Proceedings

Toward Healthy Forests: Leadership, Vision, and Action

NAFIWC

NORTH AMERICAN FOREST INSECT WORK CONFERENCE

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Compiled by

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2016 North American Forest Insect Work Conference

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Message from the Chair

Good morning everyone and welcome to the opening of the 6th NAFIWC. My name is Scott Salom and I along with several of your colleagues plus some professional conference staff at Virginia Tech have been working hard for quite some time to bring this event to you. You of course have also contributed with your presentation submissions and will make the conference what it is with your participation throughout the event. I hope your travels here were smooth, uneventful, and relatively on time.

Hopefully you all enjoyed the mixer amidst some of the ongoing landscape renovations and also found good places to eat dinner. I want to welcome all of you to this once in every 5-year event. I have had an opportunity to attend all of the NAFIWCs except No. 3 in Alberta, and they always have tremendous energy and focus within our profession and discipline. I am usually exhausted but at the same time energized by the end of one of these meetings.

Amongst all the meetings that are available and that I attend, I get the most out of our regional and continental work conferences. That is just my personal feeling.

So why do I like these meetings so much:

1. It brings all of our regional working groups together. Keeps us connected.

2. The meeting is large enough to provide a diverse program of outstanding research or discussion of issues not commonly encountered in our professional meetings.

3. The meeting is small enough so that most of us will not get lost on the way from one meeting room to the next.

4. I know a lot of the people, so it is automatically a friendly atmosphere, but there are always many new people to meet.

These meetings don't come together by themselves, and every time I volunteer to organize a meeting (always smaller than this), I quickly realize all the effort that goes into it. When you don't do this, it is easy to assume how seamlessly it all seems to work and perhaps be quick to criticize when its not quite right. I'm as guilty of this as anyone, but am usually most put off by the expense, especially registration fees for meetings. That is why we kept the registration fees down as much as possible for a venue like this, partially to offset the expense of the rooms and parking for some, and why there is not a generous breakfast waiting for you in the hallway. A meeting held here two weeks ago had a registration fee of $1500.

Even though there is recognition for those that have helped put this conference together in your program, I wanted to very thankfully acknowledge everyone that has helped us get to this point and intertwine that with various housekeeping and points of interest regarding the conference: The Organizing Committee, the Program Committee, the Sponsorship Committee and Sponsors/Exhibitors

We all hope you have a wonderful and productive time at the meeting and leave here enriched and energized. If you have any questions about the venue or any specific needs, don't hesitate to contact Erich and his group from CPE, myself, Bob Rabaglia, or Kier Klepzig.

So without further ado, I'd like to ask Kier Klepzig to come up to the podium and introduce the Plenary session and its speakers.

Conference Overview

Wednesday, June 1

8:15 – 8:30 Welcome Remarks – Scott Salom

8:30 - 10:00 Plenary Session 1

1. Keynote Speaker: Tom Tidwell, Chief, USDA Forest Service: Importance of Science to Forest Health
2. Speaker: Monica Lear, Director, Forest Health Protection, USDA Forest Service: Forest Health Challenges and Approaches
3. Speaker: Carlton Owen, US Endowment for Forestry and Communities: Toward Healthy Forests: The Role of Modern Biotechnology

10:30 – 12:00 Concurrent Session 1

A. Rediscovering Our Urban Forests – Lynne Rieske-Kinney
B. Testing an Early Intervention Strategy to Suppress a Spruce Budworm Outbreak. David A. MacLean
C. Technological Advances in Monitoring Forest Health – Frank Sapio
D. Open Session 1 – Iral Ragenovich (Harding)

1:30 – 3:00 Concurrent Session 2

A. Responses of Arthropods to Composition of Urban Landscapes – Kamal J.K. Gandhi and Dayton Wilde
B. Douglas-fir Tussock Moth in Western North America: Outbreak Trends, Current Issues, and Future Directions in Monitoring, Management, and Resource Protection – Robbie W. Flowers and Andrew D. Graves
C. Landscape Session: Regional Characterization of Forest Susceptibility to Insect Outbreaks and Their Impacts - J.T. Vogt and Randy Morin
D. Off-the-shelf kits for saving the world's forests. Available now! – Jiri Hulcr and Caroline Storer

3:30 - 5:00 Concurrent Session 3

A. Characterizing Above and Below Ground Changes in Forests Aftermath of Insect Outbreaks – Nadir Erbilgin
B. Sirex and its Complicated Food Web – Laurel Haavik, Ann Hajek, Jessica Hartshorn, and Fred Stephen
C. Forest Entomology in a Landscape Context – Robert N. Coulson and Patrick C. Tobin
D. Relevance of our Forested Lands to the Maintenance of Pollinators and Pollination Ecology in North America – Rob Progar and Justin Runyon

Thursday, June 2

8:30 – 10:00 Plenary Session 2

1. Speaker: Gwen Pearson, Purdue University: Facts are Not Enough: Stories and Emotion in

Science Communication
2. Speaker: Doug Crandall, Legislative Affairs, USDA Forest Service: Congress and the Forest Service.

10:30 – 12:00 Concurrent Session 4

A. Challenges, Paradigms, and Novel Approaches to the Forest Health Curriculum –Kamal J.K. Gandhi and Robert N. Coulson
B. Bark Beetles and Forest Management: Are Prevention and Suppression Programs Effective? – Steve Clarke, John Nowak and Chris Fettig (Hoover)
C. The Changing Face of Biological Control in Forest Ecosystems – Sandy Smith, Krista Ryall (Coolidge)
D. Getting to the First Step in Forest Restoration - Cone and Seed Insects of North American Conifers – Carl Jorgensen

1:30 - 3:00 Concurrent Session 5

A. Women in Forest Entomology – Jessica Hartshorn
B. Managing for Forest Health and Resilience – Steve Clarke, John Nowak and Chris Fettig (Hoover)
C. Forest Health Extension in North America: Challenges and Opportunities – David Coyle
D. Potentials for Restoration After Invasions by Exotic Forest Pests: East – Fred Hain

3:30 - 5:30 Concurrent Session 6

A. Open Session 2 – Molly Darr
B. Applied MPB Ecology During Severe Outbreaks in High Elevation Pine Systems – Joel Egan and Polly Buotte
C. History of Forest Entomology in North America – Beth Willhite
D. Potentials for Restoration After Invasions by Exotic Forest Pests: West – Steve Cook

Friday June 3

9:00 – 10:30 Concurrent Session 7

A. Invasions by Non-Native Forest Insects and Diseases: Efficient Solutions 1 – Kirsten Prior, Sandy Liebhold, Jiri Hulcr
B. Open Session 3 – Elizabeth Graham
C. Assessing the Impact of Populations of Bark Beetles and Woodborers with Expanding Ranges in North America 1 – Tom W. Coleman and Steven J. Seybold
D. Arthropogenic Effects: Tree-mediated Interactions Among Forest Insects – Jonathan Cale and Jennifer Klutsch

11:00 – 12:30 Concurrent Session 8

A. Invasions by Non-Native Forest Insects and Diseases: Efficient Solutions 2 – Kirsten Prior, Sandy Liebhold, Jiri Hulcr
B. Factors Influencing Forest Insects at Range Margins – Barbara Bentz and Brian Aukema

C. Assessing the Impact of Populations of Bark Beetles and Woodborers with Expanding Ranges in North America 2 – Tom W. Coleman and Steven J. Seybold
D. Changing Forests, Imperiled Habitats: The Roles Arthropods Play – Luke E. Dodd and Lynne Rieske-Kinney

2016 North American Forest Insect Work Conference – Washington, DC – Wednesday, June 1

Plenary Session 1

1. Keynote: *Tom Tidwell, Chief, USDA Forest Service*: Forest Health – Challenges, Restoration, Partnerships and Collaboration.
2. Speaker: *Monica Lear, Director, Forest Health Protection, USDA Forest Service*: Forest Health Challenges and Approaches.
3. Speaker: *Carlton Owen, US Endowment for Forestry and Communities*: Toward Healthy Forests: The Role of Modern Biotechnology

Concurrent Session 1

1. **Rediscovering Our Urban Forests.** *Moderator: Lynne Rieske-Kinney*
   a. **Session Abstract:** As urbanization encroaches further into wildland areas our urban canopy is expanding. Recognition of the importance of the urban canopy is increasing as human population centers seek to enhance their vitality to attract and retain new residents. Urban trees create a vibrant aesthetic, make significant contributions to ecosystem services, provide critical habitat for urban wildlife, affect property values and aesthetics, influence social interactions, and contribute to human health and human happiness. Urban trees are exposed to many of the same stressors as their wildland counterparts, but also have insect pest and pathogen problems unique to urban ecosystems. Protecting and engaging in our urban forests is key to enhancing their contributions and ensuring their sustainability.
   b. **Speakers and abstracts:**
      i. **Urban warming increases pest fitness and abundance and reduces tree health.** *Steven D. Frank[1], Adam G. Dale[2], Emily K. Meineke[1], Elsa K. Youngsteadt[1], [1]Department of Entomology, North Carolina State University, Raleigh, NC, [2]Department of Entomology, University of Florida, Gainesville, FL.* Urban forests provide important benefits to urban residents and in mitigating climate change. However, US urban forests are shrinking due in large part to arthropod pests which are more abundant and damaging in urban than rural forests. Our hypothesis was that elevated temperatures due to the urban heat island effect increases arthropod pest abundance in cities and that urban forests predict pest outbreaks that will occur in rural forests due to global warming. We tested these hypotheses by examining the ecological mechanisms that increase scale insect abundance on trees in the hottest parts of Raleigh, NC and by comparing our results to historical herbarium specimens. We found that urban heat affects scale insect abundance directly by increasing survival and fecundity. Urban heat increases scale fitness indirectly by altering interactions with natural enemies through phenological changes in scale and parasitoid development. These findings inform predictions about how climate change could affect natural forests. Scale abundance was greater on herbarium specimens collected from natural forests during hot years over the last century. Ultimately the

combination of warming, pests, and other stresses reduces tree condition and other ecosystem services in hot urban sites.

ii. **Causes and consequences of host range expansion: Urban landscapes provide refugia for emerald ash borer.** *Don Cipollini, Department of Biological Sciences, Wright State University, Dayton, OH.* Emerald ash borer (EAB), *Agrilus planipennis*, is an invasive pest of ash trees in North America that was recently found attacking white fringetree (*Chionanthus virginicus*) in urban landscapes. First reported in the Dayton, Ohio area, EAB has now been found attacking white fringetrees in urban landscapes across Ohio, as well as in Indiana, Illinois and Pennsylvania. At these locations, the proportion of trees infested with EAB increased as basal stem diameter increased, and trees with epicormic sprouting were more likely to be infested. Stems from three of nine infested white fringetrees collected from the Dayton and Cincinnati, Ohio areas in the winter of 2015 yielded four live adult emerald ash borers after being held in rearing containers, and numerous older exit holes were observed. Measurement and aging of feeding galleries on these stems indicated that EAB has been using this species since 2011, at least, with peak gallery densities reached in 2012 and 2013 on most of the harvested trees. On average, 32 galleries per square meter were found in these stems with about one-third of them being indicative of fourth instar larvae. This supports the assertion that emerald ash borer has been using white fringetree as a host plant with moderate to good success for as long as ash species in these particular areas have been utilized. Since white fringetree appears to be more resilient to attack than susceptible ash trees, white fringetrees in urban landscapes may serve as refuges for EAB.

iii. **Contrasting the species diversity and value of urban forests in inner-city and suburban Cleveland, OH.** *Christopher B. Riley, Daniel A. Herms, and Mary M. Gardiner, Department of Entomology, Ohio State University, Columbus, OH.* Vacant land, a product of decades of population and economic decline resulting in the abandonment of infrastructure, has increased substantially in shrinking cities around the world. In Cleveland, Ohio, vacant lots are minimally managed, concentrated within lower-income neighborhoods, and support a large proportion of the city's urban forest. This forest is comprised primarily of weedy, exotic species that are thought to provide little economic value, and whose contributions to ecosystem services remain poorly understood. We sought to compare the economic value of the ecosystem services provided by native and exotic tree species on inner-city vacant lots, residential lots, and suburban residential lots by quantifying tree diversity, abundance, and size class. The economic value of the ecosystem services provided by the respective forest assemblage on each property type was then quantified using i-Tree Eco. Vacant lots supported three times as many trees as urban and suburban residential lots, with the majority being saplings of exotic species. While vacant lots had a higher mean alpha diversity, both residential property types had higher beta diversity. The value of ecosystem services provided by urban forests was also highest on vacant lots, with exotic species contributing much of that value. We conclude that the high diversity and abundance of exotic, invasive tree species on vacant land provides valuable ecosystem services to communities that otherwise have minimal access to urban green spaces and their associated benefits. More research is needed on the ecological role and value of exotic-tree-dominated vacant lots to the larger urban ecosystem.

iv. **The Urban Forest Initiative: growing urban forestry awareness, outreach, and education.** *Nic Williamson[1], Mary Arthur[1], Lynne Rieske[2], Departments of [1]Forestry and [2]Entomology, University of Kentucky, Lexington, KY.* Urban trees contribute environmental, economic, and social benefits, significantly enhancing quality of life. Nevertheless, they are often a neglected component of urban land management. In the Bluegrass Region of Kentucky urban tree canopy cover varies with land use, tree planting initiatives, and tree care efforts, and has been heavily impacted by development, invasive species, and funding reductions. We created the Urban Forest Initiative to reverse these trends on a regional scale by growing urban forestry awareness, increasing outreach activities, and educating our citizenry. Our initiative includes (1) creating and hosting an Adopt-a-Tree program, (2) developing a campus-specific interactive map showing the ecosystem services provided by trees around specific buildings, (3) expanding the Tree Campus USA/ Tree City USA missions and associated activities to Bluegrass communities, and (4) developing a web presence highlighting the urban forest and documenting the growth, development and value of the campus tree canopy. Our goal is to increase awareness of the urban tree canopy and its contributions to sustainability through community engagement. Increasing the quality and quantity of canopy cover will contribute to the wealth of ecosystem services provided by urban trees, including decreased energy usage through shading, interception of stormwater providing relief to municipal systems, and promoting human health and social cohesion.

2. **Testing an Early Intervention Strategy to Suppress a Spruce Budworm Outbreak (Coolidge)**
   Moderator*: David A. MacLean*
   a. **Session Abstract:** As evidence mounts that eastern North America is on the cusp of another spruce budworm (SBW) outbreak, jurisdictions must weigh control options. In Québec, defoliation by SBW has increased from <3,000 hectares (ha) in 2003 to more than 4.2 million ha in 2014. SBW is the most damaging insect in North America. Detailed analyses of economic effects of SBW outbreaks in New Brunswick along with assumptions to estimate potential economic losses for forest in other jurisdictions indicated that potential direct and indirect losses of a moderate to severe SBW outbreak in the eastern Canada/US region could be $41.5 billion to $59.0 billion. An option not previously tested is an early intervention strategy to suppress SBW population growth and prevent damage. Recent R&D by the Canadian Forest Service indicates promising results from applying an aggressive early intervention strategy through maintaining low SBW mating success at low population levels. This session will describe progress on a 4-year, $18 million program to develop, test and monitor

the effectiveness of an early intervention strategy against SBW. The research involves over 30 scientists from 5 universities and the Canadian Forest Service. An early intervention strategy against SBW involves: i) intensive monitoring and early detection, ii) small area target-specific pesticide application, and iii) tools and techniques to disrupt mating and migration. The project includes multiple stakeholders, including industry, university, and government. Important research issues being addressed include: What are the early indicators of an infestation? When should treatment be initiated? What new tools and technology need to be developed? Strategies tested include short-term (applied control measures designed to suppress populations), longer-term (inoculating seedlings with endophytic fungi that have insect suppressing qualities), and improving decision support capabilities to facilitate pest management planning. The first step, increased sampling intensity of SBW populations to identify pre-outbreak SBW population increases, commenced with forest industry financing in NB in the fall of 2013. The project involves studies in northern NB and Quebec, with successful Mimic, Btk, and pheromone trials in 2013 and 2014, intensive SBW population ecology and natural enemies research, examination of satellite and airborne hyperspectral sensing of low-level defoliation, radar detection of moth flights, decision support for optimizing spray operations, a citizen science program, and an active public communications program. We will describe progress to date and the rationale and prognosis for SBW outbreak alteration.

b. Speakers and Abstracts:

i. **Spruce budworm is back. Can we intervene early to reduce outbreaks?** *David A. MacLean, Professor, Faculty of Forestry and Environmental Management, University of New Brunswick, Fredericton, NB, E3B5P7 Canada* *macleand@unb.ca*. Evidence is mounting that eastern North America is on the cusp of another major spruce budworm (*Choristoneura fumiferana* Clem.) outbreak, with defoliation in Québec increasing from <3,000 hectares (ha) in 2003 to >6.3 million ha in 2015. Spruce budworm is the most damaging insect in North America, and detailed economic analyses have indicated that potential losses of a moderate to severe outbreak in the eastern Canada/US would be $41-59 billion. We are testing an early intervention strategy to suppress spruce budworm population growth and prevent damage in a 4-year, $18 million research program that began in New Brunswick in 2014. The project includes over 30 researchers and collaborators from Natural Resources Canada, five universities, New Brunswick Department of Natural Resources, and forestry companies. An early intervention strategy would involve intensive monitoring and early detection, small area target-specific pesticide application, and tools and techniques to disrupt mating and migration. Trials in 2014 and 2015 in northern NB and Quebec demonstrated successful Mimic, Btk, and pheromone trials population reduction in identified 'hot spots'. We are also conducting intensive budworm population ecology and natural enemies research, testing inoculation of planted seedlings with endophytic fungi that have insect suppressing qualities, use of satellite and airborne hyperspectral sensing of low-level defoliation, radar detection of moth flights, and a decision support system for optimizing forest protection operations. The research includes an active public communications program. We will describe progress to date and the prognosis for spruce budworm outbreak alteration.

ii. **Dynamics of rising spruce budworm populations: opportunity for an early intervention strategy.** *Jacques Régnière. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, PO Box 10380 Stn. Ste-Foy, Quebec, Canada G1V 4C7.* Between 2008 and 2015, we investigated the dynamics of rising populations of the spruce budworm in the context of a new outbreak developing in eastern Quebec, Canada. We documented the existence of strong density dependence in mating success and population survival, together constituting an Allee-type density threshold below which populations growth rates are too low for spontaneous outbreak development. We found that moth migration around outbreak epicenters is the most likely trigger and mechanism of outbreak spread. Moths tend to emigrate from populations that reach densities causing >20% defoliation. Ongoing radar and modeling studies of moth movement in air circulation show that such displacements can be massive and occasionally cover distances in the order of 50 to 100 km. We also tested the efficacy of two insecticides (Btk and Mimic) as well as mating disruption against populations, covering the whole range between endemic and outbreak levels, We have shown that insecticides are highly effective at reducing survival and bringing populations back below the Allee threshold. This new information allows us to calculate an approximate management threshold where population growth remains <1, and propose an early intervention strategy aimed at keeping populations below that threshold at a regional scale. The objective of this strategy is to prevent or at least slow the spread of a new outbreak. This objective is very different from that of the foliage protection strategy currently used by jurisdictions in eastern Canada, which is to keep trees alive during the passage of the outbreak. Instead of prioritizing treatments on the basis of the wood-supply importance of stands, an early intervention strategy prioritizes SBW populations in terms of their importance as sources of migrating moths.

iii. **Spruce budworm 'Early intervention strategy' in Atlantic Canada: Translating theory into practice.** *Rob Johns[1], Veronique Martel[2], Deepa Pureswaran[2], Alex Smith[3], Stefaniya Kamenova[3], Eldon Eveleigh[1]. [1]Natural Resources Canada, Canadian Forest Service, Fredericton, New Brunswick, Canada. [2]Natural Resources Canada, Canadian Forest Service, Quebec City, Quebec, Canada*[3]University of Guelph, Ontario, Canada. E-mail: rob.johns@canada.ca. Spruce budworm is once again on the rise in eastern Canada, rekindling interest and discussion around how best to manage its potential impact. Several recent advancements in our understanding of how budworm populations rise and spread has led to a reconsideration of a 'hot spot' management approach, which draws heavily on concepts developed as part of regional containment programs sometimes used to manage invasive insects (e.g., 'Slow the Spread' for gypsy moth). Such programs rely on an area-wide management framework and are quite knowledge intensive, requiring deep knowledge of population dynamics, efficient and extensive monitoring, efficacious but relatively narrow spectrum treatment options, and strong outreach and communications infrastructure. However, with these challenges come opportunities to enhance our understanding of the ecological processes underlying spruce budworm outbreaks and perhaps those of other native pests. In this talk, I will lay out some of the key steps needed to render this project from theory into practice, some of the interesting innovations being developed (e.g., Citizen Science pest monitoring and barcoding approaches for assessing parasitism), as well as what questions and challenges may lie ahead. In brief, results for the first two of this four-year project suggest that monitoring of overwintering larvae and pheromone trapping (with the help of citizen scientists) may be effective for detecting 'hot spots'. Results of large-scale efficacy trials suggest that treatments are effective in suppressing low density populations (at least locally) with little apparent impact on non-target species.

iv. **Using spatial genetics to characterize spruce budworm dispersal and meta-population connectivity: the importance of spatial and temporal context.** *Patrick M. A. James[1], Colin J. Garroway[2], Rob C. Johns[3]. [1]Département de sciences biologiques, Université de Montréal, Montréal, QC. Canada. patrick.ma.james@umontreal.ca. [2]Department of Biology, University of Manitoba. Winnipeg, MN. Canada. colin.garroway@gmail.com, [3]Canadian Forest Service, Natural Resources Canada. Fredericton, NB. Canada. rob.johns@canada.ca.* The spruce budworm (*Choristoneura fumiferana*) is a native defoliating forest insect pest whose periodic population outbreaks affect millions of hectares of northern forest. Despite many years of research, we still know very little about the broad-scale spatial processes involved in outbreak dynamics, including dispersal. Understanding dispersal is essential to the success of early intervention management strategies that aim to control source populations. We investigated spruce budworm spatial-temporal genetic structure to characterise dispersal and to better understand meta-population connectivity within an ongoing outbreak. Larvae and moths were collected from multiple sites in Québec, New Brunswick, and Maine between 2012 and 2014. Spatial genetic variation was characterised using numerous (>1000) single nucleotide polymorphisms (SNPs) identified using genotyping-by-sequencing. Genetic connectivity was assessed using multivariate statistics, cluster analysis, and measures of spatial autocorrelation. We found interesting and unexpected patterns of spatial genetic variation. Along an east-west axis at the scale of the province of Québec and within areas affected by the outbreak for multiple years, we found evidence for significant population connectivity despite immense distances separating sites. However, along the north-south outbreak expansion axis we found limited connectivity between outbreak core and leading edges and identified unique genetic signatures for sites at in northern Québec and in New Brunswick. These results suggest that dispersal plays an important role in synchronizing budworm populations at large spatial scales when the outbreak is already underway but that local processes also contribute to population growth in early stages of outbreak development and at leading edges.

3. **Technological Advances in Monitoring Forest Health – Moderator:** *Frank Sapio*

   a. **Session Abstract:** Disturbances in Forest health cross various spatial and temporal scales. An integrated system is presented that addresses a range of technologies for predicting and monitoring forest disturbances that span these scales. Moderate to high spatial resolution with multi-temporal approaches are discussed in the context of forest disturbance reporting. New technologies for recording pest activity advance our capabilities for monitoring and informing predictions.

   b. **Speakers and Abstracts:**

      i. **2012 and Beyond – Validating NIDRM & where we might go from here**. *Frank J. Krist Jr.*[1]*, William B. Monahan*[1]*, Andrew J. McMahan*[2]. [1]Forest Health Protection-Forest Health Technology Enterprise Team, USDA Forest Service, Fort Collins, CO. [2]Cherokee Nation Technologies-Forest Health Technology Enterprise Team, USDA Forest Service, Fort Collins, CO. The 2013-2027 National Insect and Disease Forest Risk Assessment (NIDFRA, also referred to as the NIDRM - www.fs.fed.us/foresthealth/technology/nidrm.shtml) estimates potential tree mortality from insects and diseases in units of square feet of basal area over a 15-year future time period (2013-2027) across all treed areas of the U.S. NIDFRA provides a landscape-level summary of potential insect and disease activity (hazard) derived from science-based, transparent geospatial methods and field input. The NIDFRA contains 186 published forest pest models. Results from NIDFRA have been summarized by National Forest, National Park, American Indian Lands, and U.S. Fish and Wildlife management units. These summaries were developed in close partnership with the Department of Interior and are now available in a user friendly web application: http://foresthealth.fs.usda.gov/fhas. The Forest Health Advisory System (FHAS) provides a tool that can inform assessments of forest ecosystems and potential management opportunities. Depending on local needs, these summaries can support prevention and suppression activities for integrated forest pest management, forest restoration efforts, ecosystem resiliency management, short and long term monitoring efforts, and fuels and fire management. In an effort to ascertain if the general magnitude of potential mortality predicted by NIDFRA is reasonable, all 186 models were re-run using forest parameter input datasets characterizing the forest conditions of 2002, thereby providing an estimate of mortality for the period 2002-2017. These results were then compared at a state level to FIA estimates of cubic foot volume mortality for the period 2002-2015 (where available), extrapolated to reflect a 15-year mortality rate. At the state scale, mortality estimates from the NIDFRA are on average commensurate with rates observed across states in FIA. Future analyses could further elucidate patterns of mortality predicted by the models. More than 150 Forest Service staff and Federal partners participated in the development of NIDFRA. Feedback from partners related to future work includes development of local insect and disease risk maps, annual or real-time updates to risk models, making forest pest assessments future climate smart, enhanced integration of results with aerial and ground survey data, and identification of techniques to improve characterization of results from NIDFRA.

ii. **Making NIDFRA dynamic, local, and climate smart – ideas for boldly going where risk modelers have not gone before.** *William B. Monahan[1], Frank J. Krist Jr.[1], Andrew J. McMahan[2], John R. Withrow[2].* [1]Forest Health Protection-Forest Health Technology Enterprise Team, USDA Forest Service, Fort Collins, CO. [2]Cherokee Nation Technologies-Forest Health Technology Enterprise Team, USDA Forest Service, Fort Collins, CO. The National Insect and Disease Forest Risk Assessment (NIDFRA) is a nationwide strategic assessment and database of the potential hazard for tree mortality over the next 15 years due to major forest insects and diseases. It is produced approximately every 5 years, maturing from a simple cartographic exercise in 2001 to complex GIS models that are now parameterized by entomologists and pathologists. Building on this progression, as well as feedback from the field, we propose and demonstrate four non-mutually exclusive directions for developing the next NIDFRA. The first direction is to integrate NIDFRA with other datasets and models, principally National Insect and Disease Surveys (IDS), to monitor and update NIDFRA predictions over time. Relating the magnitude of NIDFRA-projected hazard to observed mortality from IDS helps crosswalk our results to management actions that tie to the USFS Strategic Plan (http://www.fs.fed.us/strategicplan). For example, areas of high NIDFRA-projected hazard and low observed IDS mortality may benefit especially from prevention tactics (e.g., thinning), while areas with high hazard and high mortality may require restoration – either to previous conditions or desired future conditions. Similarly, areas with low NIDFRA hazard and low IDS mortality may simply necessitate periodic monitoring to ensure resiliency, while areas having low projected hazard and high current mortality may require suppression and a possible re-evaluation of specific NIDFRA models (e.g., the recent California drought, where the 2013-2027 NIDFRA has underestimated mortality already being detected by IDS). The second direction is to simply update the existing NIDFRA with the goal of assessing change in hazard over time. This requires repeating the same modeling methods but updating the dynamic variables used by the models. For example, host conditions for mountain pine beetle have changed dramatically since the last NIDFRA, so the intervening tree mortality could be quantified using IDS and other data sources to revise estimates of current host conditions, which serve as the basis for NIDFRA's hazard predictions. Similarly, the geographic ranges of exotics and certain native pests (e.g., southern pine beetle) have changed and could be updated to reflect the new hazard extent. The third and fourth directions involve modifying the spatial or temporal scales of NIDFRA. While NIDFRA presently operates at landscape scales, looking out to 2013-2027, local risk maps (LIDRMs) may be developed for particular locations to support management decisions at local scales. An example is California, where LIDRMs have been generated from high resolution 30 m data, and new LIDRMs could be extended to include stand-level data. Similarly, at the landscape-level, new NIDFRAs could explicitly integrate future climate input variables, thereby facilitating projections of potential tree mortality further into the future, in support of long range planning. An example for limber pine projected out to 2050 under "business as usual" emissions identifies areas on the landscape where we might expect loss or extirpation, high stability and resiliency, and new areas for growth or colonization. Finally, NIDRFA is a collaborative assessment. We offer these ideas to engage partners and collaborators in the development of the next NIDFRA. Such collaboration is important not only for ensuring use and application of NIDRFA results, but also in helping overcome a number of conceptual and implementation challenges that must be addressed in pursuit of the next NIDFRA.

iii. **Remote sensing and data fusion techniques using Goddard's LiDAR, Hyperspectral and Thermal imager for early detection of forest health threats.** *Ryan P. Hanavan.* Forest Health Protection, USDA Forest Service, Durham, NH The Goddard LiDAR, Hyperspectral and Thermal imaging system (GLiHT) provides data fusion opportunities to increase accuracy and early detection of incipient infestations of forest insect and disease pests. Annual Insect and Disease Surveys (IDS) created a unique opportunity to develop an enhanced survey project between the Forest Service and NASA. The GLiHT captures both upwelling and downwelling irradiance and contains both profiling and scanning LiDAR instruments and was mounted in a plane being used for IDS. Image acquisition started in 2014 targeting northern hardwood forests and urban areas where the emerald ash borer, *Agrilus planipennis* Farimaire, had been identified. Hyperspectral remote sensing has been successfully used to map forest species, although most efforts have focused on healthy canopies in relatively homogenous stands. Our goal was to identify the most accurate approach to species-level mapping across a range of decline conditions in both urban and forested settings. Using object based segmentation techniques, spectral mixture analysis and combinations of vegetation indices along with hyperspectral bands in unmixing calibration procedures, our ability to successfully map ash across a range of health conditions was more accurate than traditional unmixing procedures using "pure" endmembers. The incorporation of vegetation indices into spectral unmixing procedures is novel and shows promise for future forest health applications.

iv. **From Alarms to maps: Forest disturbance monitoring and spatial delineation using MODIS and Landsat data.** *Robert A. Chastain[1], Mark V. Finco[2], and Ian W. Housman[3]. RedCastle Resources, Inc., under contract to the USDA Forest Service Remote Sensing Applications Center, Salt Lake City, Utah, [1] rchastain@fs.fed.us, [2] mfinco@fs.fed.us, [3] ihousman@fs.fed.us* The Forest Disturbance Monitor (FDM) and Operational Remote Sensing (ORS) programs both use space-based remote sensing data to assist the USFS Forest Health Protection by assisting insect and disease aerial detection survey (ADS) efforts and augmenting the data streams that support the annual Insect and Disease

Survey (IDS). The forest change spatial products provided by the FDM program are CONUS-wide spatially coarse MODIS-based data that are delivered in near-real time during the growing season via a web application. These data act as an alarm that promote ADS efforts as well as ORS mapping endeavors. The goal of the ORS enterprise is to provide spatially accurate representations of forest disturbances in targeted regions using Landsat-scale remote sensing image data. Spatial data produced using ORS methods are intended to augment the annual USFS Insect and Disease Survey (IDS) data stream where aerial detection survey (ADS) data are not otherwise available.

v. **A Nationwide Strategy for Improving Forest Insect and Disease Survey.** *Frank J. Sapio.* Forest Health Protection-Forest Health Technology Enterprise Team, USDA Forest Service, Fort Collins A three-part integrated strategy is presented that no longer focuses solely on aerial detection surveys (ADS) as the principal methodology for national forest health reporting. While ADS will remain as a viable part of forest health survey, it is being designed as part of a system that accepts ground data and remotely sensed data well. Technology is presented that improves the nature and quality ADS. Based upon the android operating system and consumer grade pen tablets, forest service licensed, public domain software is at the core of this strategy. This software called Digital Mobile Sketch Mapping (DMSM) has both aviation and ground components that work together. Also discussed is a remoted sensing analysis system that provides data to the DMSM units for field verification and update. A narrative based system entitled the Pest Event Reporter is also discussed. This system, originally designed to aspatially capture trends in pest populations and damage, now allows a narrative to be associated with maps generated by other parts of the system. These narratives offer information depth and detail to forest health reports, providing information not available through other parts of the system..

vi. **Cross topic discussion.** Moderated by *Chris Asaro, Forest Health Protection – USDA Forest Service, Atlanta, GA*. – no abstract.

4. Open Session 1 Moderator: *Iral Ragenovich*

a. **Session Abstract**: An open session for submitted talks on important topics

b. **Speakers and Abstracts**:

i. **Innovations Under Pressure: New Tools and Methods in Systemic Injection.** *Joseph Doccola and Donald Grosman, Arborjet, Inc.* Recent research has demonstrated that systemic tree injection with efficacious insecticides provides a useful tool in protecting ash trees. In this area, technology has evolved to meet the demands of destructive pests such as emerald ash borer (EAB, *Agrilis planipennis*) and the need to protect trees. Presented are: 1) new innovations in tree injection methods, 2) a discussion of emamectin benzoate chemistry and Tree-äge® formulations, and 3) recent updates in emerald ash borer field studies.

ii. **Development of SPLAT® Verb and Related Efforts.** *Christopher J. Fettig[1], Carmem R. Bernardi[2], Beverly M. Bulaon[3], Tim Burzloff[4], Stephen R. Clarke[3], Danny R. Cluck[3],*

Horst E. Delb[5], Monica L. Gaylord[3], Sandy Kegley[3], Laura Lowrey[3], Joel D. McMillin[3], James R. Meeker[3], Leif A. Mortenson[1], A. Steven Munson[3], John T. Nowak[3], Robert A. Progar[1], Michael Reinke[6], Johnathon Rico[2], Darrell W. Ross[7], Justin B. Runyon[1], Kavita Sharma[2], Cynthia L. Snyder[3], Lia Spiegel , Brytten E. Steed[3], and Agenor Mafra-Neto[2]. [1]Research & Development, USDA Forest Service. [2]ISCA Technologies Inc. [3]Forest Health Protection, USDA Forest Service. [4]University of Freiburg. [5]Forest Research Institute of Baden-Württemberg. [6]Great Lakes IPM. [7]Oregon State University. Fettig et al. (2015) developed a novel formulation of (–)-verbenone (SPLAT® Verb, ISCA Technologies Inc., Riverside, CA, USA) for protecting individual lodgepole pines, *Pinus contorta*, and small stands of *P. contorta* from mortality attr ibuted to mountain pine beetle, *Dendroctonus ponderosae*. Rather than a single release device, SPLAT® Verb is a flowable emulsion that allows the user to adjust the size of each release point (dollop) according to desired rates and distributions in the field. Dollops biodegrade within ~1 year of application, and do not need to be retrieved from the field unlike most other formulations of verbenone. Recently, SPLAT® Verb has also been demonstrated effective for protecting individual sugar pines, *P. lambertiana*, and whitebark pines, *P. albicaulis*, and small stands of *P. albicaulis* from mortality attributed to *D. ponderosae*. The high levels of tree protection observed in these studies is attributed to the ability of applying multiple release points per tree, and a larger zone of inhibition provided than reported for other formulations of verbenone. SPLAT® Verb was registered by the U.S. Environmental Protection Agency in August 2013, and was first used commercially in 2014. We review research that led to the development of SPLAT® Verb, and current efforts to develop similar tools for other bark beetle-host complexes in North America and Europe.

iii. **Impacts of mountain pine beetle outbreaks on lodgepole pine forests in the Intermountain West, U.S.** *Brytten E. Steed[1], Christopher J. Fettig[2], A. Steven Munson , Leif A. Mortenson[2], Carl L. Jorgensen[4], Jose F. Negrón[5], Justin B. Runyon[6], Kenneth E. Gibson[1], and Robert A. Cruz[7]. [1]Forest Health Protection, USDA Forest Service, Missoula, Montana 59807. [2]Pacific Southwest Research Station, USDA Forest Service, Davis, California 95618. [3]Forest Health Protection, USDA Forest Service, Ogden, Utah 84403. [4]Forest Health Protection, USDA Forest Service, Boise, Idaho 83709. [5]Rocky Mountain Research Station, USDA Forest Service, Fort Collins, Colorado 80526. [6]Rocky Mountain Research Station, USDA Forest Service, Bozeman, Montana 59717. [7]Forest Health Monitoring, USDA Forest Service, Ogden, Utah 84403.* Mountain pine beetle (*Dendroctonus ponderosae*) is a major disturbance in conifer forests of western North America where it colonizes several tree species, most notably lodgepole pine (*Pinus contorta*). Recent outbreaks have been severe, long lasting, and wide spread. In 2010, we initiated a large-scale study to determine the long-term impacts of mountain pine beetle outbreaks on forests. The scope of our work encompasses areas where the majority of mountain pine beetle-caused tree mortality has occurred in the U.S. Twenty-five 0.08-ha circular plots were established in Colorado, Idaho, Montana, Utah and Wyoming in lodgepole pine forests with recent evidence of trees being colonized and killed by mountain pine beetle. Within each plot, all trees ≥7.6 cm diameter at breast height (dbh) were tagged, and species, dbh, height, height to base crown, status (live or dead), and year since death recorded. Three 16.1-m Brown's transects were established at 0°, 120° and 240° from plot center to estimate surface fuels. A 1-m^2 plot was established at the end of each Brown's transect to determine forest floor composition, and a 0.004-ha plot was established at plot center to estimate tree regeneration. Increment cores were collected from the three tallest trees on each plot to determine stand age and site productivity. Levels of tree mortality and fall rates of individual trees are measured annually. Invasive weeds are surveyed every two years, while fuels are measured every fourth year. We discuss preliminary results and their implications to management of forests in the Intermountain West.

iv. **Is Great Basin bristlecone pine susceptible to mountain pine beetle attacks?** *Erika Eidson, MS Candidate, Wildland Resources Department, Utah State University. Collaborators: Barbara Bentz, Karen Mock, James Vandygriff, Matt Hansen.* Over the last two decades, mountain pine beetle (*Dendroctonus ponderosae*) populations reached epidemic levels across much of its native range in western North America. High-elevation mountain pine beetle attacks had been limited by cool temperatures over the past century, but recent large-scale outbreaks caused significant mortality among most high-elevation western pine species. Despite evidence of heavy mountain pine beetle activity occurring in other high-elevation pine species within the same stands, Great Basin bristlecone pine (*Pinus longaeva*) was not found to be attacked by mountain pine beetle. We used an attack box method to show that pioneering female mountain pine beetles have a low host attraction to Great Basin bristlecone pine in comparison to limber pine (*Pinus flexilis*), a favored mountain pine beetle host. We placed sets of female mountain pine beetles into boxes sealed onto pairs of Great Basin bristlecone pine and limber pine and recorded beetle activity after 48 hours. Beetles placed on limber pine initiated boring more frequently than those on Great Basin bristlecone pine. Additionally, beetles placed on Great Basin bristlecone pine avoided close proximity to the bole more often than beetles placed on limber pine. Our ongoing research also suggests that Great Basin bristlecone pine may not be a suitable host for mountain pine beetle reproduction. A better understanding of Great Basin bristlecone pine resistance to mountain pine beetle is important for the development of new tools for forest protection in a changing climate.

