which uses a pheromone that is not used by any related native species in the country which it is trying to invade will experience no interference in its pheromone channel, i.e., it will be invading a "pheromone-free space". Conversely, an invasive species which uses a pheromone that is also used by one or more endemic species will face major interference in finding a mate, substantially decreasing its chances of becoming established. Thus, the pheromone chemistry of potentially invasive species should be carefully considered when developing risk assessments, with species which have relatively unique pheromones being ranked higher risk than those which share pheromone components with native species.

For a more comprehensive overview of cerambycid beetle biology and the use of pheromones and related semiochemicals by cerambycids, the interested reader is referred to a new book edited by Qiao Wang, entitled "Cerambycidae of the World: Biology and Pest Management (CRC Press/Taylor & Francis) due out in 2016, and in particular, Chapter 5 entitled "Chemical Ecology of Cerambycidae."

PRESENTATIONS

New Zealand - United States Collaboration on Plant Security

NO ANSWER TO MY CALL: COMBINING TACTICS FOR ARTHROPOD ERADICATION UNDER SCARCITY

David M. Suckling[1], Lloyd D. Stringer[1] and J.M. Kean[2]

[1]The New Zealand Institute for Plant & Food Research Limited and University of Auckland, PB 4704, Christchurch, New Zealand
[2] AgResearch, Ruakura, New Zealand

ABSTRACT

As a consequence of globalisation, colonisation by exotic invasive organisms into new geographic ranges is occurring at an accelerating rate. However, invading populations may be limited by Allee effects that suppress their ability to increase. In some ranges invaders may repulsed by a high Allee threshold (a theoretical critical population density threshold, below which the population is expected to go extinct without intervention). In other situations, a low Allee threshold may allow invaders to survive and increase when starting from a low number of propagules.

During an eradication attempt, population management tools such as insecticides can reduce a population's density. Other tactics such as male removal or mating disruption interfere with the likelihood of mating success, requiring the population density to be greater than previous to maintain positive population growth. Tactics that reduce populations or interfere with mate finding when used alone may reduce population size below the Allee threshold, but combinations of tactics can produce different outcomes. Combinations of tactics that together produce the greatest reduction in population growth are most likely to be successful at avoiding unwanted spread before extirpation is complete.

The tools available to incursion response managers for use in eradication attempts are dependent on the environment infested. Broad-spectrum insecticides provide a good knock-down but can be deemed too hazardous for use in sensitive areas such as urban or high-value conservation areas. Targeted and more socially acceptable tools are a better option in such areas. These tools are often inversely density-dependant (DD), working best on small populations but struggle to control large ones. For some groups, semiochemicals are available for monitoring or suppression and an active surveillance method with lures can also significantly increase the likelihood of eradication.

We used the Global Eradication and Response DAtabase (GERDA, www.b3nz.org\gerda) to investigate eradication success, based on the number of tools used for eradication and how the tools were applied (i.e. step-wise or concurrently). When limited to DD targeted tools, we found that eradication attempts were achieved faster when multiple tactics (lure and kill, mass trapping and Sterile Insect Technique) were used over only single tactics. The application of multiple tools cause interaction between factors affecting Allee dynamics, leading to faster population reduction.

AUTONOMOUS DETECTION OF *TROGODERMA INCLUSUM* IN GRAIN

Timothy Flynn[1], David Masters[2] , Helen Hull-Sanders[1], Hady Salloum[1], Alexander Sedunov[1], Nikolay Sedunov[1] and Alexander Sutin[1]

[1]Stevens Institute of Technology, Castle Point on Hudson, Hoboken, NJ 07030, USA
asutin@stevens.edu, tflynn2@stevens.edu, hhullsan@stevens.edu, hsalloum@stevens.edu, asedunov@stevens.edu, nsednov@stevens.edu
[2]Department of Homeland Security, Science and Technology Directorate, Washington, DC

ABSTRACT

Stevens Institute of Technology in cooperation with the DHS Science and Technology Directorate and the U.S. Customs and Border Protection has been investigating engineering solutions to augment the current inspection process at ports of entry in an effort to minimize the threat posed by invasive species. Systems based upon the use of acoustic, microwave, and laser sensors were developed and tested on small insects in grains with the goal of improving the accuracy and effectiveness of current manual inspection methods.

ACOUSTIC SYSTEM FOR INSECT DETECTION

Acoustic detection of insects has been the aim of research scientists since as far back as the early 1900s. Since then, many papers have been published in an attempt to focus in on the most sophisticated and reliable methods for detection (Mankin et al. 2011,). One such publication specifically investigated the efficacy of various sensor types for grains (Mankin and Hagstrum 2012). This paper claims that vibrational sensors provide the best sensitivity to the signals generated by small insects. Recently, an article was published investigating the detection of *Trogoderma granarium* within a grain mass (Eliopoulos et al. 2015). This paper has an extended review of acoustic methods application. The described system has probability of detection too low for practical application. Our system with the sound installation and optimization of the frequency bands for signal analysis provides a higher detection rate.

Trogoderma inclusum was chosen for our tests because it is a congener for *Trogoderma granarium* (aka Khapra beetle) in the family *Dermestidae*, but *T. inclusum* are not under quarantine. The *T. inclusum* are available and can be transported across state lines and they do not need to be kept in a regulated quarantine facility, whereas *T. granarium* do. The test plan was applied to all three sensor types: acoustic, microwave, and laser.

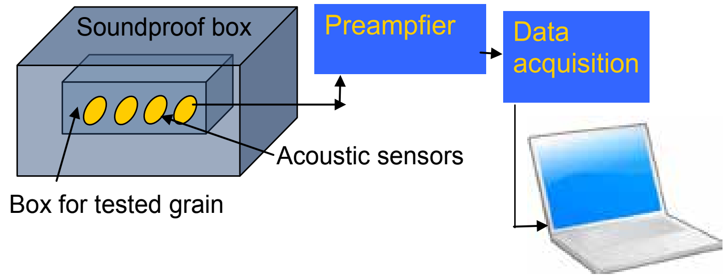


Figure 1 – *T. inclusum* larva (upper) *T. inclusum* beetle (lower)

Figure 1 shows the pictures of the tested insects. The typical length of a rice grain is about 4-5mm and the size of the *Trogoderma inclusum* beetle is about 2 mm.

An acoustic system was constructed with ceramic piezoelectric sensors crafted into the bottom of the test container. The ASB outputs 4 separate audio channels, each of which has a preamplifier before reaching a data acquisition board for recording observations

The test container was then placed within a sound attenuating box to reduce noise from external sources. The observed vibrational signals produced by *T. inclusum* were recorded and investigated to identify defining characteristics.

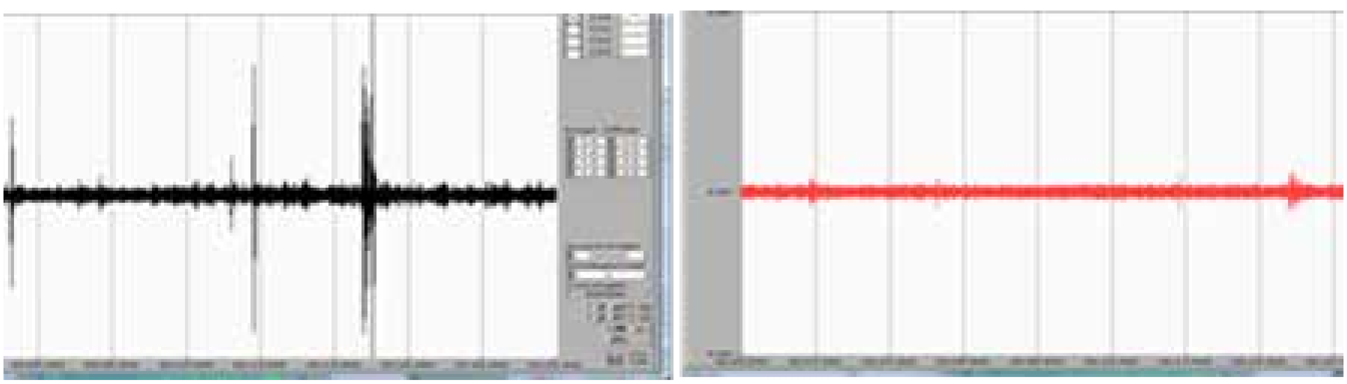


Figure 3 – Time track of the signal in time window of 50 sec with Trogoderma inclusum in rice (left) and background signal without insects (right)

The audio frequencies generated by an active *T. inclusum* ranged from 600 Hz to 1500 Hz. Occasional relatively high power external sounds were also observed in the recordings inducing wideband frequency noise into the recordings.

Based on these observations, a processing chain was devised that would autonomously identify the presence of *T. inclusum* within the test container. The recorded signal is split into two bands, 200 Hz to 600 Hz and 600 Hz to 1500 Hz, and the envelope of each band is calculated. The difference between these two envelopes is used as a detection metric. Whenever this metric crosses a threshold, a detection pulse is generated. Nearly 100 tests were performed on both the beetle and larva stages of *T.* inclusum. The larva proved to be much more active and resulted in a nearly 100% detection rate. Approximately 70% of cases containing a single adult beetle present resulted in detection of *T. inclusum*. Furthermore, the control cases where no insect was present resulted in nearly zero detections.

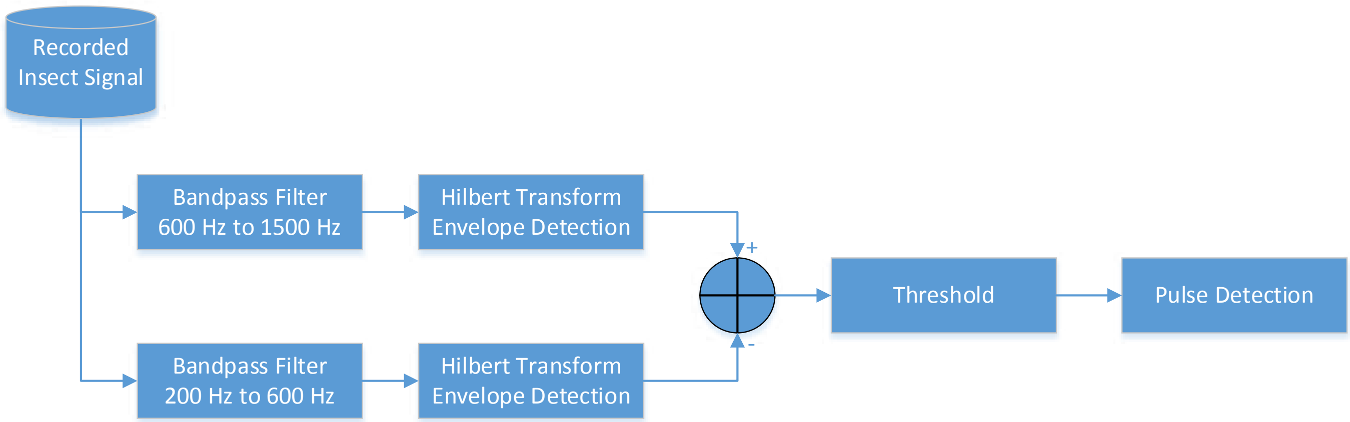


Figure 4 – Acoustic Insect Detection Algorithm

MICROWAVE SYSTEM FOR INSECT DETECTION

Microwave systems for detection of small movement are based on tiny variation of the phase of scattering RF signal in the presence of any movement in a scattering volume. A similar system can detect even human heart beating through walls and materials (Boric-Lubecke et al. (2007)).

Taking this history into account, a microwave sensor system was built using K-band bistatic Doppler sensors within an electromagnetically shielded case. The Doppler measurement outputs of these sensors are then passed through a signal conditioner before being converted to digital signals via a data acquisition card. The Doppler shift measurements induced by a small moving target, in this case *T. inclusum*, are relatively slow with respect to radar wavelength, generating low frequency components. To detect these movements autonomously, the signals are low-pass filtered and passed through a threshold detector. The schema of the system is shown in Figure 5.

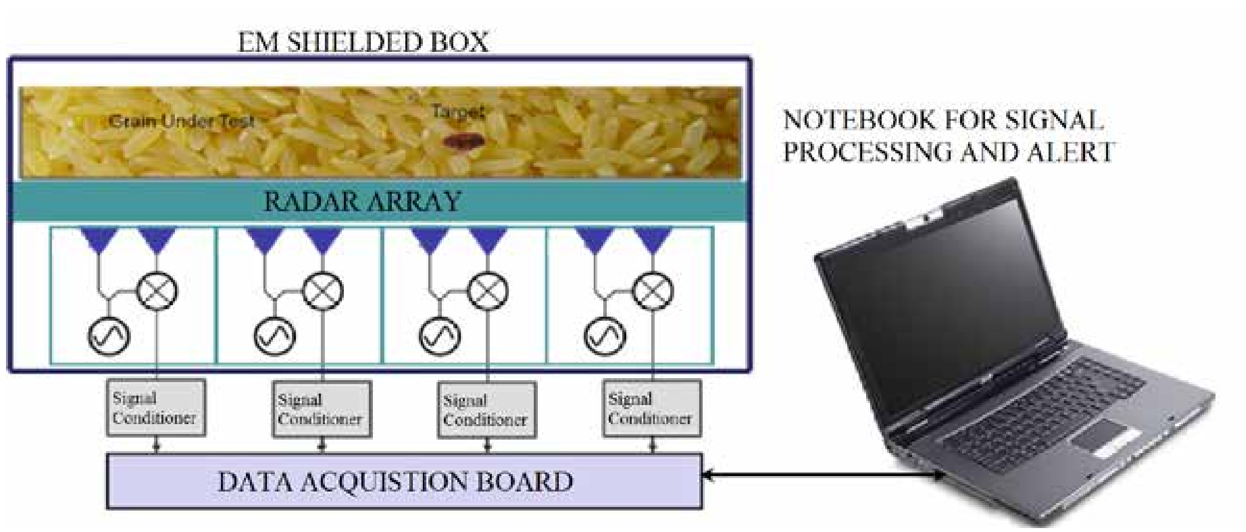


Figure 5 – System Diagram of the Microwave Sensor system

The system can detect the same small insects as the acoustic system but had a lower detection rate. Probably because it was connected with the absence of isolation from external noise. The microwave system has better potential for the investigation of larger tested objects, like boxes with fruit and vegetables. Our future research will be aimed in this direction.

LASER SENSOR TEST

The laser vibrometer test was conducted for checking the sensitivity of the system to detect small vibrations produced by tiny insect movement. In the future, this system is mainly planned for wood boring insect detection. The laser sensor system was based on a Polytech PDV-100 Digital Vibrometer. The Polytech PDV-100 generates measurements based on Doppler shifts in the reflected laser beam. The laser beam was manually focused directly onto the surface of the grain medium within the test container. The ability of this system to detect *T. inclusum* in grain was less promising than acoustic and radar based methods. The sensor required the insect to come close to the laser beam itself to a distance lower that two inches, indicating that this sensing method will prove impractical for grain based invasive species detection.

ACKNOWLEDGMENTS

This work has been sponsored by DHS's Science and Technology Directorate. The views and conclusions contained in this paper are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied of the U.S. Department of Homeland Security.

REFERENCES

O. Boric-Lubecke, J. Lin, V.M. Lubecke, A. Host-Madsen and T. Sizer. «Microwave and millimeter-wave Doppler radar heart sensing», Proc. SPIE 6547, Radar Sensor Technology XI, 65470C (May 03, 2007)

P.A. Eliopoulos, I. Potamitis, D.Ch. Kontodimas, and E. G. Givropoulou. "Detection of Adult Beetles Inside the Stored Wheat Mass Based on Their Acoustic Emissions". Journal of Economic Entomology Dec 2015 : Vol. 108, Issue 6, pg(s) 2808-2814

R.W. Mankin. «Microwave Radar Detection of Stored-Product Insects». J. Econ. Entomol. 97(3): 1168- 1173 (2004)

R.W. Mankin, D.W. Hagstrum, M. T. Smith, A.L. Roda, M.T.K. Kairo. «Perspective and Promise: a Century of Insect Acoustic Detection and Monitoring». American Etymologist January 2011

R.W. Mankin, D. Hagstrum. "Acoustic Monitoring of Insects". . In Hagstrum, D.W., T.W. Phillips and G. Cuperus (Eds.). Stored Product Protection. Kansas State University. Manhattan. KS 2012. http://www.ars.usda.gov/sp2UserFiles/person/3559/publications/Mankin-s156_ch22-acoustics-post.pdf

PRESENTATIONS

Tree Pathology: Improving Response and Management
of Native and Non-Native Forest Pathogens

THE ROAD TO APPLIED RESISTANCE DEVELOPMENT IN FOREST TREES: EXAMPLES FROM WHITE PINE BLISTER RUST, PORT-ORFORD-ROOT DISEASE AND KOA WILT

Richard A. Sniezko

USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, OR 97424

ABSTRACT

Non-native invasive pathogens and insects have caused high levels of mortality in many native tree species. This has increased public awareness that some tree species can become extinct or very rare in a small period of time. It can also lead to major changes in forest ecosystems and urban forests and can lead to serious economic losses in managed forest plantings. The impacts can be further complicated by a changing climate. Concerted efforts to exclude new pests and pathogens and confine the spread (or eradicate) existing ones can be invaluable, but when they fail, a different course of action is warranted. In some cases, biocontrol or silvicultural management can minimize the damage, but in many other cases an evaluation of the genetic resistance within the host species and consideration of harnessing this resistance may be the only course forward to retain valuable species. When this is done early, a proactive management strategy may be contemplated, but in many cases restoration or reforestation efforts will be needed. Success from a resistance program will only come when the basic research phase goes through the tree improvement phase and materials are then actually used in reforestation or restoration. Relatively few systems in forest genetics resistance programs have reached this stage, and one illustration are the operational programs developed at the USDA Forest Service's Dorena Genetic Resource Center (DGRC) (Cottage Grove, Oregon). DGRC works with the development populations of trees with genetic resistance to pathogens. Programs to evaluate white pine blister rust resistance in all eight species of white pines native to the western U.S. are underway, with the largest programs for western white pine (WWP) (*P. monticola*), sugar pine (SP) (*P. lambertiana*), whitebark pine (WBP) (*P. albicaulis*), southwestern white pine (*P. strobiformis*) and limber pine (*P. flexilis*). The programs for WWP, SP and WBP are well underway and reforestation or restoration with seed has commenced. The program to develop resistance to *Phytophthora lateralis* in Port-Orford-cedar (*Chamaecyparis lawsoniana*) is also producing resistant seed for reforestation and restoration efforts. A more recent program to develop *Fusarium oxysporum* resistance in koa (*Acacia koa*) in Hawaii headed up by HARC, but advised since 2003 by DGRC geneticist is following a similar applied path. Some keys to these programs are continuity of program, interaction with partners and cooperators, support from both Forest Health Protection and National Forest System, a reliable seedling inoculation program, a network of field sites for resistance validation, and orchards for production of resistant seed with genetic diversity for the various breeding zones within the species. Only future monitoring will eventually discern which resistances are durable, current field data makes us cautiously optimistic that we can retain these tree species in our forest ecosystems and that such work can be extended to other tree species.

RAPID 'ŌHI'A DEATH: UNRAVELING THE MYSTERY

Lisa Keith[1], Flint Hughes[2] and J.B. Friday[3]

[1]USDA Agricultural Research Service,Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center, 64 Nowelo St., Hilo, HI 96720
[2]USDA Forest Service, Institute of Pacific Islands Forestry, 60 Nowelo St., Hilo, HI 96720
[3]University of Hawai'i, College of Tropical Agriculture and Human Resources, Cooperative Extension Service, 875 Komohana St., Hilo, HI 96720

ABSTRACT

`Ōhi`a (*Metrosideros polymorpha*) is Hawai`i's most widespread and ecologically important native tree, defining native forest succession and ecosystem function over broad areas, providing critical habitat for rare and endangered native bird and insect species, and exemplifying the strong links between native Hawai`ian culture and the islands' environment. Within the past 5 years, extensive `ōhi`a mortality has been observed across Hawai'i Island. Affected trees exhibit rapid, synchronized death of leaves on individual branches that eventually spreads to the entire canopy. We conducted a preliminary survey of 31 distinct ohia stands experiencing unusual degrees of mortality and established forest inventory plots in 18 of those localities. A GIS analysis showed no correlation of ohia mortality with rainfall or elevation. Despite mortality of overstory canopy 'ōhi'a trees, understory vegetation - most of which consists of the alien *Psidium cattleianum* but in some sites includes kōpiko (Psychotria sp.) and other native species- remains healthy. Analysis of remotely sensed images showed that affected areas (defined as having between 10% and 100% mortality) increased from 915 ha in 2012 to 6,403 ha in 2014. Field monitoring plots revealed mortality across all size classes and stand compositions, with no correlation between mortality and areas of heavy competition from *Psidium cattleianum*. Repeated measurements of monitoring forest plots found that 'ōhi'a stands exhibited an average annual mortality rate of 26%. Cross sections of diseased trees revealed dark brown to black discoloration in the xylem of the trunk. A perithecia-producing fungus was consistently isolated from infected tissue and based on morphological characteristics and molecular sequencing, the fungus was identified as *Ceratocystis fimbriata*. Pathogenicity of *C. fimbriata* from this study was tested by inoculation of pot grown seedlings of `ōhi`a. Control plants were inoculated with sterile distilled water. Plants produced wilt symptoms within 17 to 88 days after inoculation. As the disease progressed, leaves withered and died, showing that *C. fimbriata* was pathogenic to `ōhi`a. Cross-sections of inoculated plants showed vascular discoloration. Control plants remained symptomless. We have termed this disease "Rapid `Ōhi`a Death" or "ROD". Confirmed locations of ROD as of January 2016 include the Puna and South Hilo districts, Volcano, Ka'u, Holualoa, Kealakekua and South Kona. This pathogen poses a severe threat to the viability and persistence of Hawai'i's native forests. Widespread mortality of 'ōhi'a due to this disease would be catastrophic for Hawai'i's watersheds and could lead to extensive loss of habitat for hundreds of native species. We are currently determining the distribution and mechanisms of spread of *C. fimbriata* in order to develop appropriate management strategies to limit the spread of the fungus.

PRESENTATIONS

Invasion Ecology and Management of Emerald Ash Borer in the US: Recent Advances and Future Directions

RECENT DEVELOPMENT AND ADVANCES IN SURVEY AND DETECTION TOOLS FOR EMERALD ASH BORER

Therese M. Poland[1], Deborah G. McCullough[2], Taylor Scarr[3], Joseph Francese[4], Damon Crook[4], Michael Domingue[5], Harold Thistle[6], Brian Strom[7], Laura Blackburn[8], Daniel A. Herms[9], Krista Ryall[10] and Patrick Tobin[11]

[1] USDA Forest Service, Northern Research Station, Lansing, MI 48910
[2] Departments of Entomology and Forestry, Michigan State University, East Lansing, MI
[3] Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, Canada
[4] Otis Laboratory, USDA APHIS PPQ CPHST, Buzzards Bay, MA
[5] Department of Entomology, The Pennsylvania State University, University Park, PA,
[6] USDA Forest Service, Forest Health Technology Enterprise Team, Morgantown, WV
[7] USDA Forest Service, Southern Research Station, Pineville, LA
[8] USDA Forest Service, Northern Research Station, Morgantown, WV
[9] Department of Entomology, The Ohio State University, Wooster, OH
[10] Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, Ontario, Canada
[11] University of Washington, School of Environmental and Forest Sciences, Seattle, WA

ABSTRACT

The emerald ash borer (EAB, *Agrilus planipennis* Fairmaire) has killed hundreds of millions of ash trees since it was discovered near Detroit, Michigan and Windsor, Ontario in 2002 (www.emeraldashborer.info 2016) and continues to spread in North America. Canadian and U.S. federal, provincial, and state regulatory agencies have used artificial traps and lures in surveys to detect new infestations since 2008. Traps used in detection surveys have evolved over the years, and several different trap designs and lures have been tested in research studies. EAB is attracted to volatiles emitted by stressed ash trees including the green leaf volatile *cis*-3-hexenol (de Groot et al. 2008) and bark sesquiterpenes also found in Manuka and Phoebe oils (Crook et al. 2008). Attraction of males to *cis*-3-hexenol may enhanced by the female-produced pheromone *cis*-lactone (Silk et al. 2011, Ryall et al. 2012). EAB adults are also attracted to particular shades of green and purple (Francese et al. 2010, Crook et al. 2012).We compared different shades of green and purple prism traps to optimize color for EAB attraction. Light green prism traps (540 nm wavelength, 66% reflectance, Fig. 1A) were 6 to 10 times more attractive than dark purple prism traps (430-440 nm, 23% reflectance, Fig. 1B) when hung high in the canopy. Prism traps of a darker shade of "Sabic" green (540 nm, 49% reflectance, Sabic Polymershapes, Kalamazoo, MI, Fig. 1C) captured 2 times more EAB than the light green (540 nm, 66% reflectance) and 10 times more EAB than the dark purple traps. In 2011 and 2012, different trap designs were compared in large scale multi-state studies at sites with very low EAB populations. In 2011, the traps included dark purple prism traps, light "Sabic" purple prism traps (420nm, 21.7% and 670 nm, 13.6%, Sabic Polymershapes, Kalamazoo, MI, Fig. 1D) dark "Sabic" green prism traps, and dark "Sabic" green multiple funnel traps (Fig. 1E). All traps were baited with *cis*-3-hexenol and Manuka oil and hung in the ash canopy. Light purple prism traps captured significantly more EAB than the other traps, and their detection rate (i.e., proportion of traps that captured at least one EAB) was 85%. Detection rates for the other traps were 58% for green multiple

funnel traps, 66% for green prism traps, and 73% for dark purple prism traps. In 2012, the trap types included green multiple funnel traps and dark purple prism traps baited with either *cis*-3-hexenol plus Manuka oil or *cis*-3-hexenol plus *cis*-lactone. Although green multiple funnel traps tended to capture more EAB than the dark purple prism traps, variation was high and differences were not significant among trap types or lures. At sites with very low EAB populations, detection rates were similar among traps and ranged from 72 to 76%. We also tested green or purple multiple funnel traps treated with different lubricants including RainX, Fluon tinted the same color as the trap, untinted Fluon, or no treatment. Green multiple funnel traps treated with untinted Fluon captured significantly more EAB than green multiple funnel traps with the other treatments or purple multiple funnel traps with any treatment. There was no significant difference in the number of EAB captured in green multiple funnel traps treated with undiluted Fluon and Fluon diluted to 50% with water; however, trap catches were significantly reduced when Fluon was diluted to 25%.

In 2014, we compared different colored "double-decker" traps (Fig. 1F) consisting of two, three-sided prisms (60-cm tall × 40-cm wide on each side), made of corrugated plastic, mounted to the top and 120-cm from the top of a 2.4-m tall, 10-cm diameter PVC pipe slid over a T-post that was driven into the ground. Color and lure combinations included 1) dark purple top and bottom prisms both baited with *cis*-3-hexenol; 2) dark purple top prism baited with *cis*-3-hexenol and dark purple bottom prism baited with Manuka oil; 3) Sabic green top and light Sabic purple bottom prisms both baited with *cis*-3-hexenol; 4) Sabic green top prism baited with *cis*-3-hexenol and light Sabic purple bottom prism baited with Manuka oil; and 5) light Sabic purple top and bottom prisms both baited with *cis*-3-hexenol. Traps with green top prisms and light purple bottom prisms captured significantly more EAB than traps with dark purple prisms on the top and bottom, regardless of lure. Traps with light purple top and bottom prisms captured an intermediate number of EAB. For traps of the same color, there was no significant difference in attraction of EAB to traps baited with *cis*-3-hexenol on both prisms or with *cis*-3-hexenol on the top and Manuka oil on the bottom prism. The detection rate for traps with green tops and light purple bottoms was 90% for traps baited with *cis*-3-hexenol on both prisms, and 100% for traps baited with *cis*-3-hexenol on the top and Manuka oil on the bottom prism. Traps with dark purple top and bottom prisms had the lowest detection rates (60% and 70% for traps baited with *cis*-3-hexenol on both prisms or *cis*-3-hexenol on the top and Manuka oil on the bottom, respectively). The detection rate of traps with light purple top and bottom prisms baited with *cis*-3-hexenol on both prisms was 80%.