<u>Concurrent Session 2</u>

1. **Responses of Arthropods to Composition of Urban Landscapes** Moderators: *Kamal J.K. Gandhi and Dayton Wilde*

a. **Session Abstract:** Currently, >80% of the U.S. population lives in urban areas, and the land under urban development is expected to expand with human population growth. Urbanization causes major shifts in habitat structure, composition, and quality due to the introduction and establishment of exotic plant species. Such replacement of native trees and shrubs with exotic species causes changes in biodiversity on multiple trophic levels, especially arthropods with cascading ecological impacts on other taxa. This is of conservation concern because of the current extent of aesthetically managed landscape (30-40 million hectares) embedded in and around forested habitats in the U.S. We propose a symposium to present recent research on the response of arthropods to urban-suburban forested landscapes, the ensuing impact on insect predators, and various landscaping options that may conserve biodiversity. We have invited noted speakers that are experts in this field, and expect to generate discussion about ways to minimize and ameliorate the effects of urbanization using arthropods as a model taxa, along with avenues for future research.

b. **Speakers and Abstracts:**

   i. **Landscaping plants with ecological function: Challenges of scaling-up.** *Dayton Wilde. Department of Horticulture, University of Georgia, Athens, GA 30602.* The USGS has projected that current development patterns will lead to a completely connected urban area from Atlanta to Raleigh. This urban expansion is expected to have a significant impact on ecosystems of the Piedmont region. Management practices in this new urban landscape could play a major role in the conservation of native biodiversity in the Piedmont. There is increasing evidence showing that the inclusion of native plants in landscaping can support a greater abundance and diversity of native insects and birds. There are challenges in providing native ornamental plants on a regional scale, though. Ecological function, cost-effective production and ornamental traits are qualities desired in native landscaping material that are potentially conflicting. The scale-up of landscaping plants that can support biodiversity would benefit from interdisciplinary research in genetics, ecology, and economics.

   ii. **Foraging hubs: The key to urban food-web restoration.** *Douglas W. Tallamy. Department of Entomology and Wildlife Ecology, University of Delaware, Newark, DE 19717.* Insects, particularly lepidopteran larvae, are essential components of terrestrial food webs that sustain bird, rodent, reptile, amphibian, and mammalian meso-predator diversity. Literature searches of Lepidoptera larval host plants has revealed a pattern of host use that is consistent across all biogeographic regions of the U.S.; approximately 1% of the plant genera in a region serve as larval hosts for 50% of the Lepidoptera species in that region. Similarly, 6% of the plant genera support 80% of all local Lepidoptera. Stated in reverse, 94% of all plant genera support only 20 % of the local Lepidoptera. We call these unusually productive plant genera “foraging hubs” as they are the plants on which foraging insectivores must rely for most of their insect food. Thus, identifying regional foraging hubs and using them liberally in managed and unmanaged plantings is key to restoring biodiversity to urban, suburban, and rural landscapes alike.

iii. **Plant provenance in urban landscapes: The influence of native vs. exotic woody plants on natural enemy biodiversity.** *Matthew H. Greenstone. USDA-Agricultural Research Service, Invasive Insect Biocontrol and Behavior Laboratory, Beltsville, MD 20705.* During the past century of rapid human population growth, urban areas have proliferated and enlarged, leaving remnants of forests and other natural systems interspersed with cities and suburbs. These coupled human and natural systems are a vegetation mosaic among which insect pests and their natural enemies can move freely. International commerce and plant breeding have enabled us to populate our urban landscapes with hundreds of plant species from all of the vegetated regions of the world. Due to similarities in climate and shared geologic histories, northern-hemisphere urban landscapes tend to be dominated by North American and Eurasian genera of woody trees and shrubs. The plant species on each continent have been physically separated for between one and tens of millions years, providing sufficient time for insect pests and their natural enemies to adapt to the structures, chemistries, and nutritional resources of the vegetation on each continent. In a North American locality (Washington, D.C., USA), I performed a residential-scale, replicated field experiment comprising identically landscaped backyards, to test the hypothesis that arthropod natural enemies will be better adapted to native than to exotic plant species assemblages. Natural enemies were quantitatively sampled from plots planted to either Eurasian ("exotic") or North American ("native") species of eighteen tree and shrub genera. Two major natural-enemy groups, parasitic Hymenoptera and spiders, are statistically more abundant and more diverse in the native than in the exotic backyards. I discuss the implications of this result for urban ornamental landscaping.

iv. **How do arthropod communities respond to native and exotic urban landscapes?** *Paula M. Shrewsbury[1], Douglas W. Tallamy[2], Michael J. Raupp[1], Holly M. Martinson[1], David E. Jennings[1], and Ellery A. Krause[1]. [1]Department of Entomology, University of Maryland, College Park, MD 20742. [2]Department of Entomology and Wildlife Ecology, University of Delaware, Newark, DE 19717.* With increasing urbanization come changes in plant communities and concerns of decline in biodiversity and reduced ecosystem function. Of particular interest is how common features of urban landscapes affect biodiversity of arthropod communities. A better understanding of the effects of urbanization on community dynamics is critical towards sustaining and restoring ecosystem function in urban environments. A common feature of urbanization is an increase in the use of alien (non-native) plants relative to native plants as you move along the urbanization gradient. Of the work that has addressed the influence of plant origin on arthropod communities, most has focused on herbivorous arthropods and fewer on arthropod natural enemies. We investigate the hypothesis that urban landscapes of native plants will sustain a greater diversity of insect herbivores, and thus their natural enemies, than landscapes of alien plants that lack an evolutionary history with native arthropods. This study used simulated urban landscapes to compare the density and diversity of phytophagous insects and natural enemies in paired plots comprised entirely of native or alien woody ornamental plants. Arthropods were sampled over three years and identified to species (or morpho-species), and assigned to their appropriate trophic or feeding guild. Comparisons were made of species richness and abundance between native and alien landscapes. This study provides insight into herbivore and natural enemy responses to plant origin and information towards the development of measures to conserve natural enemies and the ecosystem service of biological control they provide in urban environments.

v. **Effects of cultivar and wild-type native plants on hemipteran insect biodiversity.** *Kamal J.K. Gandhi[1], J.C. Poythress[2], and James Affolter[2]. [1]Daniel B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602. [2]Department of Horticulture, University of Georgia, Athens, GA 30602*. Urbanization has caused major shifts in local biodiversity due to habitat loss and changes e.g., by replacing native with non-native plant species. There is a major push to incorporate more native plants in urban-suburban areas to promote biodiversity values. At present, it is unclear whether cultivated varieties or cultivars (generally single genotype) of native plants are optimal biodiversity surrogates for wild-types. Using hemipterans as a model taxon, we assessed the responses of herbivorous species to four species of cultivars and wild-type native plants commonly used in ornamental settings. Results indicate that species diversity of hemipterans did not differ between cultivars and wild-types. However, there were shifts in species composition though only a small proportion of insect species contributed to these differences. Total insect numbers and biomass also differed between two plant-types, and the trends varied as based on plant species. Overall, it appears that cultivars of native plants can provide similar ecological roles as wild-types for maintaining herbivorous hemipteran assemblages.

2. **Douglas-fir tussock moth in Western North America: Outbreak trends, Current Issues, and Future Directions in Monitoring, Management, and Resource Protection** Moderators: *Robbie W. Flowers and Andrew D. Graves*

a. **Session Abstract:** The Douglas-fir tussock moth (*Orgyia pseudotsugata*) (DFTM) is an important defoliator of Douglas-fir, true firs, and spruces in Western North America. Severe outbreaks of DFTM have occurred in British Columbia, the Pacific Northwest, the Pacific Southwest, the Intermountain Region, and the Rocky Mountains. Outbreaks are cyclical with rapid onset and decline, usually attributed to the activity of their natural enemies. Defoliation of preferred hosts may cause widespread growth-loss, top-kill, and tree mortality alone or in association with attacks by bark beetles and/or environmental conditions. The objective of this session was to provide a brief update on DFTM trends in each region and discuss the current approaches and challenges to monitoring, management, and resource protection. The session format was a panel discussion with representatives from several regions in the western U.S. and Canada. Outbreak trends were highly variable among the regional reports, with many areas reporting more expansive and severe defoliation than has been observed historically since aerial survey monitoring began in the 1940s. In a few cases, recent outbreaks were also observed in locations where they had not been previously reported over that time. The history of forest management and fire suppression in the western U.S. and Canada has led to an increase in preferred hosts for DFTM in many areas, and this, coupled with changing climatic conditions, has the potential to impact the initiation, duration, frequency, and location of DFTM outbreaks in the future. Cooperative pheromone trapping is currently used to monitor DFTM population trends, but high variation exists in the density and extent of the trapping among the regions. Issues of concern included the difficulty in interpreting traps results, the efficacy of different trapping lures, and how to sustain a cooperative monitoring effort. Analyses of the long-term Pacific Northwest data set were presented and indicated that results of individual sites surveyed consistently across years are useful in assessing DFTM population changes, especially when interpreted in the context of findings over a larger area. Thus, trapping results may be most useful when they are collected annually at moderate trapping densities over broad scales. Ongoing efforts include collating all available DFTM trapping data from the U.S., modernizing the database, and analyzing the results at more ecologically meaningful scales to better optimize trapping efforts. Initial comparisons of current and newly-available lures were also presented, but findings were inconclusive and additional research is ongoing. Forest management of DFTM outbreaks has traditionally relied on suppression by aerial applications of insecticides. However, the challenges of timely implementation of spray projects, the decline of staff experience and products associated with these technologies, and the increased scrutiny surrounding these efforts were identified as some of the major challenges to these programs. Recent spray programs using the microbial pesticide *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) on private lands in Colorado and using biocontrol virus on provincial lands in British Columbia were described. Areas of concern for these programs include the limited expertise available for assessing the levels of natural virus within DFTM populations, the small amount of biocontrol virus remaining in the U.S., and whether the development of additional stock or other products is needed or justified. The session concluded with a brief overview of questions that will be addressed during the annual meeting of the Western North America Defoliator Working Group in Missoula, MT in October 2016. These include: 1) Should we continue to maintain DFTM trapping programs in the U.S, and if so, how can we make these more effective and efficient?, 2) What is the best approach to collate findings, analyze results, and communicate these to land managers and the public?, 3) Are there better tools available to help predict changes in populations or potential areas of defoliation?, 4) Are the current commercially-available lures equally effective, 5) Are there other treatment approaches available that would be more complementary with environmental regulations?, 6) How best do we use the remaining TM-biocontrol virus and is there a justification to develop additional stock or similar products, and 7) Should we promote, prioritize, and fund silvicultural treatments to a greater degree than traditional suppression activities. .

b. **Panelists** (no individual abstracts):
   i. *Gina Davis, USDA Forest Service, Forest Health Protection, Region 1, Coeur d'Alene, ID*
   ii. *Robert J. Cain, USDA Forest Service, Forest Health Protection, Region 2, Golden, CO*
   iii. *Andrew D. Graves, USDA Forest Service, Forest Health Protection, Region 3, Albuquerque, NM*
   iv. *Darren Blackford, USDA Forest Service, Forest Health Protection, Region 4, Ogden, UT*
   v. *Cynthia Snyder, USDA Forest Service, Forest Health Protection, Region 5, Redding, CA*
   vi. *Robbie W. Flowers, USDA Forest Service, Forest Health Protection, Region 6, Bend, OR*
   vii. *William B. Monahan, USDA Forest Service, Forest Health Protection, WO, Ft. Collins, CO*
   viii. *Lorraine Maclauchlan, Ministry of Forests, Thompson Okanagan Region, Kamloops, BC, Canada*

3. **Regional Characterization of Forest Susceptibility to Insect Outbreaks and their Impacts – Need abstracts** Moderators: *JT Vogt and Randy Morin*

a. **Session Abstract:** Invasive and native forest pests may threaten forest resources over vast land areas. Forest Inventory and Analysis (FIA) plays a central role in pest risk and forest health assessments before and after pest invasions and outbreaks. Due to the national scale and consistent protocols employed the FIA inventory is uniquely positioned to take a broad scale look at pest risk and impacts. In this session we examine routine and novel applications of FIA data to these assessments, and consider advantages and limitations offered by the FIA sampling design.

b. **Speakers and Abstracts:**
   i. **A regional examination of what the FIA data tell us about hemlock wooly adelgid effects on hemlock growth and mortality.** *James T. Vogt, Frances A. Roesch, and Mark J. Brown. USDA-FS-SRS-Forest Inventory and Analysis.* Hemlock (*Tsuga canadensis* and *T. caroliniana*) is an important component of western North Carolina forests. The invasive hemlock wooly adelgid (*Adelges tsugae*, HWA) was first reported in western NC in 2000, and by 2007 the entire range of hemlock in the state was infested. An examination of the Forest Inventory and Analysis (FIA) data for FIA Unit 4 (21 mountainous counties in western North Carolina), looking at re-measured trees for the time period 1999-2013, demonstrated that diameter net growth of hemlock decreased and mortality increased with increasing duration of HWA infestation. Hemlock trees in this study had an approximate 50% chance of survival after 12 years of HWA infestation, and growth of surviving trees was reduced by

approximately 50% over the same time period. This study demonstrates the utility of FIA data for examining effects of an introduced, invasive pest on tree growth and mortality over a relatively small area. Some advantages and limitations to our approach are discussed.

ii. **Inventory and Analysis. Species composition and succession in yellow pine stands following southern pine beetle outbreaks in Tennessee.** *Chris Oswalt, Sonja N. Oswalt, and Jason R. Meade. USDA-FS-SRS-Forest Service.* The southern pine beetle (*Dendroctonus frontalis*) is a bark beetle that is native to the southern United States, including Tennessee. The beetle is periodically epidemic, and during epidemic years can cause high levels of mortality, particularly in dense or aging pine (*Pinus* spp.) stands. An epidemic outbreak of the southern pine beetle occurred in 1999-2001. By 2001, at the peak of the epidemic, 55 counties in Tennessee were in outbreak status. Subsequent estimations suggest that over 350,000 acres of pine timber in the state were affected by the outbreak, causing hundreds of millions of dollars in damages. Given the relative scarcity of the softwood resource in the state compared to the abundance of hardwood species, and the significant economic importance of softwoods in Tennessee, the composition and successional trajectory of pine stands impacted by southern pine beetle in the most recent 1999-2001 outbreak is of interest. Here we measure and quantify the impacts of this southern pine beetle outbreak on the successional trajectory of impacted yellow pine stands. Plots from the US Forest Service Forest Inventory and Analysis program measured prior, during, and after the outbreak are used to estimate the changes that occurred in southern yellow pine systems within Tennessee. The results from this study suggest that approximately 25 percent of the softwood dominated forests in was lost following the 2000 southern pine beetle event. The majority of that lost acreage transitioned into hardwood dominated communities.

iii. **Learning from tamarack mortality due to eastern larch beetle in Minnesota, USA.** *Susan J. Crocker[1], Greg C. Liknes[1], Brian H. Aukema[2], Fraser R. McKee[3], Brian F. Walters[1], Randall S. Morin[1]. [1]USDA-FS-NRS-Forest Inventory and Analysis, [2]University of Minnesota, [3]Alberta Ministry of Agriculture and Forestry.* Mortality of tamarack (*Larix laricina* (Du Roi) K. Koch) in Minnesota has risen following an outbreak of eastern larch beetle (*Dendroctonus simplex* LeConte), which has been ongoing since 2000. Unlike historical outbreaks of this native bark beetle, the current outbreak has been marked by an unprecedented duration and severity, and has not been associated with prior disturbance events, namely defoliation from other insects. To investigate attributes associated with increased risk of tamarack mortality due to eastern larch beetle, tree- and site-level measurements were collected for 3 ecological regions during the early outbreak (2005-2009) and the late outbreak (2010-2014) and were modeled using linear regression. Early in the outbreak, diameter was positively related to tamarack mortality due to eastern larch beetle in northern Minnesota. As the outbreak progressed, diameter was most strongly associated with tamarack mortality due to eastern larch beetle across all 3 ecological regions. The relationship between large diameter trees and mortality induced by eastern larch beetle suggests that reducing the abundance of large diameter tamarack may help to mitigate some of the impacts of eastern larch beetle on the tamarack resource. We demonstrate how the results of this research can be conveyed on a highly visual and interactive platform via the ESRI Story Map Journal© web application.

iv. **The whole picture: Assessing patterns in Engelmann spruce regeneration associated with spruce-beetle-caused mortality across broad landscapes.** *Kristen Pelz[1] and R. Justin DeRose[2]. [1]USDA-FS-RMRS-Grasslands, Shrublands, and Desert Ecosystems Program, [2]USDA-FS-RMRS-Forest Inventory and Analysis Program.* Engelmann spruce (*Picea engelmannii*) forests in many areas of the western United States have experienced heavy mortality caused by spruce beetle (*Dendroctonus rufipennis*) in recent decades. However, it is difficult to get accurate and detailed broad-scale perspective on this mortality. Many research or monitoring studies are focused on areas with the heaviest mortality or areas being targeted for management. Aerial surveys and remote sensing provide landscape-scale information but cannot measure what forest remains alive and regeneration present in affected forests. Knowing the mortality level and remaining overstory and understory trees in beetle-affected areas can allow for good predictions of forest recovery. Therefore, Forest Inventory and Analysis (FIA), a spatially-unbiased sample of forest inventory across all forested lands of the United States, provides a uniquely useful dataset for assessing severity of beetle impacts and forest recovery potential. Using FIA data from 2004 to 2014, we found 10% of the 27 million acres of forest where Engelmann spruce is present in the contiguous western US had experienced recent spruce beetle mortality. Three percent of total spruce basal area had been killed. Mortality levels were highest in Arizona and Wyoming, followed by Utah, Colorado, and New Mexico, and lowest in Idaho and Montana. Spruce beetle-affected plots had more spruce basal area, were lower in elevation, and warmer and wetter than plots without beetle activity. Plots that had Engelmann spruce regeneration were cooler, higher, and drier than plots that did not have regeneration, and regeneration was greatest on north aspects, followed by east and west aspects, and lowest on south aspects. Further analysis of this powerful dataset will allow for better prediction of areas where spruce regeneration is likely and unlikely following current and future beetle outbreaks, and can be used to predict forest recovery potential, which can in turn be used to develop and prioritize management strategies.

v. **FIA Data Show Dramatic Loss of Redbay Due to Laurel Wilt.** *Frank H. Koch*, USDA Forest Service, Southern Research Station, Research Triangle Park, NC. Jason A. Smith, University of Florida, Gainesville, FL. John R. Riggins, Mississippi State University, Starkville, MS. Marc A. Hughes, University of Florida, Gainesville, FL. *email: fhkoch@fs.fed.us.* The redbay ambrosia beetle (*Xyleborus glabratus*) is an Asian native first discovered near Savannah, Georgia in 2002. The insect has since been linked to extensive mortality of redbay (*Persea borbonia*), as well as other species in the Lauraceae family, as it has spread across the southeastern United States. The actual mortality agent is a vascular wilt disease, known as laurel wilt, which is caused by a fungal symbiont (*Raffaelea lauricola*) of the beetle. We used Forest Inventory and Analysis (FIA) plot data to estimate the number of redbay trees killed by laurel wilt. For each state in the redbay range, we estimated live and dead redbay populations both before and after the arrival of the disease. We also used data on the cause of tree death to account for other common mortality agents, such as fire, drought, and silviculture, in our estimates. Although these other agents limit the number of redbay we can confidently attribute to laurel wilt, the impact of the disease has been noteworthy, especially in the states (Georgia, South Carolina, and Florida) closest to the initial detection point. Overall, the pattern of wilt-caused mortality is consistent with the disease's documented pattern of spread since 2002.

vi. **Invasions of forest pests and their impacts on regional host mortality**. *Randall S. Morin[1], Susan J. Crocker[1], and Andrew M. Liebhold[2]. [1]USDA-FS-NRS-Forest Inventory and Analysis, [2]USDA-FS-NRS Disturbance, Ecology and Management of Oak Forests Research Unit.* While invasions of individual non-native forest pests are known to affect growth and mortality of host trees, little work has been done to quantify their impacts over large regions. In this study we integrate geographical data describing historical invasion spread of the hemlock woolly adelgid (*Adelges tsugae*), beech scale (*Cryptococcus fagisuga*), gypsy moth (*Lymantria dispar*), and emerald ash borer (*Agrilus planipennis*) with regional forest inventory data collected by the US Forest Service's Forest Inventory and Analysis program to quantify the impact of these pest species on host mortality rates. This analysis indicates that regional impacts of these insects on host mortality is quite variable. While annual mortality rates for hemlock, beech, and species preferred by gypsy moth increased by two- to six-fold in invaded areas, annual ash mortality increased by as much as fifteen times in invaded areas. Such results demonstrate how forest pest invasions can profoundly modify forest dynamic processes, resulting in long-term changes in forest ecosystems.

4. **Off-The-Shelf Kits For Saving The World's Forests. Available Now!** Moderators: *Jiri Hulcr and Caroline Storer*.
    a. **Session Abstract:** Innovations in genome, transcriptome, and proteome sequencing, known collectively as the "omics", have already revolutionized human medicine. These technological advancements are also available for forest health protection, but their vast potential remains underused. For example, genetic engineering of trees is increasing our ability to respond to new pest outbreaks or bring threatened trees back from extinction. Gene drive technologies may enable us to eradicate pathogens from the landscape. How can we use these methods, and should we? This session will provide an approachable introduction to forest health "omics" and an engaging discussion of the

technological, environmental, and societal trade-offs of adopting these new approaches to forest health.

b. **Speakers and Abstracts:**

   i. **Can biotechnology save the world's forests?** *Caroline Storer. School of Forest Resources and Conservation at University of Florida.* Innovations in genetic engineering (GE) have already revolutionized human medicine and agriculture. However, its vast potential remains underused for forest health protection. For example, genetic engineering of trees is increasing our ability to respond to new pest outbreaks or bring threatened trees back from extinction. How can these methods be used, and should they? Here we will provide an approachable introduction to modern genetic engineering to facilitate a discussion of the technological, environmental, and societal benefits and trade-offs of adopting these new approaches for forest health protection.

   ii. **Regulation of Genetically Engineered Organisms**. *Sally L. McCammon. USDA, APHIS, Biotechnology Regulatory Services.* USDA-APHIS regulates genetically engineered (GE) organisms to protect plant health under the Plant Protection Act (2000). A GE organism is regulated by APHIS if it is developed with a plant pest and is to be imported, moved interstate or released into the environment (field tested). While most of the work of the agency deals with commodity crops, a number of tree species have been field tested including American chestnut, poplar, walnut, white spruce and apple with a range of genes for pest resistance, herbicide tolerance and product quality. In addition, field testing of two insects has been permitted; diamond back moth, a pest of crucifers, and pink bollworm, a major pest of cotton. Once data and information are accrued to demonstrate that no plant pest risk is presented by the GE organism, a developer/researcher may petition APHIS for a determination of non-regulated status. A plant pest risk assessment is completed and is the basis for the decision on the petition. Apple and papaya varieties have completed this process and Eucalyptus is in process. In addition, the National Environmental Policy Act (NEPA) requires an environmental assessment be done in conjunction with certain federal actions. APHIS-BRS has a web page for first time users of its system to facilitate efficient interaction with the regulatory system. If there are questions as to whether a particular GE organism is covered by APHIS-BRS regulations, an inquiry may be submitted to the agency requesting a determination as to whether the organism is regulated https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/am-i-regulated

   iii. **Transgenic blight-resistant American chestnut trees demonstrate potential for restoring threatened species after invasions by exotic pathogens.** *Andrew Newhouse, Charles Maynard, and William Powell. State University of New York College of Environmental Science & Forestry, Syracuse, NY.* Chestnut blight on American chestnut (*Castanea dentata*) is a classic example of how an introduced pathogen (*Cryphonectria parasitica*) can affect entire ecosystems by decimating native keystone forest species. The traditional means for introducing blight resistance to American chestnuts is through hybrid breeding with Asian species (which are naturally blight resistant, having evolved with the pathogen for millennia). Advances in biotechnology and 26 years of research have allowed us to produce a fully American chestnut tree with a high level of blight resistance. The transgene product that allows this blight resistance, oxalate oxidase, is naturally found in a variety of crops and native plants, so it shouldn't present any novel risks to food or the environment. Transgenic trees could potentially be used for restoration, and transgene inheritance by subsequent generations could facilitate the preservation of extant genotypes. Initiating a project like this requires considerable investments of time and resources, including extensive supporting research that can vary substantially between species and disease systems. Transgenic plants also require permits for field testing, and rigorous regulatory reviews before they can be distributed. But progress toward a blight-resistant transgenic American chestnut may be directly relevant to other threatened trees (such as the related Ozark chinquapin) or other diseases (such as *Phytophthora* root rot, which affects chestnuts and many other plants), and may indirectly facilitate development of other species for ecological restoration purposes. Long-lived native trees with safe, durable, heritable disease resistance are not quite on the shelf, but they are definitely on the horizon.

iv. **Public trust in science and genetic modification technology.** *Alison E. Adams. School of Forest Resources and Conservation at University of Florida*. Public surveys and scholarly research have established that a significant portion of the American public distrusts science and that this portion is growing. The discourse surrounding genetic modification (GM) technology is currently one of the most heated debates in public, media, corporate, and government arenas. The erosion of trust in science in general, and in genetic technology specifically, has critical implications for support for scientific innovations that have the capacity to address current environmental problems. Some social science research is already being done to determine who is more likely to be distrustful of genetic engineering. Yet, little is known about why people are distrustful of scientific innovations such as GM technology. The motivations for distrust are important to discover as the relationship between science and the public depends on clear communication, understanding, and trust. Sociological research provides a theoretical framework for examining how people assess risks associated with GM technology. The "risk society thesis" posits that we now live in a society that is characterized by the omnipresence of low-probability, high-consequence risks, which are inherently linked to continual modernization and industrialization. The risk society thesis suggests that, given the increasingly technical nature of scientific innovation, the lay public is increasingly reliant on experts to assess and communicate the risks associated with innovation to non-experts. But, what are the social implications when public trust in scientific experts erodes? This presentation will explore the complex relationship between science, institutions, and the lay public, specifically focusing on the debate over GM technology.

v. **Biotech Vs Forest Pests – An Uneven Fight.** *Adam Costanza, Institute of Forest Biosciences.* The health of many forests around the world is declining because of pests. Whether pests are invasive, or native ones accelerated by climate change, many trees are losing the battle. Biotechnologies, including genetic modification (GM), are a powerful tool to fight back against forest pests. GM technologies can be used to accelerate development of disease and pest resilient trees, but by default, current regulatory policies treat GM trees as threats to the environment. GM regulations are based on risk assessments in North America. However, these assessments focus on the potential risks of using GM trees and largely disregard the consequences of not using them. While we have the technologies, and guidelines on how to use them responsibly via the Responsible Use Initiative, organizations trying to use advanced forest biotechnologies for social and environmental benefit are fighting with one hand tied behind their backs. Using actionable, risk based analysis appropriately matched to threats posed by forest pests can tip the scales in favor of healthier forests. Doing so will lower development hurdles and costs when using advanced GM technologies. More importantly, it will provide options to use GM trees for public benefit, especially if the technology addresses a critical need in certain situations.

Concurrent Session 3

1. **Characterizing Above And Below Ground Changes In Forests Aftermath Of Insect Outbreaks.** Moderator: *Nadir Erbilgin*
   a. **Session Abstract:** During the last century, insect outbreaks have caused significant changes at both below and above ground processes of terrestrial ecosystems across the globe. These changes have had serious implications for both altering the integrity (resilience) of ecological systems and affecting economy related to natural resources. The goal of this session is to provide some examples of how outbreaks by native or invasive insects can impact ecosystems properties from different ecosystems. It will focus on both below (e.g. changes in soil chemistry and microbial communities) and above (changes in species composition) ground processes that are temporarily or permanently altered due to sudden changes imposed by insect outbreaks.
   b. Speakers and Abstracts
      i. **Belowground consequences of an insect outbreak and aboveground implications.** *Karst, J[1,2], G.J. Pec[2], N. Erbilgin[1], A. Narjar[1], P.W.Cigan[1,2], D. L. Taylor[3], J.E.K. Cooke[2], S.W. Simard[4], J. Cahill, Jr.[2]. [1] Department of Renewable Resources, University of Alberta, Edmonton, Alberta, Canada. [2] Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada. [3] Department of Biology, Castetter Hall 104, University of New Mexico, Albuquerque, New Mexico, USA. [4] Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, BC.* Tree mortality caused by mountain pine beetle (*Dendroctonus ponderosae*) is rapidly

transforming western North American landscapes. By studying the belowground ecology of beetle-killed forests through a combination of field and greenhouse experiments, we have shown that the legacy of the mountain pine beetle extends far beyond a single cohort of trees. In particular, high levels of tree mortality change the composition of soil fungi. Overall richness of fungal communities remains constant, however, fungi forming ectomycorrhizas, and dependent on living hosts for sugars, decrease in presence while saprophytic and pathogenic fungi tend to increase in soils of beetle-killed stands. Shifts in community composition happen alongside of changes in mycorrhizal function: mycorrhizal networks promote seedling growth in beetle-killed stands with neutral effects in undisturbed forests. These shifts in fungal community composition and function documented by field experiments and next-generation sequencing analysis, in turn, affect the next generation of pine seedlings. Pine seedlings grown with fungi from beetle-killed stands have lower stem and needle monoterpene concentrations and fewer monoterpene compounds compared with seedlings grown with fungi collected from undisturbed stands. Abundance and richness of monoterpenes are critical for defense against insect and pathogen attack as well as mediating complex plant-insect interactions. Pine seedling survival in the field was also lower in beetle-killed than undisturbed stands. Taken together, our research demonstrates that mountain pine beetle may indirectly affect the next generation of pine seedlings through disrupted belowground mutualisms. Such far-reaching cascading effects emphasize the interconnectedness of seemingly discrete components of forest ecosystems.

ii. **Understory tree and plant responses to bark beetle outbreaks: lessons from recent forest mortality in North America and beyond.** *Kristen A. Pelz. USDA Forest Service, Rocky Mountain Research Station, Reno, NV.* In recent decades, bark beetles have killed trees on millions of hectares of forest across North America. Widespread mortality of dominant trees has a profound effect on the resources available to regenerating trees and other plants in the understory. Light, water, and nutrients previously taken up by overstory trees become available to the other plants, resulting in increased productivity and potential increases in plant diversity. The timing of this pulse is mediated by mortality patterns that vary through space and time, and the lag between beetle infestation, tree death, and loss of needles. The effect of increased resources on tree regeneration and other plants in part depends on species composition, magnitude of beetle-caused mortality, and interaction with local site factors. This talk will explore these effects in a variety of forest communities and will attempt to identify generalizable patterns in how forest plant communities respond to bark beetle outbreaks.

iii. **How do insect outbreaks alter biogeochemical and biogeophysical processes?** *Jeffrey A. Hicke. University of Idaho, Moscow, Idaho.* Outbreaks of forest insects can have substantial effects on biogeochemical and biogeophysical processes. The recent massive tree mortality caused by insects has led to landscape to regional effects on ecosystem structure and function. In this talk I will focus on biogeochemical processes related to carbon stocks and fluxes and biogeophysical processes related to albedo and evapotranspiration. I will draw on past studies that I have been involved with as well as other publications to present general patterns of impacts by bark beetles, defoliators, and other feeding guilds. I will describe mechanisms at the tree level and responses at the regional scale, with a concentration at the broader scales that rely on forest inventories, aerial surveys, remote sensing, and/or modeling. Impacts increase with higher severity (i.e., number of trees affected within a stand), greater extent, and tree mortality (as opposed to only growth reduction). The large-scale tree mortality caused by bark beetles in western North America has resulted in large effects to carbon stocks, equivalent to those caused by wildfires. In contrast, substantial but short-lived defoliation by forest tent caterpillars caused a large effect on carbon fluxes, which recovered quickly as the trees recovered. These examples and others will be discussed.

2. **Sirex And Its Complicated Food Web.** Moderators: *Laurel Haavik, Ann Hajek, Jessica Hartshorn, and Fred Stephen*
    a. **Session Abstract**: *Sirex noctilio* occurs in many regions worldwide, and has been a more serious pest in some areas than in others. Its biology involves many complicated, multi-trophic relationships, making it an excellent and important case study in invasion biology, and evolutionary and community ecology. Complex relationships within the Sirex food web in North America and elsewhere have been difficult to decipher. We will devote 20 minutes to each of the four discussion topics, outlined below. For each topic, a speaker will lead off with a brief, < 5-minute summary on the topic, followed by a discussion among attendees, led by the discussion panel.
    b. Panelists (no individual abstracts):
        i. **How is *S. noctilio* likely to affect native pine communities in North America, and what are the potential differences in the southeast vs. the northeast?** Summary speaker: Jeremy Allison. Discussion panel: Flora-Krivak Tetley, Kamal Gandhi
        ii. **Should we proactively manage or prepare for the arrival of *S. noctilio* in the southeast? And if yes, then what strategies should we use?** Summary speaker: Jim Meeker. Discussion panel: Laurel Haavik, Dave Coyle
        iii. **Success and failure of applied biological control with Deladenus?** Summary speaker: Ann Hajek. Discussion panel: Fred Stephen, Jessica Hartshorn
        iv. **What have we learned and what do we still need to learn from the Sirex system about invasion biology and evolutionary ecology?** Summary speaker: Laurel Haavik* Discussion panel: Ann Hajek, Andrew Liebhold

3. **Forest Entomology in a Landscape Context.** Moderators: *Robert N. Coulson and Patrick C. Tobin*
    a. **Session Abstract:** To examine how landscape ecology concepts and associated technologies are being used in forest insect research, monitoring, evaluation of impacts, and invasive species assessments.

b. Speakers and Abstracts:

i. **Landscape-scale consequences of weakly coevolved tree defenses to an eruptive bark beetle.** *Allan L. Carroll and Anthony P.W. Robinson. Dept. of Forest & Conservation Sciences. University of British Columbia, Vancouver, BC, Canada.* The ongoing mountain pine beetle outbreak has affected approximately 20 million ha of western North American pine forests. Evidence suggests that populations of trees growing in areas that were historically climatically unsuitable to the mountain pine beetle have lower defensive capacity and allow greater beetle productivity. Using forest inventory data, annual aerial overview survey data of beetle occurrence and impacts, and estimates of historic climatic suitability for the province of British Columbia, Canada, we investigated whether the amount and rate of lodgepole pine mortality caused by the mountain pine beetle in putatively evolutionary naïve habitats was greater than in putatively evolutionarily experienced areas. Habitats only recently invaded by the mountain pine beetle experienced impacts that were 1.7 to 3.9 times greater than those with long-term exposure to the beetle. In addition, the rate at which impacts accrued in "naïve" habitats was significantly greater than that associated with "experienced" habitats. Expansion by the mountain pine beetle into formerly climatically unsuitable areas has allowed the beetle contact with populations of lodgepole pine in which selection for specific defensive responses has not occurred resulting in higher than predicted levels of tree mortality.

ii. **Use of Unmanned Aerial Vehicles (UAVs) in monitoring forest insect damage and their utility for evaluating hemlock woolly adelgid impact.** *T. Kantola[1], P. Lyytikäinen-Saarenmaa[1], E. Honkavaara[2], M. Holopainen[1], and R.N. Coulson[3]. [1]Department of Forest Sciences, University of Helsinki, Helsinki, Finland. [2]Department of Remote Sensing and Photogrammetry, Finnish Geospatial Research Institute, Masala, Finland. [3]Department of Entomology, Texas A&M University, College Station, TX, USA.* Hemlock woolly adelgid (*Adelges tsugae* Annand, HWA), native to Asia, poses a major threat to survival of eastern (*Tsuga canadensis* L. Carr.) and Carolina (*Tsuga caroliniana* Engelm.) hemlock communities in the eastern USA. HWA can rapidly spread, infest, and kill hemlocks in all age- and size-classes, making it a major target of monitoring and control efforts. These species occur in landscapes where extreme topographic variation is common and human access limited. The vegetation communities within these landscapes feature high diversity of tree species, including several other conifer species. Traditional forest inventory procedures and insect pest detection methods within these landscapes are impractical. However, further information is needed to evaluate the impacts of HWA-induced hemlock mortality. Very high-resolution remote sensing enables more detailed projections of landscape patterns that are suitable for estimating the magnitude of ecological and social impacts of the hemlock decline. Low-cost, miniaturized hyperspectral imaging technology is becoming available for small unmanned aerial vehicle (UAV) platforms. The technology can be efficient in carrying out small-area inspections of anomalous reflectance characteristics of trees at a very high level of detail. New methodologies enable analyzing spectral characteristic for high spatial resolution photogrammetric and hyperspectral images in forested environments, as well as for identifying individual damaged trees. This novelty remote sensing platform may have potential in landscape context as well. Small-scale and high detailed UAV information can be used as training data of lower resolution data covering the whole landscape in question. This information may also be combined with auxiliary information, such as topography and soil, and used in modeling task of the most probable areas for hemlock species within the conifer patches. These predictions will aid in developing strategies to mitigate current and future risk to hemlock communities, and planning conservation and management actions for protection of these communities.

iii. **Spatial Dynamics of Periodical Cicada Broods**. *Andrew Liebhold, USDA Forest Service, Morgantown, WV. Alexander D. Meyer, Julie Blackwood, Dept. of Mathematics & Statistics, Williams College, Willamstown, MA. John Machta, Dept. of Physics, University of Massachusetts, Amherst, MA. Alan Hastings, Dept. of Environmental Science and Policy, University of California, Davis, Davis, CA.* Periodical cicadas, *Magicicada* spp., are remarkable organisms in many ways. They are probably the most abundant, long-lived and noisy insects in N. American forests yet they spend most of their lives underground, invisible to humans. Populations in the north take 17 years to develop while southerly populations develop in 13 years. The ranges of *Magicicada* spp. are divided into 15 largely allopatric “broods”, each consisting of populations synchronized to develop synchronously in the same year. Here we use population models and GIS analyses to explore the factors responsible for the geographic distribution of *Magicada* broods. We find that brood boundaries are driven by the interaction of intraspecific competition with predator-driven Allee dynamics, and the influence of various habitat characteristics such as climate and host tree distributions. Together these processes shape the spatial dynamics of these enigmatic insects.

iv. **Variation in the speed of invasion: Roles of weather, resource availability, and landscape attributes on gypsy moth invasion dynamics.** *Patrick C. Tobin[1], Riley Metz[1], Jonathan Walter[2], Kristine Grayson[3], Derek Johnson[4], and Kyle Haynes[5]. [1]School of Environmental and Forest Sciences, University of Washington, Seattle, WA. [2] Department of Ecology and Evolutionary Biology, University of Kansas, Lawrence, KS. [3] Department of Biology, University of Richmond, Richmond, VA. [4] Department of Biology, Virginia Commonwealth University, Richmond, VA. [5]Department of Environmental Sciences, University of Virginia, Charlottesville, VA.* Understanding the suite of factors that increase or constrain the spread of invasive forest insects is critical in the development and implementation of management programs. At the edge of a distributional range, the colonization and growth or extinction of local populations interplays with weather patterns during both diapause and larval development, resource availability, and other landscape attributes such as topography to produce considerable variation in range dynamics and invasion speed across a landscape. We show the importance of these factors using spatially and temporally robust monitoring data on the gypsy moth, which is one of the most extensively documented invasion process in the world.

v. **Landscape ecological interactions between introduced tamarisk beetles, invasive tamarisk and the endangered southwestern willow flycatcher.** *J.L. Tracy[1], R.N. Coulson[1], and A.E. Knutson[2]. 1Department of Entomology, Texas A&M University, College Station, TX. [2]Texas AgriLife Extension Service, Texas A&M University, Dallas, TX.* The subtropical tamarisk beetle (*Diorhabda sublineata*) was introduced on the Rio Grande near Presidio, Texas in 2009 for biological control of tamarisk (*Tamarix ramosissima/T. chinensis*), and it is rapidly dispersing and defoliating extensive areas of tamarisk in the TransPecos region. The federally endangered Southwestern Willow Flycatcher (*Empidonax traillii extimus*, flycatchers) nests primarily in willows (*Salix spp.*) and exotic tamarisks (*Tamarix spp.*) in the southwestern U.S. Critical habitat of flycatchers dominated by tamarisk, such as Tonto Creek, Arizona, is threatened by herbivory from expanding populations of introduced tamarisk beetles (*Diorhabda spp.*). Continental-scale ecological niche models (ENMs) using the Envelope Score algorithm project suitable habitat for subtropical tamarisk beetles where flycatchers are nesting in tamarisk in western New Mexico and the Sonoran Desert. Migclim R dispersal models are used to project northwestern dispersal of subtropical tamarisk beetles into this flycatcher habitat within a few years. A fine-scale 1m flycatcher habitat suitability index (HSI) model is used to simulate potential effects of tamarisk beetle herbivory and habitat restoration for the flycatcher along a 3.5 km reach of Tonto Creek, AZ. The HSI simulation model projects a 56% loss to 19 ha of suitable flycatcher habitat the first year of tamarisk beetle herbivory. These models project that loss of flycatcher habitat to beetles could be mitigated within 3 years by restoration, involving addition 5 ha of willow patches. ENMs, dispersal models, and HSI simulations can guide planning of restoration activities to offset adverse effects from tamarisk beetles or other ecological risks to flycatcher habitat.

4. **Relevance of our Forested Lands to the Maintenance of Pollinators and Pollination Ecology in North America** Moderator: *Rob Progar and Justin Runyon*
   a. **Session Abstract:** Pollinators are critical components of forest ecosystems where they provide pollination services to many trees, shrubs and herbaceous understory plants. Evidence suggests that pollinators are declining worldwide as a result of changes in land use, fragmentation, agricultural intensification, pesticide use, invasive species, diseases, urbanization, and climate change. What is our extent of knowledge of the role of pollinators in our forest ecosystems?
   b. Speakers and Abstracts:
      i. **What the national pollinator health strategy means for pollination ecology in forest systems.** *Mary Purcell-Miramontes, Ph. D. National Program Leader for Arthropod and Nematode Biology & Management USDA-NIFA, Institute of Food Production and Sustainability.* Many forest systems provide habitats to support robust populations of pollinators which impact our Nation's economy and the environment. Pollinator

populations have experienced substantial declines in the US and other countries due in large part to the disruption and destruction of these habitats. Recently, the White House called for a National strategy to address the issue tasked several federal agencies which includes the goal to restore 7 million acres of pollinator habitat on federal and private lands within the next five years. In addition, a Pollinator Research Action Plan was developed, which reflects the current state of knowledge and sets explicit goals and priorities using resources of several federal agencies to support research. This presentation will provide an overview of the National Strategy and the Action Plan and outline aspects that will rely on innovative research by forest pollinator ecologists to advance these goals.

ii. **Role of USDA Forest Service Research and Development and efforts by forest service scientists to sustain pollinators.** Monica Tomosy. Scientists within the USDA Forest Service Research and Development (Forest Service R&D) mission area study pollinator biology and ecology, and provide information for managers of natural and cultivated areas. Nationally, Forest Service R&D scientists are conducting studies, and delivering scientific information on host-plant/pollinator relationships, ecosystem restoration, and habitat management alternatives. Pollinators we study include butterflies, moths, honey bees, native bees, wasps, beetles, flies, and birds. Partnerships between scientists and managers support restoring ecologically robust communities with intact pollination services. The Forest Service R&D role is to provide solutions through: designing land management of agricultural and forest land together to support pollinators; habitat creation; habitat restoration of roadsides, post-fire damage, and riparian areas; milkweed propagation; removal of invasive shrubs and invasive insect predators; restoration via prescribed fire; and bee monitoring on Experimental Forests and Ranges. As a result of the diverse expertise, Forest Service R&D contributed to the Forest Service Monarch Conservation Strategy, the GAO Report on Bee Health, and the federal Pollinator Research Action Plan.

iii. **Pollination Ecosystem Services: attempting to analyze pollination at the scale of an entire community.** *Andy Moldenke, Dept. of Botany, Oregon State University, Corvallis, OR 97331 (moldenka@science.oregonstate.edu).* Pollination ecology has a long history of one-bug to one-plant case histories, which are completely inadequate as a basis for how an entire community of flowers interacts with an entire community of potential pollinators. Declines in bee (and other pollinator groups) diversity are very apparent in the Oregon State University vicinity. In the 375 mile long lowland western valley system of OR, WA and s BC, there existed in pre-settlement times a minimum of 350 bee species; currently there are a maximum of 100 species, with less than 50 in any single locality. As with all other taxa throughout the world, this has been due largely to habitat conversion and fragmentation (especially the latter). Bee diversity in all natural ecosystems I have studied is very speciose, with inter-annual local population turnover (=extinction) rates of 20-40%; quite normal and not threatening as long as subsequent source areas have not been highly fragmented, however without reliable source regions, bee diversity will necessarily plummet. Distinguishing the density-independent measures of specialization (i.e., flower choices that do not depend on local circumstances) from localized comparison-shopping is critical. My techniques are designed to better estimate specialization independent of local competition and thereby better estimate the localized extinction threat of either plant or pollinator species. The typical flower-visiting interaction analyses are easily misunderstood in the frequent cases where heavily-visited flower species can waste pollen on inappropriate 'inter-specific pollinations'. (Often, what you think you see, is NOT what the plant is getting!).

iv. **Have changing forest conditions contributed to pollinator decline in the southeastern united states?** *Scott Horn and Jim Hanula. USDA Forest Service, Southern Forestry Sciences Laboratory. Athens, GA 30602.* Two conservation goals of the early 20th century, extensive reforestation and reduced wildfire through fire exclusion, may have contributed to declining pollinator abundance as forests became denser and shrub covered. To examine how forest structure affects bees we selected 5 stands in each of 7 forest types including: cleared forest; dense young pines; thinned young pines; mature open pine with extensive shrub/sapling cover; mature open pine with extensive herbaceous plant cover and little shrub cover; mature upland hardwood forest; and mature riparian hardwood forest. We sampled bees during the 2008 growing season using pan traps and measured overstory tree density, understory herbaceous plant and shrub diversity and cover, light penetration, and leaf area index. Numbers of bees and numbers of species per plot were highest in cleared forest and in mature pine stands with an herbaceous plant understory. Our results combined with many others show that thinning forests combined with shrub control provides good bee habitat, is compatible with habitat restoration and management for other species, and the resulting forests will be healthier and less susceptible to old (e.g., southern pine beetle, *Dendroctonus frontalis*) and new (European woodwasp, *Sirex noctilio*) threats.

v. **Climate change can alter floral scent and pollinator attraction.** *Justin B. Runyon[1], Laura A. Burkle[2], Will R. Glenny[2]. [1] Rocky Mountain Research Station, USDA Forest Service, 1648 S. 7th Avenue, Bozeman, MT. [2] Department of Ecology, Montana State University, Bozeman, MT.* The worldwide decline in pollinators highlights the importance of understanding how factors associated with climate change may affect plant-pollinator interactions. Components of climate change have the potential to strongly influence plant traits important for attracting pollinators, including floral volatile organic compounds. We examined how drought, elevated CO2, and leaf herbivory—key components of climate change—affected floral display, floral volatiles, and the visitation rates and community composition of pollinators to four forb species in Montana. Leaf herbivory changed floral scent and reduced pollinator attraction in one forb species. While experimental drought reduced flower size and floral display in all species, there were species-specific effects of drought on volatile emissions per flower, the composition of volatile compounds produced, and subsequent pollinator visitation rates. Drought also influenced the floral visitor community across forb species, indicating that some groups of pollinators were deterred while others were attracted. Preliminary data suggest that elevated CO2 can also influence floral traits and visitation by pollinators. These results suggest that floral volatiles provide information-rich signals to pollinators under shifting environmental conditions and that floral volatiles may be relatively more important than visual plant traits for pollinator attraction, particularly under climate change. The potential implications of these findings for pollinator and habitat conservation and restoration will be discussed.

Thursday, June 2

Plenary Session 2

1. Speaker: *Gwen Pearson, Purdue University:* Facts are Not Enough: Stories and Emotion in Science Communication
2. Speaker: *Doug Crandall, Legislative Affairs, USDA Forest Service:* Congress and the Forest Service.

<u>Concurrent Session 4</u>

1. **Challenges, Paradigms, and Novel Approaches to the Forest Health Curriculum** Moderators: *Kamal J.K. Gandhi and Robert N. Coulson*
    a. **Session Abstract:** We discuss the pedagogy of Forest Health and Protection courses at the 2016 NAFIWC. Currently, Forest Entomology and Forest Pathology are taught either individually or together as Forest Health. During the last few decades, the background and aspirations of students have changed, and much more material is being taught for less credit hours. There is also a greater ease and access to technology, and an ever-changing catalog of current pests because of exotic invasions and climatic changes. Accordingly, we critique the current structure and content of course offerings in Forest Health courses across the forested regions of the North America. Our goal is to develop a contemporary curriculum for training the next generation of forest health specialists.
    b. **Speakers and Abstracts:**
        i. **Teaching Forest Protection – What is relevant: Conclusions from the SFIWC workshop.** *Robert N. Coulson[1], Kamal J.K. Gandhi[2], and John J. Riggins[3]. [1]Department of Entomology, Texas A&M University. [2]D.B. Warnell School of Forestry and Natural Resources, University of Georgia. [3]Department of Biochemistry, Molecular Biology, Entomology and Plant Pathology, Mississippi State University.* At the 57th Annual Southern Forest Insect Work Conference in 2015, the topic of teaching forest protection was evaluated in a panel format discussion. Individuals from universities throughout the South, who teach forest protection, shared the views and philosophy that guide the presentation of their course. As a prelude to the

following discussion of Challenges, Paradigms, and Novel Approaches to the Forest Health Curriculum, we summarize the conclusions reached at the SFIWC workshop.

ii. **Forest health curriculum: Understanding biotic, abiotic and societal pressures on forests.** *Richard Hofstetter, Tom Kolb, Robert Mathiasen, and Kristen Waring. School of Forestry, Northern Arizona University*. Forests in the southwestern US face many issues: overcrowded conditions, recent insect outbreaks, drought stress, and threat of severe wildfires. Forestry undergraduate students in the School of Forestry at Northern Arizona University can get a certificate in Forest Health and Restoration. This certificate covers topics related to forest ecosystem function, how disturbance agents affect forests, and how restoring an ecosystems structure and function can help forest regain healthy conditions. The school of forestry program offers a specific course in Forest Health, which covers ecological and social aspects of forest restoration, sustainability and ecological function. I will discuss how our certificate program and courses covering Forest Health topics have changed and been modified over the past 20 years.

iii. **Metamorphosis to Dr. Bug: Lessons from the classroom.** *David L. Kulhavy, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University.* The field of Forest Entomology is changing at a rapid pace with the advent of Google Maps, Google queries and Bugwood.com. Our role as educators is to provide the most up to date and hands-on information for decision making for the 21st century for a variety of clients. The use of Unmanned Aerial Systems (UAS) for hazard rating; Pictometry® imagery with 4 inch resolution for tree and land measurements; Google Street View for rapid assessment; the intersection of art and science; and the inclusion of traditional insect identification and ecology need to be balanced with the expansion of invasive species and insects in society. The current purveyor of knowledge must be nimble, current in information and willing to teach to the audience in the way they best learn. The Scholarship of Teaching and Learning with forest insects and diseases places added emphasis on writing and the method of presentation of material. The use of music, art and interpretation will be presented as students ready themselves for their profession.

iv. **Stepping inside and outside the "Forest Health Curriculum" innovation box.** *Kamal J.K. Gandhi and Robert N. Coulson[2]. [1]D.B. Warnell School of Forestry and Natural Resources, University of Georgia. [2]Department of Entomology, Texas A&M University.* The ever-changing nature of forestry business, stakeholders, clientele, and career aspirations of students is a challenge for the forest health curriculum. Can we adapt to such rapid and diverse changes, and bring innovation to the classrooms to meet multiple objectives? What does our current course toolset look like, and how can we alter or add to the toolset for bigger impact and retention? Various steps of innovation will be discussed ranging from process and delivery to products, and ways to incorporate new technology at multiple stages of curriculum development. The goal is to train the next generation of foresters that are diverse, innovative, creative, and can think both inside and outside the box to achieve forest health objectives.

2. **Bark Beetles and Forest Management: Are Prevention and Suppression Programs Effective?**
   Moderator: *Steve Clarke*
   a. **Session Abstract:** Integrated pest management programs have been developed to mitigate the ecological and economic impacts of bark beetles. These IPM programs rely on active forest management, and their implementation has often been limited by lack of funding and personnel, poor timber markets, public opposition, and other factors. Given these difficulties, do forest managers and entomologists currently have the ability to conduct efficacious bark beetle prevention and suppression programs? Is there a need to reconsider how we address bark beetle outbreaks in the current environment? We will discuss the viability of IPM programs for several important species of bark beetles in North America.
   b. **Speakers and Abstracts:**
      i. **Southern pine beetle prevention.** *John Nowak, Forest Health Protection, USDA Forest Service, Asheville, NC.* The Southern Pine Beetle (SPB) Prevention Program was designed to take a comprehensive and integrated approach for preventing and mitigating the impacts of SPB on federal, state, and private lands. This program is administered by Forest Health Protection (FHP) and implemented by 12 National Forests and 13 southern states. At the request of Congress, the program was started to address the SPB problem after the last major outbreak impacted more than 1 million acres and caused an estimated $1.5 billion in damage. Increasing forest resiliency through good forest management is a key feature of this plan. These treatments include forest thinning and restoring native pine forests. These activities have multiple benefits beyond protecting forests from SPB, such as increasing stand resiliency, improving wildlife habitat and reducing fire risk. In 2011, the program reached the 1 million acres treated milestone and won the Chief's Award for Sustaining Forests and Grasslands. National Forest and state funding allocations are based on need, cost per acre and past performance. FHP evaluated the effectiveness of program treatments on the 2012 SPB outbreak on the National Forests in Mississippi. Results show statistically fewer spots in treated areas – only 2 spots occur in thinned stands out of more than 900 spots on the Bienville and Homochitto National Forests.
      ii. **Time for Cut and Remove or to Cut and Run: Current status of southern pine beetle suppression**. *Stephen Clarke, Forest Health Protection, USDA Forest Service, Lufkin, TX.* Cut-and-remove and cut-and leave have been the most prominent methods of southern pine beetle (SPB) suppression over the past 40 years. Cut-and-remove typically was the treatment of choice as it is highly effective and provides a return to the landowner or agency. However, in the past 10+ years cut-and-leave has replaced cut-and-remove for SPB suppression, particularly on federal lands. This shift was due to reduced timber markets and self-imposed regulations. Given

reduced budgets, current forest management strategies, and the loss of cut-and-remove, should SPB suppression remain an integral component of forest pest management in the South?

iii. **New approaches and lessons learned about bark beetle management in BC.** *Arthur Stock, Robert Hodgkinson, Lorraine Maclauchlan, Ken White and Jodi Axelson[1]. BC Ministry of Forests, Lands and Natural Resource Operations. [1]Presenting.* In British Columbia, bark beetles in the genus *Dendroctonus* reach outbreak levels threatening sustainable forest management across a wide variety of ecosystems. Notable in this regard are the mountain pine beetle (*Dendroctonus ponderosae*) and spruce beetle (*Dendroctonus rufipennis*), both of which can cause extensive and widespread tree mortality. While BC recovers from the last mountain pine beetle outbreak, a spruce beetle outbreak is building in the north-central region of the province. These outbreaks raise the question: does beetle suppression work? Based on over 40 years of excellent science, the concept of beetle management is straightforward, however the implementation is complex. Impediments to beetle management include politics, budgets, lumber markets, and at more local scales a lack of trained personnel, and appropriate harvesting equipment. Through suppression efforts we have learned that the following are critical to effective management: leadership and strategic planning in place with organized and committed stakeholders; Beetle Management Units (BMUs) at the landscape unit level are correctly designated as “suppression” and are re-assessed annually; suppression BMUs have detailed flights annually to determine precise geospatial information on outbreak location, severity and extent; priority areas are delineated from the detailed flights that are coded, ranked, and assigned plans and actions by licensees; and all available and appropriate management tactics are considered (e.g., anti-aggregation pheromones). Some tough lessons include knowing when to give up on suppression to another strategic direction such as slowing the spread (“Holding”), which can be effective at stretching out live timber supply.

iv. **Who's managing who? spruce beetles in the Rockies.** *Tom Eager, Forest Health Protection, USDA Forest Service, Gunnison, CO.* For the past decade, the south-central Rocky Mountains have undergone a significant spruce beetle (*Dendroctonus rufipennis*) outbreak. A combination of stand conditions and weather patterns have provided ideal habitat for spruce beetle which have now affected around a million acres of mature Engelmann spruce. Despite the widespread and intense nature of this outbreak, there are "green islands" scattered throughout the affected areas. In many cases these surviving stands are the result of management activities that have been completed over the past several decades. What lessons can be learned from examining the condition of stands prior to the outbreak and the stand's ability to withstand a high degree of "beetle pressure"? As managers begin to anticipate the end of the outbreak, discussion is focused on creating stand conditions that are resilient and sustainable. Managing risk by diversifying stand conditions across the landscape is a strategy that supports long-term stability of these forested lands.

3. **The Changing Face Of Biological Control In Forest Ecosystems.** Moderators: *Sandy Smith, Chris MacQuarrie, and Krista Ryall*
   a. **Session Abstract:** This symposium will review this history and current practice of biological control in forests in North America. Biological control, in particular of invasive species, has been an important tactic in the management of insect pests in North American forests. The application of biological control has focused mainly on its use against non-native species. However, work in the past and today has addressed the potential uses of biological control against native pests. This symposium will highlight current research against major non-native pests and new invasives, as well as perennial native pest insects. This symposium will examine a variety of cases from different insect-pest systems as well as a historical perspective from Canada and the United States.
   b. **Speakers and Abstracts:**
      i. **Biological control programs against forest insects in Canada with focus on the eastern spruce budworm.** *Sandy M Smith[1], Chris JK MacQuarrie[2], Véronique Martel[3], M Lukas Seehausen[1], D Barry Lyons[2]. [1] Faculty of Forestry, University of Toronto, 33 Willcocks St., Ontario, Canada M5S 3B3 s.smith.a@utoronto.ca: ml.seehausen@mail.utoronto.ca. [2] Natural Resources Canada, Great Lakes Forestry Centre, Canadian Forest Service, Sault Ste Marie, Ontario, Canada Christian.macquarrie@canada.ca. [3] Ressources naturelles Canada, Service canadien des forêts, Centre de Foresterie des Laurentides, 1055, rue du P.E.P.S. CP 10380, Succ. Sainte-Foy, Québec (Québec) G1V 4C7, veronique.martel@canada.ca.* Biological control has been a major tactic in the management of Canadian forests for over a century, but one with varied success. We review the history of programs using vertebrate and invertebrate parasitoids and predators against insects in Canadian forests. Since roughly 1882, 41 insect species have been the target of biological control, with approximately equal numbers of both native and non-native species targeted. A total of 161 species of biological control agents have been released, spanning most major orders of insects, as well as mites and mammals. Biological control has successfully suppressed nine pest species and aided in the control of another six species. Historical data clearly illustrate a rise and fall in the use of biocontrol for managing forest pests, from its dominance in the 1940s/50s to its current low. Most releases were targeted against a single pest, with the majority applied in one central province, Ontario. Of the total, 60% were classical biocontrol, 29% were new associations, and 11% were conservation and augmentation strategies. Major past programs targeted the European spruce sawfly (882 million wasps released over 20 years), while work today is directed against exotic invasive species such as the emerald ash borer. Initially, host specificity was not considered, however, modern regulatory concerns over non-target effects have shifted emphasis

to environmental manipulation and conservation biological control. Despite variable results from past work, the recent rise in cyclical spruce budworm populations throughout eastern Canada has brought renewed interest in all aspects of biological control to manage this major native pest.

ii. **Management of emerald ash borer in forested ecosystems using classical biological control.** *Leah Bauer[1,2], Jian Duan[3], Roy Van Driesche[4], Erin Morris[2], Daniel Kashian[5], Therese Poland[1,2], Toby R. Petrice[1], Juli Gould[6]. [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]USDA ARS, Beneficial Insects Introduction Research Unit, Newark DE 45433; [4] Dept. of Environmental Conservation, University of Massachusetts, Amherst, MA 01003; [5] Dept. of Biological Sciences, Wayne State University, Detroit, MI 48202; [6]USDA APHIS, Center for Plant Health Science and Technology, Buzzards Bay, MA 02542.* Emerald ash borer (EAB) (*Agrilus planipennis* Fairmaire; Coleoptera: Buprestidae), an Asian pest of ash trees (*Fraxinus spp.*), was discovered in southeast Michigan and nearby Ontario in 2002. EAB continues to spread in North America, causing widespread mortality of ash trees throughout forested and urban ecosystems. Natural enemy surveys of EAB in North America found no specific parasitoids, motivating foreign exploration for such natural enemies across its native range in Asia. In China, three EAB parasitoid species were discovered, studied in quarantine laboratories, and later approved for release as EAB biocontrol agents in the U.S. in 2007 and Canada in 2013. These parasitoids are the egg parasitoid *Oobius agrili* Zhang and Huang (Encyrtidae), and two larval parasitoids *Tetrastichus planipennisi* Yang (Eulophidae) and *Spathius agrili* Yang (Braconidae). Another EAB larval parasitoid *Spathius galinae* Belokobylskij (Braconidae) from the Russian Far East, was approved for release in the U.S. in 2015. We will provide an overview of the USDA EAB Biocontrol Program and available information on parasitoid releases and establishment or recovery in North America; current results of EAB life table research at long-term study sites in Michigan where these biocontrol agents were first introduced in 2007 at peak EAB densities; and the results of ongoing research to assess the impacts of EAB biocontrol on ash health and regeneration in southern Michigan. We will also report on recent results from research on parasitoid establishment and ash recovery in several post-invasion southeast Michigan forests near the EAB-introduction epicenter.

iii. **Anticipatory biological control of mountain pine beetle in areas of increasing impact and range expansion due to climate change.** *Kenneth F Raffa[1], Adam Krause[1], Jesse A Pfammatter[1], Philip A Townsend[2]; [1] Dept. Entomology, University of Wisconsin-Madison; [2] Dept. Forest & Wildlife Ecology, University of Wisconsin-Madison.* As global temperatures rise, many insect species are expanding their ranges further from the equator and into higher elevations. Some are pest species, which will have unknown effects in their new ranges. Their impacts will depend on a variety of factors, including natural enemies. So it is useful to proactively access the abundance and behavior of these agents in vulnerable habitats, to obtain baseline information for improving biological control. The geographic range of mountain pine beetle is largely limited by temperature, as suitable host types extend beyond its populations. This insect is experiencing higher winter survival at high elevations than in the past, and is extending its range northward. It has now reached the jack pine forests of western Canada, creating a connection with midwestern and eastern forests that harbor several susceptible pine species. Warm temperatures have also fostered outbreaks in the historical range, creating increased demand to salvage killed trees, including by shipment to midwestern markets, thus posing another potential pathway. We asked: 1a) Does the composition and abundance of mountain pine beetle's predators and competitors vary along elevational gradients? 1b) Does host tree species influence attraction of predators and competitors to mountain pine beetle? 2a) How do the composition and abundance of predators and competitors in the Great Lakes region compare with those of western forests? 2b) Are predators and competitors in the Great Lakes region attracted to mountain pine beetle's aggregation pheromone? We evaluated natural enemies in two regions of the Greater Yellowstone Ecosystem during 2012 and 2013. We used unbaited panel traps and multiple-funnel traps baited with trans-verbenol plus exo-brevicomin. We also monitored predator and competitor arrival rates in unattacked and attacked lodgepole and whitebark pines. We compared predation and competitor pressures between western and eastern forests by compiling results of extensive previous studies. We conducted field tests evaluating whether local predators and competitors would be attracted to mountain pine beetle's aggregation pheromone if it attacked trees in Wisconsin. Overall, predator loads on mountain pine beetle were lighter in high-elevation whitebark than mid-elevation lodgepole pine stands. Predators and competitors oriented equally to uninfested whitebark and lodgepole pines, but were less attracted to mountain pine beetles boring into whitebark pines. Predators and competitors appear generally more abundant in midwestern than western conifer forests. However, the major natural enemies in Wisconsin are either unattracted or only weakly attracted to mountain pine beetle's aggregation pheromone. Some predators are strongly attracted to frontalin, which is produced by male mountain pine beetles and several bark beetle species native to Wisconsin. The major local predators may also lack strong phenological synchrony with mountain pine beetle if it were to establish. Future research is needed to address: 1) How rapidly will predators in high-elevation stands adjust, numerically and behaviorally, to increased persistence of mountain pine beetle? 2) If mountain pine beetle establishes in the Midwest, to what extent would natural enemies increase attraction to its aggregation pheromone, and if necessary adjust phenological synchrony, in the presence of locally abundant historical alternate prey?

iv. **Preliminary results using silver flies for biological control of hemlock woolly adelgid in the eastern USA**. *Kimberly Wallin, Darrell Ross, Nathan Havill, Bud Mayfield.* In 2014, silver larvae collected from hemlock adelgid infested western hemlock (*Tsuga hetophylla* (Raf.) Sarg.) In Olympia and Tacoma, WA were allowed to develop in the laboratory on hemlock adelgids collected in Washington and Connecticut. There were no significant differences in survival or developmental parameters for larvae from the two geographically isolated populations. In 2015 and 2016, silver fly adults from hemlock adelgid infested western hemlock branches collected in Olympia, Tacoma, and Vashon Island, WA were released onto enclosed branches of *Adelges tsugae* Annand infested eastern hemlock (*Tsuga canadensis* (L.) Carr.) in Tennessee and New York at two different densities (2F:2M and 6F:4M). The adult flies survived under the field conditions to successfully reproduce at both locations and both adult release densities. There were no significant differences in silver fly offspring densities with the two different adult release densities. These results demonstrate that silver flies from the Pacific Northwest are capable of feeding and developing to the adult stage on *A. tsugae* in the eastern USA and they are able to tolerate environmental conditions during late spring and early summer at the southern and northern extent of the area invaded by *A. tsugae* in the eastern USA.

4. **Getting to the first step in forest restoration - Cone and Seed Insects of North American Conifers.** Moderator: *Carl Jorgensen*
    a. **Session Abstract:** Update on the management and research associated with cone and seed insects in conifer seed orchards - an open discussion. Determining if Hedlin et al. 1980 "Cone and Seed Insects of North American Conifers" needs updating, reprinting and/or the process to complete such a task. Work assignments may be discussed.
    b. **Speakers and Abstracts**: Open session attended by Carl Jorgensen, Sandy Kegley, Sean Calahan, Tim Schowalter, Ben Smith, Steve Cook, Don Grosman, Melissa Fischer, Tom Eckberg, and Daniel DePinte. Beth Willhite, Alex Mangini, and Ward Strong expressed interest, but were not able to attend. Participants focused their discussion on new technologies, current challenges, updating "Cone and Seed Insects of North American Conifers" and that many of the cone and seed insect "contacts are either retired or dead."
        i. Don Grosman discussed that the new formulation of TREE-äge G4, now labeled as a general use pesticide and for many seed and cone pests. Follow-up discussions revolved around that the cost to treat all trees in a particular orchard will likely be prohibitive, but some utility may be found in individual, high-value trees that may have some genetic value.
        ii. Sandy Kegley provided an update for US Forest Service Regions 1 and 4 seed orchards. Western conifer seed bug, *Leptoglossus occidentalis*, cone beetle, *Conophthorus ponderosae*, coneworm, *Dioryctria abietivorella*, and seed chalcid, *Megastigmas* spp., problems are being treated with synthetic pyrethroids. Sanitation is conducted but immigration from surrounding hosts is a continual problem. Monitoring is conducted using visual, pheromone traps, yellow sticky traps, and radiographs. In 2016, field trials are being conducted using black sticky traps to

monitor for western conifer seed bug. The black concept is utilizing heat sensing organs on the seed bug to attract this insect. A new formulation of glue on this trap was also used to hopefully prevent seed bugs from walking off the trap. A staining technique to detect pectinase activity from seed bug puncture wounds could be used to estimate feeding damage. Behavioral traits of a mass migration orchestrated by vibration and pheromone communication were also discussed among the group for seed bugs. But no pheromone is known for western conifer seed bug. Treatments for seed worm, *Cydia* spp., are being conducted testing imidacloprid soil injections, and results should be available next year. Larch seed cones impacted by, *Adelges laricis*, are being treated with dormant oils and insecticidal soap. Discussion lead to that soil drenches could be an option for adelgids in some situations.

iii. US Forest Service Region 8 input was provided by Alex Mangini in form of two handouts. In the South, the primary seed and cone pests are coneworms and seedbugs. The species are as follows (Ebel et al. 1981): southern pine coneworm – *Dioryctria amatella*, loblolly pine coneworm – *D. merkeli*, webbing coneworm – *D. disclusa*, blister coneworm – *D. clarioralis*, leaffooted pine seedbug – *Leptoglossus corculus*, and the shieldbacked pine seedbug – *Tetyra bipunctata*. Industry and state orchard managers use an IPM protocol that includes monitoring, sanitation and pesticides to minimize insect damage to cone crops. Several active ingredients are registered for seed orchard use; most are off-patent and numerous generic products are available. Currently, the primary issue for southern seed orchard managers is the loss of tebufenozide for seed orchard use. Tebufenozide is an insect growth regulator (IGR). It mimics the action of the natural insect hormone 20-hydroxy-ecdysone, the hormone that induces the process of molting and metamorphosis in Lepidoptera. For many years it has been used in southern pine seed orchards to control coneworms. In the late 2000's, Dow AgroSciences sold tebufenozide and its registrations to Nippon Soda, Ltd. (Nisso America, Inc.). Nisso, in turn, licensed the agricultural uses to Gowan Company (as Confirm® 2F) and the forestry uses to Valent BioSciences (as Mimic® 2LV). At present, Mimic® 2LV cannot be used by orchard managers because the term "conifer seed orchards" is not listed on the label. The "parent" Mimic® 2LV label (Enclosure 1, Nisso America EPA 8033-113) has a section "Forests, Trees and Shrubs" which contains "conifer seed orchards" as a labeled crop. This section is NOT on the current Valent BioSciences Mimic® 2LV label, making its use in seed orchards problematic. The Seed Orchard Pest Management Subcommittee of the Southern Forest Tree Improvement Program is currently working to get the label modified for seed orchard use. Also used is the systemic emamectin benzoate as Treeäge® marketed by ArborJet. It has proven effective in controlling coneworms. It can provide up to two years of control and is widely used in high-value orchard breeding trees and for controlled mass pollination (CMP) trees.

iv. Tim Schowalter and Steve Cook provided input from their long history in the field and that much of the information for seed and cone insects is not formally published and most of the information is in the form of grey literature and informal discussions from session like this. They also voiced concerns that seed and cone orchard applications are often secondary in registrations of pesticide products.

v. Daniel Dipente provided input for USFS Region 3 and reported on the seed and cone insects associated with Southwestern white pine (SWWP) in the form of a handout. In Region 3, efforts are currently underway to protect high value SWWP's and to create SWWP seed orchards which have resistance to white pine blister rust. Resource managers quickly realized the need to revise Hedlin et al. 1980 "Cone and Seed Insects of North American Conifers" which does not have a single association with seed and cone pests and SWWP. A study was conducted and the primary pests of the guild were identified. The most prevalent insect captured was Lepidoptera *Dioryctria abietivorella*. The second most observed insect was Coleoptera *Conophthorus ponderosae* followed by Lepidoptera *Eupithecia spermophaga* and Hemiptera *Leptoglossus occidentalis*. Further research is needed to develop an IPM strategy and measure the efficacy of management and monitoring methods for the SWWP seed and cone insect guild.

vi. All agreed that "Cone and Seed Insects of North American Conifers" booklet needs updating and certain sections need more information, such as the aphid and adelgid section and inclusion of Southwestern white pine host. Photos and distribution maps were also identified as major needs for updating. Several potential outlets were discussed as publishers. The discussion then lead to ideas on how to fund this work. Northwest Seed Orchards, Weyerhauser and other timber companies, inland Empire Seed Orchards, FHTET, were all discussed as potential users and/or funding opportunities that could be leveraged. Attendees of the session also identified that some key areas were not represented in this workshop and most volunteered to reach out to contacts to identify additional potential collaborators. In particular, representatives from Canada, Mexico, and the Lake States. All agreed that Ward and Alex Mangini would be the best lead contacts because of their extensive work on cone & seed insects but they were not able to attend the session.

12:00 – 1:30 Lunch

1:30 – 3:00 Concurrent Session 5

1. **Women in Forest Entomology (Wilson A/B) Moderator**: *Jessica Hartshorn*
   a. **Session Abstract**: Current trends in science and technology show women fleeing research and academia in large numbers. By the time women finish a Ph.D. in STEM, only 12% want to pursue a career in academia conducting research. The reasons behind this exodus are varied but gender bias and discrimination are two contributing factors. Two thirds of women have reported being sexually harassed in the field and more than half feel they're not taken seriously because of their gender. Many women report gender discrimination as directly inhibiting the advancement of their career. During the Women in Forest Entomology workshop, attendees broke into several small groups,

each led by a facilitator who directed discussion and represented the group with a brief summary at the end of each topic. The topics discussed were: 1) pros and cons to intentionally increasing diversity in forest entomology, 2) reasons why women choose "alternate" career paths, and 3) ways to place, and keep, women in leadership positions. Lively discussion within and among groups led to open and honest communication regarding topics such as family planning and, with a few exceptions, a lack of female mentors in forest entomology. It is clear that research, and especially academia, are not currently viewed as female-friendly and that many women choose to take their passion in a different direction to avoid the stress that comes along with these high-pressure jobs. Workshops such as this serve to connect like-minded individuals, both men and women, who seek to discuss, and learn about, social issues affecting women in science, especially forest entomology. The varied regional groups (e.g. SFIWC) should create a network or regular symposium during their individual meetings to continue these networking opportunities.

b. **Facilitators** (may change as workshop progresses):
   i. Scott Salom, Virginia Tech
   ii. Fred Stephen, University of Arkansas
   iii. Kamal Gandhi, University of Georgia
   iv. Lynne Rieske-Kinney, University of Kentucky
   v. Laurel Haavik, The Ohio State University
   vi. John Riggins, Mississippi State University

2. Managing for Forest Health and Resilience (Hoover) Moderator: *Chris Fettig and John Nowak*

a. **Session Abstract**: Several assessments have concluded that forests are increasingly vulnerable to tree mortality as a result of the direct and indirect effects of climate change (e.g., Fettig et al. 2013), and that the use of sound, ecologically-appropriate management strategies and prioritizing of their application to the landscape is critical. Relatedly, IPPC (2007, p. 543) has concluded that "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber, or energy from the forest, would generate the largest sustained mitigation benefit." We explore options for increasing resistance and resilience to disturbances exacerbated by climate change. We focus on bark beetles as widespread outbreaks of several species have recently occurred in North America.

b. Speakers and Abstracts:

i. **Resistance and Resilience: A conceptual framework for silviculture.** *Justin DeRose, Rocky Mountain Research Station, Logan, UT.* Descriptive definitions of resistance and resilience abound in the literature, but prescriptive characterizations are necessary for management implementation. A conceptual framework is introduced to explicitly differentiate resistance and resilience at multiple scales, and provide measureable context for evaluation – forest structure and composition. Resistance is characterized as the influence of structure and composition on disturbance, whereas resilience is characterized as the influence of disturbance on subsequent structure and composition. Silvicultural utility of the framework is demonstrated by describing time-bound structural and compositional objectives for building resistance and/or resilience to spruce beetles. The conceptual framework revealed the crucial insight that attempts to build stand or landscape resistance to spruce beetle outbreaks will ultimately be unsuccessful, freeing the silviculturist to focus on realistic goals associated with building resilience to inevitable outbreaks. Because structure and composition are suggested as standards for evaluation, the framework is broadly applicable to other disturbances and forest types.

ii. **Keeping forests as forests through active management.** *Chris Fettig, Pacific Southwest Research Station, Davis, CA.* Forests provide vast ecological, economic and social goods and services, but are increasingly vulnerable to mortality as a result of the direct and indirect effects of climate change. Climate change poses a significant challenge for society as it is unlikely that efforts to curb greenhouse gas emissions will eliminate the risk of climate change. As such, a sound forest carbon policy represents an important part of the solution as forests have the potential to assimilate, accumulate and sequester large amounts of carbon from the atmosphere, thus reducing one of the primary drivers of climate change. Alternatively, large amounts of CO_2 are released when forests are killed, burned, defoliated or deforested, and carbon may be lost when forests are converted to other systems (e.g., shrublands) that have smaller carbon pools. I discuss efforts to increase the resistance and resilience of forests to disturbances exacerbated by climate change, and encourage the use of flexible management approaches that promote learning along the way.

iii. **Redefining Healthy Forests: Why tree mortality from natural disturbances, and recruitment and protection of snags, are essential to the maintenance of native biodiversity and recovery of imperiled wildlife species.** *Chad Hanson, John Muir Project of Earth Island Institute, Big Bear City, CA.* There is considerable discussion and concern among land management agencies and others regarding agents of tree mortality in conifer forests of the United States, particularly in relatively dry forests of the West. Yet ecological studies are increasingly indicating that an ample supply of snags (standing dead trees) is vitally important for cavity-nesting wildlife species, and researchers are repeatedly finding that "snag forest habitat"--patches of snags from native beetles and drought or wildland fire--is one of the most biodiverse, wildlife-rich, rarest, and most threatened forest habitat types in the western U.S. Dr. Chad Hanson, Research Ecologist with the John Muir Project, will discuss this issue, and suggest a new way of viewing forest health. Dr. Hanson will also address some core questions on this issue: What are current data telling us about the present rate of natural disturbance relative to historical levels? Are fires and beetles killing too many trees currently, compared to rates before fire suppression? What about future trends with climate change? Are there areas and regions in which it would be an ecologically desired condition to have more snags, and what can land managers do to facilitate such a goal in a landscape that includes some small towns and rural communities? In regions that already have low levels of snags, what are the implications for rare and declining wildlife species associated with snag forest habitat if land managers succeed in implementing stated goals of further suppressing tree mortality from native beetles and fire?

iv. **Federal Policy and the impacts on healthy forests.** *Kirin Kennedy, Washington Representative, Sierra Club, Washington DC.* The United States Congress has created numerous environmental policies over time that have aided in both the health and destruction of our National Forests. In this presentation, we will take an in-depth look at the state of our National Forests throughout history, and the evolution of key pieces of environmental and forest policy.