We also compared several different trap designs including 1) double-decker trap with dark purple top and bottom prisms baited with *cis*-3-hexenol on the top and Manuka oil on the bottom prism; 2) double-decker traps with Sabic green top prism and light Sabic purple bottom prism baited with *cis*-3-hexenol on both prisms; 3) Sabic green prism trap baited with *cis*-3-hexenol and hung in the ash canopy; 4) Sabic green funnel trap coated with Fluon, baited with *cis*-3-hexenol and hung in the ash canopy; and 5) Sabic green modified boll weevil traps baited with *cis*-3-hexenol and hung in the ash canopy. Standard boll weevil traps were modified by replacing the bottom portion with a 40-cm long green cylinder. At a site with very low EAB population density, significantly more EAB were captured in the double decker traps of either color than in the boll weevil traps which did not capture any EAB. The green prism traps and green funnel traps captured an intermediate number of EAB. All of the green and light purple double-decker traps captured at least one EAB, 80% of the dark purple double-decker traps, 60% of green canopy prism traps and 40% of green funnel traps captured at least one EAB.

We compared small light green prism traps slid over branches in the canopy of ash trees (Fig 1G). The traps were baited with *cis*-3-hexenol with or without *cis*-lactone and had a single dead EAB decoy placed in the center or no decoy. Traps baited with *cis*-3-hexenol, *cis*-lactone, and a decoy captured significantly more EAB than traps without a decoy or *cis*-lactone.

Finally, we tested several different trap designs in a large multi-agency study replicated in sites with low to very low emerald ash borer densities in Ontario, Michigan, Ohio, and Pennsylvania. Traps included 1) double decker traps with Sabic green panel on top and light Sabic purple panel on the bottom both baited with *cis*-3-hexenol, 2) double decker traps with light Sabic purple top and bottom panels both baited with *cis*-3-hexenol, 3) Sabic green multiple funnel traps baited with *cis*-3-hexenol, 4) light Sabic purple prism traps baited with *cis*-3-hexenol; 5) dark Sabic green prism traps baited with *cis*-3-hexenol and *cis*-lactone; and 6) light Sylvar green prism traps baited with *cis*-3-hexenol and *cis*-lactone. In 2014, across all sites, we captured significantly fewer EAB in the light purple prism traps than in any other trap color or design. In 2015, preliminary results for Ontario and Michigan indicate that significantly more EAB were captured in the double-decker traps than in the light purple or light Sylvar green prism traps while dark

Figure 1. Traps used for capturing EAB. A. Light green prism trap; B. Dark purple prism trap; C. Dark “Sabic” green prism trap; D. Light “Sabic” purple prism trap; E. Dark “Sabic” green multiple funnel trap; F. Double-decker trap; G. Light green branch trap

Sabic green prism traps were intermediate. All double decker traps captured at least one EAB, 81% of the dark Sabic green prism traps and green funnel traps, 69% of light Sylvar green prism traps, and 63% of the light purple prism traps captured EAB.

Overall, double-decker traps, green prism traps, and green funnel traps are effective detection traps for EAB with 76 to 100% detection rates at sites with very low densities of EAB. Double-decker traps tended to have the highest detection rates and less variability than traps hung in the canopy where trap captures are influenced by infestation level of the trees bearing the traps or adjacent trees. The new darker Sabic green and lighter Sabic purple are more attractive to EAB than dark purple prisms. Traps baited with *cis*-3-hexenol alone were as attractive to EAB as traps with *cis*-3-hexenol plus Manuka oil lures. The pheromone *cis*-lactone increased attraction of EAB to small green branch traps baited with EAB decoys and *cis*-3-hexenol and placed over branches in the canopy of ash trees.

REFERENCES

Crook, D., Khrimian, A., Francese, J.A., Fraser, I., Poland, T.M., Sawyer, A.J., and Mastro, V.C.. 2008. Development of a host-based semiochemical lure for trapping emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae). Environ. Entomol. 37: 356-365.

Crook, D. J., Khrimian, A., Cossé, I. Fraser, and V. C. Mastro. 2012. Influence of trap color and host volatiles on capture of the emerald ash borer (Coleoptera: Buprestidae). J. Econ. Entomol. 105: 429-437.

de Groot, P., G. G. Grant, T. M. Poland, R. Scharbach, L. Buchan, R. W. Nott, L. MacDonald, and D. Pitt. 2008. Electrophysiological response and attraction of emerald ash borer to green leaf volatiles (GLVs) emitted by host foliage. J. Chem. Ecol. 34: 1170-1179.

Emerald Ash Borer Information. 2016. www.emeraldashborer.info.

Francese, J. A., D. J. Crook, I. Fraser, D. R. Lance, A. J. Sawyer, and V. C. Mastro. 2010. Optimization of trap color for the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae). J. Econ. Entomol. 103: 1235-1241.

Ryall, K. L., P. J. Silk, P. Mayo, D. Crook, A. Khrimian, A. A. Cossé, J. Sweeney, and T. Scarr. 2012. Attraction of *Agrilus planipennis* (Coleoptera: Buprestidae) to a volatile pheromone: effects of release rate, host volatile, and trap placement. Environ. Entomol. 41: 648-656.

Silk, P. J., K. Ryall, P. Mayo, P., M. Lemay, G. Grant, D. Crook, A. Cosse´, I. Fraser, J. D. Sweeney, D. B. Lyons, et al. 2011. Evidence for a volatile pheromone in *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) that increases attraction to a host foliar volatile. Environ. Entomol. 40: 904-916.

SPATIAL DYNAMICS OF EMERALD ASH BORER: ESTIMATING THE NATURAL AND ANTHROPOGENIC MOVEMENT OF A DIFFICULT-TO-DETECT FOREST PEST

Nathan W. Siegert[1], Rodrigo J. Mercader[2] and Deborah G. McCullough[3]

[1]USDA Forest Service, Northeastern Area State and Private Forestry, Forest Health Protection, Durham, NH 03824
[2]Department of Biology, Washburn University, 700 SW College Ave., Topeka, KS 66621
[3]Dept. of Entomology & Dept. of Forestry, Michigan State University, 243 Natural Sciences Building, East Lansing, MI 48824

ABSTRACT

The dynamics of emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) spread and dispersal tendencies have practical implications for survey, monitoring and management of EAB at local, regional and national scales. While understanding the spatial dynamics of the EAB invasion at these various scales is critical to effectively manage and mitigate its potential impact in North America, quantifying short-distance and long-distance movement of EAB adult beetles in natural environments remains an arduous undertaking. Nonetheless, several field studies have been conducted to date providing insight into EAB's potential and realized dispersal capabilities. While approaches to estimate movement of EAB in the field have varied, several broad general patterns are becoming apparent. This invasive pest exhibits a remarkable capacity for rapid population expansion, facilitated in part through stratified dispersal via natural dispersal of adult beetles and anthropogenic spread of infested materials such as ash firewood. Although anthropogenic mechanisms of spread are capable of moving EAB unlimited distances, natural dispersal of EAB populations are much more constrained and are known to be strongly influenced by host density and distribution. Multiple intensive field studies have shown that EAB females lay the majority of their eggs within 100 m of where they emerge, and >90% within 500 m of their emergence point when hosts are present. Studies suggest that at least a small proportion of the EAB population has a strong physiological potential for long-distance dispersal, but estimates of spread rates do not exceed 2 km yr^{-1}. Several key areas in need of future research and associated survey and management implications were discussed.

RECENT PROGRESS IN BIOLOGICAL CONTROL OF EMERALD ASH BORER

Leah Bauer[1,2], Dave Jennings[3], Jian Duan[4], Roy Van Driesche[5], Juli Gould[6], Daniel Kashian[7], Deborah Miller[1], Toby Petrice[1], Erin Morris[2] and Therese Poland[1,2]

[1] USDA Forest Service, Northern Research Station, Lansing, MI 48910 lbauer@fs.fed.us
[2] Dept. of Entomology, Michigan State University, E. Lansing, MI 48824
[3] Dept. of Entomology, University of Maryland, College Park, MD 20742
[4] USDA ARS, Beneficial Insects Introduction Research Unit, Newark DE 45433
[5] Dept. of Environmental Conservation, University of Massachusetts, Amherst, MA 01003
[6] USDA APHIS, Center for Plant Health Science and Technology, Buzzards Bay, MA 02542
[7] Dept. of Biological Sciences, Wayne State University, Detroit, MI 48202

ABSTRACT

The emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire, Coleoptera: Buprestidae), a beetle from Asia that feeds on ash trees (*Fraxinus* spp.), was inadvertently introduced to North America during the 1990s (Haack et al. 2015). Discovered in Michigan and Ontario in 2002, EAB is now found in 25 states and two Canadian provinces where it has killed tens of millions of ash trees. To conserve native ash species in North America, USDA began foreign exploration for the development of a classical biological control program for the long-term management of EAB in 2003 (Liu et al. 2003). In 2007, three species of hymenopteran parasitoids from northeast China were first approved for release in Michigan: an egg parasitoid *Oobius agrili* Zhang and Huang (Encyrtidae), a larval endoparasitoid *Tetrastichus planipennisi* Yang (Eulophidae) from Jilin province, and a larval ectoparasitoid *Spathius agrili* Yang (Braconidae) from Tianjin (Liu et al. 2003; Bauer et al. 2014, 2015a). These EAB biocontrol agents are now mass-reared at an APHIS Rearing Facility in Brighton, Michigan, and a guideline for release and recovery of the EAB parasitoids is posted online (mapbiocontrol.org 2016). To date, two or more of these EAB biocontrol agents have been released in most of the infested states and both provinces. Over the years, researchers monitoring these parasitoids in Michigan and other northern states, have confirmed establishment of *O. agrili* and *T. planipennisi* but not *S. agrili*, possibly due to asynchrony with its host. Release of *S. agrili* is now limited to regions south of the 40th parallel, where climate matching models suggest it may be better suited. Introductions of another larval ectoparasitoid, *Spathius galinae* Belokobylskij (Braconidae) from the Russian Far East, began in 2015 in Michigan and several other states north of the 40th parallel following APHIS approval.

Long-Term Studies of EAB Biocontrol in Central Michigan. In 2008, we began studying EAB population dynamics and ash health at six study sites in central Michigan where the first three EAB biocontrol agents were released from 2007 to 2010 (Bauer et al. 2015b). The mortality of immature EAB caused by woodpeckers, parasitoids, tree resistance, and unknown diseases was determined in EAB-infested ash trees (7- to 21-cm DBH) and analyzed using life table analyses. From 2009 to 2014, the majority of overstory ash trees died while the density of live EAB larvae in the remaining ash trees declined by ~90%. The decline in EAB density was correlated with an increase in larval parasitism, initially by native parasitoids, then by the introduced parasitoids (Duan et al. 2013, 2014, 2015). Larval parasitism by *T. planipennisi* averaged ~28% in both the release and control plots, indicating a rapid spread of this biocontrol agent. The other introduced larval parasitoid, *S. agrili*, was recovered for a year or two after release but not since, suggesting lack of establishment at these sites. Egg parasitism by *O. agrili* from 2008 to 2013 increased from ~2% to 29% in release plots and ~3% to 5% in control plots, indicating a comparatively slow rate of spread (Abell et al. 2014). In an effort to reduce ash tree mortality, we recommend introducing EAB biocontrol agents early in the EAB-outbreak cycle to slow its population growth rate (Duan et al. 2015).

At these sites, we are also measuring changes in ash growth and regeneration. In a 3-year period from 2012 to 2015, we found the diameter of overstory ash trees tended to be higher in release vs. control plots, and a consistent trend in increasing tree and sapling diameters in all plots over this 3-year period. To evaluate the impact of *T. planipennisi* on EAB attacking these regenerated ash, we randomly sampled and dissected 10 ash saplings (2.5- to 5-cm DBH) at 12 study plots in central Michigan. From saplings sampled during the winter of 2014-2015, 48% had no EAB attack, 22% had old calloused EAB galleries, 22% had both old and new galleries, and 8% had only new galleries. In the saplings with new galleries, we found an average of four overwintering EAB larvae per sapling. A mixture of younger (L1-L2) and older larvae (L3-L4) were found in these saplings, suggesting a two-year development time for EAB. From the younger larval cohort, 87% were healthy, 12% died from unknown causes (tree resistance and disease), and 1% were parasitized by *T. planipennisi*. From the older larval cohort, 23% were healthy, 45% were parasitized by *T. planipennisi*, 29% were eaten by woodpeckers, and 3% were parasitized by the native parasitoid *Atanycolus* spp. (Braconidae). Although EAB will continue to attack ash saplings and trees in our forests, we remain optimistic that a diverse complex of natural enemies will suppress EAB populations sufficiently for ash survival, growth, and reproduction in some stands.

Biocontrol of EAB in Post-Invasion Forests of Southeast Michigan. In a separate study, we released the parasitoids in 2011 at nine sites in southeast Michigan where ~99% of over story ash trees died in the aftermath of EAB's initial invasion. These release sites are located in forested parks ~10 to 30 km from the initial EAB-introduction epicenter (Canton, MI) and have an abundance of young, regenerating ash. In 2015, we collected data on *T. planipennisi* establishment from EAB-infested ash trees (7- to 12.5-cm DBH) at four of the sites. We found an average of 21% larval parasitism by *T. planipennisi* at the release plots and 7% at the control plots, indicating successful establishment and spread of *T. planipennisi* in EAB-infested forests with regenerating ash trees, saplings, and seedlings. These results demonstrate successful establishment of at least one EAB biocontrol agent in forests recovering from widespread ash mortality.

Long-Term Studies of EAB Biocontrol in Maryland. EAB was first detected in Prince George's County, Maryland in 2003, and the EAB biological control program in Maryland was initiated in 2009. Although *O. agrili* has been released in the state, recovery efforts to date have largely focused on monitoring the establishment and abundance of *S. agrili* and *T. planipennisi*. From 2009-2014, 56,677 *S. agrili* and 191,506 *T. planipennisi* were released at 26 and 32 sites, respectively. The release sites were located in southern, central, and western Maryland (all west of the Chesapeake Bay). Recovery efforts involved debarking trees in the field to determine the fates of EAB larvae (n = 238 trees), and harvesting trees to store in rearing barrels to record any parasitoids that emerged from the boles (n = 214 trees). This recovery work was conducted at 47 sites (23 of which received parasitoids, and 24 of which acted as controls) from 2010-2015. In total, we recovered 77 *S. agrili* from six sites (all of which had releases), and 1,856 *T. planipennisi* from 19 sites (12 of which had releases, and seven of which were controls). The low recovery of *S. agrili* precluded any further analyses from being conducted on them. However, we found that parasitism by *T. planipennisi*, and the number of trees containing *T. planipennisi* broods, were positively related to the number of years post-release of the parasitoids. Recovery sampling also indicated that *T.*

planipennisi has dispersed rapidly in Maryland, reaching control sites located up to 5.1 km away from the nearest releases. Additionally, our results showed that *T. planipennisi* parasitism was negatively associated with tree size, with over 95% of parasitism occurring on small trees with DBH < 16 cm. These results support an earlier study on the relationship of parasitism of EAB larvae by *T. planipennisi*, tree diameter, and bark thickness (Abell et al. 2012).

These findings are generally similar to those found in Michigan and elsewhere in North America, and should be useful for guiding EAB management strategies in states neighboring Maryland. Future work includes monitoring establishment of *S. galinae* and *O. agrili*. In 2015, the first releases of *S. galinae* took place at two sites in southern Maryland. *Spathius galinae* may be better suited than *S. agrili* to the climate in Maryland, and more releases are likely to follow at new sites in 2016. Meanwhile *O. agrili* has been released in Maryland since 2009, yet a comprehensive survey of the establishment and dispersal of this parasitoid remains to be conducted.

Establishment of EAB Biocontrol in North America. The establishment or recovery of *T. planipennisi* has been confirmed in Ohio, Illinois, Indiana, Kentucky, Maryland, Minnesota, New Hampshire, New York, Wisconsin, other regions of Michigan including the Upper Peninsula, and Ontario, Canada. To date, the establishment or recovery of *O. agrili* has been confirmed in Maryland, Ohio, Indiana, Kentucky, Pennsylvania, New York, as well as other regions of Michigan (mapbiocontrol.org 2016). More research is needed to ascertain establishment of these parasitoid species in different regions of North America and the impacts of biocontrol on ash resources.

References

Abell, K.J., J.J. Duan, L.S. Bauer, J.P. Lelito, R.G. Van Driesche. 2012. The effect of bark thickness on host partitioning between *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) and *Atanycolus* spp. (Hymen: Braconidae), two parasitoids of emerald ash borer (Coleoptera: Buprestidae). Biological Control 63, 320–325.

Abell, K.J., L.S. Bauer, J.J. Duan, R.G. Van Driesche. 2014. Long-term monitoring of the introduced emerald ash borer (Coleoptera: Buprestidae) egg parasitoid, *Oobius agrili* (Hymenoptera: Encyrtidae), in Michigan, USA and evaluation of a newly developed monitoring technique. Biological Control 79: 36-42

Bauer, L.S., J.J. Duan, J.R. Gould. 2014. Emerald ash borer (*Agrilus planipennis* Fairmaire) (Coleoptera: Buprestidae). Ch. 17. Pp. 189-205. In R.G. Van Driesche and R. Reardon (eds). The Use of Classical Biological Control to Preserve Forests in North America. United States Department of Agriculture, Forest Service, FHTET-2013-02.

Bauer, L.S., J.J. Duan, J.R. Gould, R.G. Van Driesche. 2015a. Progress in the classical biological control of *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) in North America. Canadian Entomologist 147: 300–317.

Bauer, L.S., J.J. Duan, J.P. Lelito, H.P. Liu, J.R. Gould. 2015b. Biology of emerald ash borer parasitoids. Ch. 6. Pp. 97-112. In R.G. Van Driesche and R. Reardon (eds). The Biology and Control of Emerald Ash Borer. FHTET 2014-09. USDA Forest Service, Morgantown, West Virginia, USA.

Duan, J. J., L.S. Bauer, K. Abell, J. Lelito, R. Van Driesche. 2013. Establishment and abundance of *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in Michigan: Potential for success in classical biocontrol of the invasive emerald ash borer (Coleoptera: Buprestidae). Journal of Economic Entomology 106: 1145-1154.

Duan, J.J., K. J. Abell, L.S. Bauer, J.R. Gould, R.G. Van Driesche. 2014. A life table analysis of the population dynamics of the invasive emerald ash borer (Coleoptera: Buprestidae) in North Central United States. Agriculture &

Forest Entomology 16:406-416.

Duan, J.J., L.S. Bauer, K.A. Abell, M.D. Ulyshen, R.G. Van Driesche. 2015. Population dynamics of an invasive forest insect and its associated natural enemies in the aftermath of invasion: implications for classical biological control of the invasive pest. Journal of Applied Ecology 52: 1246–1254.

Haack, R.A., Y. Baranchikov, L.S. Bauer, T.M. Poland. 2015. Emerald ash borer biology and invasion history. Ch. 1. Pp. 1-13. In R.G. Van Driesche and R. Reardon (eds). The Biology and Control of Emerald Ash Borer. FHTET 2014-09. USDA Forest Service, Morgantown, West Virginia, USA.

Liu, H.P., L.S. Bauer, R.T. Gao, T.H. Zhao, T.R. Petrice, R.A. Haack. 2003. Exploratory survey for the emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), and its natural enemies in China. The Great Lakes Entomologist 36: 191–204.

Mapbiocontrol.org. 2016. Agent release tracking and data management for federal, state, and researchers releasing three biocontrol agents released against emerald ash borer. http://www.mapbiocontrol.org/

PRESENTATIONS

Research Reports

UPDATE ON SPOTTED LANTERNFLY IN PENNSYLVANIA

Sven-Erik Spichiger

Pennsylvania Department of Agriculture, Room 111 - Division of Entomology,
2301 North Cameron Street, Harrisburg, PA 17110 - 9408

ABSTRACT

An update of a program to contain and eradicate Spotted lanternfly (HEMIPTERA: FULGORIDAE: *Lycorma delicatula* (WHITE)) which was implemented in Pennsylvania by the Pennsylvania Department of Agriculture is summarized and associated research projects are highlighted. An account of field recorded dates for Spotted Lanternfly show egg laying to be October 13, 2014, hatch to be May 12, 2015, second instar June 03, 2015, third instar June 24, 2015, fourth instar July 7, 2015 and adults on July 24, 2015. Tree bands were found to be effective in killing first through third instar nymphs while fourth instar nymphs and adults required active capture techniques. Adults were found to be associated primarily with tree of heaven (*Ailanthus altissima* (Philip Miller)Swingle), so a strategy of tree of heaven removal and trap tree establishment was employed. Combined control measures including egg mass scraping, tree banding, and active capture performed by volunteers and paid crew killed 793,571 spotted lanternfly in 2015. Spotted lanternfly was detected at 2,772 individual points on 435 separate properties in 2015. Many new sites were detected as a result of public reports. The insect is now known from four counties (Berks, Bucks, Chester, and Montgomery) and 15 townships in Pennsylvania, with most sites located within 5 miles of the original detection. A quarantine restricting the movement of the pest and conveyances was extended the new areas of detection. Surveys at 4,712 other locations in Pennsylvania were negative as were trace forward surveys in other states. Tree removal and trap tree establishment are taking place at several properties that were found to have the highest populations or were smaller remote populations.

Research in support of the program included studies of host volatiles, effect of chipping wood on egg mass hatch, impact on grape, growing degree day studies, host range studies, DNA analysis, investigation of parasitoids, and aerial surveillance for tree of heaven.

Excellent cooperation led to the early detection of and rapid response to this new invasive threat. Continued cooperation from the agencies and researchers involved, the local public officials, local businesses, and especially the owners of affected properties, who have in many cases volunteered, has been crucial for the response to the introduction of this new pest.

EATING INVADERS: WHY GOVERNMENT AGENCIES SHOULD THINK TWICE ABOUT MANAGING INVASIVE SPECIES WITH A FORK AND KNIFE

Joshua U. Galperin[1], Eleanor Killiam[2] and Sara E. Kuebbing[3]

[1] Yale Law School and Yale School of Forestry and Environmental Studies, 127 Wall Street, New Haven, CT 06511
[2] Yale College, New Haven, CT 06520
[3] Yale School of Forestry and Environmental Studies, 195 Prospect Street, New Haven, CT 06511

ABSTRACT

The challenge of managing nonnative, invasive species is significant. While there have been many success stories, by and large, the popular narrative is of spreading invasions, new invasive species, and the ecological, economic, cultural, or human health damages they cause. In an effort to change the narrative, to develop a viable management strategy, some actors are proposing an inventive, do-it-yourself solution: eat the invaders. The premise is simple. Humans have consumed species to extinction, or near extinction, before. So why not do it again? Pointing to examples like the Pacific blue fin tuna (*Thunnus orientalis*), American bison (*Bison bison*), or passenger pigeon (*Ectopistes migratorius*), eat-the-invader advocates argue that we should do it again, this time with our forks aimed squarely at the nonnative invasives. There are, however, serious hurdles and implications to this fledgling effort.

The proponents of an eating invaders movement, the "invasivores", are numerous, including chefs and students, activists and academics. Also among the invasivores are government policymakers. Both federal and state governments have started to join the movement. Unfortunately, there are compelling arguments against the invasivore movement, and governments, in particular, should carefully consider these arguments before taking a seat at the dinner table.

This research describes the rationale and breadth of the eating invaders movement followed by a series of important critiques that challenge the efficacy and presumptions of the movement. These critiques include legal barriers to large-scale invasivory, questions about the biological efficacy of the movement, and concerns about the negative impacts of a growing movement.

Federal and state laws may make an effective eating invaders movement impossible. Federal environmental laws, such as the Lacey Act and the Plant Protection Act, specifically prohibit the possession, transportation, and sale of certain invasive species on the premise that such activities encourage further invasions. Of the 47 species most commonly recommended as edible invaders, federal environmental law restricts six. All fifty states similarly restrict possession, transportation, and sale of many invasive species that are prime targets of the eating invaders movement. Various state laws restrict at least 33 edible invasives. Between state and federal law, a full 72% of the recommended edible invaders have some degree of restrictions on sale, transportation, and possession.

Food safety laws establish rigorous standards for slaughter and inspection of many food animals. If an animal is not slaughtered in compliance with these standards, it cannot be sold on an open market. Harvesting and

selling certain wild species, as opposed to farmed—which is necessary in order to have a biological impact on the invasive population—will be exceedingly difficult under these food safety laws.

Legal restrictions do not make it impossible to eat invasive species, but by limiting possession, transportation, and sale of many invaders, the restrictions could make it impossible to establish effective commercial markets for these species.

In many cases, the scale of an invasive species market will need to be very large in order to control the population of invasive species. Using extinction risk models, it is clear that population-reducing consumption will be a challenge for many species that invasivores hope to target. For example, invasivores encourage harvest of wild boar (*Sus scrofa*) for consumption. Existing models show that invasivores would need to annually harvest 50% of a boar population simply to keep growth flat. With many target invasives, introduction history (for instance, species that were originally introduced specifically for food, like wild boar) and current market trends (those species already marketed for consumption, like blue tilapia (*Oreochromis aureus*)), suggest that the public will not, or cannot, consume a biologically significant quantity. Where the public does consume invasives, they often source from farms or from the species' native range and, therefore, have no effect on the invasive populations.

If invasivores are able to establish sufficiently large markets despite legal barriers and current market conditions, those large markets may in fact work to entrench the target invasive and spread it beyond its current non-native range.

There are both cultural and economic aspects to invasive species entrenchment that could stem from large invasivory markets. Biologically sufficient markets will require a diverse set of economic actors. When businesses invest in an invasivore market, their incentive is to maintain and grow that market. In other words, the economic and biological goals are at odds. As an invasive species declines, economic actors may endeavor to halt the decline in an effort to maintain their investment in the market. Efforts to reduce wild boar hunting in Michigan, for example, have led to strong condemnation from hunting guides who stand to lose business if they cannot take customers on boar hunts. A similar cultural phenomenon may arise. Consumers may begin to recognize invasive species as a valuable part of their milieu and then protest declining populations that tend to remove a cultural icon. Although not food-related, the American public has shown deep attachment to wild mustangs (*Equus ferus caballus*), despite their invasiveness, and object to government management plans.

Finally, large markets could lead to target species spreading beyond their currently invaded range. If markets emerge to support invasive-species consumption at the levels necessary to impact invasive populations, there will be strong incentives to have the new commodities easily, regularly, and inexpensively available. One should expect individuals and businesses to establish more locally accessible populations for easier consumption. Hunters have previously relocated groups of wild boar, for example, to facilitate more local hunting opportunities. Likewise, many invasive species are invasive because they spread so easily. Many invasive plants can establish populations from berries or vegetative shoots. Japanese knotweed (*Fallopia japonica)* can root, grow, and produce offspring when even an individual segment of the knotweed stalk is discarded. In addition to intentional spreading, large markets can lead to accidental spreading when consumers trash, drop, compost, or otherwise release an invasive species, or part of an invasive species, into the environment.