3. **Forest Health Extension in North America: Challenges and Opportunities (Coolidge)**
Moderator: *David Coyle*
   a. **Session Abstract:** Forest health extension and outreach personnel are challenged with reaching an extremely diverse audience in North America. Forest landowners come from multiple backgrounds, ethnicities, and ages. In part, because of the various demographics of forest landowners, the use of different communication strategies is necessary to impact landowners, and these strategies may have varying levels of efficacy. This session will feature speakers from across North America with expertise in various forest health issues. Topics of discussion will focus on effective methodologies for reaching the diverse forest stakeholders in North America, including successes and failures. The audience is encouraged to discuss these and their own experiences with this distinguished panel.
   b. **Speakers and Titles:**
      i. **Advancing forest health science, policy and management in a changing world: A British Columbia perspective.** *Jodi Axelson, Cariboo Region, BC Ministry of Forests, Lands and Natural Resource Operations, British Columbia, Canada; and Lorraine Maclauchlan, Thompson-Okanagan Region, BC Ministry of Forests, Lands and Natural Resource Operations, British Columbia, Canada.*
      ii. **Challenges to extending forest health: when onslaught outpaces, people, research and budgets.** *Mark Megalos, NC State University, Raleigh, NC.*
      iii. **Transferring bark beetle technology to Central America: Needs, obstacles and accomplishments.** *Ronald F. Billings, Texas A&M Forest Service, College Station, TX.*
      iv. **Decision support smartphone app for forest health in the Eastern U.S.** (*Bargeron/LaForest*).

4. **Potentials For Restoration After Invasions By Exotic Forest Pests: East (Harding) Moderator**: *Fred Hain*

a. **Session Abstract:** Speakers will focus on the need to conserve the gene pool of trees threatened by invasive pests, the need to quickly regenerate seedlings for restoration, and the current situation of species being threatened in eastern North America.

b. Speakers and Abstracts:

i. **The role of genetic resource conservation in the restoration of forests after invasion by exotic forest insects**. *Robert M. Jetton[1], W. Andrew Whittier[1], Gary R. Hodge[1], William S. Dvorak[1], and James "Rusty" Rhea[2]. [1]Camcore, Department of Forestry and Environmental Resources, NC State University, Raleigh, NC. [2]USDA Forest Service, Southern Region Forest Health Protection, Asheville, NC.* The long-term health and sustainability of North American forests face significant threats from insects, pathogens, invasive plants, anthropogenic disturbances and their interactions with a changing climate. Of particular concern is the widespread tree decline and mortality caused by exotic-invasive forest insects and pathogens such as the hemlock woolly adelgid, emerald ash borer, and laurel wilt disease that were already widely distributed by the time of their first detection. In these situations, management is reactive, research to develop effective solutions is long-term, pests are able to expand their range and continue killing trees mostly unchecked, and the risk of numerical or functional extinction of affected tree species at local and regional levels is real. This can result in the genetic erosion of the species to a point where stand restoration based on natural regeneration may not be possible. Ex situ genetic resource conservation strategies, aimed at the acquisition of genetically diverse and broadly adaptable seed samples that are placed into seed banks or used to establish protected seed orchards, are a viable approach to conserving the genetic integrity of threatened and endangered tree species and providing genetic material for breeding and restoration in situations where in situ approaches are still being developed. Since 2003, the Camcore program at NC State University and the USDA Forest Service Southern Region Forest Health Protection have collaborated to design and implement a genetic resource conservation program for eastern and Carolina hemlocks threatened by the hemlock woolly adelgid. This project has acquired more than 2.5 million hemlock seeds for conservation, attempted to establish conservation plantings in Brazil, Chile, and the United States, and has expanded our understanding of the ecology and patterns of genetic variability and structure of both hemlock species. This presentation will describe how the hemlock genetic resource conservation program was designed and implemented, review progress and ongoing objectives, and discuss how successful hemlock gene conservation has served as a model for similar activities with other threatened tree species. Overviews of progress made in hemlock genetic resource conservation have been published in Jetton et al. 2013. Tree Planters' Notes 56: 59-71 and Jetton et al. Forest Ecology and Management 255: 3212-3221.

ii. **The American Chestnut Research and Restoration Project.** *William Powell, Andy Newhouse, Linda McGuigan, Allison Oakes, Kristen Stewart, Tyler Desmarais, Dakota Mathews, Yoks Bathula, Vern Coffey and Charles Maynard. SUNY College of*

Environmental Science & Forestry, Syracuse, NY. The American chestnut (*Castanea dentata*) and chestnut blight is the classic example of an invasion of an exotic forest pathogen. Because of its environmental, economic, and social importance, many tools have been brought to bear on the chestnut blight problem. We have focused on enhancing blight resistance by adding only a couple genes to the approximately 40,000 gene pairs in the chestnut genome using the tools of genetic engineering. The most promising gene to date encodes an oxalate-detoxifying enzyme, called oxalate oxidase (OxO). This gene comes from bread wheat (*Triticum aestivum*), but is also a common defense gene found in many plants including all grain crops as well as bananas, strawberries, and other familiar produce, and the enzyme it produces is not a pesticide, not a known allergen, and is not a gluten protein. According to chestnut leaf and small stem assays that predict the level of blight resistance, this OxO has raised resistance levels in American chestnut at least as high as those found in the blight-resistant Chinese chestnut (*C. mollissima*). This will be the first time an ecosystem restoration program will use the tools of genetic engineering. The next step is to have the trees reviewed by three federal regulatory agencies, the USDA, EPA, and FDA. Once approved, these blight resistant American chestnut trees can be used to rescue the genetic diversity and local adaptation in the remnant, surviving population of American chestnut and be an additional tool for the restoration of this important keystone tree species.

iii. **Development and production strategies for genetic resistance to hemlock woolly adelgid.** *Ben C. Smith[1], Scott A. Merkle[2], and Fred P. Hain[1]. [1]Forest Restoration Alliance, Department of Entomology, NC State University, Raleigh, NC. [2]Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA.* The exotic invasive hemlock woolly adelgid (HWA) has had a devastating impact on natural stands and ornamental plantings of eastern hemlock and Carolina hemlock throughout much of their range in the eastern United States. In order to facilitate the restoration of impacted ecosystems, the Forest Restoration Alliance seeks to develop trees genetically resistant to or tolerant of HWA, to complement chemical protection and biological control approaches for dealing with HWA. Resistance may be developed through exploitation of naturally-occurring resistance, or through interspecific hybrids with resistant or tolerant hemlock species and a backcross breeding program. We are working to identify native hemlock trees with potential genetic resistance or tolerance, and clonally replicating those trees via rooted cuttings to screen them for resistance. Since 2011, we have rooted cuttings from over 125 native trees in the southeastern U.S. for testing. These clones will undergo intentional infestations of HWA in the next several years, and subsequent evaluation of response to infestation. We are currently evaluating interspecific hemlock hybrids created by the U.S. National Arboretum for adaptability to the southern Appalachians and HWA resistance at a site in North Carolina, and also began making additional hybrid hemlock crosses in 2011. F1 hybrids identified as resistant or tolerant will be released for ornamental utilization, and included in the backcross program with the goal of eventual species restoration. We are also investigating the application of an in vitro propagation approach, somatic embryogenesis, as a means of scaling up production of both putatively-resistant/tolerant native hemlocks and interspecific hybrid hemlocks, to use for clonal testing for resistance/tolerance and eventual deployment of HWA resistant/tolerant hemlock varieties. Embryogenic cultures initiated from seeds collected from putatively resistant/tolerant parent trees and from seeds from interspecific crosses have produced populations of somatic embryos, which have been germinated to produce somatic seedlings. These trees have been transferred to ex vitro conditions, hardened off and are currently being grown in the greenhouse to a size sufficiently large for screening.

iv. **Towards restoration of ash following the emerald ash borer invasion.** *Daniel A. Herms, Department of Entomology, The Ohio State University, Wooster, OH 44691.* Emerald ash borer (EAB) threatens the genus *Fraxinus* with near extirpation. Mortality of ash greater than 2.5 cm stem diameter exceeds 99% near the epicenter of the invasion, and recruitment has ceased. However, established seedlings are abundant, and this orphaned cohort may establish a dynamic equilibrium with EAB and natural enemies. Efforts are also underway to identify, breed and screen ash germplasm for EAB resistance and silvicultural traits; and identify mechanisms of EAB resistance to facilitate breeding and screening. In Asia, EAB does not devastate its endemic hosts, which suggests that Asian ashes are inherently resistant by virtue of their coevolutionary history with EAB. Results of common garden studies are consistent with this hypothesis. Research on resistance mechanisms have focused on traits that affect larval density, growth, and survival, including female oviposition preferences and phloem chemistry. The USDA Forest Service has initiated a breeding program based on hybridization of resistant Asian ash and susceptible North American ash (following the successful chestnut blight breeding program) and are screening rare native genotypes that continue to survive. Ultimately, these efforts should lead to development of EAB-resistant ash trees that will be critical for restoration of ash in natural and urban forests.

v. **Rapid selection and opportunities for restoration of laurel wilt tolerant *Persea* species.** *Marc Hughes[1], Jason A. Smith[1], Ben Held[2], Robert Blanchette[2], Katherine Smith[3], Tyler Dreaden[3] and Randy C. Ploetz[4]. [1]School of Forest Resources and Conservation, University of Florida: Gainesville, FL; [2]Department of Plant Pathology, University of Minnesota: St. Paul, MN; [3]Southern Research Station, U.S. Forest Service: Lexington, KY; [4]Tropical Research and Education Center, University of Florida: Homestead, FL.* In little more than a decade, laurel wilt (LW) caused by *Raffaelea lauricola* (transmitted by *Xyleborus glabratus*) has spread to nine U.S. states, killing hundreds of millions of redbay (*Persea borbonia*) trees, altering ecosystems and threatening worldwide avocado production. Typically, ambrosia beetles and their fungal symbionts are not tree killers. LW is unique in that the symbiont of *X. glabratus* is highly virulent to host trees. Current efforts to manage LW focus on systemic fungicides, insect repellents, sanitation. Naturally occurring forests with high mortality (> 95%) from LW have been explored for persistent survivor trees. Propagation and subsequent disease screening have been carried out leading to the identification of disease tolerant redbay clones. Mechanisms of tolerance appear to be associated with reduced tylosis and reduced disruption of vascular function. Seedling populations from tolerant clones have been genotyped and are being phenotyped for tolerance to assist restoration efforts. Future research will focus on genomic analyses as well as examinations of how phylogeography influences host susceptibility within the Lauraceae.

3:00 – 3:30 Break (Marriott Foyer)

3:30 – 5:00 Concurrent Session 6

5. **Open Session 2 (Wilson A/B)** Moderator: *Molly Darr*

a. **Session Abstract**: An open session for submitted talks on important topics.
b. **Speakers and Titles**:
   i. **Coevolution, climate-change, and the creation of a native invasive species.** *Jordan Burke, Jorg Bohlmann, and Allan Carroll*.
   ii. **Factors that affect the establishment of *Oobius agrili* (Hymenoptera: Encyrtidae), an introduced egg parasitoid of *Agrilus planipennis*, in Michigan ash stands.** *Toby R. Petrice, F. William Ravlin, Leah S. Bauer, Therese M. Poland, Kenneth F. Raffa, and Deborah G. McCullough*.
   iii. **Laurel wilt: beyond the redbay (*Persea borbinia* (L.) Spreng) native range.** *Rabiu Olatinwo and Stephen Fraedrich*.
   iv. **Management of bark beetle outbreaks in the community forests of Oaxaca, Mexico**. *Adrian Polini and E.D. Medina*.

6. **Applied MPB Ecology during Severe Outbreaks in High Elevation Pine Systems** (Hoover) Moderator: *Joel Egan*

a. **Session Abstract**: This workshop will explore recent advances in applied ecology with respect to severe mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreaks that have impacted high-elevation pine systems in recent decades. Experts will present novel research findings and management synopses pertinent to these impacted systems. Specifically, various ecological factors impacting severe and widespread MPB outbreak dynamics will be explored in this workshop with perspectives ranging from broad factors that occur over landscape spatial scales to fine-scale host interactions that occur between individual trees and attacking beetles. This session will be focused with an applied perspective to indicate how this knowledge relates to overall high-elevation pine inter-tree resistance as well as ecosystem resilience when exposed to severe mortality caused by widespread outbreaking MPB populations.
b. **Speakers and Titles**:

i. **A comparison of climate influences on mountain pine beetle outbreaks in lodgepole and whitebark pine forests in the western US.** *Polly Buotte*.
ii. **Risk to young pine during severe mountain pine beetle outbreaks: the B.C. story** *Lorraine Maclauchlan*.

iii. **Tree response and mountain pine beetle attack preference: A tale of two ecosystems.** *Barbara Bentz*.
iv. **Integrated analysis of pine defense systems as a foundation to understand and enhance resilience of conifer ecosystems.** *Kenneth F. Raffa*.
v. **Whitebark pine restoration following MPB outbreaks**. *Sandra Kegley.*

7. **History of Forest Entomology in North America**. **(Coolidge)** Moderator: *Beth Willhite*

   a. **Session Abstract:** It is important to understand the history of forest entomology, yet we are losing many of our entomologists without the chance to collect and preserve their stories, writings, and materials. Though individual regions have committees dedicated to the history of forest entomology, there is no unified approach across North America. NAFIWC provides the perfect opportunity to discuss the need and methods for preserving our history. The objective of the session will be to discuss current efforts, share problems and successful methods, and develop training techniques on history preservation for forest entomologists. The goal is the initiation of a unified effort in North America to protect our knowledge base and retain the experience and wisdom of our forest entomologists.
   b. **Speakers and Abstracts**:
      i. **Introduction**. *Elizabeth Willhite, USDA Forest Service, Pacific Northwest Region, Forest Health Protection, Sandy, OR.* Two primary history interest areas were reviewed: human (e.g., people, programs, agencies) and insect (e.g., incidence, damage severity, biology, management), and three focus areas for history-related efforts: acquisition (e.g., conducting oral interviews, locating old documents), preservation (e.g. digital conversion, archiving hardcopy materials), and synthesis (e.g. information analysis, narrative histories). This workshop was organized to foster discussion about North American historical information regarding forest entomologists and forest entomology, and to build on progress to date in creating a framework and standards for the preservation of historical unpublished and published materials produced by forest health specialists (forest entomologists and pathologists). Efforts to develop and implement infrastructure and input procedures for an internet-accessible forest health protection digital collection at the National Forest Service Library digital repository have been ongoing since 2010. A national process for online contributions to this digital collection is expected to be available by the fall. During the open discussion period following the presentations, various efforts, challenges, ideas, and options for digital repository of historical materials were discussed. As an result of this discussion, the group decided to prepare a

recommendation that the three Work Conferences in the US (Southern, North Central, and Western) work together to create a unified digital archive system for North American forest entomologist history. This recommendation was presented at the final business meeting of this conference.

ii. **Compiling a 70 year history of aerial insect and disease surveys in Oregon and Washington**. *Julie Johnson*, *USDA Forest Service, Forest Health Protection, Portland, OR.* Aerial insect and disease detection surveys have been systematically conducted in the Pacific Northwest since 1947; completion of the 2016 survey season will mark 70 consecutive years. A General Technical Report is being compiled 1) to document the history of the program, and 2) as a contextual reference to accompany the related geospatial dataset. Some of the primary resources used to compile this report were presented, with a focus on grey literature. Then, primarily using grey-literature-based examples, some of the people and organizations whose efforts have made the Oregon and Washington program possible were highlighted.

iii. **Preserving historical information through the National Forest Service Library**. *Sally Dunphy (presented by Elizabeth Willhite), USDA Forest Service, National Forest Service Library, Ft. Collins, CO.* Information was presented on how to find historical information for use in projects and available resources at the National Forest Service Library (NFSL). The topics covered included: search operators, bibliographic databases, description of a process for finding gray literature, requesting document delivery from the NFSL and National Agriculture Library (document search and delivery services are limited to federal employees), and NFSL digital collections (available to anyone through the Internet), which also includes the beginnings of a forest health protection (FHP) historical document collection. This collection is in process of development and will be ready to accept contributions this fall. "How to Contribute" webinars may be requested by contacting Sally Dunphy at the NFSL.

iv. **Move Over Marc…Say hello to CONTENTdm**. *Lisa Stringfield. USDA Forest Service, Pacific Northwest Region, Forest Health Protection, Sandy, OR.* The time has come for the USDA Forest Service to adopt a better process for cataloging and keeping historical Forest Health Protection documents. This presentation outlines and illustrates the necessity for a new national process for repositing historic insect and disease documents at the National Forest Service Library. The existing complicated VIRTUA MARC cataloging system will be replaced by a streamlined CONTENTdm (Content Digital Management) webform metadata template. This new system will enable not only librarians but also trained Forest Service staff across the agency the ability to contribute selected Forest Health Protection items to this important and ever-growing historical digital collection. One of the many advantages of using CONTENTdm is the ability to choose and or change metadata schemas and field names that are appropriate or best reflects the contents of a collection. Also, items can be added to the collection from the convenience of an individual's desktop via a Project Client. Another advantage is that users can add indexed items to a collection in real time, with the results posting immediately to the online collection.

Additionally, CONTENTdm enhances the discoverability of cataloged items by making them available and searchable via the Web and through popular search engines as well as providing text search capabilities across collections. In all, this new cataloging and repositing system is an optimal choice for the Forest Health Protection special collections because it's a simpler, more efficient way to help interpret, capture and present this valuable historical gray literature to the entire agency and the public.

7. **Potentials For Restoration After Invasions By Exotic Forest Pests: West.** Moderator: *Steve Cook*
   a. **Session Abstract**: Speakers will focus on the need to conserve the gene pool of trees threatened by invasive pests, the need to quickly regenerate seedlings for restoration, and the current situation of species being threatened in western North America.
   b. **Speakers and Abstracts**:
      i. **Condition of whitebark pine stands following outbreaks of mountain pine beetle.** *Kendra Schotzko: USDA-Forest Service, Forest Health Protection; Region 2, Rapid City, SD, kschotzko@fs.fed.us; Stephen Cook: University of Idaho; Department of Plant, Soil and Entomological Sciences, Moscow, ID. stephenc@uidaho.edu; Carl Jorgensen: USDA-Forest Service, Forest Health Protection, Region 4; Boise, ID. cljorgensen@fs.fed.us; Sandra Kegley: USDA-Forest Service, Forest Health Protection, Region 1; Coeur d'Alene, ID. skegley@fs.fed.us; Laura Lowrey: USDA-Forest Service, Forest Health Protection, Region 4; Boise, ID. laurallowrey@fs.fed.us; John Schwandt: USDA-Forest Service, Forest Health Protection, Region 1; Coeur d'Alene, ID. jschwandt@fs.fed.us; Jim Hoffman: USDA-Forest Service, Forest Health Protection, Region 4; Boise, ID. jhoffman@fs.fed.us*. Whitebark pine, *Pinus albicaulis,* is a keystone species of high elevation ecosystems throughout western North America. Although whitebark pine has a large range, individual stands are often small and relatively isolated. Recent aerial detection surveys have documented increasing mortality of whitebark pine overstory that is primarily being caused by two biotic agents: white pine blister, *Cronartium ribicola*, and mountain pine beetle, *Dendroctonus ponderosae*. While aerial detection surveys have provided estimates of dead trees, information about residual stand composition following mountain pine beetle infestations has been lacking. Residual stand composition measurements are crucial for understanding future stand trends and determining restoration needs. The three objectives of our work that we will address in the current presentation are: 1) to quantify the remaining live overstory (mature) whitebark pine, 2) to assess the whitebark pine understory (regeneration) and 3) to predict possible stand trajectory. We documented stand composition before mountain pine beetle outbreaks for comparison with the species composition of remaining live trees (overstory and understory) post-outbreak. All of the stands we surveyed had been impacted by mountain pine beetle, and results indicate substantial mortality occurred among overstory whitebark pine in many areas. However, overstory and understory stand

composition varied greatly among sites. Based upon measurements of species composition of the remaining tree community, some stands appear to be retaining a high percentage of whitebark pine. Other stands, however, appear to be having whitebark pine replaced by competing species such as subalpine fir.

ii. **A severity rating system and risk evaluation for stand-level balsam woolly adelgid (Hemiptera: Adelgidae) damage in western North America**. *R. A. Progar[1], K. H. Hrinkevich[2], and D.C. Shaw[2]. [1]USDA PNW Research Station, Forestry Sciences Lab, 1401 Gekeler Lane, La Grande, OR 97850. [2]Oregon State University, Dept. For. Eng. Res. Mgmt., Corvallis, OR 97331.* Severity rating systems are fundamental to understanding the impacts of disturbance agents in forest stands. The balsam woolly adelgid (BWA), *Adelges piceae* (Ratzeburg) (Hemiptera: Adelgidae) is an invasive forest pest in North America that infests and causes mortality in true fir, *Abies* spp. We developed a new rating system for two western host species: grand fir and subalpine fir. This index is proposed as an improvement over existing rating systems for western North America because of its broader scope, demonstrated ability to distinguish between severity classes, and identification of predominant indicators that improve efficiency and efficacy of field assessments. The adoption of this system will facilitate long-term monitoring through site resurveys that will be directly comparable over time, also allowing future studies to conduct risk assessments and target stands that face the greatest threat to forest health. We also developed a risk model and map that predicts potential BWA impacts to subalpine fir using a two-step process. Our data indicate a pattern of decreasing climatic susceptibility from north to south in the Rocky Mountains. This work provides an initial step for modeling the relationship between climate and BWA damage severity across the range of subalpine fir in the western United States.

iii. **Long term management of native Monterey pine (*Pinus radiata*) in the presence of pitch canker caused by the exotic fungus *Fusarium circinatum***. *Andrew J. Storer[1], David L. Wood[2], Thomas R. Gordon[3], Brice A. McPherson[2] and Nadir Erbilgin[4]. [1] School of Forest Resources and Environmental Science, Michigan Technological University, Houghton MI 49931. [2] Department of Environmental Science, Policy & Management, University of California, Berkeley, CA 94720. [3] Department of Plant Pathology, University of California, Davis, CA 95616. [4] Department of Renewable Resources, University of Alberta, Edmonton, Canada, T6G 2E3.* In the absence of fire, understory vegetation in many areas in the native range of Monterey pine limits light penetration to the forest floor to the point that regeneration is entirely absent or nearly so. For this reason, many stands are over-aged and without a cohort of young trees to replace those nearing the end of their life span. Pitch canker, caused by the exotic pathogen *Fusarium circinatum*, has been present in the native stands of Monterey pine on the Monterey peninsula since the early 1990s. Given that some trees are resistant to the pitch canker pathogen, we hypothesize that regeneration will be important to increase the level of resistance to pitch canker at the stand level. We characterized pitch canker resistance in young trees that had become established in the presence of pitch canker following development activities that resulted in the opening up of a native stand. This enabled us to determine whether resistance to pitch canker was more common in trees that became established in the presence of pitch canker than in older trees that were established prior to the arrival of pitch canker. We also conducted a series of studies that have shown that it may be possible to increase the regeneration of Monterey pine through management of overstory and understory vegetation. These studies have included understory vegetation removal at different scales, as well as the creation of canopy gaps. Enhanced regeneration in natural stands may enhance stand level resistance to pitch canker in future generations of this tree species as part of native Monterey pine forest restoration.

iv. **Sudden oak death in California: potential for recovery of coast live oak-bay laurel forests**. *Brice A. McPherson and David L. Wood, Department of Environmental Science, Policy, and Management, University of California, Berkeley, CA 94720.* The introduced pathogen *Phytophthora ramorum* causes the disease called sudden oak death (SOD) in red oaks (*Quercus* spp., section Lobatae) and tanoak (*Notholithocarpus densiflorus*) in California. Coast live oak, CLO, (*Q. agrifolia*) is the dominant masting hardwood species in many coastal California forests and is considered a terminal host, incapable of supporting sporulation. California bay laurel (*Umbellularia californica*) and other foliar hosts serve as spore sources but are not killed by the pathogen. The wide host range includes most of the native hardwood species in these sites. In Marin County plots that we have monitored since 2000, mortality of mature CLOs exceeds 40%. As with other oaks, CLO does not regenerate well under closed canopies. Factors that influence the long-term capacity of these forests to maintain the present species composition include the unusually wide host range of *P. ramorum*, the proportion of CLOs that are resistant to it, and CLO seedling recruitment. Attacks by both native and introduced ambrosia beetle species on infected CLOs drive mortality in this species. Introduced insect species not presently found in northern California that pose potential threats to CLO and other tree species include gold-spotted oak borer (*Agrilus auroguttatus*), polyphagous shot hole borer (*Euwallacea fornicatus*), Kuroshio shot hole borer (*Euwallacea sp*.), and red bay borer (*Xyleborus glabratus)*. Due to the limited diversity of overstory tree species in these forests, post-epidemic stand composition may differ considerably from the present. The epidemic is still expanding within the range of host oaks.

Friday June 3

8:30 – 9:00 Business meeting and awards (Thurgood Marshall Northeast)

9:00 Concurrent Session 7

1. **Invasions by Non-Native Forest Insects and Diseases: Efficient Solutions 1 (Thurgood Marshall Northeast)** Moderators: *Kirsten Prior, Sandy Liebhold, Jiri Hulcr*
   a. **Session Abstract:** Worldwide, the field of forest health is increasingly dominated by problems associated with non-native insects and diseases. Trends of increasing globalization are driving the arrival of these species and as establishments of these pests accumulate, their impacts on forest resources continue to grow. This session will cover the various options that exist for managing the forest pest invasion problem. One tactic involves measures to prevent these species from arriving in the first place, through pre-invasion risk assessments and pathway management. Once a species is introduced, surveillance and rapid-decision making are important for practical eradication programs. Once a species establishes and spreads, implementing a successful eradication becomes increasingly difficult. At these stages management strategies via classical biological control or the development of resistant tree genotypes holds promise for at least partially mitigating the impacts of invading pest populations. In this session, invited speakers will discuss current research on each of these management strategies from scientific and socio-economic perspectives. Advantages and disadvantages of each strategy will be discussed.
   b. **Speakers and Abstracts**:
      i. **Pre-introduction risk assessment of fungi associated with Asian ambrosia beetles**. *Jiri Hulcr[1], Craig Bateman[1], You Li[1], Adam Black[1], James Skelton[1], D. Rabern Simmons[1], Wang Bo[2], Jiang-Hua Sun[3], Hou-Feng Li[4], Chi-Yu Chen[4], Stanley Freeman[5], Miroslav Kolarik[6], Ji-Hyun Park[7], Masato Torii[8], Shin-ichiro Ito[8], and Wisut Sittichaya[9]. [1]School of Forest Resources and Conservation, University of Florida, Gainesville, FL. [2]Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Menglun, Mengla, Yunnan, China. [3]Institute of Zoology, Chinese Academy of Sciences, Chaoyang District, Beijing, China. [4]Department of Entomology, National Chung Hsing University, Taiwan. [5]Department of Plant Pathology and Weed Research, Agricultural Research Organization, The Volcani Center, Bet Dagan, Isreal. [6]Institute of Microbiology, Czech Academy of Sciences, Czech Republic. [7]Korea Forest Research Institute, Republic of Korea. [8]Mie University, Tsu, Japan. [9]Department of Pest Management, Faculty of Natural Resources, Prince of Songkla University, Had Yai, Songkhla, Thailand.* Several exotic fungi vectored by bark beetles or ambrosia beetles caused major tree death epidemics after their establishment in the US. To prevent future such epidemics, it would be best to eradicate each newly established wood borer, but agencies do not have data on which wood borers and fungi are potentially important and which are harmless. We have been assessing whether additional beetle-borne fungi with similar potential invasion impact exist in Asia and Europe. We have focused on fungi of beetles specific to Pinaceae and Fagaceae, given the significance of pines and oaks to the American economy and ecosystems. During three years, we have sampled in 10 Asian and European countries, collected 115 species of bark and ambrosia beetles (one of which is new to science), and from them isolated 340 isolates of unique fungal species. Of these, 33 of the most highly

specific or abundant fungi were used for tests of their pathogenicity to two species of pines (slash and loblolly) or two species of oak (live and white) fungi. So far, none is a systemic pathogen and therefore a major threat, which was the main test of this project. Five fungus species can act as localized but not systemic pathogens on pines, and the rest are no more damaging than a negative control. New collections and assessments of more isolates are currently in full swing.

ii. **Potential establishment and economic assessment of ambrosia beetles: where, how many, and the economic impact on the US loblolly pine industry.** *Jose R. Soto[1], Damian C. Adams[1], Jiri Hulcr[1], Frank H. Koch[2], and Andreas Susaeta1. [1]School of Forest Resources and Conservation, University of Florida, Gainesville, FL. [2]U.S. Forest Service, United States Department of Agriculture, Southern Research Station, Research Triangle Park, NC.* International trade has been widely acknowledged as a vector for ambrosia beetles in the US. Exotic woodborer damage in the US is estimated to cost over $2.5 billion in local government expenditures and lost residential property values each year (Aukema et al., 2011). Approximately 1.7 new alien forest insect species are estimated to establish each year in the US, and at least one is predicted to emerge as a significant pest every 5-6 years (Koch et al., 2011). The recent arrival of ambrosia beetles from Asia with unknown consequences to US forests has led to roughly 90% tree mortality of redbay trees in almost 100 counties of the Southeast coastal plains (Spiegel and Leege, 2013). The lack of understanding of ambrosia beetle (Coleoptera: Curculionidae: Scolytinae & Platypodinae) establishment rates and the potential economic costs of its symbiotic fungus has proven to be a Trojan horse inside these insects. This study assesses the likelihood of successful entry of new ambrosia beetles arriving from Asia, using historical merchandise imports and insect incursions data, to estimate the potential annual establishment rate at more than 500 urban areas in the US (e.g., Koch et al., 2011). Furthermore, this study applies the projected establishment rates, using a stand level simulation model (e.g., Susaeta et al., 2014), to estimate the economic costs of a hypothetical new ambrosia beetle outbreak that affects loblolly pine in the US. This framework will inform future policy regarding potential new invasions of ambrosia beetles in the US.

iii. **Managing Forest Insect Invasion Pathways**. *Andrew Liebhold[1], Eckehard Brockerhoff[2]. [1]U.S. Forest Service, United States Department of Agriculture, Northern Research Station, Morgantown, WV. [2]Scion Research, Christchurch, New Zealand.* Temporal patterns of invasions by non-native forest insects during the last two centuries can be explained by historical patterns in invasion pathways. The dominant pathways by which these species have arrived include on live plants (entering both legally and illegally), in wood and solid wood packing material and hitch-hiking with cargo. National and international policies have adapted in order to minimize invasions but 100% exclusion is unlikely to occur. We discuss what options are available for preventing arrival and likely trends for future new establishments in the future.

iv. **Federal policy responses to potential insect invasions.** *Damian C. Adams[1], Tom Reynolds[1], and Jiri Hulcr[1]. [1]School of Forest Resources and Conservation, University of Florida, Gainesville, FL.* To avoid significant economic and ecological harm from future tree pests, it is imperative to understand potential barriers to a proactive regulatory approach to preventing a new forest insect invasion. A 1999 Executive Order established the National Invasive Species Council and directed them to make a plan for the management of invasive species (IS). The most recent National Invasive Species Management Plan indicates that to effectively address IS at the federal level, there is a critical need to "Complete an analysis of current federal laws and regulations dealing with invasive species" (2008 NISMP, Implementation Task OC.1.1.). To address this information gap, we conducted a descriptive analysis of the US federal legal and regulatory framework for IS control, including a review of agencies and institutions that could affect IS establishment, movement, growth, and impacts in the US. Work is ongoing, but to date, our review includes an assessment of more than 50 federal statutes, dozens of pertinent regulatory provisions, and consolidation and coordination efforts (e.g., National Invasive Species Council and its management plans [1999, 2008]). We focus on five primary types of authority to manage and control IS: restrictions against IS movement, restrictions against producing and propagating IS, authority to direct eradication of IS, authority to quarantine IS, and strategic planning and coordination. When coupled with ongoing economic analyses, our goal is to identify feasible and effective proactive approaches to prevent new introductions and establishment of high-risk invasive tree pests.

v. **Investing in surveillance for early detection and eradication**. *Rebecca Epanchin-Niell. Resources for the Future, Washington, DC 20036*. Detecting new invasions earlier, when they are smaller, enhances the success and decreases the costs of post-detection control efforts. Thus, investments in surveillance activities to detect new populations of invaders have the potential to reduce overall management and damage costs. Indeed, designing efficient surveillance systems requires balancing investments in surveillance with the expected returns that result from increased likelihood of earlier detection. Bioeconomic modeling provides approaches for determining where and how much sampling effort should be conducted for detecting new invasions – with the goal of minimizing the total costs and damages from an invader and its management. In this talk I will highlight some of the key features of this investment tradeoff challenge and describe several applications of bioeconomic modeling for informing surveillance activities for various forest pests. These models typically account for increasing detection likelihood as invader populations grow as well as heterogeneities in establishment rates and damages across the landscape. I will describe some generalized findings and guidance derived from a synthesis of existing bioeconomic research on early detection surveillance systems.

2. **Open Session 3** Moderator: *Elizabeth Graham*
   a. **Session Abstract:** An open session for submitted talks on important topics.
   b. **Speakers and Abstracts:**
      i. **Restoration of a heritage tree: Quantifying non-target effects of transgenic blight resistant American chestnut (Castanea dentata (Marshall) on a seasonal guild of lepidopteran folivores.** *D. Parry[1], G.R. Keene[1], A.J. Brown[1], C.A. Maynard[2], and W.A. Powell[1]. [1]State University of New York, College of Environmental Science, Dept. of Environmental Biology. [2]State University of New York, College of Environmental Science, Dept of Forest and Natural Resource Management*. One of the most exciting developments in North American forestry is the recent development of a bioengineered blight resistant American chestnut. Chestnut blight, *Cryphonectria parasitica* (Murrill) Barr, an exotic fungal pathogen, eliminated American chestnut as a foundational species and canopy dominant across its range. Engineering of chestnuts with a gene construct from wheat which expresses oxalate oxidase (OxO) yields genotypes that retain the prized morphology of American chestnut with the blight resistance of Chinese varieties. Consideration of potential non-target effects of transgenic trees is critical prior to broad release into natural environments, as this is the long-term objective of the restoration program. However, transgenesis can have unintended effects on non-target species directly through expression of gene products or through pleitropic effects on other genes. We used several folivorous Lepidoptera and conducted relative growth rate (RGR) bioassays on cloned trees from eight conventionally bred and transgenic cultivars, including three engineered OxO events. In 2012, gypsy moth (*Lymantria dispar* L.), fall webworm, *Hyphantria cunea* Drury, and forest tent caterpillar (*Malacosoma disstria* Hubner) exhibited little difference among cultivars, whereas RGR of *Antheraea polyphemus* was higher on the transgenic trees. A three year ontogenetic study with gypsy moth on the same cultivars found a significant increase in RGR in 2 of the 3 years on transgenic trees. .
      ii. **Landscape-scale forest management legacies affect spatial synchrony in insect outbreaks**. *Louis-Etienne Robert (Centre d'étude de la forêt (CEF), Université du Québec à Montréal. C.P. 8888, Succ. Centre-Ville. Montréal, Québec, Canada. H3C 3P8 E-mail louis-etienne.robert@umontreal.ca); Brian R. Sturtevant (Institute for Applied Ecosystem Studies, Northern Research Station, USDA Forest Service, 5985, Highway K. Rhinelander, WI 5450. USA. E-mail bsturtevant@fs.fed.us); Patrick M. A. James (Département des sciences biologiques, Université de Montréal, C.P. 6128, succursale Centre-ville. Montréal, Québec, Canada. H3C 3J7. E-mail patrick.ma.james@umontreal.ca); Barry J. Cooke (Canadian Forest Service, Northern Forestry Centre. 5320–122nd Street. Edmonton, Alberta, Canada. T6H 3S5. E-mail: bcooke@nrcan.gc.ca); Daniel Kneeshaw (Centre d'étude de la forêt (CEF). Université du Québec à Montréal, C.P. 8888, Succ. Centre-Ville. Montréal, Québec, Canada. H3C 3P8. E-mail kneeshaw.daniel@uqam.ca). J. Meating, A. Craig, A. Winmill and V. Chaimbrone.*

iii. **Evolution of emerald ash borer management in Canada (2008 – 2016): A consultant's perspective in Oakville, Ontario**. *J. Meating, A. Craig, A. Winmill and V. Chaimbrone*. Changes in forest landscape structure (i.e., composition and configuration) as a result of human activities affect forest ecosystem processes at multiple scales. In particular, such changes can have significant unintended consequences on the spatial population dynamics of irruptive forest insect pests. To improve our understanding of how landscape-scale manipulations of forest structure affect insect outbreaks, we examined and compared spatial synchrony in outbreak dynamics of two economically important forest defoliators: the spruce budworm and the forest tent caterpillar. Both insects have different spatial dynamics (large vs small dispersion), host preferences (conifers vs hardwoods) and periodicity (less frequent vs more frequent) thus providing an opportunity to examine interacting insect dynamics and their relation to landscape structure. Time series of outbreak dynamics were reconstructed using dendrochronology and we examined the extent to which time-series variation was influenced by landscape structure. We investigated spatial variation in outbreak across a 6 million ha region with contrasting land management legacies at the border of Ontario (Canada) and Minnesota (USA). Outbreak synchrony was compared across management zones using a spatial nonparametric covariance function. We observed contrasting patterns of spatial synchronization between the two species that appear to be driven by differences in abundance and connectivity of preferred hosts. Human-caused changes in forest structure can result in long-term unintended consequences for ecosystem functioning. Incorporating the influence of changes in forest structure on insect outbreaks into forest management will be challenging because different species can exhibit different responses.

iv. **Long-distance dispersal of spruce budworm in the northeastern boreal forest – Model validation and application**. *Sturtevant[1], B.R., B.J. Cooke[2], B.J., J. Régnière[3], G.L. Achtemeier[4], J.J. Charney[5], Yan Boulanger[3], and R. Saint-Amant[3]. [1]Institute for Applied Ecosystem Studies, Northern Research Station, USDA Forest Service, Rhinelander, WI. [2]Northern Forestry Centre, Natural Resources Canada, Edmonton, Alberta, Canada. [3]Laurentian Forestry Centre, Natural Resources Canada, Quebec City, Québec, Canada. [4]Forestry Sciences Laboratory, Southern Research Station, USDA Forest Service, Athens, GA. [5]Northern Research Station, USDA Forest Service, Lansing, MI.* Long-distance dispersal is thought to play an important role in synchronizing disparate populations of forest insect defoliators, but its importance relative to other factors remains unclear due to the difficulty of quantifying dispersal. The spruce budworm atmospheric transport model (SBW-ATM) is an agent-based model developed to project flight and deposition patterns of SBW based on aerobiological principles. Our team integrated the SBW-ATM with a phenological model (BioSIM) to produce a near-operational model that identifies the phenological timing of potential mass-exodus events and generates the probabilistic deposition maps representing likely deposition patterns given the atmospheric conditions at the time of the event. We applied the model to several dates in eastern Canada where an emerging outbreak resulted in multiple instances of presumed immigration events – identified by trap captures of moths outside of their expected flight window based on local phenology. In general we found the immigration events consistent with projected deposition patterns from a large source population on the north shore of the St. Laurence River. However, model projections were also sensitive to the resolution of modeled meteorological conditions that may affect our ability to operationalize the model. We discuss the implications of SBW deposition patterns in the context of an experimental early intervention strategy currently deployed in New Brunswick, Canada.

v. **Evolution of emerald ash borer management in Canada (2008 – 2016): A consultant's perspective in Oakville, Ontario**. *J. Meating, A. Craig, A. Winmill and V. Chaimbrone, BioForest Technologies, Inc.* In 2008, Emerald ash borer (EAB) was detected in the Town of Oakville, Ontario. BioForest was contracted to develop a management strategy for the town. Many questions were asked, but in 2008, there were few good answers. The development of the EAB management strategy over the last eight years is reviewed. What worked, what didn't work and what tools were developed along the way to support decisions, are discussed.