The invasivore movement is captivating and, to its credit, is a tool for educating the public about an important issue. However, there are substantial challenges to its feasibility and the more popular it becomes, the more likely it is to exacerbate ecological problems. It may be, in other words, a self-defeating effort. For this reason, a more critical and public debate of the idea is necessary.

WHAT MAKES INVASIVE SPECIES ERADICATIONS ULTIMATELY SUCCESSFUL? A REVIEW OF INVASIVE SPECIES REMOVAL AND ECOSYSTEM RECOVERY

Kirsten M. Prior[1], Damian C. Adams[1], Kier D. Klepzig[2] and Jiri Hulcr[1]

[1]School of Forest Resources and Conservation, University of Florida, 136 Newins-Ziegler Hall, Gainesville, FL 32611
[2]USDA Forest Service, Southern Research Station, 200 W.T. Weaver Blvd., Asheville, NC 28804

ABSTRACT

Once an introduced species is detected in a new area, managers can decide to do nothing or to implement a control or eradication program. Control programs aim to reduce populations of target species to an "acceptable level", while eradication programs aim to completely eliminate or extirpate populations. When feasible, eradication is the favored management approach because in theory it is a one-time and permanent solution, compared to control or suppression that requires on-going effort.

Many eradication programs have successfully met these population-based goals, with success more likely when there is quick detection and action, when organisms are easy to detect, and when infestations are small and isolated. Determining the outcomes of an eradication program, however, is not a trivial task. Eradication is commonly defined as the elimination of every reproducing individual from a geographic area that is sufficiently isolated to prevent reinvasion. Determining if a program is successful by this standard depends on meeting the criteria that individuals are eliminated, and that reintroduction is unlikely. However, knowing if and when a program meets these criteria is challenging, and often the outcome of the program is determined with uncertain information. Certainty in determining success and the likelihood of sustained success is higher for species that are easy to detect, are detected early, and that occur in isolated habitats. For these invasions, the decision for managers to implement an eradication program should be relatively easy. However, for other invasions, managers are confronted with difficult decisions, such as when to implement eradication or control programs, and when to end programs.

An added layer of complexity is that most invasive species management programs are judged by the public and policymakers according to much broader management goals. For example, the United States Executive Order on Invasive Species (1999) suggests that agencies should, "prevent the introduction of invasive species and to provide for their control to minimize the economic, ecological, and human health impacts that invasive species can cause." These broad goals and that fact that eradication is difficult to assess for many species poses the question, should population elimination or control be the focal or only management endpoint of invasive species management programs? In this presentation, we highlighted that the proximate goals of invasive species management (i.e., removal or eradication) do not always lead to the ultimate goals of management programs (e.g., the alleviation of ecological impacts), and we discussed what this misalignment means for optimal management of invaded ecosystems.

Understanding the appropriate goals or endpoints of invasive species management programs is important because management endpoints may not always align. For example, if the proximate endpoint of an invasive species management program is eradication, a program will be scored as successful when the

population is eliminated, and unsuccessful when not, or only suppression occurs. When the ultimate goal of a management program is to alleviate the ecological impact of an invasive species to allow for ecological recovery, a program will be scored as successful when there is ecological recovery, such an increase in native populations or communities. However, there may be scenarios when eradication does not lead to ecological recovery, or when ecological recovery occurs when eradication is not declared. Understanding these conflicts, and what the appropriate endpoints are, is important in designing optimal management strategies. For example, in scenarios in which eradication does not lead to ecological recovery, managers should consider managing beyond eradication to achieve management goals. In scenarios when eradication is not necessary to allow for ecological recovery, perhaps managers do not need to focus on population elimination (especially for hard to detect species) as an endpoint to achieve ultimate management goals.

Our systematic review of studies examined how often and in what contexts do invasive species removals leads to ecological recovery. This review consisted of studies that removed (eradicated or suppressed) invasive species and measured ecological recovery. Ecological recovery was scored as positive when there was an increase in population size, biomass, or diversity of native species, or a change in an ecosystem process to a pre-invaded state. Negative outcomes occurred when there was an increase in the population, biomass, or diversity of invasive species, or a negative change in an ecosystem process. Studies compared responses pre and post invasive species management or in managed versus unmanaged plots or sites.

Out of 74 studies, just over half (51%) had positive ecological recovery post-management, and 18% mixed outcomes. Thus, the majority of removal efforts have allowed for partial or partially positive ecological recovery. Increases in damaging invasive species or negative changes in ecosystem processes occurred in 24% of cases, with no ecological change in 7% of the cases. Thus, the possibility of no recovery or a negative outcome should be a serious consideration for invasive species management programs that aim to alleviate the ecological impact of invasive species to allow for ecological recovery.

In an approximately equal number of cases, species eradication led to either ecological recovery or not. The management implication of this result is that eradication may not always be an appropriate endpoint for programs that aim to alleviate ecological impacts, and to meet these broader goals, managers should anticipate managing beyond eradication in many cases. Additional or alternative management, such as the management of multiple invasive species or active management post-removal, should be a consideration for invasive species management programs that aim for ecological recovery. Pre-assessments that determine the ecological function of the invasive species and its interactions with other species will help managers predict when additional management may be needed.

We also found an equal number of cases in which the population of the invasive species was either eradicated or suppressed, and ecological recovery was positive. The management implication of this finding is that eradication may not always be a superior management strategy as compared to suppression when the goal is to alleviate ecological impacts. Thus, especially for hard to detect species, in which determining eradication is difficult, efforts and funds may not need to be allocated to finding every last individual (i.e., confirming eradication), but can be shifted to more effective activities, including continued surveillance and minimal control when needed, and active management. Finally, several factors were highlighted that might be important in determining negative ecological outcomes. Additional or alternative management may be especially needed in heavily invaded areas, after the removal of invasive plants and vertebrates, in large infested areas, and in aquatic ecosystems. This systematic review and analysis are ongoing, and future work will include the addition of studies and a more fine-scale analysis of factors influencing the likelihood of ecological recovery post-management.

FACTORS AFFECTING TRAP CATCHES OF PINE SAWYERS (*MONOCHAMUS* SPECIES)

Dan Miller

USDA Forest Service, Southern Research Station, 320 Green St., Athens GA 30602

ABSTRACT

Lack of knowledge on trapping Cerambycidae was evident when the Asian longhorn beetle, *Anoplophora glabripennis* (Motschulsky) invaded Canada and the USA about 15-20 years ago. Various research initiatives were started to address this deficiency including funding by USDA Forest Service (WO) to study common longhorn beetles such as pine sawyers (*Monochamus* species) in North America. Adult pine sawyers feed on foliage and small branches. In epidemic situations, adult feeding can defoliate and stress pine trees, leading to mortality at times. Female sawyers lay eggs on trunks and branches of pine trees. Larval feeding can degrade lumber value. The most important consideration for pine sawyers is their ability to vector pine wood nematodes which can cause pine wilt disease and high levels of tree mortality. The threat of pine wilt disease has resulted in export restrictions on North American wood products and detection programs for exotic sawyer beetles.

Detection programs require effective traps and lures. Host volatiles such as ethanol and α-pinene attract sawyers, as do various bark beetle pheromones such as ipsenol and ipsdienol. In a continent-wide survey conducted in 2006-2008, we found that the quaternary blend of ethanol, α-pinene, ipsenol and ipsdienol was attractive to six species of pine sawyers in North America. Males of various species of Monochamus produce the pheromone monochamol which is attractive to both sexes. In a nationwide survey conducted in 2012-2014, we found that the tertiary combination of α-pinene, ipsenol and monochamol was attractive to six species of pine sawyers. In contrast, ipsenol had no effect on catches of *M. scutellatus* (Say) in traps baited with α-pinene and monochamol.

Initial studies on trap design found that dark traps such as the Intercept to be most effective. We revised the multiple-funnel trap to increase the size of funnel holes from 5cm to 12cm, thereby allowing lures to be placed inside the traps and maximizing plumes of attractants. When baited with the quaternary blend, modified traps outperformed Intercept traps by more than 100%. Black or purple traps outperform green traps for *M. titillator* F. Trap catches of sawyers also increase when traps are treated with a surfactant such as fluon or Teflon or when collection cups contain solutions of salt or antifreeze. Catches of *M. titillator* were greater when traps were placed in the canopy of trees compared to traps at breast height.

ASIAN LONGHORNED BEETLE IN EUROPE – FURTHER DEVELOPMENT OF DETECTION METHODS AND RISK MANAGEMENT (PROJECT ANOPLORISK-II)

Gernot Hoch[1], Ute Hoyer-Tomiczek[1], Gabriele Sauseng[2] and Robert Weaver[3]

[1]BFW Austrian Research Centre for Forests, Seckendorff-Gudent-Weg 8, 1131 Vienna, Austria
[2]Sonnenweg 1, 8403 Lebring, Austria
[3]Fera Science Ltd., Sand Hutton, York, YO41 1LZ, UK

ABSTRACT

Since the first European detection of an outbreak of the Asian longhorned beetle, *Anoplophora glabripennis*, in the Austrian town of Braunau in 2001, more than 25 infestations have been reported also from France, Germany, Italy, the Netherlands, UK, Switzerland, Turkey, Finland and Montenegro, the majority of which were discovered after 2012. In response the European Commission issued an implementing decision 2015/893/EU on measures against *A. glabripennis* in the European Union regulating important topics, such as import inspections, establishment of demarcated areas in case of infestations (consisting of infested zone and buffer zone), control on internal movement and survey programs. This decision is binding for all member states and shall help standardizing efforts to prevent introduction and spread of *A. glabripennis*. Early detection of life stages in the wood as well as free living adults are of great importance in this context. Therefore, several promising methods were studied in the trinational project ANOPLORISK-II (in the framework of EUPHRESCO); this presentation reports on development in the use of canine scent detection for *A. glabripennis* and deployment of pheromone-kairomone baited traps in outbreak and high risk areas.

Anoplophora detection dogs have been trained at the Austrian Research Centre for Forests (BFW) since 2009; up to the end of 2015, a total of 77 dogs have been trained. Most of these dogs and their handlers work regularly in outbreak areas in Austria, Germany, Switzerland, and France as well as at import inspections. In two tests series in 2104 and 2015, searching ability of a total of 18 dogs (of 11 different breeds) was quantified. Each test consisted of 2 positive (containing *A. glabripennis* scent material) and 6 negative samples to be inspected by a dog (3 repeats per test). Positions of samples were randomly assigned, dogs and handler were blinded. For testing under standardized conditions, samples were placed in hollow concrete building blocks covered with wooden lids with holes. Dogs detected *A. glabripennis* frass or a piece of infested wood plus larva with a mean sensitivity (number of correct positive indications divided by number of all positive samples in a test) of 91.7% and 92.6%, respectively. Specificity (number of correct negative indications divided by number of all negative samples in a test) was 85.6% and 94.4%. Searching ability for living larvae alone was slightly lower (sensitivity 85%, specificity 79.4%). The second test series was carried out under realistic field conditions. When searching for *A. glabripennis* frass hidden in the grass at the base of young poplar trees in a plantation, values were as high as in the standardized test: sensitivity was 88.1% and specificity 95.6%. Frass in test tubes with filter paper (negative samples consisted of test tubes with filter paper only) placed on the stems of young poplars at 1.8 m height was detected with 75.0% sensitivity and 86.5% specificity. The lower success occurred because some dogs responded to the visual cue of the tubes on the trees leading to premature termination of the

search. In the most complex environment, where frass was hidden in holes and bark crevices of old fruit trees in an orchard, sensitivity was 83.3% and specificity was 85%. Mean temperatures during the various tests ranged from 1.8°C to 16.4°C, indicating that dogs are able to work also at low temperature. The two test series revealed considerable variation between the dogs. Three dogs showed an overall sensitivity greater 95%, five dogs were above 91%. This indicates the importance of regular training and practical experience for reaching the required high reliability.

Traps for adult *A. glabripennis* were deployed in outbreak areas and high risk sites (stone importers) throughout two flight seasons in 2014 and 2015. Eighteen traps were installed in the infested zone of Paddock Wood, Kent, UK and 20 (plus 7 in 2015) traps were installed in the infested zone of Gallspach, Austria. Traps were hung in the crowns of broadleaved trees. Traps and lures consisting of *A. glabripennis* pheromone and host tree volatiles were purchased from ChemTica Internacional S.A. (Costa Rica): the 7 additional traps with lures in 2015 were provided from Witasek Pflanzenschutz GmbH (Austria). No *A. glabripennis* was caught in the UK. One *A. glabripennis* was caught in Austria 2015 in a ChemTica trap. The catch of nontarget beetles was recorded; no cerambycid was caught in 2014 and only 3 specimens were caught in 2015 in Austria. No cerambycids were caught in the UK. Five and 10 *A. glabripennis* traps (ChemTica), respectively, as well as 3 and 2 traps for *Monochamus* sp. (multifunnel traps from Econex, Spain; lures from SEDQ, Spain) were installed at the storage yards of two big stone distributors importing significant quantities from China. No *A. glabripennis* were caught. A total of 4 *Monochamus galloprovincialis* were caught in the Econex/SEDQ traps. Nine species of other cerambycids were caught in the *A. glabripennis* traps and 11 species in the *Monochamus* traps (total of 52 specimens). Among these were abundant native species such as *Spondylus buprestoides* or *Hylotrupes bajulus* but also one specimen of the Asian *Trichferus campestris*, which has previously been intercepted in wood packaging material entering Austria from China.

The trap catches of *A. glabripennis* were low. However, since both infestations are under eradication and the populations should therefore be extremely low, high numbers were not expected. The one caught specimen in Austria was of importance, because an infested tree that had been overlooked in the previous survey was detected in close vicinity of the trap. Overall, the two methods presented here, dog detection and trapping of adults, provide feasible methods for detecting *A. glabripennis* in addition to ground surveys and inspections by tree climbers.

EFFECT OF TRAP COLOR, TRAP HEIGHT, AND LURE ON DETECTION OF POTENTIALLY INVASIVE BARK AND WOOD BORING BEETLES

Jon Sweeney[1], Peter Silk[1], Reggie Webster[1], Cory Hughes[1], Peter Mayo[1], Jerzy M. Gutowski[2], Tomasz Mokrzycki[3], Dan Miller[4], Krista Ryall[5], Meng Qingfan[6], Li Yan[6] and Joe Francese[7]

[1]Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Centre, 1350 Regent Street, Fredericton, New Brunswick E3B 5P7
[2]Forest Research Institute, Białowieża, Poland
[3]Warsaw University of Life Science, Warsaw, Poland
[4]Southern Research Station, USDA Forest Service, 320 Green St., Athens, GA, 30602
[5]Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5
[6]Forestry College of Beihua University, 3999 Binjiangdong Road Jilin, Jilin Province, The P.R. China, 132013
[7]USDA APHIS PPQ, Otis Laboratory, 1398 West Truck Road, Buzzards Bay, MA 02542

ABSTRACT

Bark- and wood boring beetles continue to move intercontinentally in the solid wood packaging pathway in spite of phytosanitary measures like ISPM 15, and some of these species may become invasive in their new habitats. The sooner an established invasive species is detected, the more readily it can be eradicated, contained, or managed. Most exotic beetle surveys in North America use black 12-funnel Lindgren traps placed in the understory, with the collecting cups 30–50 cm above the ground. These traps are pretty good at detecting species of Scolytinae and Cerambycidae but in our experience catch few species of Buprestidae, especially *Agrilus* spp. The objective of this study was to test the effects of trap color, trap placement, and lure, on detection of Cerambycidae, Buprestidae, and Scolytinae in 12-funnel Lindgren traps.

We conducted two field experiments. Experiment 1 was a 3 x 2 factorial testing the effects of trap color (black *vs.* green *vs.*, purple) and trap placement (tree canopy *vs.* understory) and was conducted at four sites in 2015: New Brunswick, Canada; Białowieża, Poland; Georgia, USA; and Jilin, China. Each trap was coated with Fluon® to increase beetle catch and baited with the same multiple "superlure" combination of racemic 3-hydroxyhexan-2-one, racemic hydroxyoctan-2-one, *R*R**-2,3-hexane diols, *E/Z*-fuscumol, *E/Z*-fuscumol acetate, and UHR ethanol. Each of the six color-height combinations was replicated eight times per site in a randomized complete block design. Based on the positive response of *Agrilus planipennis* and other *Agrilus* spp. to green and purple traps, we predicted green and purple traps would detect more *Agrilus* spp. than would black traps. We also predicted that species composition would differ between traps in the tree canopy and traps in the understory, and therefore we would detect more species overall by placing half of the traps in the canopy and half in the understory, rather than placing all traps at a single level. Experiment 2 tested the effect of trap color (black *vs.* green *vs.*, purple) and lure (superlure *vs.* superlure + *Z*-3-hexenol) with all traps placed in the tree canopy. This experiment was replicated eight times in randomized blocks at each of three sites: New Brunswick, Massachusetts, and Ontario. We predicted the green leaf volatile, *Z*-3-hexenol, would increase detection of species that feed

on hardwood foliage during sexual maturation. Samples are still being processed for both experiments at most sites, so here we present results from Experiment 1 from New Brunswick and Poland only.

Data were subject to ANOVA and the residuals tested for normality using Shapiro-Wilks and the Kolmogorov-Smirvov tests (SAS PROC Univariate). If a log(y+1) transformation did not normalize the residuals, the data were transformed to ranks and subject to ANOVA (Friedman's test). EstimateS software and Coleman's rarefaction was used to calculate the mean number of species detected per cumulative number of traps per site, to compare the detection efficacy of each trap color-placement combination.

In Poland, we collected 51 species (3915 specimens) of Cerambycidae, 11 species of Buprestidae (807 specimens), and 25 species (1827 specimens) of Scolytinae, including some species considered rare in Poland and Central Europe. Catches were lower in New Brunswick with 37 species (723 specimens) of Cerambycidae, 5 species of Buprestidae (212 specimens), and 20 species (989 specimens) of Scolytinae. Trap color and trap placement significantly affected the number of species of Cerambycidae and Buprestidae detected per trap as well as mean catch of several species. As predicted, green traps performed well at detecting Buprestid species; four species were captured mainly in green traps in the tree canopy (*Agrilus laticornis, A. obscuricollis, A. angustulus, Trachys minuta*) and two species were caught mainly in green traps placed in either strata (*A. masculinus, A. olivicolor*). Some longhorn species (*Cortodera femorata, Molorchus minor, Grammoptera abdominalis,* and *Sternidius rusticus*) were also caught mainly in green traps placed in the canopy; *Alosterna tabacicolor* was caught almost entirely in green traps in the understory. Purple traps in the tree canopy detected the most *Agrilus sulcicollis, Diverca divaricata* (Buprestidae) and *Clytus tropicus* (Cerambycidae) whereas purple traps in the understory caught the most *Tetropium fuscum* and *Rhagium mordax* (Cerambycidae). Mean catch of four longhorn species (*Xylotrechus antilope, Poecilium alni, Neoclytus acuminatus,* and *Urgleptes signatus*) was greatest in the tree canopy but was unaffected by trap color. Detection of Scolytinae was not affected by trap color; some species were caught mainly in canopy traps (*Xyleborinus saxeseni, Hylesinus aculeatus*) and others mainly in understory traps (*Anisandrus dispar, Xylosandrus germanus*). Overall, green traps placed in the tree canopy caught the highest mean number of species of Cerambycidae and Buprestidae per trap and any color trap in the understory caught the most species of Scolytinae. Coleman's rarefaction indicated that efficacy of detecting bark and wood boring beetles in all three target taxa was increased by using more than one trap color and by placing some traps in the canopy and some in the understory. For example, in Poland, a mix of four green canopy traps and four purple understory traps detected 58 species compared to only 34 species detected in eight black understory traps.

BIOTIC AND ABIOTIC DRIVERS OF VARIATION IN SIZE, EMERGENCE, AND SEX RATIO IN *SIREX NOCTILIO* F.

Jeff Garnas[1,2], Katie Termer[2,3], Jenna Sullivan[4], Matt Ayres[5], Bernard Slippers[2,6] and Brett P. Hurley[1,2]

[1] Department of Zoology and Entomology, University of Pretoria, South Africa,
[2] Forestry and Agricultural, Biotechnology Institute (FABI)
[3] Weyerhaeuser, New Bern, North Carolina (current address)
[4] Department of Biology, Oregon State University
[5] Department of Ecology and Evolution, Dartmouth College
[6] Department of Genetics, University of Pretoria, South Africa

ABSTRACT

Variation in resource quality can influence insect oviposition choice as well as larval growth and survival. Egg and/or larval mortality rates are often influenced by aspects of host quality such as defensive chemistry, water potential or nutrient availability. Larvae exposed to low quality hosts or host tissue may take longer to mature or may yield smaller adults with knock on effects on fecundity, longevity or dispersal ability as adults. Differential mortality rates by gender can lead to skewed sex ratios as a function of resource quality. Where females have direct control over offspring gender (e.g., in haplodiploid species where unfertilized eggs develop into males), the perception of resource quality can influence fertilization rates, resulting in skewed sex ratios. Evaluating the impacts of such variation on key vital rates is critical to a deeper understanding of the population dynamics of insects across a range of conditions.

The European woodwasp, *Sirex noctilio* (Hymenoptera:Siricidae) is a globally invasive, xylophagous pest of pine, and has been particularly damaging in the Southern Hemisphere. First detected in South Africa in 1994, this insect has become a major problem for pine growers in the region, and as such has been the focus of considerable research there. With the wasp's introduction into North America (Oswego, NY) in 2005, there has been renewed interest in understanding key aspects of the biology and ecology of this insect. Unlike most siricids that occur almost exclusively in dead and dying trees, *S. noctilio* is capable of killing large, vigorously growing trees in much of its invasive range, though such behavior to date appears rare in North American native (or naturalized) pine forests.

In South Africa, *S. noctilio* is known to co-occur regularly with a handful of pine insects and fungi, most notably the North American Deodar weevil, *Pissodes nemorensis*, and the latent pathogen *Diplodia sapinea* (Botryospheriacae). Colonization by these or other biotic agents could influence resource quality from the perspective of *S. noctilio* by competing directly for xylem resources, by influencing the rate and trajectory of tree decline subsequent to attack, or by influencing the growth and survival of the wasps' symbiotic fungus, *Amylostereum aereolatum*. Likewise, intraspecific variation among trees of the dominant host of *S. noctilio* in South Africa, *Pinus patula*, could influence wasp preference and performance. In North America, *Sirex noctilio* has not yet become a widespread agent of tree mortality among healthy trees, occurring mostly in overstocked *P. resinosa* and *P. sylvestris*. In many such trees, *S. noctilio* co-occurs with a complex community of xylem and phloem-boring insects as well as numerous associated species of fungi.

Here we report on two complimentary studies of *S. noctilio*, one in South Africa (Mpumalanga Province) and the other in the US (Syracuse, NY). The South African study uses a life table approach to determining larval growth and mortality in *Pinus patula* using log dissections across three time points relative to larval development (early, middle and late) and three log sections (low, middle and high). We examined a suite of biotic and abiotic factors at the tree, tree section and site scale for possible contributions to body size variation and male biased sex ratios (commonly observed in this region). In the US, we used adult emergence data, measuring adult size (head capsule width, body length, and hind tibial length) and emergence counts by gender in experimentally girdled tress from 20 sites around the Syracuse area to ask similar questions about the role of host and site in driving variation in body size and emergence success.

We found greater than fourfold variation in female body size in *S. noctilio* from both South Africa and New York. As expected, egg number correlated strongly with body size in females. In South African *P. patula*, both male and female late instar larvae and pupae were larger in bottom log section as compared with the middle and top. For both genders, body size correlated negatively with wood moisture but only in the bottom log sections. No relationship between the cross-sectional area of bluestain (*D. sapinea*) was evident with respect to *S. noctilio* body size, larval density or survivorship. There were major differences in gender-specific survival by log section, however, which was considerably lower for males in bottom sections (35.7%) relative to middle and top sections (73.5% and 68.8% respectively). The opposite pattern was apparent for females, with 51.9%, 53.9% and 29.3% larval survival from bottom, middle and top sections respectively. As by far the largest numbers of individuals are produced in the top sections of infested trees (data not shown), it is likely that differential larval survival contributes substantively to the male bias observed in central South African plantations.

In the US, adult emergence was higher from Scots pine relative to red (Kruskal-Wallis χ^2= 11.4; df = 1; P <0.001). Mean female length was greater in red than in Scots pine (24.7 ± 2.3 mm vs. 22.3 ± 1.6 mm,; $F_{1,16}$=5.0, p = 0.04) but body length was not dependent on when trees were girdled ($F_{1,24}$ = 3.41, p = 0.08). Variance components from mixed effect model predicting female body length showed a negligible contribution of site on variation in female body length, while trees explained 36.8% of observed variation. The majority of variation in body size occurs within trees (63.2%) likely reflecting some aspects of log section height (pooled in this study). There was no evidence that body length co-varies with emergence density at the tree or site scale.

This work stands to improve understanding of environmental and host-related factors affecting key aspects of *S. noctilio* biology and life history on multiple continents.

CHALLENGES FACING BIOLOGICAL CONTROL OF INVASIVE ARTHROPODS

Ann E. Hajek[1], Brett Hurley[2], Marc Kenis[3], Jeffrey R. Garnas[2], Samantha J. Bush[2], Michael J. Wingfield[4], Joop C. van Lenteren[5] and Matthew J. W. Cock[6]

[1]Department of Entomology, Cornell University, Ithaca, New York 14853-2601 USA
[2]Department of Zoology and Entomology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, 0002 South Africa
[3]CABI, 1 Rue de Grillons, Delémont, 2800 Switzerland
[4] Department of Microbiology and Pathology, Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, 0002 South Africa
[5]Laboratory of Entomology, Wageningen University, 6700AA Wagingen, Netherlands
[6]CABI, Bakeham Lane, Egham, TW20 9TY, United Kingdom

ABSTRACT

A recent update of the BIOCAT database of classical biological control introductions listed a total of 7094 introductions of 2677 invertebrate biological control agents from the 1880s through 2009. In augmentation biological controls, >230 species of invertebrate natural enemies have been applied against 100 pest species since 1915. Thus, both classical and augmentation biological control are strategies that have been used extensively for managing insect pests. Both strategies have often focused on use of exotic natural enemies against invasive invertebrate pests. In 1983, a paper by Frank Howarth was published that began what turned into a major debate about whether biological control was too risky for our native biodiversity when exotic natural enemies were used. Especially classical biological control began to be regarded with suspicion regarding whether this practice was harming our native fauna. The paper discusses that significant damage has rarely occurred and how such problems are being prevented now. In-depth evaluations have shown that negative effects of introduced generalist predators, especially vertebrates, on biodiversity have occurred and everyone agrees that such agents should no longer be used. Non-specific natural enemies like *Compsilura concinnata* which began being released against gypsy moth in 1906, were generally introduced long ago when priorities for control programs differed from today and these agents would no longer be considered. In the past, biological control of invertebrates received less oversight than biological control of weeds and less host specificity testing was required but this has now changed. Finally, some natural enemies have moved on their own to areas where they have had impacts, e.g., *Harmonia axyridis* was not purposefully introduced to the United Kingdom but after it was released in Europe, it dispersed to the UK on its own, and the native coccinellid populations have subsequently declined; today movement of biological control agents into neighboring regions after release is considered before introductions are made.

Beginning in the 1980s, the numbers of introductions of parasitoids and predators for classical biological control began to decline and this decline has continued. This could, in large part, be due to reluctance to use classical biological control but with the host specificity testing that is now required the process of getting approval for release of new natural enemies is also more time consuming. In addition, the biological control community has evaluated the literature and only approximately 12 examples of insect natural

enemies having population level impacts on native species have been documented. In the meantime, international guidelines and natural regulations are now in place to make sure that the natural enemies that are released will have an overall positive and not negative impact on our environment. Methods for host specificity testing have been developed and/or improved and risk assessments are conducted. This results in more time for biological control agents to be approved and fewer natural enemies are acceptable for release when compared with the past. It is also agreed that post-introduction monitoring should be conducted for both targets and non-targets whenever possible and that potential indirect effects should be considered.