3. **Assessing the impact of populations of bark beetles and woodborers with expanding ranges in the USA – Session 1**. Moderators: *Tom W. Coleman and Steven J. Seybold*

a. **Session Abstract:** Native and exotic insects with expanding ranges represent significant challenges for forest and other land managers across all ownerships. Interacting factors, such as population establishment and invasion, drought, warmer winter temperatures, increased frequency of wildland fire, and deteriorating forest stand conditions and urban tree stress, have led to range expansions followed by increases in tree injury and mortality from bark beetles and woodborers. The measurement and reporting of the impact of pests in these situations has been largely ignored and potentially undervalued. Determining the extent of the injury and assessing the potential stand- and landscape-level changes caused by these threats to our forests are needed to develop and support management actions; contribute information to risk models; and address future funding allocations. Eight presenters across two workshop sessions will discuss the impacts of selected bark beetles and woodborers with expanding ranges from most regions of the USA. The topics represent emerging forest health threats within each region and speakers will the address the history, impact, risk of further expansion, and management outlook for each area. The California fivespined ips, *Ips paraconfusus*, and southern pine beetle, *Dendroctonus frontalis*, represent two native bark beetles that have recently caused elevated tree mortality at the northern edge of their ranges. The Douglas-fir beetle, *Dendroctonus pseudotsugae*; goldspotted oak borer, *Agrilus auroguttatus*; and walnut twig beetle, *Pityophthorus juglandis*, represent three examples of indigenous exotic species that have been moved in raw wood products and have caused varying degrees of impact in the USA. International trade continues to increase the number of exotic insect introductions into North America. In 2012, the exotic polyphagous shot hole borer, *Euwallacea* sp., was linked to tree injury in southern California, with rather dramatic impacts in urban forests and agroecosystems. Its impact is being quantified in riparian forest corridors in the southern California National Forest System. This ambrosia beetle, and a related species in the Southeast, the redbay ambrosia beetle, *Xyleborus glabratus*, are accompanied by pathogenic fungi that exacerbate their impacts. Finally, actual and projected impacts will be discussed and contrasted for two long entrenched hardwood woodborers of Asian origin: Asian longhorned beetle, *Anoplophora glabripennis*, and emerald ash borer, *Agrilus planipennis.*

b. **Speakers and Abstracts**:

i. **Forest responses following emerald ash borer (*Agrilus planipennis*) induced ash mortality in southeastern Michigan**. *Wendy S. Klooster[1], P. Charles Goebel[2], Catherine P. Herms[3], Deborah G. McCullough[4], Annemarie Smith[5], Kamal J.K. Gandhi[5], Diane Hartzler[5], Kathleen S. Knight[6], John Cardina[3], and Daniel A. Herms[5].* *[1]Department of Entomology, The Ohio State University, Columbus, OH 43210. [2]School of Environment and Natural Resources, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691. [3]Department of Horticulture and Crop Science, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, Ohio 44691. [4]Departments of Entomology and Forestry, Michigan State University, 243 Natural Science Building, East Lansing, MI 48824. [5]Department of Entomology, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691. [6]USDA Forest Service Northern Research Station, Delaware, OH 43015.* As emerald ash borer (EAB; *Agrilus planipennis*) continues to spread throughout North America, land owners and managers are faced with the loss of untold millions of ash (*Fraxinus spp.*) trees. Our objective was to determine if extensive ash mortality has altered the successional trajectory of the native and invasive plant communities. We established 42 transects, each containing three 0.1 ha plots, in seven natural areas in southeast Michigan. Transects were classified according to soil moisture from dry (xeric) uplands previously containing white ash, to more organic (mesic) sites previously containing green ash, to wet (hydric) sites previously dominated by black ash. In this region, ash tree mortality exceeded 99% by 2009, and the ash seed bank was depleted by 2007. Gap fraction values were calculated from hemispherical photographs taken throughout the transects. Ash importance values (IVs) (relative basal area × relative density × relative dominance) were calculated using tree data collected prior to ash mortality; values were compared across moisture levels with the highest IVs in hydric plots and the lowest in xeric plots. Based on stem counts, Simpson's index of diversity was higher in hydric than in mesic or xeric plots. Density of invasive plants was not correlated with plot mean gap fraction, ash importance, or ground layer percentage cover. Growth of selected invasive and native plants in the understory was measured annually as length × width × height. Invasive shrubs grew faster than native shrubs, and growth of native and invasive plants was positively correlated with gap fraction in hydric plots. Growth was not related to ash IV for any moisture level. Gap fraction was negatively correlated with canopy cover in the subcanopy (2-5 m) layer, suggesting that any increase in light due to canopy gaps formed by ash mortality is likely being intercepted before reaching the ground or understory layers. In 2013, over 850 trees comprising a variety of non-ash species, shade-tolerance levels, and canopy positions were cored using a standard increment borer. Initial analyses of the tree cores indicate species-specific responses to ash mortality. The majority of species exhibiting positive correlations between ash IV and increased ring widths (trunk growth) are either shade-tolerant or intermediate species, whereas the ring widths for most of the shade-intolerant species were not correlated with ash IV. Furthermore, the canopy position of the trees (whether dominant, codominant, intermediate, or suppressed) may have an affect on their response to ash mortality, with ring widths of some codominant species increasing in size; however, additional analyses are being performed to clarify the initial observations.

ii. **Asian longhorned beetle**. *Charles Canham*. No Abstract.

iii. **Impact of the walnut twig beetle, *Pityophthorus juglandis*, and the thousand cankers disease pathogen, *Geosmithia morbida*, in native and potentially naïve walnut stands in the southwestern USA.** *Andrew Graves, USDA Forest Service, Forest Health Protection, Albuquerque, NM; Tom Coleman, USDA Forest Service, Forest Health Protection, Albuquerque, NM; Corwin Parker, University of California Davis, Davis, CA; Steven Seybold, USDA Forest Service Pacific Southwest Research Station, Davis, CA.* The walnut twig beetle (WTB), *Pityophthorus juglandis*, is a bark beetle that is likely native to New Mexico and Arizona were it attacks and feeds under the bark of native Arizona walnut, *Juglans major*. It was originally collected in 1896 near Silver City, NM in the Lone Mountain mining district from *J. major*. It vectors a filamentous ascomycete, *Geosmithia morbida*, the causal agent of thousand cankers disease (TCD). As of 1960, the beetle was only known from 4 counties in the southwestern USA and from Mexico. As of Sept. 2015, the beetle has been collected from 127 counties from nine states in the West and seven states in the East. It has also been collected from at least one region in Italy. Although the origin and spread of what is now being considered two lineages of WTB are not entirely understood in the West, a phylogenetic analysis of WTB populations suggest that the WTB was transported to the East via human activity, and most likely from CA, CO, or the Northwest. Generally the same pattern holds true for the fungus, though more study is needed to determine how the complex was transported and how the WTB lineages have interacted within the current western distribution. Our first objective was to quantify the impact of WTB and TCD throughout the native range of the beetle and the fungus. In 2011 and 2012, monitoring sites were established in 10 national forests and two national parks in CA (*J. californica*), AZ (J. major), and NM (J. major). General forest characteristics were recorded and the health of each walnut tree was assessed by determining 1) whether WTB was present; 2) the impact of feeding on crown condition and crown dieback (crown rating); and 3) whether there were signs of branch staining caused by *G. morbida*. Briefly, WTB was found to be associated with larger trees throughout the Southwest. In general, crown rating was impacted negatively by the presence of WTB. Of all the *Juglans* trees surveyed, 54% showed evidence of WTB [*J. major* (47.8%) and *J. californica* (65.2%)]. Approximately 85% of all dead *Juglans* had evidence of old WTB galleries that had scored the xylem. Over 15% of *J. major* and 35% of *J. californica* had evidence of WTB without any apparent crown symptoms which suggests that crown rating, alone, cannot fully capture the extent and impact of WTB. Our second objective was to determine the flight periodicity of WTB in NM. From March 2013 to the present, we monitored a transect of funnel traps baited with the male-produced WTB aggregation pheromone on an elevational gradient in SE NM. The transect included 11 sites near Ruidoso, NM and extended eastward towards Roswell, NM. Our results show that WTB, generally, has 2 flights/year. The first occurs between mid-April through mid-June and the second, larger flight occurs around late August into September. We also found that trap catches were lowest at the upper and lower elevations, and the majority of beetles were trapped around 2000 m in elevation. A major concern with TCD is the potential for WTB to spread eastward from NM through TX by colonizing isolated populations of another potential host, little walnut, *J. microcarpa*. The behavior of native populations of WTB in NM in this and other hosts is not well understood. WTB has never been collected from *J. microcarpa* in NM or TX. Therefore, we conducted a host selection study in 2013 and 2014 when WTB was flying near Ruidoso, NM. In 2013, branch sections of *J. major, J. microcarpa, J. nigra,* and *J. hindsii* were tested, whereas.in 2014, the previous four hosts were tested, and *J. californica* was added to the experiment. The tests were conducted by hanging WTB pheromone baited branch sections on a piece of conduit around a native J. major tree. After 2-3 weeks, branch sections were removed, entrance holes counted, and the branch sections were placed in a rearing container. Emerging adults were counted, and parental adults were separated from brood adults based on cuticle color. The attack density was greatest on *J. nigra* during both studies; significantly lower on *J. microcarpa* (in 2013) and on *J. major* and *J. hindsii* (in 2014). In 2013, the highest emergence was from *J. nigra* and *J. major*. In 2013, emergence was significantly lower in J. microcarpa. In 2014, the highest emergence was from J. californica, followed by *J. nigra, J. microcarpa*, and *J. major*. Based on these studies, we know that WTB and *G. morbida* are having a pronounced impact on native walnut trees throughout their native range. These data show that WTB in NM has two flights per year and that there is an impact of elevation on the population levels of the insect, but that populations are highest where J. major is a concentrated portion of the forest. Based on the host selection studies, *J. nigra* is preferred host by New Mexican WTB and WTB can readily produce brood in this host. Although *J. microcarpa* can support development of two populations of WTB based on observations in a germplasm collection in CA and based on the host selection studies reported here, we have yet to observe colonization of *J. microcarpa* by WTB in native stands..

4. **Arthropogenic Effects: Tree-Mediated Interactions Among Forest Insects. (Harding)**
   Moderators: *Jonathan Cale and Jennifer Klutsch*
   a. **Session Abstract:** Like humans, herbivorous insect populations drastically alter the environment in which other organisms develop. From the scale of individual trees to landscapes, tree-mediated interactions among forest insects have significant effects on co- or subsequently-occurring insect species. These interactions can shift in directionality (e.g., from antagonistic to facilitative) due to altered nutritional content or quality of host plant tissue in response to insect feeding. Especially important for forest pests, these chemical ecological changes can be significant determinants of insect population establishment, reproduction, and growth. Multipartite studies are increasingly recognized for allowing researchers to look beyond comparatively simple investigations to interpret and understand insect-tree interactions through a more multifaceted, ecological lens. An understanding of tree-mediated interactions among forest insects is important to developing targeted pest management strategies, for example, in exploiting host physiological changes to mitigate forest loss or predict impacts to insect diversity. The goal of this session will be to highlight mechanisms by which non-native and native forest insects affect, and in turn are affected by, herbivore-induced changes to host condition and chemistry. Further, it will identify how an understanding of tree-mediated interactions can be used in forest pest management.
   b. **Speakers and Abstracts**:
      i. **Interactions between invasive species in a forest ecosystem: hemlock woolly adelgid, elongate hemlock scale, and eastern hemlock.** *Evan L. Preisser. Department of Biological Sciences, University of Rhode Island, Kingston, RI*. The hemlock woolly adelgid, *Adelges tsugae* (HWA) is an invasive herbivore that poses a major threat to eastern hemlock (*Tsuga canadensis*) in eastern North America. High-density HWA infestations can kill even mature trees in 4-10 years; as a result, substantial hemlock mortality has occurred from VA to MA. Despite fears that HWA would remove hemlocks from southern New England, however, stand-level mortality in this area is occurring much more slowly than predicted. Although overwintering mortality of HWA has played a role in reducing hemlock mortality, another potential (but non-exclusive) explanation involves the recent rapid range expansion of a second introduced insect, the elongate hemlock scale, *Fiorinia externa* (EHS). While EHS can reduce hemlock growth and may be capable of killing stressed trees, its impact on tree health is minimal compared to that of HWA. Neither HWA nor EHS possess natural enemies capable of substantially limiting their population growth in the invaded range, and both are now abundant in southern New England. I report the results of research exploring the interactions between these two insects and their

common hemlock host, and the herbivores' individual and joint impact on hemlock physiology. Understanding the interactions between these two invasive pests, and why they have such disparate impacts on hemlock health, may provide information important to controlling both threats.

ii. **Host tree-insect interactions in northern forest ecosystems in a changing climate.** *Deepa Pureswaran[1], Louis De Grandpré[1], Véronique Martel[1], David Paré1, Xavier Prairie[2], Christian Hebert[1], and Dan Kneeshaw[2]. [1]Canadian Forest Service, Laurentian Forestry Centre, Quebec City; [2]Université du Quebec à Montreal, Canada.* Insect outbreaks in northern forests of Europe and North America have recently been increasing in magnitude and severity. Host plant quality plays an important role in determining the performance of herbivorous insects. Synchronised emergence of insects from diapause in the spring with bud burst phenology of their hosts is crucial to successful completion of their life cycles, particularly in climates where summers are short. In response to a warmer climate, changes in phenological synchrony have consequences on outbreak behaviour of forest insects in northern latitudes. Consequences include shifts on to new or secondary host species, changes in insect life history traits, range expansions and changes in disturbance patterns in general. Using the spruce budworm as our model system, we discuss the cascading effects of phenological changes in host trees on: insect herbivory, effect of natural enemies, changes in forest composition and ecosystem productivity. We predict that northern ecosystems in which host trees have not co-evolved with severe disturbance regimes could suffer from impacts on resilience and stability. We therefore need to improve our understanding of climate-driven impacts on complex ecosystem interactions. Forest management strategies need to take into account thresholds for ecosystems beyond which changes due to severe disturbance may not be easily reversible.

iii. **Too much of a good thing: landscape-scale facilitation eventually turns into competition between a lepidopteran defoliator and a bark beetle**. *Goodsman, D. W.[1], J. S. Goodsman[2], D. W. McKenney[3], V. J. Lieffers[4], N. Erbilgin[4]. [1]Department of Biological Sciences, University of Alberta; [2] Department of Geography University of Lethbridge; [3] Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre; [4] Department of Renewable Resources, University of Alberta.* The sharing of host plants by multiple insect species can result in plant-mediated interactions between them. Interactions may be facilitative if prior infestation by one species provides a toehold for another, or they may be competitive if prior infestation by one species degrades the quality of tree tissues for the other. Using time-series and logistic regression models, we probed landscape-wide operational data on the spatial extent and severity of damage caused by the two-year cycle spruce budworm (*Choristoneura biennis* (Freeman)) and the spruce beetle (*Dendroctonus rufipennis* (Kirby)) for evidence of interspecific interactions. We found that the occurrence and severity of spruce beetle damage was positively impacted by prior low severity defoliation by the two-year cycle spruce budworm but negatively impacted by high-severity defoliation. Thus, interactions between the spruce beetle and the two-year cycle spruce budworm can shift from positive to negative depending on defoliation severity. Thus, by sanitizing stands that have been lightly impacted by the two-year cycle spruce budworm, managers may minimize subsequent damage by the spruce beetle.

10:30 – 11:00 Break (Marriott Foyer)

11:00 – 12:30 Concurrent Session 8

1. **Invasions by Non-Native Forest Insects and Diseases: Efficient Solutions 2 (Thurgood Marshall Northeast)** Moderators: Kirsten Prior, *Sandy Liebhold, Jiri Hulcr*
    a. **Session Abstract:** Worldwide, the field of forest health is increasingly dominated by problems associated with non-native insects and diseases. Trends of increasing globalization are driving the arrival of these species and as establishments of these pests accumulate, their impacts on forest resources continue to grow. This session will cover the various options that exist for managing the forest pest invasion problem. One tactic involves measures to prevent these species from arriving in the first place, through pre-invasion risk assessments and pathway management. Once a species is introduced, surveillance and rapid-decision making are important for practical eradication programs. Once a species establishes and spreads, implementing a successful eradication becomes increasingly difficult. At these stages management strategies via classical biological control or the development of resistant tree genotypes holds promise for at least partially mitigating the impacts of invading pest populations. In this session, invited speakers will discuss current research on each of these management strategies from scientific and socio-economic perspectives. Advantages and disadvantages of each strategy will be discussed.
    b. **Speakers and Abstracts**:
        i. **Learning from the legacy of historical eradication programs: when to pull no punches and when to throw in the towel.** *Patrick C. Tobin[1], Angela M. Mech[1], John M. Kean[2], David Maxwell Suckling[3], Deborah G. McCullough[4], Daniel A. Herms[5], and Lloyd D. Stringer[3]. [1]School of Environmental and Forest Sciences, University of Washington, Seattle, WA. [2]AgResearch Limited, Ruakura Research Centre, Hamilton, New Zealand. [3]The New Zealand Institute for Plant & Food Research, Christchurch, New Zealand. [4]Departments of Entomology and Forestry, Michigan State University, East Lansing, MI. [5]Department of Entomology, The Ohio State University, Wooster, OH.* Despite substantial increases in public awareness and biosecurity systems, introductions of non-native arthropods remain an unwelcomed consequence of escalating rates of international trade and travel. Detection of an established but unwanted nonnative organism can elicit a range of responses, including doing nothing (the most common response) to implementing an eradication program. Previous studies have reviewed the concept of eradication, but these efforts were largely descriptive and focused on selected case studies. We developed a Global

Eradication and Response Database (''GERDA'') to facilitate an analysis of arthropod eradication programs and determine the factors that influence eradication success and failure. At present, this database contains information on 969 eradication programs targeting 165 arthropod species in 104 countries. Important components of successful eradication programs included the size of the infested area, relative detectability of the target species, method of detection, and the primary feeding guild of the target species. The outcome of eradication efforts was not determined by program costs, which were largely driven by the size of the infestation. The availability of taxon-specific control tools appeared to increase the probability of eradication success. We believe GERDA, as an online database, provides an objective repository of information that will play an invaluable role when future eradication efforts are considered.

ii. **Ecological responses to invasive species removal**. *Kirsten M. Prior[1], Damian C. Adams[1], Kier D. Klepzig[2], Jiri Hulcr[1]. [1]School of Forest Resources and Conservation, University of Florida, Gainesville, FL. [2]U.S. Forest Service, United States Department of Agriculture, Southern Research Station, Asheville, NC.* Often the best ways to manage invasive species are to prevent their introduction or catch them before they establish and have impacts. However, for many already established and damaging species, it is too late for these approaches, and practitioners need to make decisions about how to manage invasive species and invaded ecosystems. They can take several approaches, including doing nothing, or implementing an eradication or control program. The goal and actions of most invasive species management programs aim to reduce or eliminate populations of invasive species. However, most programs are embedded within broader goals, such as alleviating the impact of invasive species on forest ecosystems. These proximate and ultimate goals of management programs may not align. Non-target effects of management actions on native species and ecosystems are a well-known example of how management goals don't align. Recent literature has also highlighted that invasive species removal may trigger collateral impacts or negative "surprise effects." We present the results of a global quantitative synthesis of over 100 studies that: (1) have eradicated or aggressively suppressed invasive species, and (2) have assessed ecosystem recovery over time. So far, our review reveals that in 69% of removal programs, ecosystems had mixed or positive recovery and that only 24% of programs resulted in unanticipated damages. Critically, we discuss the importance of expanding the definition of "management success" beyond population reduction. We discuss the relevance of this topic to forest health management by highlighting cases of ecological responses to the management of invasive forest insect pests.

iii. **Tree resistance as a primary tool to respond to established invasions by cryptic, tree killing forest pathogens and insects**. *David Showalter[1], Jason Smith[2], Kenneth Raffa[3], Richard Sniezko[4], Daniel A. Herms[5], Andrew Liebhold[6], Pierluigi Bonello[1]. [1]Department of Plant Pathology, The Ohio State University, 2021 Coffey Road, Columbus, OH 43210, USA. [2]School of Forest Resources and Conservation, University*

of Florida, P.O. Box 110410 Gainesville, FL 32611, USA. [3]*Department of Entomology, University of Wisconsin-Madison, 345 Russell Laboratories, 1630 Linden Dr., Madison, WI 53706, USA.* [4]*U.S. Forest Service, United States Department of Agriculture, Dorena Genetic Resource Center, 34963 Shoreview Dr., Cottage Grove, OR 97424, USA.* [5]*Department of Entomology, Ohio Agricultural Research and Development Center, The Ohio State University, 1680 Madison Avenue, Wooster, OH 44691, USA.* [6]*U.S. Forest Service, United States Department of Agriculture, Northern Research Station, Morgantown, WV 26505, USA.* Massive global trade of goods is facilitating movement of alien phytophagous insects and phytopathogens (PIPs) of trees. A fraction of these organisms defeat measures intended to exclude them from naïve forest ecosystems, e.g. those designed to prevent transport or to eradicate early infestations. Eventually, some cause severe economic and environmental impacts by killing vast numbers of trees, occasionally on continental scales. It is becoming increasingly clear that many of the most devastating alien PIPs become invasive largely due to a lack of bottom-up control that is otherwise exerted by host defenses in their native region. These PIPs, acting in the "defense-free space" of naïve environments, are often intimately and cryptically associated with their hosts, which makes early detection very difficult, and damage tissues with high fitness value and low compensatory mechanisms, thereby quickly killing their hosts and limiting the effectiveness of density-dependent biological control. We posit that once such PIPs become established, responses should immediately and sustainably integrate strategies that transition valuable tree populations toward an environment in which these particular PIPs exist in "defense-constrained space", i.e. through the development of host resistance. A combination of traditional selection and breeding, rapidly advancing genomic and phenotypic marker techniques, and targeted genetic engineering, offers great potential to accelerate development and deployment of diverse populations of locally-adapted, PIP-resistant trees. Integrated host resistance development programs have considerable potential to conserve and/or restore threatened tree species and their ecosystem services, as productive components of urban, plantation and naturally regenerating forests.

iv. **Safe use of exotic agents for biological control in forests***.* *Ann E. Hajek, Department of Entomology, Cornell University, Ithaca, NY 14853-2601 USA*. Classical and augmentation biological control have been successfully used over many years for controlling insect pests in forests, with particular emphasis on invasive pests. In the 1980-1990s the environmental safety of use of exotic biological control agents fell under intense scrutiny by the scientific community as well as the public. Since that time, new methods and regulations have been developed for use of environmentally safe agents, including risk assessments. Evaluation of non-target impacts across all types of systems have shown that ecologically significant impacts have rarely been reported (although some poor decisions were definitely made in the past). Biological control is presently being used to control very serious invasives in forests although the before introductions are possible is much longer and the numbers of species released is much less. However, we expect that with the increased knowledge about each agent, the percentage of releases that are successful will increase. In summary, the community of scientists working in biological control are now working toward environmental safety along with improving the success of biological control of forest insects.

2. **Factors Influencing Forest Insects at Range Margins** Moderators: *Barbara Bentz and Brian Aukema*

a. **Session Abstract**: Forest insects follow the distribution of their host tree species. In many cases, however, the distribution of the host tree species is larger than that of the insect species. Several factors influence restricted insect ranges including climate suitability for persistent population success at range margins, community associates and novel forest habits. For example, phenotypic plasticity in life-history traits can allow for population growth when released from climate restrictions, as has occurred recently with changes in precipitation and temperature patterns across North America. We will discuss factors that influence forest insect populations at range margins, including key life history traits that are being influenced by a changing climate.

b. Speakers and Abstracts:

i. **Mountain pine beetle at range margins in the western United States***.* *Barbara J. Bentz*[1]*, Matt Hansen1, Jim Vandygriff*[1]*, Anne McManis*[2] *and Jim Powell*[2]*.* [1]*USDA Forest Service, Rocky Mountain Research Station, Logan UT.* [2]*Biology and Mathematics and Statistics Departments, Utah State University, Logan, UT.* The range of mountain pine beetle (MPB, *Dendroctonus ponderosae*) in western North America has been historically dynamic, a result of pre-and post-glacial climatic changes and associated host tree distributions. Within the past century, and prior to the recent warming event, MPB occupied a thermal niche across *Pinus* forests of western North America extending from southern California and central Arizona in the southwest United States (US) to central British Columbia, Canada. Host tree resources, however, extend both to the north and south of the current distribution, and recent climate change-induced northward range expansion occurred as individuals migrated into new *Pinus* habitats that warmed sufficiently for population success. In contrast, southward range expansions are generally thought to be limited by warming temperatures that exceed the upper limits for successful development and survival. Our research is aimed at understanding life history traits and other factors that may be influencing MPB at its range margin in the southwestern US, and the potential for population expansion.

ii. **Why are southern pine beetles not so southern anymore?** *Matt Ayres*[1]*, Jeff Lombardo*[1]*, Carissa Aoki*[1]*, Ken Clark*[2]*.* [1] *Biological Sciences, Dartmouth College, Hanover, NH 03755, USA.* [2] *USDA Forest Service, Northern Research Station, Silas Little Experimental Forest, New Lisbon, NJ 08064, USA. Dendroctonus frontalis* Zimmermann is among the most aggressive tree-killing insects in the world. *D. frontalis* is indigenous to southern North America, where it has historically been the dominant source of disturbance in extensive tracts of southern pine forests. Over the last two decades, *D. frontalis* has extended its distribution northward, first in the New Jersey Pinelands, then on Long Island, and now in New England at multiple points north, east, and west of Long Island. At the same time, D. frontalis has become effectively extinct in East Texas and Louisiana, which was the epicenter for *D. frontalis* outbreaks up until only 15 years ago. Our research has addressed the following questions. Why the northward expansion of *D. frontalis*? Has the northward expansion been facilitated by *D. frontalis* reaching ecosystems that were ecologically and evolutionarily naïve to this southern pest? Is the explanation for the disappearance of southerly *D. frontalis* symmetrical to that for the expansion of northern populations (as predicted by the Climatic Envelope concept)?

iii. **Can gypsy moth stand the heat?: Performance at the southern invasion front.** *Kristine L. Grayson[1], Lily M. Thompson[1], Dylan Parry[2], Derek M. Johnson3, and Patrick C. Tobin[4]. [1]Department of Biology, University of Richmond; kgrayson@richmond.edu. [2]State University of New York, Environmental Science and Forestry. [3]Department of Biology, Virginia Commonwealth University. [4]School of Environmental and Forest Sciences, University of Washington*. For invasive insects, climate change could open new habitats to invasion or impose environmental barriers to further spread. The gypsy moth (*Lymantria dispar*) is an invasive folivore in North American hardwood forests and represents one of the best documented biological invasions in the world. Spread rates across the invasion front are extremely dynamic, with some regions experiencing expansion while the invasion front in other regions is static or contracting. The southeastern edge of the invasion front in the Piedmont and Coastal Plain of Virginia is a region experiencing stasis and contraction of the gypsy range, potentially due to high temperature exposure during larval and pupal development. The objective of our research is to quantify the geographic variation in lethal and sublethal effects of supraoptimal temperatures on gypsy moth growth and development in a variety of experimental venues. Our work compares population responses to temperature in field experiments and growth chamber experiments, both at constant and fluctuating temperature regimes. While constant temperature experiments indicate the potential for local adaptation for increased survival and developmental traits in gypsy moth, we did not find population differentiation in an outdoor reciprocal transplant experiment between the Mountain and Coastal Plain regions of Virginia. We did find evidence of sublethal effects on gypsy development in the Coastal Plain region. We are currently testing for differences in egg viability and hatching synchrony with spring bud burst under these invasion-front climates. Understanding the role of physiological tolerances and local adaption at the range edge of invasive species can inform the potential for further spatial spread.

iv. **Beyond the margins: altered dynamics of an eruptive bark beetle in novel habitats.** *Allan L. Carroll, Stanley W. Pokorny and Jordan L. Burke, Dept. of Forest & Conservation Sciences, University of British Columbia, Vancouver, BC, Canada.* Since

2006, the mountain pine beetle has expanded its range by over 400 km to the east and a similar distance to the north, invading novel pine habitats comprising putatively evolutionarily naïve host tree populations and species. Recent evidence suggests that interactions between the beetle and naïve host trees are very different than those associated with the beetle's native range. These altered interactions have been implicated in the extraordinarily high rates of tree mortality in the northern portions of the most recent outbreak, and strongly suggest that continued range expansion by mountain pine beetle could threaten the resilience of northern pine forests. We will discuss the consequences of novel trophic interactions in newly invaded habitats within the context of the eruptive population dynamics of the mountain pine beetle, and consider their implications to continued range expansion.

v. **Enhanced performance of eastern larch beetles at southern range margins**. *Brian Aukema*[1] *and Fraser McKee*[1,2]. [1]*Department of Entomology, University of Minnesota, St. Paul, MN.* [2]*Alberta Sustainable Resource Development*. In the past 15 years, the eastern larch beetle *Dendroctonus simplex* has erupted over extensive regions of tamarack *Larix laricina* in the Lake States region. These areas match the southern distribution of tamarack in North America. Sustained tree-killing behavior by eastern larch beetle is a stark departure from previous patterns of outbreak activity for this typically benign bark beetle. We present evidence for the ability of a portion of the population of eastern larch beetles to shift from uni- to fractional voltinism, and suggest that extended growing seasons concomitant with a changing climate are driving these outbreaks.

3. **Assessing the Impact of Populations of Bark Beetles and Woodborers With Expanding Ranges in North America – Session 2.** Moderators**:** *Tom W. Coleman and Steven J. Seybold*
   a. **Session Abstract:** The second sequential 90 minute session will address impacts of other bark beetles and woodborers (like EAB, ALB, tea shot hole borer, redbay ambrosia beetle, soapberry borer, etc.). This will provide even greater regional coverage. The analysis of the impact of these pests with expanding ranges has not been given much attention, but it is very valuable information for decision makers, funders, etc.
   b. **Speakers and Abstracts**:
      i. **Southern pine beetle in northeastern pitch pine forests***. Kevin J. Dodds, U.S. Forest Service, Forest Health Protection, Durham, NH.* Southern pine beetle (SPB) infestations were detected for the first time on Long Island, New York during the fall 2014. Subsequent aerial detection surveys conducted over portions of Long Island indicated a widespread SPB outbreak in pitch pine-hardwood and pitch pine forests. Southern pine beetle was also found infesting trees in Connecticut in early winter 2015. Based on detections on Long Island and in Connecticut, trapping surveys were undertaken during spring 2015 throughout southern New England and New

Hampshire. SPB was detected in Connecticut, Massachusetts, Rhode Island, and in New York outside of Long Island. Hard pine is relatively rare in these areas, but unique and rare ecosystems of red, pitch, and jack pine exist throughout New England and have high conservation value. These stands are now threatened by the potential spread of SPB. In infested stands on Long Island, large numbers of overstory pitch pine have been lost to SPB with the tree species often eliminated from the overstory. Stand structure will shift into mixed hardwood stands now that almost all pine are dead and there is very little pine regeneration present in the understory. A multiagency integrated pest management plan has been developed for SPB on Long Island. This plan involves prioritizing the Central Pine Barrens Core Preservation Area for management, including cut-and-leave treatment of spots.

ii. **Distribution and flight periods of the California fivespined Ips (*Ips paraconfusus*) in the Pacific Northwest.** *Robbie W. Flowers, USDA Forest Service, Forest Health Protection, Bend, OR. Glenn R. Kohler, Washington Department of Natural Resources, Olympia, WA. Todd A. Murray, Washington State University, Pullman, WA. Elizabeth A. Willhite, USDA Forest Service, Forest Health Protection, Sandy, OR.* The California fivespined Ips (CFI) has historically been a pest of ponderosa pine and other pine species in California and Oregon. In 2010, an outbreak of CFI along the Columbia River Gorge and adjacent private lands resulted in the first recorded detection of this species in Washington State. Higher than expected levels of mortality of ponderosa pine in these areas have occurred consistently since that time in association with damage from wildfires, storm events, and drought. Since 2010, cooperative efforts have been focused on assessing the current range of CFI, documenting the flight periods of CFI in Washington State, and conducting outreach to assist forest managers in mitigating the impacts of CFI. From 2010-2015, pheromone trapping was used to assess the relative distribution of CFI and *Ips pini* at 31 locations east along the Columbia River Gorge and north into western Washington. To date, new records of CFI have been documented in three Oregon counties and seven Washington Counties. These records extend the previously reported range of CFI by approximately 130 kilometers to the east and 160 kilometers to the north. Populations of CFI and *I. pini* did not appear to overlap at most trapping locations. The two locations with the highest captures of CFI indicated 2 generations per year consistent with previous findings in the Willamette Valley. Trees affected by CFI frequently had attacks from red turpentine beetle *(Dendroctonus valens),* while western pine beetle (*D. brevicomis*) activity was uncommon within CFI outbreak areas. It is unclear if the range of CFI reported here represents previously undetected populations, re-colonization, or range expansion. Reviews of regional insect collections have not produced any previous Washington records of CFI or *I. confusus*. Drought conditions and other environmental factors appear to have contributed to the unexpected high number of trees killed within these outbreak areas over several consecutive years. Outreach efforts are ongoing to raise awareness about CFI and relay best management strategies through site visits, workshops, and University Extension publications.

iii. **Impacts of the redbay ambrosia beetle and the laurel wilt pathogen in the Southeastern USA.** *Albert Mayfield[1], Jason Smith[2], Steven Fraedrich[1], John Riggins[3], Marc Hughes[2], and James Hanula[1]. [1] USDA Forest Service, Southern Research Station. [2] University of Florida. [3] Mississippi State University.* The plant family Lauraceae includes over 2000 species worldwide, many of which contain aromatic essential oils and have high cultural, ecological and economic importance. Since the early 2000s, a disease known as laurel wilt is estimated to have killed nearly half a billion trees this family in the Southeastern USA. The disease is caused by an ambrosial fungal symbiont (*Raffalelea lauricola*) of the redbay ambrosia beetle (*Xyleborus glabratus*) that was introduced from Asia. The insect-pathogen complex has spread from the southeastern Atlantic coast through the coastal plain and into eastern Texas, where it is now only a few hundred kilometers from the border with Mexico. In the field, laurel wilt has been confirmed in at least seven native woody species (redbay, swampbay, silkbay, sassafras, pondberry, pondspice, and northern spicebush) and three non-native cultivated or naturalized species (avocado, camphortree, and European bay laurel). Tree mortality due to laurel wilt has been dramatic in stands containing redbay and sassafras, where about 93 percent of the basal area of these species are killed within four years. In Florida, laurel wilt has killed substantial portions of the tree canopy on ecologically unique Everglades tree islands and also threatens cultural and medicinal uses of swampbay and redbay by Native American Indian tribes. Field counts of the Palamedes swallowtail butterfly, a native orchid pollinator closely associated with its primary larval host plant, redbay, have decreased in laurel wilt-affected stands compared to unaffected stands. Thousands of avocado trees have been killed by laurel wilt in commercial groves, where sanitation has become an important management strategy to prevent suspected pathogen transmission through root grafts. Artificial inoculation trials and hanging bolt studies indicate that the western species California bay laurel is susceptible to the pathogen and is a suitable brood host for the vector. Management strategies for laurel wilt in natural systems are few and need to be developed as additional spread of the disease within and beyond the Southeastern USA is anticipated.

iv. **Tree injury and mortality associated with the polyphagous shot hole borer, *Euwallacea sp*., and Fusarium dieback, *Fusarium euwallaceae*, in California, Vietnam, and China.** *Tom W. Coleman[1] Adrian Poloni[2], Robert Rabaglia[3], Gary Man[3], and Steven J. Seybold[4]. [1]USDA Forest Service, Forest Health Protection, Albuquerque, NM, USA. [2]Department of Entomology and Nematology, University of California, Davis, USA. [3]USDA Forest Service, Forest Health Protection, Washington, D.C., USA. [4]USDA Forest Service, Pacific Southwest Research Station, Davis, California, USA.* Polyphagous shot hole borer, *Euwallacea* sp. (Coleoptera: Scolytinae), and fusarium dieback (FD), *Fusarium euwallaceae* (Hypocreales: Nectriaceae), is a new insect-disease complex to southern California. Since 2012, the insect-disease complex has spread to five counties in southern California and injured and killed several native, ornamental, and agriculturally important tree species. To date, PSHB can successfully reproduce in greater than 35 tree species in California, including numerous native tree species (e.g., *Acer* spp., *Salix* spp., *Platanus* spp., and *Quercus* spp.). To assess the potential threat of PSHB-FD in North America, we surveyed the level of infestation and mortality in native stands in southern California. Forest health surveys were also conducted in southern China and northern Vietnam where the beetle may be native. From 2012 to 2015, forest stands in southern California were surveyed for injury associated with PSHB. During these surveys, individual data was collected for trees present in the stand, including tree species, diameter at breast height (DBH), infestation by PSHB (Y/N), degree of PSHB attacks along the main stem and larger branches (rating of 1: <10 attacks, 2: 10 to 30 attacks, or 3: >30 attacks), crown thinning (rating of 1: healthy, no thinning, 2: minor thinning/dieback, 3: moderate thinning/dieback, 4: severe thinning/dieback, or 5: dead), tree status (living/dead), and other insect injury present. The density of PSHB attacks was recorded in a 232 cm2 area from breast height and 30.5 cm from the root collar on severely injured and dead trees. Twenty-six (26) tree species were identified during the surveys and approximately 1,800 trees were surveyed. Following preliminary analyses, tree infestation (92%) and mortality (27%) from PSHB was most common on box elder, *Acer negundo*. California sycamore, *Platanus californica*, castor bean, *Ricinus communis*, Fremont cottonwood, *Populus fremonti*, red willow, *Salix laevigata*, and white alder, *Alnus rhombifolia*, also had high levels of infestation (>50%) and degree of injury on the main stem and larger branches (>10 attacks) from PSHB. Low levels of tree mortality (<20%) were associated with PSHB across all these tree species. The density of PSHB attacks on trees severely injured or dead trees was highest on *A. negundo* and subsequently followed by *R. communis* and *S. laevigata*. In contrast, only low levels of injury and no tree mortality were surveyed for avocado in the urban areas. During the surveys in southeast Asia, PSHB was observed attacking *Acacia mangium* at low levels (3% infestation rate) in Vietnam, whereas *Platanus orientalis* and *Acer buergerianum* were attacked at high levels (58% and 57% infestation rate, respectively) in the urban areas of Kunming, Yunnan Province. Impact surveys will continue in southern California and a risk assessment is being developed for PSHB to assess the potential host range and spread of this new insect-disease complex.