Additionally, some new concerns, aside from environmental safety, that impact biological control using exotic agents have arisen. The Nagoya Protocol of 2010 protects the 'genetic resources' of countries around the world and this influences the ability of biological control practitioners to conduct foreign exploration; a special exemption for biological control agents, which generally will result in no to little profits is being sought.

In summary, evaluation of past biological control introductions has shown that significant population-level non-target impacts have rarely been seen. We consider that today biological control using exotic natural enemies faces challenges but will continue to be practiced, perhaps without as many introductions of exotic species, but this practice is now ensured as being safer for the environment.

COMPARATIVE POPULATION ECOLOGY OF WINTER MOTH AND BRUCE SPANWORM IN NORTH AMERICA

Hannah J. Broadley[1], George H. Boettner[2] and Joseph S. Elkinton[1,2]

[1]Organismic and Evolutionary Biology, University of Massachusetts, Amherst, MA 01003
[2]Department of Environmental Conservation, University of Massachusetts, Amherst, MA 01003

ABSTRACT

Winter moth (*Operophtera brumata*), a polyphagous geometrid, was accidently introduced to the north-eastern United States from Europe in the 1990s. Prior to this introduction, it had been accidently introduced to Nova Scotia in the 1930s and to Oregon and British Columbia in the 1950s to 1970s. Since its introduction in the northeast, winter moth has exhibited population outbreaks reaching densities of up to 500 pupae/m^2 and resulting in 50% defoliation. It is considered a pest on apple, blueberry, cranberry, and stone fruits. It has spread coastal at 7 to 8 km/year throughout eastern Massachusetts, north through New Hampshire and into Maine, and south onto the Cape, across Rhode Island, onto Long Island, and most recently to Connecticut.

In Nova Scotia and in British Columbia, the tachinid fly, *C. albicans*, and the ichneumonid wasp, *Agrypon flaveolatum*, were used as biological control agents in the control of winter moth. However, at this time it is unclear whether *A. flaveolatum* is a generalist or a specialist and the phylogenetics of *A. flaveolatum* are unresolved. Accordingly, *A. flaveolatum* is not being released, but the Elkinton lab began releases of the tachinid parasitoid *Cyzenis albicans* in 2005. *C. albicans* has now been released at 40 sites and has established at 17 sites. In Welleseley, MA parasitism has reached almost 60% at one site and has spread over an area of 9 km^2 resulting in a notable decline of winter moth densities. While this parallels the trend seen in Nova Scotia, we are not seeing as complete nor widespread control by *C. albicans*. It appears that additional sources of control are needed for control. To better understand the system, we are (1) working to resolve the systematics and host-specificity of a native and the introduced Agrypon sp. and (2) are studying the controls acting upon Bruce spanworm (*Operophtera brumata*), a closely related native geometrid.

In the northeast, we have found *Agrypon* wasps (assumed to be *A. provancheri*) in our Bruce spanworm collections. In these collections, parasitism rates were highest in low-density years (19% in 2014 and 22% in 2015) as compared to a high-density year (3% in 2013). No Agrypon wasps were found in sympatric winter moth collections (N >10,000) suggesting that the Bruce spanworm *Agrypon* is host-specific. From our preliminary analyses of the CO1 barcoding gene of *Agrypon* sp. reared from winter moth (collected in British Columbia) and from our Bruce spanworm, I found 98% sequence identity. This suggests that the *Agrypon* species affecting Bruce spanworm in the northeast is *A. flaveolatum*, but it is a host-specific subpopulation of *A. flaveolatum*. Additionally, I have analyzed a pilot set of Finland *Agrypon* sp. reared from autumnal moth and found 98.5% sequence identity with *Agrypon* sp. reared from British Columbia winter moth and 98.9% identity to the *Agrypon* sp. I reared from Bruce spanworm. This is within the commonly accepted 2% genetic differences present within a species. In summary, it appears that *A. fla-*

veolatum is a cryptic species complex comprised of host-specific subspecies. This hypothesis and the host range of *A. flaveolatum* need to be tested.

Additionally, Bruce spanworm larvae collected in the same region and same time period as winter moth larvae experienced significantly higher mortality. Using microscopy, I found that Bruce spanworm cadavers showed 23x higher rates of infection by microsporidia, a pathogen that reduces fitness, than winter moth. I also scanned the cadavers for nucleopolyhedrovirus (NPV), which are known to cause epizootics in Lepidoptera populations, and found low levels of NPV in both populations. It is not known if Bruce spanworm and winter moth share pathogens, but with such a high prevalence of microsporidia in Bruce spanworm, we need to know if it has or can spread to winter moth and if it will aid in the management of this invasive pest.

Overall, we are evaluating potential sources of control to an invasive caterpillar by assessing *Agrypon flaveolatum*, a potential biological control, and evaluating regulatory agents acting on a native congener.

EARLY DETECTION AND MAPPING OF THE EMERALD ASH BORER (EAB), *AGRILUS PLANIPENNIS* FAIRMAIRE, USING REMOTE SENSING AND GIS DATA FUSION TECHNIQUES

Ryan P. Hanavan[1], Bruce Cook[2], Lawrence A. Corp[3], Rich Hallett[4] and Jen Pontius[4,5]

[1]USDA Forest Service, Forest Health Protection, 271 Mast Road, Durham, NH 03261
[2]NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD 20771
[c]Science Systems and Applications Inc., Biospheric Science Branch Code 618, Greenbelt, MD 20771
[d]USFS Northern Research Station, 271 Mast Rd., Durham, NH 03824
[e]University of Vermont, Rubenstein School of Environment and Natural Resources, 81 Carrigan Drive, Burlington, VT 05405

ABSTRACT

Biological invasions of non-native insects are both a threat to biodiversity and ecosystem stability. Almost 500 non-native insects had successfully established in the United States by 2011. Phloem feeding and wood boring insects are the most economically important. The emerald ash borer, *Agrilus planipennis* Fairmaire (EAB), is an exotic phloem feeding woodborer (Coleoptera: Buprestidae) that was introduced from Asia, and has become one of the most devastating insects to successfully establish and spread in North America. Widespread ash, *Fraxinus* spp., mortality was reported in Southeastern Michigan, USA, and Essex Co, Ontario, Canada in 2002 and EAB has been confirmed in 25 US states and two Canadian Provinces as of November, 2015.

Remote sensing data has been successfully used to map broad vegetation types (NLCD, USGS) along with the distribution of individual tree species. These efforts have been based primarily on coarse resolution mapping of healthy forest stands. High spatial resolution hyperspectral remote sensing technology has the potential to minimize these classification errors and therefore play a key role in the management of forest systems currently experiencing widespread decline and mortality. Working in collaboration with NASA Goddard scientists, our goal was to test the ability of a novel sensor (GLiHT) to map ash species at the tree level in EAB infested stands and urban areas.

Side by side comparisons of various imagery calibration inputs (hyperspectral bands only and hyperspectral bands plus vegetation indices) combined with various endmember configurations (all ash, vigor 1 ash only, and separate endmembers for each ash vigor class) allowed us to identify the most accurate approach for mapping ash species when there is a broad range of ash condition in the target mapping area. Across all endmember configurations, the hyperspectral bands plus vegetation indices resulted in greater ash identification accuracy than the hyperspectral imagery alone. This was exemplified in our imagery where we found significant differences among the most common species in almost all of the vegetation indices included in our analyses. Our results indicate that the addition of vegetation indices to hyperspectral data for input to the minimum noise fraction transform can provide additional information that is useful in distinguishing ash from other common tree species in a region of mixed forest health. In addition, we demonstrate that spectra from unhealthy ash are vastly different from those from healthy

ash foliage. We found that by training the classifier only on healthy ash, a majority of unhealthy ash were left unclassified. Our results indicate that significantly higher accuracy is achieved when utilizing hyperspectral bands and vegetation indices for inputs to minimum noise fraction transforms, in combination with the inclusion of separate endmembers to capture the full range of ash condition (e.g. canopy characteristics and resultant spectral signatures).

PROGRESS AND GAPS IN UNDERSTANDING MECHANISMS OF ASH TREE RESISTANCE TO EMERALD ASH BORER, A MODEL FOR WOOD-BORING INSECTS THAT KILL ANGIOSPERMS

Caterina Villari[1], Daniel A. Herms[2], Justin G.A. Whitehill[3], Chad M. Rigsby[4], Don Cipollini[4], David N. Showalter[1] and Pierluigi Bonello[1*]

[1]Department of Plant Pathology, The Ohio State University, 201 Kottman Hall, 2021 Coffey Rd, Columbus, OH 43210
[2]Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Thorne Hall, Wooster, OH 44691
[3]Michael Smith Laboratories, The University of British Columbia, 2185 East Mall, Vancouver, BC V6T 1Z4, Canada
[4]Department of Biological Sciences, Wright State University, 235A Biological Sciences, Dayton, OH 45435
*Presenting Author

ABSTRACT

We present a review of the literature, as well as more recent results, on resistance of ash to emerald ash borer, an invasive wood-boring insect causing widespread mortality of ash in North America. Manchurian ash (*Fraxinus mandshurica*), which coevolved with EAB, is more resistant than evolutionarily naïve North American and European congeners. Such resistance is expressed as lower preference by adults for feeding and oviposition as well as significantly lower larval feeding and development in Manchurian ash. Compared to susceptible species, Manchurian ash has higher constitutive levels of bark lignans, coumarins, proline, tyramine, and select defensive proteins, and is characterized by faster oxidation of phenolics. Consistent with EAB being a secondary colonizer of coevolved hosts, drought stress decreases resistance of Manchurian ash, but appears to have no effect on specific constitutive bark phenolics, suggesting that, on their own, phenolics do not contribute to increased susceptibility under drought stress. Instead, when compared with phylogenetically and chemically similar, but very susceptible, black ash, Manchurian ash resistance appears to be linked to higher constitutive peroxidase activity, lignin polymerization, and quinone generation, confirming that it is not the phenolic composition *per se* that may contribute to resistance, but rather the higher oxidative environment present in Manchurian ash phloem. Such higher oxidative environment in resistant ash is reflected in higher activities of quinone-protective and antioxidant enzymes in larvae feeding on Manchurian ash compared to susceptible white and green ash. This suggests that quinone-protective and antioxidant enzymes are important counter-adaptations of larvae for dealing with these resistance mechanisms. Finally, induced resistance of North American species to EAB in response to exogenous application of methyl jasmonate is associated with increased bark concentrations of verbascoside, lignin, and/or trypsin inhibitors, which decrease larval survival and/or growth in artificial diet assays. This suggests that these inherently susceptible species possess latent defenses that are not induced naturally by larval colonization, perhaps because they fail to recognize larval cues or respond quickly enough. Transcriptional profiling of resistant and susceptible ash species before and after EAB larval feeding is shedding light on the genetic basis of candidate constitutive and induced resistance genes, including those involved in phenolic biosynthesis and those coding for pro-oxidant enzymes. We propose future research directions that would address some remaining critical knowledge gaps.

BUILDING TOMORROW'S FORESTS: INTEGRATING HOST RESISTANCE INTO LONG-TERM MANAGEMENT OF SELECT TREE-KILLING INVASIVE PESTS

David N. Showalter[1], Jason Smith[2], Kenneth Raffa[3], Richard Sniezko[4], Damian Adams[2], Daniel A. Herms[5], Andrew Liebhold[6] and Pierluigi Bonello[1]

[1]Department of Plant Pathology, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210
[2]School of Forest Resources and Conservation, University of Florida, P.O. Box 110410, Gainesville, FL 32611
[3]Department of Entomology, University of Wisconsin-Madison, 345 Russell Laboratories, 1630 Linden Dr., Madison, WI 53706
[4]USDA Forest Service, Dorena Genetic Resource Center, 34963 Shoreview Dr., Cottage Grove, OR 97424
[5]Department of Entomology, Ohio Agricultural Research and Development Center, The Ohio State University, 1680 Madison Avenue, Wooster, OH 44691
[6]USDA Forest Service, Northern Research Station, Morgantown, WV 26505

ABSTRACT

Invasive insects and phytopathogens are causing historic levels of tree mortality around the world. Massive global trade of goods, particularly legal and illegal imports of live plant material and solid-wood packing, provides increasing pressure of non-native organisms[1]. A fraction of these organisms pass through measures intended to prevent transport to new areas, become established in naïve forest ecosystems, cannot be detected early enough to eradicate, and sometimes cause severe economic and environmental impacts[2,3]. To mitigate the impact of established invaders and protect host trees and ecosystems, regulatory and forest health management agencies mobilize rapidly to limit pest spread and to support research characterizing the nature of the threat and the invasion biology. Informed by experience, data, and stakeholders, responding agencies consider both short- and long-term costs and benefits of different management approaches with the objective of applying finite response capacity to an optimal mix of short-term forest maintenance and long-term forest transition goals.

Biological control has been a successful long-term response to many alien species that became invasive due to escape from their coevolved natural enemies. However, it is becoming increasingly clear that many of the most devastating alien insects and pathogens that have or are causing extensive tree mortality on a range-wide basis have become invasive largely due to a lack of bottom-up control exerted by host defenses. Pests acting in so-called "defense-free space[4]" are often intimately and cryptically associated with their hosts, and damage tissues with high fitness value. Examples include canker and wilt-inducing fungi (e.g. *Cronartium ribicola* in white pine blister rust and *Ophiostoma novo-ulmi* in Dutch elm disease) and oomycetes (e.g. *Phytophthora ramorum* in sudden oak death), bark and wood boring beetles (e.g. emerald ash borer), and sedentary stem-galling or sucking insects (e.g. hemlock wooly adelgid).

As soon as pests are identified as a threat to spread in defense-free space, responses should quickly focus on strategies that will facilitate the transition of valuable tree populations toward a "defense-constrained space", specifically the development of host resistance. Threats may be identified when pests overwhelm local containment and other mitigation efforts, or even before a potential invader establishes in a novel environment, based on patterns of tree mortality elsewhere (e.g. threats of emerald ash borer and ash

dieback to Europe and North America, respectively). By combining traditional selection and breeding with rapidly advancing genomic and phenotypic marker techniques, as well as targeted genetic engineering (e.g. American chestnut), modern host resistance development programs are accelerating and expanding the ability to identify and deploy diverse populations of locally-adapted pest-resistant trees. Well supported programs to develop host resistance, when applied to suitable pest systems and integrated with other management strategies, have the unique potential to conserve and/or restore threatened tree species and their ecosystem services as productive components of urban, plantation and, in some cases, naturally regenerating forests.

1. Liebhold, A. M., Brockerhoff, E. G., Garrett, L. J., Parke, J. L. & Britton, K. O. Live plant imports: the major pathway for forest insect and pathogen invasions of the US. *Front. Ecol. Environ.* **10,** 135–143 (2012).
2. Loo, J. A. Ecological impacts of non-indigenous invasive fungi as forest pathogens. *Biol. Invasions* **11,** 81–96 (2009).
3. Aukema, J. E. *et al.* Economic impacts of non-native forest insects in the continental United States. *PLoS One* **6,** e24587 (2011).
4. Gandhi, K. J. K. & Herms, D. A. Direct and indirect effects of alien insect herbivores on ecological processes and interactions in forests of eastern North America. *Biol. Invasions* **12,** 389–405 (2010).

PRESENTATIONS

Abstracts

RARE INFECTION OF A NON-TARGET BEETLE BY NEMATODE, *DELADENUS SIRICIDICOLA*, IN PINE INFESTED WITH *SIREX NOCTILIO*

Tonya D. Bittner, Ann E. Hajek and James K. Liebherr

Cornell University, Department of Entomology, 129 Garden Ave., Ithaca, New York 14853-2601

ABSTRACT

Serropalpus substriatus Haldeman (Coleoptera: Melandryidae) develops within the same trees as *Sirex noctilio* F. and *Sirex cyaneus* F. (Hymenoptera: Siricidae). This beetle is now reported emerging from red pine (*Pinus resinosa* Sol. ex Aiton) and balsam fir (*Abies balsamea* (L.) Mill.) (Pinaceae). Numbers of *Se. substriatus* emerging from pines were always much lower than numbers of *Sirex* in trees, and 17.9% of *Se. substriatus* required 2 years before emergence. During first years of emergence, *Se. substriatus* were found in 12 of 41 sampled red pines infested by *Si. noctilio*. Trees from which *Se. substriatus* emerged hosted higher densities of *Sirex* than trees without *Se. substriatus*. Comparing dually infested trees, *Deladenus siricidicola*, the parasitic/mycophagous nematode associated with *Si. noctilio*, was found parasitizing one of 141 (0.7%) *Se. substriatus* versus 39.5% of adult *Si. noctilio* in the same tree as the parasitized *Se. substriatus*. This is the first report of a non-target impact of *D. siricidicola* in North America, but the parasitism rate was very low in this uncommonly encountered wood borer. In Europe, a related species, *Serropalpus barbatus* Schaller, was also reported as being parasitized by *D. siricidicola*, but parasitism levels were not reported.

PUTATIVE MULTIPLE INTRODUCTIONS OF *SIREX NOCTILIO* (HYMENOPTERA: SIRICIDAE) IN NORTHEASTERN NORTH AMERICA BASED ON MULTILOCUS MICROSATELLITE GENOTYPES

Tonya D. Bittner[1], Ann E. Hajek[1], Laurel Haavik[2] and Jeremy Allison[2]

[1]Cornell University Department of Entomology, 129 Garden Ave. , Ithaca, New York 14853-2601
[2]Natural Resources Canada, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 2E5

ABSTRACT

The invasive woodwasp *Sirex noctilio* F. (Hymenoptera: Siricidae) was first collected in North America at Fulton, NY in 2004, and by 2010 it was reported in 5 U.S. states, Ontario, and Quebec. *S. noctilio* is capable of causing damage and mortality in pine stands. Understanding the genetic diversity of North American *S. noctilio* may point to new areas of inquiry, particularly regarding parasite associations, which could improve potential control methods in the U.S. We investigated the genetic diversity of 884 woodwasps from 8 populations in New York, Ontario, and Pennsylvania using 11 microsatellite loci. Most sampled woodwasps were reared from wood in 2014 and the remainder were trapped between 2006 and 2014. Given that microsatellites should not be under selection and the short time span since invasion, genetic variation is likely due to differences among founding genotypes. Genetic analyses support the hypothesis that at least two separate introductions occurred. Genetic distance measures were greatest between a site in southwestern Ontario and all other sites, suggesting that this population could represent a separate introduction event. Two methods of Bayesian clustering also support this idea; they detected 4 to 6 distinct genetic clusters with little admixture between the site in southwestern Ontario and other populations. Based on close dates of detection by trapping surveys and low confidence in trapping success, it is possible that both populations arrived earlier than first detections suggest. This study builds upon a previous worldwide analysis which suggested that the North American invasion originated from multiple sources.

KUDZU BUG IN TENNESSEE: RESPONDING TO A NEW INVASIVE SPECIES

Kadie Britt[1], Jerome F. Grant[1], Scott D. Stewart[2] and Steve D. Powell[3]

[1]Department of Entomology and Plant Pathology, 370 Plant Biotechnology Building, The University of Tennessee, Knoxville, TN 37996
[2]West Tennessee Research and Education Center, The University of Tennessee, 605 Airways Blvd., Jackson, TN 38301
[3]Box 40627 Melrose Station, Tennessee Department of Agriculture, Nashville, TN 37204

ABSTRACT

The kudzu bug (*Megacopta cribraria* (F.)), a non-native, invasive species from Asia, was first discovered in the U.S. in 2009 in several northeastern counties in Georgia. It has since spread to numerous other states, including Tennessee where it was first documented in 2012. In Tennessee, this invasive pest has spread rapidly to numerous counties across the state in only three years. The presence of kudzu bug in new areas causes agricultural (impact on soybean production), urban (home invasions), and health-related concerns (allergies, fear of insects in homes, etc.). This poster provided information on the response of the state of Tennessee (state agencies, land grant university, etc.) to kudzu bug using four stages of a typical emergency response program: 1) mitigation and prevention, 2) preparedness, 3) response, and 4) recovery.

The first phase of an emergency response program involves reducing vulnerability to potential threats and damage, such as those posed by kudzu bug. The Tennessee Department of Agriculture (TDA) and the University of Tennessee (UT) Extension Service developed plans to survey areas where kudzu bugs would be expected. The second phase involves 'preparedness'. Following the first documentation of kudzu bug in the U.S., TDA and UT personnel were aware of its potential movement into Tennessee and the resulting probable impact to soybeans, as well as to property owners, homeowners and renters. In response, partnerships were developed to provide education to employees of each potentially affected agency to learn about kudzu bug and its potential impact. Information was distributed to growers, homeowners, and the general public. The third phase involves 'response'. Following its discovery in Tennessee, statewide surveys assessed its distribution. Identifying the spread of kudzu bug and educating the public were two key agency responses. State quarantines were not enacted.

In an emergency response, the 'recovery' phase (fourth phase) is defined as restoration of the affected system. To reduce soybean impact, UT provided recommendations on kudzu bug management. Research in Tennessee addresses biology, seasonality, distribution, and natural enemies of kudzu bug. For example, the fungus, *Beauveria bassiana*, caused high mortality of kudzu bug on kudzu in 2015. This disease had not been recorded in previous years in Tennessee. The role of alternate hosts in population dynamics of kudzu bug also is under investigation.

STEAM AND VACUUM TREATMENT OF LARGE TIMBERS IN SOLID WOOD SKIDS

Zhangjing Chen[1], Marshall S. White[1] and Ron Mack[2]

[1]Department of Sustainable Biomaterials, Virginia Tech Blacksburg, VA
[2]USDA-APHIS-PPQ, 1398 West Truck Road, Buzzards Bay, MA 02542

ABSTRACT

Forest pests are commonly transported with wood packaging materials. Ports in US continue to intercept invasive pests in cross section timbers packaged with steel or heavy consignments. The large cross section timbers present a greater risk because the fumigation and kiln treatment as currently used in treating wood packaging materials are not effective on large cross section materials. The objective of our study is to determine the effectiveness of steam and vacuum for heat treating large cross section timbers in wood skids and crates, according to the heat treating requirements of ISPM 15. Three wood species of large dimension (8x8") timbers were tested. These represented a high density hardwood, a low density hardwood and a commonly used softwood. These were mixed oak (Quercus spp), yellow-poplar (Liriodendron tulipifera) and southern yellow pine (Pinus spp.). Timbers were partially air dried and are typical of large timbers used in heavy skids. Larvae of the pinewood sawyer beetles (Monochamus spp.) were used as a representative surrogate for invasive cerambycids.

During each test, three skids assembled from each wood species were treated. Separate and untreated large timber and a deckboard were set aside as controls. In each test, eight (8) larvae total were inoculated among two large timbers, and single larvae seeded in a deckboard. Four (4) larvae were inserted in the large control timber and one larva in the control deckboard. The initial vacuum pressure was 100mm Hg and test chamber temperature was set for 90°C. The treatment cycle continued until the core temperature of the large timber reached the required 56°C for 30 minutes. To measure temperature profiles within the timbers, thermocouples were placed at various locations. After each test, larvae were recovered and assessed for mortality.

Potential treatment effects on the quality of the timbers and the structural integrity of the skid structure were examined. The ends of each large timber in the skids were photographed before and after treatment to study any treatment effect.

In order to document the change in moisture content, large timbers were weighed before and after treatment. Overall heating time to achieve 56°C for 30 minutes to core was less than 7 hours for all 3 wood species tested (100 mmHg and 90°C steam). This is at least 30% less time than predicted treatment cycle using hot air at atmospheric pressure. Hot air process would split large timber. There was complete mortality (100%) of larval surrogates as a result of treatment. Quality of 8x8 timbers was not affected by the treatment. Average moisture content increased 4.1% during treatment.

MID-WINTER CHIPPING TO DESTROY EGG MASSES OF THE SPOTTED LANTERNFLY, *LYCORMA DELICATULA* (HEMIPTERA: FULGORIDAE)

Miriam F. Cooperband[1], Ron Mack[1] and Sven-Erik Spichiger[2]

[1]Otis Laboratory, USDA-APHIS-PPQ-CPHST, Buzzards Bay, MA
[2]Entomology Program, Pennsylvania Department of Agriculture, Harrisburg, PA

ABSTRACT

Spotted Lanternfly (SLF) *Lycorma delicatula* (White) was detected in September 2014 in PA. It is a broad generalist, but prefers feeding on *Ailanthus altissima* (tree-of-heaven) and grape. A chipping study was conducted in PA in February 2015 to determine if chipping would be an effective approach to destroy egg masses to treat infested wood in the quarantine zone. Infested *Ailanthus* trees were felled and egg masses were counted. Bolts were either chipped or kept intact (control). Chipped or intact wood was placed in screened barrels and monitored for emergence. Brown paper sticky bands taped to the inside rim of each barrel captured emerging nymphs, and barrels were held in a warehouse at 19° C. No nymphs were found in chipped treatments, as opposed to hundreds found in intact controls, resulting in 100% mortality (Table 1). Control barrels had on average 559 nymphs per barrel, with a hatch rate of 16.4 nymphs per egg mass, and a capture rate of 80% on sticky paper. If we assume and calculate that only the eggs in the top 2.5 cm of chips would survive due to composting effects, we would still expect roughly 28 nymphs per barrel. This suggests the eggs were killed during the chipping process rather than from other factors such as the heat and decay from composting. Mid-winter chipping was found to be a suitable way to treat wood infested with SLF egg masses.

Table 1. Number of nymphs emerging in barrels with infested chipped versus intact branches.

Chip depth per barrel (cm)	Avg. egg masses per barrel	Estimated egg masses in top 2.5 cm	Expected nymphs per top 2.5 cm on sticky band	Observed nymphs per barrel on sticky band	N
58.4	34.0	1.5	19.5	0.0	2
55.9	34.0	1.5	20.4	0.0	1
53.3	33.7	1.6	21.1	0.0	3
50.8	34.0	1.7	22.4	0.0	1
43.2	36.0	2.1	27.9	0.0	1
38.1	37.0	2.5	32.5	0.0	1
25.4	35.0	3.5	46.1	0.0	1
20.3	32.0	4.0	52.7	0.0	1
Avg. all chipped	**34.3**	**2.1**	**27.7**	**0**	**11**
Avg. all control	**34.0**	**34.0**	**448.1**	**442.4**	**5**

PRESENTATION OF VISUAL DECOY BEETLES AND PHEROMONE LURES TO EMERALD ASH BORERS ON SMALL BRANCH TRAPS

Michael Domingue [1], Stefanos S. Andreadis[1], Peter J. Silk[2], Krista Ryall[3] and Thomas C. Baker[1]

[1]Pennsylvania State University, Department of Entomology, Chemical Ecology Lab, University Park, PA 16802
[2]Natural Resources Canada, Canadian Forest Service, 1350 Regent Street South, Fredericton, NB, Canada E3B 5P7
[3]Natural Resources Canada, Canadian Forest Service1219 Queen Street East, Sault Ste. Marie, ON, Canada P6A 2E5

ABSTRACT

The emerald ash borer *Agrilus planipennis* (Coleoptera: Buprestidae) emits a macrocyclic lactone, Z3-dodecen-12-olide, that increases field trap captures when co-emitted with the green-leaf volatile compound Z3-hexenol. Here we assess attraction to these compounds using decoy-baited branch traps that also provide a visual mating signal to males of a female resting upon a leaf. In a plot of heavily infested *Fraxinus pennsylvanica,* trees with southern-facing sunlit branches were selected for trap placement. Pairs of branch traps with and without decoy beetles were placed on each tree, which were assigned one of three odor treatments. The odor treatments included no odor, Z3-hexenol alone, and Z3-hexenol with Z3-dodecen-12-olide. Male captures were positively affected by the presence of decoys and both odors. Decoy-baited traps presented with Z3-hexenol and Z3-dodecen-12-olide caught more males than any other treatment. On treatments possessing either decoys or Z3-dodecen-12-olide, male trap captures tended to occur later in the season. Female captures were not affected by decoys, but odor treatment did influence captures, with the Z3-hexenol plus Z3-dodecen-12-olide treatment catching the most females. Furthermore, female trap captures were negatively correlated with males captures on the control and Z3-hexenol baited traps, but not correlated with males when Z3-dodecen-12-olide was added. Thus, Z3-dodecen-12-olide attracts both sexes independently. The positive effects of decoys, Z3-hexenol, and Z3-dodecen-12-olide on the capture rates of these biologically realistic branch traps clarify that each component is needed to optimize attraction of males for mating. Female attraction was influenced most strongly by Z3-dodecen-12-olide emission, but in the context of previous studies remains less clearly understood.