4. **Changing Forests, Imperiled Habitats – The Roles Arthropods Play** (Harding) Moderators: *Luke E. Dodd and Lynne K. Rieske*

a. **Session Abstract:** As human disturbance and habitat fragmentation become increasingly pervasive, management and stewardship of unique forest ecosystems reaches its highest priority. Given the ubiquity and abundance of insects and other arthropods in forests, consideration of the roles that invertebrates play within these ecosystems is of primary concern. This is particularly true in unique and sensitive ecosystems that are often restricted in their distribution across the continent. The goal of our symposium is to highlight research aimed at understanding the interactions of insects and other arthropods within sensitive forest ecosystems across North America. Our session will attempt to present a widespread perspective of many such forest systems across North America.

b. **Speakers and Abstracts**:

i. **Boreal systems: Chemicals in novel host plants support climate-driven host expansion of the invasive mountain pine beetle in western Canada**. *N. Erbilgin[1], J. A. Cale[1], J Colgan[1], A. Hussain[1], G. Ishangulyyeva[1], S. Kanekar[1], J. G. Klutsch[1], M. Muskens[1], A. Najar[1], S. Taft[1], J. S. Manson[2]. [1] Department of Renewable Resources, University of Alberta. Edmonton, AB, Canada. [2] Department of Biological Sciences, University of Alberta. Edmonton, AB, Canada*. The invasive mountain pine beetle (MPB, *Dendroctonus ponderosae*) has recently invited the novel jack pine (*Pinus banksiana*) forests in western Canada. We have investigated suitability of Jack pine as a host for MPB and particularly focused on the compatibility of Jack pine chemicals with MPB and its symbiotic fungi. We have identified four likely mechanisms facilitating MPB host range expansion. First, Jack pine trees appeared to have less pronounced chemical defenses than a historical host of MPB, lodgepole pine (*P. contorta*). In particular, Jack pine not only lacks secondary compounds, such as limonene, necessary to defend itself, but also contains large amounts of chemicals, such as α-pinene and myrcene, that may facilitate beetle aggregation. These mechanisms potentially help beetles overcome jack pine resistance when the beetle population is particularly low. Second, prior to beetle arrival to Jack pine forests, MPB invaded a zone of Jack-lodgepole pine hybrids in Alberta. This has likely facilitated host shift and improved beetle success in jack pine because hybrids show chemical characteristics of both the novel and historical hosts. Third, changes in Jack pine chemistry due to prior insect and disease attacks likely affected the successful colonization of Jack pine by altering its suitability to MPB. Finally, the composition of secondary compounds and fatty acids in Jack pine is similar to that in the beetle's historical host. This may have allowed MPB to successfully colonize jack pine tree as its chemicals are compatible for pheromone production, aggregation on host trees, larval development, and fungal symbiont growth.

ii. **High elevation systems: Forest health threats cascade upward: Whitebark pine treeline communities and ecosystem functions in the Rocky Mountains**. *D.F. Tomback, Department of Integrative Biology, University of Colorado - Denver. Denver, CO, USA; E.R. Pansin, Department of Integrative Biology, University of Colorado - Denver. Denver, CO, USA; L.M. Resler, Department of Geography, Virginia Tech University. Blacksburg, VA, USA. G.P. Malanson, Department of Geographical and Sustainable Sciences, University of Iowa. Iowa City, IA, USA.*

Within the last decade, mountain pine beetles (*Dendroctonus ponderosae*) have ranked as the most important tree mortality agent in the United States. In 2009 alone, mountain pine beetle outbreaks were active across more than 3.5 million hectares of forest habitat. Although the outbreaks are declining yearly, widespread losses of large-diameter, cone-producing whitebark pine (*Pinus albicaulis*) to mountain pine beetles and also to *Cronartium ribicola* (white pine blister rust) have reduced seed availability for dispersal by Clark's nutcracker (*Nucifraga columbiana*) and thus regeneration in some Rocky Mountain regions. Whitebark pine is an important species in many Rocky Mountain subalpine communities but also a dominant conifer in many treeline communities. At treeline, whitebark pine is often the most common solitary tree and functions as a tree island initiator by providing windward protection for leeward tree establishment. Clark's nutcrackers cache whitebark pine seeds at treeline, leading to tree recruitment, but between whitebark pine mortality from blister rust and potentially lower seed dispersal rates, there may be a net loss. We examined the implications of reduced seed dispersal at the community level using datasets that estimated the fate of investigator-cached seeds at treeline. We extrapolated this information to explore the consequences of reduced whitebark pine establishment at treeline to snow retention, regulation of downstream flows, and protect against soil erosion. With potentially fewer whitebark pine, shifts in community composition, density, and treeline function are likely, especially with a warming climate.

iii. **Coastal forests: All that we let in: Exotic scolytine beetles, their fungal partners, and the diseases they cause.** *M.T. Kasson, Division of Plant and Soil Sciences, West Virginia University. Morgantown, WV, USA.* Over the last decade and a half, several destructive fungal plant pathogens have invaded American landscapes and forests, as co-evolved mutualists of exotic scolytine (bark and ambrosia) beetles. This includes laurel wilt, thousand cankers disease, and Fusarium dieback, which are responsible for the death of hundreds of millions of native trees throughout the eastern and western U.S. The diseases caused by these exotic beetles and their fungal partners continue to pose a significant threat to endemic deciduous tree species as well as cultivated fruit and nut trees. Another recent concern is that some of these beetles, once established, also serve as vectors for plant diseases not previously associated with beetles including diseases of non-native plants, some of which these beetles have co-evolved with in their native ranges. This includes Verticillium wilt, a historic native tree disease of various native plants that has recently caused unprecedented mortality of the invasive tree of heaven. This plant host is a preferred reproductive host of Euwallacea ambrosia beetles and in its diseased state may enhance the reproductive success and dissemination of these beetles into areas where novel interactions among native plants, beetles, and their fungal partners may give rise to novel tree diseases.

iv. **Appalachia: Disturbances in eastern deciduous forests lead to changes in lepidopteran communities.** L.*E. Dodd, Department of Biological Sciences, Eastern Kentucky University. Richmond, KY, USA. L.K. Rieske, Department of Entomology, University of Kentucky. Lexington, KY, USA.* Lepidoptera are among the most abundant and conspicuous of forest insects. Comprehensive inventories of nocturnal Lepidoptera exist across the eastern deciduous and northern boreal forests of North America, and data to date suggest these insects respond to a broad array of disturbance types in forests. In our presentation, we summarize emergent patterns for this group of insects, emphasizing the effects of disturbance scale and intensity. Additionally, we present novel data from two studies that describe the independent impacts of silvicultural harvest (Central Appalachians) and prescribed fire (Interior Plateau) on the diversity and community structure of nocturnal Lepidoptera. Considering the central role that Lepidoptera play within forest food webs, this group of insects is in need of increased depth and breadth of study.

12:30 Adjourn

Poster Session

1. **Allen-Abrahamson Student Poster Competition** Moderators: *Robert Jetton and Darren Blackford*; Student Poster Organizer: *Holly Wantuch*

    1. **Behavioral chemical disruption of the host selection behavior of the walnut twig beetle: A chemical ecological approach.** Jackson Audley[1], Steven J. Seybold[2], Paul L. Dallara[1], and Wittko Francke[3], *[1]Department of Entomology and Nematology, University of California, Davis HDH 001 Rm 116 Orchard Park Dr. Davis, CA; [2]USDA Forest Service Pacific Southwest Research Station 1731 Research Park Dr. Davis, CA 95681; [3]Institute of Organic Chemistry, University of Hamburg, Martin-Luther-King Platz 6, D-20146 Hamburg, Germany.* The California walnut industry is threatened by thousand cankers disease (TCD). The invasive walnut twig beetle (WTB), *Pityophthorus juglandis* Blackman (Coleoptera: Scolytidae), vectors the fungal pathogen, *Geosmithia morbida,* which causes necrosis around WTB galleries in the phloem. TCD is expressed as crown dieback, culminating in mortality, and will likely cause significant losses for the industry. Disrupting WTB's capacity to detect its host and conspecifics by applying repellent, non-host semiochemicals may reduce attack success and protect walnut trees from TCD. WTB flight trapping trials will be conducted with Lindgren funnel traps to test the efficacy of potential repellents: limonene, chalcogran, conophthorin, and verbenone. Traps will be baited with the WTB aggregation pheromone and a repellent (none for controls). First, tests of enantiomers at three release rates will be conducted for each of the potential repellents independently. Combinations of the most biologically active enantiomers, each at their optimal release rate, will be screened using the subtractive-combination method. Finally, the most effective repellent will be deployed on pheromone-baited English walnut, *Juglans regia*, trees. Landing rates will be compared with sticky card traps, and tree health will be monitored annually by using crown rating classes to compare treated and untreated (pheromone-baited, no repellent) trees.
    2. **Flight activity and oviposition pit distribution: comparative analysis of southeastern *Monochamus* species.** *Jake Bodart, L. D. Galligan, and F. M. Stephen, Department of Entomology, University of Arkansas, Fayetteville, AR 72701.* There are eight recognized species of *Monochamus* (Coleoptera, Cerambycidae) in North America. It is common to find two sympatric species of *Monochamus* co-occurring in regions where the genus is present. The distributions of southern pine sawyer (*Monochamus titillator*), and Carolina sawyer (*M. carolinensis*) overlap in the Ozark National Forest of Arkansas, where both species are reported to occupy the same ecological niche. Field studies were conducted to investigate height preference and timing of flight activity, oviposition pit height preference, and emergence densities of adult *M. titillator* and *M. carolinensis*. We found that 99% of *Monochamus* flight is crepuscular. A significantly higher number of *M. titillator* were captured in traps suspended at both breast height and canopy height than *M. carolinensis*. Density of *Monochamus* oviposition pits was highest on study bolts suspended at canopy level and lowest at breast height.

3. **Phenology and synchrony of Scymnus coniferarum (Coleoptera: Coccinellidae) and its adelgid prey in Tacoma, Washington.** *Molly Darr (mdarr@vt.edu)[1], Scott Salom[2], Thomas McAvoy[2], Richard McDonald[3], Rachel Brooks[4], [1]Virginia Polytechnic Institute and State University, Blacksburg, VA, [2]Virginia Tech, Blacksburg, VA, [3]Symbiont Biological Pest Management, Sugar Grove, NC,[4]Thurston County Washington, Olympia, WA***.** *Scymnus (Pullus) coniferarum* Crotch (Coleoptera: Coccinellidae) is a small lady beetle that preys hemlock woolly adelgid (HWA), *Adelges tsugae* Annand in the western U.S. and is absent from hemlock stands in the East. HWA infestations on western hemlock are rarely lethal, and it is thought that *S. coniferarum* may be an important predator that contributes to keeping HWA populations below injurious levels, although that assessment remains to be done. While preliminary studies show the release of this beetle to be of limited ecological risk, more information is needed on the life history of *S. coniferarum* in its native range, as it relates to phenology and host choices. To relate seasonal abundance of *S. coniferarum* and HWA and other adelgid species, six sites are being sampled near Tacoma, WA twice monthly, for one full year. Three types of sites are being sampled: pure hemlock stands; non-hemlock conifer stands, and mixed species stands containing hemlock and other conifers. This study will help us determine if other adelgid hosts are necessary for *S. coniferarum* to survive.
4. **Impacts of laurel wilt disease on insect herbivores of North American Lauraceae.** *Natalie Dearing[1], John Formby[1], Kelly Oten[2], Adam Chupp[3], Hannah Bares[1], and John Riggins[1], [1]Mississippi State University, [2]North Carolina Forest Service, [3]University of South Alabama, Mobile.* The redbay ambrosia beetle (*Xyleborus glabratus*) is an invasive wood-boring insect originating from southeast Asia, and carries the fungus responsible for laurel wilt disease (*Raffaelea lauricola*). Laurel wilt is causing widespread mortality in redbay (*Persea borbonia*), swampbay (*Persea palustris*), and sassafras (*Sassafras albidum*), and has potential to decimate at least 8 other North American trees and shrubs within Lauraceae. Lauraceous trees under attack by laurel wilt provide a vital food source and habitat for many native insect herbivores. The purpose of this study is to determine the risks native North American forests insects face from the mass die-off of their lauraceous hosts. A preliminary literature review is ongoing, and all insects reported associated with North American laurels were assigned a risk rating based on their level of specialization on laurel hosts. We found that ~30% of all insects associated with Lauraceae are specialist herbivores of laureaceous hosts. Laurel wilt could have dramatic impacts on native forest insects as this disturbance continues to radiate outwards through time, space, and trophic levels.
5. **Modeling the spring activity of larch casebearer and eastern larch**. *Samuel J. Fahrner and Brian H. Aukema, University of Minnesota.* Larch casebearer *Coleophora laricella* (Lepidoptera: Coleophoridae) is a defoliator of larch trees (*Larix* spp.) that is native to Europe. Larch casebearer was accidentally introduced into Massachusetts in the late 1800s and began causing severe defoliation of eastern and western larches. A classical biological control program was initiated in the early 1900s and is considered to have brought casebearer populations under control throughout the invasive range. In eastern

larch, also known as tamarack, larch casebearer appears to be re-emerging as a problem. Aerial surveys in Minnesota have detected thousands of acres of defoliation each year since 2000 after no defoliation was detected since the aerial survey program began in the 1950s. We investigated the role of plant-insect synchrony in spring in the resurgence of defoliation by larch casebearer. Seedlings of eastern larch and field collected larch casebearers were stored outside and then placed into both laboratory growth chambers and a greenhouse incrementally throughout the winter. We aimed to determine when the host could flush and/or insect could reactivate when placed at ecologically relevant temperatures and photoperiods (16 °, 22 °C; natural, 8, 11, and 14 hours of light). Implications to the population dynamics of larch casebearer are discussed.

6. **Walnut twig beetle (Coleoptera: Scolytidae) reproduction varies across host species.** *Andrea R. Hefty[1], Mark C. Coggeshall[2], James R. McKenna[3], Brian H. Aukema[1], Robert C. Venette[4], and Steven J. Seybold[5], [1]Department of Entomology, University of Minnesota, 1980 Folwell Ave., 432 Hodson Hall, St. Paul, MN 55108, [2]The Center for Agroforestry, University of Missouri, 203 ABNR Bldg. Columbia, MO, 65211, [3]Hardwood Tree Improvement and Regeneration Center, Purdue University, 1007 North 725 West, West Lafayette, IN 47906, [4]USDA Forest Service Northern Research Station, 1561 Lindig St., St. Paul, MN 55108, [5]USDA Forest Service Pacific Southwest Research Station, HDH001 (F039) Orchard Park Drive, Rm 116, Davis, CA 95616.* Walnut twig beetle, *Pityophthorus juglandis* Blackman, is a domestic invasive insect that has expanded its geographic range within the United States from the Southwest, through the West, and into isolated areas of the East. This beetle vectors a phytopathogenic fungus, *Geosmithia morbida* (Kolařík et al.), found to cause cankers in walnut, butternut, and wingnut trees. This insect-pathogen complex causes Thousand Cankers Disease (TCD), currently found in over 115 U.S. counties and northeastern Italy. We are presenting an assessment of reproduction (total brood per female) from laboratory breeding assays using a range of hosts and potential hosts. Ten trees per species were sampled in July 2014 and July-August 2015 from Texas, Missouri, Minnesota, and Indiana. We found significant differences, both years, in mean total brood per established female across hosts selected from three genera: *Juglans*, *Carya*, and *Pteryocarya*. In 2014 and 2015, *J. nigra* from a Missouri source had the highest mean total brood per female. These results are important to understanding the potential movement of walnut twig beetle across and between host ranges in the United States.
7. **Impact assessment of *Laricobius nigrinus* (Coleoptera:Derodontidae), a predator of hemlock woolly adelgid.** *Ariel Heminger[1], Albert Mayfield[2], Gregory Wiggins[3], Jerome Grant[3], Joseph Elkinton[4], Tom McAvoy[1], Andrew Tait[5], Jeffery Lombardo[4], Bryan Mudder[2], and Scott Salom[1], [1]Virginia Tech, Blacksburg, VA, [2]USDA - Forest Service, Asheville, NC, [3]University of Tennessee, Knoxville, TN, [4]University of Massachusetts, Amherst, MA, [5]Camcore, NCSU Dept of Forestry and Env Sci, Asheville, NC. Laricobius nigrinus* (Coleoptera: Derodontidae) is a predator of hemlock woolly adelgid (HWA), *Adelges tsugae* (Hemiptera: Adelgidae). HWA is a serious pest of eastern and Carolina

hemlocks causing dieback and death. We are currently trying to control HWA through several different methods including the use of predators such as *L. nigrinus*. Releases of *L. nigrinus* began in 2003, and its establishment has been well documented throughout much of the eastern U.S. where it has been released. Enough time to has now elapsed to allow for the assessment of its efficacy as a predator. In fall 2014, we set up nine field sites across six states from New Jersey to Georgia. Exclusion cages were placed over HWA-infested branches and population densities of HWA were compared inside (no predators present) and outside the cages (predators should be present).

8. **Quantifying potential sources of bottom-up, lateral, and top-down feedback in two bark beetles, *Ips pini* and *Ips grandicollis*.** *Michael C Howe[1], Jun Zhu[1,2], Brian H Aukema[3], and Kenneth F Raffa[1], [1]Department of Entomology, University of Wisconsin – Madison, [2]Department of Statistics, University of Wisconsin – Madison, [3]Department of Entomology, University of Minnesota.* Bark beetle populations are driven by multiple bottom-up, lateral, and top-down factors, but the extent to which various agents influence densities, interact with climatic factors, and differ among systems is poorly understood. The predominant tree-killing species in the Great Lakes region are pine engravers, which typically cause relatively chronic losses in contrast to the sudden landscape-scale outbreaks of irruptive species. In red pine plantations, belowground herbivory and drought can be important predisposing factors. We sampled populations of ten species of root- and lower-stem colonizing beetles, three bark and wood-boring species, and seven predator species in 24 sites across Wisconsin. Insects were trapped every two weeks for 5 years, using various lures. Plantations were approximately the same age and planting density, but varied from being asymptomatic to undergoing substantial decline. A total of 260,000 insects were obtained. Pine engraver population data were visualized and summarized across space, over time, and relative to other species. Stepwise regression models were constructed to select potential covariates influencing abundances of *Ips pini* and *Ips grandicollis*. Initial analyses focused on potential sources of negative and positive feedback from insects. Subsequent stages will incorporate temperature and precipitation data to develop comprehensive spatial-temporal models of *Ips* population dynamics.
9. **Seasonal and Regional Distributions of the Major Vectors, and their Associated Phoresy Rates for the Oak Wilt Fungus, *Ceratocystis fagacearum*, in Wisconsin.** *Stephanie M Jagemann[1], Jennifer Juzwik[2], Patrick Tobin[3], and Kenneth F Raffa[1], [1]University of Wisconsin-Madison, Department of Entomology, Madison, WI 53706, United States*, *[2]USDA Forest Service, North-Central Research Station, St. Paul, MN 55108, United States*, *[3]School of Environmental and Forest Sciences, University of Washington, Seattle, WA 98195, United States.* Oak Wilt is a lethal disease caused by the fungus, *Ceratocystis fagacearum*. Short-distance spread occurs via root grafts, but long-distance spread is by sap beetle (Nitidulidae) vectors. Attempts to limit spread and impact of *C. fagacearum* are partially based on limiting cutting to periods of vector inactivity. There is limited information on these beetles' activity periods, responses to temperature, and frequency carrying *C. fagacearum*. We sampled dispersing populations of two

predominant vector species in Wisconsin, *Carpophilus sayi* and *Colopterus truncatus*, to quantify seasonal and geographic abundance. Trapping was done in twelve oak stands across Wisconsin. Beetles were also assayed for the pathogen. In 2015, *Carpophilus sayi* peaked at the beginning and middle of the trapping period and *Colopterus truncatus* peaked only in the beginning. These trends shifted along a latitudinal gradient. Populations varied regionally, and beetles of each species were present at oak wilt-free sites. Most field locations yielded beetles with viable fungal propagules, although the frequency of association varied dramatically. Trap catches and temperature data were used to construct preliminary degree-day models for *C. sayi* and *C. truncatus*. Future data collection will refine these models, and provide a basis for refining guidelines for oak harvesting in Wisconsin.

10. **Phenology of emerald ash borer and its introduced larval parasitoids in the Northeast.** *Michael I. Jones[1], Juli R. Gould[2], & Melissa K. Fierke[1], [1]SUNY ESF, Environmental Forestry and Biology, 1 Forestry Dr., Syracuse, NY, 13210, [2]USDA-APHIS-PPQ Center for Plant Health Science and Technology, 1398 West Truck Rd., Buzzards Bay, MA, 02542.* A classical biological control program was started for emerald ash borer (EAB), *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) to develop a long-term and sustainable management option. Larval parasitoids *Spathius agrili* Yang (Hymenoptera: Braconidae) and *Testrastichus planipennisi* Yang (Hymenoptera: Eulophidae) were recovered from China and *S. galinae* Belokobylskij was recovered from Russia. Where parasitoids have been released, *T. planipennisi* appears to be establishing well, while *S. agrili* is not establishing in the north. Climate matching suggests *S. galinae* may be better suited to the north than *S. agrili*. To document the phenology of the larval parasitoids relative to EAB, we felled and peeled bark from ash trees biweekly from a woodlot in Syracuse, NY. Mature larvae were detected throughout the sampling period suggesting in established northeast infestations that parasitoids are not asynchronous with their host. To document parasitoid phenology we introduced adult parasitoids to EAB infested ash and allowed them to oviposit. We reared multiple generations of all parasitoids, with emergence continuing into early November. Late fall emergence and oviposition of the last generation suggests *Spathius* spp. may develop too late to reach the overwintering stage before the onset of freezing temperatures. For at least *S. agrili*, poor overwintering survivability may prevent establishment in the northeast.
11. **The dispersal capacity of late instar gypsy moth larvae (*Lymantria dispar*) and its implications for wood products movement.** *Rachael Nicoll[1], Scott Myers[2], Brian Aukema3, [1]Natural Resources Science and Management Program, University of Minnesota, St. Paul, MN, [2]USDA-APHIS-PPQ, Center for Plant Health, Science, and Technology, Buzzards Bay, MA, [3]Department of Entomology, University of Minnesota, St. Paul, MN.* The gypsy moth (*Lymantria dispar*) is an invasive forest defoliator of over 300 tree and shrub species, most notably oak and aspen. Our poster highlights results of a pilot study of the dispersal capacity of late instar gypsy moth larvae within a lumber yard. Currently, a 100-foot host vegetation-free buffer zone surrounding log decks is required to prevent infestation of logs and adjacent forest by crawling gypsy moth

larvae. Our study evaluates the effectiveness of this mitigation measure of the gypsy moth quarantine to facilitate wood product movement. To the best of our knowledge, the scientific basis for this 100-foot regulatory distance is unknown. Using a visual assessment of larval movement supplemented by harmonic radar, we found that late instar gypsy moth larvae are capable of movement greater than 100 feet over a 12-hour period. Our results suggest that alternative mitigation measures to reduce movement of caterpillars, such as short barrier fences, may be more effective than current regulations.

12. **Interactions between subcortical insects and longleaf pine physiology under various prescribed fire regimes.** *Haley M.W. Ritger: University of Georgia, Warnell School of Forestry and Natural Resources; Joseph W. Jones Ecological Research Center, Lindsay Boring: Joseph W. Jones Ecological Research Center, Joseph O'Brien: USDA Forest Service Southern Research Station, Steven T. Brantley: Joseph W. Jones Ecological Research Center, Kamal J.K. Gandhi: University of Georgia, Warnell School of Forestry and Natural Resources*. Longleaf pine is a fire-dependent tree species that has become relatively rare on the southeastern U.S. landscape. During the last few decades, there has been a major incentive to maintain and restore biologically diverse longleaf pine forests using prescribed fire as a tool. Our research objectives are to determine the effects of different prescribed fire regimes, including biennial burning, fire exclusion, and fire reintroduction, on the interactions between longleaf pine tree physiology and associated subcortical (bark and woodboring) beetle communities that can affect tree health. We sampled subcortical beetle populations and communities during the summer of 2016 to assess the impacts of burn regimes using funnel and pitfall traps at the Joseph W. Jones Ecological Research Center in southern Georgia. Multivariate statistical analysis will be used to determine differences in beetle communities across the treatments and analysis of variance for differences in relative abundance of species of particular interest, such as those in the genus *Ips*. Future data collection will focus on tree stress and physiology under the various fire regimes to correlate bark beetle activity with stand characteristics and health. Results from this study will assist with understanding the risks and benefits of various fire regimes in relation to forest health for longleaf pine restoration.
13. **Evaluating a potential area-wide ipm strategy for managing hemlock woolly adelgid in the eastern United States.** Kenton Sumpter[1], Scott Salom[1], Carlyle Brewster[1], Troy Anderson[1], Albert Mayfield III[2], Tom McAvoy[1], Virginia Polytechnic and State University[1], USDA Southern Research Station[2]. Use of the neonicotinoid insecticide, imidacloprid, has been found to be highly effective in suppressing hemlock woolly adelgid, *Adelges tsugae* Anand, (HWA). Similarly, *Laricobius nigrinus* Fender (Coleoptera: Derodontidae) has been found to be a likely candidate for biological control. Each control tactic has different objectives and outcomes. In an attempt to utilize the best of both approaches, a project was designed to develop a pest management strategy that utilizes both tactics concurrently within the same sites. The goal of this project is to assess the efficacy of a combined chemical – biological control strategy designed to reduce HWA populations

and improve the health of hemlock forests as well as achieve recovery of *L. nigrinus*. The project is being conducted across three states; Kentucky, West Virginia and Tennessee, and began in 2010 with data having been collected annually since then. Continued data collection will be carried out at all three sites through spring 2016. Data collected describe tree health, HWA population and recovery of *L. nigrinus* predators. Thus far, tree health has declined across all sites regardless of treatment type, and HWA population indices have been shown to be highly variable. *L. nigrinus* was initially recovered from its release plots (KY = 2010-2013, WV = 2011-2013) however, there have been no successful recoveries in 2014 and 2015 at any site.

14. **Bloom or Bust? An examination of the southern pine beetle (*Dendroctonus frontalis)* spring trap deployment dates.** *John Thomason[1], Dr. John Riggins[1], Dr. Steve Clarke[2], Dr. Jim Meeker[2], Mississippi State University[1], Region 8 Forest Health Protection[2].* Since 1987, 13 southeastern US States participate in a consecutive four-week annual spring southern pine beetle (SPB, *Dendroctonus frontalis*) trapping survey. The purpose of the survey is to assess SPB outbreak potential and anticipate control needs. This prediction system relies on capturing the peak SPB spring dispersal, thus timing of trap deployment is crucial. The blooming of flowering dogwood (*Cornus florida*) is a longstanding phenological cue commonly assumed to coincide with SPB peak spring dispersal, however this is based largely on tradition. Based on this phenological observation, forest managers attempt to initiate SPB trapping at the onset of dogwood bloom. The objective of this study is to examine the validity of dogwood bloom as an indicator of peak SPB spring dispersal. Year-round trapping data in 2014 and 2015 from Mississippi and Florida were used to identify peak SPB dispersal periods. Peak SPB dispersal was then compared with dogwood blooming dates from the US National Phenology Network and personal records. Lastly, both dogwood bloom dates and peak SPB dispersal were compared with timing of actual historic State SPB trapping efforts. On average, mean onset of dogwood bloom occurred 2.5 weeks after the peak 4-week window of SPB dispersal.
15. **Phenology of the pine bark adelgid, *Pineus strobi*, in forests of southwestern Virginia.** *Holly Wantuch, Scott Salom and Thomas P. Kuhar, [1]Virginia Polytechnic Institute and State University, Blacksburg, VA.* The pine bark adelgid, *Pineus strobi* (Hemiptera: Adelgidae) is a native herbivore of eastern white pine, *Pinus strobus*, in eastern North America. Little work has been done to study this adelgid's natural history, especially in the southern reaches of its range. Like other adelgid species, the pine bark adelgid is a phloem feeding insect with limited mobility. The only known predator to specialize on pine bark adelgid is *Laricobius rubidus* (Coleoptera: Derodontidae), which is closely related to *Laricobius nigrinus*, a biological control agent introduced for hemlock woolly adelgid. Recently it was found that the two predator species successfully hybridize and produce fertile offspring. It is unknown what, if any, this interaction will have on adelgid populations. Thus, it is important to better understand the detailed life cycle of the pine bark adelgid in Virginia forests. Though patterns in life stage frequency become difficult to interpret as the warm season progresses due to greatly overlapping generations, the

following study suggests up to 6 possible pine bark adelgid generations yearly in southwestern Virginia.

16. **Link between a scale insect and eastern white pine dieback: overview and future directions.** *Thomas D Whitney[1], Rima D Lucardi[2], and Kamal JK Gandhi[1], [1]Daniel B. Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA 30602, [2]USDA Forest Service, Southern Research Station, Athens, GA 30602.* Since 2006, patterns of dieback and mortality of eastern white pine (*Pinus strobus* L.) have been observed across its range, including the southern Appalachians. Symptoms have commonly included canker development, branch flagging, crown thinning, resinosis, and mortality. Given the economic and ecological importance of white pine, substantial research efforts have been initiated to determine the main factors affecting tree health. Our work conducted thus far strongly indicates that a pine bast scale insect (*Matsucoccus macrocicatrices* Richards), along with multiple fungal pathogens, is a primary cause of the dieback. Investigation of sites from the Northeast and Southeast revealed that 87.5% of symptomatic trees were infested with the pine scale. Furthermore, proportion of dead to living branches, as well as fungal canker surface area were both positively correlated with scale insect prevalence. Previously considered a benign grazer of white pine, native only to southeastern Canada and New England, these results suggest the wide presence of this insect is highly associated with the dieback. Published information about this insect, however, is extremely scant. Therefore, to better understand the biology and ecology of this insect, we plan to conduct several studies, including an investigation of its historical biogeography.
17. **Hitchhiking with the best ride without a cost: ectosymbiont load does not affect dispersal capacity of mountain pine beetles.** *G. Haydee Peralta-Vazquez and Mary Reid***,** *University of Calgary.* Dispersal decisions depend on the phenotypic characteristics of individuals (e.g. body condition, sex and age). Theoretical models suggest that individuals in better condition are more competitive dispersers and therefore should manage better the energetic costs of dispersal. However, phenotypic-dependent dispersal is expected to decrease with environmental pressures that individuals cannot control such as parasitic or ectosymbiont load. Using mountain pine beetle (*Dendroctonus ponderosae*) and its phoretic mites 'dispersing' on automated flight mills, we examined whether beetle dispersal is phenotype-dependent and whether there is a cost associated with ectosymbiont load. So far, our results indicate that phoretic mite load did not negatively affect any aspect of beetle flight performance and, contrary to our expectations, total distance flown was positively correlated with phoretic mite load. These results suggest that beetles in good condition are a better ride for associated arthropods such as mites without impairing the hosts.
18. **Development time and synchrony of emergence in individual broods of mountain pine beetles.** *Leanna Lachowsky and Mary Reid***,** *University of Calgary.* In mountain pine beetles, *Dendroctonus ponderosae*, adult populations tend to have female-biased sex ratios (~2:1) and females are 37% larger by volume than males. Female-biased sexual size dimorphism and changing sex ratios during the emergence period suggest different

growth trajectories of males and females. Male-biased mortality has been demonstrated in this species, biasing sex ratios and likely influencing selection. Life history traits such as body size at maturity, development time and growth rate are likely related to mortality during development and are expected to depend on maternal or habitat quality. We reared mountain pine beetles in the lab at a constant temperature and examined individual broods for emergence date as an indicator of development time in relation to the mortality experienced during development, sex and final body size. When statistically controlling for sex, larger individuals emerged earlier, thus supporting predictive models for threshold body size. Males, the smaller sex, emerged earlier than females, suggesting faster development which may reflect viability selection on male body size.

2. General Poster Session Moderators: *Robert Jetton and Darren Blackford*

1. **A meta-analysis of the impact of trap type and design features on survey and detection of bark and woodboring beetles and their associates.** *Allison, Jeremy D.[1] and Richard A Redak[2]. [1]Research Scientist, Canadian Forest Service, Natural Resources Canada. [2]Professor and Chair, Department of Entomology, University of California-Riverside.*
2. **Exotic ambrosia beetle (Coleoptera: Curculionidae: Scolytinae) establishment factors and hosts for newly detected species in southern Alabama.** *Hannah M. Bares[1], John J. Riggins[1], Richard L. Brown[1], Natalie A. Clay[2], Robin M. Verble-Pearson[3], [1]The Department of Biochemistry, Molecular Biology, Entomology, & Plant Pathology, Mississippi State University, [2]School of Biological Sciences, Louisiana Tech University, [3]Department of Natural Resources Management, Texas Tech University.* Three non-native scolytine ambrosia beetle species from Asia were detected in Mississippi and Alabama in 2012: *Ambrosiodmus minor* (Stebbing), *Ambrosiodmus lewisi* (Blandford) and *Xyleborinus octiesdentatus* (Murayama). Their North American hosts are unknown. Exotic species host preference helps determine the range where establishment is possible. In addition, management practices and substrate characteristics are important in determining the distribution and abundance of scolytines. Prescribed fire is a widely used forest-management technique, yet its effect on exotic ambrosia beetle assemblages is not well understood. The goals of this study are to: 1. Determine if the non-native ambrosia beetles *A. minor*, *A. lewisi* and *X. octiesdentatus* are attracted to several common tree species in southern Alabama. 2. Determine if recently burned forest stands provide a significantly more or less suitable habitat for exotic ambrosia beetles as compared to non-burned stands. To accomplish this, window traps and Lindgren funnel traps will be placed in four recently burned and four non-burned stands in southern Alabama in 2016 and 2017. The window traps will contain bolts of tree species commonly encountered in the trap locations. Coarse woody debris will be measured in each stand to take into account substrate differences between burned and non-burned stands. Collection of the target species from the window traps will provide information on primary attraction to

likely North American hosts. Understanding the effects of prescribed fire and the characteristics of coarse woody debris most strongly linked to exotic ambrosia beetle establishment will aid in management of both native and non-native species.

3. **Ecological and social factors affecting pine health in the southeastern U.S.** *Barnes, Brittany F.[1], David R. Coyle[1], Christiane Helbig[1], Gary T. Green[1], Kier D. Klepzig[2], Frank H. Koch[3], Larry A. Morris[1], John T. Nowak[4], William J. Otrosina[5], William D. Smith[3], and Kamal J.K. Gandhi[1]. [1]University of Georgia, D.B. Warnell School of Forestry and Natural Resources, Athens, GA, USA; [2]USDA Forest Service, Southern Research Station, Asheville, NC, USA; [3]USDA Forest Service, Southern Research Station, Research Triangle Park, NC, USA; [4]USDA Forest Service, Forest Health Protection, Asheville, NC, USA; [5]USDA Forest Service, Southern Research Station, Athens, GA, USA.*
4. **The Forest Pest Management Cooperative: Twenty years of accomplishments in applied research and technology transfer.** *Ronald F. Billings, Texas A&M Forest Service, Donald M. Grosman, Arborjet, Inc., and Melissa J. Fischer, Washington Department of Natural Resources, rbillings@tfs.tamu.edu, dgrosman@arborjet.com, Melissa.Fischer@dnr.wa.gov.* To address the need for applied research on pests of pine seed orchards and young pine plantations, the Texas A&M Forest Service (TFS) established the Western Gulf Forest Pest Management Cooperative in 1996. Now known simply as the Forest Pest Management Cooperative (FPMC), this successful partnership recently completed its 20th year. Dues paid by FPMC members, financial support from TFS, and research grants from the US Forest Service and various chemical companies are used to support a small staff of 4-5 full- and part-time TFS employees. The mission of the FPMC is to conduct applied research on forest health problems that coop members consider important, develop pest management recommendations, and transfer information and new technology to the field. Under the capable leadership of TFS forester entomologists Drs. Ron Billings (1996-present), Don Grosman (1996-2012), and Melissa Fischer (2013-2014), membership in the coop has increased from an initial 6 members - mostly forest industries - to 10 in 2016. In the late 1990s, as forest industries sold their lands, most dropped from the coop, to be replaced by the new landowners, various Timber Investment Management Organizations (TIMOs) and Real Estate Investment Trusts (REITS). TFS and US Forest Service, Forest Health Protection, are charter members that continue to support the coop. Coop research has focused on development of methods to protect valuable cone and seed crops in pine seed orchards and newly-planted pine seedlings in commercial plantations. Based on coop findings, several new chemical insecticides have been registered with the Environmental Protection Agency (EPA) to improve forest pest management. These insecticides include Volcano® (no longer available), Amdro® Ant Block, and PTM™ for control of Texas leaf-cutting ants (*Atta texana*) and Pounce® for control of regeneration weevils (*Hylobius* and *Pachylobius* spp.) affecting pine seedlings. One systemic chemical, emamectin benzoate (EB), injected into selected seed orchard trees, proved particularly effective for reducing cone losses to coneworms (*Dioryctria* spp.). Up to six years of protection were achieved with a single injection. But the Initial field trials in east Texas showed

that injections of EB alsowere effective for totally preventing attacks by engraver beetles (*Ips* spp.) in both weakened trees and fresh log sections. In cooperation with other researchers, FPMC entomologists tested EB for efficacy against more aggressive bark beetles. These included the southern pine beetle (*Dendroctonus frontalis*) in Alabama, Virginia and Mississippi, and the mountain pine beetle (*D. ponderosae*), western pine beetle (*D. brevicomis*), and the spruce beetle (*D. rufipennis*) in the western U.S. and British Columbia. Results showed efficacy, particularly for western pine beetle in ponderosa pine and southern pine beetle in loblolly pine. In 2010, emamectin benzoate was registered in all states except Alaska as a restricted use pesticide for operational use in seed orchards and prevention of a wide variety of bark beetle and wood-boring insects. It remains the only insecticide currently registered for use against southern pine bark beetles in forest situations. EB also has been deemed one of the most effective means for protecting ash trees from the invasive emerald ash borer, *Agrilus planipennis,* now killing ash trees in 24 states and two provinces in Canada. FPMC research has addressed the impact of Nantucket pine tip moth (*Rhyacionia frustrana*) on young pine plantations, developed hazard rating methods, and tested new insecticides for prevention. Results from FPMC field trials supported the registration of Bayer's SilvaShield™ Forestry Tablets (containing 20% imidacloprid plus fertilizer) in 2006 for tip moth and other plantation pests. In 2007, further FPMC research led to registration of PTM™ (9% fipronil), a BASF product, for control of pine tip moth and aphids in young pine plantations. The same chemical also proved effective for controlling the Texas leafcutting ant and fire ants. These pests have been added to the PTM™ label. Recent research has focused on developing more effective toxic baits for the Texas leafcutting ant, treatments for pinewood nematodes and conifer mites, and chemicals for protecting black walnut trees against the walnut twig beetle, vector of the fungus that causes thousand cankers disease. In addition, field trials are being conducted in Virginia and Alabama to ascertain whether EB can be incorporated into a trap-tree method for maintaining southern pine beetles at low population levels. Future plans are to expand research activities to include urban tree pests and invasive plants and insects. Other accomplishments include preparation and distribution of the quarterly newsletter entitled *PEST* (*Progress, Education, Science, and Technology*), and periodic reports and training sessions on pest management for members. To keep membership dues low, the FPMC has captured federal grants from the US Forest Service and donations from insecticide companies amounting to more than $900,000 since 1996. The dedicated staff of TFS employees and FPMC members, past and present, are to be congratulated for making this partnership for research and technology transfer a success.