THE ROLE OF STARVATION IN THE SYNERGY BETWEEN A FUNGAL PATHOGEN AND A PESTICIDE

Joanna J. Fisher and Ann E. Hajek

Department of Entomology, Cornell University, Comstock Hall, Ithaca, NY 14853-2601

ABSTRACT

Asian longhorned beetles, *Anoplophora glabripennis* (Motschulsky), are invasive wood borers which have been introduced into North America and Europe and the entomopathogenic fungus *Metarhizium brunneum* Petch is being developed for their control. A synergistic effect has been demonstrated between imidacloprid and *Metarhizium* in *A. glabripennis*. We investigated potential mechanisms for this synergy.

Shortly after exposure to imidacloprid beetle feeding is reduced. We determined whether or not the synergy between imidacloprid and *M. brunneum* in *A. glabripennis* is due to imidacloprid's ability to prevent feeding shortly after administration by starving beetles and exposing them to *M. brunneum.* We also investigated how starvation and pesticide exposure influence the beetles' encapsulation and melanization immune responses as these immune responses have been shown to be important in defense against fungal pathogens in other systems. We inserted nylon implants into the abdomens of beetles 24 h after treatment and allowed the beetles to respond to the immune challenge for 12 h after which the filaments were removed and analyzed using Fiji image analysis software. Melanization was measured as the darkness of the filament while encapsulation was measured as the total area of cellular material adhered to the filament.

Starvation had a similar impact on the survival of *M. brunneum*-inoculated beetles as exposure to imidacloprid. Beetles that were either starved or exposed to imidacloprid died in median of 11 d which was significantly faster than beetles exposed to *M. brunneum* alone that died in a median of 17 d. Inoculation with *M. brunneum* increased the melanization response compared to naive controls. Exposure of *M. brunneum*-inoculated beetles to imidacloprid reduced the melanization response compared to beetles treated with *M. brunneum* alone while starvation of *M. brunneum*-inoculated beetles did not significantly impact the melanization response. There was no significant impact of treatment on the encapsulation response. Our results suggest that part of the synergy between imidacloprid and *M. brunneum* is due to the pesticide's ability to reduce beetle feeding. However the synergy is not completely due to starvation since among *M. brunneum*-inoculated beetles, imidacloprid reduced the beetles' melanization response while starvation had no impact on melanization.

PESTLENS: AN EARLY-WARNING SYSTEM SUPPORTING U.S. SAFEGUARDING AGAINST EXOTIC PLANT PESTS

Jennifer Fritz[1], Heather Moylett[1] and Sherrie Emerine[1]

[1]North Carolina State University, Center for Integrated Pest Management, 1730 Varsity Drive, Raleigh, NC 27606, USA

ABSTRACT

Safeguarding actions aimed at preventing the introduction and minimizing the impact of exotic plant pests rely on current information about those pests. PestLens, a cooperative effort of the United States Department of Agriculture's Plant Protection and Quarantine (PPQ) and the Center for Integrated Pest Management at North Carolina State University, is PPQ's phytosanitary early-warning system that helps PPQ to stay current on newly emerging pest information. PestLens gathers information from a wide range of sources, including several hundred scientific journals, web sites, e-mail groups, newsletters, and automated internet search queries; summarizes this information and provides relevant background knowledge; and reports the information in a weekly e-mail notification. In addition, PestLens provides a web-based platform for making, coordinating, and documenting safeguarding decisions and actions. Existing groups within PPQ that are responsible for specific safeguarding functions use their own internal decision-making processes, guidelines, and criteria to respond to the information reported in each PestLens article. They then record their decisions and actions in the PestLens web system, ensuring a timely response to new pest information, as well as transparency within PPQ.

METARHIZIUM F52 MICROSCLEROTIA APPLIED IN HYDROMULCH TO CONTROL ASIAN LONGHORNED BEETLES

Tarryn Anne Goble[1*], Ann Hajek[1], Sana Gardescu[1] and Mark Jackson[2]

[1]Department of Entomology, Cornell University, Ithaca, NY, 14853-2601
[2] USDA-ARS-NCAUR, Crop Bioprotection Research Unit, 1815 N University Street, Peoria, IL, 61604

ABSTRACT

Metarhizium brunneum F52 (Hypocreales: Clavicipitaceae) produces persistent microsclerotia (aggregates of hyphae), which are mixed with inert carriers (clay or diatomaceous earth) to produce granules. Granules are incorporated into a hydromulch formulation (mixture of wheat straw, water, and a tackifier to increase adhesion) that retains moisture long enough for microsclerotia to grow and produce conidia. This novel and environmentally-friendly mycoinsecticide can be sprayed onto the trunks of forest trees to control Asian longhorned beetle (ALB), *Anoplophora glabripennis* (Coleoptera: Cerambycidae). In 2015, conidia production, efficacy and persistence of F52-hydromulch sprayed onto wood pieces, placed outdoors on tree trunks in an organically managed apple orchard for 6 weeks and a forest habitat for 8 weeks in New York were evaluated. Viable conidia production continued to increases over time in the field and was ten times higher in the forest (average across 3 spray trials was 3.5×10^5 conidia/cm^2) than the orchard (5.4×10^4 conidia/cm^2). This was attributed to increases in relative humidity and decreased UV in the forest. In 2 d-quarantine bioassays, in which ALB were exposed to field-collected wood pieces, insect mortality varied greatly between sites and spray trials. For example, ALB mortality in the forest varied between (21-71%); (42-54%); (8-21%) for spray trials 1, 2 and 3, respectively while mortality in the orchard was (25-33%); (4-83%); (8-46%). Total conidia production in the 2015 summer in the forest (above) was compared with total conidia production over the 2014 summer in the same location because the methods used were the same. In both years, the max number of conidia produced in June to early July was similar at $<1.5 \times 10^6$ conidia/cm^2. Median survival (if calculable) at this conidia concentration ranges between 25-36 days for females. However in mid-July and August, ten times more conidia were produced in 2014 $>5.3 \times 10^6$ conidia/cm^2) compared to this time in 2015 ($<4 \times 10^5$ conidia/cm^2). At the former conidial densities, female beetle median survival ranged from 15.5 to 21.5 days. Increased conidia production in 2014 was the result of wood samples being exposed to more rainfall (which also increased RH) subsequently moistening the hydromulch formulation compared to 2015, which was much drier. Optimizing the formulation to better retain moisture is our goal and future studies will also evaluate the use of follow up water sprays to remoisten the hydromulch.

OBSERVATIONS ON THE "WALNUT ALERT" EXPERIENCE: THE 'NUTS AND BOLTS' OF A REGIONAL OUTREACH PLAN

Jerome F. Grant[1], Alan S. Windham[2], Frank A. Hale[2], Paris L. Lambdin[1], Mark T. Windham[1] and Gregory J. Wiggins[1]

[1]Department of Entomology and Plant Pathology, 370 Plant Biotechnology Building, The University of Tennessee, Knoxville, TN 37996
[2]Soil, Plant and Pest Center, The University of Tennessee, 5201 Marchant Drive, Nashville, TN 37211

ABSTRACT

In summer 2010, the health, viability, and survivability of forested, urban, and rural ecosystems in the eastern U.S. faced a new, non-native threat – thousand cankers disease [TCD] – to black walnut, *Juglans nigra* L., in its native range. TCD, caused primarily by the fungus *Geosmithia morbida* Kolarik, is vectored by walnut twig beetle, *Pityophthorus juglandis* Blackman. Unfortunately, in many areas, the general public is still not aware of the problem, its potential impact, or mitigation efforts. How do you best convey information to the public and to the industry? OUTREACH PROGRAMS are tremendous avenues to publicize invasive species and new pest threats, enhance knowledge of the public, and stimulate mitigation efforts. The success of Outreach Programs depends upon proper selection, development, and use of educational tools. Are active tools more effective than passive tools? Which 'nuts and bolts' best strengthen an Outreach Program? This poster outlined an Outreach Program – *WALNUT ALERT* – that was developed in response to TCD and considers the benefit and effectiveness of various tools. This Outreach Program is presented as a model of what can be done well and what can be done better to ensure information is delivered in a timely and effective manner to a wide audience.

'Active' outreach tools directly engage the enduser (i.e., hands-on), and 'passive' tools involve only the enduser (i.e., reading a text). We developed a regional Outreach Program to integrate active and passive tools to inform growers, industry, scientists, regulators, students, and the public of TCD in black walnut's native range. Four tools were most effective: 1) Educational Displays, 2) Retractable/ Self-Standing Banners, 3) Pocket-sized ID Cards, and 4) Hands-On Workshops ('Train the Trainers'). Two passive-oriented tools were least effective: 1) Trifold Educational Pamphlet and 2) Field Guide (ease of use/access). One passive-oriented tool (website) was not as beneficial as we had intended; no person was dedicated to keep it current. A non-current, out-of-date website is not well received, well visited, or well used by its audience.

Our Outreach Program produced numerous products and reached 1,000s of individuals in 25+ states. Active and passive tools have advantages and disadvantages; both are important to reach a wide audience. We continue to: 1) inform the public, 2) educate the industry/consumers, 3) identify donors, and 4) enhance research and management efforts. The most effective 'nuts and bolts' program depends upon your overall goals. Have fun and educate either way!

DISTRIBUTION AND DISPERSAL OF WALNUT TWIG BEETLE IN FORESTS

Jerome F. Grant[1], Gregory J. Wiggins[1], Paris L. Lambdin[1], Mark T. Windham[1] and Paul R. Merten[2]

[1]Department of Entomology and Plant Pathology, 370 Plant Biotechnology Building, The University of Tennessee, Knoxville, TN 37996
[2]200 WT Weaver Blvd., USDA Forest Service, Forest Health Protection, Southern Region, Asheville, NC 28804

ABSTRACT

Walnut twig beetle (WTB), *Pityophthorus juglandis* Blackman, has a pivotal role in the spread of thousand cankers disease (TCD) and the resulting decline and death of black walnut trees. WTB vectors the fungus *Geosmithia morbida* Kolarik, which forms numerous cankers on the tree trunk, reducing nutrient flow throughout the tree. Although WTB and TCD have been documented in urban and rural areas in numerous states, little is known about their presence in forest systems. Thus, the overall goal of this research is to further enhance our knowledge and understanding of the incidence, distribution, and dispersal of WTB on black walnuts in forests. This research will inform management decisions on TCD in forests and also contribute to our understanding of TCD spread in urban and rural environments. Specific research objectives are to: 1) document incidence and distribution of *G. morbida* and/or WTB on black walnut in Appalachian forests (in eastern Tennessee and western North Carolina), 2) assess dispersal ability of WTB within a forest, and 3) assess the vertical dispersal ability of WTB (in tree cages).

From 2013-2015, WTB were collected from traps in forested areas in NC and in TN. Results suggest that WTB incidence in/near the forest may be strongly influenced by human activities. The greatest number (n=338) of WTB was collected from a forested location in an urbanized area near a known TCD-positive tree. The other two forested locations where WTB (n=3) was collected were in areas where camping is common; infested firewood may have unintentionally introduced WTB. In 2014, only three traps yielded WTB (145 adults); all traps were located in an urbanized forest area. To date, only nine WTB have been collected from 2015 samples, with all collected from the urbanized forest.

Following WTB releases in the forest to assess dispersal, five adults were collected on 8 Sept. 2016 within 16 m of the release (three 16 m downhill and two 8 m uphill); one beetle was found 88 m downhill from the release. One male WTB emerged from a bolt placed 56 m downhill from release. Thus far, no WTB have emerged from bolts that were hung at different heights (i.e., to assess vertical distribution) within the tree cages (results are pending).

Knowledge of the factors that may enhance or limit movement of WTB in the environment, especially in a forest, is critical to defining TCD epidemiology. Is there a vulnerable link in dispersal and movement of WTB that can be exploited and manipulated in IPM programs? These studies were conducted in low walnut density forested areas; studies in higher walnut density forests are planned.

TRAIL PHEROMONE DETECTION IN ASIAN LONGHORNED BEETLE (*ANOPLOPHORA GLABRIPENNIS*)

Fern Graves[1], Tom Baker and Kelli Hoover[2]

Department of Entomology, 501 ASI Building, Penn State University, University Park, PA 16802
[1]Email: fbg106@psu.edu [2]Email: kxh25@psu.edu

ABSTRACT

The Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky; ALB) is a xylophagous cerambycid species that feeds on many hardwood tree species, including those in the genera *Acer, Salix, Betula* and *Ulmus*. Native to China and Korea, this species has become an invasive threat in Europe and North America, where it was introduced through infested packing materials.

ALB has a complex set of host- and mate-finding behaviors, some of which are still not well understood. These behaviors may be elicited through both visual and chemical cues. Such cues include male-produced volatile pheromones, a cuticular hydrocarbon profile acting as a sex-identification contact pheromone, and a female-produced trail pheromone that mate-seeking males use to locate sexually mature females. However, the sensory structures used to detect the trail pheromone and the location of these sensilla is unknown.

Using a two-choice behavioral bioassay, we assessed the ability of male ALB to follow a pheromone trail after removal of the four terminal antennal segments and/or the maxillary and labial palps. Our data suggest that the palps are primarily responsible for sensing the pheromone, with only half of males without palps choosing the pheromone, compared to the majority of intact males that chose the pheromone trail. Trail-following capabilities of males with removed antennal segments were also impaired in comparison to the control, but this effect was not statistically significant.

This work is helpful in revealing behaviors and biology involved in this step of mate-finding, and in determining whether the trail pheromone has practical applications for pest management.

EVALUATION OF SYSTEMIC INSECTICIDE AND FUNGICIDE FOR PROTECTION OF SYCAMORE FROM POLYPHAGOUS SHOT HOLE BORER / *FUSARIUM* DIEBACK

Donald Grosman[1], Akif Eskalen[2] and David Cox[3]

[1]Arborjet Inc., 99 Blueberry Hill Road, Woburn, MA 01801
[2] University of California - Riverside, Department of Plant Pathology and Microbiology, 3401 Watkins Ave., Fawcett Lab. #232, Riverside, CA 92521
[3] Syngenta Crop Protection LLC, 14446 Huntington Road, Madera, CA 93636

ABSTRACT

The polyphagous shot hole borer (PSHB), *Euwallacea sp.,* and its associated fungi has recently caused dieback and mortality of California Sycamore in southern California. Direct control option for PSHB were limited to frequent bark sprays. Recently, a systemic insecticide, emamectin benzoate alone or combined with a systemic fungicide, propiconazole has been shown to be effective in protecting pines against several pine bark beetles and their associated fungi. Two separate trials were established in 2013 and to evaluate efficacy of recommended rates of emamectin benzoate (TREE-age™) alone or combined with propiconazole (Propizol™) for protection or therapeutic treatment of individual California sycamore trees for PSHB/Fusarium Dieback. Treatments containing emamectin benzoate were effective in reducing the number of new attacks, level of sap flow on the bark surface, and tree mortality compared to untreated checks. Emamectin benzoate alone can protect trees for at least one full year. The combination of insecticide + fungicide, propiconazole, provides extended protection against new attacks and fungal infection through the second year.

EMERGENCE OF ADULT FEMALE *SIREX NIGRICORNIS* F. AND *S. NOCTILIO* F. (HYMENOPTERA: SIRICIDAE) COINCIDES WITH A DECREASE IN DAILY MINIMUM AND MAXIMUM TEMPERATURE

Jessica A. Hartshorn[1], Laurel J. Haavik[2,3], Jeremy D. Allison[3], James R. Meeker[4], Wood Johnson[4], Larry D. Galligan[1], Kevin D. Chase[5,6], John J. Riggins[5] and Fred M. Stephen[1]

[1]Department of Entomology, University of Arkansas, Fayetteville, AR 72701, USA
[2]Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, KS 60045, USA
[3]Natural Resources Canada – Canadian Forest Service, Great Lakes Forestry Centre, Sault Ste. Marie, ON P6A 2E5, Canada
[4]USDA Forest Service, Forest Health Protection, Pineville, LA 71360, USA
[5]Department of Biochemistry, Molecular Biology, Entomology, and Plant Pathology, Mississippi State University, Mississippi State, MS 39762, USA
[6]School of Biological Sciences, University of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand

ABSTRACT

Sirex noctilio F. (Hymenoptera: Siricidae), is established and spreading throughout pine stands of the eastern United States and southeastern Canada. Reliable monitoring methods are needed to detect and manage this alien woodwasp pest. *Sirex nigricornis* F., a species native to eastern North America, is common in pine forests and has been studied as a proxy for *S. noctilio*. Predicting emergence of *S. noctilio* is an important component of monitoring efforts. Predicting flight phenology of *S. noctilio* and *S. nigricornis* in eastern North America has been the target of degree day models. Previously published degree day model parameters were tested using three years of *S. nigricornis* collection data from two locations (Ozark and Ouachita National Forests) in Arkansas. Neither of the proposed models accurately predicted emergence in either location. For both *Sirex* species female emergence was significantly negatively correlated with minimum and maximum temperature, suggesting that emergence increases as minimum and maximum temperatures decrease. These results suggest that as *S. noctilio* spreads south to warmer climates, it will emerge later in the season (as temperatures decline) compared to the existing northeastern populations. We propose that monitoring for the spread of *S. noctilio* in the southeastern United States should begin slightly before daily temperatures are expected to decline (i.e. mid-September).

USING CLIMATE AND GENETIC DIVERSITY DATA TO PRIORITIZE CONSERVATION SEED BANKING FOR IMPERILED HEMLOCK SPECIES

John Hastings[1], Kevin Potter[1], Mark Megalos[1], Frank Koch[2] and Robert Jetton[1]

[1]Department of Forestry & Environmental Resources, NC State University, Raleigh, NC
[2]USDA Forest Service, Southern Research Station, Research Triangle Park, NC

ABSTRACT

Hemlock Woolly Adelgid (HWA) is an invasive forest insect sweeping across the native range of Eastern and Carolina Hemlock at an alarming rate. Now infesting 19 states and over 400 counties, HWA poses a significant threat to the eastern US natives. The current biological and chemical methods for protecting these keystone species are expensive, time consuming, and short-lived. For the long-term preservation of the species, genetic conservation efforts such as seed collection and storage may be the best solution. With this in mind, it is urgent to prioritize populations within the native range of Eastern and Carolina Hemlock for such *ex situ* conservation actions. Using a geographic information systems (GIS) technique called gap analysis in congruence with eight genetic diversity estimates, areas of significant Eastern and Carolina Hemlock genetic diversity were located and threats to those areas were identified. Using the Multivariate Adaptive Constructed Analogs (MACA) statistical downscaling method, climate projections averaged over twenty regional climate models were analyzed to display a minimum temperature threshold below which significant HWA mortality occurs. Models also show the temporal northward movement of that threshold to areas not yet exposed to HWA. The result is a spatially weighted index of Hemlock populations prioritized by genetic significance and climatic risk. Along with twelve years of seed banking for Eastern and Carolina Hemlock, we have collected the genetic diversity data needed to now refine ongoing efforts to prioritize populations most at risk and those that encompass the highest levels of genetic diversity.

PROGRESS TOWARDS MAPPING THE GENOMIC ARCHITECTURE OF FLIGHT CAPACITY IN GYPSY MOTHS

Nathan P. Havill[1], Melody Keena[1], Andrea Gloria Soria[2], Fan Chen[3], Sandra Hoffberg[4] and Adalgisa Caccone[2]

[1]USDA Forest Service, Northern Research Station, 51 Mill Pond Rd., Hamden, CT 06514
[2]Yale University, Department of Ecology and Evolutionary Biology, 21 Sachem St., New Haven, CT 06520
[3]Beijing Forestry University, 35 Qinghua East Rd., Beijing 100083, China
[4]University of Georgia, Department of Genetics, 120 Green Street, Athens, GA 30602

ABSTRACT

The gypsy moth, *Lymantria dispar* (Insecta: Lepidoptera: Erebidae), is a forest pest that was introduced to the United States from France over 100 years ago. Females of the European subspecies of gypsy moth are not capable of flight, but females of the Asian subspecies can fly. We report progress towards identifying genomic regions associated with flight capacity in this species. We conducted reciprocal crosses between a European strain and six different flight-capable strains from the Russian Far East, China, and Japan. Female flight propensity, flight capability, and flight muscle strength were scored for parental, F1, and F2 individuals. Whole genome SNP discovery is in progress using double digest restriction-site associated DNA sequencing (ddRAD). A linkage map will be produced and QTL analyses will be performed to establish the regions associated with flight capacity. The results will provide insight into the genomic architecture of complex behavioral traits in insects and allow us to develop cost effective genotyping methods to detect introduction of flight-capable gypsy moths to North America and Europe.

ENGINEERING TECHNOLOGIES FOR A BIOLOGICAL PROBLEM: CAN WE REDUCE THE RISK OF INVASION?

Helen M. Hull-Sanders, Hady Salloum and Alexander Sutin

Stevens Institute of Technology Department of Mechanical Engineering,
1 Castle Point Terrace on Hudson, Hoboken, NJ 07030

ABSTRACT

Invasive organisms are known to present a threat to natural, agricultural, and urban eco-systems as well as increase public health concerns. Prevention through interception at points of entry, especially points of international commodities trade, is the best strategy for reducing risk. However, in the United States alone, there are 360 commercial ports with 3200 handling facilities. Inspection requires both knowledgeable personnel and time. The development of new technologies to help decrease the time needed for inspection and increase the effectiveness of inspection personnel is vital to reducing the threat posed by invasive organisms. Insects use a variety of ways to communicate. Vibrations (sounds) can be transmitted through a substrate such as air, but also through plants to communicate position, danger, or population density. Many insects follow chemical gradients to locate mates or food resources. Phototaxis towards or away from light sources may be a source of navigation through the environment or towards mates (some moth pheromones have been found to be weakly luminescent!). Motion and movement in bees communicates not only location of a food resource, but also quality. Using existing technologies, new uses are being explored for the detection of potentially invasive insects. Technologies such as laser vibrometers, low frequency microwave and acoustic arrays, portable GC/Mass Spec analyzers may all be instrumental for the detection of unwanted organisms.

QUANTIFYING AN ASIAN LONGHORNED BEETLE ESTABLISHMENT EVENT IN AN INVADED LANDSCAPE

Helen M. Hull-Sanders[1] and R. Talbot Trotter III[2]

[1]Stevens Institute of Technology, 1 Castle Point Terrace on Hudson, Hoboken, NJ 07030
[2]USDA Forest Service Northern Research Station, 51 Mill Pond Road, Hamden, CT 06514

ABSTRACT

Invasion by an organism into a non-native region is often conceptually described as occurring in three phases: arrival, establishment, and dispersal. Dispersal by the Asian Longhorned Beetle (ALB) has been documented in Illinois, New York, New Jersey, and Massachusetts and more recently in Ohio; however, the transitional phase, establishment, is often not observed, and is less well documented. An establishment event (within four years of arrival) for ALB was studied in a small, isolated population within the regulated quarantine zone of Worcester County, Massachusetts, USA. Seventy-one infested red maple (*Acer rubrum*) trees and 456 un-infested trees were surveyed. Tree ring analyses show that within this establishing population, ALB initially infested one or two trees, before moved through the stand below the canopy and infesting new trees based not on distance or direction but on tree size. Outside of this stand, survey data suggest long-distance dispersers may have emerged above the canopy from this establishment area, and followed the direction of prevailing winds.

INHERITANCE AND WORLD VARIATION IN THERMAL REQUIREMENTS FOR EGG HATCH IN *LYMANTRIA DISPAR* (LEPIDOPTERA: EREBIDAE)

Melody Keena

USDA Forest Service, Northern Research Station, 51 Mill Pond Rd., Hamden, CT 06514

ABSTRACT

The mode of inheritance of hatch traits in *Lymantria dispar* L. were determined by crossing populations nearly fixed for the phenotypic extremes. The non-diapausing phenotype was inherited via a single recessive gene and the phenotype with reduced low temperature exposure requirements before hatch was inherited via a single dominant gene. There was no evidence for sex-linkage or cytoplasmic effects with either gene. Eggs from 43 geographic populations were evaluated for hatch characteristics after being held for 60 d at 5°C followed by incubation at 25°C. There was considerable variation both within and among the populations in the proportion able to hatch, time to first hatch, and average time to hatch. Egg masses with the reduced requirement for low temperatures before the eggs were ready to hatch were present in all subspecies of *L. dispar* and the phenotype was not fixed in most populations. The highest relative percentage hatch of embryonated eggs after 60 d at 5 °C (57.7 to 74.4%) was in two Russian populations from the Far East, the Connecticut and New Jersey Standard Strain populations originating from the United States, and a single population from China. The following populations had low percentage hatch of embryonated eggs after 60 d at 5 °C (0.0 to 12.3%): populations from Poland, Greece, Austria, Slovakia, Switzerland, and Croatia; four of seven German populations; two populations from France; half the populations from China; three of five populations from the United States (MA, WV, NC); and one Japanese population. The remaining populations had intermediate percentage hatch of embryonated eggs after 60 d at 5 °C that ranged from 15.1 to 46.5%. The populations clustered into 3 distinct groups and climatic variables were found to be rough predictors of those groups. Variation in hatch phenotypes between populations is likely an adaptation to local climate and within a population provides a bet-hedging strategy to ensure that at least some hatch synchronizes with host leaf-out. Continued vigilance to prevent movement of populations both within and between countries is warranted, because some of the alleles that confer non-diapause or reduced low temperature requirements before egg hatch are not be present in all populations and their introduction would increase variation in egg hatch within a population.

RAPID 'ŌHI'A DEATH: UNRAVELING THE MYSTERY

Lisa Keith[1], Flint Hughes[2] and J.B. Friday[3]

[1]USDA Agricultural Research Service, Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center, 64 Nowelo St., Hilo, HI 96720
[2]USDA Forest Service, Institute of Pacific Islands Forestry, 60 Nowelo St., Hilo, HI 96720
[3]University of Hawai`i, College of Tropical Agriculture and Human Resources, Cooperative Extension Service, 875 Komohana St., Hilo, HI 96720

ABSTRACT

`Ōhi`a (*Metrosideros polymorpha*) is Hawai`i's most widespread and ecologically important native tree, defining native forest succession and ecosystem function over broad areas, providing critical habitat for rare and endangered native bird and insect species, and exemplifying the strong links between native Hawai`ian culture and the islands' environment. Within the past 5 years, extensive `ōhi`a mortality has been observed across Hawai'i Island. Affected trees exhibit rapid, synchronized death of leaves on individual branches that eventually spreads to the entire canopy. We conducted a preliminary survey of 31 distinct ohia stands experiencing unusual degrees of mortality and established forest inventory plots in 18 of those localities. A GIS analysis showed no correlation of ohia mortality with rainfall or elevation. Despite mortality of overstory canopy 'ōhi'a trees, understory vegetation - most of which consists of the alien *Psidium cattleianum* but in some sites includes kōpiko (Psychotria sp.) and other native species- remains healthy. Analysis of remotely sensed images showed that affected areas (defined as having between 10% and 100% mortality) increased from 915 ha in 2012 to 6,403 ha in 2014. Field monitoring plots revealed mortality across all size classes and stand compositions, with no correlation between mortality and areas of heavy competition from *Psidium cattleianum*. Repeated measurements of monitoring forest plots found that 'ōhi'a stands exhibited an average annual mortality rate of 26%. Cross sections of diseased trees revealed dark brown to black discoloration in the xylem of the trunk. A perithecia-producing fungus was consistently isolated from infected tissue and based on morphological characteristics and molecular sequencing, the fungus was identified as *Ceratocystis fimbriata*. Pathogenicity of *C. fimbriata* from this study was tested by inoculation of pot grown seedlings of `ōhi`a. Control plants were inoculated with sterile distilled water. Plants produced wilt symptoms within 17 to 88 days after inoculation. As the disease progressed, leaves withered and died, showing that *C. fimbriata* was pathogenic to `ōhi`a. Cross-sections of inoculated plants showed vascular discoloration. Control plants remained symptomless. We have termed this disease "Rapid `Ōhi`a Death" or "ROD". Confirmed locations of ROD as of January 2016 include the Puna and South Hilo districts, Volcano, Ka'u, Holualoa, Kealakekua and South Kona. This pathogen poses a severe threat to the viability and persistence of Hawai'i's native forests. Widespread mortality of 'ōhi'a due to this disease would be catastrophic for Hawai'i's watersheds and could lead to extensive loss of habitat for hundreds of native species. We are currently determining the distribution and mechanisms of spread of *C. fimbriata* in order to develop appropriate management strategies to limit the spread of the fungus.

WHAT HAVE WE LEARNED FROM INTERCEPTIONS IN WOOD PACKING MATERIAL: FINDINGS FROM IDENTIFICATION OF INSECTS AND WOOD MATERIAL

Sindhu Krishnankutty[1], Ann Ray[1], Hannah Nadel[2], Scott Myers[2], John Molongoski[2], Yunke Wu[3], Adam Taylor[4] and Steven Lingafelter[5]

[1]Department of Biology, Xavier University, 104 Albers Hall, 3800 Victory Pkwy., Cincinnati, OH 45207
[2]USDA-APHIS-PPQ-CPHST Otis Laboratory, 1398 W. Truck Rd., Buzzards Bay, MA 02542
[3]Department of Ecology and Evolutionary Biology, Corson Hall, Cornell University, Ithaca, NY 14853
[4]Tennessee Forest Products Center, University of Tennessee, 2506 Jacob Drive, Knoxville, Tennessee 37996
[5]USDA-ARS Systematic Entomology Laboratory, National Museum of Natural History, P.O. Box 37012, Washington, DC 20013

ABSTRACT

Live larvae of potentially destructive exotic wood borers are frequently intercepted at U.S. ports of entry in “treated” wood packing material (WPM). Intercepted larvae often remain unidentified beyond family level. As a result, valuable information is lost about risk pathways and trade routes for particular genera and species. A cooperative effort between U.S. Customs and Border Protection (CBP) and USDA Animal and Plant Health Inspection Service (APHIS) began in 2012 to identify intercepted cerambycids and buprestids in WPM by a combination of rearing to adult and genetic barcoding. Specimens are linked to data on wood origin and treatment, and consignment details and routing, while vouchered barcodes expand capacity to identify immature stages. So far, 838 intercepted larvae and a section of host wood (if possible) were sent from six to eleven participating ports and were reared in the wood or artificial diet. By December, 2015, 43 species and 32 genera of wood boring beetles were identified. Of these, several are key pest or pests of quarantine concern. Exotic species belonging to seven cerambycid genera (Anoplophora, Chlorophorus, Hylotrupes, Monochamus, Phoracantha, Tetropium, Trichoferus, Xylotrechus) are at high risk of becoming invasive or are already invasive in North America. Thirteen species were intercepted more than once. Interception frequency of exotic species and intended destination of consignments appear to be correlated with risk of establishment. Of the identified host wood samples, 63% were softwoods, and 37% were hardwoods. The commonest woods came from the following tree genera: Pinus (40%) and Picea (19%) (family Pinaeceae; softwood), and Populus (20%) (family Salicaceae; hardwood). Woodborer identifications and associated interception data can be applied toward predicting species at high risk of establishment, areas at high risk of introductions, and high-risk trade routes.

ZOMBI ENCEPHALITIS-ASSOCIATED INCREASES IN THE GERMINATION AND GROWTH OF FOUR THISTLE SPECIES (FAMILY: ASTERACEAE)

Christy Leppanen

Department of Ecology and Evolutionary Biology, University of Tennessee, 569 Dabney Hall, Knoxville, TN USA 37996-1610

ABSTRACT

Worldwide escalating and unsustainable economic losses due to new weed problems from 1998 to 2005 necessitated a better understanding of these problems and the rapid implementation of more effective control and management efforts. Concurrent increases in populations of some species of thistle (Family: Asteraceae) and of populations of individuals testing positive for Zooanthroponotic Occult MetaBiomimetic Infectious (ZOMBI) Encephalitis or "zombies" prompted evaluations of possible relationships between zombies and two weedy thistle species, *Cirsium arvense* (L.) Scop. and *Cirsium vulgare* (Savi) Ten., and two previously rare thistle species, *Cirsium lecontei* Torr. & A. Gray and *Cirsium ownbeyi* S. L. Welsh. Correlations between the distribution of zombie populations and populations of these four thistle species led to site-specific field evaluations that documented cutaneous germination of thistle seeds in zombie tissue. In laboratory trials, thistle seeds collected from areas with documented zombie populations and germinated in zombie tissue germinated earlier, at a greater rate, grew more quickly, and maintained viability better over time compared with seeds germinated in soils more typical of historically natural conditions and collected from areas without zombie populations. Management and conservation implications are discussed.

Developed for use in education, this poster is taken from the second "manuscript" in the pseudoscientific journal, the *Bulletin of ZOMBIE Research: Volume 1* (BOZR). Via popular culture, BOZR introduces students to the methods, language, and structure of scientific literature. The same skills and knowledge used by scientists are demonstrated in an application that also relies heavily on the creativity that is fundamental to good science. After students are provided with BOZR and an example poster, they work together to develop and produce their own pseudoscientific studies and posters based on topics of their choice. Students learn how to brainstorm ideas, access and evaluate literature, form hypotheses, develop and troubleshoot experimental approaches, analyze and present data, form conclusions, and consider broader impacts. Enticing students with unconventional topics contained in chapters that mimic authentic scientific journal articles dissolves barriers to accessing and understanding science.

CONSIDERING SMALL POTATOES: CAN CUMULATIVE MINOR INTERACTIONS IN DIFFERENT LOCATIONS EXPLAIN VARIABLE IMPACTS OF AN INVASIVE SPECIES?

Christy Leppanen and Daniel Simberloff

Department of Ecology and Evolutionary Biology, University of Tennessee, 569 Dabney Hall, Knoxville, TN USA 37996-1610

ABSTRACT

A sap-feeding insect native to Asia, the hemlock woolly adelgid or HWA (*Adelges tsugae* Annand (Hemiptera: Adelgidae)) has spread to eastern North America, where its presence is correlated with mortality of native hemlocks, *Tsuga canadensis* (L.) Carriére and *Tsuga caroliniana* Engelm. HWA control efforts have not yet proven successful. Chemical control is not sustainable and the inability of introduced biocontrol organisms to control HWA suggests the effects of natural enemies may not be transferable from one system to another and/or that other mechanisms may help maintain HWA populations at lower levels in the native range. HWA and its natural enemies have been introduced from areas where HWA feeds on different hemlock species in different systems with different climate profiles. Differences and changes in climate within and between native and introduced ranges may create new interactions, hinder past interactions, or create shifts in the composition of species controlling a pest population or imbalances that preclude control (e.g., predator-prey asynchronization due to phenological shifts).

A variety of undescribed biotic and abiotic, direct and indirect interactions may influence HWA population size, and thus its impacts. Early results of ongoing surveys to identify such interactions in different locations are described. To date, several areas of research have been selected for further study: 1) effects of lichen on HWA crawler movement, implantation, and survival, 2) predator-prey interactions affecting predator success (e.g., predator entrapment in liquid exuded by HWA adults), and 3) interactions with mites (e.g., disruption of HWA eggs and crawlers, facilitation of predation). To help identify potentially significant interactions and increase the breadth and applicability of this work, collaborators and contributors of observations made throughout the HWA native and introduced ranges are also solicited.

Considered singly, the impacts of some interactions may be considered minor. But not only may these interactions cumulatively contribute to HWA and natural enemy population size, but their prevalence may vary substantially from one location to another. Some non-native species become prominent invaders in some areas but remain minor components of the community or even fail to establish in others. Differences in the presence and prevalence of such interactions in different locations may provide understanding of variable HWA impacts, insight into the efficacy of HWA control, as well as yield insights for the management of other biological invasions.

EFFECT OF LURE AND TRAP HEIGHT ON DETECTION OF LONGHORN BEETLES (CERAMBYCIDAE) IN JILIN, CHINA

Yan Li[1], Qingfan Meng[1], Peter Silk[2], Peter Mayo[2], Wentao Gao[1] and Jon Sweeney[2]

[1]Forestry College of Beihua University, 3999 Binjiangdong Road, Jilin, Jilin province, The P. R. China, 132013
[2] Natural Resources Canada, Canadian Forest Service, 1350 Regent St., PO Box 4000, Fredericton, NB Canada E3B 5P7

ABSTRACT

In spite of international phytosanitary measures (ISPM 15) and subsequent audits that suggest the percentage of wood packaging with live insects is low, the sheer volume of goods shipped intercontinentally ensures that wood boring insects will continue to be introduced to new habitats. Some introduced species establish and become invasive pests, e.g., the Asian longhorned beetle, *Anoplophora glabripennis*(-Coleoptera: Cerambycidae), established at sites in North America and Europe, and the red turpentine beetle, *Dendroctonus valens* (Coleoptera: Scolytinae), a native to North America now established in China. Monitoring and early detection is critical for successful management of both native and invasive species of longhorn beetles. We conducted a 2 x 3 factorial experiment to determine the effects of trap height (tree canopy *vs.* understory) and lure (monochamol + ipsenol + a-pinene + ethanol (=MO) *vs. E/Z* fuscumol + *E/Z* fuscumol acetate + ethanol (=EZ) *vs.* racemic 3-hydroxyhexan-2-one + racemic 3-hydroxyoctan-2-one + *R*R**-2,3-hexane diols + ethanol (=K)) on detection of longhorn beetles in an oak/Korean pine forest in Jilin province, 9 July-20 September 2014. We collected 19 species (757 specimens) of longhorn beetles in four subfamilies (Cerambycinae, Spondylidinae, Prioninae and Lamiinae). Trap height affected detection of two species: mean trap catch of *Massicus raddei* (Cerambycinae), a damaging pest of oaks in China, was significantly greater in the tree canopy than in the understory while the reverse was true for *Prionus insularis* (Prioninae). Lure combination significantly affected mean catches of five species: *P. insularis*, *Monochamus saltuarius* (Lamiinae), and *Arhopalus rusticus* (Spondylidinae) were caught mainly in MO-baited traps, *Plagionotus pulcher* (Cerambycinae) was caught almost exclusively in K-baited traps, and *Mesosa myops* (Lamiinae) was caught mainly in EZ-baited traps. On average, MO-baited traps detected more longhorn species per trap than did EZ-baited traps; K-baited traps were intermediate. Many species were detected by only one lure type or at only one trap height. Our results suggest that the efficacy of detecting longhorn beetles in Jilin is increased by placing traps in both the canopy and understory, and by using more than one lure type.

EFFECTS OF TEMPERATURE ON THE LARVAL DEVELOPMENT OF ASIAN GYPSY MOTH (*LYMANTRIA DISPAR ASIATICA* AND *L. D. JAPONICA*)

Samita Limbu[1], Melody Keena[2], Fang Chen[3], Gericke Cook[4], Hannah Nadel[5] and Kelli Hoover[1]

[1]Department of Entomology, Pennsylvania State University, University Park, PA
[2]Northern Research Station, USDA – Forest Service, Hamden, CT
[3]Beijing Forestry University, Beijing, China
[4]USDA-APHIS-PPQ-CPHST Collins, CO
[5]USDA-APHIS-PPQ-CPHST, Buzzards Bay, MA

ABSTRACT

Gypsy moth (*Lymantria dispar*) is a major defoliator of numerous tree species in most of the northern hemisphere. In North America, European gypsy moth (EGM: *L. d. dispar*), one of the subspecies, has been present for over 100 years and has decimated hardwood forests periodically. Periodic introductions of Asian subspecies (*asiactica* and *japonica*) of L. dispar have been detected in North America and different parts of the world. Asian gypsy moth (AGM) poses a greater threat to the commercial and urban forest because females are capable of flight, it has broader host range, and some strains produce eggs that have a shorter chill requirement than the European strain. Since AGM is not yet an established pest, our goal was to develop phenology models of AGM strains under different temperature regimes to facilitate detection and management/eradication efforts. This study evaluated the development of eight strains of AGM from a broad range of geographic latitudes reared on artificial diet at five constant temperatures (10-30°C). Our results suggest that AGM larvae developed more rapidly as rearing temperature increased. Larvae experienced significant problems during molting at the highest and lowest temperatures tested (10 and 30°C). At 30°C adult fitness was compromised as their eggs were not fertile and fecundity was reduced. These findings suggest that AGM development and survival may be limited by summer temperatures in the southern U.S. Our findings will benefit pest managers in developing management strategies and pest risk assessment since timing is critical for both bio-pesticides application and trapping.

ASH MANAGEMENT IN PENNSYLVANIA STATE FORESTS IN RESPONSE TO EMERALD ASH BORER

Houping Liu, Scott Miller, and Donald A. Eggen

Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry,
400 Market Street, RCSOB, 6th Floor, Harrisburg, PA 17105-8552

ABSTRACT

A 10-year management plan was created in Pennsylvania in 2014 to manage the ash resources on state land under the pressure from the emerald ash borer (EAB). Silviculture, chemical and biological control measures are used to maintain ash component in the forest, to protect endangered/rare ash species, to mitigate potential negative impacts from EAB infestation, to conserve economic value of ash trees, to manage seed orchards, and to collect seeds.

Almost 6 million board feet ($2.2 million) of ash timber has been harvested. In addition to the 348 seed orchard trees, a total of 1,063 ash trees (984 white, 33 black, 30 pumpkin, and 16 green) at 61 sites on state forest land have been treated chemically. Several thousands of EAB parasitoids *Oobius agrili* and *Tetrastichus planipennisi* were released at two state forest sites (D19 and D16) as part of the biological control effort. Mature seeds from 42 ash trees (25 white, 7 pumpkin, 5 green, 3 black, and 2 blue) were collected and sent to the USDA Forest Service Seed Laboratory for long-term storage. In the meantime, efforts were also directed to search and protect endangered/rare ash species and to provide public outreach on EAB and ash management in various local communities.

CHARACTERIZING PHYTOSANITARY RISK: MEALWORM SURROGATES FOR *ANOPLOPHORA GLABRIPENNIS* IN WOOD CHIPS

Ron Mack and Phil Lewis

USDA-APHIS-PPQ, Otis Laboratory, 1398 West Truck Road, Buzzards Bay, MA 02542

ABSTRACT

Chipping as a regulatory treatment has been implemented successfully by USDA-APHIS-PPQ in programs for Asian longhorned beetle and emerald ash borer. The current regulation stipulates a "not to exceed" dimension of 1" in 2 dimensions, and was largely based on experimental survivorship with respect to knife action. However, questions persist on the potential survival of life stages in larger chips that may occasionally exceed the mandated regulatory chip size. In this study, we evaluated the effectiveness of 12" drum and disc style commercial chippers at both factory and wide open throat (anvil) setting on a wide diameter range of soft maple log sections that were artificially seeded with an Asian longhorned beetle surrogate mealworm (*Zophobas morio).* A total of 120 infested maple sections (2ft) containing 2,334 mealworm larvae were processed at each setting. Assay of chip piles indicated 100% mortality of surrogate mealworms on all tests. The sieved chip size increased from 1" to just 1.25" in 2 dimensions for both disc and drum style chippers at wide open setting. Additional chipping experiments conducted with chips that were seeded with mealworms produced a number of chips that remained intact through processing. Examination of these processed larvae found that all were killed from physical forces other than knife action. This result demonstrated that chipping is actually a combination treatment, and overall mortality is due to knife action and physical forces (e.g. accelerative, concussive) in combination. Results obtained here should have positive impact on risk management decisionmaking with respect to chipping and movement of material, and should also apply to other soft bodied insect pests of comparable size in wood.

EXTENSION OUTREACH TOOLS FOR INVASIVE PESTS AND DISEASES

Mary Kay Malinoski[1], David L. Clement[1] and Chuck Bargeron[2]

[1]University of Maryland Extension, Home and Garden Information Center, Ellicott City, MD 21042
[2]University of Georgia, Center for Invasive Species and Ecosystem Health, Tifton, GA

ABSTRACT

This is an "Extension Project." Invasive insects and diseases pose an enormous threat to our forests, agronomic crops and landscapes. Their threat is second only to habitat loss and biodiversity with an estimated annual cost of $1.4 trillion worldwide. Our national resources and ecosystems are under constant pressure from new and invasive species. Prevention is the first-line of defense, but unfortunately numerous pathways for introduction increase the possibilities of invasive entry. The best IPM option for invasives is early detection coupled with a rapid response. Early reporting of invasives increases the likelihood that localized populations will be found and eradicated. Utilizing new smart phone technologies such as phone apps enable easy reporting and location of new invasive species. This project modified an existing Mid-Atlantic Early Detection Network (EDDMapS) iPhone app created a new Android phone app to report new key invasive insect and disease pests throughout the northeast and southern regions. A key component of the apps is the enhanced flow of reporting information back to key local experts, and state and federal, agencies that have managerial responsibilities. In addition, sets of color identification cards featuring key invasive insects and diseases and a QR tag that connect to the phone app have been distributed to further enhance successful identification and timely reporting.

Increased and more accurate reporting of targeted invasive insects and diseases should occur as a result of this project through the use of user-friendly new technology. Smartphone apps and mobile websites allow users to compare photos and descriptions to field conditions while still in the field without any additional tools or equipment, leading to fewer false reports. Apps and websites are available to the target audience of natural resource professionals as well as lay citizens, further increasing the availability of quality identification and reporting tools. Early detection of invasive species safeguards the environment and reduces the overall costs and increases the likelihood of successful eradication. More accurate reporting equates to less staff time and less travel funds spent on report verification. A follow-up survey of registered users of the EDDMapS tools will be developed to determine the need for any modifications and to request suggestions for new insect and disease additions to the database.

Early detection of invasive species safeguards the environment and reduces the overall costs and increases the likelihood of successful eradication. Eight Field ID cards with four insects and four diseases allow users to compare photos and descriptions of target species to field conditions, leading to fewer false reports.

The full EDDMapS website offers photo submission and manual entry of location data, The apps feature both photo submission and automatic geo-location features. In contrast to the mobile website, the apps also allow full functionality on iPhones, iPads, and iPhone Touches without need for a cellular data signal

or data plan. Additional features include a tool for viewing the user's current map location and the location of nearby confirmed reports.

Key collaborators were identified in each state to serve as initial verifiers for invasive insects and diseases. The Mid-Atlantic Early Detection Network (MAEDN) iPhone and Android apps were developed by the Center for Invasive Species and Ecosystem Health (Bugwood.org) are available for free download. The apps enable accurate reporting and location of new invasive species to key local experts, and state and federal, agencies. The Bugwood App site: http://apps.bugwood.org/apps.html The ID cards were updated for use nationally and are available.New invasive posters have also been produced are available at presents.bugwood.org.

The first report of Kudzu bug in Montgomery county Maryland was reported using the MAEDN App (2014). Japanese Cedar Longhorned beetle was identified by a commercial IPM scout using the MADEN app (2014). A sample was brought into our office for confirmation. Boxwood blight was identified in a landscape by an IPM professional using the app and brought into our office for confirmation. This was a first report for Baltimore County in 2014.

App Data for Mid Atlantic Early Detection Network (MAEDN) States:

672 android downloads

1,403 iOS downloads

Overall reports for MAEDN states:

203,055 County Reports
54,586 Point Reports
1,099 Species

2200 reports from smartphone apps in MAEDN states

1433 from iOS

767 from Android

183 users reporting from apps in MAEDN states

148 unique species reported from apps in MAEDN states

As a spin-off of the project the PD's worked with Bugwood to produce six educational posters on invasive insects and diseases. The posters can be downloaded from Bugwood Presents at: http://presents.bugwood.org/.

A QUANTITATIVE FRAMEWORK FOR DEMOGRAPHIC TRENDS IN SIZE STRUCTURED POPULATIONS: ANALYSIS OF THREATS TO FLOODPLAIN FORESTS

Christian O. Marks[1,†] and Charles D. Canham[2]

[1] The Nature Conservancy, 136 West Street, Suite 5, Northampton, Massachusetts 01060 USA
[2] Cary Institute of Ecosystem Studies, Box AB , Millbrook, New York 12545 USA

ABSTRACT

Studies of population dynamics are continually seeking to develop quantitative approaches that can be easily applied to widely available data in ways that can guide management decisions. We present a method for quantifying demographic trends in size structured populations that we applied to forest tree species and changes in forest structure associated with different threats to help identify forest health priorities. Strengths of the approach are that tree size and growth rate can be controlled for to separate mortality impacts of particular threats from background rates associated with stand self-thinning. We illustrate the method with tree census data from Connecticut River floodplain forests. We found that these floodplain forests are currently declining demographically across all sizes, with floodplain pioneer tree species particularly affected. Cutting by a large beaver population is contributing to this decline. Specifically, beavers are cutting 11.4% of the *Salix nigra* and 1.6% of the *Populus deltoides* trees annually. We also showed quantitatively that Dutch elm disease and invasive lianas are important threats to the health of these forests. We estimated that Dutch elm disease caused at least 9.5% of all tree mortality. Invasive *Celastrus orbiculatus* lianas were implicated in 9.8% of the mortality of large floodplain trees (i.e. DBH = 60 cm) on the Lower Connecticut River (i.e. GDD > 3463, base 0°C). Overall, we found that the method is flexible and could be applied to a wide range of forest types and threats.

IMPLICATIONS OF POPLAR DEFENSES ON ADULT ASIAN LONGHORNED BEETLE BEHAVIOR AND FITNESS

Charles J. Mason and Kelli Hoover

The Pennsylvania State University, Department of Entomology,
501 ASI Building, University Park, PA 16802

ABSTRACT

The Asian longhorned beetle, *Anoplophora glabripennis*, is a wood-boring beetle native to China that has established several populations in the United States. This insect has been reported to attack and kill multiple hardwood species in both its native and introduced range. Among the trees that *A. glabripennis* attacks include poplars (*Populus* spp.), but colonization on this species in the United States are relatively sparse compared to the infestations documented in China. The objectives of our study were to assess if one of the major poplar chemical defenses, phenolic glycosides, affect adult *A. glabripennis* feeding behavior and physiology. We purified a mixture of phenolic glycosides from poplar, and applied them in concentrations emulating those present in poplar to the bark of red maple twigs (*Acer rubrum*). Under high concentrations of phenolic glycosides, *A. glabripennis* adults avoided feeding on maple twig segments containing the compounds. However, adults more readily consumed the phenolic glycoside treated twigs when concentrations were reduced to lower levels. Surprisingly, the consumption of low concentrations of these compounds was accompanied by physiological effects on the beetle, including apparent deterioration to the anterior midgut, a significant reduction in egg production in females, and early death. These physiological effects of phenolic glycosides on *A. glabripennis* occurred over a relatively short timespan (7 days) and with consumption of relatively small quantities (~3 mg). Collectively, these results suggest that phenolic glycosides can substantially impair adult *A. glabripennis* fitness, having both antixenotic and antibiotic properties. Future studies in China will aim to compare effects of phenolic glycosides on native versus introduced populations of *A. glabripennis* to determine if this profound toxicity of phenolic glycosides is due to a bottleneck incurred upon introduction. We will also determine the mechanism(s) of the physiological effects of phenolic glycosides on the *A. glabripennis* midgut.

COMPARING BOTTLE TRAPS TO MULTIPLE-FUNNEL TRAPS FOR AMBROSIA BEETLES

D.R. Miller[1], C.M. Crowe[1], M.D. Ginzel[2], C.M. Ranger[3] and P.B. Schultz[4]

[1] USDA-Forest Service, Southern Research Station, 320 Green St., Athens GA 30602
[2] Purdue University, 901 W. State St., West Lafayette IN 47907
[3] USDA-Agricultural Research Service, 1680 Madison Ave., Wooster OH 44691
[4] Hamptons Road AREC, 1444 Diamond Springs Rd., Virginia Beach VA 23455

ABSTRACT

Ambrosia beetles (Curculionidae: Scolytinae) are an important target group in detection programs for invasive and exotic insects. To date, >25 species of ambrosia beetles have invaded the USA with several species such as *Xylosandrus crassiusculus* (Motschulsky) and *X. germanus* (Blandford) causing economic damage in fruit orchards and horticultural nurseries. Detection programs for exotics typically employ multiple-funnel traps while orchards and nurseries typically employ plastic bottle traps. Bottle traps are easy to make and considerably cheaper than multiple-funnel traps. Our objective was to determine the effect of trap type on catches of three common species of ambrosia beetles in eastern USA: *X. crassiusculus*, *X. germanus* and *Xyleborinus saxesenii* (Ratzeburg). In 2015, we conducted the same experiment at four locations across the USA: (1) Greene Co., Georgia (1 April – 23 June); (2) Tippecanoe Co., Indiana (6 May-30 June); (3) Wayne Co., Ohio (14 May – 8 July); and (4) Virginia Beach, Virginia (1 April – 27 May). 4-Unit multiple funnel traps (Synergy Semiochemicals Corp., Burnaby BC) were compared to clear, plastic bottle traps for efficacy in trapping ambrosia beetles. Funnel traps were modified by increasing the center hole of each funnel from 5 cm to 12 cm, allowing placement of all lures within the trap. Each trap was baited with ethanol and conophthorin lures from Contech Enterprises (Victoria BC), releasing at 0.25 g/d and 0.5 mg/d, respectively. Conophthorin can enhance catches of some species to traps baited with ethanol. At each location, we deployed 10 bottle and 10 funnel traps, in ten replicate blocks of two traps (one bottle and one funnel) per block. Traps were spaced > 8m apart. Cups contained a solution of propylene glycol. Means with different letters are significantly different at $P = 0.05$ (t test). We obtained larger catches of *X. germanus* in bottle traps than in funnel traps in Ohio but not Indiana and Georgia. Catches of *X. saxesenii* were larger in funnel traps than in bottle traps in Georgia, Indiana and Virginia but not Ohio. Similarly, catches of *X. crassiusculus* were larger in funnel traps than in bottle traps in Georgia and Virginia but not Indiana. Additionally, bottle traps were preferred by two more species whereas funnel traps were preferred by five more species.

CAN *SPATHIUS GALINAE* SAVE LARGE ASH TREES?