5. **Cold tolerance and seasonality in mountain pine beetle: implications for the spread of a native invasive insect in Canada.** *Bleiker K. and G. Smith. Canadian Forest Service, Natural Resources Canada.*
6. ***Cerceris fumipennis* foraging for general buprestid survey in New England.** *Bohne, Michael, Rebecca Lilja, and Kevin Dodds. US Forest Service, Forest Health, Durham NH.*

7. **Rearing survey of wood inhabiting insects in Boston and New York arboreta.** *Bohne, Michael[1], Kevin Dodds[1], Marc DiGirolomo[1], Andrew Gapinski[2], Arnold Arboretum[2], and Joseph Charap[3]. [1]US Forest Service, Forest Health, Durham NH; [2]Harvard University; [3]Green-Wood Cemetery.*
8. **Elevated light levels reduce HWA infestation and improve carbon balance in eastern hemlock seedlings.** *Steven T. Brantley[1, *], Albert E. Mayfield III[2], Robert M. Jetton[3], Chelcy F. Miniat[1], David R. Zietlow[1], Cindi Brown[1], and James R. Rhea[4], [1]USDA Forest Service, Southern Research Station, Coweeta Hydrologic Lab, Otto, NC, [2]USDA Forest Service, Southern Research Station, Asheville, NC, [3]Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC, [4]USDA Forest Service, Forest Health Protection, Asheville, NC, *Present address: Joseph W. Jones Ecological Research Center, Newton, GA.* The rapid loss of eastern hemlock (*Tsuga canadensis*) due to infestation with hemlock woolly adelgid (*Adelges tsugae*, HWA) has greatly altered community composition and ecosystem function in eastern forests. Multiple strategies have been implemented or proposed to increase hemlock resilience including chemical treatments, biological control with predators, and silvicultural treatments that increase incident light. We conducted a nursery experiment using potted eastern hemlock saplings to investigate the effects of light exposure (from 0–90% shade) on HWA infestation severity and plant carbon balance. We hypothesized that higher light levels would result in reduced HWA densities, improved short and long-term carbon balance, and improved sapling growth. Live HWA densities increased significantly with increasing shade and were lowest in 0 and 30% shade treatments. Leaf stress increased and net carbon assimilation decreased with increasing light. Despite tradeoffs between reduced infestation and reduced leaf function, both leaf and root starch content and sapling growth were positively correlated with ambient light. Our results indicate that forest management practices that emphasize increased light levels for surviving hemlock may improve hemlock resilience in the presence of HWA and suggest that silvicultural treatments may be an effective component of large-scale conservation and restoration strategies.
9. **Fungal volatiles can mediate interspecific interactions among mountain pine beetle's (*Dendroctonus ponderosae*) fungal symbionts.** *Jonathan A. Cale[a], R. Maxwell Collignon[b], Jennifer G. Klutsch[a], Sanat S. Kanekar[a], Altaf Hussain[a], and Nadir Erbilgin[a], [a]Department of Renewable Resources, 4-42 Earth Sciences Building, University of Alberta, Edmonton, Alberta T6G 2E3, Canada, [b]Department of Entomology, Entomology Building, University of California, Riverside, CA 92521, USA.* Mountain pine beetle (*Dendroctonus ponderosae*) has killed millions of hectares of pine forests in western North America. Beetle success in part is dependent upon a community of symbiotic fungi comprised of *Grosmannia clavigera*, *Ophiostoma montium*, and *Leptographium longiclavatum*. Factors regulating the dynamics of this community during host pine infection are poorly understood. However, fungal volatile organic compounds (FVOCs) help shape fungal interactions with other species in model and agricultural systems and thus may in part drive interactions among bark beetle associated fungi. We investigated whether FVOCs

mediate interspecific interactions among the fungal symbionts of mountain pine beetle. In particular, we studied how volatiles emitted by competing fungi regulate the growth and reproduction of other co-occurring species. Headspace volatiles were collected and identified to determine species-specific volatile profiles. Interspecific effects of volatiles on fungal growth and conidia production were assessed by pairing physically separated fungal cultures grown on an artificial medium inside a shared-headspace environment. We show that FVOC profiles differ by species and, depending on species-specific FVOC concentrations, influenced the growth and/or conidia production of the other species. Our results demonstrate that FVOCs mediate antagonistic and beneficial interactions among these fungi, and thus likely influence the dynamics of bark beetle fungal symbiont communities.

10. **Silent springtails: effects of vehicular pollution on arboreal collembolan.** *Callahan, Sean, Amanda Bidwell, Thomas DeLuca, and Patrick Tobin. School of Environmental and Forest Sciences, University of Washington.*
11. **Walnut twig beetle mortality and reduced brood production following exposure to commercial strains of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium brunneum*.** *Louela Castrillo[1], John Vandenberg[2], Michael Griggs[2], Robert Camp[3], Adam Taylor[3] Bryan Mudder[4] and Albert Mayfield[4], [1]Department of Entomology, Cornell University, Ithaca, NY 14853, [2]USDA-ARS, Robert W. Holley Center for Agriculture & Health, Ithaca, New York 14853, [3]Department of Forestry, Wildlife and Fisheries, University of Tennessee, Knoxville, TN 37996, and [4]USDA Forest Service, Southern Research Station, Asheville, NC 28804.* Thousand cankers disease (TCD), caused by the walnut twig beetle (WTB), *Pityophthorus juglandis*, and its associated fungal symbiont, *Geosmithia morbida*, is a deadly disease of the eastern black walnut, *Juglans nigra*. Numerous attacks and gallery formation by the WTB and subsequent development of cankers caused by the fungus result in progressive crown dieback, killing affected trees within a few to several years following initial infestation. Very few management options are available for preventing or reducing impact of TCD on black walnut trees. Since the development of TCD requires numerous beetle attacks before cankers coalesce and girdle branches, and multiple beetle generations likely contribute to crown dieback, control strategies that reduce beetle attacks and brood production, without completely eliminating infestation, could still significantly benefit tree health and survival. We are evaluating the use of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium brunneum* against the WTB. Laboratory and field studies conducted in 2014 and 2015 showed that WTB adults are susceptible to both entomopathogenic fungi. In addition, exposure of adult beetles to sprayed walnut logs resulted in smaller brood production. Infected females produced shorter galleries and died prior to laying eggs or laid fewer eggs. These results show the potential use of entomopathogenic fungi in the management of TCD.
12. **Growth response of *Fraxinus nigra* used to predict high-quality sites in Maine and northern New York: An approach to prioritizing preparedness and management of *Agrilus planipennis* Fairmaire.** *Kara K.L. Costanza[1], William H. Livingston[1], John J.*

Daigle[1], Robert J. Lilieholm[1], Darren J. Ranco[2], Nathan W. Siegert[3], [1]School of Forest Resources and [2]Department of Anthropology, University of Maine, [3]Northeastern Area State and Private Forestry, Forest Health Protection, US Forest Service. *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) (emerald ash borer) is causing widespread mortality in North American *Fraxinus* spp. One vulnerable species, *F. nigra* Marsh (Lamiales: Oleaceae) (black ash), is important both socio-economically and ecologically. Native Americans weave *F. nigra* baskets, which feature prominently in their histories, cultures, and economies. *F. nigra* also fills a particular ecological niche: it colonizes wetland sites, yet is one of the most drought-tolerant ash species. To maintain the species in the face of *A. planipennis* and other threats, it is essential to identify and map high-quality sites. This study investigated characteristics associated with high-quality sites, defined as sites where *F. nigra* (1) is capable of successful regeneration, and (2) exhibits consistent, large radial growth (>2.0 mm/yr for 10 consecutive years). This radial growth measure was used to classify sites as basket-quality or non-basket-quality. To predict the location of basket-quality *F. nigra* sites, a logistic regression model was developed using data from 24 calibration sites in Maine. The best-fit logistic model associated basket-quality sites with (1) increased site drainage (i.e., flow accumulation) and (2) decreased softwood cover. Both independent variables were also recommended by Native American basket-tree harvesters. The model accurately classified 75% of calibration sites. To test the robustness of the model and its applicability, we evaluated an additional 14 sites in New York. The New York model only used softwood cover type to classify sites. The model correctly classified 64% of New York sites. To compare models with traditional ecological knowledge, the Maine model was applied to 28 additional sites in Maine, which were located and classified by Wabanaki basket-tree harvesters. Harvesters classified sites as basket-quality or non-basket-quality based on site and tree characteristics, and the percent of basket-quality trees per site was calculated. The Maine logistic model correctly classified 79% of the harvester-classified sites, and 71% of sites based on percentage of basket-quality trees. The successful development of this model demonstrates how incorporating multiple information sources, such as scientific and traditional ecological knowledge, can result in powerful research outcomes. With careful application to *A. planipennis* control strategies, this comprehensive spatial model can help slow the mortality of a culturally and ecologically significant species, while preserving the basket-making tradition in Maine and northern New York.

13. **Evaluation of unmanned aircraft systems utility for forest health and forest management: pilot project in the Southwestern Region.** *Damsgaard, Kris[1], Amanda Grady[2], Jennifer Jones[3], Karen Jones[4], Jeff Mai[5] and Matt Oberle[6]. [1]USDA Forest Service, Fire and Aviation Management, Albuquerque, NM 87102; [2]USDA Forest Service, Forest Health Protection, Flagstaff, AZ 86001; [3]USDA Forest Service, Fire and Aviation Management, Boise, ID 83705; [4]USDA Forest Service, Forest Management, Albuquerque, NM 87102; [5]USDA Forest Service, Forest Health Technology Enterprise Team, Fort Collins, CO 80526; [6]USDA Forest Service, Forest Management, Fort Collins, CO 80526.*

14. **Cone and seed insects of southwestern white pine, *Pinus strobiformis*, in Arizona, New Mexico, and Texas**. *Daniel E. DePint, Gennaro A. Falc, Kristen M. Warin, Richard W. Hofstette, Joel D. McMilli, and John Anhold*, *School of Forestry, Northern Arizona University, Flagstaff, AZ..S.D.A. Forest Service, Forest Health Protection, Boise Field Office, Boise, ID..S.D.A. Forest Service, Forest Health Protection, Arizona Zone, Flagstaff, AZ.* Southwestern white pine (*Pinus strobiformis*; SWWP) is one of the least studied five needle pines in the United States. We conducted a study to identify the cone and seed insects and quantify their damage, which can negatively impact annual seed production and future regeneration of the SWWP. We collected mature cones (during August-October, 2012-2015) from across Arizona, New Mexico, and the Guadalupe Mountains of Texas. Then we individually caged each cone for seven months to rear and collect emerging insects. Additionally, in the summer of 2014 we implemented methods which capture insects in situ. The new methods included caging developing cones on individual trees, funnel traps supplemented with pheromones, and the use of Tanglefoot. We have collected more than 2000 insects from 65 different sites. Infestation rates varied widely between sites along with insect composition. The SWWP seed and cone insect guild included the orders of Lepidoptera, Hemiptera, Coleoptera, and Diptera. The most prevalent insect captured from 2012-2014 was the lepidopteran fir cone worm *Dioryctria abietivorella*. In 2015, the lepidopteran *Eupithicia spermophaga* was the most captured species. From these results, we will produce a photographic resource guide intended to aid managers in identifying and managing seed and cone insect pests of SWWP and a corresponding peer-reviewed journal publication focused on the quantitative results.
15. **Reducing firewood movement by the public: effective combination of regulation, education and persuasion, 2006 – 2014.** *Andrea Diss-Torrance[1] and Kim Peterson[2], [1]Wisconsin Department of Natural Resources, Bureau of Forest Management, Madison, WI, [2]Alpha Tech Group, Madison WI.* Many invasive pests and diseases of trees can be moved in firewood. For example, emerald ash borer was found at several state campgrounds in MI far from other known populations and infested firewood was suspected as a likely mode of introduction. In order to reduce the risk of introductions of invasive pests to state parks and forests and slow their spread by reducing movement of firewood, the WI Department of Natural Resources in 2006 initiated regulation of firewood that could enter state lands. An education campaign was linked to these restrictions with the ultimate goals of persuading the camping public to not move firewood. Campers arriving at a state campground are already thinking about how they value trees and campfires so they are primed for a message on these topics. When checking in, campers are asked by park staff if they have firewood allowing for a brief conversation about the risks of moving pests and diseases in firewood. If the firewood is from beyond the allowable distance and not certified as treated, the camper is asked to surrender the wood if they want to camp at the park. Further enforcement has not been necessary. To measure camper awareness, motivations to comply, compliance and movement of firewood in other situations, mail surveys of about 800 campers were

done following the camping seasons of 2006, 2008, 2010, 2012 and 2014. Awareness of both the regulations and the reason behind them rose rapidly in the first two years of the program to over 90% of campers surveyed. Over the period 2006-2014, there was a highly significant, steady increase in how important campers felt it was to not move firewood long distances and in how much of a threat they felt invasive species were to Wisconsin forests. Camper compliance with regulations followed behind awareness of regulations and the risk of moving invasive pests in firewood. After four years, awareness and compliance were similar at near or over 90% for the primary source of wood used and by trip. This suggests those who know of regulations understand the reason for them and take action to not move firewood. We also asked if campers moved wood in bulk to their homes for camping or heating purposes. Only 12% of campers obtained wood in bulk for use in camping in 2006 and by 2014 this had dropped to 1%. More obtained wood for home heating, 17% in 2006 but this too decreased to 11% in 2012 with a small increase to 14% in 2014, possibly attributable to a shortage of heating propane in the winter 2013-14. When these campers did obtain wood though, they got it from a much closer source; between 2006 and 2014 the average reported distance dropped from 55 miles to 22. We conclude that a combination of mild regulation with a message delivered from a trusted source when the recipient is sensitized to receive it can be very effective in raising awareness, increasing the importance of an issue, and changing behavior of the recipient.

16. **Insect community responses to prescribed fire and white-nose syndrome in eastern deciduous forests.** *Dodd, L.E.[1], S. A. Fulton[1], R. E. Griffitts[1], and L. K. Rieske[2]. 1Department of Biological Sciences, Eastern Kentucky University. Richmond, KY, USA; [2]Department of Entomology, University of Kentucky. Lexington, KY, USA.*
17. **Phytochemical patterns vary among trembling aspen genotypes during leaf expansion.** *Michael Falk[1], Rick Lindroth[1], Ken Raffa[1], [1]The University of Wisconsin – Madison.* Climate change has the potential to alter phenological synchrony, a key mediator of plant-insect interactions. Asynchrony between events like folivore egg hatch and host tree budbreak could disturb forest ecosystems by altering the frequency and severity of defoliation patterns. To better understand potential impacts of phenological asynchrony in these systems, it is important to characterize foliar chemical patterns during leaf expansion, and their effects on outbreak folivores. Many studies have reported differences between early- and late– season foliar chemistry, with a common pattern being increased concentrations over time. However, few studies have focused on the narrow period of leaf expansion, a critical window during which early instars often feed. We characterized the phytochemical patterns of 8 trembling aspen genotypes throughout leaf expansion. We observed high initial phenolic glycoside concentrations in 7 of 8 genotypes, and these concentrations rapidly declined shortly after budbreak. Magnitudes and rates of decline, however, differed substantially among genotypes. These results indicate that high defense chemical concentrations in newly flushed foliage may be an important, yet overlooked aspect of aspen defense against spring defoliators, especially neonates. Additionally, genetic variation in rates of phytochemical

change, in addition to magnitudes of chemical defense, may influence tree susceptibility to herbivory.

18. **Drought and tree mortality: An example from the southern Sierra Nevada.** *Leif A. Mortenson[1], Christopher J. Fettig[2], Patra B. Foulk[1,3], and Beverly M. Bulaon[4], [1]Pacific Southwest Research Station, USDA Forest Service, Placerville, CA, [2]Pacific Southwest Research Station, USDA Forest Service, Davis, CA 95618, [3]Volunteer, [4]Forest Health Protection, USDA Forest Service, Sonora, CA.* California is now in its fourth consecutive year of drought. Water Year 2015 (ended 30 September 2015) was the hottest and driest on record, while 2014 was the third driest and second warmest. In 2015, USDA Forest Service Aerial Detection Survey reported extensive tree mortality in the central and southern Sierra Nevada Mountains, and most recently the Agency has estimated that >66 million trees have been killed statewide. We review the role of drought in inciting bark beetle outbreaks, and discuss causal agents and rates of tree mortality, and associated impacts on forest structure and composition based on 40 11.3-m (1/10 acre) fixed-radius sampling plots installed in the most heavily-impacted areas.
19. **Influence of pheromone-enhanced lures and trap height on the detection of potentially invasive bark- and wood-boring insects.** *Leah Flaherty[1], Greg Pohl[2], Peter Silk[3], Peter Mayo[3], David Langor[2], Jon Sweeney[3], [1]Department of Biological Sciences, MacEwan University, Edmonton, AB, [2]Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, AB, [3]Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Centre, Fredericton, NB.* The traps used operationally for detecting exotic bark- and wood-borers are typically baited with host plant volatiles (e.g., ethanol), which attract many species, but with unknown or low sensitivity. Pheromones of several cerambycids have been identified and since pheromone structure in this group is parsimonious, a small number of compounds attract many species. These compounds also tend to be more sensitive than host volatiles and therefore have strong potential for use in biosurveillance. Recent research also suggests that traps placed in the understory vs. canopy may catch a different array of species, suggesting that using both trap placements may improve detection. Here, we present the results of an experiment evaluating the impact of trap height (understory vs. canopy) and lure (standard UHR ethanol lures vs. pheromone-enhanced lures) on the diversity and abundance of captured bark- and wood-boring insects in the families Buprestidae, Cerambycidae, Curculionidae, Siricidae and Xiphydriidae. This study was conducted in a mixedwood forest in an industrial area in Edmonton, AB, Canada. We used a 2x2 factorial design with 8 replicates in a randomized complete block design. Lindgren 12-funnel traps were checked every 2 wks from May-August 2014. We caught 901 bark- and wood-boring insects, representing 62 species. Twenty-two species were represented by just one or two specimens. The number of specimens detected (but not the number of species) varied among treatments for all families. Mean catch varied among treatments for six species of Cerambycidae, two Curculionidae and one Siricidae. Mean catch was higher in the canopy for some species, and in the understory for others. The addition of pheromones to ethanol lures increased catch for four species. Detection

rate was influenced by trap height for six species, and was increased by the addition of pheromones for three species. Ethanol-baited understory traps detected the fewest species of any treatment; this is the standard trap height and lure currently used operationally in North American trapping programs. Canopy traps generally detected more species than understory traps, but our results suggest that deploying traps at both heights will result in the greatest number of species detected. Results also suggest that using more than one lure-trap height combination at a site increases the number of species detected. A combination of canopy traps baited with ethanol and understory traps baited with pheromone-enhanced lures detected more species than any other two-treatment combination tested.

20. **Winter is (not) coming: Characterizing Douglas-fir beetle dynamics in a changing climate.** *Freeman, Michael[1], Patrick Tobin[2], and Amy LaBarge[3]. [1]Master's of Science Student, School of Environmental and Forest Science, University of Washington, Seattle; [2]Assistant Professor, School of Environmental and Forest Science, University of Washington, Seattle; [3]Forest Ecologist, Seattle Public Utilities.*
21. **Balsam woolly adelgid distribution survey in Montana.** *Gannon, Amy. Montana Department of Natural Resources and Conservation.*
22. **Distribution of balsam woolly adelgid in western North America.** *Gannon, Amy[1], Leland Humble[2], Gabriella Zilahi-Balogh, PhD[3], Laura Lowry[4], Gina Davis, PhD[5], and Lia Spiegel[6]. [1]Montana Department of Natural Resources and Conservation; [2]Natural Resources Canada; [3]Canadian Food Inspection Agency; [4]USFS Forest Health Protection, Boise Field Office;*
    [5]USFS Forest Health Protection, Couer d'Alene Field Office; [6]USFS Forest Health Protection, La Grande Field Office.
23. **Pheromone divergence among populations of western pine beetle (*Dendroctonus brevicomis* LeConte) across its range in the western United States.** *Brian Sullivan[1], Amanda Grady[2] Rich Hofstetter[3], Deepa Pureswaran[4], Cavell Brownie[5], Daniel Cluck[6], William Woodruff[7], Tom Coleman[8], Daniel Ryerson[9], Andrew Graves[10], Beth Willhite[11], Lia Spiegel[12], Dwight Scarbrough[13], Andrew Orlemann[14], and Cayenne Engel[15], [1]USDA Forest Service, Southern Research Station, Pineville, LA 71360, USA, [2]USDA Forest Service, Forest Health Protection, Flagstaff, AZ 86001, USA, [3]Northern AZ University, School of Forestry, Flagstaff, AZ 86001, USA, [4]Canadian Forest Service, Laurentian Forestry Center, Quebec City, QC G1V 4C7, Canada, [5]Department of Statistics, North Carolina State University, Raleigh, NC 27695, USA, [6]USDA Forest Service, Forest Health Protection, Susanville, CA 96130, USA, [7]USDA Forest Service, Forest Health Protection, Susanville, CA 96130, USA, [8]USDA Forest Service, Forest Health Protection, Albuquerque, NM, 87102, USA, [9]USDA Forest Service, Forest Health Protection, Albuquerque, NM, 87102, USA, [10]USDA Forest Service, Forest Health Protection, Albuquerque, NM, 87102, USA, [11]USDA Forest Service, Forest Health Protection, Sandy, OR 97055, USA, [12]USDA Forest Service, Forest Health Protection, La Grande, OR 97850, USA, [13]USDA Forest Service, Forest Health Protection, Boise, ID 83709, USA, [14]USDA Forest Service, Fishlake National Forest, Beaver, UT 84713, USA, [15]Nevada Division of Forestry, Las Vegas, NV*

89108. Pheromone systems of aggressive bark beetles vary substantially with regard to the differing contributions of the two sexes, behavioral effects of individual compounds and blends, role of host odors, as well as the chemistry and apparent ecological roles of components. We investigated geographic variability in the composition of the aggregation attractant of an aggressive species of pine bark beetle (the western pine beetle, *Dendroctonus brevicomis* LeConte) across its range in the western United States. Volatiles were collected from individual females and analyzed by both gas chromatography-mass spectrometry and coupled gas chromatography-electroantennographic detection. Additionally, we performed field trapping bioassays to investigate regional variation in beetle response to (1) the exo/endo isomers of the brevicomin component of this species' aggregation pheromone and (2) host monoterpenes *alpha*-pinene and myrcene, since previous studies had suggested possible regional variability in responses to these compounds. We found a significant difference in the ratios of *exo*:*endo*-brevicomin produced by females in populations examined on either side of the Great Basin Desert. Eastern populations produced these in an average 0.03:1 ratio whereas western populations produced an average 5:1 ratio. Males east of the Great Basin had stronger olfactory responses to *endo*- than *exo*-brevicomin, whereas this was reversed for western populations. Furthermore, eastern populations generally had highest trap responses to the lure combination of frontalin, *endo*-brevicomin, and *alpha*-pinene whereas western populations preferred the combination of frontalin, *exo*-brevicomin, and myrcene. Our results indicate that the aggregation attractant has diverged between the eastern and western populations of the western pine beetle. Our findings support published evidence that *D. brevicomis* on either side of the Great Basin are genetically distinct and likely different species.

24. **Utilizing an integrated approach to mitigate the emerald ash borer invasion.** *Graziosi, Ignzzio, David Olson, Thais Rodrigues, Jian Duan, Reddy Palli, and Lynne Rieske. Department of Entomology, University of Kentucky, Lexington, KY 40546-0091; USDA ARS Beneficial Insects Introduction Research Unit, Newark, DE 19713.*
25. **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. [2] Department of Plant Pathology and Microbiology, University of California - Riverside, [3] Syngenta Crop Protection LLC.* The polyphagous shot hole borer (PSHB), *Euwallacea sp.,* and its associated fungi have recently caused dieback and mortality of California Sycamore in southern California. Direct control option for PSHB was 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.

26. **An evaluation of mountain pine beetle impacts to a viewshed and fuels project near Stanley Lake Sawtooth National Recreation Area, Idaho.** *Jorgensen, C.L. and Laura Lowrey. USDA Forest Service, Forest Health Protection, Boise Field Office.*
27. **Whitebark pine mortality from the last Mountain pine beetle outbreak: what we don't know.** *Jorgensen,C.L., L. Lowrey, A. Saavedra, and C.W. Nelson. USDA Forest Service, Forest Health Protection, Boise Field Office.*
28. **Collection of native Japanese predatory beetle, *Laricobius osakensis*, and challenges associated with its mass rearing at Virginia Tech, for control of *Adelges tsugae*.** *Carrie S. Jubb[1], Thomas J. McAvoy[1], Shigehiko Shiyake[2], Scott M. Salom[1], [1]Department of Entomology, Virginia Tech, 216A Price Hall, Blacksburg, VA 24061, [2]Osaka Museum of Natural History, Nagai Park, Osaka 546-0034, Japan.* *Laricobius osakensis* Shiyake and Montgomery was first imported to the United States in 2006 to be studied as a potential biological control agent of hemlock woolly adelgid (*Adelges tsugae* Annand), a devastating pest of eastern and Carolina hemlock (*Tsuga canadensis* Carrière and *Tsuga caroliniana* Engelmann) in the eastern United States. The hemlock woolly adelgid (HWA) in the eastern U.S. was found to be genetically identical to those in Japan. Since *L.osakensis* develops on this same strain of HWA in Japan, it was thought that this beetle would be a good candidate for biological control in the U.S. In 2010, after substantial study and risk assessment, *L. osakensis* was approved for release. The Virginia Tech Department of Entomology has since made three trips to Honshu Island, Japan to collect parent beetles to bring back to the Virginia Tech Insectary for mass rearing and subsequent release. In 2011, after the initial collection trip and while performing genetic testing on these beetles, it was discovered that an additional cryptic species, *Laricobius naganoensis*, was inadvertently brought back to the United States. Since these two species are impossible to differentiate visually, and *L. naganoensis* is not approved for release, this creates numerous challenges for mass rearing in the laboratory. How we address these challenges is presented.
29. **Chemical defenses mediate interactions among native biotic disturbances and mountain pine beetle in the novel host, jack pine, in Canada.** *Jennifer G. Klutsch[1], Ahmed Najar[1], Patrick Sherwood[2], Enrico Bonello[2], Jonathan A. Cale[1], Nadir Erbilgin[1], [1]Department of Renewable Resources, University of Alberta, Edmonton, AB T6G 2E3, Canada, [2]Department of Plant Pathology, The Ohio State University, Columbus, OH 43210, USA.* Conifers have complex and systemically inducible defenses that become activated when under attack, and which may influence subsequent attack success. However, whether these induced defenses impact interactions among different insects and pathogens, and how the chemical mechanisms underlying this resistance are coordinated is unclear. Our research investigated the expansion of mountain pine beetle (MPB, *Dendroctonus ponderosae*) into the novel host, jack pine (*Pinus banksiana*), by

assessing whether infection by a native pathogen (dwarf mistletoe, *Arceuthobium americanum*) could alter several defense chemical classes. Specifically, we examined whether these changes could induce pine resistance to a fungal symbiont of MPB, *Grosmannia clavigera*, and alter interactions between MPB and competitor beetles. Mistletoe infection severity has a positive effect on phenolic concentrations in the absence of *G. clavigera*. In contrast, mistletoe infection had a non-linear effect on induction of monoterpene accumulation, with the highest systemic induction in trees with moderate mistletoe severity compared to trees without infection or with high severity infections. Furthermore, these trees with moderate mistletoe severity and high monoterpene concentrations had the lowest local increase in α-pinene after *G. clavigera* inoculation. This suggests a trade-off in defense induction between systemically- and locally-induced compounds. Mistletoe-induced changes to monoterpenes, but not phenolic compounds, likely mediate systemic induced resistance because trees with moderate mistletoe severity were most resistant to *G. clavigera*. We also found that while mistletoe-induced changes to pine physical characteristics (i.e. phloem thickness) negatively impacted MPB success, the induced chemical changes decreased the adverse effects of competing subcortical insects on MPB performance. Tree-mediated interactions among multiple, often simultaneous, biotic disturbances may impact MPB establishment through systemic induced resistance mediated by the coordination of different host defense chemical pathways.

30. **Developing tools to detect and monitor low densities of mountain pine beetle at the edges of beetle expansion in Canada.** *Jennifer G. Klutsch[1], Jonathan A. Cale[1], Sanat S. Kanekar[1], Nadir Erbilgin[1], [1] Department of Renewable Resources, University of Alberta, Edmonton, AB T6G 2E3, Canada.* While effective methods to detect mountain pine beetle (*Dendroctonus ponderosae*; MPB) at outbreak densities are available, we lack tools to detect and monitor low-density populations on the edges of beetle expansion in Canada. Ours is an ongoing, multi-year project to develop such tools. First, we investigated if the attractiveness of commercial lures could be improved. We found that traps baited with the standard MPB lure (*trans*-verbenol, *exo*-brevicomin, terpinolene) plus myrcene caught more beetles than the standard beetle lure alone. Second, we used this lure to test the optimum density of baits and distance between sites in Alberta. We baited trees in three possible trap-tree configurations: triangle (three trap-trees), square (four trap-trees), and rectangle (six trap-trees). Three sets of each configuration were spaced one, four, or eight km apart along transects. Each configuration-distance combination was repeated three times in different locations, yielding 27 baited locations and a total of 351 baited trees over a 16,000 km^2 area. The number of attacks on baited trees ranged from 0 to 75 and about 91.3% of all baited trees were attacked. There was no difference in the proportion of trees attacked or the attack density on each baited tree among the three trap-tree formations. Neither the number of unbaited trees attacked nor the attack density varied by configuration. However, the square configuration seems to be the best arrangement because the number of mass attacked

baited trees tended to be higher than in other configurations, and it had the least spill-over attacks onto neighbouring unbaited trees.

31. **What have we learned from interceptions in wood packing material: Findings from identification of insects and wood material.** *Krishnankutty, Sindu[1], Ann Ray[1], Hannah Nadel[2], Scott Myers[2], and 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.*
32. **Using *a forest insect alphabet and song cycle* in forest entomology teaching and outreach.** *David L. Kulhavy Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, Nacogdoches, Texas and Charles D. Jones, La Nana Creek Press, Stephen F. Austin State University, Nacogdoches, Texas.* A Forest Insect Alphabet and Song Cycle, developed as both a fine arts handmade book and a trade edition, were prepared by David Kulhavy, Laurence C. Walker Distinguished Professor, Arthur Temple College of Forestry and Agriculture and Charles Jones, Master Printer, La Nana Creek Press. The fine arts limited edition book contains hand printed art, music quatrains and science of 26 forest insects from Atta texana, the Texas leaf-cutting ant, to the Zebra swallowtail. The book is used in teaching and outreach in Forest Entomology as each student selects one of the insects each semester and develops a timed PowerPoint and a comprehensive workbook on the importance of the insect in Forest Entomology and in society. One example is M, the Monarch Butterfly, with its iconic migration, symbol as a state insect and management to maintain the habitat in oyemel forests and migration routes. The Pine Beetle (P), the Emerald Ash Borer (E), *Xyleborus glabratus* (X) (Red-bay Ambrosia Beetle), and the Ladybird Beetle (L) for biological control, are examples of the 26 letters. The semester culminates in timed PowerPoints, prepared posters and an interpretive dance and presentative of the music to the faculty and students. The fine arts book tradition is continuing with handmade paper, original composed music and museum exhibitions for the Monarch Butterfly, Pollinators, and the Dirty Bug Book.
33. **Shade and hemlock woolly adelgid (HWA) infestation affect eastern hemlock (*Tsuga canadensis*) nutrient content.** *Marika Lapham[1,2,3], Chelcy Miniat[2], Albert Mayfield[3], Robert Jetton[4], David Zietlow[2], Steven T. Brantley[5], and Rusty Rhea[6],[1]University of North Carolina, Asheville, NC, [2]Coweeta Hydrologic Laboratory, USDA Forest Service, Southern Research Station, Otto, NC, [3]USDA Forest Service, Southern Research Station, Asheville, NC, [4]Camcore, Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC, [5]Joseph W. Jones Ecological Research Center, Newton, GA [6]Forest Health Protection, USDA Forest Service, Asheville, NC.* Hemlock Woolly Adelgid (*Adelgis tsugae*, HWA) infestation has resulted in rapid loss of eastern hemlock and changes in ecosystem function. HWA infestation rates are variable among populations,

and whether trees with low light and high nutrient availabilities are more susceptible to HWA infestation than those in high light and low nutrient availability is a current knowledge gap. We conducted a nursery experiment and exposed replicate eastern hemlock saplings to five light levels (0–90% shade) followed by artificial HWA infestation. Before and after shade and infestation treatments, we measured HWA density, new shoot growth, and foliar [N], [P], and [K]. We hypothesized that foliar nutrient investment would vary with shade, and would be positively correlated with HWA density. Shade increased foliar [N] (P = 0.001), but not [P] and [K]. Shade had no effect on new growth amounts. After 9 mos. of shade treatments, each sapling was infested with *ca.* 10,950 HWA eggs. Saplings growing in heavy shade had greater settlement rates and subsequent densities of HWA (P = 0.001). Shade and HWA infestation combined continued to increase foliar nutrient concentrations over increases from shade alone. With each 10% increase in shade, foliar [N] increased by an additional 0.079% (P = 0.012), and [P] increased by an additional 5.8% (P = 0.011). While shade alone didn't affect new growth amounts, the amount of new growth put on after HWA infestation was negatively correlated with HWA density.

34. **Spotted lanternfly: A new invasive pest in North America.** *Houping Liu (hliu@pa.gov), Pennsylvania Department of Conservation and Natural Resource, Sven-Eric Spichiger (sspichiger@pa.gov), Pennsylvania Department of Agriculture.* The spotted lanternfly, *Lycorma delicatula* (White) (Hemiptera: Fulgoridae), an exotic pest of tree-of-heaven (*Ailanthus altissima*) and other trees and grape vines in Asia, was recently discovered in North America. It is now found in four eastern counties (Berks, Bucks, Chester, and Montgomery) in Pennsylvania. We report its origin and distribution, host range, biology, potential impact, and natural enemies. Current efforts on its containment and ongoing studies on biological control and chemical control will also be discussed.
35. **Knowledge gaps and management needs for balsam woolly adelgid.** *Laura Lowrey[1] and Gina Davis[2], [1]USDA Forest Service, Forest Health Protection, 1249 South Vinnell Way Suite 200, Boise, ID, [2]USDA Forest Service, Forest Health Protection, 3815 N. Schreiber Way, Coeur d'Alene, ID, Contributed to field work: David Beckman, Tom Eckberg, Jeff Fidgen, Neal Kittelson, Sandy Kegley, Ladd Livingston, Kathy Matthews, Phil Mocettini, Chad Nelson, Lee Pederson, Contributed to concepts presented in future work: Steve Cook, Darci Dickinson, Amy Gannon, Fred Hain, Nathan Havill, Lee Humble, Carl Jorgensen, Lia Spiegel***.** Historic and on-going assessments regarding the impact of balsam woolly adelgid (BWA) (*Adelges piceae* Ratzeburg) to Idaho's *Abies* forests were presented. Our objective was to advance the conversation among forest health specialists and other scientists toward developing strategies to address the knowledge gaps needed to manage this pest; particularly in high elevation areas where subalpine fir (*Abies lasiocarpa*) provides the dominant forest cover. The extent of *A. lasiocarpa* survival averaged 16 and 60 percent at BWA infested locations monitored for 18 years and locations identified during previous year aerial detection survey, respectively. Societal and ecological importance of *A. lasiocarpa* will continue to increase in sensitive high elevation forests, where species diversity is limited to two or three species. *Abies*

lasiocarpa and *Pinus albicaulis*, whitebark pine, often dominate high elevation forests of Idaho. The future of *P. albicaulis* is uncertain due to climate change, mountain pine beetle outbreaks, and white pine blister rust, leaving *A. lasiocarpa* as a primary species. Management opportunities need to be addressed before BWA colonizes much more of our high elevation forests. Suggested focus areas include: (1) continued detection surveys for BWA in northern and central Rocky Mountains, supported by molecular species confirmation; (2) improved monitoring and quantification of host mortality through integrating data from aerial and ground surveys; (3) determine temperature thresholds for BWA to support decision models for higher elevations and changing climates; and (4) develop viable management options such as biological control for newly invaded ranges and genetic resistance to restore impacted forests.

36. **Smothering the forest: Gypsy moth growth rates and forest fragmentation.** *Metz, Riley and Patrick C. Tobin. University of Washington: School of Environmental and Forest Science.*
37. **Effect of trap height on catches of bark and wood boring beetles in a stand of white oak and shortleaf pine in Georgia.** *Miller, D.R.[1,] C.M. Crowe[1] and J.D. Sweeney[2]. [1]USDA-Forest Service, Southern Research Station; [2]Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Center.*
38. **Ipsenol, monochamol and α-pinene: Trap lure blend for *Monochamus* species (Cerambycidae) in Canada and USA.** *Miller,D.R.[1], J.D. Allison[2], C.M. Crowe[1], D. Dickinson[3], A. Eglitis[3], R.W. Hofstetter[4]; A.S. Munson[5], T.M. Poland[6], L.S. Reid[7], B.E. Steed[8], and J.D. Sweeney[9]. [1]USDA-Forest Service, Southern Research Station; [2]Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Center; [3]USDA-Forest Service, FHP Region 6; [4]Northern Arizona University, School of Forestry; [5]USDA-Forest Service, FHP Region 4; [6]USDA-Forest Service, Northern Research Station; [7]South Carolina Forestry Commission; [8]USDA-Forest Service FHP Region 1; [9]Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Center.*
39. **Physiological responses of eastern hemlock to biological control & silvicultural release: Implications for hemlock restoration.** *Miniat, Chelcy[1], Steven T. Brantley[2], David Zeitlow[1], Albert Mayfield[3], Rusty Rhea[4], Robert Jetton[5], and Paul Arnold[6]. 1Coweeta Hydrologic Laboratory, USDA Forest Service, Southern Research Station, Otto, NC; [2]Joseph W. Jones Ecological Research Center, Newton, GA; [3]USDA Forest Service, Southern Research Station, Asheville, NC; [4]Forest Health Protection, USDA Forest Service, Asheville, NC; [5]Camcore, Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC; [6]Department of Biology, Young Harris College, Young Harris, GA.*
40. **Invasive forest insects in Southcentral Alaska: Past and present.** *Moan, Jason E.[1] and Lundquist, John E.[2], [1]Alaska Division of Forestry, 550 W. 7th Ave, Suite 1450, Anchorage, AK 99501, Jason.Moan@alaska.gov, [2]USDA Forest Service, Forest Health Protection, 161 E 1st Avenue, Door 8, Anchorage, AK 99501, jlundquist@fs.fed.us.* Southcentral Alaska is bounded by the Alaska Range to the north and west, Canada to the east, and the Gulf of Alaska to the south. Because this is the most populated region in Alaska, its forests are

more accessible and thus more exposed than elsewhere in the state. Furthermore, tree diversity within its predominantly boreal and temperate rainforests is low. The mix of high human traffic and low tree diversity makes Southcentral Alaska especially vulnerable to invasive forest insect pests. As a consequence, non-native forest insects are impacting both native and urban forests in Southcentral Alaska. Recently, the spruce aphid (*Elatobium abietinum* Walker) was found causing extensive damage to Sitka spruce on the southwestern Kenai Peninsula. This is a significant expansion of the known range of this pest within the state. During the same period, Sitka spruce weevil (*Pissodes strobi* Peck) was found infesting ornamental spruce imported from the conterminous United States. This insect has periodically have been introduced into Anchorage over the last ten to twenty years, but is not believed to be established. Well-established invasive forest insects include a variety of both internal and external leaf-feeding sawflies, including the amber-marked birch leaf miner (*Profenusa thomsoni* Konow) and the green alder sawfly (*Monsoma pulveratum* Retzius). The current status and extent of major and emerging invasive forest insects in Southcentral Alaska will be discussed.

41. **First detectors in the last frontier.** *Moan, Jessie and Gino Graziano. University of Alaska-Fairbanks, Cooperative Extension Service.*
42. **Western trials of emamectin benzoate for protection of walnut from walnut twig beetle and thousand canker disease.** *Munson, A. Steven[1], David Cox[2], Donald M. Grosman[3], John Preece[4], Daniel Kluepfel[5], Yigan Chen[6], Jackson Audley[6], and Steven J. Seybold[7]. [1]USDA Forest Service Forest Health Protection 4746 South 1900 East Ogden, UT 84403; [2]Syngenta Crop Science 14446 Huntington Rd. Madera, CA 93636; [3]Arborjet Inc. 99 Blueberry Hill Rd. Woburn, MA 01801; [4]USDA ARS National Clonal Germplasm Repository/National Arid Land Plant Genetic Resource Unit One Shields Ave. University of California Davis, CA 95616; [5]USDA ARS Crops Pathology and Genetics Research Department of Plant Pathology University of California 284 Hutchison Hall Davis, CA 95616; [6]Department of Entomology and Nematology, University of California Davis, HDH 001 Rm 116 Orchard Park Dr. Davis, CA 95616; [7]USDA Forest Service Pacific Southwest Research Station 1731 Research Park Dr. Davis, CA 95618.*
43. **The efficacy of SPLAT® Verb for protecting lodgepole pine, ponderosa pine and sugar pine from colonization by mountain pine beetle.** *A. Steven Munson[1], Christopher J. Fettig[2], Brytten E. Steed[3], Beverly M. Bulaon[4], Leif A. Mortenson[2], Robert A. Progar[5], Agenor Mafra-Neto[6], [1]Forest Health Protection, USDA Forest Service, Ogden, UT, [2]Pacific Southwest Research Station, USDA Forest Service, Davis, CA, [3]Forest Health Protection, USDA Forest Service, Missoula, MT, [4]Forest Health Protection, USDA Forest Service, Sonora, CA, [5]Pacific Northwest Research Station, USDA Forest Service, La Grande, OR, [6]ISCA Technologies Inc., Riverside, CA.* Verbenone is the principal antiaggregation pheromone of mountain pine beetle (MPB). Although several formulations are registered for tree protection, failures in efficacy are not uncommon. Fettig et al. (2015) recently developed a novel formulation of (–)-verbenone (SPLAT® Verb, ISCA Technologies Inc., Riverside, CA, USA; EPA Reg. No. 80286−20; 10.0% a.i.) opposed to a

single release device is a flowable emulsion that allows the user to adjust the size of each release point (dollop) according to desired rates and distributions. SPLAT® Verb applied at 7.0 g of (−)-verbenone/tree as four equally-sized dollops on the four cardinal directions to the tree bole was effective for protecting lodgepole pine, but not ponderosa pine, from mortality attributed to MPB. In sugar pine, 4.0, 7.0, and 10.0 g of (−)-verbenone/tree were effective. Rates as low as 250 g of (−)-verbenone/0.4 ha were effective for protecting stands of lodgepole pine. We discuss the implications of these and other results to the management of MPB. SPLAT® Verb was registered by the U.S. Environmental Protection Agency for use on pines in 2013, and first used operationally in 2014.

44. **Objective prioritization of exotic pests: Development of a new model for PPQ.** *Neeley, Alison[1], Byejoong Kim[2], Leslie Newton[1], Lisa Jackson[3], and Ernie Hain[2], Godshen Pallipparambil[2]. [1]United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Center for Plant Health and Science Technology (CPHST), Plant Epidemiology and Risk Analysis Laboratory (PERAL); [2]North Carolina State University, Center for Integrated Pest Management (NCSU-CIPM); [3]United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Plant Protection and Quarantine (PPQ), Science and Technology (S&T), Center for Plant Health and Science Technology (CPHST).*

45. **Transgenic blight-resistant american chestnut trees demonstrate potential for restoring threatened species after invasions by exotic pathogens.** *Andrew Newhouse, Charles Maynard, and William Powell, SUNY College of Environmental Science & Forestry, Syracuse, NY, USA.* American chestnuts (Castanea dentata) were unique, valuable, and ecologically important trees in eastern North American forests until the chestnut blight (caused by the invasive fungus Cryphonectria parasitica) decimated nearly all mature trees. American chestnuts now survive primarily as stump sprouts, which usually succumb to the blight before they reach maturity. SUNY-ESF's American Chestnut Research and Restoration Project aims to address the chestnut blight by introducing a detoxifying enzyme called oxalate oxidase (isolated from wheat) into American chestnuts. New lines called Darling 54 and Darling 58 show very high levels of blight resistance, while retaining their original American chestnut form and growth patterns. Non-target effects observed to date are smaller than those produced through traditional breeding, and genetic diversity present in remnant populations can potentially be recaptured through outcrossing. However, unlike traditional breeding, trees produced through genetic engineering must be approved by federal regulators prior to distribution. Potential and necessary considerations for applying this technology to other threatened tree species are discussed.

46. **Pheromone differentiation between two syntopic species of *Dendroctonus* bark beetles in Mesoamerica.** *Alicia Níño-Domínguez [1], Brian T. Sullivan[2], and Jorge Macías-Sámano[1], [1]El Colegio de la Frontera Sur (ECOSUR), Tapachula, Chiapas, México. [2]USDA Forest Service Southern Research Station, Pineville, Louisiana, USA.* It was recently

determined that in the Central American region the southern pine beetle, *Dendroctonus frontalis*, contained a cryptic species, the recently-described *Dendroctonus mesoamericanus*. These two sibling species apparently mass-attack the same trees with substantial overlap in both the timing of attack and the portions of the host bole utilized. Crossing experiments indicated that, when confined together in artificial gallery entrances on pine logs, males and females would form cross-species pairs and sometimes produce larval brood. However, cross-species pairings are not observed in nature, suggesting the existence of an effective pre-pairing reproductive isolation mechanism. Behavioral studies in a walking olfactometer indicated that male beetles strongly preferred odors of female gallery entrances of their own species. Collections of volatiles from female entrances of either species were found to contain numerous compounds that stimulated the antennae of one or both species, but only two such compounds, *endo*-brevicomin and ipsdienol (both produced only by *D. mesoamericanus* females), differed significantly between the two. Further bioassays with the walking olfactometer indicated that ipsdienol and *endo*-brevicomin strongly increased or reduced attraction of male *D. mesoamericanus* or *D. frontalis*, respectively, when presented in combination with frontalin and *alpha*-pinene, odors associated with gallery entrances of females of both species. Since this response occurred when the compounds were presented in identical concentrations as those produced from female gallery entrances, we concluded that *endo*-brevicomin and ipsdienol produced by female *D. mesoamericanus* were the semiochemicals producing the aforementioned male preference for odors of gallery entrances of conspecific females. Thus an asymmetrical production of female pheromone components apparently results in a symmetrical reproductive isolation mechanism.

47. **Multigene sequence analyses of *Amylostereum areolatum* (Russulales: Amylostereacea) symbiont associated with native *Sirex nigricornis* Fabricius (Hymenoptera: Siricidae).** *Rabiu Olatinwo [1], Wood Johnson [2], and Timothy D. Schowalter [3], [1]USDA Forest Service, Southern Research Station, 2500 Shreveport Hwy, Pineville LA 71360, [2]USDA Forest Service, Forest Health Protection, 2500 Shreveport Hwy, Pineville LA 71360, [3]Department of Entomology, Louisiana State University, Agricultural Center, Baton Rouge, LA 70803.* *Amylostereum areolatum* (Chaillet ex Fr.) is a wood-decay fungus and a symbiont of both native *Sirex nigricornis* Fabricius (Hymenoptera: Siricidae) and non-native *Sirex noctilio* Fabricius. Although both species carry different *A. areolatum*strains in their mycangia, the symbiotic association between *S. noctilio* and *A. areolatum* is particularly damaging to pines around the world. Recent studies suggest possible reciprocal exchange of *A. areolatum* between non-native *S. noctilio* and native *S. nigricornis* where both species coexist. Our objective was to investigate differences or similarities between the *A. areolatum* in the *S. nigricornis* population in Louisiana, USA (where *S. noctilio* currently does not exist), and sequences from Ontario, Canada where both *Sirex* species currently co-exist, using multigene sequence analyses. DNA sequences from three genes were evaluated: the intergenic spacer (IGS) ribosomal DNA (rDNA), the internal transcribed spacer regions (ITS) rDNA, and the small subunit

(SSU) rDNA. Results showed that some *A. areolatum* sequences from native *S. nigricornis* from populations in Ontario, Canada and Louisiana, USA were identical. However, few sequences from *S. nigricornis* in Canada shared similarities with sequences from the non-native *S. noctilio*. All *A. areolatum* sequences from non-native *S. noctilio* in Canada were different from those in the native *S. nigricornis* in the USA. It is possible that the *A. areolatum* strain in non-native *S. noctilio* could spread from regions where both *Sirex* species currently coexist to the southern forests via the native *S. nigricornis*, if reciprocal exchange continues.

48. **Naturalization of a native invasive: mountain pine beetle in novel pine habitats.** *Pokorny, Stanley and Allan Carroll. University of British Columbia, Faculty of Forestry, Forest Insect Disturbance Ecology Lab, 2424 Main Mall, Vancouver, BC V6T 1Z4, Canada.*

49. **Impact of severe drought and bark beetle-caused tree mortality in southern California pine forests.** *Adrian Poloni[1], Tom W. Coleman[2], and Steven J. Seybold[3], [1]Department of Entomology and Nematology, University of California, Davis, [2]USDA Forest Service, Forest Health Protection, San Bernardino, CA, [3]USDA Forest Service, Pacific Southwest Research Station, Davis, California.* Four years of consecutive drought in southern California have led to increased mortality of pines associated with bark beetle colonization. Historically in this region, severe bark beetle outbreaks have been linked to several years of consecutive drought. Following the severe drought of the early 2000's in southern California, the level of tree mortality and associated forest stand conditions were poorly assessed. Our objective was to assess the level of pine mortality associated with drought and bark beetles from 2014 to 2015 across the four national forests of southern California. Areas of pine mortality were identified by aerial and ground surveys. We surveyed stands primarily on the Mt. Pinos Ranger District of the Los Padres National Forest. Fixed-radius (0.4 ha) and variable-radius prism (10 BAF) plots were used to assess tree mortality and forest stand characteristics in the impacted areas. Following preliminary analyses, *P. jeffreyi* was identified as the most killed pine in these stands. The primary bark beetle mortality agents were the California fivespined ips, *Ips paraconfusus*, and the pine engraver, *Ips pini*. The mean diameter of dead trees was in the 25.4 to 38.1 cm DBH size class, but dead trees were observed from <12.7 cm to 101 cm DBH. Mean tree mortality attributed to bark beetles was 44% across all pine stands in the survey. Pine stands experiencing tree mortality had greater tree densities (ha^{-1}) than pine stands with no tree mortality. Total stand basal area (m^2ha^{-1}) was higher in pine stands with tree mortality than stands with no mortality, but this difference was only marginally significant. Bark beetle attacks did not differ on pines with varying levels of dwarf mistletoe infection or Keen's crown class ranking. Principal component analysis associated higher levels of tree mortality in steeper, drier sites at lower elevations, which agrees with previous reports that assessed the interaction of drought and bark beetles from California. Additional pine stands will be surveyed in 2016 if the drought and tree mortality continue in southern California.

50. **Signal convergence and divergence for sympatric populations of western (*Dendroctonus brevicomis* LeConte) and southern (*D. frontalis* Zimmermann) pine**

beetle in Arizona. *Deepa Pureswaran[1], Richard Hofstetter[2], Brian Sullivan[3], Amanda Grady[4] and Kristen Potter[5], [1]Canadian Forest Service, Laurentian Forestry Center, Quebec City, QC G1V 4C7, Canada, [2]Northern AZ University, School of Forestry, Flagstaff, AZ 86001, USA,[3]USDA Forest Service, Southern Research Station, Pineville, LA 71360, USA, [4]USDA Forest Service, Forest Health Protection, Flagstaff, AZ 86001, USA, [5]Northern AZ University, School of Forestry, Flagstaff, AZ 86001, USA.* When related species coexist, selection should favor species recognition mechanisms that prevent interspecific pairing. *Dendroctonus frontalis* (southern pine beetle) and *D. brevicomis* (western pine beetle) are sympatric in a narrow zone in Arizona and co-attack ponderosa pine. We tested whether heterospecific pairings between *D. frontalis and D. brevicomis* occurred in the laboratory, compared beetle pheromone profiles and acoustic signals, and tested for cross-attraction to synthetic pheromone blends associated with either species at sites within the zones of sympatry (Arizona) and allopatry (California). When males were given a choice between galleries initiated by con- or heterospecific females, they made the right choice 85% of the time. For the sympatric populations of northern Arizona, pheromone profiles of each sex of *D. frontalis* resembled those of the opposite sex in *D. brevicomis*; the summed pheromone production of the sexes was similar for both species. Pheromone blends produced by female *D. brevicomis* formed two distinct clusters corresponding to the sampled California and Arizona populations. Male pheromone compositions showed no distinct clustering by location. Field response by *D. brevicomis* to isomers of brevicomin in Arizona was more similar to sympatric *D. frontalis* than allopatric (California) *D. brevicomis.* Regional preference for isomers of brevicomin appeared to mirror differences in production *D. brevicomis.* Female acoustic "chirps" revealed interspecific differences in temporal pattern. Hence, males may use interspecific differences in acoustic signals to identify conspecific females. Overlap in the aggregation pheromones of *D. frontalis* and *D. brevicomis* in Arizona is probably favoured because joint mass attacks would enable both species to overcome host defenses more easily. Our results are concurrent with evidence that *D. brevicomis* populations on either side of the Great Basin are genetically distinct and may be different species.

51. **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.* 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.

52. **Status of USDA-FS-FHTET supported classical biocontrol programs for invasive species for protection of forested ecosystems in the US.** *Richard Reardon[1], Yun Wu[1], Denise Binion[1], Carol Bell-Randall[2]. [1]USDA-FS, Forest Health Technology Enterprise Team, Morgantown, WV, [2]USDA-FS, Forest Health Protection, Coeur D'Alene, ID.* Biological control can be used for management of invasive forest pests in several ways: 1) natural enemy conservation, 2) biopesticides, 3) augmentative releases, and 4) classical biological control. The focus of this poster is the current status of classical biological control (i.e., foreign exploration for natural enemies from a pest's native range, importation, risk assessment, regulatory analyses, and if approved, their release and studies on establishment and impact) against seven invasive insects: ambermarked birch leafminer, beech scale, emerald ash borer, gold spotted oak borer, hemlock woolly adelgid, Sirex woodwasp and winter moth as well as seven invasive plants: Chinese privet, garlic mustard, Japanese knotweed, Japanese stiltgrass, kudzu, mile-a-minute and tree of heaven. Agents released and established for invasive insects ambermarked birch leafminer in Alaska, emerald ash borer, hemlock woolly adelgid and winter moth, and for invasive plant mile-a-minute. Petitions submitted to TAG/APHIS proposing the release of agents for Chinese privet, garlic mustard, Japanese knotweed and tree of heaven have been pending for many years without final decisions.
53. **Development of mountain pine beetle in four novel eastern pines.** *Derek W. Rosenberger[1], Robert C. Venette[2], Brian H. Aukema[1], [1]Department of Entomology, University of Minnesota, St. Paul, MN, [2]USDA Forest Service, Northern Research Station, St. Paul, MN.* The mountain pine beetle (*Dendroctonus ponderosae*), is native to western North America and intermittently undergoes large-scale outbreaks in lodgepole (*Pinus contorta*) and ponderosa (*P. ponderosa*) pines. This insect threatens eastern pine forests due to recent eastward spread from western lodgepole pine forests into novel

eastern jack pine (*P. banksiana*) forests, which expand through the Great Lakes region to eastern North America. Introduction the Great Lakes region may also occur through transport of infested green pine logs from western regions. The relative effects of pine species on reproduction and development in common eastern North American pines is unknown, yet is critical in determining if population growth is possible in eastern forests. Here we report the results of experiments designed to determine reproductive capacity and development rate of mountain pine beetle in logs of four common northeastern pines; jack, red (*P. resinosa*), eastern white (*P. strobus*) and Scots (*P. sylvestris*) pine. Mountain pine beetle was able to reproduce and complete development in logs of all four pine species. Pre-winter reproduction was similar in eastern and historic hosts, but development was generally faster in eastern pines. However, more rapid development resulted in higher winter mortality among less cold tolerant advanced life-stages, which were abundant in eastern pine logs. Summer emergence occurred one to three weeks earlier in eastern than historic hosts. Our results suggest that while mountain pine beetle reproduction can occur in novel eastern pines, more rapid development may necessitate cooler climates than historically needed for this insect to ensure appropriate seasonality and population growth.

54. **The non-native emerald ash borer alters forest structure and the associated arthropod community.** *Savage, Matthew B. and Lynne K. Rieske. Department of Entomology, University of Kentucky, Lexington, KY.*
55. **A "primary" wood borer of low elevation Douglas-fir in southwest Oregon.** *Schaupp, Jr, Willis C.[1] and Kathryn E. Strawn[2]. [1]USDA Forest Service, Pacific Northwest Region, Forest Health Protection; [2]USDA Forest Service, Pacific Northwest Region, Data Resource Management.*
56. **Effects of volatiles from decaying pines on attraction of three southern *Ips* species.** *William P. Shepherd, Brian T. Sullivan, USDA Forest Service, Southern Research Station, Pineville, LA*. *Ips avulsus* (Eichhoff), *I. grandicollis* (Eichhoff), and *I. calligraphus* (Germar) can cause significant tree mortality in the southern United States. The ability of these bark beetle species to discriminate among potentially suitable hosts is not fully understood. We hypothesized that volatile compounds released by decaying host logs may signal their unsuitability to early-arriving beetles. Traps baited with *Ips* attractant pheromone components and attached to polyethylene tents containing decaying loblolly pine logs captured significantly fewer *I. avulsus* than similar traps with no logs. Fewer *I. avulsus* and *I. grandicollis* were caught in decaying log traps than fresh log traps. Three volatiles, *alpha*-fenchene, fenchone, and nonanal, had higher relative concentrations in decaying logs than fresh logs and may have contributed to the observed *I. avulsus* inhibition. Conversely, volatiles present in lower concentrations in the decaying logs may have decreased their attractiveness to *I. avulsus* and *I. grandicollis*, relative to the fresh logs. Antennal responses of *I. grandicollis* to synthetic volatiles identified in aerations of decaying logs were highest/most consistent for terpinen-4-ol, isopinocamphone, camphor, 4-allylanisole, nonanal, and fenchone.

57. **Coarse woody debris accumulation in emerald ash borer invaded forests supports a rich and abundant community of Scolytinae.** *Shouhui, Sun[1,2], Matthew B. Savage[1], and Lynne K. Rieske[1]. [1]Department of Entomology, University of Kentucky, Lexington, KY; [2]Department of Forest Protection, Shenyang Agricultural University, Shenyang, China.*
58. **Susceptibility of selected Asian, European, and North American ash species to emerald ash borer: Preliminary results of no-choice bioassays.** *Siegert, Nathan W. (US Forest Service), Andrew R. Tluczek (Michigan State University) and Deborah G. McCullough (Michigan State University).* Many species of *Fraxinus* have not been adequately evaluated for their susceptibility to emerald ash borer (EAB). We assessed the susceptibility of several North American, European and Asian ash species to EAB under controlled laboratory conditions in no-choice bioassays using bolts collected from the limbs of non-infested ash trees growing at the Arnold Arboretum of Harvard University in eastern Massachusetts. Arnold Arboretum holds a collection of ash species numbering 175 individual trees across 100 accessions, comprising approximately 20 species. Asian ash species, which co-evolved with EAB, are presumably relatively resistant to this pest. Several species from North America and Europe, however, have yet not been encountered by EAB. In this study, we focused on the relative suitability of various *Fraxinus* species for EAB larval feeding and development. In 2013-2014, two laboratory trials were conducted at Michigan State University (MSU) using small bolts collected from 19 different ash species. Branches of 2-3 individual ash trees from selected North American, European and Asian species at the Arnold Arboretum were collected in 2013, first in June (Trial 1) and next in July (Trial 2). For Trial 1, samples included North American green ash (*F. pennsylvanica*), white ash (*F. americana*), pumpkin ash (*F. tomentosa* [syn. *F. profunda*]), and Texas ash (*F. texensis*); European species included Manna ash (*F. ornus*), narrow-leafed ash (*F. angustifolia ssp. oxycarpa*), Pallis' ash (*F. pallisae*), and European ash (*F. excelsior*); while Asian species included Chinese ash (*F. chinensis*), Manchurian ash (*F. mandshurica*), and Japanese ash (*F. longicuspis*). For Trial 2, North American species included green ash, white ash, black ash (*F. nigra*), blue ash (*F. quadrangulata*), Oregon ash (*F. latifolia*), and velvet ash (*F. velutina*); Asian species included Korean ash (*F. chinensis var. rhynchophylla*), Chinese flowering ash (*F. sieboldiana*), Japanese flowering ash (*F. lanuginosa*), and Chinese red ash (*F. platypoda*). Cut ends of the branches were sealed after cutting to reduce desiccation and delivered to MSU within 48 hours for further processing. At MSU, 12 sections from the branches of each ash species (n = 132 sections in Trial 1; n = 120 sections in Trial 2) were cut to 14 cm lengths. One cut end of each section was waxed to prevent drying. Approximately 100 eggs collected from laboratory-reared EAB were placed on each section and wrapped with parafilm. Sections were placed in trays of water and held in growth chambers to allow eggs to hatch and EAB larvae to feed, following rearing methods developed by Jonathan Lelito, formerly of USDA APHIS. After 3 to 4 months, sections were moved to cold storage for an additional 4 months, then returned to growth chambers to allow larvae to complete development, pupate and emerge as adults. Sections from Trial 1 and Trial 2 were debarked and survivorship of

EAB larvae was assessed in late February and mid-April 2014, respectively. Results of our no-choice bioassays indicate that EAB larvae could feed and develop on all North American, European and Asian ash species included in our trials. Overall, average (± SEM) survivorship of EAB tended to be greater on North American ash species (63.3 ± 7.2%) compared to ash species native to Europe (51.4 ± 17.0%) or Asia (26.6 ± 10.5%). The percentage of EAB larvae that developed to prepupal or adult stages, however, was highly variable among ash species, including species of similar continental origin. For instance, survivorship of EAB reared on European species ranged from 10.5 to 79.5% (European ash and narrow-leafed ash, respectively) and 0 to 80.0% on Asian species (Japanese ash and Chinese ash, respectively). North American species exhibited similar variability, ranging from a high of 93.2% survivorship on green ash in Trial 1 to a low of 25.7% survivorship on velvet ash in Trial 2. Whether this variability represents actual differences in susceptibility among ash species or merely an artifact of using cut sections is unknown. While all ash species included in our trials appear to be potential hosts for EAB, survivorship values should be interpreted with caution. Some differences, for example, could reflect varying rates of desiccation among ash species that subsequently affected larval feeding and development. Furthermore, larvae feeding on cut sections would not encounter any inducible defenses that could affect development rates or survival. Further research is needed to evaluate relative susceptibility of live trees of these ash species to EAB colonization and reproductive success.

59. **The invasive species Cannonball Run: A case study of firewood movement to the New Hampshire Motor Speedway.** *Piera Y. Siegert[1], Bryan Nowell[2], Mark Michaelis[3], Nathan McShinsky[4], Nathan W. Siegert[5], [1]New Hampshire Dept. of Agriculture, Markets & Food, Concord, [2]New Hampshire Dept. of Resources & Econ. Development, Concord, NH, [3]USDA APHIS PPQ, Berlin, VT, [4]New Hampshire Motor Speedway, Loudon, NH, [5]US Forest Service, Northeastern Area State & Private Forestry, Forest Health Protection, Durham, NH.* Firewood transportation has been identified as a significant vector for dispersing invasive forest insects, such as emerald ash borer (EAB) and Asian longhorned beetle (ALB), much greater distances than they could disperse through natural spread. Several factors exacerbate the risk of moving pests in firewood compared to other wood products. For instance, minimal processing and incremental burning increase the likelihood of firewood harboring live insects which may emerge over time to initiate new infestations. Seasoning firewood may reduce the risk in some cases, but is not effective against certain life stages of wood-boring insects. The firewood movement pathway includes wood harvested for both commercial and recreational purposes, which makes it a challenge to effectively regulate. While commercial firewood enterprises can be identified and targeted for education on how to safely move their product, people moving firewood for camping and recreation are poorly reached through regulatory and outreach efforts. In July 2011, New Hampshire implemented an out-of-state firewood quarantine, generally prohibiting the importation of any tree material intended for use as fuel for fires, to reduce the risks to its forest resources through firewood movement. The New Hampshire Motor Speedway (NHMS) is a

popular camping and recreational destination for people from across North America, making it a prime candidate for firewood outreach activities. Moreover, NHMS hosts the two largest camping activities in the state – the days leading up to the July and September NASCAR races – with approximately 75% of its 5,000 campsites occupied by out-of-state race fans. In cooperation with other state and federal partners and NHMS, New Hampshire's Forest Rangers coordinated outreach to NASCAR fans regarding the risks of moving out-of-state firewood. Outreach has included messaging on the NHMS website, displays at NHMS fan days, brochures in mailings and grab bags, and surveys of fans on their firewood transportation habits. Firewood quarantine enforcement activities at NHMS were developed and implemented prior to the two NASCAR races in 2013 and before the July race in 2014. Enforcement activities were conducted from 9 a.m. to 10 p.m. Wed.-Fri. preceding each race, when most campers arrive. The NHMS provided space at the entrance so NH Forest Rangers could identify violators and issue notices of violation and summonses upon entry. Cooperating state and federal partners assisted the Rangers in confiscation of firewood, documentation of violations and, most importantly, providing outreach to violators about invasive pests of concern and the risks associated with moving firewood long distances. Confiscated firewood was examined and burned at a nearby transfer station to mitigate risk. Vouchers for local heat-treated firewood were provided as available. The firewood quarantine enforcement at NHMS resulted in 225 confiscations of out-of-state firewood over 9 days. Confiscated firewood included both green and seasoned wood, with volumes ranging from only a few sticks to full truckloads per violation. Most intercepted firewood (80%) originated in neighboring northeastern states and was transported 49 to 200 miles to NHMS (primarily from Maine, Massachusetts and Vermont). As expected, the number of firewood confiscations from out-of-state decreased with increasing distance from NHMS, with 12% being transported 201-300 mi, 6% transported 301-400 mi, and 2% transported 401-700 mi. This reduction in confiscations with distance may be due to the geographic draw of NHMS rather than to a change in the willingness to transport firewood based on distance. For instance, transcontinental firewood movement from as far as Florida, California and Washington were also observed. Additionally, confiscated firewood originating from the Canadian provinces of Quebec and Prince Edward Island was also found during this enforcement activity in spite of Customs and Border Protection inspections. No firewood originating from known ALB-infested areas was intercepted, although 2% of confiscated firewood originated from towns adjacent to ALB quarantine areas in Massachusetts and New York. Fifteen percent of confiscated firewood originated in areas with known EAB infestations. The targeted firewood quarantine enforcement activities conducted at NHMS are a model of an effective outreach partnership between private industry and state and federal government. These enforcement activities would not have been possible without the support and cooperation of NHMS and results have provided resource managers and policymakers considerable information on the prevalence of transportation of recreational firewood into New Hampshire. Ongoing and continued outreach efforts about the risks to forests posed by the transportation of firewood are necessary to effect long-term change in the habits of attendees at large recreational camping events. Although expensive, providing firewood vouchers lessens the inconvenience associated with confiscation. Future firewood quarantine enforcement and outreach activities at large recreational events should consider including parallel enforcement at private campgrounds in proximity to the event, conducting additional outreach throughout the event grounds rather than solely on the entry road, and collaborating with local firewood vendors so out-of-state attendees may be readily aware of locally-sourced and affordable firewood at or near the event.

60. **Pheromone background can alter lure responses of southern pine beetle (*Dendroctonus frontalis* Zimmermann): A consequence of the dose-response curve for *endo*-brevicomin?** *Brian T. Sullivan[1] and John A. Byers[2]. [1]USDA Forest Service Southern Research Station, Pineville, LA; [2]Department of Entomology, Hebrew University of Jerusalem, Rehovot, Israel.* Trapping experiments in Mississippi demonstrated that the male-produced component of the aggregation pheromone of the southern pine beetle, *endo*-brevicomin, has a peaked dose-response curve, synergizing attractiveness of *alpha*-pinene/frontalin up to a peak activity (a 5-fold increase over *endo*-brevicomin – lacking controls) at an approximately 0.1 mg/d release rate. At still higher release rates, attraction declined until at 30 mg/d attraction was inhibited. This indicates that *endo*-brevicomin, at least in its racemic form, has a "multifunctional"-type dose-response. Additionally, in experiments in which pairs of adjacent (6 m separation) traps were both baited with *alpha*-pinene/frontalin, but only one trap received successively higher release rates of *endo*-brevicomin, catches of southern pine beetle in both traps showed a peaked dose response, with catches peaking (a 30 to 50-fold increase over controls) in both traps at approximately 1 mg/d release. However, catches were never greater in the *endo*-brevicomin-amended trap of the pair, and, at the peak of the curves, catches were significantly higher in the trap that was lacking *endo*-brevicomin. We believe this result validates the procedure of displacing devices of *endo*-brevicomin several meters away from traps to maximize the effectiveness of this lure adjuvant. Furthermore, we believe that the dose-response curve can explain the phenomenon in which *endo*-brevicomin devices reduce beetle catches in traps located inside southern pine beetle infestations but increase catches in traps located far from infested trees. Presence of an artificial background of *endo*-brevicomin in the environment of single traps reversed the effect of adding an *endo*-brevicomin device directly to the trap, with catches being increased in the absence of background but reduced in the presence of background. We believe that the background-generating devices duplicated the effects of low-rate release devices placed on the traps themselves, thereby concealing or reducing the synergistic effects normally observed when relatively low rate devices are added to traps. The area-wide synergistic effects of *endo*-brevicomin likely explain the variability in the apparent "activity" of *endo*-brevicomin depending on the proximity of beetle-infested trees, which represent natural sources of background of this pheromone component in the environment.

61. **Efficacy of detecting bark- and wood boring beetles (Cerambycidae, Buprestidae, Scolytinae) is improved by using a mix of trap colors and trap placements.** *J.D. Sweeney[1], P.J. Silk[1], R.P. Webster[1], D.R. Miller[2], C. Hughes[1], K. L. Ryall[3], J.M. Gutowski[4], T. Mokrzycki[5], J.A. Francese[6], Q. Meng[7], and Y. Li[7], [1]Natural Resources Canada, Canadian Forest Service, Atlantic Forestry Centre, 1350 Regent Street, Fredericton, New Brunswick E3B 5P7, [2]Southern Research Station, USDA Forest Service, 320 Green St., Athens, GA, 30602, [3]Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre, 1219 Queen Street East, Sault Ste. Marie, Ontario P6A 2E5, [4]Instytut Badawczy Lesnictwa, 17-230 Białowieża, Poland, [5]Warsaw University of Life Science, Warsaw, Poland, [6]USDA APHIS PPQ, Otis Laboratory, 1398 West Truck Road, Buzzards Bay, MA 02542, [7]Forestry College of Beihua University, 3999 Binjiangdong Road Jilin, Jilin Province, The P.R. China, 132013.* Due to the sheer volume of global trade, bark- and wood boring beetles continue to move in solid wood packaging and arrive in new habitats, in spite of international phytosanitary agreements like ISPM 15. The sooner an established invasive species is detected, the more likely it can be eradicated, contained, and managed. We present results of field trapping bioassays conducted in 2015, testing the effects of trap color (black, green, red) and trap placement (tree canopy, understory) on the rate of detecting species of Cerambycidae, Buprestidae, and Scolytinae in Fluon-coated 12-funnel Lindgren traps. Trap color and trap height significantly affected the efficacy of detecting buprestids and cerambycids. Mean (±SE) number of species detected per trap (buprestids and cerambycids combined) was greatest in green traps placed in the tree canopy and lowest in black traps in the understory, but individual species had different color preferences. Scolytinae detection was affected by trap placement but not trap color; traps in the understory detected more species than traps in the canopy. Results suggest that efficacy of exotic beetle trapping surveys would be increased by using more than one trap color and by placing traps in the tree canopy as well as the understory.
62. **A burning question: User attitudes and firewood as a vector of non-native wood borers in mississippi parks.** *M. Thorn[1], J. J. Riggins[1], R. Brown[1], & J. Gordon[2], [1]Mississippi State University Department of Biochemistry, Molecular Biology, Entomology, and Plant Pathology, [2]Mississippi State University College of Forest Resources.* Non-native wood borers are being introduced to North America at an increasing rate. Introductions of pest species, such as the redbay ambrosia beetle (*Xyleborus glabratus*), emerald ash borer (*Agrilus planipennis*), soapberry borer (*Agrilus prionurus*), and Asian long-horned beetle (*Anoplophora glabripennis*), are already causing significant economic, ecological, and cultural harm. Firewood has been implicated as a vector of many non-native wood borers in the U.S., allowing for long distance dispersal and hastening the spread of these species. Intercept surveys will be performed at four Mississippi parks to give insight into how campers procure and move firewood, as well as, their camping habits, attitudes towards non-native wood borers, and regulations concerning the movement of recreational firewood. Camper attitudes and habits are an under researched area of non-native wood borer movement that this study seeks to add data to. Future work will

extract and identify non-native wood borers from firewood collected from surveyed campers in Mississippi campgrounds.

63. **Are insects (and/or pathogens) contributing to sugarberry mortality in Georgia and South Carolina?** *Michael D. Ulyshen[1*], Scott Horn[1], Michelle Cram[2], Steve Fraedrich[1] and Rabiu Olatinwo[1], [1]USDA Forest Service, Southern Research Station; [2]USDA Forest Service, FHP.* We aim to determine what role, if any, insects and/or pathogens are playing in the declining health and mortality of sugarberry (*Celtis laevigata* Willd.) in and around Augusta, Georgia. A severe ice storm in February 2014 may have weakened the trees but it remains unclear whether this alone is responsible for observed levels of ongoing mortality. A preliminary survey indicates that at least two insect species are commonly associated with stressed sugarberry. The first is the Asian Woolly Aphid (*Shivaphis celti* Das), which is widely found on sugarberry foliage and commonly results in thick layers of sooty mold forming on the leaves. The second is a species of wood-boring buprestid beetle (prob. *Agrilus macer*) that lays egg masses on the bark of weakened trees, often at very high densities (e.g., >1000 egg masses/m^2 with ~16 eggs per mass). Sapwood surrounding galleries created by early instars of the beetle commonly exhibit staining. So far, several species of *Fusarium* have been found in association with these stained areas. Of the 46 dead sugarberry trees we inspected, 38 (83%) had visible beetle egg masses. An insecticide trial was initiated in October 2015 to determine whether trees protected from aphids (imidacloprid), buprestids (emamectin benzoate) or both insects (both compounds) exhibit better survivorship relative to untreated controls.
64. **Western Forest Insect Work Conference Founder's Award: An Amazing Legacy Founder's Award Committee.** The Founder's Award is given to an individual who has made an outstanding contribution to forest entomology in the West. The award recognizes significant contributions in pest management, extension-consultation, research, and teaching. The Founder's Award committee presented a poster that highlights the amazing legacy of the WFIWC Founder's Award and includes pictures of prior recipients. Beginning in 1991 through 2015, there have been 23 recipients of the Founder's Award. For more information concerning Founder's Award recipients view the WFIWC website (http://www.wfiwc.org/awards/founders-award). We acknowledge and appreciate Joel Egan's assistance in our efforts to record and upload videos of recent Founder's Award presentations.
65. **Toward more precise tree-ring estimates of mountain pine beetle outbreaks.** *Estelle Arbellay[1], Lori D. Daniels[1], Shawn D. Mansfield[2] and Alice S. Chang[1], [1]Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, British Columbia, Canada, [2]Department of Wood Science, University of British Columbia, Vancouver, British Columbia, Canada.* The negative impacts of mountain pine beetle (MPB) outbreaks on forest health have created a pressing need to gain information on the spatial and temporal dynamics of outbreaks to guide forest management. A number of tree-ring studies have reconstructed MPB outbreaks through the dating of scars caused by MPB boring galleries into the bark. However, frequent difficulties in conclusively separating MPB scars from fire scars have been a

limiting factor in developing chronologies over large spatial and temporal scales. In this study of MPB and fire scars of lodgepole pine, we measured and analyzed annual variations of wood properties in rings formed prior to and after injury. We tested the hypotheses that injury caused by either MPB or fire would elicit wood anomalies and that such wood anomalies would differ in type, magnitude, and/or duration between MPB and fire. The main objective was to decipher an injury signal specific to MPB. As a result of injury, ring width increased significantly in both MPB and fire scars. However, the increase was more marked and shorter-lived in MPB scars compared with fire scars. Latewood density decreased significantly in MPB scars, while increasing in fire scars. Changes were once again more marked and shorter-lived in MPB scars. Fine-scale attributes of fibers only decreased significantly in MPB scars. These findings highlight MPB injury as more acute than fire injury and present methods to positively differentiate MPB scars from fire scars in order to provide forest managers with more precise tree-ring estimates of MPB outbreaks.

66. **Toward more precise tree-ring estimates of forest defoliator outbreaks: western spruce budworm and larch bud moth**. *Estelle Arbellay, Lori D. Daniels, Raphaël D. Chavardès, and Ingrid Jarvis, Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, British Columbia, Canada.* Western spruce budworm (WSB) and larch bud moth (LBM) outbreaks are currently devastating forests in the Pacific Northwest and in the European Alps, respectively. A clear understanding of the timing, frequency and spatial distribution of outbreaks is essential for forest management in a changing climate. Tree-ring studies have successfully used periods of growth suppression caused by forest defoliators to reconstruct outbreaks over large spatial scales. However, a number of those studies have shown a one to four-year lag in response to insect defoliation. In this study of increment cores of Douglas-fir (WSB) and European larch (LBM), we measured and analyzed annual variations of ring width for periods of growth suppression. We then also analyzed annual variations of latewood width and blue intensity, i.e. the reflectance of blue light occurring in latewood, which is recognized as a proxy for latewood density. The main objective was to improve the temporal accuracy of tree- ring reconstructions of outbreaks. Results show that latewood width was generally more greatly suppressed than ring width and in certain cases allowed for more temporal precision. Blue intensity was generally less markedly suppressed than ring width but in certain cases also allowed for more temporal precision. Blue intensity was a more successful proxy in the lighter section of the cores, i.e. the sapwood made of the most recent rings. The use of proxies other than ring width contributes to obtaining higher temporal resolution in tree-ring reconstructions and thereby more precise tree-ring estimates of forest defoliator outbreaks to provide forest managers.

Back Row: Shouhui Sun, Rabiu Olatinwo, Derek Czokajlo, Bud Mayfield, Dough Allen, Chris Asaro, Keith Douce, Iral Ragenovich, Tom Schowalter, Sarah Phipps
Front Row: Drew Sheaffer, David Olson, Robert Jetton, Val Cervenka, Audrea Diss-Torrance, Marie Cook, Sue Crocker, Rosa Yoo, Haley Ritger, Kamal Gandhi

Back Row: Laurel Haavik, Lisa Strongfield, Beth Willhite, Sandy Kegley, Will Shepherd, Carrie Jubb, Ariel Heminger, Max Ragozzino
Front Row: Ben Smith, William Monahan, Ken Raffa, Robert Coulson, Jake Bodart, Melissa Fischer, Kenton Sumpter, Katlin Mooneyham, Jennifer Klutsch, Brytten Steed

Back Row: Jon Sweeney, Celia Boone, Nadir Erbilgin, Tom Coleman, Steve Munson, David Wakarchuk, Chandler Barton, Thomas Whitney, Chris Crowe
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