Theresa C. Murphy[1,2], Joseph S. Elkinton[1,2], Roy G. Van Driesche[2] and Juli R. Gould[3]

[1]Graduate Program in Organismic and Evolutionary Biology,
University of Massachusetts, Amherst, MA 10003
[2]Department of Environmental Conservation, University of Massachusetts, Amherst, MA 10003
[3]USDA-APHIS-PPQ, Buzzards Bay, MA 02542

ABSTRACT

Since its discovery in Michigan in 2002, the emerald ash borer (EAB), *Agrilus plannipennis* Fairmaire, has spread to half the states in the US, killing millions of native ash trees. Eradication using mechanical control has been unsuccessful and systematic insecticides are prohibitive at a forest scale, making biological control the only known feasible population-wide tool to combat EAB. Management is consequently focused on the introduction of four parasitic wasps including larval parasitoids *Spathius agrili* Yang, *Spathius galinae* Belokobylskij and Strazenac, and *Tetrastichus planipennisi* Yang. *Tetrastichus planipennisi,* one of the most successful introduced parasitoids, cannot oviposit in trees larger than 11.2 cm in diameter at base height (DBH). *Spathius agrili* was approved for release in 2007 but has failed to establish north of the 40^{th} parallel. Because of its failure to establish, *S. agrili* is no longer being released as a biocontrol agent in northern states. Instead the USDA has started releases of *S. galinae* in 2015, after climate matching predicted a better fit between *S. galinae's* native distribution and EAB populations in the north than is true for *S. agrili*. *Spathius galinae's* long ovipositor of 4-5.3mm, as compare to *T. planipennisi* ovipositor of 2.0 to 2.5 mm, is expected to help target trees with a large DBH. The objective of this study was to quantify the limits and preferences for oviposition of *S. galinae,* to help understand its potential impact on EAB management. Initial results show that *S. galinae* can oviposit across a wide range of log diameters and at a minimum can parasitize through an average valley (furrow) thickness of 4.7 mm. More data are needed using large logs to determine the upper limit of *S. galinae* oviposition.

STRATEGIES FOR CONSERVING ASH REGENERATION IN FORESTS INVADED BY EMERALD ASH BORER

Erin M. O'Brien and Daniel A. Herms

The Ohio State University, Department of Entomology, Wooster, OH 44691

ABSTRACT

Emerald ash borer (EAB, *Agrilus planipennis*) continues to kill ash (*Fraxinus*) trees throughout eastern North America. Near the epicenter of the EAB invasion (southeast Michigan), nearly all mature ash trees have died and regeneration has stopped. This trend is expected to continue throughout range of the EAB invasion. Ash species are common trees in North American forests and are important sources for food and shelter to other organisms. Thus, management is necessary to conserve ash populations and preserve biodiversity in forests. Emamectin benzoate, a systemic insecticide, effectively protects ash from EAB. Treating clusters of ash trees with emamectin benzoate may protect neighboring untreated ash trees and maintain reproduction and regeneration. However, it is unclear what density of treated ash (i.e., cluster size) is needed to meet these objectives. We are collaborating with Five Rivers MetroParks (FRMP) in Dayton, OH, which is treating 600 ash trees biannually in forests within their parks. Green ash (*F. pennsylvanica*), white ash (*F. americana*), and blue ash (*F. quadrangulata*) are common canopy to subcanopy trees in these forests. Green and white ash trees are highly susceptible to EAB, but blue ash has shown greater resistance to infestation. This offers a unique opportunity to test the effects of a density gradient of treated ash trees in forests with both highly susceptible and more resistant species. Our objectives were to 1) compare survival of treated and untreated green, white, and blue ash, and 2) test various densities of treated ash trees on survival of untreated trees and density of ash seedlings. We established 24 one hectare (ha) quadrats that comprise a gradient of four densities of treated trees: 0, low 2-3, medium 4-6, or high 7-9 treated ash/ha; n=6 quadrats per density. In each quadrat we quantified ash survival and seedling density. We observed high survival of both treated ash and untreated blue ash (>97% and >60; respectively), but low survival of untreated green and white ash (<40%). Survival of blue ash was high across all densities of treated ash trees. However, survival of untreated green and white ash was low where no trees were treated and increased as density of treated trees increased. From 2014 to 2015, seedling density also increased in quadrats with high densities of treated ash trees, but remained low in other quadrats. These findings suggest that treating higher densities of ash trees has the potential to maintain green and white ash survival, reproduction, and regeneration in forests invaded by EAB. However, the presence of blue ash may also be influencing survival of green and white ash and seedling densities.

STATE OF THE SCIENCE FOR INVASIVE SPECIES −A NATIONAL ASSESSMENT

Toral Patel-Weynand[1], Deborah Hayes[2], Deborah Finch[3], Jennifer Juzwik[4], Chelcy Miniat[5], Therese M. Poland[6] and Steven Seybold[7]

[1] USDA Forest Service, Sustainable Forest Management Research, Washington DC
[2] USDA Forest Service, Invasive Species National Program, Washington DC
[3] USDA Forest Service, Rocky Mountain Research Station, Albuquerque, NM
[4] USDA Forest Service, Northern Research Station, St. Paul, MN
[5] USDA Forest Service, Southern Research Station
[6] USDA Forest Service, Northern Research Station, Lansing, MI
[7]USDA Forest Service, Pacific Southwest Research Station, Davis, CA

ABSTRACT

The USDA Forest Service works with a wide assortment of partners to detect, respond to, and manage invasive species that threaten the Nation's wildland and urban forests and rangelands. Increased science that focuses on quantifying invasive species biology, impacts, and interactions, along with managing invasive species and altered ecosystems were identified as major priorities in a Forest Service Technical Report, *A Dynamic Invasive Species Research Vision: Opportunities and Priorities 2009-2029.* A current, comprehensive and integrated assessment of the state of invasive species science and research is lacking for the U.S. In December 2015, a national stakeholder workshop was held in Phoenix, Arizona with leading experts on invasive pests, climate change, social sciences, and forest and rangeland management to highlight the science and identify knowledge gaps in a diverse array of topics related to invasive species.

We presented results of the workshop at which professionals from many federal and state agencies and universities shared highlights of research progress and participated in discussions to prioritize topics and issues related to invasive species. Discussion topics included: Impacts of Invasive Species on Ecosystem Processes and Structures; Climate Change and Invasive Species; Influence of Natural Disturbances on Invasive Species; Management and Prevention; Risk Assessment; Tools and Technologies; Changing the Culture of Invasive Species Science and Management; International Perspectives; Economic Consequences of Invasive Species; and Challenges and Opportunities.

One outcome of the workshop will be a U.S. National Assessment on Invasive Species that synthesizes the available science and information on invasive species science in one place for reporting and use by multiple stakeholders and decision makers.

FOREST DISTURBANCE INCREASED GROUND BEETLE (CARABIDAE) SPECIES DIVERSITY

Kayla I. Perry[1], Kimberly F. Wallin[2,3], John W. Wenzel[4] and Daniel A. Herms[1]

[1]Department of Entomology, The Ohio State University, 1680 Madison Ave., Wooster, OH 44691 [2]Rubenstein School of Environment and Natural Resources, University of Vermont, 312H Aiken Center, Burlington, VT 05405
[3]USDA Forest Service, Northern Research Station, 707 Spear Street, South Burlington, VT 05403
[4]Powdermill Nature Reserve, Carnegie Museum of Natural History, 1847 PA-381, Rector, PA 15677

ABSTRACT

Theory predicts biodiversity is maximized at intermediate levels of disturbance due to trade-offs in traits that enhance colonization and competitive ability, with good colonizers and competitors coexisting at intermediate disturbances. To test the competition – colonization trade-off model, ground beetle assemblages were characterized at three levels of forest disturbance intensity (low, intermediate, and high) at Powdermill Nature Reserve. We conducted a manipulative experiment by imposing canopy gap and understory vegetation disturbance treatments in factorial combination. We predicted that 1) species diversity would be highest in plots receiving one treatment, either canopy or understory disturbance; 2) species composition would change from undisturbed forest to the highest intensity treatment of combined canopy and understory disturbance; and 3) the proportion of beetles capable of flight would increase in the highest intensity treatment of combined canopy and understory disturbance. Contrary to our prediction, ground beetle diversity was highest in the most disturbed treatments, as the number of highly mobile, flying species increased, while species associated with interior forest habitats were retained. Understanding how changes in species diversity and composition affect ecosystem services is critical for fostering sustainable forest management.

ADAPTATIONS OF STRAINS OF GYPSY MOTH NUCLEOPOLYHEDROVIRUS TO HOSTS FROM SPATIALLY ISOLATED POPULATIONS

J. Podgwaite[1], S. Pavlushin[2], I. Belousova[2], V. Martemyanov[2], J. Slavicek[3] and S. Bakhvalov[2]

USDA Forest Service: [1]Hamden, CT 06514 and [3]Delaware, OH 43015, USA
[2]Institute of Systematics and Ecology of Animals, Novosibirsk 630091, Russia

ABSTRACT

Gypsy moth, *Lymantria dispar* L. (Lepidoptera: Erebidae) nucleopolyhedrovirus (LdMNPV) is a gypsy moth-specific pathogen. Gypsy moth displays a high level of genetic variation between populations which may lead to the evolution of LdMNPV strains that are tightly adapted to the host population in order to facilitate viral-reproductive success. We studied this concept through reciprocal bioassays and sub-lethal viral challenges using American and Asian strains of LdMNPV and American and Asian gypsy moth larvae.

Gypsy moth larvae from both a North American (Pennsylvania) and an Asian (Siberian) population were challenged with virus strains collected from areas of North America (New York, New Jersey and Massachusetts) and Asia (Tatarsk, Karasuk and Chistoozernyi). For each viral strain we challenged second instar larvae with a series of doses ranging from 10^6 to 10^2 viral occlusion bodies (OBs) per ml of artificial diet. Larval mortality was recorded daily until the fifteenth day post challenge and Probit analysis (PoloPlus 2.0, LeOra Software) was used to determine and compare lethal concentration (LC_{50}) values. Ninety-five percent confidence limits around the LC_{50} were used to detect statistically significant potency differences between the virus strains. PCR was used to detect covert infection in eggs from mated Pennsylvania females surviving low dose (10^2) viral challenges. Standard techniques were used to isolate DNA from pooled samples of Formalin-treated and untreated eggs. PCR primers specific to a 730 bp LdMNPV polyhedrin (*polh*) gene fragment were used to detect viral DNA.

North American gypsy moth nucleopolyhedrovirus strains demonstrated higher potency than Asian virus strains, both in North American (*Lymantria dispar dispar*) and Asian (*Lymantria dispar asiatica*) larvae. Only North American virus strains persisted in the next-generation of North American larvae following sub-lethal challenges. Results indicated that the potency of LdMNPV is primarily independent of the locality of host population while vertical transmission of the virus may be dependent upon the co-evolution of the host and pathogen within a certain locality.

ISOLATION AND IDENTIFICATION OF A MALE-PRODUCED ATTRACTANT PHEROMONE FOR THE INVASIVE VELVET LONGHORNED BEETLE, *TRICHOFERUS CAMPESTRIS* (CERAMBYCINAE: HESPEROPHANINI)

Ann M. Ray[1], Joseph A. Francese[2], Yunfan Zou[3], Kristopher Watson[4], Jocelyn G. Millar[3], Damon J. Crook[2] and Baode Wang[2]

[1]Department of Biology, Xavier University, 104 Albers Hall, 3800 Victory Pkwy., Cincinnati, OH 45207-1035
[2] USDA-APHIS-PPQ-CPHST Otis Laboratory, 1398 W. Truck Rd., Buzzards Bay, MA 02542-5008 [3]Department of Entomology, University of California, 900 University Avenue, Riverside CA 92521
[4]Utah Department of Agriculture and Food, 350 North Redwood Road, PO Box 146500, Salt Lake City, Utah 84114-6500

ABSTRACT

The velvet longhorned beetle, *Trichoferus campestris* (Faldermann)(VLB; Cerambycidae: Cerambycinae: Hesperophanini), is native to east Asia where it feeds on 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 quarantine facilities. Populations of VLB have established outside of the native range of the species, including near Salt Lake City, UT USA. Adults are nondescript and nocturnal, and nothing is known of their pheromone-mediated biology, which hinders monitoring and control efforts. Beetles were not significantly attracted to traps baited with any of the known cerambycid pheromones, including 2,3-alkanediols or hydroxyketones, which are male-produced pheromone components of multiple species in the subfamily Cerambycinae. Subsequently, we isolated and identified a novel variant of the conserved 2,3-alkanediol/ hydroxyketone chemical structure from headspace volatiles of males but not females. The male-produced compound will be tested in field bioassays in 2016. In addition, histological sectioning revealed subcuticular metathoracic glands present in males, but not females. Glands were connected to pits in the cuticle. The glands and pits are diagnostic for production of volatile pheromones of the 2,3-alkanediol/hydroxyketone structure by males of other cerambycine species. Our work demonstrates the utility of the metathoracic gland trait for predicting pheromone use in cerambycines. Moreover, our results support the hypothesis that cerambycid species with novel pheromones may be more successful invaders than exotic species that share pheromone components with native species.

INVESTIGATIONS INTO THE ANTIBIOSIS AND ANTIXENOSIS RESISTANCE MECHANISMS OF MANCHURIAN ASH TOWARDS EMERALD ASH BORER

Chad M. Rigsby[1], David N. Showalter[2], Nathaniel B. McCartney[3], James H. Tumlinson[3], Daniel A. Herms[4], Pierluigi Bonello[2] and Don Cipollini[1]

[1] Department of Biological Sciences, Wright State University, Dayton, OH 45435
[2] Department of Plant Pathology, The Ohio State University, Columbus, OH 43210
[3] Center for Chemical Ecology, Department of Entomology, The Pennsylvania State University, University Park, PA 16802
[4] Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691

ABSTRACT

Manchurian ash (*Fraxinus mandschurica*) has a coevolutionary relationship with emerald ash borer (EAB; *Agrilus planipennis*), resulting in much higher resistance of this species relative to naïve North American green, white, and black ash. Here, we review several investigations of independent antixenosis and antibiosis resistance mechanisms of Manchurian ash. Antixenosis is characterized by nonpreference resulting in selection of an alternate host. We monitored oviposition rates on Manchurian ash and several North American ashes and found strong preferences for the North American species, demonstrating that antixenosis contributes to the high EAB resistance of Manchurian ash. To understand the mechanistic basis of host preference, we compared volatile organic carbon (VOC) emissions of stressed Manchurian ash to the closely related but susceptible black ash (*F. nigra*). The two species had distinct VOC profiles including several antennally active compounds. In several experiments, we used manual egg inoculation to control for oviposition preference and observed clear antibiosis as reductions in survival and growth of larvae feeding in Manchurian ash phloem compared to white ash. However, the underlying phloem-based mechanisms of antibiosis have been difficult to elucidate. Recently we found that larvae that had fed on Manchurian ash had higher activity and functional expression of antioxidant and quinone-protective enzymes relative to larvae that had fed on susceptible North American species. Additionally, Manchurian ash had a much greater capacity than black ash to oxidize phenolic substrates and cross-link proteins. Together, these two studies suggest that antibiositic effects of Manchurian ash are based in its ability to create an oxidatively stressful diet for EAB larvae. Collectively, these investigations have increased our understanding of resistance mechanisms of Manchurian ash to EAB, and application for development of monitoring approaches and development of EAB-resistant ash species.

ASIAN LONGHORNED BEETLE (ALB) *ANOPLOPHORA GLABRIPENNIS* ERADICATION PROGRAM

Robyn Rose[1] and Josie Ryan[2]

[1]USDA Animal and Plant Health, Inspection Service, Riverdale, MD 20737
[2]USDA Animal and Plant Health, Inspection Service, Amityville, NY 11701

ABSTRACT

Asian longhorned beetle (ALB), *Anoplophora glabripennis*, initial detections in the United States include Brooklyn, NY (August 1996), Chicago, IL (July 1998), Jersey City, NJ (October 2002), Worcester, MA (August 2008), and Bethel, OH, (June 2011). ALB has the potential to be one of the most destructive and costly invasive species to enter the United States. Some of the industries at risk include timber export, saw logs, fuel wood, nursery stock, lumber, maple syrup, and fall foliage tourism. ALB also has the potential to cause significant ecological and environmental impacts. The goal of the ALB program is to eradicate this pestiferous beetle in the United States to protect forest products industries, U.S. hardwood forests and park lands, and the quality of the urban environment. To achieve this goal, the ALB program has developed and implemented area-wide, science-based eradication protocols. The eradication strategy is based on a combination of tactics, including: 1) exclusion; 2) visual survey of host trees; 3) tree removal; 4) chemical treatment; 5) regulatory activities to prevent the pest's spread; 6) replanting to mitigate the effects of trees lost to ALB; 7) outreach efforts; 8) quality assurance to ensure survey, removals, and treatments are conducted correctly to maintain effectiveness; and 9) methods development to improve program efficacy and delivery. The program has declared eradications of infestations in Illinois (2008), Islip, NY (2011), New Jersey (2013), Manhattan and Staten Island, NY (2013) and Boston, MA (2014). The program continues efforts to eradicate ALB in New York, Massachusetts and Ohio.

SPECIES OCCURRENCE DATA FOR THE NATION – USGS BIODIVERSITY INFORMATION SERVING OUR NATION (BISON)

Annie Simpson

U.S. Geological Survey, 12201 Sunrise Valley Dr. Mailstop 302, Reston, Virginia 20192

ABSTRACT

USGS Biodiversity Information Serving Our Nation (BISON, http://bison.usgs.ornl.gov) is a unique, Web-based Federal mapping resource for species occurrence data in the United States and its Territories. BISON's size is unprecedented, including records for most living species found in the United States and encompassing the efforts of more than a million professionals. As of January 2016, BISON contained more than a quarter billion species occurrence records from almost 1,500 datasets, and growing.

A value-added feature enables BISON users to search for results including all taxonomic synonyms for any scientific name found in the Integrated Taxonomic Information System (ITIS), an automated and authoritative reference database of scientific and common names for species. Exact-name-match scientific name searches are also possible in BISON, as are ITIS-enabled searches for larger taxonomic groups (e.g., to see records for all of the species and subspecies of *Agrilus*, along with all of their synonyms).

In addition to the Web site, BISON has numerous Web services (http://bison.usgs.ornl.gov/#api): the Application Programming Interface provides access to the BISON system for Web developers; a Web Map Service delivers maps remotely; a REST (REpresentational State Transfer) service generates links to individual species searches in BISON; and a direct interface to the BISON Solr index (a stand-alone enterprise search server) returns query results in JavaScript Object Notation (JSON or JSONP).

BISON includes much of the information that is available from the Global Biodiversity Information Facility, an organization dedicated to facilitating free and open access to biodiversity data worldwide. While Federal datasets are BISON's main area of emphasis, the project also actively recruits for inclusion all U.S. datasets containing invasive species and pollinator species locational information.

POTENTIAL IMPACT OF SPOTTED LANTERNFLY ON GRAPEVINES: A PRELIMINARY STUDY

Erica C. Smyers and Michael C. Saunders

Dept. of Entomology, The Pennsylvania State University, 501 Agricultural Sciences and Industries Building, University Park, PA, 16802

ABSTRACT

Spotted lanternfly, *Lycorma delicatula* (White), is a newly introduced pest that has a wide range of host plants including fruit trees, ornamentals, hardwood trees, and grapevines. Spotted lanternfly feeding reduces overall plant vigor and feeding puncture wounds increase disease susceptibility and attract secondary pests. Additionally, spotted lanternfly secret a sticky, sugar-rich liquid called "honeydew" which accumulates at the base of their feeding area and encourages sooty mold growth and the formation of fungal mats. Previous studies indicate spotted lanternfly has a preference for tree of heaven (*Ailanthus altissima*) and grapevine (*Vitis vinifera*). This new pest could threaten Pennsylvania's more than $20.5 million grape industry. Korean literature indicates increased spotted lanternfly contributes to annual grapevine damage however there is currently no known research on how exactly this species impacts grapevines. To date, vineyards in the Berks Co., PA quarantine zone have reported spotted lanternfly around their properties but not in their vineyards or on their cultivated grapevines. We established colonies in quarantine facility at Penn State University with eggs collected from Berks Co., PA. Initial observations indicate that most nymphs did not survive past the third instar when only offered grapevines (Baco noir) as a host. Late summer and fall of 2015, spotted lanternfly adults were commonly observed on wild grapevines, particularly in courting pairs or clusters. In addition to spotted lanternfly-grapevine interactions, we observed predation, courtship, mating, and other behaviors. In the summer of 2015, we established a small vineyard within the Berks Co. quarantine zone that contains four varieties of grapes: Chardonnay, Niagara, Concord, and Baco noir. Whole grapevines and single canes were caged and exposed to different quantities of spotted lanternfly for five consecutive weeks. Overall plant health, damage, cage performance, and spotted lanternfly survival was documented. Data and observations from this preliminary field test will be used to construct future studies that will focus on how *L. delicatula* damage may impact overall grapevine health, and grape quality and quantity. We plan to perform insecticidal bioassays to test the efficacy of insecticides registered for grapevines and will continue to observe and record spotted lanternfly behavior on cultivated and wild grapes within the quarantine zone. Results from these studies will be made available to grape growers to inform them about the potential impact of this pest and aid them in making pest management decisions.

THE ROLE OF FIA DATA AND GENETIC TESTS IN ASSESSING SPECIES VULNERABILITY TO INVASIVE PESTS AND CHANGING CLIMATE

Richard A. Sniezko[1] and Heather E. Lintz[2]

[1]USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, OR 97424 [2]Oregon Climate Change Research Institute, College of Earth Ocean, and Atmospheric Science, Oregon State University, Corvallis, Oregon, 97330

ABSTRACT

U.S. tree species and the associated ecosystems, managed forests and urban plantings are becoming increasing vulnerable to the impacts of non-native invasive pathogens and insects as well as effects associated with a changing climate. Some species such as whitebark pine (*Pinus albicaulis* Engelm.) have been proposed for listing under the Endangered Species Act (ESA). To fully assess the vulnerability of the tree species and ecosystems we need to more fully harness data that shows temporal trends in mortality and forest health. With these data, forest managers and the U.S. public will have a greater sense of urgency to debate the full extent of possible management actions. Several unique types of data are available to help quantify changes over time and the potential impacts of the associated biotic and abiotic agents. Forest inventory data can be used to identify at-risk species and temporal trends in forest health. Here, Continuous Vegetation Survey (CVS) data was used to examine sustainability of 22 forest tree species on U.S. Forest Service lands in the Pacific Northwest Region (Oregon and Washington). In the future, the more comprehensive Forest Inventory and Analysis (FIA) program will supplant the CVS data. The FIA data will provide a probabilistic sample across all land ownerships so that results from the analysis can be reliably extrapolated to all lands. The FIA sample design will consist of the new annual inventory, which is consistent across the United States and is currently completing the first round of plot re-measurement. The other data comes from long-term progeny tests, provenance trials and clone banks which serve as defacto permanent sentinel plots with the advantage of known genetic components. We will provide examples from each and show examples of species that are on the decline.

SAVING OUR TREES AND FORESTS FROM INVASION BY NON-NATIVE PATHOGENS: THE ROLE OF GENETICS AND TREE IMPROVEMENT

Richard A. Sniezko and Lisa Winn

USDA Forest Service,

ABSTRACT

The health of native forest ecosystems, and managed and urban forests, are being heavily impacted by non-native pathogens and insects. These pests are impossible to eliminate and continue to decimate our forests. Genetic resistance is the first line of defense for trees, but is often rare. Resistance is also the 'natural' solution with little or no adverse impacts. With a combination of research, tree improvement, and planting resistant seedlings we can mitigate some of the damage, help restore ecosystems, and keep affected tree species on the landscape and better utilize our managed forests. The U.S. Forest Service is a leader in the development of resistant populations for operational use, with programs such as those at Dorena Genetic Resource Center (DGRC) for white pine blister rust (caused by the fungal pathogen *Cronartium ribicola* J.C. Fisch.) and Port-Orford-cedar root disease (caused by the pathogen *Phytophthora lateralis* Tucker & Milbrath being at the forefront. These programs aim to find the rare resistances, combine them or increase their levels, while maintaining both genetic diversity and genetic adaptability. The genetic diversity and adaptability will provide the hedge against other biotic agents and a changing climate. A successful program usually involves long-term commitment and continuity as well as cooperators over the range of the species to help in restoration or reforestation. The long-standing programs at DGRC can be used to illustrate the progress made, the limitations to resistance, and some silvicultural tools that may be used to complement resistance. Extensive experiences from existing programs as well as new technologies offer potential to fast-track the future development of resistance.

DNA SEQUENCE BASED ANALYSIS OF THE INVASIVE SPOTTED LANTERNFLY, *LYCORMA DELICATULA*

Julia L. Stevens[1,2], Heather Farrington[3] and Julie M. Urban[1]

[1]Genomics & Microbiology Laboratory, North Carolina Museum of Natural Sciences, 11 West Jones St., Raleigh, NC 27601
[2]Department of Applied Ecology, North Carolina State University, 127 David Clark Labs, Raleigh, NC 27695
[3]Cincinnati Museum Center, 1301 Western Avenue, Cincinnati, OH 45203

ABSTRACT

Using DNA sequence based analyses, research currently being conducted seeks to 1) perform microsatellite analyses to identify the origin(s) of the invasive Pennsylvania population of *Lycorma delicatula* (White), and 2) characterize the bacterial communities harbored by the insect.

Six microsatellite loci were sequenced for 32 individuals from the Pennsylvania population of *L. delicatula*, 25 individuals from each of three Korean populations, and 10 individuals from Beijing, China. Results indicate 1) the Pennsylvania population appears to represent a single introduction, and 2) Korea does not appear to be the origin of this invasion. Additional Chinese samples are currently being processed and will be added to the existing data set.

The 16S rRNA gene was amplified and deep sequenced on the Illumina platform to characterize the bacterial communities harbored in the abdomen and proboscis of *L. delicatula* from the Pennsylvania population. Bacteria from the proboscis did not amplify for any individuals. Abdominal bacterial communities were dominated by three obligate endosymbionts, *Sulcia muelleri, Vidania fulgoroideae*, and an uncharacterized Gammaproteobacterium, consistent with other sampled outgroup species of Fulgoridae. However, principal components analysis indicated *L. delicatula* was distinctly different from other sampled Fulgoridae and Dictyopharidae, perhaps reflecting a unique bacterial community within the gut due to feeding on *Ailanthus*. Future work will test this hypothesis by sequencing dissected digestive tracts separately from the rest of the abdomen (where the endosymbionts are housed).

A VARIABLE-INSTAR, TEMPERATURE-DRIVEN, INDIVIDUAL BEETLE-BASED PHENOLOGY MODEL FOR THE ASIAN LONGHORNED BEETLE (*ANOPLOPHORA GLABRIPENNIS* COLEOPTERA)

R. Talbot Trotter III, Melody A. Keena

USDA Forest Service, Northern Research Station, 51 Mill Pond Rd., Hamden, CT

ABSTRACT

Here, a climate-driven, individual based phenology model for the Asian longhorned beetle which provides simulated life-tables for populations of beetles under variable climatic conditions, and which takes into account the variable number of instars beetles may undergo as larvae is described. The model was built for the Asian longhorned beetle within MATLAB R2013b (8.2.0.701) and carries individual beetles through up to 15 steps in the beetles life history including: egg, instars 1-11, pupa, sclerotizing adult (time between eclosion and initiation of chewing to exit the tree), emerging adult (time spent chewing out of tree), and emerged adult. For each of these steps the lower and upper critical temperatures for development were used to calculate the daily accumulation of the instar-specific heating degree days calculated using the modified sine method with daily minimum and maximum temperatures for the target location. Within the simulation, the beetles are treated as a fixed population, such that each adult beetle is replaced with an individual egg.

Initial phenology parameters were based on published and Keena unpublished phenology data, and modified using an iterative approach using validation data as a benchmark. Model output was validated using a dataset derived from a laboratory population of Asian longhorned beetles reared at temperatures mimicking the timing and seasonality of those typical of Central Park in New York City. The model exhibits stability at time periods longer than 50 years and beetle populations larger than 150 beetles

Three simple but informative outputs that can be generated: the distributions of durations between egg and adult beetles, the total number of cycles (egg-adult) completed by a set number of beetles in a set simulation length (a proxy for population growth potential), the estimation of the adult flight season, and comparisons of polyvoltanism among locations. Because population growth rate is a function of generation time, it is interesting to note that the slowest population growth in the infestations in the United States is likely to occur in the one in Worcester, MA. While this location has one of the largest infestations yet documented, the population may be slow to spread in comparison to other infestations. Boston, MA and Chicago, IL had slightly faster generation times, but were smaller populations when found and occurred in landscapes with more limited host material, factors which may have facilitated eradication. Bethel, OH, with its large and well established population in a heavily wooded landscape, may have relatively rapid generation times compared to other infestations.

PROGRESS AND GAPS IN UNDERSTANDING MECHANISMS OF ASH TREE RESISTANCE TO EMERALD ASH BORER, A MODEL FOR WOOD-BORING INSECTS THAT KILL ANGIOSPERMS

Caterina Villari[1], Daniel A. Herms[2], Justin G.A. Whitehill[3], Chad M. Rigsby[4], Don Cipollini[4], David N. Showalter[1] and Pierluigi Bonello[1*]

[1] Department of Plant Pathology, The Ohio State University, 201 Kottman Hall, 2021 Coffey Rd,, Columbus, OH 43210
[2] Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Thorne Hall, Wooster, OH 44691
[3] Michael Smith Laboratories, The University of British Columbia, 2185 East Mall, Vancouver, BC V6T 1Z4, Canada
[4] Department of Biological Sciences, Wright State University, 235A Biological Sciences, Dayton, OH 45435
*Presenting Author

ABSTRACT

We present a review of the literature, as well as more recent results, on resistance of ash to emerald ash borer, an invasive wood-boring insect causing widespread mortality of ash in North America. Manchurian ash (*Fraxinus mandshurica*), which coevolved with EAB, is more resistant than evolutionarily naïve North American and European congeners. Such resistance is expressed as lower preference by adults for feeding and oviposition as well as significantly lower larval feeding and development in Manchurian ash. Compared to susceptible species, Manchurian ash has higher constitutive levels of bark lignans, coumarins, proline, tyramine, and select defensive proteins, and is characterized by faster oxidation of phenolics. Consistent with EAB being a secondary colonizer of coevolved hosts, drought stress decreases resistance of Manchurian ash, but appears to have no effect on specific constitutive bark phenolics, suggesting that, on their own, phenolics do not contribute to increased susceptibility under drought stress. Instead, when compared with phylogenetically and chemically similar, but very susceptible, black ash, Manchurian ash resistance appears to be linked to higher constitutive peroxidase activity, lignin polymerization, and quinone generation, confirming that it is not the phenolic composition *per se* that may contribute to resistance, but rather the higher oxidative environment present in Manchurian ash phloem. Such higher oxidative environment in resistant ash is reflected in higher activities of quinone-protective and antioxidant enzymes in larvae feeding on Manchurian ash compared to susceptible white and green ash. This suggests that quinone-protective and antioxidant enzymes are important counter-adaptations of larvae for dealing with these resistance mechanisms. Finally, induced resistance of North American species to EAB in response to exogenous application of methyl jasmonate is associated with increased bark concentrations of verbascoside, lignin, and/or trypsin inhibitors, which decrease larval survival and/or growth in artificial diet assays. This suggests that these inherently susceptible species possess latent defenses that are not induced naturally by larval colonization, perhaps because they fail to recognize larval cues or respond quickly enough. Transcriptional profiling of resistant and susceptible ash species before and after EAB larval feeding is shedding light on the genetic basis of candidate constitutive and induced resistance genes, including those involved in phenolic biosynthesis and those coding for pro-oxidant enzymes. We propose future research directions that would address some remaining critical knowledge gaps.

FOURIER-TRANSFORM INFRARED (FT-IR) SPECTROSCOPY TO RAPIDILY-IDENTIFY GENETIC RESISTANCE TO INVASIVE PATHOGENS

Caterina Villari[1], Richard A. Sniezko[2], Luis E. Rodriguez-Saona[3] and Pierluigi (Enrico) Bonello[1]

[1] Department of Plant Pathology, The Ohio State University, 201 Kottman Hall, 2021 Coffey Rd, Columbus, OH 43210
[2] USDA Forest Service, Dorena Genetic Resource Center, 34963 Shoreview Dr., Cottage Grove, OR 97424
[3] Department of Food Science and Technology, The Ohio State University, 325 Parker Food Science and Technology Building, 2015 Fyffe Ct., Columbus, OH 43210

ABSTRACT

One unwanted consequence of rapidly increasing international trade is the introduction of forest pathogens and insects into North American naïve habitats where they lack an evolutionary history with their hosts. This constitutes a serious threat to the ecological integrity of forests, and often results in devastating damage. The cases of Dutch elm disease, chestnut blight, and gypsy moth are just some of the iconic examples, while sudden oak death, emerald ash borer and thousand cankers disease represent more recent introductions.

Once measures aimed at keeping invaders at bay fail, genetic resistance remains the only solution for protecting naïve plants against novel pests in environments favorable to the attacking organisms. However, the largest obstacle to the use of tree resistance is the lack of rapid phenotyping tools. In the time required to identify resistant trees using classical screening techniques, which in the current state ranges from a few to many years, most of the forest and landscape populations affected by the spread of an attacking agent will already be extensively damaged, leaving little margin for restoration. If resistant trees could be rapidly identified in the field, they could be protected from any other potentially destructive disturbance to favor natural regeneration, and be promptly propagated in the interest of conservation and restoration efforts aimed at preserving lands and tree populations that may otherwise be lost.

Fourier-transform infrared (FT-IR) spectroscopy, a chemical fingerprinting technique, has been recently shown to be suitable for the rapid identification of oaks resistant to Sudden Oak Death prior to infection. The long-term goal of this project is to develop a proof-of concept protocol for the use of FT-IR or other vibrational spectroscopy-based approaches (such as Raman) through a handheld device to identify, in *real-time,* trees that are resistant to pathogens directly in the field, before the pathogens have an opportunity to expand into new areas. Within this overarching objective, the aim of this specific study is to determine if FT-IR spectroscopy can be used for the rapid identification of resistant trees in other pathosystems as well, such as Port-Orford-cedar (*Chamaecyparis lawsoniana) / Phytophthora lateralis* (the

causal agent of root rot disease), and whitebark pine (*Pinus albicaulis)* / *Cronartium ribicola* (the causal agent of white pine blister rust).

For both pathosystems, we collected and analyzed plant material that had been previously characterized in terms of resistance/susceptibility to its specific pathogen. Port-Orford-cedar sampling comprised both roots and twigs of rooted cuttings of parent trees whose self-pollinated families were screened for resistance at the USDA-Forest Service Dorena Genetic Resource Center, OR. Twigs were included in the analyses because they are far more accessible than roots, and would allow for less invasive sampling. Whitebark pine trees were sampled at Crater Lake National Park, OR. Samples included current-year needles, previous-years needles and the resulting naked shoots, in order to identify the tissue that might better distinguish different phenotypes. Phenolic extracts were analyzed on a bench top FT-IR spectrometer equipped with an attenuated total reflectance accessory, and data were processed using chemometric approaches. Soft independent modeling of class analogy was used to discriminate between resistant and susceptible trees, while partial least squares regression was used to predict mortality rates or severity of symptoms in the progenies.

Preliminary results strongly suggest that FT-IR can discriminate between resistant and susceptible trees in both species, predict mortality rates in the progenies of Port-Orford-cedar parent trees, and predict severity of symptoms in the progenies of whitebark pines. Port-Orford-cedar twig analysis was a better predictor of resistance to root rot than analysis of root material, while current year needles were best for predicting resistance of whitebark pine.

The next step will be validation of current models using a set of completely blind samples that were not used to develop the classification model. Once the models developed with tissue extracts are validated, we will expand our work to developing new models using handheld devices capable of taking chemometric snapshots of freshly exposed tissues directly in the field, thus bypassing the tissue extraction step. The implementation of vibrational spectroscopy-based approaches has the potential to facilitate the selection and breeding of resistant trees, for instance by allowing quick pre-selection of resistant genotypes before greenhouse screening. Furthermore, those approaches could be applied to other pathosystems as well, or to classify silvicultural and many other traits, including in agricultural crops.

TOTAL RECORDS OF VELVET LONGHORN BEETLE *TRICHOFERUS CAMPESTRIS* FALDERMANN (COLEOPTERA, CERAMBYCIDAE) FROM UTAH

Kristopher Watson, Caressa A. Pratt and Joey Caputo

Utah Department of Agriculture and Food, Plant Industry and Conservation Division,
350 N. Redwood Road, PO Box 146500, Salt Lake City, Utah 84114

ABSTRACT

The velvet longhorn beetle (*Trichoferus campestris* Faldermann) is a potential threat to Utah's urban, orchard, and riparian wood land areas. Field sampling and actions taken in association with the detection efforts by the Utah Department of Agriculture and Food (UDAF) are necessary to maintain productive commercial tree fruit production, and healthy urban forests. Expanded detection trapping along natural waterways and orchards indicate that the velvet longhorn beetle (VLB) distribution, first discovered in South Salt Lake City in July 2010, is widespread in Salt Lake and Utah counties. The insect was first detected in North America in the province of Quebec, Canada in 2002 and 2006 (Grebennifov et al. 2010). The VLB has been found in warehouse settings in Ohio (2009), Rhode Island (2006), New Jersey (2007, 2013), and Illinois (2009) (Blackwood 2010), it has also been detected in Colorado (2013), and New York (2014). It spreads into new areas through infested wood packing material that accompanies a wide variety of imported commodities such as: building supplies, machinery, tools, glass, tiles, etc. (Cavey 1998). Published reports from the European Plant Protection Organization, CABI and Global Pest Disease Database have been summarized in the USDA-APHIS-National Identification Services Plant Pest Risk Assessment (1998). The conclusion of this literature review is that VLB is polyphagous and prefers to attack apple (*Malus*), and mulberry (*Morus*) in its native range. In Utah, a new county record has been recorded in Davis County and VLB larva, pupae, and adult life stages have been recovered though destructive sampling from peach and cherry (*Prunus*).

INFLUENCE OF RECORD COLD IN THE SOUTHEASTERN U S ON HEMLOCK WOOLLY ADELGID AND ITS INTRODUCED NATURAL ENEMIES

Greg Wiggins[1], Jerome Grant[1], Pat Parkman[1], Jesse Webster[2], Elizabeth Benton[1], Rusty Rhea[3] and Paris Lambdin[1]

[1]The University of Tennessee, Department of Entomology and Plant Pathology, 2505 E. J. Chapman Drive, Knoxville, TN 37996
[2]National Park Service, Great Smoky Mountains National Park, 107 Park Headquarters Road, Gatlinburg, TN 37738
[3]USDA Forest Service, Forest Health Protection, 200 W.T. Weaver Blvd., Asheville, NC 28804

ABSTRACT

Two species of predatory beetle (*Sasajiscymnus tsugae* and *Laricobius nigrinus*) have been released throughout the U.S. as biological control agents of hemlock woolly adelgid (HWA), *Adelges tsugae*. These species have established throughout the southern Appalachians, and both species have been recovered in ca. 20% of release sites in the Great Smoky Mountains National Park (GRSM). The success of these predatory species is partially dependent on suitable climates that enable continued populations. From December 2013 through April 2014, record low temperatures, due to a southward shift in the North Polar Vortex, were experienced throughout much of the eastern U.S. The following winter, record low temperatures were observed in over 70 cities in the eastern and central U.S. during February 2015, due to the incursion of a northerly frigid air mass. Low temperatures in some areas of Tennessee reached ca. 16°C below historical average lows for several consecutive days during both of these events. What impacts have these recent climate events had on HWA and associated predator populations? HWA populations in several sites in eastern Tennessee were surveyed for mortality during Winter 2014 and 2015. Greater percent mortality of HWA was observed during 2014 (ca. 88% overall) than 2015 (ca. 20% overall). Also, a Biological Control Demonstration Site established in 2013 in GRSM where *L. nigrinus* and *S. tsugae* were released was periodically sampled using beat-sheet sampling. Following the record cold temperatures, *L. nigrinus* were recovered from the Site during both 2014 (n = 19) and 2015 (n = 45). No *S. tsugae* have been recovered following either cold event, despite additional releases (n = 400 adults) during Summer 2014. Due to its native range in northwestern North America, *L. nigrinus* may be more tolerant of periodic frigid temperatures. *S. tsugae* may be less cold-tolerant, as temperatures in its native range in Japan are similar to those in the southeastern U.S. Further monitoring is necessary in this and other release sites to assess the impact of these types of climatological events on predators of HWA.

IMPACT OF TWO INVASIVE HERBIVORES ON RESOURCE ALLOCATION IN A NATIVE CONIFER

Claire Wilson[1], Mauri Hickin[1], Colin Orians[2], Robert Schaeffer[1,2] and Evan Preisser[1]

[1]Department of Biological Sciences, University of Rhode Island, 120 Flagg Road, Kingston, RI 02881
[2]Department of Biological Sciences, Tufts University, 419 Boston Avenue, Medford, MA 02155

ABSTRACT

The hemlock woolly adelgid (*Adelges tsugae*) and the elongate hemlock scale (*Fiorinia externa*) are common invasive insects that attack *Tsuga canadensis* (eastern hemlock) in the eastern United States. Hemlock, a native shade-tolerant conifer that plays an important role in structuring ecosystems and providing unique habitat, is threatened throughout much of its range by the adelgid.

Hemlock saplings were planted in the field under a deciduous forest canopy, infested with adelgid only, scale only, adelgid and scale, or neither insect, and harvested after four years. Adelgid-infested trees, regardless of scale presence, invested ~15% more biomass belowground than control trees. The wood/needle ratio of adelgid-infested trees were ~20% higher than that of control trees, a result consistent with the needle desiccation and drop indicative of adelgid infestation. Production of new-flush foliage in adelgid-infested trees was one-third that of control trees, suggesting that adelgid infestation limits the ability of hemlocks to maximize early-spring carbon gain prior to hardwood leaf-out. The consequences of decreased new-flush production for adelgid-infested trees are compounded by delays in bud break (averaging three days later) and changes in chemical composition.

Scale affected neither foliar production nor timing of bud break. Adelgid-induced decreases in new foliage production and delays in bud break, in concert with the accelerated bud break of co-occurring hardwoods due to climate change, threaten early-spring resource gain in hemlocks. While scale has virtually no impact, the adelgid substantially alters resource acquisition and allocation in eastern hemlock.

STEAM AND VACUUM TREATMENT OF LARGE TIMBERS IN SOLID WOOD SKIDS

Zhangjing Chen[1], Marshall S. White[1] and Ron Mack[2]

[1]Department of Sustainable Biomaterials, Virginia Tech Blacksburg, VA chengo@vt.edu
[2]USDA-APHIS-PPQ, 1398 West Truck Road, Buzzards Bay, MA 02542 ron.mack@aphis.usda.gov

ABSTRACT

Forest pests are commonly transported with wood packaging materials. Ports in US continue to intercept invasive pests in cross section timbers packaged with steel or heavy consignments. The large cross section timbers present a greater risk because the fumigation and kiln treatment as currently used in treating wood packaging materials are not effective on large cross section materials. The objective of our study is to determine the effectiveness of steam and vacuum for heat treating large cross section timbers in wood skids and crates, according to the heat treating requirements of ISPM 15. Three wood species of large dimension (8x8") timbers were tested. These represented a high density hardwood, a low density hardwood and a commonly used softwood. These were mixed oak (*Quercus* spp), yellow-poplar (*Liriodendron tulipifera*) and southern yellow pine (*Pinus* spp.). Timbers were partially air dried and are typical of large timbers used in heavy skids. Larvae of the pinewood sawyer beetles (*Monochamus* spp.) were used as a representative surrogate for invasive cerambycids.

During each test, three skids assembled from each wood species were treated. Separate and untreated large timber and a deckboard were set aside as controls. In each test, eight (8) larvae total were inoculated among two large timbers, and single larvae seeded in a deckboard. Four (4) larvae were inserted in the large control timber and one larva in the control deckboard. The initial vacuum pressure was 100mm Hg and test chamber temperature was set for 90°C. The treatment cycle continued until the core temperature of the large timber reached the required 56°C for 30 minutes. To measure temperature profiles within the timbers, thermocouples were placed at various locations. After each test, larvae were recovered and assessed for mortality.

Potential treatment effects on the quality of the timbers and the structural integrity of the skid structure were examined. The ends of each large timber in the skids were photographed before and after treatment to study any treatment effect.

In order to document the change in moisture content, large timbers were weighed before and after treatment. Overall heating time to achieve 56°C for 30 minutes to core was less than 7 hours for all 3 wood species tested (100 mmHg and 90°C steam). This is at least 30% less time than predicted treatment cycle using hot air at atmospheric pressure. Hot air process would split large timber. There was complete mortality (100%) of larval surrogates as a result of treatment. Quality of 8x8 timbers was not affected by the treatment. Average moisture content increased 4.1% during treatment.

ATTENDEES

First Name	Last Name	Email
Allison	Jeremy	jeremy.allison@canada.ca
Andersen	Jeremy	jandersen@berkeley.edu
Antipin	Judy	jantipin@fs.fed.us
Aronowitz	Hannah	haronowi@uvm.edu
Ayres	Matthew	matthew.p.ayres@dartmouth.edu
Ballard	Meg	mballard@udel.edu
Baranchikov	Yuri	Baranchikov_Yuri@yahoo.co
Barringer	Lawrence	lbarringer@pa.gov
Bauer	Leah	lbauer@fs.fed.us
Bloem	Ken	kenneth.bloem@aphis.usda.gov
Bonello	Pierluigi	bonello.2@osu.edu
Broadley	Hannah	hannahjbroadley@gmail.com
Brockerhoff	Eckehard	eckehard.brockerhoff@scionresearch.com
Bulman	Lindsay	lindsay.bulman@scionresearch.com
Cannon	Phillip	pcannon@fs.fed.us
Clement	David	clement@umd.edu
Connor	Michael	
Coons	Sharon	scoons@pa.gov
Covell	Stephen	scovell@fs.fed.us
Craig	Allison	acraig@bioforest.ca
Crandall	Ryan	rscranda@syr.edu
D'Amico	Vince	vdamico@fs.fed.us
Davidson	William	william.davidson@DRGD.NH.gov
Daw	Adrian	adrian.daw@nasa.gov
Dodds	Kevin	kdodds@fs.fed.us
Dombroskie	Jason	jjd278@cornell.edu
Dombroskie	Lindsay	glinesay@gmail.com
Domingue	Michael	mjd29@psu.edu
Driscoll	Jarred	jarred.driscoll@ncagr.gov
Driver	Jessica	jessica.driver@vdacs.virginia.gov
Duan	Jian	jian.duan@ars.usda.gov
Duerr	Don	dduerr@fs.fed.us
Eggen	Don	deggen@pa.gov
Elder	Chris	Chris.Elder@ncagr.gov
Elkinton	Joe	elkinton@ent.umass.edu
Faulkenberry	Mark	markfaulke@yahoo.com
Fei	Songlin	sfei@purdue.edu
Felton	Karen	kfelton@fs.fed.us

First Name	Last Name	Email
Fierke	Melissa	mkfierke@esf.edu
Fisher	Joanna	jjf236@cornell.edu
Flowers	Robbie	robbieflowers@fs.fed.us
Frank	Steven	sdfrank@ncsu.edu
Galperin	Joshua	joshua.galperin@yale.edu
Garnas	Jeff	jeff.garnas@fabi.up.ac.za
Ginzel	Matt	mginzel@purdue.edu
Goble	Tarryn	tag99@cornell.edu
Golivets	Marina	mgolivet@uvm.edu
Gonzales	Luis	lgonzales@embassyofperu
Goodman	Gregg	gregg.b.goodman@aphis.usda.gov
Gould	Juli	juli.r.gould@aphis.usda.gov
Grant	Jerome	jgrant@utk.edu
Graves	Fern	fbg106@psu.edu
Griesmer-Zakhar	Rachel	Rachel.Griesmer-Zakhar@fairfax-county.gov
Grosman	Donald	dgrosman@arborjet.com
Guo	Qinfeng	qguo@fs.fed.us
Hajek	Ann	aeh4@cornell.edu
Hanavan	Ryan	rhanavan02@fs.fed.us
Hartsell	Jonathan	jhartsell@blueridgercd.org
Hartshorn	Jessica	jhartsho@uark.edu
Havill	Nathan	nphavill@fs.fed.us
Herms	Dan	herms.2@osu.edu
Hoban	Jacqueline	jhoban1@umd.edu
Hoch	Gernot	gernot.hoch@bfw.gv.at
Hoover	Kelli	kxh25@psu.edu
James	Joanna	Joanna.James@inspection.gc.ca
Jennings	David	david.e.jennings@gmail.com
Jetton	Robert	rmjetton@ncsu.edu
Jones	Michael	mljones01@syr.edu
Kaye	Amanda	amanda.kaye@aphis.usda.gov
Keena	Melody	mkeena@fs.fed.us
Keith	Lisa	lisa.keith@ars.usda.gov
Kinder	Brad	blkinder@fs.fed.us
Klepzig	Kier	kklepzig@fs.fed.us
Koehler	Klaus	klaus.koehler@inspection.gc.ca
Kopper	Brian	brian.j.kopper!aphis.usda.gov
Krishnankutty	Sindhu	Sindhu.Krishnankutty@aphis.usda.gov
Krivak-Tetley	Flora	flora.e.krivak-tetley.gr@dartmouth.edu

First Name	Last Name	Email
Kuhn	Craig	craig.kuhn@maryland.gov
Kurtz	Paul	pjkurtz@hotmail.com
Lance	David	david.r.lance@aphis.usda.gov
Lear	Monica	monicalear@fs.fed.us
Ledoux	Doug	douglas.ledoux@mda.mo.gov
Leppanen	Christy	cleppane@utk.edu
Leskey	Tracy	Tracy.Leskey@ARS.USDA.GOV
Liebhold	Sandy	aliebhold@fs.fed.us
Limbu	Samita	szl@psu.edu
Liu	Houping	hliu@pa.gov
Lopez	Vanessa	Lopezv@xavier.edu
Lovett	Gary	lovettg@caryinstitute.org
Lucardi	Rima	rlucardi@fs.fed.us
Lusk	Rob	
MacIntyre	Tina	tina.mcintyre@vdacs.virginia.gov
Maguylo	Karen	karen.l.maguylo@aphis.usda.gov
Malinoski	Mary Kay Malinoski	mkmal@umd.edu
Man	Gary	gman@fs.fed.us
Marks	Christian	cmarks@tnc.org
Mason	Charles	
Mayfield	Albert	amayfield02@fs.fed.us
McClelland	Beth	beth.mcclelland@vdacs.virginia.gov
McDonald	Richard	drmcbug@skybest.com
McManus	Michael	mlmcmanus@fs.fed.us
Mech	Roger	MECHR@michigan.gov
Millar	Jocelyn	millar@ucr.edu
Miller	Daniel R.	dmiller03@fs.fed.us
Moltzan	Bruce	bmoltzan@fs.fed.us
Morisette	Jeffrey	morisettej@usgs.gov
Morrison	William R.	william.morrison@ars.usda.gov
Motley	Kyle	kyle.motley@uvm.edu
Murphy	Theresa	tcmurphy@umass.edu
Nielsen	Anne	nielsen@aesop.rutgers.edu
Oldland	Bill	woldland@fs.fed.us
Onken	Brad	tsugae@hotmail.com
Orlinski	Andrei	orlinski@eppo.fr
Parkman	James	jparkman@utk.edu
Parra	Gregory	gregory.r.parra@aphis.usda.gov
Payne	John	john.h.payne@aphis.usda.gov

First Name	Last Name	Email
Perry	Kayla	perry.1864@osu.edu
Pfister	Scott	scott.c.pfister@aphis.usda.gov
Podgwaite	John	jpodgwaite@fs.fed.us
Poland	Therese	tpoland@fs.fed.us
Preisser	Evan	preisser@uri.edu
Prior	Kirsten	priorkm@gmail.com
Rabaglia	Robert	brabaglia@fs.fed.us
Ragozzino	Max	maxri@vt.edu
Ray	Ann	raya6@xavier.edu
Reardon	Richard	rreardon@fs.fed.us
Rice	Kevin	Kevin.Rice@ars.usda.gov
Rice	Kimberly	kimberly.rice@maryland.gov
Rice	Kevin	kevin.rice@ars.usda.gov
Rice	Kimberly	halletdc@mda.state.md.us
Rieskie-Kinney	Lynn	lrieske@uky.edu
Riggins	John	silvicare.llc@gmail.com
Rigsby	Chad	preisser@uri.edu
Rigsby	Chad	rigsby7@wright.edu
Ring	Jeanne	jeanne.ring@state.co.us
Rondeau	Kristian	kristian.c.rondeau@aphis.usda.gov
Ryan	Josie	josieredmond@aphis.usda.gov
Sapio	Frank	fsapio@fs.fed.us
Schneeberger	Noel	nschneeberger@fs.fed.us
Schultz	Barbara	Barbara.Schultz@vermont.gov
Schwartzberg	Ezra	ezra@adkres.org
Showalter	David	showalter.53@buckeyemail.osu.edu
Siegert	Nathan	nwsiegert@fs.fed.us
Simpson	Annie	asimpson@usgs.gov
Smith	Jason	jasons@ufl.edu
Smyers	Erica	ericasmyers@gmail.com
Sniezko	Richard	rsniezko@fs.fed.us
Solter	Lee	lsolter@illinois.edu
Spichiger	Sven-Erik	sspichiger@pa.gov
Steiner	Warren	steinerw@si.edu
Stephen	Fred	fstephen@uark.edu
Stevens	Julia	juliastevens@gmail.com
Storer	Andrew	storer@mtu.edu
Suckling	David (Max)	max.suckling@plantandfood.co.nz
Sullivan	Brian	briansullivan@fs.fed.us

First Name	Last Name	Email
Sutin	Alexander	asutin@stevens.edu
Swearingen	Jil	jilswearingen@gmail.com
Sweeney	Jon	jsweeney@nrcan.gc.ca
Tatman	Bob	robert.tatman@maryland.gov
Teale	Steven	sateale@esf.edu
Tichenor	Robert	robert.h.tichenor@aphis.usda.gov
Tomon	Tim	ttomon@pa.gov
Travis	Matthew	matthew.a.travis@aphis.usda.gov
Trotter	Talbot	rttrotter@fs.fed.us
Trumbule	Robert	robert.trumbule@maryland.gov
Urban	Julie	julie.urban@naturalsciences.org
Vazquez	Ryan	ryan.vazquez@aphis.usda.gov
Villari	Caterina	cate.vill82@gmail.com
Wallin	Kimberly	kwallin@uvm.edu
Watson	Kristopher	kwatson@utah.gov
Weeks	Ron	rdweeks@aphis.usda.gov
Whitmore	Mark	mcw42@cornell.edu
Yoo	Rosa	Rosa.Yoo@dep.nj.gov
Young	James	jim.d.young@usda.gov
Yturralde	Kasey	kasey.yturralde@de.gov